Travel Behaviour and Society 33 (2023) 100612

Contents lists available at ScienceDirect

Travel Behaviour and Society

journal homepage: www.elsevier.com/locate/tbs

Evaluating the effects of social capital on travel behavior: Modeling the choice of an innovative transport mode

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ARTICLE INFO

Keywords:
Social capital
Travel behavior
Hybrid choice model
Cable car
Bogotá

ABSTRACT

This paper aims to evaluate the effects of social capital on the willingness to use a new cable car service in Bogotá (Colombia) that connects the Bus Rapid Transit system with a vulnerable zone with low accessibility. We estimated a hybrid discrete choice model for the new cable car service considering social capital as a latent variable and a stated preference survey issued before the cable car implementation. Social capital is measured through six domains associated with membership of civic groups, social networks, interpersonal trust, institutional trust, cooperation, and empowerment. Results suggest that the social capital stock in the influence zone of the cable car depends principally on age, sex, education level, and time living in the neighborhood. Results also show that higher social capital stocks are associated with a greater willingness to use the new cable car service, suggesting that social capital is a potential determinant for mode choice. Finally, we discuss implications for social capital and policymaking.

1. Introduction

The links between social interactions and travel preferences have attracted the interest of many researchers with diverse perspectives. Some approaches are motivated by the hypothesis that social contact, beyond intra-household social interactions, might be a key factor determining the motivations for and characteristics of travel behavior (Dugundji et al., 2011). In a determined market context, the economic decisions of consumers (i.e., choice of transport mode) are not only based on individuals' self-interest but also influenced by their social relations and interactions, which can be measured in the form of social capital. Under this hypothesis, incorporating this construct could improve the capabilities of choice models and their goodness of fit, while contributing to the understanding of the underlying factors that influence choices.

Transport planning and policymaking require understanding the factors that affect travel behavior. These factors include individual characteristics, the trip context, and attributes of the available alternatives. These factors determine transport demand allowing to assess policies, infrastructure investments, and the design of transport supply. During the last two decades, there has been growing interest in the explicit incorporation of perceptions, attitudes, habits, and social interactions into travel behavior analysis. Therefore, social capital might help to explain economic behavior, providing insights that will be useful for policy evaluation and decision-making (Robison et al., 2012). However, there are still some comprehensive challenges in representing subjective data and latent constructs such as social networks, well-being, and social capital (Ben-Akiva et al., 2012).

Given this background, this research aims to determine the effect of social capital on mode choice, evaluating the willingness to use a new cable car (TransMiCable), located in the southern urban periphery of Bogotá (Colombia). The study zone is characterized by low-income levels and poor accessibility conditions. We propose an approach based on hybrid discrete choice models to estimate the influence of capital social on mode choice, considering that the choice set is composed of the new cable car and the traditional transport modes used before the cable car implementation. Social capital is measured as a second-order latent variable formed by six domains: membership of civic groups, social networks, interpersonal trust, institutional trust, cooperation, and empowerment. We hypothesize that social capital stocks are associated with the willingness to use the cable car because of a greater sense of community development that generates a stronger

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https://doi.org/10.1016/j.tbs.2023.100612
Received 30 March 2022; Received in revised form 30 May 2023; Accepted 31 May 2023
Available online 16 June 2023

adoption of the new infrastructure. This research contributes to the discussion of the links between social capital and travel behavior in the context of cities in the Global South.

2. Exploring the links between social capital and transport

Social capital is considered a complex, polysemic, and multidimensional construct (Li, 2005; Paldam, 2000). Social capital is a property of communities, but this collective characteristic is consistent with individual attitudes (Brehm and Rahn, 1997). Some of the most notable definitions of social capital are the ones proposed by Bourdieu (1986): "Social capital is the aggregate of the actual or potential resources which are linked to the possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition"; and Putnam (2001): "Social capital refers to the features of social organization such as networks, norms and social trust that facilitate coordination and cooperation for mutual benefit." Considering this, individuals' social capital stocks are determined by the social connections that the individual can successfully summon, as well as by the volume of economic, cultural, and symbolic resources he or she can derive from those connections.

Besides the individual advantages generated by the possession of these features, the strength of these interactions could enhance a sense of community, facilitating social development and the capabilities to solve collective problems. Furthermore, there is some evidence suggesting that social capital accumulation might help to achieve Sustainable Development Goals (SDGs) by improving the connection of social networks that facilitate resource flows and collective actions (Kusakabe, 2012).

The links that connect social capital with transport work in two ways (Sharmeen et al., 2014). Most of the associated literature explores the effects of transport on social capital levels in communities and individuals, while fewer works have evaluated the relation in the opposite direction. There is some consensus that transport improvements facilitate social interactions and promote social inclusion through the provision of better access to opportunities (Östh et al., 2018; Oviedo and Guzman, 2020; Stanley et al., 2010). Poor transport conditions hinder people's access to opportunities, damaging the sustainability of social and economic networks, causing social exclusion (Lucas, 2012).

Improving transport connections might be done in part by implementing adequate infrastructure and policy (Church et al., 2000). For instance, transit-oriented developments (TOD) complemented by policies that encourage public transport usage, walking, and cycling could enhance the creation of social networks, trust, and reciprocity, reducing social exclusion and improving the well-being of transport-disadvantaged groups (Currie et al., 2010; Currie and Stanley, 2008; Kamruzzaman et al., 2014; Stanley and Lucas, 2008; Stanley and Vella-Brodrick, 2009; Utsunomiya, 2016). Increasing trip-making could promote a sense of community (Stanley et al., 2012), while policies restricting movement could reduce the number of social trips, affecting social capital (Munford, 2017). Thus, sociodemographic and mobility-related characteristics such as car availability, access to affordable public transport, income, and trip frequency are determinants of social capital levels (Carrasco and Cid-Aguayo, 2012; Lucas et al., 2016). There is evidence that social exclusion, transport disadvantage, and social capital have complex and non-linear relationships that require more quantitative research for a better understanding (Schwanen et al., 2015).

In contrast, there is less evidence regarding the effects of social capital on transport preferences. These effects and the interactions between sociodemographic characteristics, activity participation, and travel behavior could be evaluated using structural equation modeling (SEM) and discrete choice models. Discrete choice models have also been applied in diverse contexts to model the effects of social influences and social interaction on individual decision-making (Brock and Durlauf, 2001; Dugundji and Gulyás, 2008; Maness et al., 2015; Páez et al., 2008). Furthermore, considering that activity participation might be a driver of travel behavior (Lu and Pas, 1999), incorporating the attributes of social networks might provide a promising modeling framework for activity and travel behavior (Carrasco and Miller, 2006) and could be useful to describe the social context that determines travel behavior. The research by Di Ciommo et al. (2014) explores the influence of social capital on the willingness to use a new metro line in Madrid (Spain). The modeling approach based on discrete choice modeling incorporated two dummy variables as social capital proxies representing participation in voluntary activities and receiving help with tasks. Their results indicated that people who participated in voluntary activities had a lower willingness to shift to the new metro service, while those who received help with tasks had a higher probability of using the new metro line. This difference in the effects might suggest that different social capital domains might have different effects on travel behavior. To our knowledge, this is one of the few studies evaluating the effects of social capital in transport mode choice modeling.

3. TransMiCable background

TransMiCable is a cable car service that is part of Bogotá's Public Transport System. The cable car system was formulated to improve accessibility to zones where hillside conditions require alternative solutions to mobility. Currently, one line operates in the southwest periphery of Bogotá in a low-income district named *Ciudad Bolívar*. The population in the influence zone of TransMiCable can be considered socially vulnerable, characterized by low income, transport disadvantages, and unplanned urbanization. This situation generates a certain level of social exclusion in the community, where individuals have to trade-off valuable resources (i.e., time) to meet their mobility needs.

The context of *Ciudad Bolívar* represents the history of TransMiCable well. Initially, the area was informally urbanized with self-built settlements. A high proportion of the residents are rural to urban migrants and victims of forced internal displacement as a product of the armed conflict and the waves of violence that hit the country in the last century. The population living on the periphery of Bogotá faces constant struggles with public amenities, including (low) transport supply and job accessibility (Guzman et al., 2017). Despite these challenges, residents of the study area have historically organized to guarantee the provision of infrastructure and public services. This sense of collective work to improve the neighborhood conditions emerged once again in 2007 when a group of social leaders, motivated by the success of the cable car implemented in Medellín (Davila et al., 2013), started a mobilization to demand a similar solution for *Ciudad Bolívar*. In fact, the community's organization was one of the key factors that led to the successful implementation of TransMiCable in *Ciudad Bolívar* with crucial leadership of women and mother heads of households (Sarmiento et al., 2020).

TransMiCable started operations in December 2018. The line is 3.4 km long and is composed of four stations. The average travel time of the route is 14 min and the capacity is around 3,600 passengers per hour and close to 27,000 passengers on a typical day. Before the cable car started operating, an average trip between the BRT terminal station could take up to one hour and the typical modes used for it were regular bus and informal paratransit services. At the base station, the BRT terminal station *Portal Tunal*, shifts between the cable car and the BRT system (TransMilenio) can be made without additional charges. In addition to the cable car, public investments in the zone consider a complementary urban redevelopment plan with facilities for cultural, recreational, and social activities, community centers, and a program to support home improvements to reduce geomorphological hazards in the zone. Given this background, TransMiCable is an interesting case study to evaluate the influence of social capital on the travel behavior of vulnerable users.

4. Modeling approach

The proposed methodological approach is based on the specification

of discrete choice models where social capital is explicitly considered as a latent variable. This formulation is also known in the literature as hybrid choice or Integrated Choice and Latent Variables (ICLV) models. The data come from a survey inquiring about the environmental and social determinants of health and physical activity, such as perceptions of the physical environment, availability of recreational and cultural facilities, transport accessibility, employment, use of leisure time, and quality of life (Sarmiento et al., 2020). The models were estimated using a subsample from this survey. The subsample faced a Stated Preference (SP) experiment evaluating the willingness to use the new cable car service, and a set of attitudinal questions measuring social capital dimensions, including membership of groups, social networks, interpersonal and institutional trust, cooperation, and empowerment. We developed an orthogonal design of nine choice scenarios using the Ngene software (http://choice-metrics.com). All respondents faced the same choice situations. Each choice scenario comprised two alternatives, continue using their current transport mode or use the cable car to complete their trip.

4.1. Data

The survey responses were collected before the inauguration of the cable car, between February and November 2018. The target population was adults living within an 800 m buffer from the cable car stations without plans of moving out for at least two years. The sample was selected using a multi-stage sampling design where blocks were selected with a probability proportional to the density of parcels. Every third household was systematically selected, and we randomly selected one eligible adult per household. This procedure made it possible to achieve a sample size of 1,031 individuals for a general questionnaire, which was powered to detect changes equivalent to standardized mean differences in outcomes ranging between 0.3 and 0.4 (Sarmiento et al., 2020).

From the above sample, we randomly selected 343 individuals to participate in an SP experiment assessing their willingness to use the cable car service. They also answered a series of attitudinal questions measuring some aspects and domains of the social capital concept (Kamruzzaman et al., 2014), particularly membership of groups, social networks, interpersonal and institutional trust, cooperation, and empowerment. The questions obtained dichotomous (yes/no) and Likert scale responses (indicators), which were used to measure the dimensions of social capital considered. Sections 4.2 and 4.3 present the framework used to measure social capital, while Supplementary Table A1 contains the indicators and corresponding attitudinal questions used in the modeling. After the data were collected and processed, a debugging process resulted in the elimination of 25 individuals from the general survey and 3 from the SP data due to missing information on key variables, resulting in final sample sizes of 1,006 and 340, respectively.

Table 1 presents the description of the sample, including the respondents' characteristics. The study sample was characterized by having low education, low income, and high unemployment levels. Around 54% of the households subsisted with less than one monthly minimum wage (approximately less than 250 USD in 2019), and 98% earnt less than two minimum wages. The mean household size was 3.8 people, so per capita income is very low. All households were classified as being in the two lowest socioeconomic strata (SES) of a housing classification system (six categories according to physical characteristics) associated with income level in Colombia (Cantillo-García et al., 2019).

In many low-income and informal settlements from Latin America, including *Ciudad Bolívar* in Bogotá, women play a crucial role in community development, community engagement, and social mobilization. Furthermore, the sample comprised a random sample of adults in selected households that fulfilled the following inclusion criteria: adults without known cognitive disability, who have lived in the study area for at least 2 years, who were not planning to move to another neighborhood that is not part of the study area within the next 2 years, and who were willing to be follow-up in the next two years. In this context, women were more likely to meet the sample criteria. Moreover, the categorization of non-occupied respondents was based on the activities developed during the previous week when the survey was made. As many adults in the study rely on informal and intermittent jobs, many could be categorized as unemployed at this specific time. Considering this, the modeling approach considers including these variables as covariates, to account for statistical differences in preferences and attitudes between these groups.

Table 1
Sample description.

		Survey	SP
Sample Size		1,006	340
Attribute		**Proportion**	
Time living in a dwelling	< 8 years	32%	26%
	8–25 years	36%	39%
	> 25 years	33%	35%
Age	18–28	25%	21%
	28–41	23%	24%
	41–58	25%	26%
	> 58	28%	29%
Sex	Female	65%	74%
	Male	35%	26%
Marital status	Single	20%	21%
	Married or domestic partner	53%	53%
	Divorced, separated, or widow	26%	27%
Education level	Primary	39%	44%
	Secondary	46%	43%
	Higher education	16%	13%
Occupation	Studies or works	64%	59%
	Non occupied	36%	41%
Vehicle ownership	Motorcycle	16%	14%
	Car	7%	6%
Household income	< 1 Monthly minimum wage	54%	56%
	> 1 Monthly minimum wage	46%	44%
Socioeconomic strata	SES 1	84%	96%
	SES 2	15%	3%
Owns the dwelling where living		42%	42%
Household size < 4		46%	39%

The SP component corresponds to a choice experiment where each respondent faced 9 situations where they had to choose whether to use the new cable car or their most frequently used transport mode before the cable car was available. Hence, we obtained 3,060 observations. The cable car alternative was described according to travel time savings, waiting time, walking time, and cost savings compared to the conditions before TransMiCable was available. The levels of the attributes considered in the choice experiment are presented in Table 2.

Table 2
Attribute levels in the SP experiment.

Choice situation	Travel time savings [min]	Additional waiting time [min]	Additional walking time [min]	Cost savings [COP] *
1	10	5	2	$0
2	30	8	2	$800
3	20	10	2	$1,500
4	20	5	4	$800
5	10	8	4	$1,500
6	30	10	4	$0
7	30	5	6	$1,500
8	20	8	6	$0
9	10	10	6	$800
The expected effect on the willingness to use the cable car	+	−	−	+

*1 USD = 2,956 COP.

The levels associated to the attribute travel time savings in the SP experiment (i.e., 10, 20, and 30 min) reflect the conditions expected with the implementation of the cable car (Guzman et al., 2023). According to the data collected, the average travel time for mandatory trips (study and work purposes) before the cable was 110 min, while after the project was implemented, the average travel time decreased to 90 min. One of the main benefits of the cable car is direct access to the BRT system. On the other hand, cost savings are associated with different levels of integration of the cable car line with the public transport system of the city.

The cable car project is well known by most of the participants, as the success and implementation of the project were highly determined by social mobilization and community engagement (see Section 3). This situation facilitated the collection of the SP survey and the understanding of the hypothetical choice situations by the participants. It is relevant to mention that the cable car alternative was chosen in 79% of the total observations. This might evidence some policy bias in the responses, given that the cable car is a project that generates a lot of expectations and is highly desired by the community (Guzman et al., 2023).

4.2. Measuring social capital

Social capital is a multidimensional construct that embeds a wide range of domains depending on the context and data availability. Following the definition by Putnam (2001), social capital domains must reflect the features, norms, and characteristics that facilitate social coordination between individuals for mutual benefit. Even though the domains could vary depending on the theoretical definition used for social capital, there is consensus that they should reflect the features of civic engagement, trust, and social links (Brehm and Rahn, 1997; Congdon, 2010; Narayan and Cassidy, 2001; Östh et al., 2018; Owen and Videras, 2009; Utsunomiya, 2016). Hence focusing on a single component can generate results that do not correspond to the concept as a whole (Owen and Videras, 2009), so a robust measurement model for social capital requires the inclusion of the most relevant dimensions according to the project goals. The studies measuring social capital usually select some of these domains considering the research objectives, the context of the study, the availability of data, and the polling methods (Paldam, 2000). The most recurrent domains are included in practical measurement models; among these domains, trust in people, trust in institutions, availability of social networks, and group membership stand out as can be seen in Table 3, where a set of selected empirical studies measuring social capital are summarized.

The design of social capital questions in this study is based on three main sources: The World Bank social capital questionnaire (Grootaert et al., 2004), the Development Bank of Latin America-CAF survey[1], and the *Encuesta Multipropósito*[2] from Bogotá. This set of questions assessed the domains of groups, social networks, interpersonal trust, institutional trust, cooperation, and empowerment. We selected the measurement model following the literature review, the criteria of experts on measuring social capital in informal settings, and previous research on the assessment of the impact of cable cars (Milan and Creutzig, 2017). The questionnaire was tested and adapted to the context after training and fieldwork sessions.

We define social capital as a second-order latent variable formed by six first-order domains, which are also latent variables. These domains reflect indicators established from the attitudinal questions included in the survey and defined following the literature review. Supplementary Table A1 describes the final set of indicators for each selected domain, the scale used, and the proportion of responses in each category. The indicators' responses were ordered in such a way that the relation between them and the domain's score was expected to be positive. Furthermore, to capture part of the heterogeneity between them, the domains are formed by observed socioeconomic attributes of the individuals and modeled through a Multiple Indicator Multiple Cause (MIMIC) model (see Section 4.3). Fig. 1 includes a diagram of the structure used to measure social capital. Note that the relations between domains and indicators are omitted for visualization purposes. The

Table 3
Social capital dimensions measured in previous studies.

Authors	Study region	Social capital dimensions	Approach
Brehm and Rahn (1997)	USA	Confidence in government, civic engagement, interpersonal trust	SEM
Paldam (2000)	–	Trust, networks, ease of cooperation	Discussion
Narayan and Cassidy (2001)	Ghana and Uganda	Groups, generalized norms, togetherness, everyday sociability, neighborhood connections, volunteerism, trust	Factor analysis
Grootaert et al. (2004)	–	Groups and networks, trust and solidarity, collective action and cooperation, information and communication, social cohesion and inclusion, empowerment, and political action	Questionnaire
Li et al. (2005)	Britain	Neighborhood attachment, social network, civic participation	Generalized latent models
Owen and Videras (2009)	United States	Trust, fairness, groups membership	Latent class
Congdon (2010)	England	Social support, trust, groups membership	MIMIC
Savage et al. (2013)	Britain	Contacts and connections	Latent class
Kamruzzaman et al. (2014)	Brisbane	Trust, reciprocity, connections with neighbors	Factor analysis
Neves and Fonseca (2015)	Lisbon	Bridging, social participation	Latent Class
Utsunomiya (2016)	Japan	Trust, networks, participation	Regression
Munford (2017)	London	Social trips made	Regression
Östh et al. (2018)	Sweden	Community connectivity	Regression

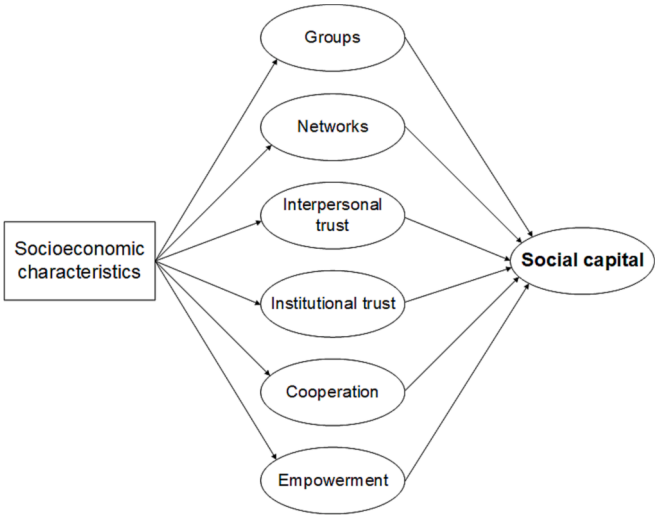

Fig. 1. Social capital dimensions and measurement structure.

[1] https://www.caf.com/es/temas/i/investigacion-*para*-el-desarrollo/encuesta-caf-investigacion/encuesta-caf/.

[2] https://www.sdp.gov.co/gestion-estudios-estrategicos/estudios-macro/encuesta-multiproposito.

domains included to define social capital are intended to measure the following:

1. Groups: Measures the tendency of the individual to belong to civic groups.
2. Networks: Measures the availability of social networks and connections that might help the individual in the case of an unfortunate event.
3. Interpersonal trust: Measures the extent of social connections on which it is possible to rely in case of an emergency.
4. Institutional trust: Measures the level of trust in the government and civic institutions.
5. Cooperation: The perception of individuals regarding the level of cooperation in the neighborhood to improve its condition and solve problems.
6. Empowerment: Degree of cooperation, autonomy, and joint mobilization to deal with problems and special circumstances in the neighborhood.

The data analysis process started by using the Confirmatory Factor Analysis (CFA) technique to evaluate the consistency of the indicators associated with each social capital domain. We tested different sets of indicators for each domain considering the goodness of fit, statistical significance, and theoretical congruence of the parameters. Supplementary Table A2 presents the CFA results for the final set of selected indicators from Table A1. The overall fit indices suggest an acceptable goodness of fit, while all parameters associating domains and indicators are positive, as expected according to the variable codification.

Moreover, the relation between the domains and social capital is causational (see Fig. 1). We postulated that social capital is a composite formed by the six domains. It is specified as a linear combination of first-order latent variables representing the domains. Hence, we consider that social capital levels result from group participation, availability of social networks, interpersonal trust, institutional trust, community cooperation, and empowerment.

Measuring social capital is a difficult task. Social capital is a multidimensional concept with several hard-to-measure determinants and indicators that might not be observable by the modeler. Using surveys to collect these determinants can induce biases associated with the respondent's beliefs, which are conditioned to social and economic constraints. Even though these difficulties might rise no matter the context when comparing developed and developing countries, it is possible to find that the determinants of social capital change with economic conditions and development levels. For instance, robust public and social programs may influence perceptions towards social capital dimensions such as institutional trust and cooperation networks. If basic needs are met, the valuation of cooperation networks might be lower compared to socially vulnerable communities where social networks, trust, and interactions between neighbors is crucial to subsist. These differences can also be observed within population segments from the same context. Moreover, most existing studies measuring social context come from developed economies. In these cases, civic participation, social cohesion, trust, and bridging social capital seem to be the most common dimensions. In contrast, in low-income and developing contexts the focus is required on cooperation and bonding social capital dimensions.

4.3. Modeling framework

The methodological framework is based on the modeling of discrete choice models incorporating the latent variable social capital. Discrete choice models are grounded in the random utility theory, which states that consumers make economic decisions that maximize their benefit, subject to legal, financial, and physical constraints (McFadden, 2001). These benefits are related to the theoretical concept of utility, representing the attractiveness of the available alternatives in a choice situation.

On the other hand, the relationship between socioeconomic characteristics, latent variables, and indicators might be modeled by a MIMIC model (Bollen, 2014), which describes the latent variable η_{ip} as a function of a set of observed variables S_{ip} affected by the parameters α_{ip} to be estimated plus an error term ϑ_{ip} (Eq. (1) is known as structural equations). The incorporation of S_{ip}, also known as the causes, allows the heterogeneity of the latent variables to be captured using observed attributes of the individual such as socioeconomic characteristics as regressors. At the same time, the latent variable explains a set of attitudinal indicators C_{ip} through ordered logit regressions that recognize the ordinal nature of the indicators. In this case, each categorical response k of indicator p is a function of the latent variable, a set of parameters γ_{ip} to be estimated, an error term ζ_{ip}, and a set of thresholds to be estimated, as shown in Eqs. (2) and (3) (measurement equations). In the case of the latent variable social capital, the set of regressors S_{ip} in the structural equation Eq. (1) corresponds to the set of social capital domains considered. Under this formulation, the latent variable value represents the score of the individual's social capital stock.

$$\eta_{ip} = \sum \propto_{ip} S_{ip} + \vartheta_{ip} \tag{1}$$

$$C^*_{ip} = \sum \gamma_{ip} \eta_{ip} + \zeta_{ip} \tag{2}$$

$$C_{ip} = \begin{cases} 1 if C^*_{ip} \le \tau_1 \\ 2 if \tau_2 < C^*_{ip} \le \tau_2 \\ \cdots \\ k if \tau_{k-1} < C^*_{ip} \end{cases} \tag{3}$$

To consider the effects of latent constructs in a discrete choice model, the latent variable η_{ipj} could be included in the utility function as shown in Eq. (4), where θ_{ipj} is the marginal utility of the latent variables in the choice process. Given this, the model structure of Fig. 2 is formulated. Even though the notation and subindices used suggest that the utility function depends on the individual i, alternative j, and latent variable p, it is important to mention that it could also depend on the choice situation. However, this is not the case for the current analysis.

$$U_{ij} = \mathrm{ASC}_{ij} + \sum \beta_{ij} X_{ij} + \sum \theta_{ipj} \eta_{ipj} + \varepsilon_{ij} \tag{4}$$

Given this model structure, the unconditional choice probability is given by Eq. (5) (Walker and Ben-Akiva, 2002) where y_{ij} is the vector of observed choices, $f(*)$ is the density function of the indicators used to measure the latent variables, and $g(*)$ is the density function of the latent variables. If the choice component is specified as an MNL, then the term $Pr(y_{ij}|X_{ij},\eta_{ipj},\beta_{ij},\theta_{ipj})$ follows the structure of Eq. (3). This functional form can be estimated using simulated maximum likelihood methods (Train, 2009 allowing for the simultaneous estimation of all ICLV components.

$$Pr(y_{ij}|V_{ij}) = \int_{\eta_{ipj}} Pr(y_{ij}|X_{ij},\eta_{ipj},\beta_{ij},\ \theta_{ipj})\ f(C_{ipj}|\eta_{ipj},\gamma_{ipj})\ g(\eta_{ipj}|S_{ipj},\propto_{ipj})\ d\eta_{ipj} \tag{5}$$

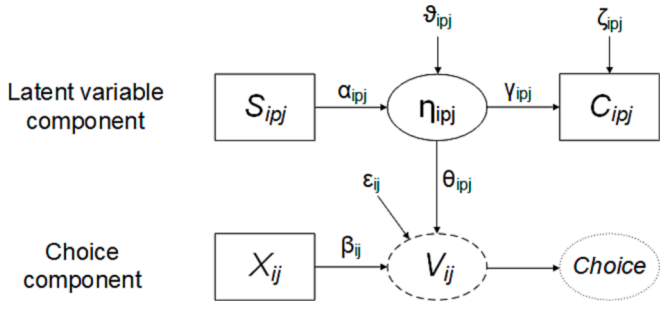

Fig. 2. Integrated choice and latent variable model structure.

In summary, the proposed framework allows the cognitive process that underlies the choice process to be modeled, relying on the measurement of latent constructs (Vij and Walker, 2016). We propose an ICLV model with two components. First, social capital is measured with a MIMIC model. The structural equations (see Eq. (1) allow the estimation of a score for the latent variable, which is a proxy for the stock of social capital of each individual. Then, the latent variable social capital is included in the utility function of a choice model estimated using the SP data.

5. Results and discussion

5.1. Resulting modeling approach

Following the modeling framework described in Section 4.3, the latent construct social capital (Fig. 1) is introduced in the utility function interacting with the ASC along with the cost and travel time savings, additional walking time, and waiting time of the TransMiCable (see Fig. 3). The parameter associated with the latent variable allows the marginal effect of social capital stocks on the willingness to use TransMiCable to be captured. We tested different specifications, including interactions of travel time and cost savings with the social capital latent variable. However, this turned out to be futile. Results including these interactions suggested a poorer fit than the initial formulation. Also, in most cases, the maximum likelihood solution did not meet behavioral theories such as positive marginal utility for cost savings and travel time savings.

The systematic utility function specified for the alternative TransMiCable (TMC) is presented in Eq. (6). It considers the attributes of social capital (SC), travel time savings (TT), additional waiting time (WTT), additional walking time (WKT), and cost savings (C). Since the choice exercise consists of two alternatives and the attributes of the cable car are referenced to the current traditional mode, the systematic utility for the latter was normalized to zero. The attribute cost savings was scaled to hundreds of Colombian Pesos (COP). The ICLV model was estimated using a simultaneous estimation approach implemented in the Apollo package (Hess and de Palma, 2019), available in R.

$$U_{TMC} = ASC_{TMC} + \theta_{SC} \bullet SC + \beta_{TT} \bullet TT + \beta_{WTT} \bullet WTT + \beta_{WKT} \bullet WKT + \beta_{C} \bullet C \quad (6)$$

5.2. Modeling results

Measurement equations (Eq. (2)) and respective thresholds (Eq. (3)) are not presented for the sake of the simplicity of the manuscript. However, it is relevant to mention that all parameters were statistically significantly different from zero at the 95% confidence level. Also, the results confirmed the positive relationship between domains and indicators. Table 4 presents the estimation results for the structural equations of the latent variable component of the ICLV model. All parameters were statistically significantly different from zero at the 95% confidence level, except for owning a motorcycle in the structural equation associated with the interpersonal trust domain.

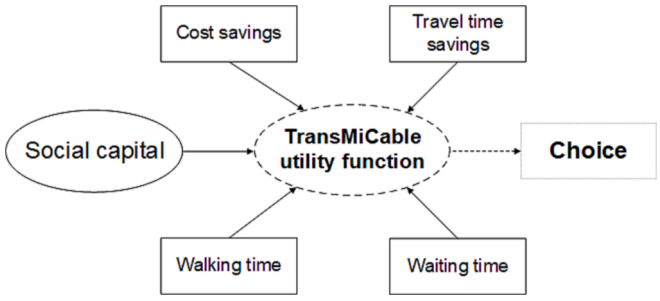

Fig. 3. ICLV model structure.

Table 4
Estimation results from structural equations from ICLV model's latent variable component.

Domain	Attribute	Estimate	*t*-test	Pr(>|t|)
Groups	Time in dwelling < 8 years	−0.39	−4.84	<0.01
	Owns dwelling	0.28	4.31	<0.01
	Higher education	0.35	4.57	<0.01
Networks	Female	0.19	2.23	0.03
	Age 18–28	−0.56	−5.30	<0.01
	Age 28–41	−0.38	−3.48	<0.01
Interpersonal trust	Female	0.36	2.91	<0.01
	Higher education	0.47	2.92	<0.01
	Unemployed	−0.36	−2.92	<0.01
	Owns motorcycle	0.20	1.28	0.20
Institutional trust	Household size < 4	0.18	2.89	<0.01
	Age 18–28	−0.65	−6.99	<0.01
	Age 28–41	−0.69	−7.37	<0.01
	Age 41–58	−0.45	−5.40	<0.01
Cooperation	Female	0.15	1.73	0.08
	Age 18–28	−0.29	−2.79	0.01
	Divorced or separated	−0.15	−1.69	0.09
Empowerment	Female	−0.33	−3.02	<0.01
	Age 41–58	0.34	2.89	<0.01
	Lower zone	−0.58	−5.67	<0.01
Social capital	Groups	12.18	2.28	0.02
	Networks	6.67	2.30	0.02
	Interpersonal trust	2.23	1.99	0.05
	Institutional trust	12.43	2.28	0.02
	Cooperation	7.53	2.27	0.02
	Empowerment	4.92	2.22	0.03

The heterogeneity related to social capital domains is mainly captured by the individual's age, sex, education level, house ownership, and time living in the neighborhood. We calculated the total effect of the observed variables in the structural equations to determine how sociodemographics influence the stock of social capital. We found that individual stocks of social capital are significantly lower for younger individuals (i.e., less than 41 years old), separated/divorced individuals, and those who have been living in the neighborhood for less than eight years. In contrast, social capital levels are higher for people with higher education levels, females, households with less than four residents, and homeowners. Surprisingly, social capital levels are not sensitive to income, private vehicle ownership, or occupation. This might be explained by the uniformity of the sample in these aspects, given that most of the respondents could be categorized into low-income segments (see Table 1) without cars.

As expected, all the domains have a significant positive effect on the measurement of social capital, meaning that the higher the domain score, the higher the general social capital stock. In the study population, group membership and institutional trust have a higher impact on social capital stocks. We also noticed that residents of the lower zones of the cable car, that is, closer to the interchange base BRT station *Portal Tunal*, seem to have a lower level of domain empowerment, even though the average income and urban physical conditions are somewhat better in this area. This situation might be related to the sense of community and cooperation developed in the upper zones to deal with the poorer living conditions. Civic participation and community leadership in the upper zones were crucial for the implementation and community appropriation of the TransMiCable project. As an illustration of the community appropriation, in the year 2019 during a large strike in the city when the public transport system was highly affected by buses and stations being burned and to some extent destroyed, the community surrounded the TransMiCable stations to protect the system and none of the cabins or urban transformation were affected. It should be considered that these people are the most affected by the low accessibility, job informality, and transport disadvantages that characterized the study

area before the project. This result suggests that individual social capital might develop in adverse situations where the solution to collective problems requires social organization.

Table 5 presents the estimation results for the parameters of the choice component in the ICLV model. All parameters were significant at the 95% confidence level except for walking time. The probability of using TransMiCable is negatively affected by the additional waiting time and increases with travel time savings and cost savings. This is in line with econometric behavioral theories. We also compared the choice component of the ICLV model with the corresponding reduced model, that is, the choice model in which all observed attributes used as regressors in the ICLV model are explicitly included in the utility function as a linear combination, interacting with the ASC, and no latent variables are considered. The estimation results of the reduced model are presented in Supplementary Table A3. The outcomes indicate a better fit and the parameters show more statistical significance in the ICLV model, suggesting that the inclusion of the latent variable social capital improves the forecasting capabilities of the mode choice model. Social capital seems to successfully account for a relevant part of the preferences and attitudes that determine the process of choosing a transport mode.

The results suggest that higher stocks of social capital are associated with a higher probability of choosing the new cable car service. This supports the hypothesis that the use of the cable car might be related to the adoption process of the project, which should be more important for those with a more solid sense of community. Moreover, it is confirmed that social capital levels determine the willingness to use new public infrastructure, so social capital is a relevant factor to consider in transport demand forecasting and project evaluation.

The success of a public transport project might be related to the social capital levels of the individuals interacting in the influence zone, particularly when the project involves vulnerable communities. This might be because networks of social interaction broaden an individual's sense of self, developing a sense of community, enhancing interest in collective benefits, and producing pride of public infrastructure that facilitates social development. Historical analysis suggests that organized reciprocity and civic solidarity networks, that is, higher social capital stocks, are a precondition for socioeconomic modernization (Putnam, 2001).

Fig. 4 shows the density distribution of the social capital score among the individuals included in the general survey sample. It also shows the probability of using TransMiCable in a *ceteris paribus* scenario, where the cable car has the same travel, walking, and waiting times and costs as the alternative. It also shows how the probability varies if social capital scores increase by 10 and 20%.

The social capital distribution in the sample seems to be left-skewed, with a mode of 1.0, mean of −6.14, and standard deviation of 7.14, suggesting relatively high dispersion. Results suggest that women have higher stocks of social networks, interpersonal trust, and cooperation, while lower stocks of empowerment. Therefore, analyzing aggregated averages such as social capital stocks in Fig. 4 and the market shares of indicators in Table A1, it should be noted that 65% of the respondents are female.

The willingness to use the cable car increases with the social capital score. In our sample, increments of 10 and 20% in the individual's social capital level raise the mean probability of using TransMiCable by 3.9 and 7.5%, respectively. Investing in social capital could be an alternative to improve the use of public transport and increase demand for it, even though in our case study demand is not very elastic with respect to social capital scores. For the population living in the influence zone of TransMiCable, the most efficient way to achieve this could be by facilitating the development of social groups and improving the general trust in official institutions. This could be done by providing public infrastructure, funding communal activities, simplifying official procedures, improving customer service in official institutions, reducing corruption, and taking measures to improve the image of public institutions.

Table 5
Estimation results from choice component ICLV models.

Parameter	Description	Estimate	*t*-test	Pr(>|t|)
ASC_{TMC}	ASC: TransMiCable	6.15	7.08	0.00
θ_{SC}	Interaction social capital with ASC	0.41	2.25	0.02
β_{TT}	Travel time savings	0.39	4.08	0.00
β_{WTT}	Waiting time	−1.39	−3.61	0.00
β_{WTT}	Walking time	−0.59	−1.24	0.22
β_C	Cost savings	1.03	7.66	0.00
Log-Likelihood (whole ICLV model)		−31,734.6		
Log-Likelihood (choice component)		−842.0		
Rho2 (choice component)		0.603		

6. Conclusions and recommendations

This research evaluates the influence of social capital on the willingness to use a new cable car line in Bogotá. To do this, we estimated a hybrid choice model, where social capital is explicitly incorporated in the utility function of the alternative as a second-order latent variable formed by six domains: groups, networks, interpersonal trust, institutional trust, cooperation, and empowerment. The major findings can be summarized in three points. First, higher social capital stocks are associated with a greater willingness to use the new transport alternative. This suggests that social capital is a determinant for travel behavior, and supports the hypothesis that accounting for social interactions, social influence, attitudes, and perceptions could help to improve the understanding of the complex relations that make up the economic behavior of individuals (i.e., the process of mode choice) (Dugundji et al., 2011, Dugundji et al., 2008). Second, differences in individual social capital stock are explained by sociodemographic attributes, principally age, sex, education level, house ownership, and time living in the neighborhood. Third, the inclusion of the latent variable social capital improves the capabilities and goodness of fit of the mode choice model, allowing evaluation of the cognitive relations that underlie the user's process of mode choice, which are very hard to identify and model using other formulations. This result suggests that social interactions have a relevant role in the process of mode choice, particularly, in the adoption and use of new transport services and urban transformation projects, in the context of poverty and poor accessibility.

The findings suggest that social capital is a relevant factor to consider in public transport decision-making and the definition of risks, demand forecasting, and general evaluation of new transport infrastructure. However, the relationship between social capital and transport mode choice could be not static. The influence of social capital on mode choice may vary depending on the context and the particular transport mode in question. For instance, sometimes can increase as a result of collective efforts, such as the community's organization that led to the successful implementation of the project or the defense of cable car facilities at a time of city riots, and sometimes it may decrease, as a result of political apathy and low levels of service, as was the case for 12 years with the city's BRT system. On the other hand, the use of social capital as a focalization tool has some issues, since it could generate perverse incentives that prioritize public investments in areas with better social conditions, broadening inequality gaps. This is especially relevant in cities of the Global South characterized by high levels of poverty and segregation. We encourage researchers and policymakers to consider that travel behavior is conditioned by the characteristics of the social interactions in a community, which could be measured in the form of social capital. So, these are factors that could define the success and financial viability of transport investments.

Lastly, this study presents a series of limitations that must be addressed in future research. First, the study population belongs to a very specific context, so evaluations using general samples are required

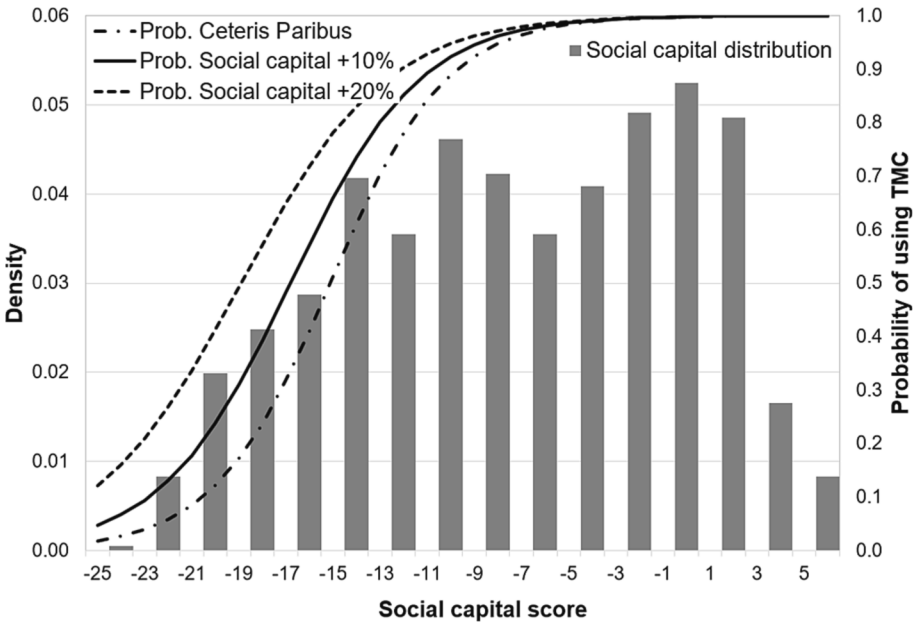

Fig. 4. Social capital score distribution and probability of using TransMiCable.

to analyze the implications for different population segments and contexts. Also, the hypothetical nature of the stated choice experiment might produce biased results. Further model specifications using data from different sources with mixed revealed and stated preferences may be necessary (Guzman et al., 2021). In particular, the expectations of the community regarding TransMiCable could induce some policy bias in the responses to the survey (Guzman et al., 2023), so further exercises incorporating a wider range of public and private mode alternatives are advised. Moreover, the MIMIC-based ICLV framework assumes that the latent variable is continuous, so social capital is considered as a stock variable. Given the characteristics of the concept, the specification of discrete choice models addressing latent classes would allow the evaluation of different types of social capital, rather than a unidimensional score. Future research should aim to evaluate the impact of TransMiCable on social capital and follow the demand of the cable car to evaluate the links in the long term. Future research also should evaluate the differences in social capital determinants between countries and population segments, evaluating the transferability of conclusions between contexts.

CRediT authorship contribution statement

Luis A. Guzman: Conceptualization, Investigation, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Victor A. Cantillo-Garcia:** Validation, Data curation, Formal analysis, Writing – original draft. **Julian Arellana:** Resources, Validation. **Olga L. Sarmiento:** Validation.

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.

Acknowledgments

We would like to express our gratitude to the Bogotá Urban Planning Department (www.sdp.gov.co), for the funding and general support given for the development of this study through Agreement 369 of 2018. The study was partially funded by The Salud Urbana en América Latina (SALURBAL)/Urban Health in Latin America project funded by the Wellcome Trust [205177/Z/16/Z]. Also, thank Diana Higuera-Mendieta and Dr. Eliana Martínez-Herrera for their insights and contribution to defining the social capital construct.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tbs.2023.100612.

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