Transportation Research Part A 110 (2018) 107–117

Contents lists available at ScienceDirect

Transportation Research Part A

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

Applying gradient boosting decision trees to examine non-linear effects of the built environment on driving distance in Oslo

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ARTICLE INFO

Keywords:
Compact development
Land use
Travel behavior
Machine learning
Employment center

ABSTRACT

Although many studies have explored the relationship between the built environment and travel behavior, the literature offers limited evidence about the collective influence of built environment attributes, and their non-linear effects on travel. This study innovatively adopts gradient boosting decision trees to fill the gaps. Using data from Oslo, we apply this method to the data on both weekdays and weekends to illustrate the differential effects of built environment characteristics on driving distance. We found that they have a stronger effect on weekdays than on weekends. On weekdays, their collective influence is larger than that of demographics. Furthermore, they show salient non-linear effects on driving distance in both models, challenging the linearity assumption commonly adopted in the literature. This study also identifies effective ranges of distance to different centers and population density, and highlights the important role of sub-centers in driving reduction.

1. Introduction

During the past three decades, a large number of studies have explored the relationship between the built environment and travel behavior (Ewing and Cervero, 2010; Stevens, 2017). Most studies conclude that compact development, characterized by higher density, accessibility, etc., tends to reduce driving and encourage the use of transit and non-motorized travel. These studies offer critical support of using land use policies (such as compact development and transit-oriented development) to reduce auto dependence and the associated negative consequences to the society. In line with this, California Senate Bill 375 requires regions to use integrated land use and transportation to reduce vehicle miles travelled (VMT) and greenhouse gas (GHG) emissions, particularly densification and infill development near transit stations. Densification is also a pronounced urban policy in Oslo since the mid-1980s.

On the other hand, a recent review study concludes that compact development has a marginal effect on driving (Stevens, 2017). Several scholars argue against this conclusion from multiple perspectives (Ewing and Cervero, 2017; Handy, 2017; Knaap et al., 2017). Furthermore, most studies assess only the effect size of individual attributes, but “the combined effect of several built environmental variables on travel could be quite large” (Ewing and Cervero, 2010 p. 11). Therefore, the critical questions are: How large is the *collective* influence of built environment variables? How important is it compared to the effect of individual characteristics? The answers to these questions will inform planners about the degree to which land use policies that lead to built environment

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https://doi.org/10.1016/j.tra.2018.02.009
Received 31 August 2017; Received in revised form 12 February 2018; Accepted 19 February 2018
0965-8564/

changes in various dimensions influence travel behavior. However, the literature offers limited evidence (van Wee and Handy, 2016).

Besides their collective influence, the individual effects of built environment variables on VMT also merit further scrutiny. Density is a critical component of compact development. Promoting dense development in low- and medium-density areas could be an effective strategy to reduce driving. However, additional density in high-density areas may not produce desirable outcomes. It is evident that density has diminishing returns on travel choice (Holtzclaw et al., 2002). This potentially undermines the effect of densification policies in Europe, China, and other countries with relatively dense development. However, most studies in the field assume a linear relationship between the built environment and travel behavior (van Wee and Handy, 2016). Accordingly, these studies do not provide nuanced guidance on land use planning. For example, how dense is enough to reduce driving effectively?

Furthermore, compact development is not only to increase density, but also facilitate clustered development (Ewing, 1997). The literature offers ample evidence on the role of proximity to the city center on travel behavior (Cao et al., 2010; Næss, 2013; Chatman, 2009). However, a limited number of studies examine how proximity to sub-centers reduces motorized travel. If any, their influence is not as promising as that of the city center (Næss, 2010, 2006a).

Using data from the Oslo metropolitan area, this study aims to fill three gaps by answering the following research questions: (1) to what extent do built environment characteristics collectively influence driving distance? (2) How important is the effect of sub-centers, relative to the city center? (3) Are the effects of built environment variables on driving distance linear? This study adopts a machine learning approach, gradient boosting decision trees, to address the questions.

The organization of this paper is as follows. Section 2 reviews the literature on the connection between the built environment and travel behavior, centering on the three questions. Section 3 introduces the modeling approach. Section 4 presents the data and variables. Section 5 answers the research questions. The final section recapitulates the key results and offers implications for planning practice.

2. Literature review

Land use and transportation planners hope that by changing the built environment where activities take place, land use policies such as compact development could be an effective strategy to mitigate traffic congestion, air pollution, and other negative impacts associated with motorized travel (TRB, 2009; Ewing et al., 2008). Not surprisingly, the relationship between the built environment and travel behavior attracts a lot of attention from scholars (Hu, 2015; Salon, 2015; Yang et al., 2017).

A recent review concludes that "Planners should not rely on compact development as their only strategy for reducing driving" by contending that the built environment has a limited effect on driving (Stevens, 2017 p.7). In particular, Stevens conducts a meta-analysis of 37 studies to assess the effects of the five "D"s of compact development—density, diversity, design, distance to transit, and destination accessibility—on VMT. He finds that the elasticity of density is −0.22 and concludes that compact development has a modest effect on achieving the goal of driving reduction. Stevens' study has received attention in planning circles as several scholars offer counter arguments from various perspectives (see the papers in this and the next issue). Moreover, the average effects of different built environment variables found in meta-analyses, such as those by Stevens (2017) and Ewing and Cervero (2010), do not necessarily take into consideration what other built environment attributes have been controlled for in the studies included in their analyses. For example, it is not clear whether the strong effect of street design on VMT in Ewing and Cervero's (2010) meta-analysis controlled for other relevant urban form variables (e.g., the distance from the dwelling to downtown). More fundamentally, since cities are inherently different in size, center structure as well as in their social, political and cultural conditions, the magnitude of built environment influences on travel will be context-dependent. The calculation of average elasticities between various built environment variables and travel may not be very fruitful (Næss et al., 2017b).

Furthermore, among their counter arguments, Ewing and Cervero (2017) propose an alternative explanation on the effects of the built environment. Because land use policies seldom change the built environment in only one dimension, the joint influence of all built environment characteristics induced by the policies could be substantial, even though the influence of a single attribute may be at the margin. In addition, the relative contributions of the built environment and individual characteristics to travel behavior have long been of interest to planners (Handy, 1996). Demographic characteristics are often confounding factors in the connection; they are associated with different built environment elements, and also influence travel behavior (Stead, 2001). When people living in the areas with different built environment elements behave differently, an open question emerges: to what extent is the difference attributable to the difference in the built environment or to the difference in demographics? The answer to this question will offer planners a sense on how effective land use policies are, relative to individual characteristics. If the latter account for the vast majority of the explanatory power, land use polices will have a rather limited effect and may not be worth pursuing if they conflict with other concerns in urban development. After reviewing the literature, Ewing and Cervero (2001) conclude that the built environment tends to have a stronger effect on VMT or VHT (vehicle hours travelled) than demographics. In a meta-analysis, Gim (2013) also concludes that land use variables impose stronger impacts on travel than residential self-selection, resulting from individual demographics and attitudes. However, not all studies come to the same conclusion. Using travel surveys in Britain, Stead (2001) finds that demographic characteristics have a stronger influence than land use variables. Similarly, Cao and Fan (2012) find that 64% of the observed effect of density on driving duration in Raleigh, NC is attributable to residential self-selection.

Nevertheless, local planners are interested in the collective influence of built environment variables. A fundamental issue of land use planning is that the construction of dwellings and other buildings is not something that is done in order to reduce travel—construction takes place for many reasons. Buildings are constructed regardless of whether this happens in the form of densification or outward urban expansion. The question is not whether or not construction should take place, but what kind of travel impacts society wants from the construction that will take place anyway. Do we want new buildings to contribute to more car driving