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Measuring, understanding and modelling the Walking Neighborhood as a function of built environment and socioeconomic variables

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ABSTRACT

Modelling the Perceived Walking Neighborhood (PWN) may help understanding how, changes on urban space produce potential impacts on walkability and, therefore, on health, transport, accessibility and social cohesion. This paper proposes a method to measure how the built environment and socioeconomic diversity play a role in the subjective definition of the boundaries of the PWN. The methodology is based on discrete choice models and was applied to data coming from a survey to 170 residents of Santiago, Chile, who reported their PWN shape by sketching it over a digital map. Results show that built environment and individual characteristics have a significant and heterogeneous impact on the size and shape of the PWN. As a proof of concept, the method is used to measure the potential changes in walkability generated by a large urban project in Santiago.

1. Introduction

Promotion of walking has become an increasingly important goal for urban planning due to the benefits it generates in terms of public health and sustainable mobility (Sallis et al., 2004). Moreover, encouraging walking (both as a mean of transport and as a recreational activity) may play a relevant role in the animation of public spaces, perceived safety, and even social interaction and community cohesion at a neighborhood level (Carr et al., 1992; Lochner et al., 1999; Francis et al., 2012).

The health benefits of walking have been extensively explored and measured in the public health literature (Lee and Buchner, 2008) and include, among several others, a lower risk of mortality from various causes such as cardiovascular disease, diabetes and some forms of cancer (Heath et al., 2006). From the point of view of transportation, walking is regarded as the most accessible, affordable, simple and sustainable mode of transportation. Although limited in range, it has several advantages over other transport modes and it is convenient to encourage it; not only as a mode of transport by itself, but also as the main form of access to mass transit and as a recreational activity. The large number of positive externalities associated with walking, although not always considered in project assessment and public policy-making, can be an important source of social welfare, thus justifying the construction of infrastructure and urban planning centered on it (Sallis et al., 1998; Sælensminde, 2004). Moreover, promoting walking generates a "virtuous spiral of safety" because a larger number of pedestrians on the street reduces the risk of accidents between pedestrians and motorized vehicles (Jacobsen, 2015).

One way to encourage walking is to design and build cities, neighborhoods and streets that facilitate and/or stimulate it. The relationship between the built environment and transport has been largely explored in the urban planning and transportation literature, and validated through findings of significant correlations between certain configurations of the built environment or urban design, and travel patterns (Newman and Kenworthy, 2006; Ewing and Cervero, 2010). Walking, as the most exposed and slowest way of traveling, is particularly sensitive to the built environment (Handy et al., 2006; Krizek, 2003; Saelens and Handy, 2008). While some of these correlations may be explained by residential self-selection, several have been proved to be causal (Cao et al., 2006;Handy et al., 2006; Cao, 2010a, 2010b) hence validating urban design and planning as tools that can be used to induced desired behavior in this regard. However, identifying when and how to intervene is not a simple task.

Urban form at the neighborhood scale plays an important role in travel behavior (Krizek, 2003; Wen et al., 2007) because it is the environment surrounding the origin of every home-based trip, including utilitarian and recreational ones. While there are several approaches to understand the relationship between neighborhood attributes and walking, most of the transport literature focuses on the amount of walking (frequency, distance, duration) at an aggregate level as dependent variable (Saelens and Handy, 2008). While this allows to understand how elements like density and land use diversity influence walking, it does not permit to understand the role of the built environment at a more disaggregate level. For example, some people may be willing to walk further in order to reach a particular landmark or land use, or may be discouraged by the presence of barriers in their way

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(Tirachini, 2015).

An alternative approach is to use the concept of the Perceived Walking Neighborhood (PWN) which has already been explored in the literature as a way to measure the relation between walking and the built environment (Smith et al., 2010; Humpel et al., 2004; Moudon et al., 2006). There is no consensus on how to define or measure the PWN. In this work, we understand the PWN as the environment surrounding the residence of an individual, where the use of space generates a sense of belonging and where this use is related with walking as the main mode to reach places and activities. The principal advantage of using the PWN idea is that it includes both walking and neighborhood in a single concept. So, it is possible to understand the interaction between the individual and the environment, in the sense of walkability and neighborhood boundaries perception.

This paper proposes a method to measure and model the PWN of an individual, something that has not been done yet (to the extent of our knowledge and the literature review performed). The method assumes that each location around the individual's residence has a probability of belonging to her PWN. This probability is a function of attributes of the location (land use, presence of landmarks, etc.), the distance between the location and the individual's residence and socioeconomic characteristic of the individual. Space is treated in a discrete way; hence locations are defined by a grid. The model is estimated over data of reported frontiers of PWNs, as perceived and drawn by respondents from a survey performed in three different areas of Santiago, Chile. Estimation results are consistent with behavioral insights reported in the walkability literature. As a proof of concept, the model is then applied to a hypothetical scenario of a major infrastructure project in Santiago de Chile.

The proposed method allows understanding and predicting the subjective perception of boundaries of the walking neighborhood for groups of individuals. It can be used to simulate and forecast the impact of built environment modifications on the boundaries of the PWN and, potentially, on the walking behavior of a population.

The remainder of the paper is structured as follows. Section 2 proposes a definition of the PWN from the walkability and the neighborhood concepts. Section 3 describes the modelling methodology. Section 4 describes the data collection effort and Section 5 present modelling and simulation results. Finally, Section 6 discusses the main findings, potential uses for public policy and limitations of the proposed approach.

2. The walking neighborhood

Active transportation, like walking and cycling, have a positive impact on population health (Heath et al., 2006; Davis, 2010; Sinnett et al., 2011; Davis, 2014; Wen et al., 2007) and promoting it can increase the efficiency of urban transport systems (Handy et al., 2002; Sælensminde, 2004; Newman and Kenworthy, 2006; Cavill et al., 2008). The concept of "Walkability", understood as a measure of how the built environment induces physical activity and active transportation (Leslie et al., 2007; Owen et al., 2007; Marshall et al., 2009), is one of the main approaches used to explore this relationship. Most studies on walkability use the amount of walking or physical activity as the main dependent variable, with built environment attributes as explanatory variables. There are several approaches to measure the amount of walking and physical activity: it can be a self-reported or perceived variable (see for example (Saelens et al., 2003a, 2003b); Cerin et al., 2006), collected through travel diaries or surveys (see Salon, 2016) or measured with GPS devices (see Neatt et al., 2017). Most of the literature on walkability uses an aggregate approach, with explanatory variables being computed with some level of spatial aggregation (usually census districts, TAZs or predefined buffers). Using predefined zones or buffers comes as a practical way to treat and compute the urban form attributes, but ignores the fact that different individuals may be influenced by different scales of the built environment.

Another way to understand walkability comes from the Walking Neighborhood idea, understood as the relationship between walking intensity and neighborhood attributes, computed within boundaries. Some authors have studied this relationship using predefined zones as neighborhoods (Saelens et al., 2003a, 2003b; Wen et al., 2007; Salon, 2016; Neatt et al., 2017) finding significant effects. However, these definitions of neighborhood may be arbitrary, inadequate, or not flexible enough to understand walkability in a more detailed and spatially disaggregate way. A flexible definition of neighborhood and its boundaries, as the immediate environment that influences behavior, is needed (Flowerdew et al., 2008).

The neighborhood concept is used in many academic areas, with many different purposes. It has been analyzed as the canvas where several different social processes happen (Lee, 1968; Sampson et al., 2002; Chaskin et al., 2006), as a factor that affects both physical and mental health (Flowerdew et al., 2008; Marshall et al., 2009) and as an element that influences perception and willingness to pay for a location (Iglesias et al., 2006; Torres et al., 2013; Navarro et al., 2018) just to name a few examples beyond walkability. There are several definitions of neighborhood (Guest and Lee, 1984; Galster, 2001; Chaskin, 2006), with many of them acknowledging the fact that the neighborhood is a subjective construct (Campbell et al., 2009) meaning that there are as many neighborhood as individuals, who define the boundaries based on their perceptions. Some definitions are focused in walking, although there is still a large variety of them (Moudon et al., 2006).

Some studies have directly measured the perceived walkable or walking neighborhood, explicitly identifying its boundaries, as perceived by individuals (Coulton et al., 2001; Smith et al., 2010). We define the Perceived Walking Neighborhood in similar terms: as a subjective boundary that defines an environment where walking is spontaneous for an individual. We find that there are no attempts to quantitatively model the perceived boundaries of the PWN reported in the literature. It is usually analyzed in terms of its size and shape, while its relation with built environment elements (as potential explanatory variables) is usually studied qualitatively. This paper proposes a method to perform this analysis in a quantitative way, hence allowing to model and simulate PWNs in hypothetical scenarios, as described in the following sections.

3. Methodology

We assume the PWN can be described by a grid diving the space surrounding the residential location of an individual, where each cell belongs to the PWN with a probability. This probability is assumed to be a function of attributes of the cell, characteristics of the induvial and variables that describe the relation between each cell and the residential location, such as network distance and presence of barriers. Each of these elements is described in detail next.

3.1. Definition of variables and space discretization

We assume each individual n has a vector of characteristics X_n, including both personal and household features. Each location j is described by a vector of attributes X_j, related to land use patterns or opportunities like, for example, surface dedicated to commerce or the presence of a subway station. Finally, the interaction between locations is described by X_{ij}, which includes the distance over the network, d_{ij}, and a dummy, W_{ij}, indicating if there is an urban barrier between location i and j.

To discretize space, a grid is placed above the study area, with each cell corresponding to a location, with a total of M locations. Cell features include attributes (X_j) corresponding to the area where it is superimposed. All cells are equal in size and square, with an edge of length l.

The individual n, whose residence is in cell i, decides to either