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Design of flexible partitions for physical distancing in buses in Colombia during COVID-19

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ABSTRACT

The scientific community recognizes that the transport of cargo and passengers is a key factor in the spread of infectious disease pandemics. In particular, during the COVID-19 pandemic, public transport systems have been considered high-risk environments for the transmission of the virus; therefore, in many places around the world, restrictions have been imposed on passenger transport. Although different aspects of transport have been studied during the pandemic, there are still gaps in knowledge about the effect of different means of transport and specific interventions for vehicle design strategies to reduce transmission rates. In this context, this article presents the process of co-designing a flexible partition to divide seats on articulated, standard and complementary vehicles of a bus rapid transit system in a Colombian capital city as a vehicle design strategy to contain the spread of the virus and generate a physical barrier when the physical distance of one meter, as required by national regulations, was unable to be maintained. The design methodology followed an incremental and iterative process of 6 stages until reaching the final design. The process began with the identification of the need, the establishment of the design requirements and determinants, the generation of proposals framed within the requirements, the performance of functionality and cost feasibility tests and the building of the prototype with the chosen design. Additionally, a participatory evaluation was carried out based on the identification of relevant aspects, doubts, criticisms and new contributions to the prioritized prototype. Finally, the generated prototype met the design requirements in addition to a significant cost reduction of 70% compared with the initial proposal by the bus rapid transit. The low cost allows the implementation of the partition throughout the bus fleet, but controlled observational and clinical studies on the effectiveness of the partition in the prevention of COVID-19 are required.

1. Introduction

At the international level, it is recognized that the transport of cargo and passengers in global transport networks is a key factor in the spread of infectious disease pandemics (Tatem et al., 2006). During the COVID-19 pandemic (WHO, 2020a), several aspects and effects of transport have been addressed. For example, there is a positive relationship between the number of airway passengers in a country and the number of patients with COVID-19 (Oztig and Askin, 2020), and there is a relationship between the propagation speed of the pandemic and the presence of an airport or high-speed train station in cities (Zhang et al., 2020). However, there are important gaps in the knowledge regarding the dispersion of COVID-19 and the role of different modes of transport on the effect of infection in travelers, changes in travel habits (Jenelius and Cebecauer, 2020), and on measures and barriers to contain the virus during passenger transport. Likewise, there are questions about the effects of the pandemic on different transport services perceptions by users. It is estimated that in perceived quality measurements, variables such as vehicle occupancy, vehicle cleanliness and hygiene, are likely to increase their prominence (Aloi et al., 2020), among others.

SARS-CoV-2, the causative virus of the COVID-19 pandemic, is transmitted between humans mainly by direct contact with contaminated fomites or surfaces and by microdroplets (droplets or aerosols) that come into contact with the eyes, nose and mouth (Li et al., 2020). These microdroplets are generated when sick people talk, laugh, cough, or sneeze (Holland et al., 2020) and can contaminate different surfaces.

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Given the above, public transport stations and vehicles are recognized as high-risk environments for the transmission of COVID-19 if proper measures are not taken (Pardo et al., 2021). The latter due to the limited physical space available, the abundance of surfaces that help spread the virus (Musselwhite et al., 2020), the recirculation of air through air conditioning, and user behavior (use of mask and eye protection) (Pardo et al., 2021). Likewise, in public transportation, it might be difficult to identify and control people who may be infected with COVID-19 since the virus is contagious before showing any symptoms (Kłos-Adamkiewicz and Gutowski, 2022).

To reduce the transmission of the virus, different strategies have been implemented such as the rapid diagnosis and isolation of individuals with positive tests and their contacts, physical distancing to reduce microbial transmission and hand hygiene and surface cleaning (Li et al., 2020). Likewise, around the world, different countries took unprecedented measures to slow down the spread of the virus such as lockdowns and curfews to prevent social contact. The latter included closing schools, shops, restaurants, bars, and prohibiting public events, among others (De Vos, 2020). Also in many cities around the world, authorities have imposed restrictions on the use of public transport (WHO, 2020b) or have proposed other strategies such as requests for passengers to work from home or shift to other modes of transport such as bikes (De Vos, 2020; Ruth Shortall and Wee, 2022). These restrictions and strategies have meant changes in transport and mobility, particularly in travel patterns, modal share and public transportation demand as evidenced in Lisbon-Portugal (Aparicio et al., 2021), Santander-Spain (Aloi et al., 2020), Budapest-Hungary (Bucsky, 2020), and Ghana (Sogbe, 2021), among others.

The restrictions and strategies adopted to cope with COVID-19 produced significant adjustments to infrastructure and transportation operations around the world (Fridrisek and Janos, 2022; Kamga and Eickemeyer, 2021) e.g., Latin American countries experienced varied restrictions from the total closure or up to restrictions in occupancy, but all countries had reductions of up to 50 % in public transport use at the beginning of the pandemic (Pardo et al., 2021). The reduction in traffic volume had positive impacts on the air quality worldwide (Liu et al., 2021), but negative consequences on the quality of life of people (De Vos, 2020) and the finances of different public transport systems.

The decrease in the number of users of public transportation is associated with the restrictions imposed by authorities. However, it is also likely to be associated with decisions by travelers who may prefer other alternatives such as bicycles and private cars because of the threat of becoming infected (Jenelius and Cebecauer, 2020; Kłos-Adamkiewicz and Gutowski, 2022; Paul et al., 2022). During pandemics, people's understanding, perceptions and attitudes also affect travel decisions and the mode of transportation choices (Abdullah et al., 2020). As evidenced by Campisi et al. (2020), using public transport after the beginning of the pandemic was affected significantly due to security issues, as security concerns, anxiety, and stress levels increased in society (Campisi et al., 2020). Therefore, the turn of commuters towards private and perceived as less risky modes than public transport constitutes a major caveat to consider (Tsavdari et al., 2022), if new outbreaks, epidemics, and pandemics appear.

Although a group of commuters may change to less risky modes of transportation, for those who do not have access to other modes, public transportation is necessary to meet various travel needs, for example, shopping for necessities, attending medical appointments, or commuting to work. As evidenced in Lisbon, the impact of COVID-19 on public transportation demand was considerably lower in the stations located in rural areas and zones with lower income, which may suggest that some daily commuters continue relying on these transport modes to commute to work (Aparicio et al., 2021). Thus, transport operators should make their services safer, especially for people who are disabled, have mobility problems, or do not have a car (Kłos-Adamkiewicz and Gutowski, 2022). This has been a major challenge for mass transit systems, which have not only had their finances affected by lower demand but, must also make investments to protect users who continue to demand the service.

During the COVID-19 pandemic, a main concern in transportation has been to protect commuters and drivers from contracting the disease while traveling. The latter has raised a plethora of ideas for modifying and redesigning public transportation and shared mobility vehicles (Sanguinetti et al., 2023, 2021). However, industry guidance sources have had a strong emphasis on policies and procedures and not on vehicle design specifically, which makes it difficult to delve into a high level of detail for vehicle design strategies (Sanguinetti et al., 2023). An example is the recommendation by industry guidance to install plexiglas or other barriers in transit and rail vehicles during COVID-19 pandemic. The latter leaves a lot to be determined by the operator concerning the barrier size, material, location, and cleaning procedure, among other variables that vary considerably in practice (Sanguinetti et al., 2023).

For operators and regulators, facing the pandemic in public transport has been a major challenge which involved implementing actions in a complex and highly uncertain context. Likewise, much is unknown about the specific actions that transport systems operators resorted to propose and implement vehicle design strategies to face COVID-19. Therefore, this article seeks to present the process of co-designing a flexible partition to divide the seats of articulated, standard and complementary vehicles of a bus rapid transit system (BRT) in a Colombian capital city as a vehicle design strategy to contain the spread of the virus and generate a physical barrier when the physical distance of one meter required by national regulations was unable to be maintained. In this sense, the aim of this article is not to test the effectiveness of the partition to prevent COVID-19 transmission but to illustrate its design process with the operators of the BRT under a context of economic restriction and great uncertainty due to COVID-19. The paper is organized as follows. In section 1.1 measures adopted by the bus rapid transit system in Colombia during COVID-19 are reviewed. Section 1.2 presents the case of the BRT in Santiago de Cali-Colombia. Section 2 describes the research methods. Results are provided and discussed in sections 3 and 4, respectively, while Section 5 is devoted to the conclusions derived from the research.

1.1. The bus rapid transit system in Colombia during COVID-19

In Colombia, in the main cities in the last 25 years, public transport based on BRT became popular. During the COVID-19 pandemic, BRT public transportation operated with restrictions. Between April 24, 2020, and September 3, 2020, public transportation operated at a maximum of 35 % of its capacity to comply with national restrictions imposed by the Ministry of Health and Social Protection (*Ministerio de Salud y Protección Social* in Spanish; Resolution 677 of 2020). As of September 3, the Ministry of Health and Social Protection authorized maximum operation at 50 % capacity (Resolution 1537 of 2020). Therefore, during the quarantine period, operators decided to decrease the transport supply due to the low expected demand for public transport in cities. But the lower revenues from the low demand and the high fixed costs during this virus crisis worsened the precarious economic situation that these systems had been experiencing (Arellana et al., 2020).

In the face of the pandemic, BRT in main Colombian cities has implemented measures to contain the virus, such as requiring the use of face masks for all passengers and the delivery of sanitation kits, containing items such as mouth masks, alcohol, and sanitizing gel to drivers as recommended by Centers for Disease Control and Prevention (2021) and WHO (2020b). Likewise, sanitizing gel has been made available in stations, terminals and standard and complementary vehicles; portable sinks have been installed, and segregating curtains have been set up to separate drivers from passengers. Periodic disinfection of stations and terminals has also been implemented using products such as sodium hypochlorite, chlorine, 96° deodorized ethyl alcohol, and quaternary ammonium (fifth-generation), among others; the entire bus fleet as well as bus depots and the break areas for the drivers were disinfected at least twice a day. Temperature screening and confirming sense of smell have also been implemented in stations and terminals. In areas with high virus transmission, stops have been suspended, among other measures (Alcaldía de Pereira, 2020; Alcaldía de Santiago de, 2020; TRANSCARIBE, 2020; TRANSMETRO, 2020; TRANSMILENIO, 2020).

1.2. The case of the bus rapid transit system in Santiago de Cali-Colombia

The BRT in Santiago de Cali, a city of 2,241,491 inhabitants (DANE, 2022), began operating in 2008 under the brand Massive Integrated of the West (MIO- *Masivo Integrado de Occidente* in Spanish). The BTR is managed and controlled by METRO CALI, S.A, an official organization, which has 4 concessionaires for the operation and 1 for collection. Before the pandemic, as of December 2019, the BRT and its integrated modes (air-suspended cable system – MIO-Cable) had a spatial coverage in the urban area of 92.28 %. The BTR had 41.15 km of segregated lanes (exclusive lanes), and 431.1 km of pre-segregated and complementary lanes (mixed traffic lanes). Likewise, it had 55 stations, 3 terminal portals, 2 intermediate terminals and 4 bus depot-workshops with a capacity of 169 m2/bus (METRO CALI S.A., 2020).

In 2019 the BRT mobilized over 450.000 passengers per business day, reaching a maximum of 458.000 that year (de Santiago de Cali, 2023). In 2019 the fleet corresponded to 967 buses, 200 articulated buses (capacity: 160 passengers-18 m long), 528 standard buses (capacity: 80 passengers-12 m long) and 239 buses (capacity: 50–60 passengers-10 m long) (Mintransporte, 2020). In 2019, the BRT had 101 routes, which were operated with 640 to 760 buses simultaneously on a business day, and ran between 132,000–148,000 km on a business day, with an average passenger per kilometer index of 2.9. The user fee corresponded to COP 2200 and a technical fee of COP 2727, $0.56, and USD 0.69 respectively[1] (METRO CALI S.A., 2020; Mintransporte, 2020). Since March 21, 2020, due to the COVID-19 outbreak, the number of buses to provide the service was reduced by almost 40 %. The preventive isolation decreed by the National Government caused a significant reduction in passenger demand by around 85 %, and 70,000 passengers began to be mobilized on business days. The BRT decreased to 80 active routes on a business day, and also the operation time of 23 active routes was restricted to operate only during rush hours. The spatial coverage in the urban area was reduced to 88.79 %. In 2022, the BRT increased to 94 active routes on a business day,[2] with 657 scheduled buses and a spatial coverage in the urban area of 88.79 %, which shows the impact of the pandemic and social protests in the city throughout 2021 (de Santiago de Cali, 2023).

In Santiago de Cali, in May 2020 the directors of the BRT, with the endorsement of the leading epidemiologist of the city, raised the possibility of installing partition dividers in articulated, standard and complementary vehicles, seeking to generate barriers to reduce the dispersion of droplets inside buses. This measure was considered especially important because: i) not all people on buses are provided with certified masks or do not have protection that covers their eyes, providing a mucosal layer through which contamination can occur (Bacherini et al., 2020); ii) the rapid spread of the virus in Colombia at the time; iii) the need to comply with national restrictions, i.e., not exceeding 35 % occupancy and maintaining one meter of distance between each passenger, and other local provisions to maintain mandatory preventive distancing of one meter between each passenger, placed in a zigzag or diagonal pattern; and, iv) the need to increase the capacity of the BRT given the drastic revenue losses and the gradual opening of the economy due to the immense economic and social consequences of extreme physical distancing strategies (Perencevich et al., 2020).

The situation described in which epidemiologists and transportation managers explore specific measures to confront the pandemic evidences how around the world “public transit and shared mobility operators and their regulatory bodies are faced with the challenge of deciding which of the myriad proposed strategies to adopt, with a dearth of specific research on their effectiveness“ (Sanguinetti et al., 2023:642). Particularly, in early 2020 partitions made from glass, plastic, or plexiglass were popularized in public indoor spaces and became a key component of the initial public health response to COVID-19. Initially, the evidence on the use of barriers to control a respiratory disease outside of clinical healthcare settings was limited, but the early initiatives considered the previous infection prevention and control experience in clinical settings; as well as logical assumptions on COVID-19 propagation and the ways the public might interact and adopt other available public health measures such as masking (Eykelbosh, 2021). In this context, in May 2020 during the lockdown that limited the free mobility of the Colombian population, the main author was contacted by the city’s leading epidemiologist and the vice-presidency of operations of the BRT in order to move forward on the design of a flexible partition.

2. Methods

For the design of the flexible partition, 6 phases adapted from (Villareal, 2005) were used (Fig. 1) following an incremental and iterative process until reaching the final design. The process started with the identification of the need for a flexible partition by different stakeholders through unstructured interviews. The interviews inquired about the effects on the operation of the BRT generated by the pandemic, the restrictions imposed by national regulations, the adjustments generated inside the buses to comply with the permitted occupancy, about the need or importance they gave to a partition as a solution and about previous

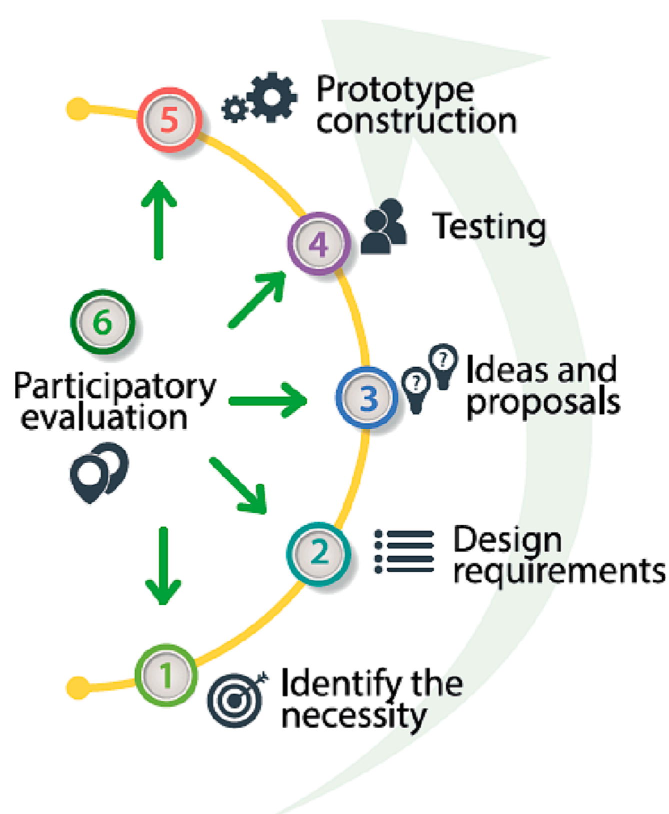

Fig. 1. Design process phases.

[1] Based on the exchange rate for 1 dollar of $3,932.9626 on January 26, 2024.

[2] The general service map of the BRT MIO can be consulted at https://mio.com.co/images/stories/MAPA%20GENERAL%2030.05.2022-1_compressed%201.pdf.

attempts or experiences in the development of the partition. The interviews were conducted with the vice-president of operations and the director of operations of the official entity that manages and controls the operation of the BRT. Likewise, the operations directors of the three companies that have assigned routes in the city participated in the interviews.

All the interviews were performed in compliance with the AAA Statement on Ethics (American Anthropological Association., 2012). Therefore, the participation was voluntary and the answers or information provided was recorded anonymously. The participants were informed about the study objective and context and provided with verbal informed consent regarding privacy before participating in the research. The interviews for the development of the partition were conducted by the first author in Spanish in May 2020, they were not recorded and the relevant aspects were written in the field diary. These interviews were conducted in person in a bus depot of the BRT, which also allowed the observation of the buses and the adjustments made for COVID-19.

Subsequently, the determinants and design requirements were established, serving as the premise and limitations that guided the design. For this, the chief epidemiologist of the city was interviewed regarding desired partition characteristics. The unstructured interview was conducted by telephone and inquired about the desirable characteristics of the partition from the point of view of public health, its size, possible materials and cleaning needs. The interview was not recorded and the relevant aspects were written in the field diary. Likewise, a participatory group workshop was also held on May 21 of 2020 with managers, operation managers, maintenance managers, and fleet technicians in a bus of the BRT in the bus depot. The 12 participants were asked about the necessary characteristics of a partition, its function and desired shape, the regulatory restrictions for its installation, the needs and characteristics for maintenance and any desired characteristics or restrictions for its installation in the bus fleet. The workshop was led by the first author, who facilitated contributions by asking unstructured questions to the participants who responded freely with their points of view. The workshop lasted approximately one hour, and the relevant aspects for the determinants and requirements referred by the participants were recorded in the field diary.

Next, the creative process was initiated by the authors, framed within the requirements and determinants, generating different ideas and sketches that were critically evaluated regarding cost, biosecurity criteria, safety for passengers during use, ease of installation, productive viability and form. Following, the prioritized ideas were subjected to tests regarding the availability of materials in the market, structure, use, assembly, maintenance and cleaning, production and installation costs, and feasibility of implementation. During this stage, checks were also carried out on the fastening mechanisms (tapes and ropes) on a bus of the BRT. Subsequently, the design team evaluated the preliminary designs and determined which design most closely met the majority of requirements and determinants, after which the chosen prototype was built.

Subsequently, a workshop was also held on June 24, 2020 in a bus of the BRT in the bus depot, with managers, operation managers, maintenance managers, and fleet technicians. The partition prototype was installed on a bus and was described to the 12 participants who were asked to individually identify and write in a matrix the relevant aspects, doubts, criticisms and new contributions regarding the prototype. Subsequently, the participants commented on their observations and delivered the completed matrices to the first author to be unified. The workshop lasted 1.5 h and the first author recorded the most relevant aspects of the discussion in the field diary. After the workshop, a structured in-person interview was conducted with the vice-president of operations and the director of operations of the BRT, as well as the director of operations of one of the BRT concessionaries, in which their perception of the partition and the design process carried out was investigated. These interviews were audio recorded, maintaining anonymity, and were transcribed for analysis.

Finally, the final prototype was built and installed in each seat of one standard bus that operated for a week throughout the city in July 2020 for fleet technicians to observe the operation of the partition, the behavior of the tape and ropes of the fastening mechanisms, its behavior during cleaning and disinfection and whether the partition was subject to vandalism. Also, for logistical aspects, taking into account the curfew imposed in Colombia, it was requested that one of the technicians travel on the bus to photograph it with commuters, and to ask anonymously, to some passengers about their perceptions of the partition. The technician was instructed to identify himself as a BRT official, mention the purpose of the partitions installed on the bus, and ask for permission to inquire about the perception by users of the partition and authorization to audio record their response anonymously only for academic purposes. The technician sent 4 photographs and recordings of the responses of 2 users.

3. Findings

3.1. Identification of the need for a partition in the bus rapid transit system

Restrictions on public transport services in Colombia during the COVID-19 health emergency forced service providers to maintain one meter of distance between passengers and an occupancy of less than 35 % capacity (Ministry of Health and Social Protection, Resolution 677 of 2020). The BRT (*Masivo Integrado de Occidente-MIO*), mobilized over 450 thousand passengers per business day in 2019 before the health emergency. However, by complying with the restriction of maintaining one meter of distance between passengers, the capacity of the BRT was reduced since March 21, 2020 to nearly 70,000 passengers on business days. Under this circumstance, fixed and operating costs were not covered by user fees, leaving the system in a complex financial situation (de Santiago de Cali, 2023).

Therefore, an alternative to avoid the financial collapse of the BRT in 2020 was to increase the operating capacity, which is why system directives proposed a scenario that allows one passenger in every 2 seats, sitting one behind the other, and standing passengers in demarcated sites in a zigzag distribution that takes into account the distance of one meter (Fig. 2). Under this scenario, the physical distance of one meter between passengers is achieved, except among the passengers in window seats (0.7 m), for whom it was necessary to generate a physical separation through the installation of a flexible partition between blocks of seats on all buses of the fleet at the lowest possible cost. The initial proposal by technicians within the BRT system consisted of a 75 × 75 cm plastic sheet supported on 2 aluminum tubes, fixed to the bus body with screwed curtain brackets and tensioned with plastic ties to the handles of the seats (Fig. 3). The cost of the materials for each proposed partition was 10 USD, and 12,000 partitions were needed; therefore, it was financially unfeasible to install these partitions throughout the bus fleet.

3.2. Design requirements and determinants

From the interview with the chief epidemiologist of the city and the participatory group workshop with managers, heads of operation, maintenance managers, and technicians of the BRT (12 experts), the following requirements and determinants were established:

- The partition should cover the height of a standing person so that when the person sits down and stands up from the seat, it is effective.
- The partition must fit the bodywork of 2 bus models: with and without side rails for user support.
- Side rails (for buses that have them) must remain free of obstacles for users to hold on, per national standards.
- The partition must be able to be removed at the top for air conditioning duct maintenance.

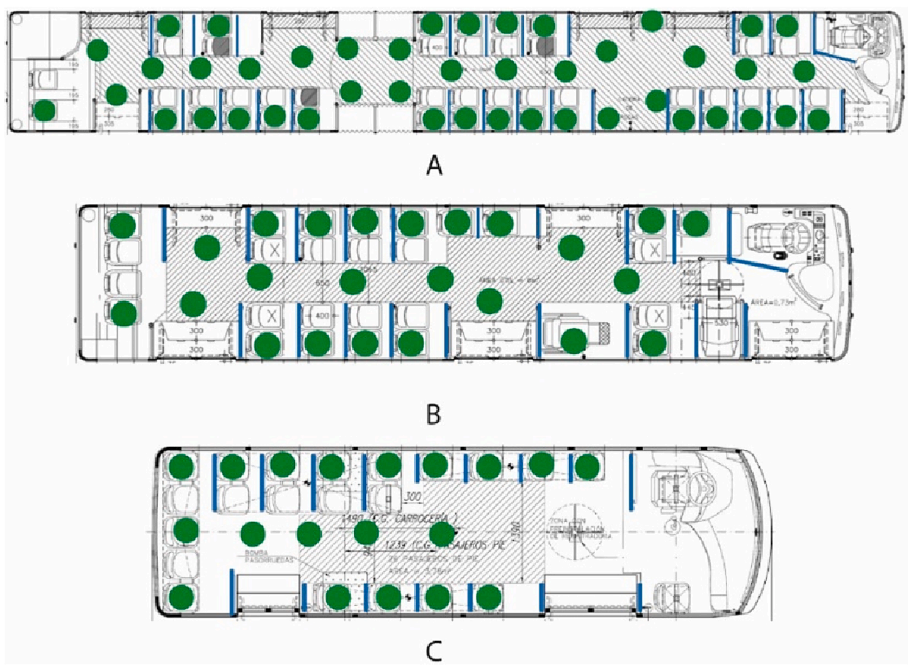

Fig. 2. Proposed occupancy in vehicles by type. A. Articulated. Total capacity:160 passengers; adjusted capacity: 25 seated passengers and 19 standing passengers. B. Standard. Total capacity: 80 passengers; Adjusted capacity: 15 seated passengers and 8 standing passengers; and C. Complementary. Total capacity: 48 passengers; Adjusted capacity: 15 seated passengers and 4 standing passengers. .
Source: adapted from basic bus plans, supplied by METRO CALI S.A

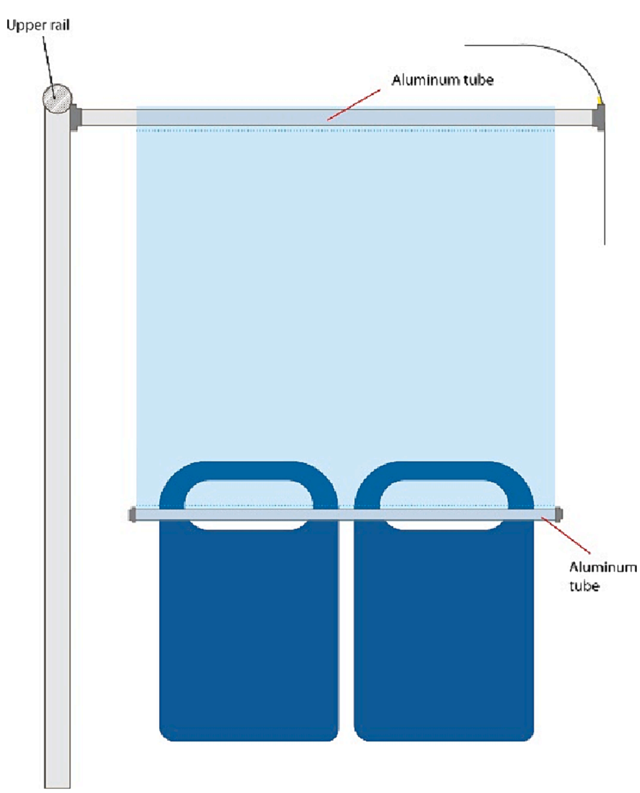

Fig. 3. Partition proposed by mass transit system technicians.

- In electric buses with stainless steel rails, the rails should not be broken.
- When a partition is broken by contact from users, briefcases or other objects when abruptly stopping, no pointy edges can be generated that put passengers at risk, e.g., when acrylic breaks.
- The handles of the seats cannot be covered, keeping in mind that older or overweight people often lean on them.
- The partition must be able to be washed with water, soap and cloth; therefore, the material must be resistant to the condensation created when washing and the high humidity in buses.
- The partition cannot be perceived as economically attractive because buses in the BRT are subject to a high level of vandalism and frequent robberies. Ideally, it should have a fastening system to prevent theft.
- The partition should be easy to install. It should be a single preassembled unit that can be easily replaced. Ideally, the unit should be completely replaced in case of deterioration. Many pieces can make material management in the warehouse difficult and can lead to robberies.
- Each partition must have a low cost because 12,000 partitions are required for the entire bus fleet.

3.3. Design ideas and proposals

Framed within the requirements and determinants, the creative process began, from which four partition designs were generated. Initially, the elimination of aluminum tubes was considered in the proposal by the BRT technicians because they increased the cost; therefore, one proposal involved fixation of the plastic sheet to the window and the side rail of the bus with double-sided tape or high-performance Velcro (Dual Lock ™ by 3 M ™) (proposal 1, Fig. 4A). As an alternative to the lower aluminum tube, one proposal involved the fixation of the plastic sheet to the handle of the seat with a high-performance Velcro (proposal 2). Taking into account that proposals 1 and 2 would only serve on buses with side rails, an alternative was considered for fixing the plastic sheet to the upper rail and to the window using metal eyelets in the plastic and a system of ropes, integrating the previous ideas for lower partition fixation (proposal 3, Fig. 4B). Finally, to save material and reduce costs, the fixation of the lower partition involved a system of twine and eyelets (proposal 4, Fig. 4C).

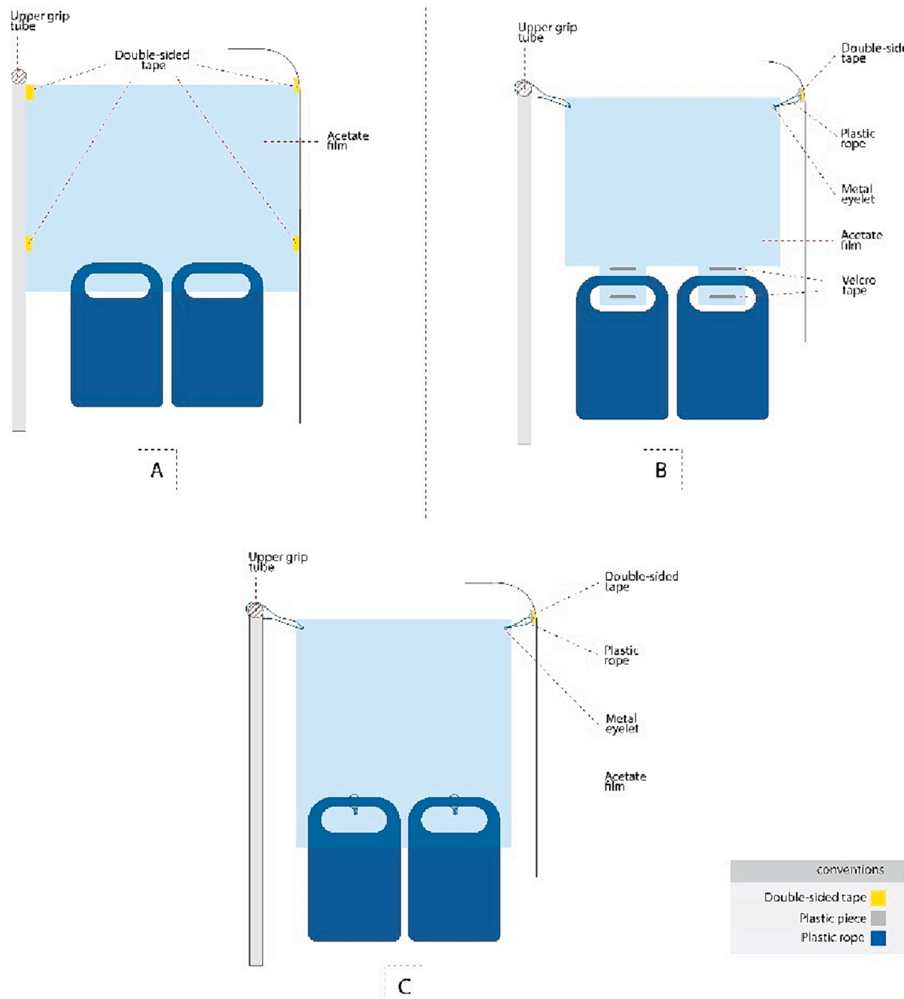

Fig. 4. Proposals and ideas for the design of the partition

3.4. Tests and construction of the prototype

The ideas and design proposals generated were subjected to different tests, including a review of alternative materials available in the market, tests of mechanisms in vehicles and analyses related to the sequence and ease of assembly, production costs, and cleaning and maintenance, among other assessments. It was verified under real conditions that alternative 1 (Fig. 4A) was feasible; the double-sided tape exhibited good performance using 5-cm sections, allowing the elimination of the aluminum tubes, which represented approximately 50 % of the costs in materials of the proposal by the BRT technicians. However, the tape limited the removal of the partition for the maintenance of air conditioning ducts. High-performance Velcro tests were performed using 5-cm sections, showing good results. Although the cost of Velcro is greater than that of tape, its resistance is 4 lbs/m^2; therefore, very long sections are not required. Additionally, the recommendation by the tape manufacturer was to apply short sections to facilitate removal of the partition when no longer needed. With the Velcro, the partition is easy to remove, facilitating the maintenance of ducts but making the partition susceptible to theft. Additionally, using the Velcro, the tension to hold the plastic cannot be high because a user's head could detach it upon contact, disabling the function of the partition as a physical barrier.

To proposal 3 (Fig. 4B), alternative mechanisms were tested, and a functional prototype was constructed with metal eyelets and a rope system that was installed in a bus. In the construction of the prototype, the lower fastening system created a substantial waste of plastic and higher costs for cutting and installing Velcro; therefore, the fastening system in proposal 4 was integrated into proposal 3 (Fig. 4C). The tests showed that the metal eyelets properly fulfilled their intended function, i.e., preventing the plastic from tearing. Likewise, it was evident that a seam was not necessary at the edge of the plastic whenever a straight cut was made. The rope system, which employs smooth nylon ropes, is economical and allows easy installation in buses with and without side rails; however, the use of an elastic rope is also recommended in buses in which seats are not installed symmetrically. Additionally, the upper right fastening system with double-sided tape worked properly; however, adequate cleaning of the surface where it will be glued and 24 h of curing for maximum adhesion are required.

The design team evaluated the proposals and verified that proposal 4 (Fig. 4C) met the determinants and requirements, presenting a 70 % reduction in the cost of materials (reduction to 3 USD per unit); therefore, a participatory evaluation was carried out with BRT personnel (12 people). This evaluation concluded that the design was framed within the requirements and proposed determinants; i.e., the system was simple, easy to install, and low cost, among other factors (Table 1). The doubts generated by the design were related to the durability and resistance of the materials and their susceptibility to vandalism and strength against disinfection protocols. The main criticism of the design was concerning the free space between the window and the bus structure if the support was fixed to the body of the bus and not to the glass. Likewise, it was noted that the partition was very easy to remove and thus susceptible to theft. The new contributions were related to

Table 1
Matrix of relevant aspects, doubts, criticisms, and suggested improvements to the prototype.

Relevant aspects	Doubts
The design meets the requirements Very simple, adaptable and economical design Simplicity is fundamental for the ease of installation and maintenance work Cost reduction is a key factor Very practical and easy to install Low cost and easy to replace materials Vision is not obstructed A good solution for the practicality of the installation Easy to install	Strength, durability and hygiene of the material Vandalism resistance because it is very flexible Doubts about the double-sided tape It is important to determine the cleaning issues Caliber of the plastic and cost of the machine to place eyelets Securing the partition and firmness of the fixation Frequency of cleaning Durability of materials and damage
Criticism	**Suggested improvements**
Improve fastening so that the partition is not so easy to remove More tensionAfter installation, there is free space against the bus structure (window)	Improve the caliber of the plastic The string could be tied with a sliding knot, allowing a good fit Use tape on the glass on both the upper and lower parts of the partition Fix the partition to the upper part of the body of the bus Install tensioning rubber bands for the plastic Use elastic ties to improve fastening Improve the fastening against the window Place the edge of the partition closer to the window

improving the caliber of the plastic and the use of elastic cords and sliding knots to improve the tension of the partition (Table 1).

Subsequently, the final prototype was generated based on the evaluation matrix, cleaning protocols were validated with epidemiologists, and 16 flexible partitions were manufactured for installation between each row of seats on a standard bus that conducted service routes in July 2020 (Fig. 5). The performance results for the partitions were as expected. Vandalism was not observed, and cleaning, which was performed at least twice a day with nebulized quaternary ammonium (fifth-generation), and drying with 2 rags, one for each side of the plastic, was completed without difficulty; cleaning was performed from the bottom up to avoid detaching the double-sided tape as a result of excess tension.

3.5. Description of the flexible partition prototype

The partition is a physical barrier that serves to divide the spaces between rows of seats inside a bus (Fig. 6; Table 2). The main component of the partition is 12-gauge translucent vinyl sheet (1000 mm high × 750 mm wide) that is located vertically parallel to the back of the seats, occupying the space between the roof and the sidewall (left or right) and the top of seats. The additional elements hold the vinyl sheet in position by tension at 4 fixed fastening points on the bus: 2 at the top attached to the upper grip rail and to the sidewall (left or right) and 2 at the lower part attached to the grip rail on the upper part of the back of the seats. Overall, 4 fastening elements at these 4 fixed points keep the sheet tensioned in the position for use.

The fasteners for the vinyl sheets are 1/8-inch nylon ropes that act as tensioners, joining the fixed fastening points on the bus to the sheet using a simple tie. From the upper grip of the bus and the 2 grips on the seats, the vinyl sheet is secured through perforations with metal eyelets that cross the nylon rope and secure the partition in position; similarly, the partition is secured to the upper part of the internal wall of the bus (left or right) using a rope and pin constructed with plastic tube and placed in position with double-sided tape attached to the glass at the top of the window.

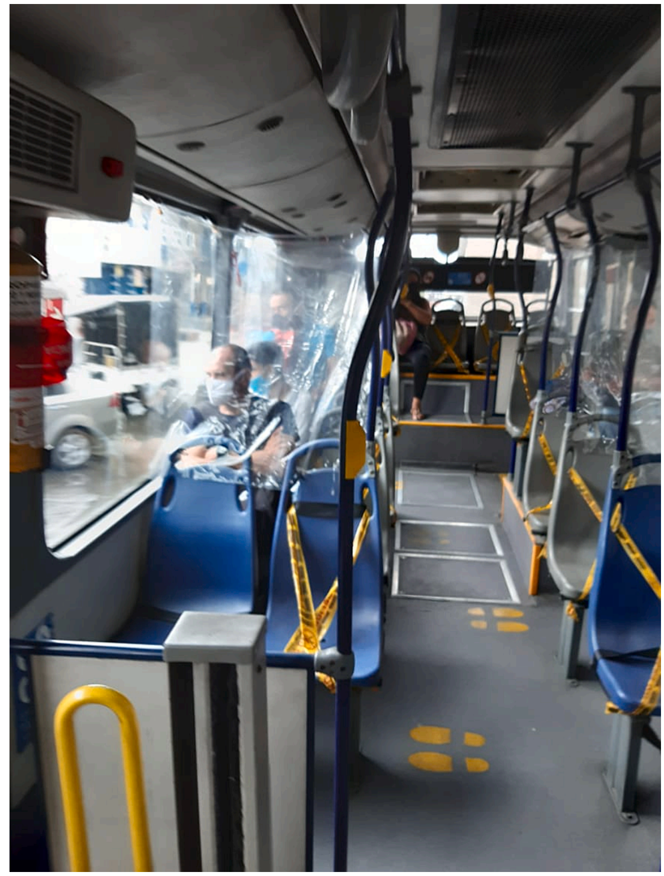

Fig. 5. Flexible partitions installed in a bus carrying users.
Source: (Anonymous technician, 2020)

3.6. Perception of the design process and the partition prototype by operators and users

From the perspective of the BRT directives, the design process and the resulting partition were highly valued, because they allowed an option to increase the capacity of the BRT and comply with the restrictions imposed on public passenger transport during the COVID-19. Some managers provided the following comments regarding the proposed partition and the design process:

> *The design team provided excellent ideas, with improvements to the designs that we had proposed for the partition and with interventions that allowed us to be more economical and more usable within the system.* Vice-president of operations and infrastructure of the transportation system (female)
> *The contribution to achieving the biosafety objectives in the design was exceptional. The reduction in the production cost of the partitions was significant, so much that if it had not been for the improvement in the design and the simplification achieved, it would have been very difficult for us to think about implementing partitions throughout the entire bus fleet.* Director of Operations of the transportation system (male)

These comments demonstrate the potential of the appropriate technology framework in vehicle design strategies. Appropriate technology encompasses a wide range of technologies that have one or several characteristics, such as the low cost of manufacturing or operation, high simplicity of use, a high degree of adaptation to a particular social or cultural environment, and rational use of local resources, among others (Jéquier and Blanc, 1983). Using this approach allowed the partition to

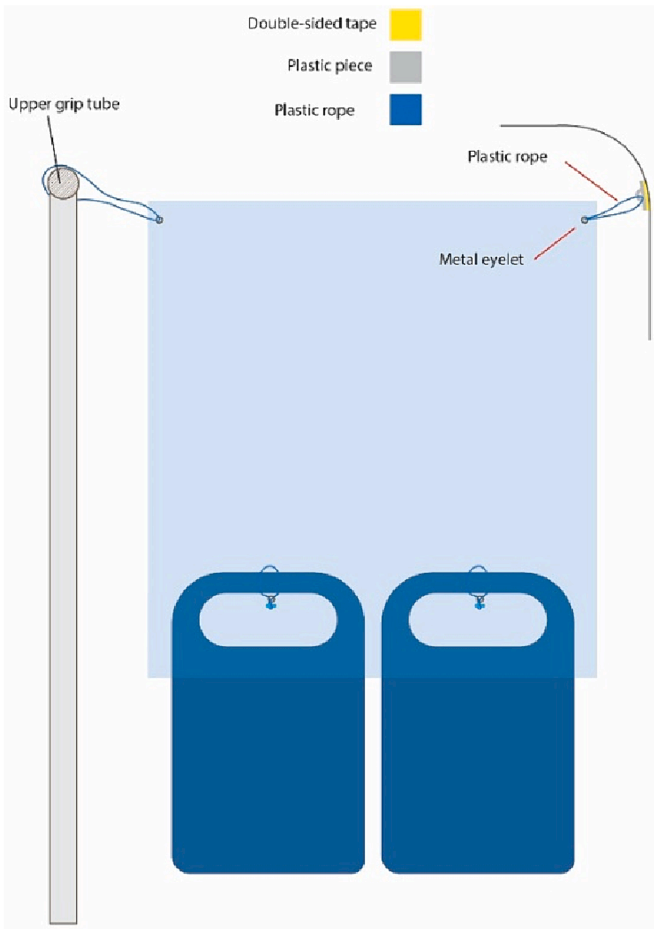

Fig. 6. Illustration of the final flexible partition prototype.

Table 2
List of materials for the construction of the partition.

Material	Detail	Quantity
12 gauge clear vinyl	Cut sheet 0.75 × 1 *m*	1
12 gauge clear vinyl	Sheet 3 × 8 cm	1
Metallic eyelet	Internal diameter 8 mm	5
Nylon rope (from a draper)	Diameter 1/8 (2 sections, 20 cm; 2 sections, 10 cm)	60 cm
Thick-walled transparent hose	External diameter 6 mm (3 sections, 1.5 cm)	6 cm
Double-sided tape	Black 3 M™ VHB 5952F tape (1.1 mm) 12 mm	8 cm

adjust to the needs of the BRT context and to particular situations such as a low budget, taking into account the complex financial context of the BRT due to the reduction of users and the stable fixed costs of the operation.

Although financial issues and changes in BRT directives led to the partitions not being implemented throughout the bus fleet, they were implemented on a test bus that ran through the city on its usual routes. The users of the bus service reported good acceptance of the partitions. In this regard, a male user mentioned: “The partition is very good since it gives us more protection, and thus, we do not have much contact between users”. Precisely, contact with other users has been one of the main concerns for commuters, taking into account that it is really hard to maintain distance in public transport (Kłos-Adamkiewicz and Gutowski, 2022). Likewise, many commuters experience fear they might contract the virus due to the seating proximity. According to Lucchesi et al. (2022) in Brazil, the system characteristics that force constant interaction with other passengers are the main barriers to users for using public transport during virus transmission. Also, they established that crowded vehicles and crowded stops/stations affected users the most in terms of feeling safe while riding during the COVID-19 outbreak (Lucchesi et al., 2022).

The feeling of security in users is associated with the risk perception for COVID-19, which is considered a complex phenomenon, influenced by different determinants including sociodemographic and epidemiological factors, but also psychological variables (Tagini et al., 2021). Regarding the psychological predictors of risk perception, it is suggested that people with high levels of anxiety, an anxious attachment, and an external locus of control predicted higher perceived risk. The latter possibly favors their engagement in preventive behaviors, at least to a certain extent, because experiencing very intense fear and psychological distress may be paralyzing and promote dysfunctional behaviors. In contrast, high levels of openness in personality and avoidant attachment predicted a lower perception of risk and less motivation to engage in preventive measures (Tagini et al., 2021).

These factors are very relevant for public passenger transport, taking into account that the perception of risk could affect its use or that users prefer other modes of transport. In this regard, it has been demonstrated in the context of COVID-19 that the main reason commuters choose different modes of transport for daily trips is a lower sense of personal safety. The latter due to factors such as physical distancing, use of sanitizers, occupants wearing a face mask covering the mouth and nose and cleanliness of the vehicle, instead of factors such as cost of fare, availability of buses before COVID-19 (Ashraf Javid et al., 2021; Sogbe, 2021).

However, to make users feel safe while riding it has been considered useful to adopt countermeasures that reduce contact with other passengers (Lucchesi et al., 2022), such as partitions. In this regard, a female user of the BRT mentioned: “I think the fact that they are setting up partitions to divide each of the two-person seats is excellent, especially because there are people who do not respect the distance and the signs on the seats that can be used”. Therefore, it is necessary to continue with the development of vehicle design strategies that lead to improving feeling of security in travelers regardless of whether the COVID-19 emergency is overcome. The above, taking into account the possibility of the appearance of new waves of the virus or other pandemics, which will probably lead to a higher risk aversion towards transport and travel (Christidis et al., 2021). Likewise, failure to do so could promote the purchase of private vehicles, which would generate greater financial burdens on public transportation systems, exacerbating inequalities, and increasing the ecological footprint (Aaron Gutiérrez and Domènech, 2021).

4. Discussion

From the identification of the necessity to the definition of a response to the formulated problem, the design process described herein responded to several requirements with multiple origins and was formulated with help from groups of people related to the project, i.e., users, BRT directors, the transport company, manufacturers and expert epidemiologists, who from their particular perspective identified technical, commercial, economic, functional, formal-aesthetic, legal and regulatory needs. Therefore, in the design process, by identifying and delimiting the variables related to the problem, the developers of the design were involved not only in their traditional tasks of communication through the form of objects but also in understanding the problem at levels of greater complexity. Jones defines 4 different design domains that facilitate advancements, from the simple to the complex in different stages (Jones, 2014).

The development of the design response considered requirements regarding “traditional design”, i.e., formal, aesthetic, compositional, structural, and productive design factors among others; but above all, the task was seen as a complex social problem, the COVID-19 pandemic, which generated the need for protection and physical distancing. In this context, designers created proposals that not only considered material elements but also policies, understanding, as Buchanan (1985) states, that the problem involves the interaction of a subject with elements from their material environment, with higher levels of concern related to political, economic and social systems.

It is necessary to identify the “causal chain” (Rittel and Webber, 1973) of complex problems, where there are a series of situations and actors involved in the definition of the so-called “problem”. To locate this problem is to identify, within this network of elements and interactions, the specific situation that must be modified and foreseen as far as possible, given the complexity of the problem how the designed product will interact with the environment. In this way, it can be understood that when addressing the solution to the problems identified at lower levels, e.g., the selection of materials, one must recognize the higher phases of problem complexity, such as the need for users to commute to work or policies and restrictions of use for BRT during the pandemic.

The design response in this case has a minor relation to the so-called traditional design, but is related to design advances in complex contexts, where the impact is not evident in novel and attractive formal-aesthetic elements but in its ability to positively impact complex social situations. Therefore, considering the pandemic, the situation was analyzed from the fundamental dimensions of the user, the need and the context, which can be described and studied from multiple disciplines. The elements that were described and defined in this specific situation and their complex relationships such as requirements and determinants, generated the necessary characteristics of the design response. “Perverse problems do not have a definitive formulation, but each formulation of a perverse problem corresponds to the formulation of a solution” (Buchanan, 1985: 14). These responses demand coherence and balance between requirements that sometimes seem opposed, e.g., the highest quality against cost constraints, and those who respond commit themselves by accepting as part of the complex process a dichotomous vision (univocity-equivocity) of their field of action (Arámbula-Ponte and Uribe-Becerra, 2016).

Although the prototype generated for the partition meets the design requirements and achieves a significant cost reduction of 70 % compared to the initial proposal by the BRT, which makes implementation of the prototype feasible throughout the bus fleet, it is necessary to perform controlled observational and clinical studies on the effectiveness of the partition in the prevention of COVID-19 in buses. Although the use of partitions is effective in reducing the COVID-19 spread and can prevent the infection to a certain extent by effectively blocking the droplet and direct airborne transmission between people at short distances (Epple et al., 2021; Mirzaie et al., 2021; Ye et al., 2021), it has been shown that ventilation within a room plays an important role in the effectiveness of a partition (Rooney et al., 2021). Particularly, many buses were designed without windows and a high-concentration of expiratory air from passengers could be generated, placing a risk of cross-infection, as warned by Ye et al. (2021) in restaurants with partitions. Moreover, even in the hospital context, there is limited evidence to support the use of partitions for face-to-face interactions or between bed spaces (Rooney et al., 2021).

Despite the need for controlled observational and clinical studies on the effectiveness of partitions in the reduction of disease transmission in public transportation, partitions may still offer benefits in specific settings or situations, during the COVID-19 pandemic and in the future (Eykelbosh, 2021). Therefore, further research is needed on the optimal forms, material, size and position of the partitions in combination with air suctioning or ventilation systems (Epple et al., 2021) and the decontamination options (Rooney et al., 2021). In any case, the implementation of additional biosecurity measures, such as partitions, could generate a perception of safety for users in public transportation, as established in section 3.6. This could positively affect the travel decisions of users and the choice to use this mode of transport during a pandemic. Finally, as evidenced by the development of partitions in the context of the pandemic, co-design, understood as the process in which the creativity of designers and people not trained in design is applied together in the process of design development (Sanders and Stappers, 2008), is a useful tool to address and seek solutions to complex problems.

5. Conclusion

Although it is recognized at the international level that the transport of cargo and passengers is a key factor in the spread of viruses and diseases due to the high concentration and rapid mobility of people and vectors, during the COVID-19 pandemic there are still gaps in knowledge about the effect of different means of transport and especially of design interventions on transmission rates. This article presented the co-design process for a flexible partition to divide rows of seats on articulated, standard and complementary vehicles of a BRT system in a Colombian capital city. The designed prototype is a low-cost vehicle design strategy that might reduce the propagation of the virus inside buses because it generates a physical barrier to the mobility of droplets that can contain the virus. The prototype responds to the demand by a BRT during the lockdown in Colombia, to be able to separate passengers and comply with national and local regulations (maintain a physical distance of one meter between passengers and diagonal positioning).

Taking into account that the impact of the pandemic on transport systems is a complex problem, we began by understanding the design reflection-action as a single process. For the design, the construction of a theoretical framework and the collection of data, information and knowledge about the problem situation were used to formulate a practical solution. Therefore, effective design interventions in complex systems should methodologically include rethinking of the problem, leading to the generation of various solution scenarios. In this way, it was possible to create a flexible partition for the BRT. Likewise, it is necessary to analyze the context, carrying out analyses of the system in which the social challenge coexists: a complex system in which technical, medical, productive, economic and aesthetic requirements are related.

The methodological process followed for the development of the partition in the context of the pandemic, based on the principles of co-design, was a useful tool to address and seek solutions to a complex problem in a short time and with a small budget. For this task, an interdisciplinary approach and recognition of the BRT personnel as experts were essential for generating a solution to this specific need. The prototype generated for the partition meets the design requirements, with a significant cost reduction of 70 % compared to the initial proposal by the BRT. This allows for the implementation of the prototype throughout the bus fleet, but controlled observational and clinical studies on the effectiveness of the partition in the prevention of COVID-19 are required.

Finally, among the main limitations and constraints with the methodological steps are the lockdown, the curfew and the restriction on mobility imposed on citizens in Colombia during the COVID-19. At the time of the development of the partition, the authors could not move freely and could do so only on specific days to purchase groceries or access health services. This affected the participation of the co-authors in the fieldwork to conduct interviews and workshops with BRT staff. Likewise, the mobility restrictions and fear of contagion experienced by the authors limited the possibility of conducting observations and interviews with BRT users during the operation of the test bus with partitions. Additionally, the physical interaction of the authors was not possible and they had to work with the support of virtual means. Finally, there was no formal financing for the development of the partition, so the materials for the initial prototypes and tests were acquired through donations from companies raised by the first author. It is important to mention that none of the authors received monetary compensation for the development of the partition.

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CRediT authorship contribution statement

Mauricio Quintero Angel: Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Angel Miguel Uribe-Becerra:** Writing – review & editing, Visualization, Validation, Investigation, Formal analysis. **Alexander Pereira-Mosquera:** Writing – review & editing, Visualization, Validation, Resources, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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References

Aaron Gutiérrez, D.M., Domènech, A., 2021. COVID-19 and urban public transport services: emerging challenges and research agenda. Cities & Heal. 5, S177–S180. https://doi.org/10.1080/23748834.2020.1804291.

Abdullah, M., Dias, C., Muley, D., Shahin, M., 2020. Exploring the Impacts of COVID-19 on Travel Behavior and Mode Preferences. Transp. Res. Interdiscip. Perspect. 100255 https://doi.org/10.1016/j.trip.2020.100255.

Alcaldía de Pereira, 2020. MEGABÚS adopta medidas de prevención y protección ante la emergencia por COVID-19. [WWW Document]. URL https://www.pereira.gov.co/publicaciones/1619/megabus-adopta-medidas-de-prevencion-y-proteccion-ante-la-emergencia-por-covid-19/. (accesed 12.03.2020).

Alcaldía de Santiago de Cali., 2023. Memorias de Gobierno/Legado Metro Cali [WWW Document]. URL https://metrocali.gov.co/legado-metro-cali-2020-2023/ (accessed 1.26.24).

Aloi, A., Alonso, B., Benavente, J., Cordera, R., Echániz, E., González, F., Ladisa, C., Lezama-Romanelli, R., López-Parra, Á., Mazzei, V., Perrucci, L., Prieto-Quintana, D., Rodríguez, A., Sañudo, R., 2020. Effects of the COVID-19 lockdown on urban mobility: empirical evidence from the city of Santander (Spain). Sustainability 12. https://doi.org/10.3390/su12093870.

Alcaldía de Santiago de Cali., 2020. Por el bien de todos, el MIO rueda con estrictos protocolos de bioseguridad [WWW Document]. URL https://www.cali.gov.co/movilidad/publicaciones/156744/por-el-bien-de-todos-el-mio-rueda-con-estrictos-protocolos-de-bioseguridad/ (accesed 13.11.2021).

American Anthropological Association., 2012. AAA statement on ethics [WWW Document]. URL https://www.americananthro.org/%0ALearnAndTeach/Content.aspx?ItemNumber=22869&navItemNumber=652 (accessed 9.9.23).

Aparicio, J.T., Arsenio, E., Henriques, R., 2021. Understanding the impacts of the COVID-19 pandemic on public transportation travel patterns in the city of Lisbon. Sustainability 13. https://doi.org/10.3390/su13158342.

Arámbula-Ponte, P., Uribe-Becerra, M., 2016. Entendiendo el proceso de diseño desde la complejidad. KEPES 171–195. https://doi.org/10.17151/kepes.2016.13.13.9.

Arellana, J., Márquez, L., Cantillo, V., 2020. COVID-19 Outbreak in Colombia: an analysis of its impacts on transport systems. J. Adv. Transp. 2020, 8867316. https://doi.org/10.1155/2020/8867316.

Ashraf Javid, M., Abdullah, M., Ali, N., Dias, C., 2021. Structural equation modeling of public transport use with COVID-19 precautions: An extension of the norm activation model. Transp. Res. Interdiscip. Perspect. 12, 100474 https://doi.org/10.1016/j.trip.2021.100474.

Bacherini, D., Biagini, I., Lenzetti, C., Virgili, G., Rizzo, S., Giansanti, F., 2020. The COVID-19 pandemic from an ophthalmologist's perspective. Trends Mol Med. https://doi.org/10.1016/j.molmed.2020.03.008.

Buchanan, R., 1985. Declaración por diseño: retórica, argumento y demostración en la práctica del diseño. Des. Issue 2, 4–22.

Bucsky, P., 2020. Modal share changes due to COVID-19: The case of Budapest. Transp. Res. Interdiscip. Perspect. 8, 100141 https://doi.org/10.1016/j.trip.2020.100141.

Campisi, T., Basbas, S., Skoufas, A., Akgün, N., Ticali, D., Tesoriere, G., 2020. The Impact of COVID-19 pandemic on the resilience of sustainable mobility in sicily. Sustainability 12. https://doi.org/10.3390/su12218829.

Centers for Disease Control and Prevention, 2021. COVID-19 Employer Information for Bus Transit Operators [WWW Document]. Centers Dis. Control Prev. URL https://stacks.cdc.gov/view/cdc/96230 (accessed 03.12.2023).

Christidis, P., Christodoulou, A., Navajas-Cawood, E., Ciuffo, B., 2021. The post-pandemic recovery of transport activity: emerging mobility patterns and repercussions on future evolution. Sustainability 13. https://doi.org/10.3390/su13116359.

DANE, 2022. Cali en cifras: Demografía, economía y mercado laboral [WWW Document]. Dep. Adm. Nac. Estadística. URL https://www.dane.gov.co/files/investigaciones/planes-departamentos-ciudades/220322-Foro-Cali-en-cifras.pdf (accessed 1.26.23).

De Vos, J., 2020. The effect of COVID-19 and subsequent social distancing on travel behavior. Transp. Res. Interdiscip. Perspect. 5, 100121 https://doi.org/10.1016/j.trip.2020.100121.

Epple, P., Steppert, M., Florschütz, M., Dahlem, P., 2021. Partition walls as effective protection from bio-aerosols in classrooms–an experimental investigation. GMS Hyg. Infect. Control 16, 1–10. https://doi.org/10.3205/dgkh000380.

Eykelbosh A., 2021. A rapid review of the use of physical barriers in non-clinical settings and COVID-19 transmission. Vancouver, BC.

Fridrisek, P., Janos, V., 2022. COVID-19 and suburban public transport in the conditions of the Czech Republic. Transp. Res. Interdiscip. Perspect. 13, 100523 https://doi.org/10.1016/j.trip.2021.100523.

Holland, M., Zaloga, D.J., Friderici, C.S., 2020. COVID-19 Personal Protective Equipment (PPE) for the emergency physician. Vis. J. Emerg. Med. 19, 100740 https://doi.org/10.1016/j.visj.2020.100740.

Jenelius, E., Cebecauer, M., 2020. Impacts of COVID-19 on public transport ridership in Sweden: Analysis of ticket validations, sales and passenger counts. Transp. Res. Interdiscip. Perspect. 8, 100242 https://doi.org/10.1016/j.trip.2020.100242.

Jéquier, N., Blanc, G., 1983. The World of Appropriate Technology: A Quantitative Analysis. Development Centre of the Organisation for Economic Co-operation and Development, Paris.

Jones, P.H., 2014. Systemic Design Principles for Complex Social Systems. In: Metcalf, G. S. (Ed.), Social Systems and Design. Springer Japan, Tokyo, pp. 91–128. https://doi.org/10.1007/978-4-431-54478-4_4.

Kamga, C., Eickemeyer, P., 2021. Slowing the spread of COVID-19: Review of "Social distancing" interventions deployed by public transit in the United States and Canada. Transp. Policy 106, 25–36. https://doi.org/10.1016/j.tranpol.2021.03.014.

Kłos-Adamkiewicz, Z., Gutowski, P., 2022. The outbreak of COVID-19 pandemic in relation to sense of safety and mobility changes in public transport using the example of Warsaw. Sustainability 14. https://doi.org/10.3390/su14031780.

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., Tong, Y., Ren, R., Leung, K.S.M., Lau, E.H.Y., Wong, J.Y., Xing, X., Xiang, N., Wu, Y., Li, C., Chen, Q., Li, D., Liu, T., Zhao, J., Liu, M., Tu, W., Chen, C., Jin, L., Yang, R., Wang, Q., Zhou, S., Wang, R., Liu, H., Luo, Y., Liu, Y., Shao, G., Li, H., Tao, Z., Yang, Y., Deng, Z., Liu, B., Ma, Z., Zhang, Y., Shi, G., Lam, T.T.Y., Wu, J.T., Gao, G.F., Cowling, B.J., Yang, B., Leung, G.M., Feng, Z., 2020. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. N. Engl. J. Med. 382, 1199–1207. https://doi.org/10.1056/NEJMoa2001316.

Liu, F., Wang, M., Zheng, M., 2021. Effects of COVID-19 lockdown on global air quality and health. Sci. Total Environ. 755, 142533 https://doi.org/10.1016/j.scitotenv.2020.142533.

Lucchesi, S.T., Tavares, V.B., Rocha, M.K., Larranaga, A.M., 2022. Public transport COVID-19-safe: New barriers and policies to implement effective countermeasures under user's safety perspective. Sustainability 14. https://doi.org/10.3390/su14052945.

METRO CALI S.A., 2020. Informe de Gestión Metro Cali S.A. Vigencia 2019 [WWW Document]. URL https://metrocali.gov.co/wp/wp-content/uploads/2020/01/Informe-de-Gestión-Metro-Cali-S.A.-2019.pdf (accessed 1.26.24).

Mintransporte, 2020. Transporte en cifras vigencia 2019. Ministerio de Transporte, Bogotá D.C.

Mirzaie, M., Lakzian, E., Khan, A., Warkiani, M.E., Mahian, O., Ahmadi, G., 2021. COVID-19 spread in a classroom equipped with partition – A CFD approach. J. Hazard. Mater. 420, 126587 https://doi.org/10.1016/j.jhazmat.2021.126587.

Musselwhite, C., Avineri, E., Susilo, Y., 2020. Editorial JTH 16 –the coronavirus disease COVID-19 and implications for transport and health. J. Transp. Heal. 16, 100853 https://doi.org/10.1016/j.jth.2020.100853.

Oztig, L.I., Askin, O.E., 2020. Human mobility and coronavirus disease 2019 (COVID-19): a negative binomial regression analysis. Public Health 185, 364–367. https://doi.org/10.1016/j.puhe.2020.07.002.

Pardo, C.F., Zapata-Bedoya, S., Ramirez-Varela, A., Ramirez-Corrales, D., Espinosa-Oviedo, J.-J., Hidalgo, D., Rojas, N., GonzÃ!'lez-Uribe, C., GarcÃ\-a, J.D., CucunubÃ!', Z.M., 2021. COVID-19 and public transport: an overview and recommendations applicable to Latin America. Infectio 25, 182–188.

Paul, T., Chakraborty, R., Anwari, N., 2022. Impact of COVID-19 on daily travel behaviour: a literature review. Transp. Saf. Environ. 4, tdac013. https://doi.org/10.1093/tse/tdac013.

Perencevich, E., Diekema, D., Edmond, M., 2020. Moving personal protective equipment into the community: face shields and containment of COVID-19. JAMA.

Rittel, H.W., Webber, M.M., 1973. Dilemmas in a general theory of planning. Policy Sci. 4, 155–169.

Rooney, C.M., McIntyre, J., Ritchie, L., Wilcox, M.H., 2021. Evidence review of physical distancing and partition screens to reduce healthcare acquired SARS-CoV-2. Infect. Prev. Pract. 3, 100144 https://doi.org/10.1016/j.infpip.2021.100144.

Ruth Shortall, N.M., Wee, B.V., 2022. COVID-19 passenger transport measures and their impacts. Transp. Rev. 42, 441–466. https://doi.org/10.1080/01441647.2021.1976307.

Sanders, E.-B.-N., Stappers, P.J., 2008. Co-creation and the new landscapes of design. CoDesign 4, 5–18. https://doi.org/10.1080/15710880701875068.

Sanguinetti, A., DePew, A., Hirschfelt, K., 2023. Vehicle design strategies to reduce the risk of COVID-19 transmission in shared and pooled travel: inventory, typology, and considerations for research and implementation. Transp. Res. Rec. 2677, 641–655. https://doi.org/10.1177/03611981221141631.

Sanguinetti, A., DePew, A., Hirschfelt, K., Ross, C., Khoe, E., Ferguson, B., 2021. Practitioner Guide: An Inventory of Vehicle Design Strategies Aimed at Reducing COVID-19 Transmission in Public and Private Pooled and Shared Transportation. Davis, CA. https://doi.org/10.7922/G23X84XB.

Sogbe, E., 2021. The evolving impact of coronavirus (COVID-19) pandemic on public transportation in Ghana. Case Stud. Transp. Policy 9, 1607–1614. https://doi.org/10.1016/j.cstp.2021.08.010.

Tagini, S., Brugnera, A., Ferrucci, R., Mazzocco, K., Pievani, L., Priori, A., Ticozzi, N., Compare, A., Silani, V., Pravettoni, G., Poletti, B., 2021. Attachment, personality and locus of control: psychological determinants of risk perception and preventive behaviors for COVID-19. Front. Psychol. 12 https://doi.org/10.3389/fpsyg.2021.634012.

Tatem, A.J., Rogers, D.J., Hay, S.I., 2006. Global Transport Networks and Infectious Disease Spread, in: Hay, Simon I, Graham, A., Rogers, David J (Eds.), Global Mapping of Infectious Diseases: Methods, Examples and Emerging Applications, Advances in Parasitology. Academic Press, pp. 293–343. https://doi.org/https://doi.org/10.1016/S0065-308X(05)62009-X.

TRANSCARIBE, 2020. Transcaribe instala dispensadores de gel antibacterial para usuarios del sistema. [WWW Document]. URL https://transcaribe.gov.co/index.php/noticia/transcaribe-instala-dispensadores-de-gel-antibacterial-para-usuarios-del-sistema/. (accessed 09.08.2020).

TRANSMETRO, 2020. TTransmetro regula ocupación de sus buses como medida preventiva contra el COVID-19. [WWW Document]. URL https://transmetro.gov.co/noticias/transmetro-regula-ocupacion-de-sus-buses-como-medida-preventiva-contra-el-covid-19/. (accessed 21.03.2021).

TRANSMILENIO, 2020. Así operará TransMilenio en la nueva normalidad. [WWW Document]. URL https://www.transmilenio.gov.co/publicaciones/151910/asi-operara-transmilenio-en-la-nueva-normalidad/. (accessed 24.10.2020).

Tsavdari, D., Klimi, V., Georgiadis, G., Fountas, G., Basbas, S., 2022. The anticipated use of public transport in the post-pandemic era: insights from an academic community in Thessaloniki. Greece. Soc. Sci. 11 https://doi.org/10.3390/socsci11090400.

Villareal, C. 2005. La ergonomía es parte del proceso de diseño industrial. Universidad de Monterrey. México [WWW Document] <http://www.semac.org.mx/archivos/5-4.pdf> 20/11/23.

Who, 2020b. Supporting healthy urban transport and mobility in the context of COVID19. World Health Organization, Geneva.

WHO, 2020a. WHO Director-General's opening remarks at the Mission briefing on COVID-19 - 12 March 2020 [WWW Document] URL https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-mission-briefing-on-covid-19—12-march-2020#:~:text=First%20of%20all%2C%20I%20would,speed%20and%20scale%20of%20transmission. 12 March 2020.

Ye, J., Ai, Z., Zhang, C., 2021. A new possible route of airborne transmission caused by the use of a physical partition. J. Build. Eng. 44, 103420 https://doi.org/10.1016/j.jobe.2021.103420.

Zhang, Y., Zhang, A., Wang, J., 2020. Exploring the roles of high-speed train, air and coach services in the spread of COVID-19 in China. Transp. Policy 94, 34–42. https://doi.org/10.1016/j.tranpol.2020.05.012.