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Are users willing to walk more to access a better transit service? Application of best-worst scaling and stated preference survey

Disposição dos usuários do transporte público a caminhar para obter um serviço mais frequente: aplicação de best-worst e preferência declarada

Ana Margarita Larranaga[1], **Julián Arellana**[2], **Luis Garzón**[3], **Bárbara Jansson Almeida**[4], **Shanna Trichês Lucchesi**[5]

[1]Federal University of Rio Grande do Sul, Rio Grande do Sul – Brazil, analarra@producao.ufrgs.br
[2]Universidad del Norte, Barranquilla – Colombia, jarellana@uninorte.edu.co
[3]Universidad Técnica del Norte, Ibarra, Ecuador, lagarzon@utn.edu.ec
[4]Federal University of Rio Grande do Sul, Rio Grande do Sul – Brazil, barbjansson@hotmail.com
[5]Federal University of Rio Grande do Sul, Rio Grande do Sul – Brazil, slucchesi@gmail.com

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ABSTRACT
The study analyzes users' willingness to walk to obtain a more frequent public transport service. Best-worst, stated preference (SP) and attitudinal data were collected in Porto Alegre, Brazil. Integrated choice and latent variable (ICLV) models allowed combining the classical discrete choice models with the structural equation model to address the attitudinal variables. The contributions are fourfold: quantification of the trade-off between these attributes, the inclusion of attitudinal and urban characteristics, study context, and a new methodological approach through the use of best-worst for PD search attribute selection. The results showed that users are willing to walk 520 m to reduce waiting time by 10 minutes, 375 m to reduce vehicle crowded by 50%, 98m to increase the number of police officers by 1 unit, and 100 m to increase quality sidewalk pavement (bad to good state). Also, users are willing to wait 7,2 minutes to reduce vehicle capacity by 50%**.**

RESUMO
O objetivo do estudo é analisar a disposição a caminhar dos usuários para obter um serviço com maior frequência. Dados best-worst, preferência declarada (PD) e atitudinais foram coletados em Porto Alegre e estimados modelos híbridos de escolha discreta simultâneos. Os modelos permitiram a combinação dos modelos clássicos de escolha discreta com equações estruturais. O estudo contribui em:quantificação do trade off entre estes atributos, inclusão de características atitudinais e urbanas, contexto do estudo e nova abordagem metodológica através da utilização de best-worst para seleção de atributos da pesquisa PD. Os resultados mostraram que os usuários estão dispostos a caminhar 520m para reduzir 10 minutos o tempo de espera, 375m para reduzir a lotação do veículo 50%, 98m para aumentar o número de policiais em 1 unidade e 100m para incrementar a qualidade do pavimento das calçadas. Os usuários estão dispostos a esperar 7,2 minutos para reduzir a lotação do veículo em 50%.

1. INTRODUCTION

Public transport is essential for economic vitality, social equity, quality of life, and cities' efficiency. It guarantees social inclusion and guarantees access to essential daily activities like those related to work, education, health, shopping, and leisure (Currie *et al.*, 2007; Daniels e

Mulley, 2013; Lucas, 2005; Lucas 2010). In Brazilian cities, public transport represents an average of 28% of travel, with 24% representing the share of transport by bus and 4% by rail (ANTP, 2020).

Walking is the primary mode of access to public transport. Several studies show that the distance to the public transport stop significantly influences the willingness to use transit (Ewing *et al*., 2009; Frank *et al*., 2009; Rajamani *et al*., 2003). This distance can affect the user's decision on which modal to use and public transport operation (e.g., distance between stopping points, capacity, travel time, and reliability). Bus network planning is often centered on service coverage to ensure that the network provides minimal resident accessibility. Government public transport planning guidelines generally use the maximum walking distance to the stop to measure service coverage. The distance of approximately 400 m (0.25 miles) is often used as an estimate of willingness to walk (El-Geneidy, 2010; Gutiérrez and García-Palomares, 2008; Hsiao *et al.*, 1997; Kimpel *et al.*, 2007; Murray and Wu, 2003; Neilson and Fowler, 1972; O'O'Neill*t al.*, 1992; Zhao *et al.*, 2003).

Individual's characteristics (car availability, income, age, attitudes, and perceptions), trip purpose, and the built environment (population density, diversity of land use, urban design, and characteristics of road infrastructure) can alter the perception of acceptable distances (Arellana *et al*., 2020; Baran *et al*., 2008; Cao *et al*., 2006; Ewing and Cervero, 2001, 2010; Larranaga *et al.*, 2014; 2018; Lee and Moudon, 2006; Lucchesi et al., 2021a,b; Ruiz-Padillo *et al.*, 2018). Recently, studies have emerged seeking to incorporate some of these elements in determining acceptable walking distance, based on a spent energy approach (Chaug-Ing and Yau-Ching, 2014; El-Geneidy, 2010; Páez et al., 2020). According to this approach, the walking energy expenditure (WEE) represents the effort spent during walking.

Although 400 m is the walking distance generally adopted in government planning guidelines, international evidence shows that people can walk more to obtain better transport services (Rose *et al*., 2013). For example, a study conducted by O'Sullivan Morrall (1996) in Calgary, Canada, discovered that the distance depends on the type of transit. People walk more to reach a Light Rail Station (LT) than to get to a bus stop. A similar result was found by Burke e Brown (2007) for the Southeast Region of Queensland, Australia. Studies that showed greater walking distances than the one usually adopted were carried out by Agrawal et al. (2008) in California and Oregon, United States; by Ker and Ginn (2003) in Perth, Australia; and by Daniels and Mulley (2011) in Sydney, Australia. Alshalalfah and Shalaby (2007) identified that in Toronto, Canada, people walk an average of 170 m to bus stops that offer a service with a headway greater than or equal to 15 minutes. However, this distance increases to 220 m when the headway decreases to less than 10 minutes. The difference is greater in the suburbs than in the central areas of the city. Another study in Canada, in Montreal, carried out by El-Geneidy et al. (2010), shows that the walking distance to bus stops is approximately 550 m and 1,212 m to train stations. Additionally, they identified that these distances increase when the stops offer more frequent service. Using data from Australian cities, Mulley et al. (2018) concluded that users are willing to walk between 226m and 302m for a reduction of 10 minutes of waiting, while in the UK and the USA, the distance varies between 370m and 475m for the same reduction.

These studies discussed above suggest that public transport users are willing to walk further to access public transport with better service quality. In those cases, quality of service is weighted by the frequency of service from the passengers' point of view (Currie and Wallis, 2008; Rose et al., 2013). However, it is difficult to separate the effect of the built environment, characteristics of the trip, and the individual from the quality of public transport services. Some authors, like Daniels and Mulley (2011), suggest that environmental factors generally determine the ease of walking. Moreover, the public transport service characteristics could be a more critical factor in determining how far people would be willing to walk to access public transport once the decision to use public transport has been made.

The previous discussion supports an alternative approach for planning the public transport network by bus, where resources and service provision are concentrated in the corridors to provide greater frequency. This approach emerged from the European experience, in which resources are concentrated in the corridors, offering high-frequency services, reducing waiting time, which has a substantial impact on the perception of total travel time for users (Nelson et al., 2005; Rose et al.; 2013). However, budget restrictions might reduce coverage, leading to a greater walking distance to the bus stop (Mulley et al., 2018). Thus, there is a trade-off between coverage and frequency.

The studies previously discussed, except for Rose et al. (2013) and a more recent version Mulley et al. (2018), analyzed the revealed behavior of individuals about the walked distance and the frequency of the transport service. However, revealed preference studies are limited to the observed actions of individuals, do not allow analyzing how individuals would behave in alternative scenarios, facing changes in transport services. On the other hand, many of these works do not cover bus services. Rose et al. (2013) and Mulley et al. (2018) carried out a study of stated preference to evaluate these multiple circumstances. However, the studies were carried out in Australian cities, the United Kingdom, and the USA. The specific characteristics of the Brazilian context (cultural, socioeconomic, urban, modal division) demand focus studies. Moreover, the studies considered only characteristics of the service, without including elements of the individual, the trip, and the built environment.

This study aims to analyze the users' willingness to walk to obtain a more frequent service. Best-worst scaling stated preference (SP) and attitudinal data were collected in Porto Alegre, and integrated choice and latent variable (ICLV) models were estimated. The proposed study contributes to the overall literature in four aspects. Firstly, it contributes with quantitative evidence concerning the compensatory exchange between walking distance and frequency of a bus transport service. There are few studies in the international literature in this research field. Secondly, it is a new approach including attitudinal characteristics of the individual and the built environment in this analysis. Few studies with these characteristics have been identified. Thirdly, it is the practical implication for the Brazilian context. No studies were found discussing the issue for Brazilian cities. Finally, this study presents a new methodological approach, selecting the attributes to include in the SP experiment from multinomial logit models applied to best-worst data, instead of the traditional approach based on qualitative research or literature review. Additionally, the use of these attributes in estimating integrated choice and latent variable models from SP and attitudinal data. The ICLV models adopted allowed the inclusion of attitudinal variables in the discrete choice models, combining the classical discrete choice models with structural equations for the latent attitudinal variables.

2. METHOD

The proposed method consists of two main steps. Firstly, identify the elements that influence the perception of the quality and convenience of bus service and access walking to the bus stop.

Then, the relative importance and quantification of the trade-off between bus frequency and walking distance will be determined. In the first step, the best-worst scaling data (case 1) were collected and modeled using multinomial logit models. The most relevant elements identified in this stage were used to elaborate a stated preference survey (second stage). Thus, we collected SP data and estimated integrated choice and latent variable models. The complete description of the steps is detailed in the following sections.

2.1. Identification of the elements that influence the transit quality and convenience perception of the bus service and the walking access to the bus stop

The best-worst (B/W) technique is based on the random utility theory (McFadden, 1974). It involves choosing the best and worst attributes/attribute levels (the most and least attractive extremes) within a set of choice situations presented to each individual (Louviere and Swait, 1997). Studies discuss different types of B/W (Flynn, 2010). The most commonly applied approaches are the ones called Object (case 1) (e.g., Louviere et al., 2013), Profile or Level of attributes (case 2) (e.g., Larranaga et al., 2018), and Multi Profile (case 3) (Adamsen and Whitty, 2013). In case 1, the study objects (which can be an attribute or profile of choice) are presented to the individual, and the individual must choose the best and the worst object. In case 2, profiles of choice are presented to the individual, one at a time, and the individual must choose the best and worst attributes within each profile. In case 3, the attributes are grouped into a product or service, and several profiles of choice are presented to the individual. Respondents must choose between the best and worst profiles, extending traditional discrete choice experiments (Flynn, 2010).

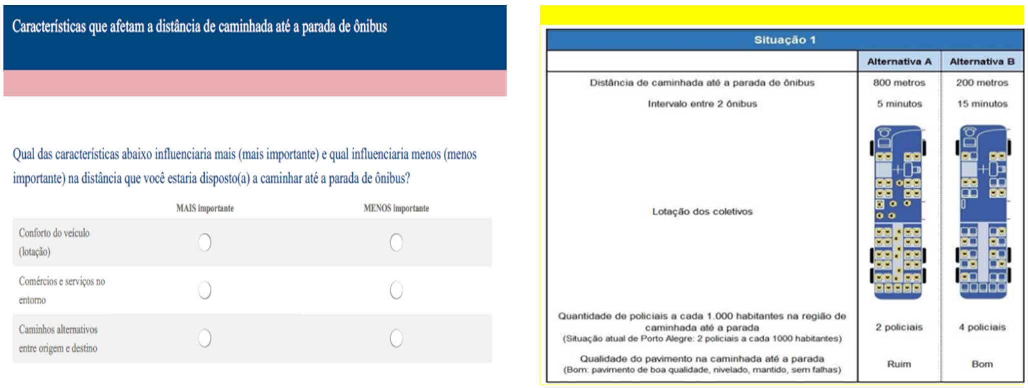
In this work, the Object case (case 1) was used to identify the most valued attributes for the walking access to bus stops. We identified nine attributes based on a literature review (Alshalalfah e Shalaby, 2007; Daniels, 2013; El-Geneidy et al., 2009; Kimpel et al., 2007; Larranaga et al., 2014; 2018; Murray and Wu, 2003; Zhao et al., 2003). Then, we elaborate an experimental BIBD (Balanced Incomplete Block Design) project (project suitable for best-worst data case 1, see details in Louviere et al. 2013), and a research questionnaire was developed. Table 1 present the attributes selected and included in the experimental design.

Table 1 – Attributes used in the B / W survey

	Attribute	Specification
	Headway	Time interval between buses
	Capacity	Degree of bus capacity
Features of service	*Connectivity*	Road connectivity around the stop used - few or many alternative ways to get from an origin to a destination
	Slope	Sidewalk slope
	Public security	Pedestrian safety sensation around the public transport stop concerning crime
	Quality	Quality, construction, and maintenance of the sidewalk
	Amenities	Quantity and quality of stores and other services around the bus stop
	Attractiveness	Visual and aesthetic aspects of the environment, such as building quality and sidewalk cleanliness
Features of the built and natural environment	*Traffic safety*	Risk of traffic accidents, risk of being run over.

Groups combined the attributes into three, based on the BIBD experimental project, totaling 12 choice sets presented to the interviewee. Figure 1a illustrates an example of one of the scenarios.

The best-worst questionnaire contains two sections: (i) personal characteristics and characteristics of the trip (age, gender, usual trip, trip purpose, and trip duration) and (ii) best-worst choices. The second section comprises the 12 choice scenarios obtained from the experimental design described above. The questionnaire was developed using Survey Monkey and released online through social networks and e-mail during October of 2016, resulting in 155 respondents.



(a) (b)

Figure 1. Examples of the choice situation in the questionnaire in Portuguese. Figure (a) Example B/W. Figure (b) Example SP

For each comparison set (the groups of three attributes), the interviewees chose the best and the worst attribute, determining order among the attributes presented in each choice scenario. Thereby, we exploded the classification responses in N-1 statistically independent choices (ranking explosion technique, Luce and Suppes, 1965) to consider the order explained in the answers. Then, data is ready for the multinomial logit models estimation.

The parameters were estimated using maximum likelihood techniques. We used the apollo package (Hess and Palma, 2019) available in the R. language. The effect of each attribute can be calculated as (Equation 1) (Larranaga et al., 2018):

$$Effect_m = \frac{\exp(A_m)}{\sum_j exp(A_j)} \tag{1}$$

Where A_m and A_j are the estimated parameters of the attributes in the choice set.

2.2. Determination of the relative importance and quantification of the trade-off between bus frequency and walking distance

A stated preference survey was developed based on the attributes selected in the previous step, complemented with an attitudinal survey. The SP survey was based on an efficient experimental design implemented in NGene (Choice Metrics, 2013). The goal of the efficient design is to obtain parameter estimates with standard errors as minor as possible (Rose and Bliemer, 2009). We used the initial values of the study developed by Rose et al. (2013). The D_error, measure of efficiency (calculated with the determinant of the variance and covariance matrix for only one individual) was equal to 0.193. D_error is used for comparing different designs and selecting the final design.

The experimental design comprised nine situations of choice presented to each interviewee. Four sets (blocks) of choice situations were generated (with nine scenarios each). Each one presented an interval between buses that the user usually experienced to provide realism to the experiment. The block presented to the respondents depends on their answer to the question: "What is, on average, the interval between two buses on the lines you use?"."Blocks averaging were set as 10, 15, 25, and 30 minutes. Each choice situation presented two alternatives of bus lines, asking the interviewee to choose their favorite. The context of the experiment was as follows: "Suppose you are going on a bus trip and need to walk to the bus stop. There are two stops that you can choose from. Both stops have bus services that take you to your destination, but the characteristics of the bus service and the walking route to the stop may vary. Which of the alternatives presented would you choose?"

Regarding the attributes that characterize the public transport service, we included *Headway*, which was directly related to the frequency of the service, and *Capacity*, which describes the capacity of the vehicles. Whereas, to characterize the walkability of the walking route to the bus stop, we included *Public security*, represented in the SP experiment as the number of police officers per 1000 inhabitants (Larranaga et al., 2018), and *Quality*, representing the sidewalk pavement quality. These attributes were shown to be valued by users in models with the best-worst data. In addition, the Walking distance to the bus stop attribute is related to the study's objective. Table 2 summarizes the attributes used and their levels.

Table 2 – Description of attributes and levels

Attributes	**Quantity of Levels per block**	**Levels**
Walking distance to the bus stop	*4*	200/400/600/800 meters
Headway (Interval time between two buses)	*3*	5/10/15 10/15/20 20/25/30 25/30/35 minutes
Capacity	*5*	40/70/100/130/160 % percent of people with the number of seats in the vehicle
Police officers (Number of police officers per 1000 inhabitants, public security indicator).	*2*	2/4 police officers
Quality (Sidewalk pavement quality)	*2*	1=bad/2=good

Figure 1b shows an example of a choice situation presented to the respondent. The questionnaire consisted of three sections. The first section included questions about the socioeconomic characteristics of the interviewees. In the second section, the nine scenarios of the SP research are presented. Finally, the third section completed the questionnaire with the attitudinal sentences. Four attitudinal statements were made, presented on a 5-point Likert scale (5: greater agreement with the statement): (i) "When I take the bus, I prefer to wait at the nearest stop than to walk to another stop" (*Stop preference*), (ii) "I like to perform physical activities" (*Physic_Activ*), (iii) "Whenever possible I go walking or cycling to perform my daily activities" (*Walk_Bic*) and "I prefer to climb the stairs instead of waiting for the elevator" (*Stairs*). The attitudinal questions sought to describe the interviewees' attitude towards a more or less active behavior concerning walking (*Inconvenience walking*). This second questionnaire was applied online, implemented with the Google Forms tool, and released through social networks.

The inclusion of attitudinal variables in the discrete choice models was performed by estimating integrated choice and latent variable models, combining the classical models of choice with the structural equations approach for the latent variables. In evaluating the attitudes of individuals, models of structural equations Multiple Causes and Multiple Indicators (MIMIC) were used, which in addition to testing a measurement theory, incorporate other observable explanatory variables as possible causes of latent variables and can lead to a better understanding of the choice process. The ICLV model followed the conceptual proposal by Ben-Akiva et al. (1999). The parameters were estimated through maximum likelihood estimation techniques, using the apollo package (Hess and Palma, 2019) available in the R language. In these simultaneous models, the latent variables and the choice models were estimated together by programming the likelihood function and employing numerical integration routines, resulting in consistent and efficient estimators. The model included systematic variations in preferences, estimating interactions between observed variables and attributes. In addition, we also modeled interactions between latent variables and the attributes included in the SP.

We calculated the impact of each attribute on the utility function (product of the mean value of the attribute and the estimated parameter) and the subjective value (SV) of different attributes, specifically between *Headway* and *Distance*. The SV represents the marginal substitution rate between pairs of attributes. It indicates the trade-off between attributes, measuring how much the respondents are likely to substitute one attribute for another, maintaining the same level of utility. Equation 2 present the for of the subject value calculation (Ben-Akiva and Lerman, 1985) (2):

$$SV = \frac{\partial U/\partial_a}{\partial U/\partial_b} \qquad (2)$$

where: $\partial U/\partial a$ = partial derivative of the utility function to attribute a;
$\partial U/\partial b$ = partial derivative of the utility function to attribute b.

3. SAMPLE STATISTICS

Table 3 shows the distribution of responses for the best-worst case 1 and the stated preference data.

Table 3 – Sample statistics

Data type		B/W data	SP data
Occupation	Private sector employee	17,4%	19,0%
	Public agent	18,1%	13,3%
	Student	60,6%	46,2%
	Retiree	1,9%	3,0%
	Housewife/housekeeper	1,9%	0,5%
	Self-employed/ Businessperson	-	13,6%
	Unemployed/Other	-	4,4%
Age	Less than 15 years old	0,0%	0,5%
	From 16 to 20 years old	21,0%	7,1%
	From 21 to 30 years old	54,0%	59,8%
	From 31 to 40 years old	4,0%	16,1%
	From 41 to 50 years old	4,0%	7,7%
	From 51 to 60 years old	13,0%	7,7%
	Over 60 years old	4,0%	1,1%
Gender	Female	49,7%	53,0%
	Male	50,3%	47,0%
Education level	Incomplete elementary school	-	0,3%
	Complete elementary school	-	0,3%
	Incomplete high school	-	1,1%
	Complete high school	-	3,8%
	Incomplete graduation	-	41,8%
	Complete graduation	-	19,9%
	Incomplete postgraduate	-	12,0%
	Complete postgraduate	-	20,8%

Table 3 – Sample statistics (continuation)

Data type		B/W data	SP data
Family income	Less than BRL 2000.00	-	16,0%
	Less than BRL 3000.00	14,2%	-
	From BRL 2001,00 to BRL 5000.00	-	37,0%
	From BRL 3001.00 to BRL 6500.00	23,9%	-
	From BRL 5001.00 to BRL 10000.00	-	29,0%
	From BRL 6501.00 to BRL 11000.00	27,1%	-
	From BRL 10001.00 to BRL 15000.00	-	9,0%
	From BRL 11001.00 to BRL 15000.00	16,1%	-
	More than BRL 15001.00	18,7%	9,0%
Residents per household	One person	7,7%	14,0%
	Two people	23,9%	32,0%
	Three people	31,6%	30,0%
	Four people	29,7%	17,0%
	Five people	7,1%	7,0%
Cars per household	None	20,0%	-
	One car	42,6%	-
	Two cars	30,3%	-
	Three cars	5,2%	-
	Four cars or more	1,9%	-
Number of bus trips per week	Less than five trips	-	36,4%
	5 to 10 trips	-	30,4%
	10 to 15 trips	-	24,5%
	15 to 20 trips	-	5,2%
	More than 20 trips	-	3,5%
The average interval between two buses on frequently used lines	Less than 10 minutes	-	21,3%
	10 to 20 minutes	-	54,4%
	20 to 30 minutes	-	18,0%
	above 30 minutes	-	6,3%
The usual time of travel by bus (more than one possible answer)	7 am to9 am	56,8%	-
	9 am to 5 pm	64,5%	-
	5 pm to 7 pm	49,7%	-
	After 7 pm	18,1%	-
The typical duration of bus trips taken (more than one possible answer)	Less than 15 minutes	28,4%	-
	15 to45 minutes	67,1%	-
	More than 45 minutes	25,2%	-

3.1. Best-worst survey - case 1

The B/W survey received responses from 155 public transport users. Regarding gender, the distribution was homogeneous, 50.3% men and 49.7% women. Regarding occupation, 60.6% declared to be a student. The extensive participation of students among those surveyed is due to the circle of dissemination of online research and social media for the application of research (proximity to the university). However, the sample also includes a diversity of occupations, like employees from the private and public sectors, which constitute significant portions of the population of regular public transport users. Most respondents use the public bus system on working days, for the purpose of studies mainly (64.5%), but also with relevant use for work (45.8%) and leisure (31%).

Regarding the usual duration of the bus trips, the trips have a predominant period of 15 to 45 minutes (67.1%). The research objective was to select, based on econometric techniques, the attributes to include in the SP experiment. This selection is usually made from qualitative research and/or literature review. In this way, the researched sample satisfactorily meets the research objective, providing diversity in the characteristics of the respondents.

3.2. Stated Preference Survey

A total of 366 users answered the questionnaire. 7% of respondents are between 15 and 20 years old, 59% between 21 and 30 years old, 24% between 30 and 50 years old, and approximately 10% over 50 years old. Regarding gender, 195 were women (53%) and 171 (47%) men, similar to the distribution of Porto Alegre in the last census survey. A large part of the interviewees (37%) declared a monthly family income between R$ 2,001 and R$ 5,000 and another significant portion (29%) between R $ 5,001 and R $ 10,000. Most interviewees usually travel 10 times per week, using the buses as a transport mode.

Regarding the average interval between buses on the lines that the respondent usually uses, 21% indicated headway less than 10 minutes, 54% between 10 and 20 minutes, 18% between 20 and 30 minutes, and 6% above 30 minutes. Data on public transport operation by bus in Porto Alegre (Prefeitura de Porto Alegre, 2021) show that the average headway in a working day (considering all lines and times) is 19 minutes.

4. RESULTS AND DISCUSSION

4.1 Elements that influence the perception of the quality and convenience of the bus service and walking access to the bus stop - Multinomial logit model results

Table 4 presents the results of the multinomial logit models estimated with the best-worst data, using the ranking explosion technique.

Table 4 – Results of the multinomial logit model with best-worst data (case 1)

Attribute	Effect (%)	Coefficient	Robust t-test	P-value
Attractiveness	2,0	0	-	-
Amenities	2,4	0,2	1,94	0,05
Connectivity	3,0	0,44	4,22	0
Slope	3,0	0,43	3,95	0
Headway	26,7	2,61	20,57	0
Capacity	7,2	1,3	9,48	0
Quality	2,4	0,21	1,96	0,05
Public security	46,2	3,16	22,88	0
Traffic Safety	7,1	1,29	12,01	0
Rho-square		0,238		
Number of individuals: 155		Nº observações: 1860		

The estimated models showed a satisfactory adjustment (Rho-square of 0.238), considering that values of 0.4 can represent good adjustments (Ortúzar and Willumsen, 2011). All attributes considered in the B/W experiment were significantly different from zero, considering a 95% confidence level (p-value less than 5%). *Attractiveness* was considered a reference attribute (necessary practice to guarantee the identifiability and estimation of the model). Thus, the estimated parameter values reflect the importance of each attribute under *Attractiveness*. The relative importance (effect) shown in Table 4 indicates that *Public Security* is the most critical attribute for the respondents (coefficient of 3.16). Studies in Porto Alegre already presented similar findings (Larranaga et al., 2014, 2018; Ruiz-Padillo et al., 2018) and seemed to reflect how the fear of crime affects the choices of individuals in the city. *Headway*, related to the frequency of the service, is the second most valued attribute by users, which corresponds to less waiting time at the stop. *Traffic Safety* and *Capacity* are also highly valued by respondents, followed by *Connectivity* and *Declivity*. The least essential attributes were *Quality*, *Amenities*, and *Attractiveness*. Considering the most critical attributes identified in the models, *Headway* and *Capacity* are the ones related to the quality of the bus service; and *Public Security* is associated with walkability. These three attributes represent 80% of the total effect. Thus, they were considered the ones to the SP. Additionally, *Quality* (quality of sidewalk pavement) was included. Although the impact of this attribute was lower than the other attributes previously presented, studies in Porto Alegre and other Latin American cities show the importance of including urban microscale characteristics in walkability studies (Arellana et al., 2020; Larranaga et al., 2018).

4.2. The trade-off between bus frequency and walking distance - Integrated choice and latent variable model results

Figure 3 shows the structure of the integrated choice and latent variable model, estimated from SP and attitudinal data. The results of the estimation are presented in Table 5.

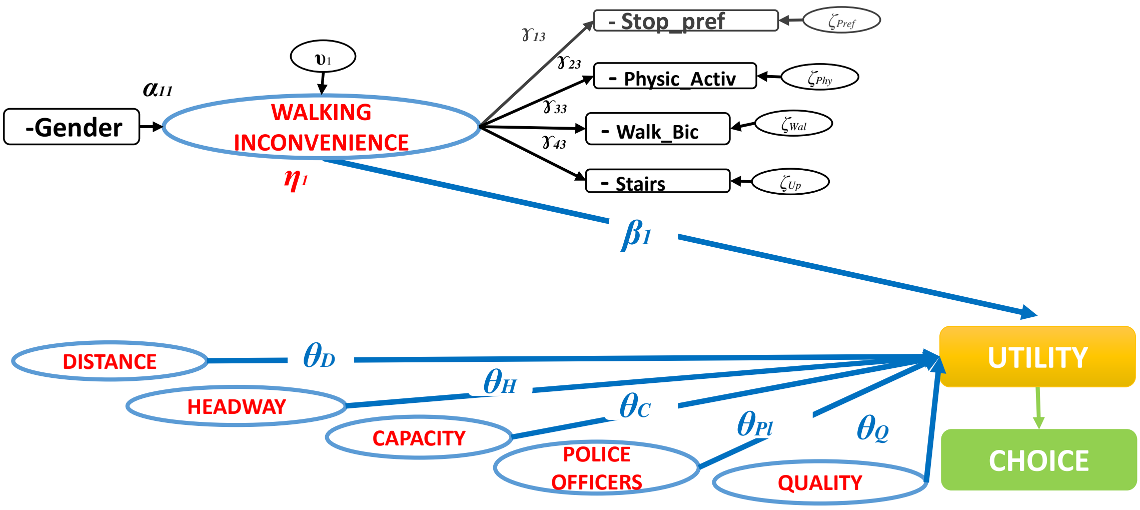


Figura 1. Structure of the integrated choice and latent variable

The parameters ϴi and βi are the parameters estimated. They represent the impact of the SP research attributes in the latent variable (η1) on the Utility function. The α11 represents the effect of the observable characteristic on the latent variable(η1). On the other hand, γi are the factor loadings of the latent variable indicators and νi and ζi error terms.

The attitudinal variables *Physic_Activ, Walk_Bic,* and *Stairs* were the indicators of the latent variable *Inconvenience to Walk* included in the MIMIC model. The positive sign of the estimated parameters shows that the more active the individual is (the greater the preference for physical activities, using a bicycle or walking for commuting and using stairs instead of an elevator), the greater the preference or perception of the convenience of walking (called in the model as "Inconvenience","so the use of negative signs in the indicators in the model structure shown in Figure 2). The variable *Stop_pref* was not statistically significant (95% confidence level). Among the different socioeconomic characteristics tested (income, age, education level, number of trips, duration of trips), *Gender* was the only one influencing the latent variable significantly. The explicit inclusion of these variables (attitudinal, socioeconomic) in the model allows a better representation of the behavior of choice, making it possible to estimate the parameters of the attributes included in the SP with greater precision.

Table 5 – Results of the integrated choice and latent variable model

Variable	Coefficient	Robust standard error	Robust t-distribution
Constant_alt1	0.095	0.045	2.096
Constant _alt2	0.000	NA	NA
Distance (m)	-0.002	0.000	-13.426
Headway (min)	-0.104	0.008	-12.398
Capacity (nº)*	-0.015	0.001	-14.368
Police officers (nº)	0.196	0.026	7.560
Quality (1:bom, 0:ruim)	0.205	0.048	4.237
Walk Inconvenience x Distance	0.001	0.000	2.030
Walk Inconvenience x Headway	-0.019	0.012	-1.652
Walk Inconvenience x Capacity	-0.004	0.002	-2.299
Gender	-0.541	0.156	-3.467
Physic_Activ	0.941	0.220	4.273
Walk_Bic	0.924	0.203	4.548
Stairs	1.722	0.313	5.500
tau_ Physic_Activ _1	-2.994	0.258	-11.599
tau_ Physic_Activ _2	-1.869	0.194	-9.653
tau_ Physic_Activ _3	-0.400	0.143	-2.796
tau_ Physic_Activ _4	1.060	0.160	6.635
tau_ Walk_Bic _1	-1.781	0.193	-9.239
tau_ Walk_Bic _2	-0.869	0.158	-5.497
tau_ Walk_Bic _3	0.058	0.141	0.413
tau_ Walk_Bic _4	1.066	0.154	6.933
tau_ Stairs _1	-2.998	0.370	-8.095
tau_ Stairs _2	-1.562	0.266	-5.862
tau_ Stairs _3	0.386	0.208	1.856
tau_ Stairs _4	1.938	0.275	7.049

Nº individuals: 368 Nº observations: 3312 LL (final, entire model): -3310.017 AIC: 6668.03

* Capacity is expressed in total value (Ex:40, 100, 130), representing the percentage of people concerning the number of seats in the vehicle.

Average values of the attributes: Distance =466,67 m; *Headway* =16,7 min; *Capacity*=93.3; *Police* officers =2,89; *Quality*=1,44

The attributes *Distance, Headway* and *Capacity*, presented a negative sign. On the other hand, the sign was positive to *Police officers and Quality*. The results show, as expected, that the users' reference (utility) for a bus stop decreases with an increase of the walking distance to the bus stop, an increase in the interval between vehicles, and an increase in vehicle capacity. It also increases with the more significant number of police officers around the bus stop and better quality of the sidewalks on the walking route to the bus stop. Users tend to minimize walking distance, waiting time, and vehicle capacity, maximizing public security and pavement quality in the surroundings. The interaction of the latent variable (*Walking Inconvenience*) with the previous attributes (*Distance, Capacity* and *Headway*) indicated that users with less active behavior (less/more convenience/inconvenience for walking) are more sensitive to an increase in the walking distance to the stop, less sensitive to vehicle capacity and less susceptible to increases in vehicle spacing. They are willing to walk less, use more crowded vehicles and expect more time than users with more active behavior.

Comparing the impact of the attributes, carried out using the product of the estimated coefficient and the average value of the attribute shown at the bottom of table 5, it is possible to see that *Headway* (1.74) presented the greater value, followed by *Capacity* (1.40); *Distance* (0.93); *Police officers* (0.57) and *Quality* (0.3). The subjective value of the attributes (Equation 2) provided the marginal substitution rate between pairs of attributes, allowing the calculation of the willingness to move forward to improve the quality of the service. In the case of linear utility functions in the parameters, the subjective value is simplified to the ratio between the coefficients of the analyzed attributes. Therefore, the results showed that users are willing to walk 520 meters to reduce the interval between vehicles by 10 minutes (waiting time), 375 meters to reduce vehicle capacity by 50%, 98 meters to increase the number of police officers in 1 unit, and 100 meters to increase the pavement quality of the sidewalks (bad to good conditions). Also, the trade-off calculation between *Headway* and *Capacity* shows that users are willing to wait 7.2 minutes to reduce the vehicle's capacity by 50%.

5. CONCLUSIONS

The study showed that users of bus services are willing to walk more to obtain a service more frequently. Best-worst scaling stated preference (SP) and attitudinal data were collected in Porto Alegre, and integrated choice and latent variable models were estimated.

The results obtained reveal that users in Porto Alegre are willing to walk 520 meters to reduce the waiting time by 10 minutes, a higher value than reported in Australian, American, and UK cities. The Australian results presented values of 226 m and 302 m for a 10-minute reduction in waiting times for the bus, and in the UK and the USA, the reported distance was between 370 m and 475 m for the same reduction in waiting time (Mulley et al., 2018, Rose et al. 2013). The different conditions of the built environment and walkability possibly impacted the individuals' perception. The quantification of the trade-off in the Brazilian context brings indications of possible political implications for the planning of the transport network, showing the possibility of increasing the distance between stops in exchange for an improvement in the quality of service. In this way, a policy of concentrating buses on corridors prevails over a coverage policy, consistent with finds from other contexts.

Further studies that consider the estimated parameters concerning the sample or that analyze the willingness of users to walk to different segments of the sample could contribute to comparing the results in different strata. The inclusion of attitudinal factors improved the representation of human behavior in the choice process, reducing the risks related to endogeneity problems, which omitted variables can generate. The omission of attributes relevant to the choice behavior produces aimed to avoid biased results.

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