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Research paper

Increased ridership and improved affordability: Transforming public transport subsidies in developing contexts

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A B S T R A C T

In Latin American cities, the affordability of public transport presents a significant obstacle to mobility. To address this challenge, several cities have implemented subsidies. Understanding the effectiveness of these subsidies is crucial, particularly in cities where a substantial portion of the population, especially those with low incomes, rely on public transport systems. This paper presents a case study conducted in Bogotá, Colombia, employing a randomized controlled field experiment involving 1607 participants. In this intervention, a randomly selected group of frequent public transport users received a cash transfer on their travel cards (a transport voucher) for four months. We aim to estimate the causal effects of providing these vouchers on ridership and affordability. The findings indicate that vouchers on average, increased ridership by up to 9% compared to the control group. This increase was most pronounced on weekdays and during peak hours. Vouchers proved particularly advantageous for populations with low fare-demand elasticity, who constitute the primary users of public transport. Furthermore, it improved their affordability by between 18 and 26%. In summary, our results indicate that providing subsidies in the form of vouchers can effectively boost public transport usage, thereby enhancing affordability for users.

1. Introduction

Public transport subsidies serve various purposes, such as reducing social inequality, compensating for the underpricing of private car/motorcycle usage, achieving economies of scale, and gaining political support. However, the implementation of efficient transport pricing remains uncommon (Eliasson, 2021) and prices for car/motorcycle usage remain lower than their social cost, creating an unbalanced competition with public transport. In large Latin American cities characterized by significant social and spatial segregation (Tiznado-Aitken et al., 2023), transport subsidies are prevalent to enhance affordability (Rivas et al., 2018). The justification for these subsidies becomes a critical concern, as low-income populations often face difficulties in regularly accessing these services. As a result, transport costs pose a considerable burden, particularly for low-income individuals who rely heavily on public transport (Estupiñan et al., 2018).

This study aims to contribute to the discussion about the efficacy of public transport subsidies and their delivery methods by presenting a case study in Bogotá, Colombia. Specifically, this paper evaluates the impact of an alternative subsidy program, cash transfers, named public transport vouchers, on ridership and affordability. This inquiry is motivated by recent evidence suggesting that the effectiveness of the current pro-poor subsidy scheme in Bogotá, consisting of a 28% fare discount, has decreased over time, failing to encourage system usage (Guzman & Hessel, 2022). Additionally, affordability remains a persistent challenge, particularly for lower-income population segments (Guzman & Oviedo, 2018). The city is spending a large amount of money on a program that is not completely fulfilling its main objective: to improve affordability and increase access to the city's public transport system. Given these circumstances, we hypothesize that the voucher scheme could encourage greater use of public transport and enhance affordability for users. Consequently, there is a pressing need to explore alternative subsidy models to improve their efficacy. This study does not aim to compare the two subsidy schemes directly.

This evaluation employed a randomized controlled experiment. Our study focused on 1607 randomly selected regular public transport users with personalized travel cards who were not beneficiaries of any subsidy. Among this group, half received a monthly cash transfer in the form of a voucher loaded onto their travel cards. Over 4 months, we allocated $7.5 and $5.6 USD to the travel cards of each participant in the

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treatment group, roughly equivalent to between 11 and 9 trips per month, respectively. The other half comprised the control group. Our research aimed to establish a causal estimate of the impact of the voucher on ridership. It is noteworthy that the transport voucher does not necessarily imply an increase in ridership, as recipients may opt to use the voucher for their usual trips without undertaking additional trips beyond their pre-voucher travel and expense patterns. Please note that the system fare never changes. The fares remained the same for both the control and treatment groups throughout the study.

Voucher schemes are particularly popular because they give people a certain element of choice while promoting desirable behaviors, which has positive effects (Minnich et al., 2022). According to the literature, vouchers, by reducing costs by one unit, have an effect equivalent to an increase of one unit in income (Epple & Romano, 2012; Podesta et al., 2021). Moreover, unlike fare reduction schemes, vouchers mitigate issues related to insufficient cash for travel (even if the price is reduced), which is the case for many people in Bogotá living day-to-day (no regular income). Our findings suggest that the vouchers were partially utilized for additional trips, leading to reduced participant expenditures. Moreover, if the city aimed to stimulate ridership to the extent achieved by the voucher, it would need to offer discounts ranging from 53% to 75% off the regular fare (according to some assumptions). These findings highlight the need to re-evaluate the existing subsidy scheme for vulnerable users within the public transport system and refine its delivery method.

2. Public transport subsidies and ridership

There are economic efficiency arguments for subsidizing public transport (Hörcher & Tirachini, 2021). There are also justifications based on distributional effects and equality arguments (Börjesson et al., 2020; Guzman & Oviedo, 2018). Fare discounts are some of the most well-known instruments designed to alleviate the financial burden of public transport systems for low-income households. Despite the prevalence of studies on free and subsidized public transport fares in developed economies, there are only a few studies on this topic in Latin America. The literature contains mixed results on the impacts of subsidies on ridership.

Empirical methods can be used to identify the effects of subsidies on the efficiency of public transport service provision, financial sustainability, and infrastructure expansion (de Grange et al., 2012; Gupta & Mukherjee, 2013; Zhong et al., 2020). Other studies use structural models to identify the impact of supply-side subsidies on the equality of transport service provision and to evaluate the financial results of public transport operators (Gómez-Lobo, 2009; Jin & Chen, 2011; Nilsson et al., 2016; Rambaldini-Gooding et al., 2021; Ševrović et al., 2015). These studies show that supply-side subsidies have positive impacts on commuter welfare, improve route efficiency, increase service quality, and reduce financial problems. In addition, supply-side subsidies should not be uniform, as there are differences among routes. Routes have different spatial locations, ridership, and cycle times (Luo et al., 2022). Therefore, great care must be taken when designing subsidy programs to balance the loss of operational efficiency and welfare gains (Yang et al., 2020).

Regarding demand-side subsidies, the most studied topic is the effect of this type of subsidy on ridership (Batarce & Galilea, 2018; Brough et al., 2022; Bull et al., 2021; Bureau & Glachant, 2011; De Witte et al., 2006; Guzman & Hessel, 2022; Parry & Small, 2009; Zhou & Schweitzer, 2011) and their redistributive effects (Asensio et al., 2003; Börjesson et al., 2020; Bueno et al., 2016). These schemes are a common policy implemented in Latin America to increase the affordability of public transport, especially for low-income groups. However, subsidy policies have mixed and inconsistent results because of problems identifying and helping the target groups (Rivas et al., 2018). Despite their flaws, demand-side subsidies are still preferable because they can be used to target specific groups (Serebrisky et al., 2009).

Randomized controlled trials (RCTs) are prospective methods that measure the effectiveness of an intervention. RCTs are a key tool for studying cause and effect because randomization reduces bias and provides a rigorous tool for examining the causal relationships between an intervention and outcome. Few studies have used RCTs to evaluate the impact of subsidies on public transport ridership, and only one was performed in Latin America. In Santiago, Chile, the effect of assigning a free public transport pass for two weeks to a subsample of 200 workers was evaluated. An increase in ridership of 12% compared to the control group was found, with most of the increase taking place during off-peak hours (Bull et al., 2021). In other parts of the world, the federal state of Hesse (Germany) introduced a free public transport ticket for all state employees, which caused a substantial increase in the use of public transport for commuting and other trip purposes. Car use and availability, however, did not decrease (Busch-Geertsema et al., 2021). Brough et al. (2022) studied the effect of a free fare program for 6 months in King County, Washington (USA), creating panel data at the individual level in a vulnerable area. The results showed that the free fare program caused the participants to use public transport up to four times as often compared to the control group, mainly during off-peak hours. Zhou and Schweitzer (2011) evaluated UCLA employees' participation in a free-pass public transport program in Los Angeles, California. The program involved randomly giving the 12-week free pass to frequent car users. It was found that the program encouraged 33% of the participants to use public transport. These participants lived less than 800 m away from a public transport station. Despite the evidence available, there is a lack of experimental data regarding the impact of subsidies on ridership changes in real-world public transport systems. Additionally, few studies are exploring how a new way of delivering the subsidy impacts affordability, which is a second purpose of this study.

3. Case study and design

The integrated public transport system (SITP in Spanish) of Bogotá is one of the largest in Latin America, with around 4 million trips per day. The system is currently bus-based (BRT and regular buses), although a cable car has been in operation since late 2018 (Guzman, Cantillo-Garcia, et al., 2023), and the first metro line is under construction. The SITP is widely available across the city and is the most common transport mode for middle-low and low socioeconomic population segments in Bogotá. Out of 100 SITP commuters, 90 live in the lowest socioeconomic strata (SES) areas, SES 1 to 3. SES 1 corresponds to the poorest households and SES 6 corresponds to the wealthiest residents, who also live in zones with the best urban conditions (Cantillo-García et al., 2019).

In Bogotá, transport affordability is a major challenge, as transport expenses consume around 14% of a household's income on average. This percentage can reach up to 25% for the poorest households, who must also deal with long travel times and access costs (Guzman & Oviedo, 2018). This means that for most of the users of Bogotá's SITP, the fare is not affordable, despite the supply-side subsidies reaching 730 million USD in 2023, while demand-side subsidies were just 2.8% of that figure.

3.1. The SITP fare

The current public transport fare scheme in Bogotá is a flat fare. In 2021, the regular fare for BRT services was 2500 Colombian pesos (COP) (about 0.67 USD) and the regular fare for regular bus services was 2300 COP (about 0.61 USD). Currently, there is a targeted subsidy scheme for vulnerable populations that offers a fare discount for users who meet certain requirements. The eligibility for subsidies varies according to a person's socioeconomic conditions. This scheme includes preferential fares for elderly people (older than 62 years old), people with physical disabilities, and the poorest segment of the population. To identify eligible beneficiaries for this program, the city uses a social policy targeting mechanism called SISBEN[1] (Guzman & Hessel, 2022).

The demand-side subsidy scheme was established in 2013 to provide greater access for people with a low ability to pay. It consisted of a 40% fare discount and up to 21 monthly trips for people over 16 years of age with a SISBEN score of lower than 40 points. This scheme was restricted over time until it reached a fare discount of 28%, a maximum SISBEN score of 30.56, and a maximum of 30 monthly trips (Decree 131 of 2017). In 2021, fares with the SISBEN benefit were 0.48 USD (1800 COP) for BRT and 0.44 USD (1650 COP) for regular buses. Additionally, a personalized travel card (*Tullave Plus card*) is required. However, as mentioned above, this subsidy scheme no longer encourages SITP use among low-income travelers, and it continues to be active even though its other effects and cost-effectiveness are not well understood. Therefore, we propose and test a new subsidy scheme in the form of a voucher.

3.2. Experimental design

We randomly selected a sample of 1607 people from a universe of approximately 176,000 frequent SITP users on a typical pre-pandemic day.[2] Half of these participants (801) were randomly chosen to receive monthly vouchers on their travel cards. We divided the participants into three groups:

- Treatment A: received a monthly public transport voucher of 7.5 USD (28,000 COP), which allows for about 11 trips per month. This group had 402 participants.
- Treatment B: received a voucher of 5.6 USD (21,000 COP), 9 trips per month, with 399 participants.
- Control group: received an 8.0 USD grocery voucher at the end of the experiment if they participated throughout the intervention and continued to use the system at regular fares.

The experiment implemented transport vouchers (monetary transfers) to the participants' personalized travel cards in May, June, July, and August 2021. Starting on the third week of each month, a new voucher was available, and participants in the treatment groups had to activate their vouchers. The voucher value corresponds to 43 (group A) and 32% (group B) of participants' monthly public transport expenses and allows them to make between 11 and 9 trips per month. Before the experiment, the participants made an average of 37.8 trips on the SITP and on average, recharged their travel cards with 18.3 USD (68,300 COP) every month. The voucher behaves as a fresh cash recharge, and the travel card credit can be used to make trips at regular fare prices. Providing money on a travel card (as a voucher) is not the same as reducing the fare. International literature and accepted practices in these cases regard this as an increase in income (Epple & Romano, 2012; Podesta et al., 2021). The randomized design allows us to derive an unbiased estimate of the impact of the transport vouchers on ridership changes for those individuals who were assigned to the treatment group. Participants in each group were informed about the incentives that they would receive. The use of the SITP was captured by administrative registries of the personalized travel cards of each participant. Among the participants, 81.8% live in the poorest areas of the city (SES 1 and 2 zones), as shown in Fig. 1.

The data was collected in three stages. The first stage took place during March and April 2021. A household survey was conducted with the entire sample to collect information on travel patterns (vehicles, activities, and travel times), quality of life (perceptions about life, safety, government, and public transport), and sociodemographic characteristics (type of housing, educational level, income, employment, and spending patterns). The second stage lasted four months. During this period, the intervention was carried out (delivery of the vouchers). Information on expenses incurred and travel patterns was collected weekly by phone or instant messaging. Finally, in stage 3 (closing survey), the same information as in stage 1 was collected.

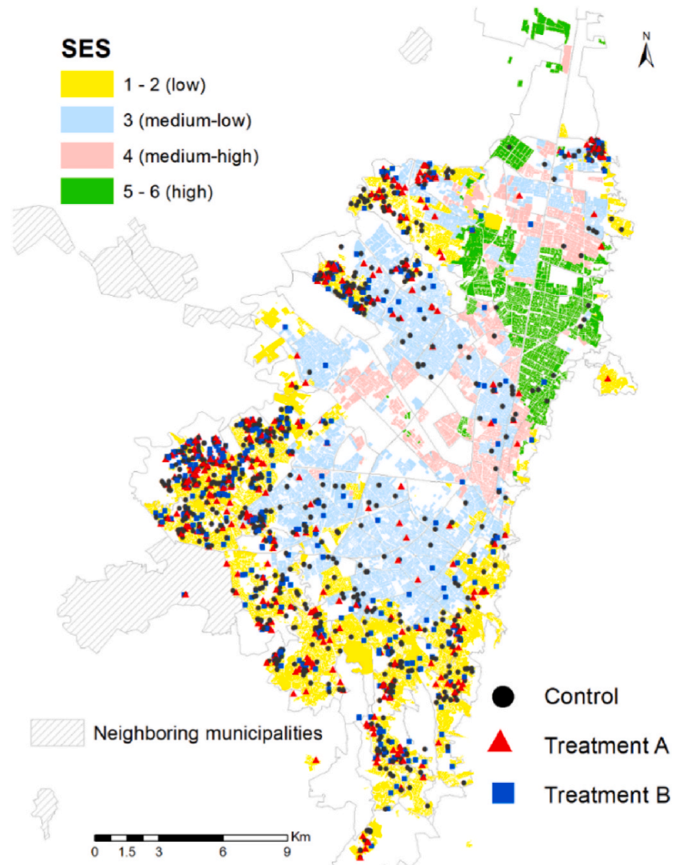

Fig. 1. Spatial distribution of the participants in the experiment.

The intervention period began when the first of the four vouchers was transferred (mid-May) and ended one month after the fourth voucher was activated (mid-September). We also have data for each participant on the number of trips (boardings) made, as well as the exact time, date, and station of each trip throughout the analysis period.

3.3. Empirical strategy

The randomized nature of this experiment means that there are no expected systematic differences in SITP use in the different groups before the intervention. This implies that other factors that could influence SITP use are orthogonal to the treatment. This allows us to interpret causal links between the treatment and the observed changes.

The proposed design allows us to analyze the effect of the vouchers by comparing the SITP use of those receiving the treatment with those in the control group. To do this, we obtained travel card data from each participant during the study period and consolidated it by week. We then applied the model described by Eq. (1) to estimate the average difference in SITP use between the treatment and control groups:

$$\mathrm{Y}_{it} = \gamma_i + \lambda_t + \sum_g \left(\beta_g \mathbf{T}_{it}^g + \tau_g \mathbf{P}_{it}^g\right) + \epsilon_{it} \tag{1}$$

where Y_{it} refers to the average number of daily trips made using travel card i during week t. γ_i represents the individual fixed effect and refers to the average daily trips made using card i, making it possible to control for the use of the SITP. λ_t represents the weekly fixed effects and refers to

[1] This program score ranges between 0 (most vulnerable people) to 100 (least vulnerable).

[2] Nine or more monthly trips during a typical work day in the time-slot between 4:00 and 9:00 h.

the average level of trips during the week t, making it possible to control for factors that could have affected the travel demand in a particular week (e.g., strikes or roadblocks). g indicates the type of group, either control or treatment (A or B). T_{it}^{g} identifies the card i of group g in week t. This variable acts as a dummy that takes the value of 1 for those travel cards assigned to group g during the intervention period. Otherwise, it takes the value of 0. P_{it}^{g} identifies the post-intervention period (after the end of the intervention), and it takes the value of 1 for a card i assigned to the group g; it is equal to 0 in other cases. Finally, ϵ_{it} refers to the idiosyncratic error. The error term is clustered to account for the correlation of the error at the participant level. The parameters β_g recover and identify the average difference in SITP use due to the intervention. In other words, they capture the average difference in SITP use between the treatment and control groups. The parameter τ_g captures the average difference in SITP use among participants in the treatment groups after the intervention is complete.

The basic model estimates the intention of treatment effect (ITT), which is the average change in the outcome variable among all participants in the treatment groups (A and B). Another measure, the average treatment effect on the treated (ATT), excludes participants in the treatment groups who did not activate the voucher. Thus, the ITT effect considers a mixture of participants who received and activated the voucher and others who received but did not activate the voucher. The ATT effect estimates the increase in trips among those who effectively activated the voucher. This model is presented in Eq. (2):

$$\mathrm{Y}_{it} = \gamma_i + \lambda_t + \sum_{g} \left(\beta_g \widehat{\mathbf{ET}_{it}^{g}} + \tau_g \widehat{\mathbf{EP}_{it}^{g}} \right) + \epsilon_{it} \tag{2}$$

Here, the T_{it}^{g} variable from Eq. (1) is replaced with ET_{it}^{g}, which is the result of calculating the probability that a participant in the treatment group activates the voucher. Mathematically, this is equivalent to rescaling the β_g estimates by dividing it by the proportion of participants who activate the voucher. Thus, the results from Eq. (2) provide the difference in the number of daily trips made by participants who cashed the voucher and by the control group.

Finally, an affordability measure (Eq. (3)) is proposed to analyze the financial burden of SITP costs and the effect of the vouchers on the treatment and control groups before, during, and after the experiment. Despite its limitations, this proposed indicator could be a useful approximation that can measure SITP affordability and the effectiveness of the vouchers in alleviating the financial burden of public transport costs for the participants:

$$Aff_g = \frac{\mathrm{f} \bullet T_g}{Ing_g} \tag{3}$$

where the observed affordability index per group g (Aff_g) is expressed as a function of the price of trips (f), the trips made using the SITP per group g before, during, and after the experiment (T_g), and the monthly household income per capita (Ing_g). The income per capita is the reported household income from the closing survey divided by the corresponding household size. We consider all the trips made using the SITP.

4. Results

There are no pre-existing differences between the groups that could affect the outcome variables. The control and treatment groups only differ in terms of the intervention (the vouchers). According to the summary statistics of the sample shown in Table 1, most of the participants belong to the low-income segment and live in the SES 2 areas (see Fig. 1). The monthly household income is around 412 USD (1,540,000 COP) in a household made up of 3.7 people on average. This implies an average per capita monthly income of 111 USD (416,200 COP). In addition, 12% of the participants have a car at home, 10.2% have a motorcycle, 27.9% have a bicycle and 55.8% do not have any type of vehicle. Just 41.5% of the participants have a professional degree and work an average of 5.2 days a week for 9 h a day.

Table 1
Summary statistics and balance between treatment and control groups.

Variable	Control (Std. Dev.)	Treatment (Std. Dev.)	Mean difference (p-values)
Transport modes used to the main activity	1.79	1.76	−0.03
	(0.790)	(0.760)	(0.480)
Journey time (trip yesterday) [min]	89.4	87.3	−2.11
	(80.51)	(69.95)	(0.610)
Journey time (regular trip) [min]	99.4	90.7	−8.72
	(104.33)	(59.98)	(0.200)
Distance to transport [min]	7.97	7.92	−0.05
	(7.390)	(7.640)	(0.910)
Distance to transport [blocks]	4.3	4.6	0.30
	(3.830)	(4.560)	(0.210)
Waiting time [min]	12.8	12.4	−0.41
	(9.99)	(8.91)	(0.450)
Fare price paid (trip yesterday) [COP]	3150	3225	74.94
	(4034.7)	(3747.8)	(0.740)
Weekly trips to the main activity [trips]	4.7	4.8	0.09
	(1.92)	(1.75)	(0.380)
Transport cost (all transport modes) to the main activity [COP]	3912	4020	107.43
	(2684)	(2,4602)	(0.610)
Household size	3.6	3.8	0.16
	[1.45)	(1.51)	(0.030)
Age [years]	43.8	43.3	−0.45
	(11.84)	(11.81)	(0.450)
Married [%]	0.22	0.23	0.01
	(0.42)	(0.42)	(0.590)
Women [%]	0.72	0.72	0.00
	(0.45)	(0.45)	(0.890)
Current worker [%]	0.88	0.90	0.010
	(0.32)	(0.30)	(0.360)
Car ownership [veh/HH]	0.16 (0.37)	0.12 (0.33)	−0.04 (0.01)
Motorcycle ownership [veh/HH]	0.11 (0.31)	0.10 (0.30)	−0.01 (0.65)
Bicycle ownership [veh/HH]	0.31 (0.46)	0.28 (0.45)	−0.03 (0.16)

A means difference could provide the effect of the treatment among the participants, but this is not the most efficient estimator. This is because it does not use information regarding participants' characteristics and panel data. However, socioeconomic characteristics relevant to the estimation (e.g., age, income) are constant within the analyzed period, allowing control by using fixed effects at the individual level. The only significant difference is car ownership, which remained unchanged throughout the evaluation period; participants who owned a car before treatment continued to own the same car afterward. However, these differences are controlled for by the models' fixed effects.

Regarding the differences in the participants' weekly trips, before the intervention, there is no statistically significant difference between the control group and the treatment group (p-value = 0.5). This means that there is also a balance in the use of public transport. Fig. 2 shows graphically that there is no difference between groups before the intervention and how the voucher delivery changes ridership over time.

The results shown here, indicate that the two treatment groups and the control group are balanced and that the control group is correctly identified as a comparison group. This allows us to recover the causal effect of the transport voucher.

4.1. Ridership impacts

Table 2 presents the results of the changes in ridership caused by the vouchers, according to the models presented in Eqs. (1) and (2). The outcome is the average number of trips per day, which allows a direct

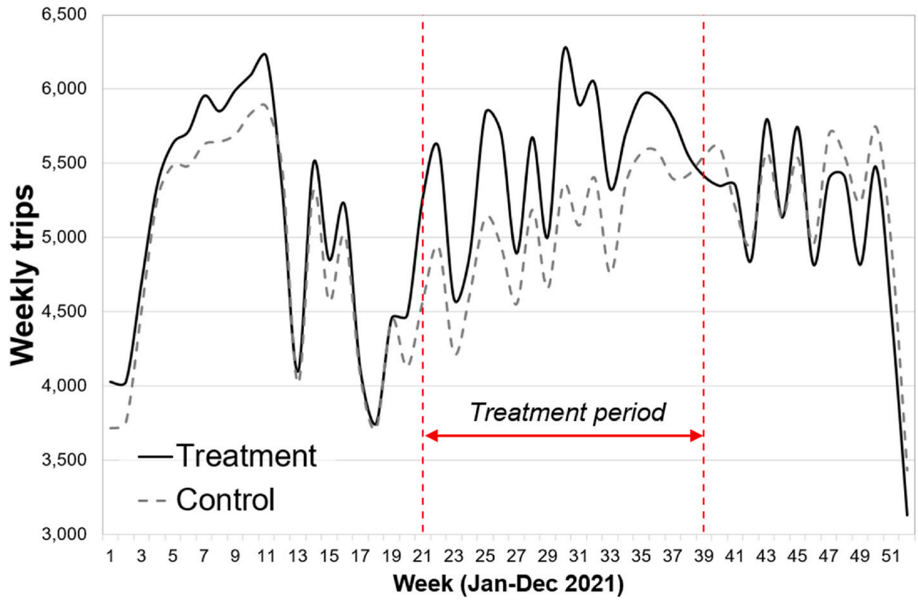

Fig. 2. Weekly trips of the entire sample.

Table 2
Voucher impacts on the average of daily trips.

	Dependent variable: Boardings					
	ITT (model from Eq. (1))			ATT (model from Eq. (2))		
	Week	Working days	Weekends	Week	Working days	Weekends
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment B	0.075**	0.097**	0.024	0.093**	0.120**	0.030
	(0.037)	(0.043)	(0.029)	(0.046)	(0.053)	(0.036)
Treatment A	0.084**	0.106**	0.024	0.101**	0.128**	0.030
	(0.037)	(0.043)	(0.029)	(0.044)	(0.052)	(0.034)
Post-treatment B	0.034	0.042	0.024	0.041	0.051	0.028
	(0.051)	(0.059)	(0.041)	(0.058)	(0.067)	(0.047)
Post-treatment A	−0.060	−0.046	−0.076	−0.065	−0.049	−0.085
	(0.052)	(0.060)	(0.039)	(0.059)	(0.068)	(0.045)
Base value: control group	1.16	1.33	0.71	1.16	1.33	0.71
Treatment B change [%]	6.50	7.27	3.36	8.04	8.98	4.15
Treatment A change [%]	7.22	7.93	3.39	8.73	9.58	4.13
N	62,446	62,446	62,446	62,446	62,446	62,446
R2	0.557	0.551	0.353	0.557	0.552	0.353
Fixed effects: individuals	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects: week	Yes	Yes	Yes	Yes	Yes	Yes
Standard errors cluster	ID	ID	ID	ID	ID	ID

Standard errors of the estimated coefficients are shown in parentheses. Columns 1–3 show the estimates of Eq. (1). Columns 4–6 show estimates of Eq. (2). Estimates are made using Ordinary Least Squares (OLS). The "base value: control group" row shows the average of the variables in each column using only the control group. Significance level: ***p < 0.001 **p < 0.01 *p < 0.05, p < 0.1.

comparison between the effects over a complete week and the disaggregated effects for working days and weekends. Columns (1) to (3) of Table 2 show the effects for the treatment groups, including the effects for those who did not activate the voucher (ITT). Columns (4) to (6) provide the results for only those participants who did activate the voucher (ATT), which produces, as expected, a larger effect. To better understand these results, we provide the average value of the variable for the control group (row *Base value: control group*) and the corresponding effect of the treatment as the percentage change relative to this base value (rows *Treatment B change [%]* and *Treatment A change [%]*). Of the 801 participants in the treatment group, 648 claimed the voucher (subsidy), meaning that 80.9% of the total treated participants used it. This group includes 153 non-compliant participants. By calculating the ATT using treatment assignment as an instrumental variable, we isolate the effect specifically associated with participants who actually received treatment. This approach ensures no differences or confusion arise between those who did not claim the voucher and the control group.

The ATT effects show that the weekly travel increased by 8.04% for the Treatment B group and 8.73% for the Treatment A group (column 4). These average effects are the results of additional trips made on workdays, as there are no significant effects on the weekends. This is not in line with evidence from other contexts (Bull et al., 2021; Busch-Geertsema et al., 2021), which indicates that there is an increase in non-mandatory trips (trips in off-peak hours). If our participants had used the voucher to make non-mandatory trips, we would expect to observe more trips over the weekend, when most trips are not mandatory.

On the other hand, as is shown in Table 3, after the intervention, there were no differences in the SITP use between the treatment and control groups (see Fig. 2) before treatment started. Additional trips are

Table 3
Voucher impact on daily trips by the time of the day.

	Peak-hours		Off-Peak hours	
	ITT	ATT	ITT	ATT
	(3)	(4)	(5)	(6)
Treatment B	0.094***	0.117***	−0.004	−0.005
	(0.032)	(0.040)	(0.025)	(0.031)
Treatment A	0.098***	0.118***	0.017	0.021
	(0.032)	(0.038)	(0.025)	(0.030)
Post-treatment B	0.104**	0.121**	−0.045	−0.051
	(0.048)	(0.054)	(0.031)	(0.036)
Post-treatment A	0.029	0.034	−0.068**	−0.075**
	(0.046)	(0.052)	(0.032)	(0.036)
Base value: control group	0.76	0.76	0.49	0.49
Treatment B change [%]	12.79	15.80	4.81	5.94
Treatment A change [%]	13.95	16.86	4.85	5.91
N	62,498	62,498	62,498	62,498
RMSE	0.60	0.60	0.53	0.53
Fixed effects: individuals	Yes	Yes	Yes	Yes
Fixed effects: week	Yes	Yes	Yes	Yes
Standard errors cluster	ID	ID	ID	ID

Standard errors of the estimated coefficients are shown in parentheses. Columns 1–3 show the estimates of Eq. (1). Columns 4–6 show estimates of Eq. (2). Estimates are made using Ordinary Least Squares (OLS). The "base value: control group" row shows the average of the variables in each column using only the control group. Significance level: ***p < 0.001 **p < 0.01 *p < 0.05, p < 0.1.

Table 4
Voucher impacts on public transport spending.

	Dependent variable: expenses and recharges			
	ITT		ATT	
	Expenses	Recharge	Expenses	Recharge
	(1)	(2)	(3)	(4)
Treatment B	0.247**	−0.401***	0.305**	−0.496***
	(0.102)	(0.104)	(0.125)	(0.129)
Treatment A	0.299***	−0.592***	0.362***	−0.715***
	(0.103)	(0.104)	(0.123)	(0.127)
Post-treatment B	0.163	0.207	0.192	0.222
	(0.146)	(0.149)	(0.167)	(0.170)
Post-treatment A	−0.140	−0.091	−0.150	−0.114
	(0.144)	(0.148)	(0.163)	(0.167)
Base value: control group	3.54	3.55	3.54	3.55
Treatment B change [%]	6.96	−11.31	8.59	−13.98
Treatment A change [%]	8.44	−16.70	10.21	−20.15
N	62,446	62,446	62,446	62,446
R2	0.511	0.259	0.512	0.259
Fixed effects: individuals	Yes	Yes	Yes	Yes
Fixed effects: week	Yes	Yes	Yes	Yes
Standard errors cluster	ID	ID	ID	ID

Standard errors of the estimated coefficients are shown in parentheses. Columns 1–2 show the estimates of Eq. (1). Columns 3–4 show estimates of Eq. (2). Estimates are made using Ordinary Least Squares (OLS). The "base value: control group" row shows the average of the variables in each column using only the control group. Significance level: ***p < 0.001 **p < 0.01 *p < 0.05, p < 0.1.

made predominantly during peak periods (5:30–8:30 and 16:30–19:30 h), with an increase between 15.8% and 16.9% for peak hours and an increase of 5.9% for off-peak hours (columns (4) and (6), respectively). Nevertheless, when the vouchers are no longer being provided, a trade-off between peak and off-peak periods arises. In other words, either there is a significant increase in peak-hour trips, with a non-significant decrease in off-peak trips (row 8, *Post-treatment B*, −0.051), or there is a non-significant increase in peak-hour trips with a significant decrease in off-peak trips (row 9, *Post-treatment A*, −0.075). Given that the total number of trips does not increase in the post-treatment period (Fig. 2), this is most likely a reassignment of trips from off-peak to peak hours. Table 3 presents results that have been disaggregated according to the time of the day; they have been separated into peak and off-peak hours.

The ridership increase during peak hours indicates a probable modal substitution. This implies that trips previously undertaken by active modes, informal, or slower transport modes could now be using the SITP. Furthermore, we cannot dismiss the likelihood of individuals engaged in informal employment making new trips via the SITP due to the voucher. Essentially, those involved in informal activities may be embarking on extra trips during peak hours, as they are not constrained by fixed schedules or specific locations (such as street vendors who have access to new areas). Additionally, participants could be decreasing their off-peak trips to keep making these extra trips or to keep making at least some of them. Since not all coefficients are statistically significant, this is the only clear evidence that such a change is occurring. To further interpret these results, it is worth remembering that the transport voucher can only be used for the SITP. However, this does not mean that the voucher is automatically converted into additional trips, as said before.

On the other hand, as the average monthly SITP expenditure per participant is higher than the voucher value (more than double), a rational commuter could make the same number of trips as before, or even make fewer trips, while spending the entire voucher, thus, saving their own money. By doing this, they would also free up money from their budgets that would otherwise have been spent on transport. In fact, the value of the additional trips is less than the voucher value. This means that users save some of the money that was allocated to using public transport in their budgets, as shown in Table 4. Here, two outcomes were used: the SITP expenses and travel card recharges. In the latter case, the recharge only includes the money paid directly by the user (not the voucher).

Columns (1) and (3) of Table 4 show the amount of money spent on additional trips by participants in the treatment groups (in USD). Columns (2) and (4) show the amount of money that participants used to recharge their travel cards, excluding the value of the vouchers. The additional trip expenses (+0.305/+0.362, column 3) are lower than the value of the vouchers, leading to a decrease in the travel card recharges paid for by the participants (−0.496/−0.715, column 4). In short, participants in the treatment groups used their travel cards more (+8.6% and +10.2%) but had to spend less of their own money to travel on the SITP. Participants recharge (with their own money) between −14% and −20% on their travel cards compared to the control group (column 4). I.e., participants in the treatment groups saved money on transport that they could use for other expenses. This improves affordability immediately.

As has been shown, the voucher induced a ridership increase between 8 and 9%. However, as Bogotá has high spatial segregation and public transport accessibility inequalities (Guzman et al., 2017), the response to the voucher might be different. Price elasticities measure how ridership changes in response to fare price adjustments. In our case, the fare elasticity value is not uniform across the city. Previous studies have found that fare elasticity varies according to income levels, time of day, and residential location (Guzman et al., 2020, 2021). These elasticities were calculated using disaggregated smart travel card data from 2010 to 2018, which provides insights into users' travel behavior. The analysis incorporated demand heterogeneity arising from spatial, temporal, and socioeconomic dimensions using a fixed-effect model. The data includes all recorded boardings at each station every 30 min at the origin stations. Explanatory variables such as transport supply, unemployment rate, and fuel price were also included in the analysis (Guzman et al., 2021).

Neighborhoods located in the urban periphery, which are associated with low-income areas, show null or low responses to fare increases (captive users), unlike the neighborhoods located in the wealthiest zones (central zone, see Fig. 3). This spatial configuration facilitates a general comparison of an estimate of the fare discount needed to achieve the same level of demand increase as produced by the voucher. In this case,

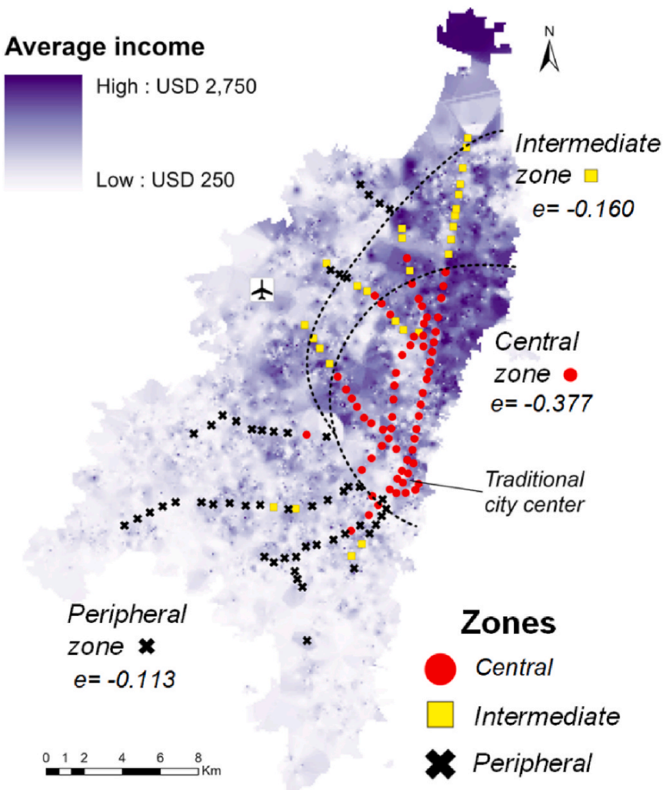

Fig. 3. Spatial variation of fare-demand elasticities.
Source: own elaboration based on Guzman et al. (2021).

we acknowledge that the elasticities used may not be symmetrical. However, we believe that this approximate result could be valuable to authorities, as it indicates the potential effects of the alternative subsidy scheme. Therefore, by analyzing the average change in ridership due to the voucher, it is possible to estimate the fare discount (as an indicative value) necessary to achieve the same positive effect on travel demand. As we previously know, changes in ridership vary according to the area of the city, as shown in Fig. 3

Results from Table 5 show the existing fare reduction level achieves a similar ridership increase produced by the voucher only in the higher-income area (central zone). In the rest of the city, where more than 90% of SITP users live, it would be necessary to make larger fare discounts if we wanted to have the same ridership increase that the voucher produces. I.e., in those areas, predominantly represented in the experimental data, the required fare reduction ranges from 53% to 75%, which would imply much higher costs for the city (assuming that those estimated elasticities are symmetrical).

4.2. Affordability

Table 6 shows the calculated affordability index from Eq. (3) for each group during the experiment. This indicator represents about a quarter of the participants' per capita income. It is important to note that this index does not account for the costs of other transport modes. The results show some differences at a 99% confidence level when the control group

Table 5
Equivalent fare reduction to reach the same effects as the voucher.

Zone	Avg. elasticity (*e*)	Avg. fare reduction
Peripheral zone	−0.113	−75%
Intermediate zone	−0.160***	−53%
Central zone	−0.377***	−23%

***p < 0.01, **p < 0.05, *p < 0.1.

Table 6
SITP affordability indices according to groups and time.

Group	Before	During	After
Control	19.1%	20.5%	23.6%
Treatment A	20.5%	16.3%[a]	24.3%
Treatment B	21.2%[b]	18.0%[a]	26.2%[c]

[a] p-value <0.01.
[b] p-value <0.05.
[c] p-value <0.10 (treatment groups vs control group).

is used as a baseline. There are significant differences in affordability between the treatment groups and the control group when transport vouchers are provided. In other words, the vouchers had a significant and positive effect in terms of alleviating the financial burden of public transport for participants in the treatment groups compared to participants in the control group.

The results show that SITP vouchers have a positive impact on SITP affordability. This implies a monthly savings of 4.1 USD (15,200 COP) during the intervention, which the participants could have used for other things. After the intervention ended, the index worsened; it was even slightly worse than it was before the intervention began. This may be because, after the experiment, participants made more trips on the SITP. Depending on the group, between 5.2 and 7.6 more trips/month were made on average after the intervention ended (although this difference is not statistically significant).

5. Policy recommendations

In Colombia, public transport subsidies have existed for more than a decade, but their impacts are still unknown. This is due in part to the ongoing debate among politicians about investment priorities, particularly when budgets are tight. Since 2013, Bogotá has invested more than 230 million USD in demand-side subsidies, but the impact of these subsidies is not precisely known.

The design of an effective public transport subsidy scheme is critical to its success. The scheme must be flexible and have different objectives when it comes to setting fares for different vulnerable population groups. Since the provision and quality of public transport are positively related to the quality of life (Guzman, Arellana, et al., 2023; Hybel & Mulalic, 2022), the reallocation of public funds in the form of a voucher subsidy scheme in Bogotá should improve affordability and travel satisfaction encouraging ridership (Guzman & Cantillo-Garcia, 2024). This new approach acknowledges the significant importance commuters place on non-work-related trips. Life satisfaction extends beyond work, so public transport should also facilitate other types of trips that contribute to high levels of well-being. Furthermore, in cities such as Bogotá, where lower-income areas experience significant deficits in recreational and leisure facilities (Guzman et al., 2024), the public transport system must enable these populations to easily access such opportunities.

Controlled field experiments are a useful tool that can help transport planners and decision-makers generate robust evidence concerning the actual effects of a transport policy. The findings from this experimental study in a developing city context provide novel evidence of subsidies' impact on ridership and affordability gains. This methodological approach controls time dynamics and differences in personal characteristics in public transport usage using fixed effects, which further improve the precision of the estimation. Using this approach, it is shown that the vouchers are an improvement over the current fare discount scheme since the voucher scheme reaches higher levels of ridership.

If Bogotá (or any city) wants to implement a voucher scheme on a large scale, it is highly recommended that first an investigation of the operating costs of the operator companies should be conducted, rather than reviewing the operating costs reported by the companies. Another crucial element to consider is determining the value of the voucher.

While cities like ours may face budgetary constraints that limit this value, it is important not to overlook this issue. Establishing the appropriate voucher value involves several factors and largely depends on the desired objectives. For example, the voucher's value may vary depending on whether the goal is to maximize the beneficiaries' welfare, improve their affordability to a certain extent, or cover a specific number of people. Perhaps this way, even more benefits can be obtained. Addressing this question requires further research. We strongly believe that it is necessary to carefully consider these subsidies and to recognize the need for a common understanding that a high-quality and affordable public transport system is not only a viable and sustainable alternative to private vehicles but is also an incentive to make more efficient use of the urban space, promoting other forms of mobility and accessibility.

The results presented here show that the voucher subsidy shows positive and very interesting results in terms of ridership and affordability. The vouchers encourage public transport use, particularly during weekdays and peak hours, which implies that they encourage high-value trips, perhaps for work or study purposes. We show evidence of the effects that a subsidy has on commuters, highlighting the great positive impact that an affordable public service in a developing city has on its poorest users. However, the policy effectiveness depends on the value that people give to their trips (fare elasticity). As seen, the city would have to make large discounts on fares (up to 75%) to achieve the same levels of increased ridership as the voucher. New and inventive public transport and subsidy schemes are opportunities to increase both accessibility and affordability of users.

The reallocation of money from the city budget to public transport subsidies could encourage an increase in ridership and create affordability improvements. As is often argued in policy debates, since public transport is used more by low-income groups, the proposed subsidies have a progressive distributional profile. This requires great political and technical leadership, as it involves making decisions that may be politically unpopular. As Hörcher and Tirachini (2021) argue, a better understanding of the political processes behind transport policies is necessary, in order to bring academic findings closer to social/political acceptance and actual implementation.

6. Conclusions

This paper presents the impacts of an alternative public transport subsidy policy consisting of transport vouchers in Bogotá. The voucher policy was implemented as a direct cash transfer to participants' travel cards. The members of the experimental treatment groups experienced increased public transport usage and improved affordability than the randomly selected control group. This new scheme encourages greater public transport ridership. To produce the same additional travel demand generated by the voucher, the fare discount would have to be much higher than the current one. And the lower the elasticity, the higher the discounts need to be. This would be more expensive for the city.

Access to public transport vouchers leads to an increase in ridership, which is entirely explained by an increase in weekday and peak-hour trips. The results show that the 7.5 USD and 5.6 USD voucher values increase the travel demand by between 8.7% and 8.0% compared with the control group. The ridership increase, particularly during weekdays and peak hours, implies a need to improve access to the SITP. We also find evidence that the vouchers cause an improvement in affordability between 18 and 26%. Consequently, it becomes imperative to explore strategies for overcoming these barriers and enhancing accessibility through innovative and adaptable instruments. Thus, we may unambiguously reject the hypothesis that the travel voucher is only a benign income transfer. Furthermore, the divergence of our results from those observed in other contexts points to unique dynamics of public transport utilization in Bogotá, and potentially in analogous environments. This highlights the significance of our study and underscores the imperative for further experimental investigation in these domains, given the scarcity of such research evident in the existing literature.

The findings concerning the impact of the voucher on ridership contribute to understanding these policies' broader effects. While the effects on poverty alleviation, employment, and funding are well documented, there are too few causal estimations of ridership and affordability, particularly in large public transport systems. This research is not free from limitations. The results observed here are limited to current frequent users who mostly have low incomes. It is necessary to do more research to understand the effects of vouchers on other vulnerable people, such as those who do not use the transport system or cannot afford to pay the fare. Further analyses of the data will focus on the evaluation of heterogeneity in the results due to the socioeconomic characteristics and travel preferences of the participants. Another important point to consider is that the two subsidy schemes cannot be directly compared. This limitation does not address a comparison between the voucher scheme and the current subsidy scheme, but it highlights the effectiveness of the voucher scheme.

Finally, this study makes a valuable contribution to the existing literature by generating new evidence from one of Latin America's largest public transport systems. The findings shed light on the impact of alternative subsidy mechanisms on public transport and their effectiveness. Furthermore, the implications derived from this research provide valuable insights for shaping public transport pricing policies in large public transport systems.

CRediT authorship contribution statement

Luis A. Guzman: Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Santiago Gómez Cardona:** Writing – original draft, Methodology, Investigation, Formal analysis. **Jorge Luis Ochoa:** Methodology, Data curation.

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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

The data that has been used is confidential.

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