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Research Article

Bus design configuration for the elderly: a case study in a mega city (São Paulo, Brazil)

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Abstract

Paper aims: This article identifies and discusses the barriers older adults face when using internal bus elements, which affect providing a safe, accessible, and desirable service, aiming to improve their commuting experience and quality of life.

Originality: By integrating qualitative approaches with aging simulation kits, this study provides new insights into the barriers users face in an aging developing city, emphasizing the influence of cultural attitudes, vehicle design, and service features.

Research method: An exploratory qualitative approach was used, involving simulation with an aging kit, semi-structured interviews, questionnaires, real-time observations, and postural risk assessments. Data were collected from 75 autonomous bus users aged 60 and over.

Main findings: The study reveals that the primary barriers for older adults using bus services are linked to vehicle design, service characteristics, and societal attitudes towards aging. Significant postural issues were identified during vehicle entry and exit, the use of priority seats, the height of horizontal handles, and interaction with turnstiles.

Implications for theory and practice: The findings highlight the need for bus design and service provision improvements to accommodate older adults better. These insights can inform future transportation policies, design standards, and training programs, enhancing safety, accessibility, and overall quality of life for elderly commuters.

Keywords:

User-centered design. Public transport. User experience. Older people. Developing countries.

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Conflict of Interest
The authors declare that they have no conflict of interest.

Ethical Statement
This study was conducted in accordance with Brazilian legislation regarding research involving human participants. All participants were fully informed about the study's objectives, procedures, potential risks, and benefits before their participation. Each participant voluntarily signed an Informed Consent Form, ensuring their understanding and agreement to take part in the research. The study adhered to ethical principles established by Brazilian regulations, particularly those outlined in Resolution No. 466/2012 of the National Health Council (*Conselho Nacional de Saúde*). The researchers ensured that participants' rights, confidentiality, and well-being were safeguarded throughout the study.

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1. Introduction

The world population is aging. This phenomenon stands a challenge to all countries (United Nations, 2019) due to the increase in social and economic demands (Fisk et al., 2009) and has a significant repercussion on economic growth, transport, labor market, trade, migration, disease patterns and fundamental assumptions about growing older (Bloom et al., 2010; Lunenfeld, 2002). The impact of population ageing is expected to be greater in developing countries, where there will be less time to adjust to the consequences of demographic change (United Nations, 2015).

Public transport is one service identified as being significantly relevant for the elderly's health (World Health Organization, 2002). It is key to their independence, continuous mobility, and essential for community participation, social and daily activities (Fisk et al., 2009; Marottoli et al., 2000). In contrast, an inadequate transport system can result in social isolation and lack of mobility, which are associated with poor health, depression, loss of autonomy and lower quality of life (Davey, 2004; Fisk et al., 2009; Mackett, 2015; Wong et al., 2017). Thus, a major question remains on how to address the mobility needs for the elderly according to their lifestyles, preferences, resources, health, and abilities (Cui et al., 2017) in order to improve their experience, mobility, quality of life and support active ageing.

The ageing process involves drastic changes in abilities and occurs differently from individual to individual (Fisk et al., 2009). Overall, physical, cognitive and sensorial abilities tend to decline with ageing (Kroemer, 2005, 2006). The design of many products, services and environments disregard the implications of this process and are not well suited to older people's abilities, limitations and needs, which result in exclusion. Moreover, the transport system tends to promote the mobility of those who are physically agile and have the cognitive skills necessary to navigate sometimes-unpredictable transport provision (Corran et al., 2018; Freund, 2001). Therefore, it is necessary to create a transport system adapted to the needs of the elderly. The importance of promoting mobility emerges, resulting from a process of inclusion of this population segment (Aguiar & Macário, 2017).

The World Health Organization (World Health Organization, 2007) highlights specifically how services such as transport have difficulties meeting the needs of senior citizens. Particularly, the bus system, and although it supplies most of the transport demand in developing countries, especially in most cities in Latin America (Development Bank of Latin America, 2011), it is precarious and characterized by irregular, unreliable, unsafe and uncomfortable services (World Health Organization, 2007). It does not guarantee accessibility, coverage, or a quality service (Martínez Ortega, 2012) and despite the potential benefits that may present, there exist barriers related to the usability for all passengers, especially for the elderly (Broome et al., 2009). Thus, a major question remains on how to address the mobility needs for the elderly according to their lifestyles, preferences, resources, health, and abilities (Cui et al., 2017) in order to improve their experience, mobility, quality of life and support active ageing.

The literature reveals different factors and features of the transport system that affect the travel experience of the elderly and can act like facilitators or barriers. These aspects are related to: architecture of the physical environment (Law et al., 1996; Strong et al., 1999), such as bus design (e.g. handrails, steps, floor, bus interior) (Aceves-González et al., 2015; Barnes et al., 2016; Broome et al., 2009) or external architecture (e.g. sidewalks, bus stops, roads) (O'Hern & Oxley, 2015; Wong et al., 2017; Zeitler et al., 2012) institutional environment, that includes the bus services themselves (e.g. reliability, speed, capacity, scheduling, ticket cost) (Truong & Somenahalli, 2015); cultural environment and social environment (Boniface et al. 2015). Despite the efforts on the topic, most of the studies have been conducted in the developed world, leaving few studies that address the barriers related to urban bus usability problems in the developing world (Aceves-González et al., 2016). That might explain the mismatch between what transport organizations offer and the experience of using the bus within the developing world.

Among the factors and features of the transport system, the physical environment, which combines the components that can only affect usability of bus design (Broome et al., 2009), reveals issues related to the inadequate configuration of the internal elements of the bus, that is, its location and distribution in space. Furthermore, improving vehicle design is a major concern to promote safety, mobility and quality of life of the elderly. However, the applicability and level of impact is still a debatable issue within the academic community (Aguiar & Macário, 2017). Moreover, there is a need for more objective measures which could be integrated with the observational findings to elicit a fuller understanding of older persons' experience that might be translated to a better bus design, particularly with respect to physical demands (Aceves-González et al., 2015). Therefore, there exists the need of more detailed knowledge about barriers faced by the elderly during bus use, to have more understanding of their needs and their experience.

Thus, this paper aims to identify and discuss the barriers that older adults face in the use of internal elements of the bus that interfere with the provision of a safe, accessible, and desirable service, to contribute to improving the bus design and promoting a better commuting experience and quality of life. To do so, we conducted a case study in São Paulo City, in the urban bus system routes that circulated the region of *Armando de Salles Oliveira University City*, where the University of São Paulo's main campus is located. We implemented real-time observations, semi-structured interviews, questionnaires, and postural assessments using the Working Posture Analyzing System (OWAS).

2. Service context

Brazil is experiencing among the fastest demographic ageing worldwide, a trend that will accelerate during the 21st century (Instituto Brasileiro de Geografia e Estatística, 2018; United Nations, 2015). Within the ageing context in Brazil, the concern for a transport system that is accessible, desirable, safe and adapted to passenger's needs emerges (Lima-Costa et al., 2018). The bus service represents the main mode of public transport and plays an important role in mobility, mainly in urban areas, where it operates in 85% of the municipalities across the region (Instituto de Pesquisa Econômica Aplicada, 2011). Specifically, in the city of São Paulo, the bus service plays an important role for its citizens among other transport modes available. As is shown in Figure 1. Collective transport is responsible for 33% of the total of daily trips, of which 75% of daily trips are supplied by the bus system (Development Bank of Latin America, 2011).

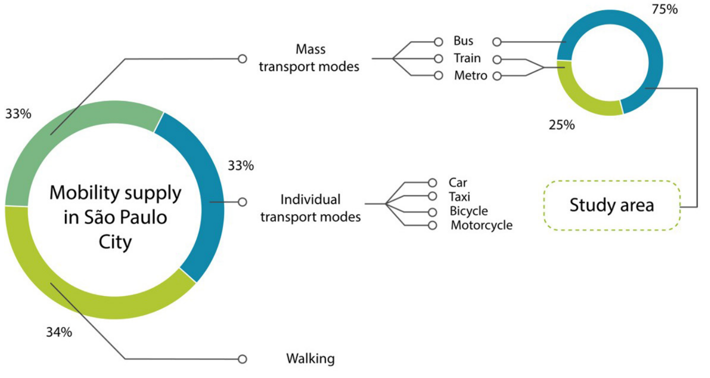


Figure 1. Travel distribution by mode of transport: adapted from The Development Bank of Latin America (2011). The figure depicts the percentages of daily trips made by each transport mode available in the city of São Paulo.

The study was conducted in the urban bus system routes in the University of São Paulo campus. Three different bus types circulated the campus: high-floor bus, front low-floor bus, and articulated bus (Figure 2). These bus configurations have different layouts, entrances, and capacities (see Figure 3).

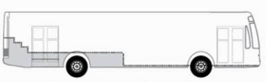
Bus type	Exterior	Route number	Route name
 High-floor bus		7181-10 7725-10	Terminal Princesa Isabel-Cidade Universitária Terminal Lapa-Rio pequeno
 Front Low-floor bus		8012-10 8022-10 702U-10 177H-10 809U-10 7411- 10	Metrô Butantã-Cidade Universitária Metrô Butantã-Cidade Universitária Terminal Parque dom Pedro II-Butantã USP Metrô Santana-Butantã USP Metrô Barra Funda-Cidade Universitária Praça da Sé-Cidade Universitária
 Articulated		701U-1	Metrô Santana-Butantã USP

Figure 2. Types of buses and route lines that served the campus.

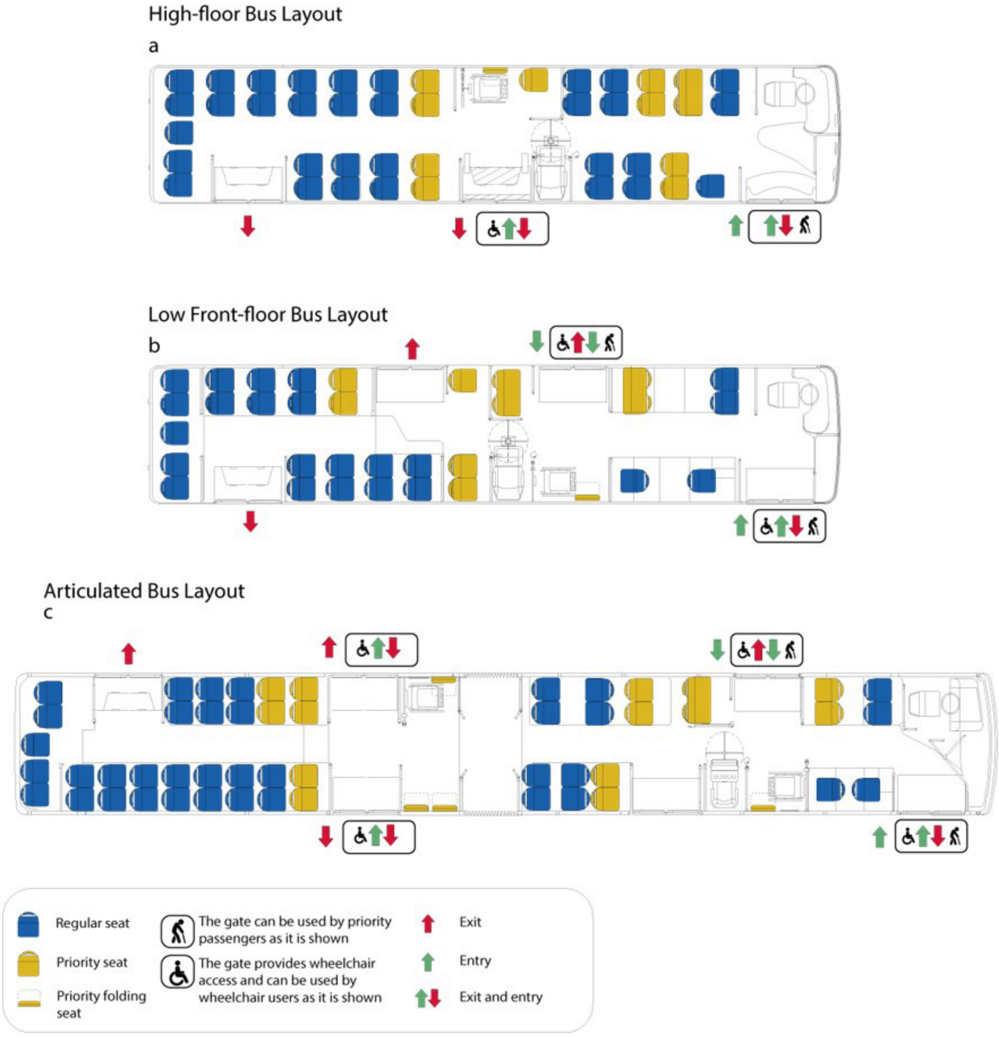


Figure 3. Layout from each bus type present in the campus: The image depicts the entrances and exits for older adults and wheelchair users, number and distribution of regular and priority seats, some divisions and handlers. By law, older people and other priority passengers can alight from the main entrances at the front of the bus (see b and c).

3. Material and methods

This exploratory study employed a qualitative approach, as outlined by Yin (2003), to address the main objective of understanding the barriers faced by older adults in bus systems. Qualitative research is particularly suited for exploring complex real-world phenomena, as it allows for an in-depth investigation of participants' lived experiences and the contextual factors influencing their interactions with the environment (Creswell & Poth, 2018; Denzin & Lincoln, 2018). This approach is ideal for understanding how older adults perceive and navigate the design and service aspects of buses, where diverse social, physical, and cultural factors interplay.

A case study design (Creswell & Poth, 2018; Stake, 2005) was employed, incorporating multiple qualitative data collection instruments to capture a comprehensive understanding of the users' experiences. The methodology consisted of three key stages:

1. **Semi-structured interviews:** Interviews were conducted to elicit personal experiences and perceptions of bus usage among older adults. This method is particularly effective for exploring subjective realities, allowing participants to articulate their challenges and perspectives in their own words (Kvale & Brinkmann, 2009). Such an approach provides nuanced insights into the participants' interaction with the physical environment and service characteristics of buses.

2. **Real-time observations:** Observations were used to contextualize participants' interactions with the bus environment in situ. This method is critical for understanding user behavior and identifying unarticulated challenges that may not surface in interviews, such as difficulties with navigating bus entrances or using support handles (Angrosino, 2007). Observational data also provide a rich description of the physical and social context, which is vital for designing user-centered solutions (Spradley, 1980).
3. **Postural assessments:** The Working Posture Analyzing System (OWAS) was applied to evaluate the physical challenges and ergonomic risks faced by older adults while using bus elements. This method allows for systematic assessment of postures and movements, highlighting areas where physical strain occurs (Karhu et al., 1977). Such assessments are particularly relevant for identifying design shortcomings that exacerbate physical barriers for elderly users (David, 2005).

3.1. Research immersion

During the early phase of the study researchers used an age simulator suit as a complementary tool to provide an understanding of age-related changes on physical and sensorial functions and experience how capability loss may impact the experience of bus use (Zavlanou & Lanitis, 2019). Age simulator suits are wearable equipment that allows designers and developers to experience age-related capability loss (Goodman et al., 2007) by artificially immobilizing parts of the human body, modifying the perception by the use of ear plugs and specially designed glasses as well as restricting movement and agility by using inflexible suit materials (Breiner et al., 2011) – see Figure 4.

Figure 4. Ageing simulation kit experience.

The age simulator suit was used to help the researchers to immerse within the urban bus system context, empathize with the older user and identify possible barriers related to bus configuration and any aspect of the service that may be problematic for them (Fisher & Walker, 2014). Age simulator suits are wearable equipment that allows designers and developers to experience age-related capability loss (Gonzalez Bolivar et al., 2018) by artificially immobilizing parts of the human body, modifying the perception by the use of ear plugs and specially designed glasses as well as restricting movement and agility by using inflexible suit materials (Breiner et al., 2011) – see Figure 4. Some studies present the benefits of age simulation suits as a desirable support tool to put younger students, designers and researchers into the elderly perspective (Breiner et al., 2011; Fisher & Walker, 2014; Gonzalez Bolivar et al., 2018; Hitchcock et al., 2001).

The session was performed with 3 researchers, two men and one woman of ages ranging from 21 to 24 years old. The participants were asked to wear the ageing simulation kit and to execute the following tasks in the university city: walk to the nearest bus stop; board the bus; travel and alight at the previous bus stop; walk back to the starting point. Photos were taken and participants shared their experiences after task conclusion.

During immersion, it was observed that within the campus, there is only one type of collective transport - the urban bus. Three different bus types that circulated within the campus were identified: high-floor bus, front low-floor bus and articulated bus. Figure 2 depicts these three different bus configurations offered by the city's transport system. These bus configurations have different layouts, entrances, capacities and sizes (see Figure 3) that can affect differently their experience.

3.2. Interviews and questionnaire

A semi-structured interview (Davey, 2007) and a questionnaire (Ipingbemi, 2010) were implemented with 75 elderly participants (*n*=75) between 60 and 86 years old, the majority was female (75.5%). All participants were bus service users and 61% used the bus service more than one day a week. Table 1 summarizes the participants' characterization.

Table 1. Interviewed participants characterization (*n*=75).

Variables		
Age (Years)	Mean	67.2
	Range	60-86
Sex	Male	26.7%
	Female	73.3%
Use frequency	Always (Every day)	36.0%
	Frequently (4-6 days per week)	12.0%
	Occasionally (1-3 days per week)	14.7%
	Rarely (1-3 days per month)	37.3%

The participants were part of the Open University for Senior Citizen, a program from the University of São Paulo that offered education to older people in several areas of knowledge (PRCEU, 2014). They used the bus primarily to travel to their class locations and use other services on the campus. The group was reached inside the campus at the facility of the Pharmacy of the University of São Paulo (FARMUSP), where they took some lessons from the university's program. FARMUSP was an institution associated with the university's pharmaceutical faculty, which offered different health assistance services and physical and sporting activities for the elderly. Also, it operated as an education center where older people took health-related classes. Its services and premises, oriented towards older people, made FARMUSP a focal point of interest and gathering for this population within the campus.

After the first meeting with the group, they were interviewed and were invited to answer a questionnaire. The activity was programmed with each participant and was carried out on the campus; the time for each one-on-one session was between 15 to 30 minutes. The interview was focused on identifying key aspects of their experience using the bus. Thus, the interviewers were asked about what features from the bus configuration and what internal elements they like. Furthermore, it was inquired about the difficulties that they face when using the bus service. Concerning the questionnaire, we aimed to determine the participant's preferences when using the services. The questionnaire inquired about the bus use frequency, routes used to get to the University and the existing configurations (front low-floor, high-floor, or articulated) preference. In addition, a general characterization of the user was made (*i.e.,* gender, age, etc.). Finally, each participant who voluntarily agreed to contribute signed a consent form. The study was oriented to the experiences that comprehend boarding, traveling, and alighting (see Figure 5).

Stage	Activities
Boarding	• Climbing • Using grab bars • Estabilize
Travelling	• Walking along the gangway • Using Handrails and stanchions • Travel registration • Selecting a seat • Using priority seat
Alighting	• Pressing a bell button • Identifiying a bus stop • Standing up • Moving to one of the exits • Using Handrails and stanchions • Descending step(s) • Alighting

Figure 5. Scheme of activities, according to stage.

This is because we wanted to focus on identifying the barriers and facilitators that interfere with the experience when using the bus and the internal elements of the vehicle. Thus, data about their commuting experience and aspects of bus service during these specific travel stages and vehicle design were collected, registered, and analyzed.

Interviews were qualitatively analysed and discussions with research team members supported the analysis. The interviewers' opinions were transcribed and organized by the different travel stages; the barriers identified by the participants were attributed to the elements of the vehicles or bus service characteristics. The interviews pointed out two lines most preferred by the elderly: routes 8012-10 and 8022-10, which were front low-floor. As mentioned in section 3.1, layout differed from each bus type, therefore,-this study focused on these two routes.

3.3. Observations and postural assessment

The first part of the fieldwork entailed real-time observations of the bus use in real situations. During this phase, photos and videos of the activity were taken and an interview with the participants was carried out after each observation. As a result, 3 main stages were analysed: boarding, travelling and alighting as described in figure 5.

The observations had the following objectives: understanding older passengers' behaviour when using the bus, analysing the stages involved in the use situation and observing and collecting data for the postural assessment phase.

The data were collected over 3 weeks and the observations were made during the routes 8012-10 and 8022-10, identified as the most used routes by the interviewees. A total of nine adults (n=9), 2 men and from ages ranging from 60 to 79 participated in observations and postural assessment. We escorted each participant during a routine journey starting from a bus stop within the university campus that was in his/her travel program to the final bus stop destination. During the video recording, three cameras followed the participant on their journey. The cameras were at 1-2 meters, and move as the user did, maintaining the distance, and were situated at different angles to capture the sagittal and frontal plane of the participant. Each trip lasted approximately 40 minutes on average. Passengers also carried personal belongings for their daily activities (i.e., bags, bum bags, backpacks, sunglasses, caps). Observations were carried out during periods of high, medium, and low vehicle crowding, between 9 a.m. and 5 p.m., the time where most elderly passengers are present. The weather during observations was mostly dry and sunny.

The second phase entailed the postural assessment phase. We analysed video recordings from the users (n=9) that participated from the first phase to determine which stage is the most critical and represents a risk factor for the older adult. The main objectives of this section were to analyse the causes of the most demanding positions adopted along the stages and to identify the postural risks that passengers may present and require an intervention.

We used the software Kinovea™ (Kinovea, 2022) to aid the video analysis process (Figure 6). Kinovea™ is an open-source program for the analysis, comparison, and evaluation of human motion (El-Raheem et al., 2015). The features of the digital tool comprehend video processing, movement tracking, human model (mannequin), digital goniometer, measurement guides, among others. First, video recordings were analysed. The mannequin tool was used on videos to aid movement tracking and postural assessment. For that, anthropometric points were approximately located on the images of the participant's body, also a digital goniometer tool was employed in combination, to measure angles of extension and flection on legs, arms, necks, and back. A rail of captures from the video was extracted; photos were selected and categorized from the videos according to use stages and activities, as described in Figure 7. Finally, a postural assessment was conducted using the categorized images.

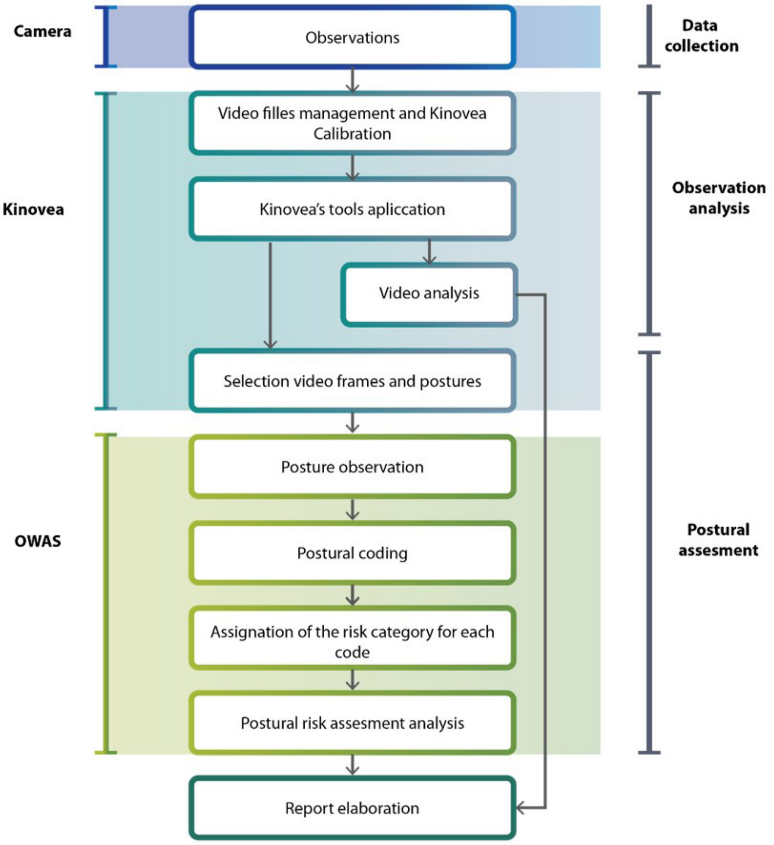


Figure 6. Research flow diagram for observations and postural assessment. Tools used during the research process are displayed on the left.

Figure 7. Visualization, tracking, image transformation, and measurement digital tools feature by Kinovea version 0.9.5 for postural assessment.

To identify the postural risks, the ergonomic evaluation tool OWAS (Karhu et al., 1977), that enables assessing the postures adopted during an activity, was used. This method allows the classification of the postures observed in 252 possible combinations according to the position of back, arms, legs and manipulated load; to each posture identified, a posture code is given, from which a category of risk is associated (Goodman et al., 2007; Zavlanou & Lanitis, 2019). This tool was chosen because its focus on health, safety and discomfort (Karhu et al., 1977).

4. Results

4.1. Interviews and questionnaire

We identified that the route choice is related to the bus type configuration. Figure 8a shows the preferred bus type (front low-floor: 78%), in contrast, the articulated bus (7%) and the front high-floor bus (2%). This matched with participants' route preference, where routes identified by the numbers 8012-10 (35%) and 8022-10 (35%) were preferred by the elderly (Figure 8b), both routes featuring low-floor vehicles. The low-floor vehicle had no steps, reducing the height between the bus deck and the sidewalk, but could lower the entire bus providing an even lower entrance. According to the participants the front low-floor bus configuration provides less effort when boarding the vehicle, providing a more accessible and safe use in comparison to the high-floor bus. Overall, the participants reported having a better experience using the front low-floor bus configuration.

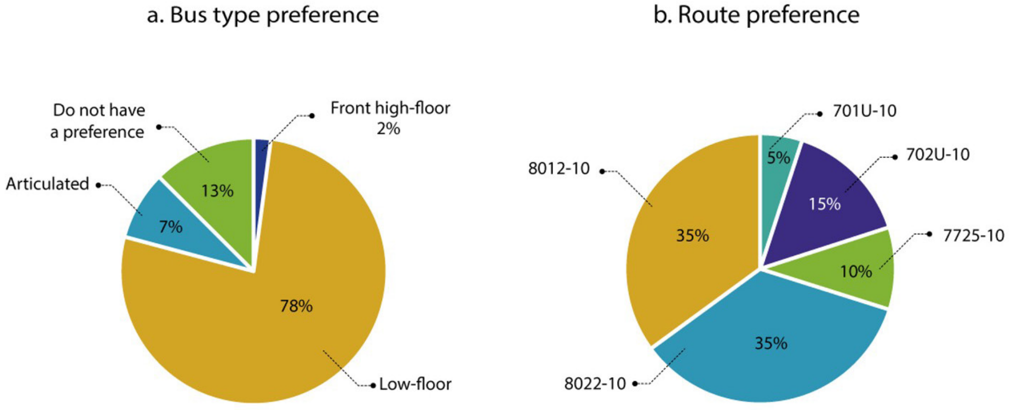


Figure 8. Bus and bus route preference questionnaire results.

The interviews revealed that the bus route were definitive for choice making for 8012-10 and 8022-10. Both routes provide a connection with metro stations and are connect the main interest locations within the campus.

During interviews, users manifested unconformities related to the elements of the internal configuration during the boarding, travelling and alighting stages. Table 2 exemplifies some participants' opinions and the barriers identified by each travel stage related.

Table 2. Identified barriers during use for each stage: Assertions made by some participants during interviews.

	Identified barriers	Participant's opinions
Boarding	• The space between the bus deck and the sidewalk represents a difficulty when entering the vehicle.	"Sometimes there is a lot of space between the sidewalk and the bus, and it is very difficult to get on without having an accident."
	• The height at which the door grab handlers are located impose a difficulty for those who cannot reach them,	
Travelling	• The stanchions represent a barrier when moving within the bus because they consider that the number is insufficient and that the handrails are located at a height that is not accessible to all users	"I am tall, and it is not difficult for me to reach the handrails, but I think it would be better if the supports were lower for people who are 1.60 or 1.50m and cannot reach them."
	• Hanging straps do not provide enough stability. • The priority seats have a negative impact on their experience of use for different reasons, among which they mentioned the presence of stairs to enter them and the location of some on the wheels of the bus.	"There are buses that have seats located on the wheel and it is very difficult to sit on them and on occasions when there are no more available, we are forced to climb the steps to sit down, and it is very difficult to use"
	• The folding seats are difficult to use. • There was evidence of disagreement with the number of priority seats, since they consider that there are not enough, a problem that is aggravated by the lack of education of younger users who occupy them and do not transfer them. • There is a preference in users to use the seats that are located near the entrances because of the ease of sitting in them in situations where the bus is very full and because they consider that going through the turnstile represents a difficulty.	"There is not enough space to pass the turnstile, there are people who have a cane and cannot pass, for me it is very difficult, so when there are no chairs in the front of the bus, I prefer to stay standing."

Table 2. Continued...

	Identified barriers	Participant's opinions
Alighting	• Getting off the bus is difficult for some users, due to problems related to the conditions of the sidewalk • There is a great distance between the platform and the bus, it represents a difficulty	"Getting off is very difficult because there are sidewalks that are damaged and have holes. I think there should be a platform where people get off and there are no risks regarding the conditions of the platform"

4.2. Observations and postural assessment

Boarding stage: from the moment that the user is waiting for a bus, then climbs a step and get in the bus, as shown in Figure 9. The user interacted with external elements such as the bus stop, the status of the platform and with bus elements such as the door supports and the vehicle floor.

Figure 9. Boarding stage sequence: images a-e are part of the photographic evidence taken from observations with a participant during boarding stage. Images a.1-e.5 depicts the images treatment using software Kinovea for analysis and postural assessment.

Boarding postural assessment: During this stage it was observed that the user presents a postural requirement for legs, arms and back (see Figure 9). From the observations made for the boarding stage, it was identified that the most demanding posture for the user is adopted at the exact time of entering the bus. As Table 3 shows, the most critical posture was coded (Figure 10, image b and c) for a risk level 4 corresponds, which means that according to the OWAS method, the posture has extremely harmful effects on the muscular and skeletal system. In this case, corrective action is required immediately.

Table 3. OWAS postural coding results for climbing stage.

Stage	Body part	Code	Postural description	Risk
Climbing	Back	3	Twisted	4
	Upper limbs	3	Both limbs above shoulder level	
	Lower limbs	5	Standing unbalanced with both limbs bent	

Figure 10. Demanding postures at boarding stage.

The travelling stage corresponds to the journey experience inside the vehicle, which is from the moment at which the passenger has already boarded the bus until the moment before alighting. It is the stage with the longest duration of the entire bus use (See Figure 11).

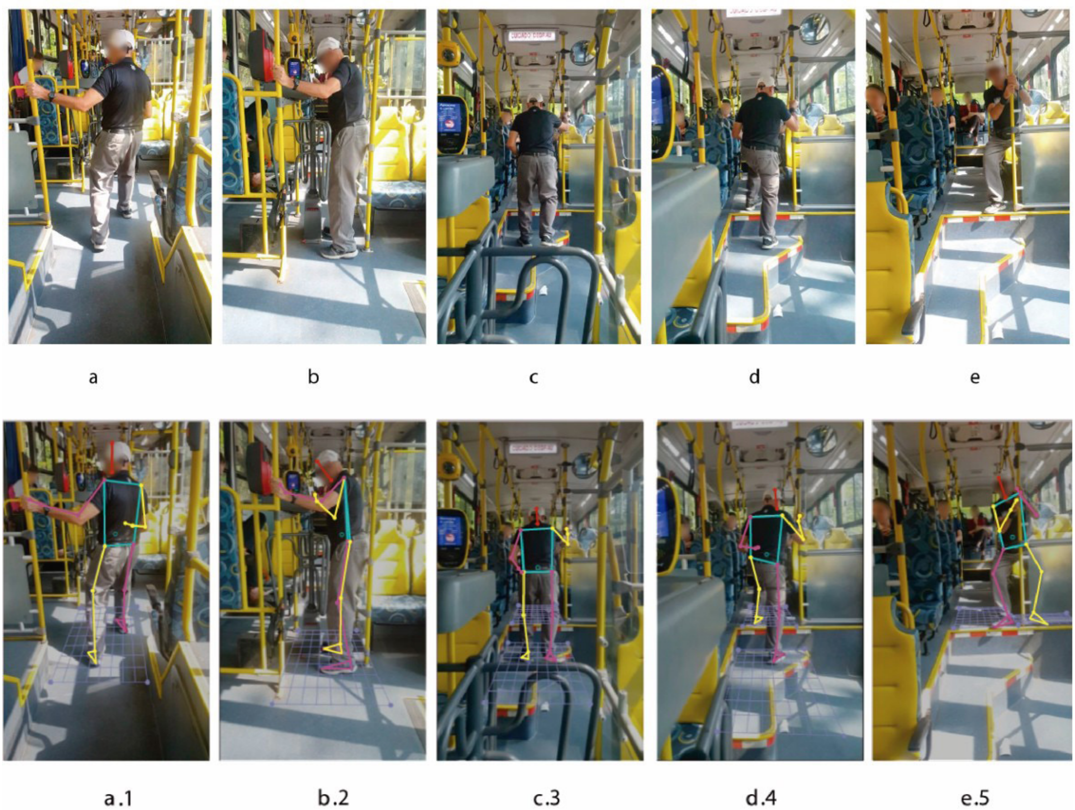


Figure 11. Travelling stage sequence: images a-e are part of the photographic evidence from observations with a participant during the travelling stage. Images a.1-e.5 depicts the images treatment using software Kinovea for analysis and postural assessment.

For the registration of this stage, 3 main use situations were identified:

Situation 1: Registering the travel and not going through the turnstile: the user registers the journey with the *senior citizen card*, after this he/she stays in the front area of the bus without going through the turnstile and finally disembarks through the front door of the vehicle (low-floor part of the bus);

Situation 2: Registering the travel and going through the turnstile: the user enters the vehicle, then registers the travel with the *senior citizen card*, goes through the turnstile, then stands at the rear of the vehicle and alights through the rear door;

Situation 3: Not registering the travel and not going through the turnstile: the user enters and stays in the front of the vehicle, then presents his/her identity document to the driver and descends at the front of the vehicle.

Travelling postural assessment: the postural problems identified in this stage are related to the use of seats with stairs, the travel registration device and horizontal handles (see Figure 12)

Figure 12. Demanding postures at the travelling stage: images a-c are part of the photographic evidence from observations with 3 participants during the travelling stage. Images a.1-c.3 depicts the images treatment using software Kinovea for analysis and postural assessment.

From the travel stage observations, the most demanding postures for the user were identified (see Table 4). For the use of a seat with a step and the registration of the passage, the posture was coded (Figure 12, image a and b) which corresponds to a risk level found to be 2. This means that the posture adopted has the possibility of causing damage to the musculoskeletal system and corrective actions are required soon. On the other hand, for the use of horizontal handles (Figure 12, image c) the risk level found was 3, which means that the posture has harmful effects on the musculoskeletal system and that corrective actions are required as soon as possible

Table 4. OWAS postural coding results for the travelling stage

Stage	Body part	Code	Postural description	Risk
Entering	Back	4	Bent and twisted	2
	Upper limbs	1	Both limbs below shoulder level	
	Lower limbs	3	Standing with one limb bent	
Passage registration	Back	2	Bent	2
	Upper limbs	2	One limb above shoulder level	
	Lower limb	3	Standing with one limb bent	
Handrails usage	Back	2	Bent	3
	Upper limbs	3	Both limbs above shoulder level	
	Lower limb	3	Standing with one limb bent	

Considering the analysis carried out, it was identified that the main causes that user adopts these positions are using seats with steps and height of steps; location of the electronic payment machine and difficulty in using the register; handrails height; gangway width.

The alighting stage from the vehicle: it is understood from the moment the user requests the stop by using the bell and then goes to the door to descend from the vehicle. There are two ways to alight: through the back door for users who go through the turnstile and through the front door for those who do not go through it. The sequence of the activity corresponding to alighting through the back door is shown in Figure 13.

a b c d e f

Figure 13. Alighting stage sequence.

Regarding the problems at this stage, it was observed that the most demanding posture is when alighting through the back door (see Figure 13.c). This posture includes tilting or turning the back, head bent forward and flexed legs.

From the observations made for the alighting stage, it was identified that the most demanding posture for the user is adopted when alighting through the back door. The most critical posture was coded in Table 5, for which a risk level 4 corresponds (see Figure 14, image c) which means that according to the OWAS method, the posture has extremely harmful effects on the musculoskeletal system and that corrective actions are required immediately.

Table 5. OWAS postural coding results for alighting stage

Stage	Body part	Code	Postural description	Risk
Descending	Back	4	Bent and twisted	4
	Upper limbs	2	One limb above shoulder level	
	Lower limbs	5	Standing unbalanced with both limbs bent	

Figure 14. Demanding postures at the alighting stage: images a-e are part of the photographic evidence from observations with 5 participants during the alighting stage. Images a.1-e.5 depicts the images treatment using software Kinovea for analysis and postural assessment.

Based on the previous evaluation, it was possible to determine the risk level of the posture and considering the analysis, it was identified that the main causes for which the user adopts this posture are height of the steps; horizontal distance between the platform and the vehicle deck; height between platform / road and vehicle deck.

We summarized the bus use problems for the elderly users making a differentiation by tools where it was evidenced along the different journey stages (see Figure 15).

Stage	Identified Problem	Problems evidenced	
		Interviews	Observations
Boarding	Entrance steps	●	
	Height between the deck and the ground	●	●
	Spacing between the bus and the sidewalk		●
	Height of the entrance´s grab rails	●	●
Travelling	Distant preferential seats from the entrance	●	
	Steps to access preferential seats	●	●
	Insufficient number of preferential seats	●	
	Preferential seats localization	●	
	Folding seats are difficult to use	●	
	Lack of stanchions	●	
	Distancing between stanchions		●
	Handrails height	●	●
	Moveable straps are unstable	●	
	Deck steps, levels or uneven floor surfaces	●	
	Steps height		●
	Turnstiles are diffucult to use	●	
	Gangways and turnstiles narrow space		●
	Turnstiles position		●
	Colour contrast between seats and the deck		●
Alighting	Steps height		●
	Height between the deck and the ground	●	●
	Spacing between the bus and the sidewalk	●	●

Figure 15. Configuration problems evidenced by tool.

We identified several barriers related to the bus use experience due to the internal configuration elements. Other factors that influence the user's experience, such as the behaviour of the driver or other passengers, will not be covered in this article. A mock-up was made to illustrate the current interior of the bus configuration and to map and allocate identified problems (Figure 16).

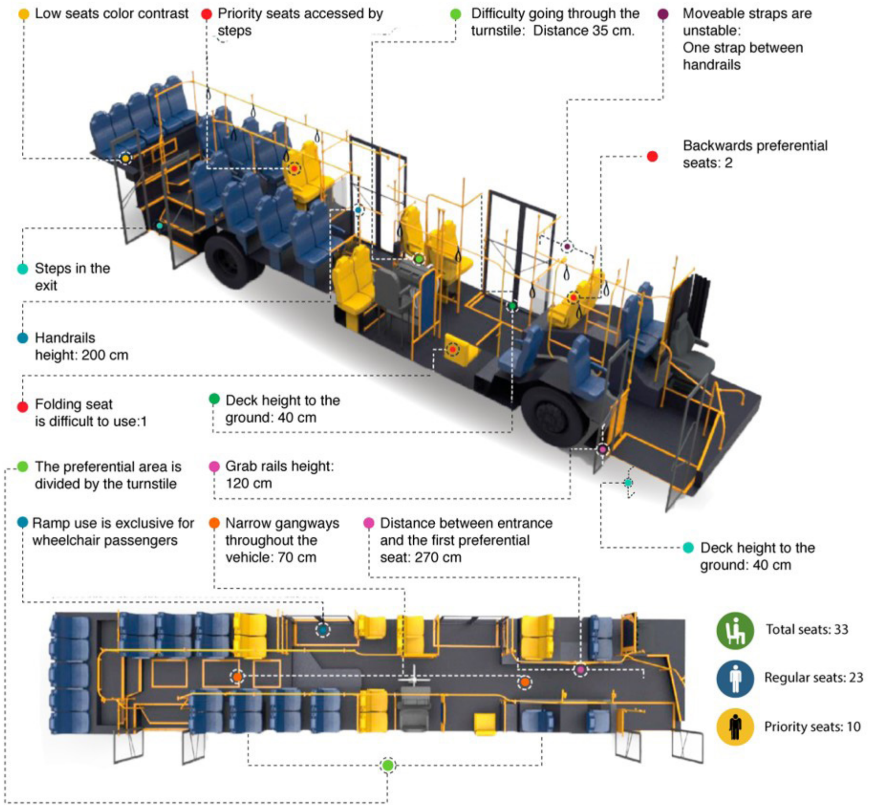


Figure 16. Bus interior configuration mockup with identified problems.

5. Discussion

The barriers that the elderly face when using urban buses are closely associated with the configuration and design of the internal elements of the vehicle, significantly impacting their ability to access, navigate, and use public transportation safely and comfortably. This study focused on identifying these barriers and their implications for the design and layout of bus interiors, with the goal of enhancing safety, accessibility, and overall user experience for elderly passengers.

One critical barrier identified is the height and configuration of the steps during boarding. While modern buses often feature lower front-floor designs, issues arise when buses stop more than 60 cm from the edge of the sidewalk, forcing passengers to step down to the track level before climbing into the vehicle. This height discrepancy demands considerable postural effort from users, particularly affecting their hands, arms, and legs. Although solutions like adjustable suspensions and extendable ramps could mitigate these issues, these measures address broader systemic design challenges.

Once inside the bus, elderly passengers face challenges related to maintaining balance, particularly during accelerations, decelerations, and turns before reaching their seats. Handrails installed at uniform heights and flexible hanging straps often fail to accommodate passengers of varying statures, leaving many without adequate support. Wider gangways could help ease movement, especially during peak hours when crowding exacerbates difficulties, but these structural modifications must balance space limitations and user needs. Priority seating arrangements also require attention, particularly their placement and design. These seats are often installed on raised platforms or face opposite the direction of travel, making them less appealing for elderly passengers who need to monitor their surroundings and prepare for alighting.

The act of alighting presents additional challenges. Elderly passengers prefer to exit through the front door, where the gap between the sidewalk and the vehicle is smaller. However, this preference requires walking against the flow of other passengers in narrow gangways, a task made more hazardous when the vehicle is in motion. Priority seating near entry doors, placed at accessible floor levels and clearly marked, could alleviate some of these difficulties by minimizing the physical effort required for both boarding and alighting.

At the rear of the bus, barriers include the elevated floor and the significant gap between the bus and the ground when using the rear door. These obstacles not only increase the physical effort required for alighting but also pose safety risks, such as falls. These challenges are amplified during peak hours when congestion hinders mobility and access to support features like stanchions and handrails. Additionally, the concentration of passengers in the rear sections makes it difficult for elderly users to navigate or safely exit the vehicle.

Through our analysis, we identified several opportunities for improving bus design by addressing the internal elements. Redesigning handrails to offer variable heights, improving the ergonomics of hanging straps, and strategically relocating and clearly marking priority seating are practical steps that can enhance the accessibility and usability of buses for elderly passengers. These changes should be complemented by considerations of spatial organization within the vehicle, such as wider gangways and safer seat configurations, to ensure an inclusive commuting experience. However, it is important to acknowledge that the sample size for the postural assessments conducted in this study was limited (n=9). While this smaller sample provided valuable insights into the physical demands elderly passengers face, it may not fully capture the variability of experiences across a broader population. Future research with larger and more diverse participant groups is recommended to validate and expand upon these findings.

Nevertheless, our findings also reveal that some barriers and their mitigation strategies extend beyond the internal design of the bus. For example, the height of the first step relative to the street level is influenced by urban infrastructure and bus stop design, necessitating alignment between vehicle specifications and city planning. Similarly, issues such as driver behavior and public adherence to priority seating rules reflect broader systemic and cultural dimensions. Beyond these, modifications to specific elements such as turnstiles—whether through redesign or replacement with alternative passenger registration methods—would require reevaluating payment systems, operational workflows, and broader infrastructure compatibility.

In conclusion, while this study emphasizes the barriers and redesign opportunities related to the internal configuration of buses, the broader context must be acknowledged. Effective solutions require coordinated efforts that extend beyond vehicle design to include urban infrastructure planning, operational policies, and cultural shifts in public behavior. Addressing these interconnected systems is essential for creating a truly inclusive and accessible public transportation service, and we recommend future research explore these dimensions in depth.

6. Conclusions

Our research identified the barriers that elderly users encounter when using the public bus transport service from a case study in the city of São Paulo. The study contributes to more inclusive bus projects since the elements that influence the usability perceived by the elderly in their commuting were identified. It is essential to enable changes in vehicles in the urban transport system to improve the experience of the elderly in terms of accessibility, safety, and protection.

Mitigating the identified barriers involves strategies at different levels of impact. At the structural level, redesigning buses with adjustable suspension systems, ergonomic handrails, and accessible priority seating can significantly improve usability. Favouring the redesign by eliminating or reducing these barriers would significantly improve this perception as positive. Other structural changes must also be implemented. For a country whose population is ageing in absolute terms, actions that improve the quality of life of this population group are urgent, as it is increasingly necessary to give them autonomy. Public urban transport policies must advance to propose continuous improvements to the system, to afford adequate care for the elderly, especially in a large city like São Paulo.

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Data availability

Research data is only available upon request.

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