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RESEARCH ARTICLE

Obstacles, Social Norms and Communication to Improve Service in Mass Transport. An Analysis in Bogotá's Bus Rapid Transit System

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ABSTRACT

Overcrowding during bus boarding contributes to delays in service waiting times due to extended boarding times. Boarding times at TransMilenio stations have increased due to the daily demographic growth in Bogotá. Despite being a global reference in mobility, its users perceive TransMilenio negatively. This study proposes a passenger dynamic to reduce boarding times on TransMilenio articulated buses by implementing obstacles and learning by rules. The dynamic aimed to improve organization on boarding platforms, facilitate access for people with disabilities, optimize space utilization, and positively influence user perception. The dynamic was validated through (a) a mixed method research phase, in which users' behavioral variables were identified during bus boarding using a nested concurrent design with a dominant model (DIAC in Spanish) to establish appropriate rule-based learning messages, (b) an agent-based simulation to select the obstacle that most effectively reduced boarding times for articulated buses, (c) a full factorial experimental model to determine the effects of rule-based learning, the selected obstacle, and their interaction on boarding times at Platform One of Portal Suba, and (d) a final phase measuring the experimental model's impact on users' perception. The study's results indicate that the passenger dynamic, which included delivering a descriptive message and a queue obstacle, reduced boarding times by 24.58%.

INTRODUCTION

Bogota's BRT (Bus Rapid Transit) system, known as TransMilenio, plays a crucial role in facilitating daily transportation for the city's residents. This public transportation alternative commenced operations in 2000 in response to the population growth experienced in the 1990s (DANE, 2005; TransMilenio en cifras, 2024). Bogotá's population surged by 35% from the 1990s to 2000 (DANE, 2005), necessitating the development of a mass transportation system to meet this growing demand. In 2023, the BRT passenger demand reached 510 million trips annually, with an average annual growth rate of 11.13 % (TransMilenio en cifras, 2024). TransMilenio has been unable to meet user demand due to discontinuity in executing the planned development strategy (Transmilenio, 2018). The system is projected to face worsening passenger overload issues, highlighting the importance of implementing short-term proposals for passenger management and control.

The excess of passengers in Bogotá's BRT system, TransMilenio, leads to significant issues related to service quality and brand perception, despite its recognition as a world-renowned BRT system and

its contributions to reducing pollution, accidents, and user travel times (25 km/h). However, according to Rincón et al. (2016), users want a faster system (88%), more comfort (51%), reduced crime (37%), order (27%), environmental benefits (25%), and improved urban ethics (23%). This study is consistent with the Bogotá Chamber of Commerce's (2016) findings, which reported that 66 % of respondents identified excess passengers as the main issue. Additionally, 65% felt that security had worsened, with 95% having been victims of theft. These perceptions are primarily due to the high density of people at stations, on platforms, and within articulated buses, defined as overcrowding (Tirachini et al., 2013).

On the other hand, overcrowding leads to user anxiety (Cheng, 2010), tension, anger, despair (Lundberg, 1976; Mohd Mahudin et al., 2011), intolerance, delays, slower bus flow, deterioration of civic culture and non-compliance with rules (Tirachini et al., 2013). Passenger demand fluctuates, peaking between 6:30- 8:30 AM and 4:30-7:30 PM. The concept of peak hour is used to express the variation in demand in these times (TRB, 2003). This variation is due to users planning their trips to arrive at their destinations on time. During these hours, boarding platforms are overcrowded, and articulated buses are filled to capacity. Reducing overcrowding requires investment in infrastructure, which involves a substantial budget, long-term planning, and commitment from stakeholders. However, a promising solution seems to lie in reducing boarding time. Boarding time impacts the average service time per passenger, total travel times, system speed, capacity, and user perception (TRB, 2003).

Boarding time is defined as the time a bus spends at a platform or stop to facilitate passenger movements, including the time required to open and close doors (TRB,2003). Overcrowding during bus boarding leads to increased wait times as boarding times are prolonged (Tirachini et al., 2013). According to Wardman and Whelan (2011), the maximum number of people per square meter in a public transportation system should be five. However, in 2018, TransMilenio averaged eight passengers per square meter, resulting in 37.5% overcrowding and an average boarding time of 79 seconds. Fernández et al. (2015) state that boarding time increases linearly with passenger density (pax/m2). Butler et al. (2013) notes that when average boarding time exceeds 60 seconds, system capacity falls below 50%.

Consequently, boarding time influences passenger capacity, vehicle capacity, traffic speed, total travel time, and service times, thereby affecting user perception of service quality. These factors are interconnected: A shorter boarding time time lowers the service time per passenger, enabling more vehicles to flow through platforms and potentially transporting more passengers. Shortening boarding time would positively impact total travel times and improve the boarding process for articulated buses, leading to improved orderliness, accessibility for disabled individuals, and more efficient use of platform space. Additionally, it would reduce risky movements during boarding and friction among passengers. Therefore, there is a clear need to devise a strategy to reduce boarding time and improve the quality of service on TransMilenio.

Boarding time and service quality are adversely affected by non-compliance with the rules. Article 146 of the National Code of Police and Coexistence outlines the regulatory framework for TransMilenio users. Non-adherence to these regulations leads to disorder at stations, preventing access to high-quality service. Users who comply with the regulations express dissatisfaction due to others who misuse the system, as 31% of users admitted to breaking a rule out of frustration with the transportation system (Bogotá Camara de comercio, 2016). This issue is particularly pronounced at Transmilenio 's main trunk stops. Indeed, the system comprises 9 portals, 138 stations, and 7,157 zonal stops. Average travel times on Transmilenio have increased by 12.62% over the past three years (Bogotá Chamber of Commerce, 2016), leading to user protests (TransMilenio, 2018). In 2016, the Transmilenio administration reported 146 citizen demonstrations. According to Bocarejo (2015), the quality of service offered by TransMilenio is severely limited because the system is operating

beyond its capacity. As of 2018, TransMilenio was transporting up to 43 000 passengers per hour per direction (Hidalgo et al., 2013), exceeding the capacity limit by 8000 passengers per hour per direction, especially during morning and evening peak hours.

Regarding the issues identified in the system, overcrowding is the most common complaint in quick passenger surveys of BRT systems in Latin American cities. In Mexico City's Metrobus, 87% of respondents consider overcrowding the main issue, and 42% find bus waiting times excessive (Murata et al., 2017). In Bogotá's TransMilenio, passenger surveys conducted by the Bogotá Chamber of Commerce indicate that "too many passengers" is the primary complaint about the BRT system (Bogotá Camara de comercio, 2016). Travelers may respond to overcrowding by adapting their transportation habits (Pels et al., 2005). Literature has demonstrated that passengers perceive overcrowding as equivalent to extra time on their journey, and in some cases, they are willing to change their behavior to avoid it. In addition, overcrowding on public transportation in major cities has become a global issue (Gakenheimer, 1998). To mitigate it and reduce boarding times, research has shown that providing information about overcrowding can influence passengers' social behavior. For example, in Korea, qualitative studies have indicated that informed overcrowding influences passengers' decisions about whether to wait for a later service (Kim et al., 2013).

Research has extensively examined using spatial elements or obstacles as channeling devices. Helbing et al., (2005) found that a column opposite the exit door in a corridor can stabilize and streamline flow by up to 50%. Frank and Dorso (2011) found that an obstacle (e.g., a pillar or flat panel) placed at a distance L from an exit door of width L in a hallway can achieve the highest evacuation speed. Alonso-Marroquín et al., (2012) identified that in a "bottleneck" scenario, an obstacle increased flow by 16%. They also found that flow reaches its maximum value when adjusting the distance to the obstacle rather than its diameter. Shiwatoki (2013), found that architectural adjustments at the entrance, forming a conical shape, could reduce evacuation time by more than 160%. Yanagisawa et al. (2018) identified that increasing the number of pedestrian lines formed in an evacuation or boarding system inceases, the passenger flow (passengers/m*s) through the door, decreases. Zhibin et al. (2018) verified that a flow control strategy limits the number of passengers ready to board and stabilizes the flow at the entrance door. Feliciani et al., (2018) stated that signage-based obstacles help improve evacuation efficiency.

The presence of electronic boards providing real-time information about bus arrivals influences some users' decisions regarding whether to wait for the service. For others, the timing does not affect their decision, as they remain indifferent to entering the bus amid pushing and shouting instead of boarding passively while adhering to safety regulations (TransMilenio, 2018). In Bogotá, the TransMilenio user manual specifies that passengers should always stay behind the yellow line at stations, portals, and inside the bus, maintaining a line behind it to avoid accidents due to overcrowding (TransMilenio, 2018). However, these rules are often not followed during peak hours. This behavior reflects broader issues within the transportation system, where non-compliance with regulations and a lack of civic culture are evident (TransMilenio, 2018). As a result, communication strategies have been implemented to encourage adherence to the rules and mitigate the negative impact of some of the problems on TransMilenio. For instance, the "*Todos pagamos el pato*" (We all pay the price) campaign (2016) was developed and implemented to address fare evasion. This campaign utilized appeals to follow rules (prescriptive norms) to mitigate the adverse effects of fare evasion.

Indeed, social norms are based on the assumption that individual behavior is influenced by the social group within a context of normality and under the premise of what is socially approved and desirable (Cialdini et al., 1990; Jacobson et al., 2011). Consequently, individuals may act based on their observations of others or the expectations of reference groups, following two normative paths: descriptive norms and prescriptive norms (Cialdini et al., 1990). Descriptive norms dictate that

people behave in ways considered normal; this behavior is repeated and reinforced because what is deemed "normal" is effective and adaptive to the environment. In contrast, prescriptive norms guide individuals to act according to what is socially approved or disapproved, motivated by the potential consequences of their behaviors (Cialdini, 2003; White et al., 2009); (Carrus et., 2009; Fornara et al., 2011).

The influence of norms on various behaviors, for instance, pro-environmental behaviors related to garbage and waste management (Cialdini et al., 1990), enhanced positive behavior and willingness to cooperate by assuming material and individual costs to correct violators of such norms (Fehr & Gächter, 2002). Additionally, norms guide the choice of eco-labels based on descriptive norms (Charalambides et al., 2015), household energy savings (Nolan et al., 2008), and energy conservation (Kantola et al., 1984). The effect of descriptive norms on public transportation behavior has also been confirmed (Kormos et al., 2015). These findings suggest that descriptive local norms are crucial in promoting behaviors that benefit the common good in particular physical-social environments.

Based on the above, this research aims to implement a dynamic system of obstacles, in conjunction with a communication strategy focused on regulatory compliance, to reduce overcrowding at stations and boarding times. This aligns with improving the perception of the service, positively impacting civic culture, and enhancing the overall use and reach of the TransMilenio system in Bogotá.

MATERIALS AND METHODS

For this study, it was noted that Portal Suba is one of the terminals with the highest levels of overcrowding during peak hours, with 78,825 entries per day (TransMilenio en cifras, 2024). Among these users, 56.5 % use the articulated buses on Platform One of Portal Suba. In 2023, TransMilenio reported an average boarding time of 79 seconds for these articulated buses, resulting in a limited capacity (50%). Given this data, the project focused on platform one of Portal Suba. In summary, TransMilenio lacks effective planning and strategies to ensure the system's proper functioning. Although there have been initiatives to strengthen the system over the past few years, developing and proposing alternatives to improve service quality is necessary, thereby positively impacting users' perceptions of the system. Minimizing boarding time has a positive impact on these aspects.

This research aimed to design a rule adherence dynamic to reduce boarding times for articulated buses on a passenger platform of TransMilenio S. A. in Bogotá – Colombia. The following objectives were proposed to achieve this: 1- Identify behavioral variables that influence the boarding of articulated buses at Portal Suba through a nested concurrent dominant model design. 2. Determine the effects of the interaction between norm adherence and the use of obstacles on boarding articulated buses using a general full factorial design of several replications. 3. Measure users' perception of passenger dynamics based on rule adherence and the obstacle applied, according to Cialdini et al. (1990) normative focus theory.

The dynamic was developed in three phases: Mixed research, experimental model, and impact measurement a) in the mixed research phase, user behavior variables influencing the boarding of articulated buses were identified using a concurrent nested design with a dominant model (DIAC) to establish the most appropriate message for applying normative messages. (b) In the second phase, an agent-based simulation was conducted to select the obstacle with the most significant effect on reducing boarding time. (c) In the experimental model phase, two factorial experiments were carried out to determine the impact of the interaction between rule adherence and using the selected obstacle on boarding articulated buses. (d) In the final testing phase, the impact of the implemented solution on user perception of the applied dynamics was measured.

The mixed-method research process was developed in three steps: (1) participant observation, (2) qualitative research, and (3) quantitative research. This approach made it possible to determine applicable variables for constructing the appropriate message for norm adherence when boarding

articulated buses. Information was collected, interpreted and analyzed through participant observation. For the qualitative research process, in-depth interviews were conducted, with questions validated by experts in the field. These interviews provided valuable information, judgments, and evaluations. The interviews were conducted with 10 randomly selected users from platform one at Portal Suba. The results were analyzed through textual data analysis to identify the density and frequency of words used by the participants, which helped to identify the variables influencing the boarding of articulated buses.

The quantitative research commenced after identifying variables influencing the boarding of articulated buses. The sample size was determined based on a universe of 2,441 individuals, with a heterogeneity of 50% and a confidence level of 95% (N=333). The survey instrument was administered to 385 users recruited during peak hours on platform one at Portal Suba. Among the respondents, 51% were women and 49% were men. The age distribution of respondents was as follows: between 18 and 25 (37 %), between 26 and 33 (25 %), between 34 and 41 (19 %) and 42 or older (19 %). A statistical analysis of the association of variables was applied using SPSS Statistics to identify the associations between variables affecting boarding behavior. Finally, the log-linear test was used to identify associations between gender, age, perceptions of civic culture in TransMilenio, and boarding behavior. Based on the quantitative findings and the identified user behavioral variables influencing the boarding process, an appropriate message was developed for applying rule following. This message was designed to appeal to both (a) descriptive norms and (b) prescriptive norms.

In the experimental phase, factorial designs (c) were used to assess the effects of the interaction between obstacles and rule following on boarding time (Gutiérrez and De la Vara, 2008) The dependent variable studied was boarding time, which indicated the impact of each experimental condition (Montgomery, 2004). The independent variables (factors) examined were: 1) obstacle (with or without an obstacle) and 2) Prescriptive norm (with and without prescriptive norm). There were 8 factorial groups as follows: with obstacle- with descriptive norm, with obstacle-without descriptive norm, without obstacle- with descriptive norm, without obstacle- without descriptive norm, with obstacle-with prescriptive norm, with obstacle- without prescriptive norm, without obstacle- with prescriptive norm, and without obstacle-without prescriptive norm. Thus, 2x2 factorial designs were employed to examine both individual and interaction effects of various factors on the response variable (Gutiérrez and De la Vara, 2008). Sample sizes for each treatment were determined based on Kirk's table (1995), using a power of 0.7 and a moderate effect size, which indicated that 25 articulated buses per treatment were required (Cohen, 1988; Ledesma, Macbeth and de Kohan, 2009; Morales, 2012).

PROCEDURE

A total of 150 experimental applications were defined, requiring 6 days of study, with each day dedicated to a specific factorial group. Samples were taken from 6:30 a.m. - 8:30 a.m. on Platform One of the H15 service at the Portal Suba station of TransMilenio S. A. On day one, the treatment was studied without an obstacle and a norm. On day two, the treatment had an obstacle and a prescriptive norm. Day three focused on the treatment with an obstacle and a descriptive norm. Day four examined the treatment with an obstacle and without a norm. On day five, the treatment was studied without an obstacle and with a prescriptive norm. Day six assessed the treatment without an obstacle and with a prescriptive norm. The experimental application was supported by 10 mediators equipped with the necessary logistical tools. Mediators 1, 2, and 3 indicated the start of each row; mediators 4, 5, and 6 conducted perception surveys; mediator 7 collected samples, and the remaining three mediators distributed the normative message. The normative message was delivered as a bookmark, chosen for its practical utility, and distributed to passengers using the service during peak hours.

The articulated buses included in the study were those operating within the designated time range. The analysis was conducted on each experimental group based on the response variable. The normality of the response variable was verified using the Kolmogorov-Smirnov test ($p>.05$). The boarding time for the treatment with an obstacle and descriptive norm was M=59.48 s (SD=11.79), with obstacle- without descriptive norm M=65.88 s (SD=11.83), without obstacle and with descriptive norm M=63.36 s (SD=10.08), without obstacle – without descriptive norm M=79.12 s (SD=12.29), with obstacle-with prescriptive norm M=62.68 s (SD=10.21), with obstacle- without prescriptive norm M=65.88 s (SD=11.83), without obstacle- with prescriptive norm M=64.12 s (SD=16.81) and without obstacle- without prescriptive norm M=79.12 s (SD=12.29). A Univariate General Linear Model (GLM) was employed, considering $p<.05$, to test hypotheses regarding the effects of other variables on the dependent or response variable. The Univariate GLM analyzed variance for the response variable, examining each factor and their interaction. (IBM Knowledge Center, 2011).

Users' perceptions regarding passenger dynamics were measured based on adherence to norms and the applied queue obstacle. In alignment with the quantitative research questions used prior to the dynamics, the survey was re-administered with an additional question. This question asked respondents if they believed that standing in line at the TransMilenio boarding platform improved behavior. Considering the articulated bus capacity of 160 individuals, with a heterogeneity of 50%, a margin of error of 5%, and a confidence level of 95%, a minimum sample of 114 individuals per treatment was established.

The resulting instrument was administered to 721 individuals over the course of six study days. (Among the respondents, 49% were women and 51% were men. The age distribution was as follows: between 18 and 25 years old (35%), between 26 and 33 years old (30 %), between 34 and 41 years old (25 %), and 42 years old or older (10 %). A statistical analysis of the association of variables was applied based on these results and the experimental, descriptive, or prescriptive groups. This analysis focused on the selected factorial groups from the experimental model phase and the dependent variables under investigation: perception of civic culture, boarding behavior, attitudes towards using TransMilenio, overall experience with TransilMenio, the most important rule, the impact of personnel responsible for maintaining order, and perceptions of civic culture during queueing.

To compare users' perceptions before and after the intervention, a random sample was drawn from the total pre-intervention perception survey sample. The sample size was determined based on the number of individuals surveyed within each selected factorial group. A statistical analysis of variable associations was then applied between the pre-intervention and post-intervention analysis groups, focusing on the dependent variables under study. The Chi-square statistic made it possible to identify resulting associations and examine how the intervention influenced users' perceptions.

To further corroborate these results, an additional test was conducted on the selected factorial group on the same day and at the same time as the initial test. The initial sample size was maintained across all factorial groups throughout the study. Normality of the response variable was assessed using the Kolmogórov-Smirnov ($p>.05$) test based on the obtained times. A t-test for independent samples was used, with a 95% confidence level, to determine if there were significant differences between the two samples during the experiment and the verification phase. Additionally, the study included two questions to assess whether individuals recalled the message and if they had shared it with others. Responses were analyzed using descriptive statistics. This additional testing ensured the reliability of the results obtained in the study.

RESULTS

Mixed Methods Results

Participant Observation

The diversity of roles provided a broad perspective on the phenomenon under study. It became evident that there was inappropriate behavior among individuals when boarding the bus due to overcrowding at the entrances of the articulated buses, a lack of civic culture, and inadequate enforcement of order by the staff responsible for maintaining order within Transmilenio. Inappropriate behavior refers to users not adhering to TransMilenio 's rules. Observations highlighted those users disregarded the queue arrival order, pushed to board the articulated buses, shouted and argued with one another, and failed to grant priority access to individuals who are entitled to it (pregnant women, elderly individuals, passengers with infants in their arms, children under seven and passengers with disabilities or reduced mobility).

Qualitative research

The empirical research led to the formulation of 11 research questions. Four experts' evaluations yielded a Cronbach's alpha of .88, indicating the instrument's strong reliability for the research. Following this, in-depth interviews were conducted with 10 users at Platform One of the Suba Portal during peak hours. The results were analyzed using the textual data analysis tool, which identified the research axes and variables influencing boarding behavior on articulated buses: gender, age, reason for using TransMilenio, perception of civic culture, individual behavior, most frequently used mode of transport, experience with TransMilenio, sentiments towards using Transmilenio, boarding behavior, waiting time to board the articulated bus, knowledge of rules, the most crucial rule, knowledge of personnel responsible for maintaining order, frequency of personnel in charge of maintaining order, impact of the personnel responsible for maintaining order, and service solutions.

Quantitative research

Once the variables likely influencing boarding behavior on articulated buses were identified, 11 evaluation hypotheses were formulated along with their respective variables and attributes. Subsequently, quantitative research questions were established. A sample size of N=333 was determined, with a 5% margin of error, 50% heterogeneity, and a 95%—confidence level. The survey was then administered to the subjects, resulting in a total of 385 respondents.

Based on the obtained results and considering the hypothesis for each pair of variables: a) Ho: Homogeneity hypothesis: No association exists between the variables b) Ha: Difference hypothesis: There is a correlation between the variables, a statistical analysis of variable associations was conducted. The analysis was performed with a 95% confidence level, a universe size= 385 and $\rho < .05$ was taken into account to reject the null hypothesis. The findings revealed the following associations between boarding behavior and the sentiments towards using TransMilenio, $\chi 2$ (16, N=385) =37.76, p=.01. There is an association between perceptions of very little civic culture and pushing like animals, with 81.3% of individuals who believe there is little civic culture, push like animals. $\chi 2$(12, N=385) =30.749, p=.0. There is an association between the very little civic culture and experiencing crowds at the entrance to the buses, with 69.03% of individuals who perceive very little civic culture in TransMilenio also experiencing crowding at bus entrances $\chi 2$(20, N=385) =42.62, p=.0. There is an association between stress and crowds at the entrance to buses, with 70.8% of individuals who have felt stressed when using TransMilenio, also reporting crowding at bus entrances $\chi 2$(20, N=385) =43.15, p=.0. There is an association between the attributes of pushing and pushing like animals. It was observed that 83.3% of those who push when boarding the bus perceive others as pushing like animals $\chi 2$(12, N=385) =22.17, p=.04. There is an association between pushing and stress, with 81.7% of individuals who push when boarding the bus feeling stressed when using

TransMilenio $\chi 2(16, N=385) = 37.76$, $p=.01$. An association was found between stress and waiting more than 12 minutes for a bus. It was observed that 68.5% of individuals who wait longer than 12 minutes for a bus report feeling stressed $\chi 2(16, N=385) = 27.39$, $p=.04$. There is an association between waiting 7-9 minutes and a few minutes. It was observed that 47.1% of individuals who spend between 7-9minutes waiting for a bus have little knowledge of TransMilenio's rules $\chi 2(16, N=385) = 44.76$, $p=.0$. There is an association between the attributes almost always and none. It was observed that 33.9% of those who almost always see the personnel in charge of maintaining order in TransMilenio consider that their work has had no effect $\chi 2(16, N=385) = 162.85$, $p=.0$. There is an association between women and the belief that sending more buses would improve service, with 68.0% of women, considering that increasing the number of buses would improve TransMilenio' s service $\chi 2(3, N=385) = 9.75$, $p=.02$. An association was found between experiencing crowds at the entrance to buses and waiting in line for the bus in an orderly fashion and respecting arrival turns $\chi 2(15, N=385) = 41.28$, $p=.0$. It was observed that 40.6% of those who experience crowding at bus entrances believe that waiting in line in an orderly fashion and respecting arrival turn is the most important rule in TransMilenio. $\chi 2(15, N=385) = 41.28$, $p=.0$

A Log-linear test was performed to identify associations between pairs of variables, a method used to analyze the types of relationships between factors in a contingency table (Christensen, 2006). The results indicate a significant association, particularly among men aged 26-33, who perceive a lack of civic culture in the TransMilenio service and fail to queue when waiting for and boarding the articulated buses ($\chi 2(12, N=385) = 28.53$, $p=.01$).

Message for the implementation of norm adherence

After identifying the associations between variables, the messages for the study on norm adherence were formulated as follows:

The message for the prescriptive norm is Queuing helps speed up the service.

The message for the descriptive norm is: Respecting the queue. Everyone who contributes to good service does so.

Experimental Model Results

The experimental model was implemented after selecting the most effective queue obstacle to reduce boarding time. On the first day of the experiment, it was observed that arranging the queue in an L-shape was preferable due to user behavior. The same experimental conditions were maintained throughout all days of the experiment. The Kolmogórov-Smirnov test confirmed that the response variable was normally distributed with $p > .05$. For analysis, the sample was divided into experimental groups. The univariate analysis of variance for the prescriptive norm experimental group revealed a significant difference in mean boarding times between the obstacle, the norm and their interaction ($F(1,100) = 5.13$, $p = .02$). Similarly, the univariate analysis of variance for the descriptive norm experimental group also indicated significant differences in mean boarding time between the obstacle, the norm and their interaction ($F(1,100) = 4.11$, $p = .04$). The lowest mean boarding time was observed in the factorial group with the obstacle-with descriptive norm with $M=59.48s$ ($SD=11.79$), which indicated that this factorial group had the most significant effect on reducing boarding time.

These results are consistent with Deutsch et al., (1955), who argue that behaviors exhibited by the majority are perceived as consensual and reliable indicators of appropriate conduct in those circumstances. This perception guides individuals in acting most effectively and successfully. Accordingly, Cialdini et al., (1990) demonstrated that individuals are more influenced by the behaviors they perceive others engaging in than by sanctions. Therefore, the descriptive norm, which reflects typical behavior, has a greater impact on adherence to norms.

Results of Design Validation

Once the dynamic with the most substantial effect on reducing boarding time had been selected, the impact of this solution on user perception was evaluated. A statistical analysis of the association of variables was conducted using perception surveys, focusing on the experimental group's "descriptive norm" and the dependent variables. Statistical significance was found in the following areas: perception of civic culture while queueing (p=.0), behavior when boarding a bus (p=.0), perception of culture (p=.0), feelings when using TransMilenio (p=.0), experience with TransMilenio (p=.0), the most important rule (p=.0), and the impact of staff in charge of maintaining order (p=.0).

On the other hand, a random sample of N=121 was drawn from the total perception survey sample to compare user perceptions before and after the dynamic. A statistical analysis of variable associations was performed based on the groups (a) before and, (b) after the intervention, alongside the dependent variables. The analysis revealed a statistically significant difference in the perception of civic culture $\chi 2(4, N=242) = 43.93$, p=.0. Before the intervention, 51.2 % of individuals perceived very little civic culture; this figure dropped to 15.7% after the intervention. Additionally, 50.41% perceived it as average. The impact of the personnel responsible for maintaining order on TransMilenio also showed a statistically significant difference $\chi 2(4, N=242) = 107.8$, p=.0. Prior to the intervention, 39.6 % of individuals considered the staff's impact to be minimal, which fell to 19.83 % after the intervention. Conversely, 59.5 % rated the staff's impact as substantial following the intervention. These results highlight the effect of passenger dynamics on user perception.

Additionally, regarding message recall, 41.1% of randomly surveyed individuals reported remembering the message. However, most (91.9%) did not share the message with others. Furthermore, the Kolmogórov-Smirnov test confirmed that the response variable in the verification test for the dynamic was normally distributed with $p > .05$. An independent samples t-test was performed comparing the response variable values from the selected factorial group and the verification test to assess the hypothesis of equal means. The results, with $t(48) = .192$, p=.84, indicated no significant difference between the means of the two analysis groups, ensuring the reliability of the study's results. These findings positively impact user perception of the system and a 24.58% reduction in boarding time for articulated buses.

DISCUSSION

The qualitative study provided an initial insight into users' perception of Bogotá's BRT system. It identified key behavioral variables influencing the boarding process for articulated buses. The findings indicated that men aged 26-33 consider that there is little civic culture within Transmilenio and report failing to queue properly when boarding the articulated buses. Furthermore, consistent with Cialdini et al., (2006), the study found that individuals tend to mirror the behavior of those around them.

On the other hand, boarding time influences users' perception (TRB, 2003). This was reflected in the passenger dynamic, where the effect of reducing boarding time was most pronounced. The study's findings reveal that users exposed to the dynamic with the obstacle, combined with the descriptive norm, perceived a significant improvement in civic culture. This result aligns with Biel & Thogersen (2007), who assert that using obstacles as channeling devices enhances the flow of people and that adherence to norms significantly influences individual behavior. Indeed, the results showed that before the intervention, individuals perceived very little civic culture, while after the implementation of the dynamic users rated civic culture as average.

Furthermore, consistent with Rincón et al., (2016), the study indicates that users desire a more orderly system and improved urban ethics. Specifically, participants experienced order at the entrance of the articulated buses (61,2%) and identified the most critical rule as queuing in an

orderly fashion and respecting arrival turns (52,4%). Overall, the dynamic resulted in a 24.58 % reduction in boarding time on the articulated buses.

With an average boarding time of M=59.48s (SD=11.79) for the selected passenger dynamic, the literature suggests that the system's capacity is slightly above 50%. Transmilenio should direct its efforts toward organizing the system using its existing resources. For instance, nine boarding zones function without company intervention at Portal Suba. Specifically, the articulated bus boarding platform H15 has approximately 40m2 of underutilized space. This issue is replicated throughout the system. The boarding dynamic involving queuing proved crucial in shaping user perception and should be integrated into Transmilenio 's short-term solutions.

The experimental model validated the results from the agent-based simulation. In the simulation, the queueing boarding dynamic yielded an average time of M=61.33s (SD=2.99), which differed by +1.85s from the time observed in the implemented passenger dynamic. The simulation also anticipated a reduction in the variation of boarding times when applying the queuing dynamic. However, the experimental model, which included the human factor in the equation, revealed behavior that had not been modeled. Examples include individuals forcefully taking a spot at the front of the queue, the relationship between passenger aggression and bus delays, and users who opted not to board the next bus upon arriving at the front of the queue.

The intervention's impact on boarding articulated buses resulted in improvements in orderliness, access for disabled individuals, and more efficient use of available space on the platforms. When implementing the queuing obstacle, careful consideration should be given to the platform's characteristics to design an effective queuing scheme, optimize space, and ensure users clearly understand the queueing scheme.

Future research should continue investigating obstacles, norm adherence, and user behavior in public spaces. This study, conducted over six days, analyzed variables affecting user perceptions of the Transmilenio service, yielding positive results. However, further exploration into new dynamics for reducing boarding times for articulated buses and improving user perceptions of the service is recommended. The study's limitations, such as the number of evaluation days, participant willingness, logistical aspects, corporate permissions, research restrictions, and the timing of application and observation, should be considered for future investigations. Additionally, it is crucial to complement this research with studies examining the impact of interventions across various productive and social sectors (Burbano, Carvajal, 2005), the reduction of accidents, citizen behavior, and cultural factors that may exacerbate risks (Gutierrez, 2009).

Finally, in line with Echeverry et al. (2005), it is undeniable that, due to its impact on social quality of life and urban economic development, there is a pressing need to expand empirical research on the deficiencies of Transmilenio as a mass public transportation system, aligned with the characteristics and specificities of this industry.

AUTHORS' CONTRIBUTIONS

Conceptualization, MM and FM; methodology, MM and FM. software, MM; validation, MM; formal analysis, MM and FM; investigation, MM, FM, JGB, DMG and MVPB; resources, MM, FM, JGB, DMG and MVPB; data curation, M.M. and F.M.; writing—original draft preparation, MM, FM, JGB, DMG and MVPB; writing—review and editing, MM and FM; supervision, M.M.; project administration, M.M.; funding acquisition, MM and FM. All authors read and approved the final manuscript.

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