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Effect of distance from home to school and spatial dependence between homes on mode of commuting to school

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ABSTRACT

Active commuting to school (i.e., walking and cycling) has health implications for young people. Therefore, it of interest to determine how the distance students walk to school varies depending on where they live and how their decision to walk is affected by contextual/environmental variables. This study aimed to examine which of the distances (Euclidean, Manhattan, walking-network and driving-network) is the best predictor of the decision to walk to school and determine the areas of influence of active commuting to school for four high schools in Granada, Spain. To achieve these aims, the regression-kriging method was used. The results indicated that the Euclidean and the walking distances were the best predictors of the decision to walk to school. Spatial dependence produced by some locational variables and spatial contagion among students was found to be moderate to strong. In addition, the spatial range of this spatial dependence is approximately 1000 m to 1600 m. Regression-kriging could be implemented in a geographic information system to determine the areas of influence of schools and aid urban designers and planners in developing neighborhoods that support active modes of commuting. Identifying the areas of influence is important for promoting active modes of transport by local governments.

1. Introduction

Most urban models, such as "new urbanism", aim to minimize car use and its negative impact on the environment while promoting more pedestrian-friendly features (Crane and Crepeau, 1998). These models focus on reducing the distance between locations and increasing the feasibility of alternative modes of transport, such as walking, cycling or public transportation. To this end, policies have been designed to reduce road congestion, as well as urban pollution and dispersion. These factors are also associated with the location of schools in urban areas. Studies that have investigated the effects of school location have been based on aggregated (zonal) or detailed (household) data. The latter type are more appropriate when studying the effects of distance and accessibility on the choice of commuting mode (Handy, 1996).

The commuting mode children use to go to school has been widely discussed in recent years and has economic, social, health and environmental effects (Faulkner et al., 2013; Li and Zhao, 2015; Mandic et al., 2015; Wilson et al., 2010). The effect of the distance from household to school on transport mode choice is well known. Several studies have shown that the distance from home to school is a stronger predictor of active commuting to school (ACS) in school-age students (Chillón et al., 2015; Davison et al., 2008; McDonald, 2008) and that shorter distances are associated with higher rates of active travel (Mandic et al., 2015; Pont et al., 2009; Rodríguez-López et al., 2017). Previous evidence is available on the current distance that young people are willing to walk to school. In the United States, 31% of trips from home to school made by walking are under one mile (1.6 km) (US Department of Health Human Services, 2008). The criterion distance for walking to school has been reported to be 1.2 miles (2.0 km) among Belgian adolescents (Van Dyck et al., 2010) and 1.5 miles (2.4 km) among Irish adolescents (Nelson et al., 2008). In the UK, the statutory walking distance for English children has been set at 3 miles (4.8 km) (Government/DfES, 2005), while for Japanese students it is approximately 2.5–3.7 miles (4.0–6.0 km), although the actual distance depends on the children's age (Mori et al., 2012). Although there is no universal criteria, some studies have shown that a distance of about 2.5 miles (4.0 km) is considered reasonable for adolescent walkers (Nelson et al., 2008). Therefore, one question of interest is to determine the distance that children and adolescents are expected to walk from home to school. In this study, walking distance is defined as the radius

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of influence around the school, which may vary depending on the particular locational factors of each area of the city, such as crime, traffic, the environment, urban design, socioeconomic characteristics, and others.

As a result of these factors, the area of influence of schools need not be necessarily circular but may form irregular polygons within which the school is located. To the best of our knowledge, few studies have investigated the effects of spatial dependence and distance between households on travel mode choice and the presence of spatial distribution patterns (Mitra et al., 2010). In our study it has been assumed that households located close to each other in a given geographic area are affected by similar locational factors. These locational factors may cause young people living in the same area to encourage others located nearby to make similar transport mode choices, thus leading to the presence of spatial autocorrelation. In addition, these variables are not always easy to observe, measure or specify in a specific model. Moreover, since the decision to walk to school may depend on locational factors, it could cause a contagion effect, which can have a major impact on urban traffic, environmental pollution and climate change, but also provide substantial health benefits (de Hartog et al., 2010).

ACS provides an opportunity for increasing daily physical activity level (Chillon et al., 2011; Panter et al., 2016; Sun et al., 2015; van Loon and Frank, 2011). Indeed, it has been shown that youth who walk to school are more physically active than those who are driven (Faulkner et al., 2009). Because ACS is a complex behavior influenced by multiple factors at different levels of the person-environment system and has several public health benefits, it is of interest to conduct research that can aid policymakers in implementing effective strategies targeted at promoting ACS.

Several methods have been used in the literature to measure distance, among them self-reported questionnaires to determine the distance of the route from home to school (Burke and Brown, 2007; Panter et al., 2010), geographic information systems (GIS) (Panter et al., 2010; Timperio et al., 2006), sketch maps of the route (Schantz and Stigell, 2009), Google Maps™ (Mendoza et al., 2011; Voss and Sandercock, 2010) or global positioning systems (GPS) (Duncan and Mummery, 2007; Duncan et al., 2007). Discrete choice models, such as the classic logistic regression model or logit model which are equivalent to log-linear models (Wasserman and Pattison, 1996), have been used to determine the probability that an individual will choose a particular means of transport based on a set of explanatory variables. The classic logistic regression model has been widely used in the literature on the mobility of children to schools (Pont et al., 2009). Different types of geometric distances can be measured in different ways. Although the most commonly used measure of distance in the literature on child mobility is the Euclidean distance (McDonald, 2007a), other measures of distance, such as the Manhattan distance, the walking distance and the driving distance, are also used in this study (a graphical description of each is shown in Fig. 1). In addition, the classic logistic regression model is based on the assumption of independence of perturbations, which are considered unobserved random variables. This hypothesis is not satisfied when the presence of spatial autocorrelation between perturbations is suspected due to the presence of locational factors and contagion effects. If spatial autocorrelation is present in the model perturbations, a spatial regression model is more suitable (Overmars et al., 2003). Therefore, to account for the presence of spatial autocorrelation in perturbations, the regression-kriging method is used (Cressie, 1991). In addition to spatial dependence, spatial heterogeneity is another aspect to be considered in the regression model (Anselin, 1988). Geographically weighted regression is a method that has been shown to be suitable for modeling spatial heterogeneity in the field of transportation (Feuillet et al., 2018).

Although the Euclidean distance is the most commonly used metric in research on child mobility, other types of geographical distances have also been analyzed, such as the network and Manhattan distances (Arafat and Abed Al Musa, 2017). These authors examined the network and Manhattan distances and the presence of spatial autocorrelation in the model perturbations. Model perturbations are due to the contagion effect of household, family and unobserved locational factors (crime, traffic, the environment, urban design, socioeconomic characteristics, etc.).

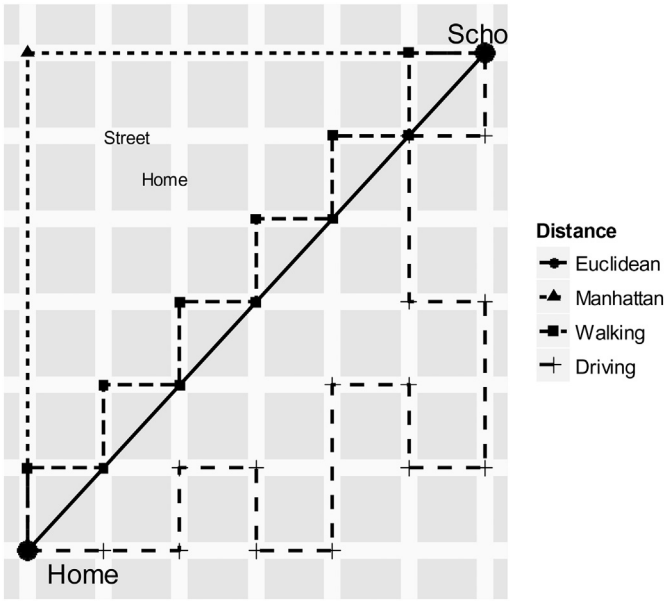

Fig. 1. Graphical representation of the four types of distances.

Using a survey conducted in 2012 of 527 students aged 12–18 years old attending four high schools located in the city of Granada, Spain, the areas of influence of active commuting for each school have been determined for four types of distances. The study has two aims: (a) to examine which of the four types of distances (i.e., Euclidean, Manhattan, walking-network and driving-network) could be the best predictor of the decision to walk to school and (b) to determine the areas of influence of ACS for four high schools in the city of Granada, Spain, considering the distance from home to school and the spatial dependence between households.

The rest of the paper is structured as follows. In the next section, a review of the literature on the factors that influence children's decision to walk to school is presented, focusing on the presence of spatial dependence. The data and methodology are then described in the following section. Finally, the results are discussed and analyzed and conclusions are drawn, highlighting the most important findings of the research.

2. Literature review

ACS behavior is associated with different demographic, personal, school, family, environmental and social factors (Chillón et al., 2014; Hume et al., 2009; Sirard and Slater, 2008). The main predictive factor of ACS is distance from home to school, which is examined here in relation to spatial dependence.

2.1. Accessibility, distance and proximity

Geographic information systems (GIS) use different methods to measure accessibility. The measure of accessibility between two locations includes the concept of time, transport mode and physical distance (Jang and Kang, 2015). Accessibility can be measured as the distance, cost or time between two locations. In a study by Apparicio et al. (2003), the authors examined whether physical distance and time are correlated, and concluded that at the metropolitan level using distance to estimate the shortest network time does not introduce major