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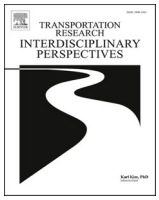

Disentangling social capital – Understanding the effect of bonding and bridging on urban activity participation

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ABSTRACT

Social capital is a critical glue for economic and social development in urban areas. Yet, to effectively guide research and practice, there is a need for careful measurement of social capital and how it links to important aspects of urban system functions. This study is aimed at examining the multi-dimensional nature of social capital and the relationship between these dimensions and travel behavior. Prior research has shown connections between stand-alone social capital concepts, such as resources gathered via social networks, with specific aspects of travel behavior. In this work, we expand the definition of social capital to cover separate dimensions, modeled via multiple indicators. Specifically, we make use of over 1400 observations from the Pew Internet Networks and Community Survey dataset to build a Structural Equation Model dividing social capital into two latent dimensions: *bonding* and *bridging* to examine the relationship of both these dimensions with discretionary urban activity participation diversity and frequency. Moreover, broader measures of neighborhood and community engagement are included in the model to explain how such engagement can help with the accumulation of social capital. Our results indicate a positive but differential relationship between both social capital dimensions and activity participation. Further, the results also suggest an absence of correlation between bonding and bridging capital, strengthening the hypothesis that social capital is multi-dimensional. In terms of explaining the social capital accrual, we find that while community engagement is positively correlated to bridging capital, no evidence was found for a relationship between community engagement and bonding capital. Further, neighborhood engagement was not found to be associated with any of the social capital dimensions. This suggests that individuals predominantly rely on close-knit and stronger relationships for social/emotional support, while instead, community engagement significantly helps in the accumulation of bridging capital. The result from the study can be used by policy makers to improve transportation planning, management, and community well-being.

Introduction

The importance of *social capital* in shaping the development and character of urban systems is well known. Social capital can be described as the glue that holds together institutions, maintains a sense of community identity, and governs interactions among people, thereby contributing to economic and social development (Dasgupta and Serageldin, 1999). Social capital is a resource embedded in social relations and it can be "*…accessed and/or mobilized in purposive actions*" (Lin, 2002). Thereby, social relations encapsulate a "*capital effect*" that facilities the flow of information, and affects decisions such as empowering communities and building support for pro-environmental policies in cities (Alvarez et al., 2017; Dean et al., 2016).

Since its conception, social capital has received growing attention and has been studied in a variety of contexts. For example, there is strong evidence that social capital has a positive impact on general health, subjective well-being, and quality of life (Hamdan et al., 2014; Kawasaki et al., 2019; Nilsson et al., 2006; Yip et al., 2007). Further, it has also been studied concerning its impact on the success/failure of organizations (Nahapiet and Ghoshal, 1998); individual success and income attainment (Boxman et al., 1991); and resilience and accessibility in urban systems (Aldrich, 2017; Aldrich and Meyer, 2015; Östh

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et al., 2018; Sadri et al., 2021). There is also growing evidence that social capital is deeply connected with travel, mobility, and activity participation, where its association has primarily been studied in two ways: 1) to understand its role in enabling travel and activities (Maness, 2017a, b; Nguyen et al., 2017); and 2) to understand how travel and activities help in the creation of social capital and thus reduce the chances of social exclusion (Coutts et al., 2018; Schwanen et al., 2015).

Despite the central role of social capital in urban development analysis, a gulf between its theoretical understanding and the ways it has been measured in empirical work has persisted (Paxton, 1999). Though the initial use of social capital was qualitative in nature, a more quantitative approach has gained momentum in the last few decades (Borgatti et al., 1998; Lin, 1999). An important insight that has emerged is the existence of multiple dimensions of social capital. There is mounting evidence that this multi-dimensionality must be recognized to have a complete understanding of its impact on various phenomena (Nahapiet and Ghoshal, 1998; Neira et al., 2019; Putnam, 2000; Van Der Gaag and Snijders, 2005).

In light of the above discussion, the goal of this study is to advance our understanding of the role of social capital in underpinning urban travel and activity participation to support sustainable urban systems via three main research objectives.

First, we examine and identify separate social capital dimensions that are, in turn, tied to mobility and activity participation. Though there are numerous existing efforts to quantify facets of social capital on some aspects of travel, most work has taken single indicators as evidence for social capital effects and investigated its relationships with travel decisions. In this paper, we seek to take a broader view and provide a more robust modeling approach by examining how social capital is defined, measured, and explained in relation to travel behavior.

Second, building on the evidence from other fields that social capital is multi-dimensional, we use measurement models to identify and analyze two social capital dimensions, namely '*bonding social capital*' and *'bridging social capital'*. As noted above, previous travel-related studies have relied on single question/indicator constructs such as receiving help for tasks like childcare or housekeeping, etc. (Calastri et al., 2018; Di Ciommo et al., 2014), or the number of ties in alters' personal social network (Maness, 2017a) to measure social capital[1]. While the use of single indicators does provide valuable information, this potentially leads to measurement errors and loss of explanatory power. Here, we take the view that the measurement of multiple social capital dimensions requires the use of multiple indicators to reliably understand the relationship both among dimensions and their connections to travel behavior.

Third, we use a structural equation model to gain insights into how different social capital dimensions impact activity behavior, both separately and by exploring synergies.

Drawing on data from 1,434 respondents in the Pew Internet Networks and Community Survey (Hampton et al., 2009), we build a structural equation model (SEM) dividing social capital into two dimensions: bonding and bridging social capital, and then study the relationship of these dimensions with discretionary urban activity participation *diversity* and *frequency*. Moreover, we also include neighborhood and community engagement as two separate latent variables in the model to explain how these are associated with the accumulation of different social capital dimensions.

The proposed framework reveals the differential impact of bridging and bonding social capital on activity participation frequency and diversity. The model also highlights the role of neighborhood/community participation in supporting social capital accrual, which will potentially have wide-ranging implications for transportation planning, management, and community well-being.

The remainder of the paper is structured as follows. Next section presents a brief review of the literature on social capital definition, multi-dimensionality, measurement, and linkage to mobility. Third section describes the available data and mathematical details of the SEM framework, which is followed by our view of social capital in this paper and the research hypotheses linking different dimensions of social capital with urban activity frequency and diversity, along with a conceptual path diagram for the structural equation model. SEM estimation results are presented next, followed by policy implications, summary, conclusions, and limitations from this study.

Literature review

In this section, we summarize the literature on three relevant aspects of social capital: 1) social capital definition and multi-dimensionality; 2) linkage between social capital and mobility or activity participation, and 3) social capital measurement.

Social capital definition

There is lingering interpretive fuzziness in defining social capital in the literature. Social capital is often termed a polysemic and is a contested concept with a variety of different forms and definitions (Daly and Silver, 2008; Schwanen et al., 2015; Woolcock, 2010). Field (2008) summarizes the theory of social capital in two words – 'relationships matter' and Crossley (2008) points out that most definitions of social capital revolve around how social networks act as a resource for their members.

Two main ideas related to social capital exist in the literature (Crossley et al., 2015; Field, 2008) namely: 1) social capital as access to resources (Bourdieu, 1986; Lin, 2002), 2) social capital as social cohesion and brokerage across structural holes (Coleman, 1988; Putnam, 2000).

Social capital as access to resources originates from the work of Bourdieu (1986), for whom social capital is one of four forms of unevenly distributed capitals in the society (the other three being financial, cultural, and symbolic capitals). In this view of social capital, connections provide direct or indirect access to other forms of capital and hence are of value. For Bourdieu, only ties that provide access to other forms of capital count in the analysis of social capital (Crossley et al., 2015). Lin (2002) takes a similar view and adds that ties between low and high-status individuals (i.e. ties between individuals with a difference in status) tend to be weak, compared to in-group ties, which tend to be stronger. This is also in line with the theory of homophily which postulates that similar individuals are more likely to be connected to each other (McPherson et al., 2001; Monge et al., 2003; Yuan and Gay, 2006).

Putnam (2000)'s view of social capital differs from that of Bourdieu's. While Bourdieu focuses on ties with higher-status individuals as access to resources, Putnam *also* emphasizes the value of strongly bonded, closely knit networks. Putnam makes two important distinctions in terms of social capital. Firstly, he refers to *bonding* capital, which corresponds to a network of closely knit individuals and favors both the individual and their group. Bonding capital cultivates trust, cooperation, and mutual support thereby shifting the focus from an individualistic view to a more collective analysis perspective. Coleman (1988) argues that actors in such close-knit networks have an incentive to cooperate to avoid reputation damage or exclusion.

A second distinction is of *bridging* social capital, which refers to the ties across groups, which tend to result in the flow of novel information and resources. Bridging helps prevent social segregation in close-knit communities (Putnam, 2000). The concept of bridging social capital echoes the popular work on '*strength of week ties*' by Granovetter (1973)

[1] The terms ego and alter comes from the egocentric view of the social network analysis domain where social network around a particular social actor is of interest. The central social actor is called ego and the actors connected to the ego are called alters. The alternative view is where the analysis is done on entire network of ties between the actors. For more information on egocentric network analysis, readers are referred to Crossley et al., 2015.

and the work on structural holes and brokerage by Burt (1992).

From the discussion presented above it emerges that there are two main social capital dimensions, first related to the stronger ties between individuals (i.e. bonding) who tend to be similar to each other following the principle of homophily, *versus* weaker ties between individuals who are different from each other and hence bring novel resources (i.e. bridging).

While several other studies point to the likely existence of distinct social capital dimensions (Nahapiet and Ghoshal, 1998; Neira et al., 2019; Van Der Gaag and Snijders, 2005; Vilhelmsdóttir, 2012), much of this work is based largely on the social capital conception by Bourdieu/Putnam/Lin/Coleman/Burt and the identified dimensions are closely related to bonding and bridging capital. Further, several studies already identify bonding and bridging as two dimensions of social capital (Gittell and Vidal, 1998; Nicholas et al., 2018; Putnam, 2000; Stanley et al., 2019; Stone et al., 2003; Kawamoto and Kim, 2019). Note that apart from bonding and bridging, several studies also present *linking* as the third dimension of social capital, which captures ties with individuals with different levels of authority (i.e. vertical ties) (Kyne and Aldrich, 2020; Szreter and Woolcock, 2004). However, given a potential overlap between bridging and linking capital dimensions, in this study, we focus our attention on the broadly defined *bonding* and *bridging* dimensions of social capital only. A deeper investigation of the *linking* dimension of social capital is an avenue for future research. Further discussion on bonding and bridging capital is presented in 'Social Capital Dimensions and Research Hypotheses' section.

Links to travel, mobility and activity engagement

There is growing evidence of the association between social capital and mobility or activity participation. Table A1 in appendix A provides a summary of existing literature in this context. The majority of the existing literature is focused on understanding the role of individual social networks on travel or travel-related choices. For example, Sadri et al. (2015) argue that joint travel or activity participation intrinsically occurs within a social context, and thereby social network data is likely to contribute to understanding joint travel. Di Ciommo et al. (2014) examined the role of social capital in the context of modal shift after the opening of a new metro train station and found that including social capital variables improved the prediction performance in a mode choice model. They argue that social capital variables used in their study capture network resources (and trip generating capacity), which influence the time availability constraints of travelers. Maness (2017a) focuses on weak social networks in his study and argues that weak social network ties increase the diversity of information available to an individual about activities, thereby impacting travel. Further, Maness (2017b) presents a theory of strong and weak ties and their relationship with leisure activity participation, arguing that strong ties are related to leisure activity participation due to individual tendency to seek social safety. Several studies in the literature also model social influence instead of social capital as a way to capture the effect of alters' choices on ego's choice making (Bartle et al., 2013; Trivedi and Beck, 2018; Whitcomb et al., 2017).

Other work has studied the opposite effect, where social capital is *generated* as a result of travel. For example, Schwanen et al. (2015) proposed that social exclusion and disadvantage can be rethought from a social capital lens and argued that it could reduce or enhance social exclusion and transport disadvantage. Coutts et al. (2018) studied the commuting behavior of school children in Toronto, Canada, and found that longer commute time and more use of public transit led to discouragement from attending school, and participation in extra-curricular activities and hence impacted long-term social capital growth.

In this study, we take the view that different dimensions of social capital are related to travel; however, the impact of these dimensions may not be homogenous. Further, while understanding social capital generation as a function of travel is of interest, we take the view that it is a rather longer-term phenomenon. Hence our modeling explores separate social capital dimensions and assumes the correlation to run in a single direction.

Social capital measurement

In transportation research (and social network literature, in general), a variety of approaches have been proposed and used to measure social capital including social network measures like size/degree (calculated as the number of alters that an ego is connected to in a personal social network), density (proportion of pairs of alters that are connected), heterogeneity (variety of alters concerning relevant dimensions like gender, age, race, etc.), closeness (total graph-theoretic distance from ego to all others in the network), and betweenness (number of times an ego falls along the shortest path between two other actors) (Borgatti et al., 1998; Burt, 2009; Freeman, 1978). Researchers have also devised other advanced methods to measure social capital like the position generator (Lin and Dumin, 1986) and resource generator (Van Der Gaag and Snijders, 2005). Table A1 also summarizes the measures of social capital and its dimensions typically used in the transportation literature. The measures used in these studies are diverse, including receiving help for tasks like childcare, housekeeping, etc., number of ties in ego's social network, occupational diversity, etc. In general, these indicators can be broadly divided into the following five categories:

- Personal social network-based measures like network size, density, alter attributes, spatial proximity to alters, and homophily
- Social network resource-related measures like network diversity, and occupational prestige
- Civic/Community engagement related measures like whether a respondent engages in community participation or service
- Neighborhood engagement related measures like the connection with neighbors, whether the respondent received help from neighbors on issues like household chores, or lending money.
- Attitudinal measures of social capital like trust in neighbors, decision makers, sense of belonging, etc. as included in the world values survey, Afrobarometer, etc. (Inglehart et al., 2014; Kamruzzaman et al., 2014; Kawamoto and Kim, 2016).

Importantly, most studies use these indicators as stand-alone measures, or do not recognize the multi-dimensionality of social capital. Admittedly, few prior studies recognize the multi-dimensionality of social capital (Liu et al., 2020; Nicholas et al., 2018; Stanley et al., 2019; Wang et al., 2021), but do not use multiple indicators to measure these dimensions. An exception to this includes the work by Kyne and Aldrich (2020), who propose a Social Capital Index (SoCI) defined as a linearly additive composite of 19 publicly available indicators of social capital. However, they assign equal weights to each indicator used in their metric. In this study, we anchor the measurement of different dimensions of social capital in the existing literature using a multiple indicator approach, and a detailed discussion on this is provided later.

Data and methodology

Data

We make use of data from the Pew Internet Networks and Community Survey (Hampton et al., 2009), which was conducted in 2008 in the United States. The survey was interviewer-administered to a US national sample via telephone with a response rate of ~ 22%. Potential respondents were contacted as many as 10 times and were offered post-paid cash incentives for participation. The survey was targeted at adults over 18 years of age and consisted of the following 7 modules:

Table 1
Descriptive statistics of the personal, household, and social activity participation characteristics of the respondents.

Variable		Statistic
Gender	Male	47.8 %
	Female	52.2 %
Income	Less than $10,000	6.1 %
	$10,000 - $20,000	9.2 %
	$20,000 - $30,000	12.8 %
	$30,000 - $40,000	11.4 %
	$40,000 - $50,000	11.2 %
	$50,000 - $75,000	16.3 %
	$75,000 - $100,000	14.2 %
	$100,000 or more	18.8 %
Race/Ethnicity	White	80.4 %
	Black or African American	11.6 %
	Asian or Pacific Islander	2.2 %
	Mixed race	1.9 %
	Native American/American India	1.1 %
	Other	1.5 %
	Don't know / Refused	1.3 %
Employment Status	Employed full-time	51.8 %
	Employment part-time	11.4 %
	Retired	18.9 %
	Not employed	13.7 %
	Disabled	2.7 %
	Student	0.7 %
	Other	0.7 %
Education Status	None, or Grade 1–8	1.7 %
	High school incomplete	5.0 %
	High school graduate	29.9 %
	Technical, trade, or vocational school	2.4 %
	Some college, no 4-year degree	24.5 %
	College graduate	21.3 %
	Post-graduate	15.1 %
Age	Less than 25 years	10.7 %
	25–39 years	23.8 %
	40–59 years	40.8 %
	60–75 years	19.9 %
	More than 75 years	4.9 %
Marital Status	Married	51.9 %
	Living with a partner	6.8 %
	Divorced	11.2 %
	Separated	2.2 %
	Widowed	7.7 %
	Never been married	18.6 %
	Single	1.3 %
	Don't know/Refused	0.4 %
No. of children in the household	None	62.1 %
	One	14.8 %
	Two	14.3 %
	Three or more	8.9 %
No. of adults in the household	One	25.0 %
	Two	54.7 %
	Three or more	20.3 %
Social Activity diversity	Mean	4.0
	Median	4
	S.D.	1.7
Social Activity frequency	Mean	13.9
	Median	13
	S.D.	8.03

S.D.: Standard Deviation.

- *Internet usage:* this module asked respondents about their internet usage behavior including frequency of internet use at home and at work, type of internet connection, engagement in instant messaging, online blogging, use of social network websites, etc.
- *Name generator and interpreter:* consisted of two questions designed to gather information on names of alters: a) with whom the ego (respondent) discussed important matters in the last 6 months and b) who were especially significant in the ego's life. The number of names was restricted to a maximum of 5 in each case (10 total). In addition, respondents were asked for various information about their alters including gender, length of ego's relationship with the alters, frequency of contact with alters via face-to-face conversation, phone, email, geographic distance between the home locations of the ego and alters, alters' race, and political inclination. Note that the name generator is a popular technique to delineate the characteristics and structure of ego-centric networks and has been used by many studies in the past several decades (Burt, 1984; Kowald and Axhausen, 2014).
- *Position generator:* this module collected information on resources embedded in the respondent's social network (Lin, 2001). Specifically, respondents were asked whether he/she knew anyone active in each of the following 22 occupations: a nurse, a farmer, a lawyer, a middle school teacher, a full-time babysitter, a janitor, a personnel manager, a hairdresser, a bookkeeper, a production manager, an operator in a factory, a computer programmer, a taxi driver, a professor, a policeman, a chief executive officer in a large company, a writer, an administrative assistant in a large company, a security guard, a receptionist, a congressman, or a hotel bell boy.
- *Neighborhood involvement:* This module inquired about the type of housing, dwelling duration, to what extent the respondent knows the names of his/her neighbors, frequency of conversation between the respondent and the neighbors via various modes of conversation, and whether the respondent has received or given help to his/her neighbors in form of listening to problems, help with household chores, caring for the family members, or financial assistance.
- *Community involvement:* a module focused on assessing respondents' community involvement and the role of the internet in helping the respondents become more involved in community groups. Specifically, the survey inquired about involvement in any community group, local sports league, youth group, religious groups like a church, or any other social club.
- *Public spaces:* this module gathered information on the respondents' frequency and diversity of activity participation in public places. Specifically, the respondents were asked the number of times they visited a café or a coffee shop, a religious center, a public library, a restaurant (fast food or any other type), a community center, a public park or plaza, or a bar in the last month.
- *Personal and household characteristics* module asked the respondents for information on various personal and household characteristics such as age, gender, race, household income, number of adults and children in the household, education, employment, and marital status.

The dataset from the survey consisted of 2,512 observations in total with several observations having missing variables, which is typical in large social networks related surveys. After cleaning the data to remove observations with missing relevant variables, we were left with a total of 1,434 complete observations for the analysis[2]. Table 1 presents the descriptive statistics of the personal and household characteristic and social activity participation behavior of the respondents. Note here that we did not find any significant differences between the distribution of household income and ethnicity variables across the original and processed data while a *slightly* higher proportion of lower-aged individuals were present in the processed data compared to the original data. For household income, we found that those who refused to report their income or those who didn't know their household income in the original data were evenly distributed across various income groups in the processed data.

Note that the social activity diversity variable was defined as the total number of public places (out of a total of 6), as mentioned in the public space module, visited at least once in the last month. Further, the

[2] Note here that while we use listwise deletion to obtain the final dataset used in the study, following a reviewer's suggestion, we also tested the robustness of findings from this study using multiple imputed datasets using chained equations with MICE algorithm to account for missing data (Van Buuren, S., 2018). More information on this can be found in footnote 3.

social activity frequency variable takes the number of times each of the six places were visited in the last month and counts the total number of social / leisure trips made in the last month.

Structural equation modeling

We make use of a generalized structural equation modeling (SEM) framework (Muthén, 1984) in this study to understand the multi-dimensional nature of social capital and its relationship with social activity participation behavior. Structural equation models are multivariate regression structures that allow reciprocal, direct, and indirect relationships among variables. SEMs also allow the estimation of latent variables, which are measured through various observable indicators (Asgari et al., 2016). A generalized SEM consists of two components: 1) a *structural* model that captures the inter-relationship between various latent variables; 2) a *measurement* model that captures the relationship between continuous latent variables and their observed indicators. The structural component of an SEM can be written as:

$$\eta = \alpha + \mathrm{B}\eta + \epsilon \tag{1}$$

where,

η = vector of latent variables.
α = vector of intercepts.
B = matrix of parameters governing the relationship between latent variables.
ϵ = vector of error terms associated with the latent variables.

The measurement component can take two different forms depending upon whether the observed indicators are considered categorical or continuous. For categorical indicators, the measurement model is specified using the following equation:

$$y^* = \nu + \Lambda\eta + \mu \tag{2}$$

where,

y*=a vector of continuous latent variables or propensity function.
ν = a vector of intercepts.
Λ = a factor loading matrix.
μ = vector of measurement errors.

The relationship between observed indicator value y and y^* is expressed using the following mapping function:

$$\tilde{y} = \begin{cases} 0 & \text{if} \quad y^* \le \psi_1 \\ j & \text{if} \quad \psi_{j-1} < y^* \le \psi_j \forall j \in (2, \cdots, J-1) \\ J & \text{if} \quad \psi_{J-1} \le y^* \end{cases} \tag{3}$$

where,

J = number of ordered categories in a categorical indicator.
ψ_j = threshold parameter dividing y^* in various categories.

For continuous indicators, the relationship between the indicators and the latent variables is written as:

$$y = \nu + \Lambda\eta + \mu \tag{4}$$

We make use of the "*lavaan*" package in R programming language to estimate the SEM model (Rosseel, 2012), which uses the popular mean and variance adjusted weighted least square (WLSMV) procedure in cases where categorical indicators are involved (Olsson et al., 2000; Suh, 2015). For more information on structural equation modeling, readers are referred to Kline (2015).

Social capital dimensions and research hypotheses

In this study, we measure social capital as a property of an individual rather than group-based. In Putnam's definition, while social capital associated with a person is also associated with the group they belong to, we measure social capital associated with an individual since the scope of this study is related to understanding individual travel behavior. While several different dimensions of social capital exist in the literature, we adopt two broadly defined dimensions of bonding (network of closely tied individuals) and bridging (ties between heterogeneous individuals). These two dimensions offer the advantage of encompassing most niche dimensions identified in other studies. To formally define, *bonding capital* is described as the capital gathered from close contacts, people who are similar in characteristics and ideologies (Nicholas et al., 2018), and helps people 'get by' in life (Stone et al., 2003). *Bridging social capital* involves overlapping networks and helps gain access to resources and opportunities that do not exist in one's own network (Stone et al., 2003). Bridging capital is described to cover networks between heterogeneous individuals (Nicholas et al., 2018).

Regarding the ties between social capital and travel, here we take the view that urban travel activity participation is a function of social capital, i.e., social capital helps generate travel. The opposite causation, where social capital may be facilitated by travel activity, may also be in play, but here we take the view that this is rather a long-term phenomenon and is beyond the scope of this study. Further, we also emphasize that the travel discussed in this study is not limited to joint trip-making (i.e. travel that takes place with other individuals), since solo travel can still be rooted in social networks.

Regarding the impact of different dimensions of social capital on travel, we take the view that both of the identified dimensions (i.e. bonding and bridging) impact leisure/discretionary travel and activity participation but the impact these dimensions have on travel are differential. In the context of bonding capital, we propose that individuals that score high on bonding (i.e. those embedded in a more a tightly knit network) have a higher number of social constraints to abide by and thus are compelled to make more discretionary travel to avoid network contraction and loss of social safety or support (Rubin and Bertolini, 2016). In the context of bridging capital, we argue that individuals with higher bridging social capital make more discretionary travel since they have access to novel resources and information through their social connections. This includes access to a mobility tool, information regarding a newly opened restaurant, or access to membership in a club, etc., which otherwise would not have been available.

Further, we assume that the social capital dimensions are latent and cannot be measured correctly using a single indicator. Hence, a conceptual SEM framework is presented, where we use multiple indicators to measure the social capital dimensions and their association with urban activity participation. An important note here is that while several studies have used community and neighborhood participation as an indicator of social capital, two major issues arise with this approach. First, neighborhood or community participation propensities of an individual are latent in nature and need multiple indicators to provide a reliable measurement. Second, even when multiple indicators are used, neighborhood or community engagement should not be taken as a proxy for social capital, rather it is a way to accumulate social capital. This distinction is important to fully characterize social capital and its relationship with travel. In the next two sub-sections, we present the specific research hypotheses that we test in this study using an SEM framework and the indicators used to measure different latent variables involved, respectively.

Research hypotheses

Fig. 1 presents the conceptual framework used in the structural equation model relating social capital dimensions and urban activity participation. In the framework, we test four different hypotheses as

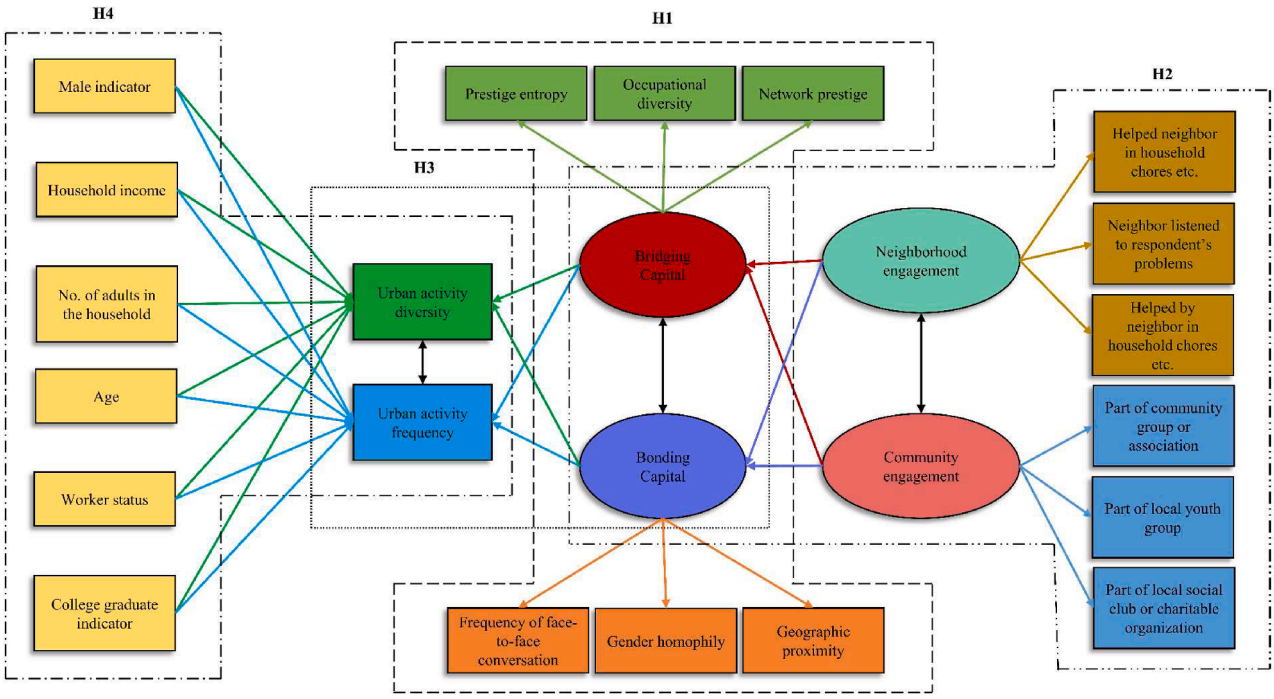

Fig. 1. Conceptual SEM Framework.

presented below:

Social capital is latent and multi-dimensional and is separable into two main dimensions: bonding and bridging. To test this hypothesis, we have incorporated two dimensions of social capital as different latent variables measured via three indicators each. Further, we also allow the estimation of error covariance between these two dimensions, to examine whether these dimensions are truly separable.

Neighborhood and community engagement are latent variables and require multiple indicators for measurement. Further, these engagement dimensions help to accumulate (strengthen) different social capital dimensions. To test this hypothesis, we consider neighborhood and community engagement as two separate latent variables measured via multiple indicators. Further, we specify path coefficients linking each engagement dimension to the social capital dimensions. Thereby we capture the accumulation of social capital via neighborhood and community engagement. Note here that we again allow error covariance between the two constructs to examine their connection.

Different dimensions of social capital have a significant and differential impact on urban activity participation frequency and diversity. To test this hypothesis, we allow paths from the two social capital dimensions to different urban activity diversity and frequency measures. Further, given that urban activity frequency and diversity are potentially correlated, we allow error covariance between these two variables as well.

Part of the variation in urban activity frequency and diversity can be explained by individuals' socio-demographic information. We formally test this hypothesis by allowing paths from individuals' socio-demographic characteristics to urban activity frequency and diversity variables. The joint control for social capital and socio-demographic variables allows us to gain a more cohesive image of the relative importance of each category of factors. The socio-demographic variables included in the model are respondents' gender, household income, household size, age, employment status, and education level status.

Measurement of the latent variables

We capture the four latent variables in our conceptual framework (which are bonding capital, bridging capital, neighborhood engagement, and community engagement) using three indicators each. The information regarding the indicators used in this study for each of the four latent variables is given below:

Bonding capital

The measurement of bonding capital is anchored in the existing literature. Since bonding capital is derived from a network of closely tied individuals who are similar to each other, potentially geographically closer, and interact more frequently, we use the following three indicators derived from the name generator to measure bonding capital:

- The average **frequency of face-to-face conversations** with alters.
- **Geographic proximity**, calculated as the average distance between the home location of the ego and the alters.
- **Gender homophily**, calculated to measure similarity between the respective gender of ego and alters. We used the negative of the E – I index (Krackhardt and Stern, 1988) given below as a measure of homophily:

$$\boldsymbol{E-I\ index} = \frac{\boldsymbol{ties}_{a-b} - \boldsymbol{ties}_{a-a}}{\boldsymbol{ties}_{a-b} + \boldsymbol{ties}_{a-a}} \tag{2}$$

where $ties_{a-b}$ is the number of alters different from the ego (w.r.t gender) and $ties_{a-a}$ is the number of alters similar to the ego (w.r.t gender). Gender homophily varies between 1 and −1, where 1 corresponds to higher homophily (meaning higher similarity between ego and his/her alters).

Bridging capital

Since bridging capital is derived from ties with individuals who are potentially different from an individual and have access to novel resources that are otherwise not available to the ego, we use the position generator to measure the resources embedded in one's social connections. Based on the position generator, we use the following three indicators of bridging capital in this paper:

- **Occupational diversity:** Following Maness (2017a), we calculated occupational diversity as the number of occupational ties (out of 22 occupations listed in the position generator) connected to the respondents. Occupational diversity is designed to capture the variety of resources potentially available to the respondent.
- **Network prestige:** Using the Standard International Occupational Prestige Scale (Ganzeboom and Treiman, 2003; Treiman, 2013) and following Maness (2017b), we associated each occupation in the position generator with a prestige score. The prestige score and the information on whether a respondent knows someone with a given occupation was used to calculate the implied amount of prestige present in an individual's social network. Along with the absolute value of the network prestige, we calculated a normalized value using the maximum possible prestige value of 1036, which occurs if a respondent would know someone from each of the 22 listed occupations. The tenet here is that higher prestige leads to better access to resources and hence contributes to higher bridging capital.
- **Prestige entropy:** In addition to the above network prestige, diversity is also considered. Given that, a more even distribution of prestige is likely to be more effective in leading to higher bridging capital, we used normalized entropy (Shannon, 2001) as a measure of evenness in the distribution of occupational connections in the network. The normalized prestige entropy is calculated as:

$$\textit{Normalized Prestige Entropy} = \sum_{1}^{\kappa} \frac{p_k \ln(p_k)}{\ln\left(\frac{1}{k}\right)} \tag{3}$$

where p_k is the proportion of total prestige associated with the k_{th} occupation and K is the total number of occupations known to the respondent (same as the occupational diversity). The maximum possible value of the normalized entropy is 1, which means that the total prestige embedded in the network is equally distributed among the occupations.

Neighborhood engagement

To measure neighborhood engagement, respondents were asked:

- Whether the respondent has helped his/her neighbors with household chores, shopping, repairs, house-sitting, or lending tools or supplies.
- Whether the respondent's neighbor has ever listened to the respondent's problems
- Whether the respondent has received help from his/her neighbors with household chores, shopping, repairs, house-sitting, or lending tools or supplies.

We use the responses to these questions as indicators of neighborhood engagement. These responses were captured as binary indicators, where 1 represents if someone engages in a particular activity (like helping neighbors with household chores) and 0 otherwise.

Community engagement

To measure community engagement, respondents were asked:

- Whether the respondent is part of a community group or neighborhood association that focuses on issues or problems in your community
- Whether the respondent is part of a youth group, such as scouts or the YMCA
- Whether the respondent is part of a local social club or charity

We used the binary responses to these questions to measure community engagement. Table 2 presents the descriptive statistics of the various indicators used in this study.

Table 2
Descriptive statistics of the indicators.

Variable	Measure	Value
Occupational diversity	Mean	10.0
	Median	10
	S.D.	4.9
Normalized Network prestige	Mean	0.5
	Median	0.5
	S.D.	0.2
Normalized Prestige entropy	Mean	0.9
	Median	1.0
	S.D.	0.2
Mean frequency of face-to-face conversation (on 7-point Likert scale)	Mean	2.9
	Median	3
	S.D.	1.4
Mean geographic proximity (on 9-point Likert scale)	Mean	4.2
	Median	4.3
	S.D.	1.8
Gender homophily	Mean	0.0
	Median	0
	S.D.	0.6
Helped neighbor with household chores	Yes	44.5%
	No	55.5%
Neighbor listened to respondent's problems	Yes	38.8%
	No	61.2%
Helped by neighbor in household chores	Yes	34.2%
	No	65.8%
Part of a community group or association	Yes	17.1%
	No	82.9%
Part of a local youth group	Yes	17.6%
	No	82.4%
Part of a local social club or charitable organization	Yes	28.1%
	No	71.9%

S.D.: Standard Deviation.

Results and discussion

Table 3 presents the estimation results from the structural equation model and Fig. 2 shows these results on the path diagram. In this figure, paths, where the corresponding parameter was statistically significant at the 95% confidence level, are shown using a solid arrow, while the paths which were hypothesized but resulted in an insignificant parameter are shown using a dashed arrow. For brevity, error variances are not presented in the path diagram but are reported in Table 3. Note that the results presented in Table 3 are from the final estimated model where all the insignificant variables have been removed. Table 4 presents various model fit measures for the structural equation model. Given the nature of the estimator used, we present both the standardized and robust versions of the fit measures, where applicable. Given the relatively large sample size, the most reliable measures of fit for our model are comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR) (Hooper et al., 2008; Kenny, 2015). We also present the expected cross validation index (ECVI) (Browne and Cudeck, 1992) which measures the discrepancy between the covariance matrices of the fitted model and an external sample of the same size. Typically, a CFI/TLI value greater than 0.90 (0.95 as suggested by some studies) is considered a good fit. For the presented model, the robust CFI value was 0.839 and the robust TLI value was 0.886. While these values are slightly lower than the generally prescribed cut-offs, the CFI/TLI values in our model were greatly affected by the inclusion of socio-demographic information (H4) and the CFI/TLI values in the model without the socio-demographic variables were well above 0.95. Nevertheless, prior research suggests these metrics to be lower in magnitude as model complexity increases (Allen et al., 2018; Biehl and Stathopoulos, 2020). The RMSEA value (upper bound of 90 % confidence interval) for our model was 0.059, which is well below the 0.08 value of acceptable cut-off. Further, our model shows an SRMR value of 0.036, which is lower than the maximum acceptable value of 0.08, and the ECVI value was 0.639. Note that there are no prescribed cut-off values for ECVI since this is a comparative fit measure though the

Table 3
Structural Equation Model Estimation Results.

Variables	Parameter Estimates	t-stats
Latent Variables		
Occupational diversity ← Bridging Capital	0.657	10.6
Prestige Entropy ← Bridging Capital	0.405	8.5
Network Prestige ← Bridging Capital	0.688	11.0
Helped neighbors with household chores ← Neighborhood Engagement	0.766	15.6
Neighbors listened to respondent's problems ← Neighborhood Engagement	0.716	16.7
Received help from neighbors with household chores ← Neighborhood Engagement	0.736	14.7
Part of a local social club or charity ← Community Engagement	0.683	18.4
Part of a community group or association ← Community Engagement	0.728	18.0
Part of a local youth group ← Community Engagement	0.588	13.2
Geographic proximity ← Bonding Capital	0.930	23.7
Gender homophily ← Bonding Capital	0.307	11.9
Frequency of face-to-face contact with alters ← Bonding Capital	0.784	21.8
Regression Parameters		
Bridging Capital ← Community Engagement	0.747	8.3
Activity diversity ← Bonding Capital	0.093	3.5
Activity diversity ← Bridging Capital	0.526	11.0
Activity diversity ← Dummy for age between 40 and 60 years	−0.070	−2.5
Activity diversity ← Dummy for age more than 60 years	−0.143	−5.1
Activity diversity ← College graduate indicator	0.216	8.1
Activity diversity ← Household Income	0.153	5.5
Activity diversity ← Worker indicator	0.071	2.8
Activity frequency ← Bridging Capital	0.486	10.5
Activity frequency ← Bonding Capital	0.056	2.0
Activity frequency ← Dummy for age between 40 and 60 years	−0.133	−4.7
Activity frequency ← Dummy for age more than 60 years	−0.161	−5.6
Activity frequency ← College graduate indicator	0.154	5.6
Activity frequency ← Worker indicator	0.084	3.2
Activity frequency ← Household Income	0.154	5.6
Error Covariance		
Activity diversity ↔ Activity frequency	0.718	14.974
Neighborhood Engagement ↔ Community Engagement	0.567	13.2
Occupational diversity ↔ Network Prestige	0.973	12.7
Occupational diversity ↔ Prestige Entropy	0.140	3.6
Helped neighbors with household chores ↔ Received help from neighbors with household chores	0.352	2.3
Error Variances		
Occupational diversity	0.568	13.2
Prestige Entropy	0.836	21.9
Network Prestige	0.527	12.6
Helped neighbors with household chores	0.413	–
Neighbors listened to the respondent's problems	0.487	–
Received help from neighbors with household chores	0.458	–
Part of a local social club or charity	0.534	–
Part of a community group or association	0.470	–
Part of a local youth group	0.654	–
Geographic proximity	0.135	2.2
Gender homophily	0.906	21.4
Frequency of face-to-face contact with alters	0.386	9.0
Activity diversity	0.589	18.4
Activity frequency	0.677	20.2
Bridging Capital	0.443	–
Neighborhood Engagement	1.000	–
Community Engagement	1.000	–
Bonding Capital	1.000	–
Thresholds for binary endogenous variables		
Helped neighbors with household chores	0.510	4.6
Neighbors listened to the respondent's problems	0.400	3.6
Received help from neighbors with household chores	0.690	6.0
Part of a local social club or charity	1.195	9.2
Part of a community group or association	1.744	11.5
Part of a local youth group	1.407	10.1
Intercepts		
Occupational diversity	1.151	13.4
Prestige Entropy	4.669	39.8
Network Prestige	0.961	10.9
Geographic proximity	2.232	25.8
Gender homophily	0.294	3.3
Frequency of face-to-face contact with alters	2.065	23.5
Activity diversity	1.682	20.2
Activity frequency	1.196	13.8

— t-statistics not available as the corresponding variables were fixed to allow for identification of parameters.
A ← B: Represents a path from variable B to A in the path diagram.
A ↔ B: Represents the error covariance between variables A and B.

ECVI value of the presented model was better compared to other variations of the path diagram we tested. Overall, from various measures of model fit, our model seems to fit reasonably well with the data, highlighting the confidence in our results and findings.

Several interesting observations can be made from the estimation results and are presented in the following subsections on social capital multi-dimensionality, foundations of social capital, resulting travel behavior, and demographic determinants.

Social capital multi-dimensionality

Firstly, there is clear evidence of two separate social capital constructs with different impacts on travel behavior and different anchoring in broader social engagement. From exploratory and confirmatory model testing we confirm the first research hypothesis that these dimensions are latent and can be measured using multiple indicators, showcased by the statistically significant parameters describing the relationship between the social capital constructs and the respective indicators. Moreover, as can be seen from Fig. 2, the error covariance between bonding and bridging capital was statistically insignificant. Taken together, this supports our hypothesis H1 that social capital is latent and multi-dimensional, with a clear distinction between bonding and bridging. It is worth mentioning that we examined several alternative specifications of the core social capital constructs, including a simplified version assuming that social capital was a unidimensional latent variable, measured by all six indicators. However, the presented model with separate dimensions of social capital had a better fit to the data.

Several important observations arise from the measurement model results. First, *bridging capital*, i.e., resources that can be activated via weak social ties surrounding a person, are positively correlated with both the diversity of occupations and the prestige entropy. This finding confirms that a higher prevalence of (high-status) occupations among acquaintances need to be coupled with diversity to effectively bolster bridging capital. On the other hand, *bonding capital* representing close ties, not surprisingly, is positively correlated with spatial proximity, gender homophily, and frequency of face-to-face conversations. Here we note a caveat about the apparent importance of spatial proximity for bonding capital accumulation. We expect that a more recent dataset would reflect a greater role of virtual/remote social support indicators to support close ties.

Foundations of social capital

The second research question seeks to determine the grounding of the social capital measures in the broader social engagement of respondents. In support of hypothesis H2, we identify that neighborhood and community engagement are latent and can be measured using multiple indicators. This is evident from the fact that the parameters

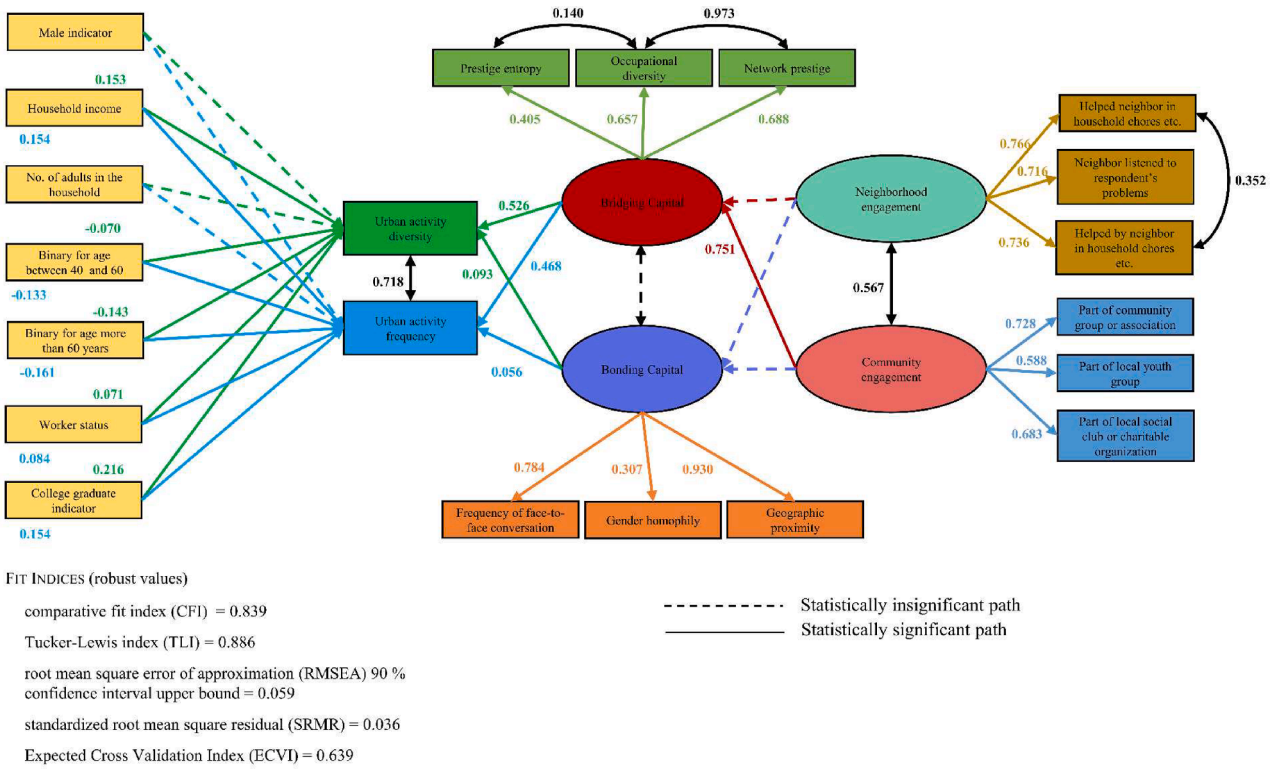

Fig. 2. Result from the SEM shown on a path diagram (Note: Dashed lines represent statistically insignificant paths).

Table 4
Fit measures for the present structural equation model.

Fit Measures	Standard	Robust
Number of observations	1434	–
Degree of freedom	91	–
Comparative Fit Index (CFI)	0.882	0.839
Tucker-Lewis Index (TLI)	0.917	0.886
Root Mean Square Error of Approximation (RMSEA)	0.061	0.055
90 percent confidence interval – lower bound	0.057	0.051
90 percent confidence interval – upper bound	0.065	0.059
Standardized Root Mean Square Residual (SRMR)	0.036	0.036
Excepted Cross Validation Index	0.639	–

associated with the two latent variables and their indicators are statistically significant. Of more practical relevance, we find neighborhood and community engagement latent variables to be two separate entities though with moderate overlap. Furthermore, while we find a statistically significant relationship between community engagement and bridging capital, no relationship was found between the two engagement variables and bonding capital. This suggests that while individuals are expected to expand their bridging capital via community engagement (and indirectly via neighborhood engagement given the partial overlap), they still predominantly rely on much closer contacts for bonding capital. These findings are in line with prior research that suggests neighborhood engagement to be geographically local and restricted compared to community engagement and hence potentially does not contribute to the attainment of novel resources (Wellman, 1979; Wellman and Leighton, 1979).

Overall, this suggests that community engagement is the main booster of the bridging aspect of social capital. This makes sense as we generally expect engagement outside our immediate neighborhood, with community members, to contribute to the accumulation of social network-related resources.

Resulting travel behavior

The third goal is to investigate the association between social capital dimensions and travel. As mentioned earlier, there is an intuitive linkage: travel is needed to maintain social connections, and vice versa, social resources can enable or promote travel by providing information on events, transportation options or offering support for travel to take place (Di Ciommo et al., 2014; Liu et al., 2020). The results reveal that different dimensions of social capital affect travel behavior differently, resonating well with our third research hypothesis. Specifically, while the results suggest that both social capital dimensions have a positive and statistically significant effect on social activity diversity and frequency, the magnitude of the impacts is drastically different. This can be seen from the path diagram in Fig. 2, where the path parameters from bridging capital to urban activity diversity and frequency are equal to 0.526 and 0.468, respectively. On the contrary, the parameters associated with paths from bonding capital to social activity diversity and frequency are much lower (0.093 and 0.056, respectively). This difference is significant and is only evident since we allow social capital to be captured multi-dimensionally. From a behavior standpoint, these differences can be explained from a combination of the following three main perspectives:

network maintenance: urban activity participation is needed to maintain ties with individuals in one's network.
information flow: activity participation is likely the result of gaining novel information like a recommendation for a new café or restaurant.
accessibility: activity participation results from improved accessibility to activity locations due to access to either a new mobility tool or membership in groups/clubs etc., via social ties.

Since bridging capital is related to access to novel resources and information and bonding capital is associated with a stagnation effect as mentioned earlier, there is a large difference between the effect of these

two social capital dimensions[3]. Drawing together all these findings we note that bridging capital appears to be the key dimension shaping urban discretionary travel behavior. Moreover, weak ties underpin the bridging capital formation precisely because they require more maintenance, give access to more novel information, and are more likely to supply access to resources like mobility tools or club membership that are otherwise not available to the ego.

Demographic determinants

Lastly, in line with hypothesis H4, the model also captures the impact of personal and household characteristics on urban activity participation. The results suggest that households with higher income, which are larger, with respondents who are full-time workers and those who have a college degree, engage in much higher urban activity frequency and diversity. This mirrors results in Stroope (2021) where respondents with a college degree or higher were more likely to engage in community participation. Interestingly, while male respondents were more likely to have a higher frequency of social participation than female respondents, no difference was found in the activity diversity between male and female respondents. Further, the impact of age on social activity diversity and frequency is non-linear, with respondents under the age of 24 having the highest activity diversity and frequency, while both frequency and diversity decrease more than proportionally with age.

Discussion and policy implications

Several potential implications are emerging from our analysis. We discuss the practical implications of this work starting from the enhanced understanding of travel activity decisions to the social capital interactions, onto the broader foundations related to neighborhood and community engagement.

Travel activity drivers

The results of this study suggest a strong relationship between social capital (and networks, in general) and travel. Going forward, this points to a need to account for dimensions related to bridging and bonding social capital in transportation planning and management. Specifically, we suggest a need to focus on three areas, namely expanding data-collection, travel modeling, and planning/forecasting analysis.

First, our findings point to an opportunity for **travel surveys** to broaden data-collection plans to capture the social embeddedness of travelers, expanding on the current practice of collecting (more narrow individual and household) socio-demographic information. For example, the National Household Travel Survey (NHTS) in the United States typically does not collect information beyond household/individual socio-demographics and intra-household interactions and thereby may overlook valuable information on the broader social network surrounding an individual or household. In this study, we highlight two main constructs and several relevant indicator questions, that show a path to account for multi-dimensional social capital. In proposing social capital data-collection, it is important to carefully balance the added insight against the respondent burden. We note that collecting ego-centric network data is a relatively straightforward addition to existing survey efforts. Also, position generator data – which is typically a shorter instrument than name generator approaches – shows relevance in explaining activity diversity and frequency. Our analysis suggests transportation planning agencies will benefit from data on the social context in which travel decisions are made, to better model the frequency and diversity of urban travel behavior.

Second, richer data can inform new **modeling** practices. Specifically, incorporating social-capital data sources into travel demand forecasting involves the dual challenge of creating socially embedded synthetic populations and modeling interdependent decision making. Illenberger (2012) presents a framework to incorporate social network data into travel demand modeling where: (1) social network data is analyzed to discover social network properties, (2) these properties are combined with land use data to spatially model social networks to generate synthetic social networks, (3) and these synthetic populations are used in travel demand models to forecast travel demand. The next important step involves creating socially embedded synthetic populations at the population synthesis level. Findings from the current study strongly suggest that the population synthesis component needs to build not only on structurally sound social networks but also incorporate social network resources into such networks. Current social network models (e.g., exponential random graph models (ERGMs), discrete choice generative network models, game-theoretic network models) can be calibrated using name generator and name interpreter data. However, further research is needed to incorporate weak ties. These weaker tie networks likely do not need to be modeled explicitly (or it would be computationally prohibitive), but there is no agreed-upon method for generating this type of social capital in a population synthesis model.

Third, taken together this will help create a network theory approach to travel demand forecasting where the social networks affect travel **behavior outcomes**. As a result, the socially informed analysis will lead to new insights involving the planning and coordination of activity schedules and travel plans beyond immediate households. For example, this study shows that the generation of (urban) activities involves social capital – specifically, activity diversity, and thereby diversity in travel destinations likely involves bonding and bridging capital. Given these results, it becomes important to account for social capital (and its sub-dimensions) to understand activity coordination and travel.

Community engagement to increase well-being and livability in cities

The results in this study highlight the role of community/neighborhood engagement in social capital (bridging capital, in particular) accrual. Further, the study also shows a relationship between social capital and urban activity participation. An important implication of these relationships lies in the design and targeting of information campaigns by policy makers to promote travel behavior changes, such as increasing local travel engagement with urban third places to promote *urban revitalization*. That is, rather than focusing directly on activity participation promotion campaigns aimed at individuals, agencies might take the larger view and focus on supporting and boosting social networks that connect residents. This could potentially be done by facilitating community engagement, which can boost bridging capital and thereby leads to more urban activity participation. Ultimately, this indirect causation path promotes the value of supporting place-making, facilitating local community engagement, and promoting community-building efforts like collective bike rides, and pop-up pedestrian infrastructure.

Further, the results from this study also highlight a well-being perspective. Mokhtarian (2019) points out that the efforts to reduce discretionary travel present a policy dilemma where: "*attempts to curtail (personal vehicle) travel to achieve sustainability goals may simultaneously diminish our collective well-being…*" (p. 504). Other studies have also

[3] To establish the robustness of this finding in the presence of missing data, we generated 10 different imputations of the dataset using the MICE algorithm, which were then used to re-estimate 10 different versions of the SEM model. We pooled the estimated parameters from different versions of the data using Rubin's parameter pooling rules and compared the estimated parameters related to the relationship between different social capital dimensions and activity participation. Specifically, the pooled parameters for the relationship between bonding and activity diversity and frequency were 0.028 (1.225) and 0.005 (0.192) while the relationship between bridging and activity frequency and diversity were 0.460 (16.242) and 0.426 (14.809), respectively. The values in the parentheses are t-statistics. These values clearly align with the values in the previously presented model, establishing the robustness of our results in the presence of missing data.

pointed out that the ability to engage in leisure/social activities with others has a significant impact on life satisfaction and well-being (Reardon and Abdallah, 2013; Spinney et al., 2009). The current study shows a linkage between activity engagement and social capital. Several prior studies have pointed out a positive association between social capital and well-being (Chatman et al., 2019; Dharmowijoyo et al., 2020; Hamdan et al., 2014; Nilsson et al., 2006; Van Den Berg et al., 2016; Yip et al., 2007). The current study thereby adds to this existing body of works by analyzing the positive association between neighborhood/community engagement and social capital, which in turn promotes socially oriented travel. Overall, the observed paths in our model suggest positive indirect effects between community/neighborhood engagement and well-being via social capital accrual and increased urban activity participation. Given these results, planners and policy makers should pay attention to creating better opportunities for neighborhood and community engagement too, ultimately, improve community well-being.

Summary, conclusions and extensions

Summary of findings and conclusions

In this study, we examined the multi-dimensional nature of social capital and its respective relationship with travel behavior. Specifically, we made use of data from the Pew Internet Networks and Community Survey to build a structural equation model dividing social capital into two latent dimensions: *bonding* and *bridging,* and then studied the relationship of these dimensions with urban activity participation diversity and frequency. Furthermore, we analyze the sources of accumulation of social capital via neighborhood and community engagement, modeled as two separate latent variables. The main ***conclusions*** from the study are as follows:

- The results show strong evidence of two separate social capital dimensions, namely bonding (linked to a network of closely tied individuals who are similar to each other) and bridging (linked to ties with individuals who are different and provide access to novel resources). The multi-dimensional nature of social capital is further validated by confirming an absence of correlation between the constructs.
- Our results indicate a positive relationship between both social capital dimensions and urban travel activity, shown by the positive linkage to both activity participation diversity and frequency. This suggests that travel activities that are essential for urban functions are tied to social capital. Moreover, the results suggest that the strength of this relationship is higher between bonding capital and urban activity participation, highlighting that weak ties are the primary boosters of urban travel.
- Lastly, we found that while community engagement contributes to bridging capital accrual, it does not contribute to the accrual of bonding capital. Furthermore, no support was found for a postulated relationship between neighborhood engagement and social capital dimensions. These results suggest that individuals predominantly rely on much closer and stronger relationships for social and emotional support. Ultimately, the most important channel of causation to model urban travel activity appears to be related to the following path: community engagement → accumulation of bridging capital → more urban travel activities.

Limitations and future research

There are several limitations to the presented study, and these naturally lead to avenues for future research. These are presented below:

- Our measurement of the bonding capital dimension focuses on face-to-face contacts rather than virtual/online connections. While the role of in-person contacts to maintain social networks and capital is important, the increasing penetration of ICT and personal device ownership is not reflected in this work. In current times, virtual and remote communities, and networks, will complement and/or replace in-person contacts, triggered further by the ongoing COVID-19 pandemic and social distancing measures. Hence, while we hold our model approach to be valid, there is a need for continued research with more recent data to understand the role of virtual/online contact technologies, virtual communities, and social capital accumulation.
- The definition and measurement of urban activity/travel participation frequency and diversity in this study were relatively limited and can potentially be expanded. Specifically, the survey data used in this study asked respondents about the number of times they visited each of eight different social activity locations in the last month (see section on Data). Urban activity participation is neither limited to only these locational activities nor is there a guarantee that these are socially motivated, as participation in activities at these locations can also be done in solitude without being socially motivated. We encourage future research to identify a more robust measurement of urban activity participation, along with joint/solo activity participation, to develop a complete understanding of the relationship between travel, social networks, and the vibrancy of life in cities.
- As noted earlier, since we used listwise deletion to process the data which led to the sample being biased towards younger respondents and those who are willing to report income or social network-related information, some of the estimated parameters in our model may be slightly different than the population parameter estimates (specifically in hypothesis 4). Further, our model does not focus on the variation of social capital with respect to socio-demographic parameters. Understanding the distribution of social capital dimensions across different socio-demographic groups like age/income groups and gaining a deeper understanding of the impact of listwise deletion on the estimated parameters is an important avenue for future research.
- Another important avenue of future research is to measure bridging capital using alternative instruments. Specifically, we derived our indicators for bridging capital from a position generator. However, other recently popular methods like a resource generator (Van Der Gaag and Snijders, 2005) are also of interest to better characterize social network resource capital.
- Lastly, further work is needed to validate and potentially expand the understanding of social capital multi-dimensionality. Specifically, we call for a deeper understanding of how specific dimensions relate to mobility (e.g. timing, mode, frequency, destinations, trip-chains). For example, our study identifies bridging capital which is linked to diverse resources. However, this dimension could be further divided into components like mobility, and financial and information resources. A deeper characterization of social capital can increase our understanding of the relationship between these dimensions and urban travel patterns.

CRediT authorship contribution statement

Divyakant Tahlyan: Methodology, Software, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Amanda Stathopoulos:** Methodology, Writing – review & editing, Funding acquisition, Supervision. **Michael Maness:** Conceptualization, Writing – review & editing, Funding acquisition, Supervision.

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.

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Appendix

Table A1.

Table A1
Review of the literature on the use of social capital concepts in transportation-related studies.

Study	Travel and Social Capital Context	Social Capital Indicators Used	Main Findings
Carrasco and Cid-Aguayo (2012)	To assess the role of transport in social support	• Communication pattern between alters and ego via various modes Whether individuals have received/ given advice/money etc. from others.	• Argues that having a car at home does not necessarily imply a difference in social capital
Chang (2020)	To understand the effect of building environment and social features like social capital and cohesion on outdoor activity participation of older adults.	Neighborhood social capital: People in this neighborhood share similar values I would seek personal advice from my neighborhood I would attend a neighborhood organization Neighborhood social cohesion People around here are willing to help their neighbor People in this neighborhood feel connected to one another People in this neighborhood can be trusted People in this neighborhood generally get along with one another	• Found that participants with higher levels of neighborhood social capital participated in more outdoor activities but no support was found for social cohesion impacting outdoor activity participation
Coutts et al. (2018)	To study the influence of commute on post-secondary student's social capital	• Whether commute discourage students from coming to campus, If students pick courses based on commute If commute discourages a student from participating in extra-curricular events	• A student with higher commute times and those who used public transit have a higher level of discouragement
Di Ciommo et al. (2014)	Modal shift after the opening of new transit stations. Social capital as a proxy for trip generating capacity and network resources	• Receiving some help for child-care or housekeeping Voluntary participation in some non-compulsory meetings or activities	• Social capital variables improved the fit for mode choice models The shift was higher for people receiving help than for people participating in voluntary activities
Elias and Shiftan (2017)	To understand the relationship between interpersonal ties and driving behavior mediated via activity participation	• Frequency of contact	• Higher interpersonal ties lead to a lower propensity for leisure trips outside the community, lowering exposure to the high-risk driving environment
Isbel and Berry (2016)	To investigate the role of transportation in accessing activities that contribute to the connectedness and well-being of older people.	• Community participation Personal social cohesion	• Conceptualizing driving a vehicle is important in engagement in social activities and is linked to well-being.
Kamruzzaman et al. (2014)	To analyze the patterns of social capital associated with transit-oriented development	• Trust and reciprocity Connections with neighbors	• Found that individuals living in transit-oriented developed regions had higher social capital than others.
Liu et al. (2020)	To understand outdoor activity patterns of older adults to help in the development of tailored physical activity programs.	Social Capital How many people in your neighborhood do you know well enough to talk with? Social Cohesion How do you rate the social relations with your neighbors?	• Older adults reporting low social capital are more likely to belong to clusters representing low frequency/short duration and high frequency leisure-time physical activity patterns. Older adults reporting high social cohesion are less likely to belong to clustering representing long duration leisure-time physical activity patterns.
Liu et al. (2021)	To examine the association between neighborhood characteristics and frequency of type-specific outdoor activities	Social capital (5-point Likert scale): How many people in their neighborhood do the respondents know well enough to talk to? Social cohesion (5-point Likert scale): How do you rate the social relations with your neighbors in five categories from very poor to very good	• Social capital positively correlated with the frequency of leisure walking and skill-based leisure activities
Love et al. (2020)	To understand the effectiveness of three intervention programs to change the travel behavior of children to/from schools. Special focus on how social capital affects children's independent mobility.	• Child plays in street often School is close by Child has friends in the area Home location is a good place for children to grow up	• The study found the degree of connectedness of the school and the individuals to have the most impact on the effectiveness of the intervention program

(*continued on next page*)

Table A1 (*continued*)

Study	Travel and Social Capital Context	Social Capital Indicators Used	Main Findings
		Local organizations involved in school site Number of businesses involved in school Parents attend meetings regularly Intervention programs assist the community to change	
Maness (2017a)	To use a position generator to measure network resources and their impact on predicting activity selection	• Core network size Homophily Spatial proximity Tie dispersion Alter attributes Network diversity Upper reachability	• Network diversity measures calculated using position generation were a better predictor of activity participation than measures from the name generator
Maness (2017b)	Present a theory to understand how strong social ties and diversity of weak social ties are associated with a difference in leisure activity frequency and variety	• Network size Upper reachability of weak network calculated based on status levels associated with each alter in the weak ties network	• The positive association between measures of network capital and leisure activity frequency and variety.
Nguyen et al. (2017)	To study the role of social capital on trip generation and destination choice for discretionary activities	• Number of close social contacts in the region where the respondent lives Number of acquaintances inside and outside the region where the respondent lives Participation in community service	• Social capital is associated with both trip generation and trip destination choice for discretionary activities
Nicholas et al. (2018)	To understand the relation between social capital and the impact of long-distance commuting on a regional community	• Studied two dimensions of social capital: bonding and bridging Strength of social networks, neighborhood social cohesions Bridging social cohesion	• Results indicate a negative relationship between long-distance commuting and subjective well-being but no mediating role of social capital
Parady et al. (2019)	To understand the connection between social networks, social interactions, and out-of-home leisure activity	• Network density Network size Club membership	• A positive association between network size/club membership and leisure activity A negative association between network density and leisure activity
Sadri et al. (2015)	Role of social networks in joint trip frequency between alters and egos.	• Network density Homophily Heterogeneity	• Found that personal network measures and heterogeneity among alter-ego ties had a significant impact on the joint-trip making process.
Schwanen et al. (2015)	To understand the link between social exclusion and transport disadvantage via social capital	—	• Suggest that social capital is Janus-faced and is a medium of both effectuation of progressive social change and the creation of social inequalities.
Stanley et al. (2019)	• To understand the role of mobility in promoting social inclusion Role of bridging social capital in reducing the risk of social exclusion	• Frequency of contact with alters	• Bridging social capital is negatively associated with the risk of social exclusion
Stroope (2021)	To understand the relationship between active transportation behavior and three indices of social capital	Community participation Written a letter or made a telephone call to influence policy issue Attended an event that provided information about community services Attended a meeting to pressure for city or county policy change Sense of community I can get what I need in this neighborhood This neighborhood helps me fulfill my needs I feel I belong in this neighborhood	• Found active transportation participation to be associated with community participation but not with a sense of community
Utsunomiya (2016)	To understand the role of local public transportation in social capital	• Participation in regional festivals, NGOs, etc. Trust index Network index	• Found that the network and participation indices standing for social capital are positively correlated with the level of local bus services
Wang et al. (2021)	Identification of determinants of low carbon travel by incorporating social relations information	Structural social capital (strong ties) Intimacy level with the head of household Cognitive social capital Head of household's low-carbon preference Family reciprocity Community of low carbon atmosphere	• Structural social capital affects travel behavior by influencing resources available via the head of household In terms of cognitive social capital, the head of household's preferences also impact the low carbon travel preferences of household members.

– No indicators of social capital used or mentioned in the study.

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