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Urban developments and daily travel distances: Fixed, random and hybrid effects models using a Dutch pseudo-panel over three decades

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ABSTRACT

As people require time to adjust their travel behaviour to changes in residential location and transport infrastructure, there is a need for long-term empirical studies quantifying the relationships between locations, individuals and travel behaviour. Such empirical evidence is critical for assessing previous and candidate future land use-transport policies. Existing research however, has mostly investigated travel behaviour during relatively short time periods and for a single transport mode. This paper examines the development of travel behaviour and its socio-demographic and location determinants, using Dutch National Travel Survey data from 1980 to 2010 among other sources, for the Randstad, the Netherlands. A pseudo panel analysis is conducted to investigate the effect of various indicators on average daily distance travelled by train, car and bicycle over three decades. Econometric models including pooled ordinary least squares, fixed and random effects and a hybrid model were tested to identify the best fit. The results indicate that average daily distance travelled rose until the mid-1990s before witnessing a decrease till 2010. Interestingly, half of the Randstad inhabitants have been travelling ≤ 26 km per day over the past thirty years. Furthermore, as people grow older, they increasingly travel more by train and bicycle. Finally, a rise in suburban inhabitants decreases the average distance travelled by train and increases that of bicycle, while a rise in rural inhabitants encourages higher distances travelled by car.

1. Introduction

Measuring and modelling individual travel behaviour is highly relevant for infrastructure decisions and policies for achieving sustainable environmental and societal development. Travel is the result of decisions by which individuals try to meet their needs and preferences. They aim to achieve their goals by allocating and prioritising their activities, thereby taking into account the relative position of locations. It is assumed that distances between residential, employment and service locations directly affect individual's total travel distances, as nearby destinations will be chosen rather than more distant ones (Maat and Timmermans, 2009). Consequently, it is assumed in this paper that travel behaviour is determined by the structure of the built environment, including the location of urban cores in relation to suburbs, the rural area, and other urban cores, as well as their accessibility by transport infrastructure connections. This is a dynamic process in which travel influences the demand for infrastructure investments, leading to improvements in accessibility and thus the attractiveness of locations, which in turn encourages adjustments to the built environment (Giuliano, 2004; Wegener and Fürst, 1999). This market-driven process is also subject to exogenous influences, such as the demand for housing, developments in transport technology and changing views on environmental sustainability (Bertolini, 2012; Kasraian et al., 2016b). Policy makers aim to adjust this market process by inventing policy concepts such as ‘compact urbanisation’. However, policy concepts also change over time.

Changes in transport infrastructure and the built environment, as well as changing policy responses, are assumed to have varying effects on travel behaviour. Moreover, we assume that there is a certain degree of delay in the system. Travel behaviour requires time to adjust to changes in the spatial context, new transport infrastructure and changing policies. It takes time for households to relocate to a new residential or work location, or to relocate their other activities, such as shopping to new locations. Furthermore, all market-driven developments and policy responses have their own time horizons. It is therefore the aim of this study to understand the effects of the built environment on travel behaviour, taking into account the adaptation of spatial policy concepts, over a longer period of time.

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Cross-sectional studies on the determinants of travel behaviour cannot provide answers to whether and to what extent changes in various built-environment and socio-demographic determinants affect the demand for travel. Studies quantifying the relationships between locations, individuals, and travel behaviour development over time are scarce (Ellder, 2014). This is mainly due to the unavailability of longitudinal travel surveys over a long time period. Of the studies that investigated this relationship over the long term, some analysed changes in travel patterns and its determinants at an aggregated level such as municipalities or tracts. Examples are induced travel demand studies (Noland and Lem, 2002), 'before-and-after' studies which test for instance the effect of new infrastructure (Baum-Snow and Kahn, 2000). Another strand of research investigated changes in travel behaviour at the individual level over time, using genuine panel data, such as the Dutch and the German mobility panels. Examples are studies which examine the concept of self-selection with longitudinal designs (e.g. Van de Coevering et al., 2016).

However, genuine panel data, where the same individuals are traced over time, are often costly, small-scale and suffer from sample attrition problems. In the absence of genuine panels, the most long-term and accessible travel behaviour data are repeated cross-sectional data. A major advantage of independent cross-sectional samples is that they are available over longer periods of time, such as the Dutch National Travel Surveys, a data set we used in this paper. Another advantage is that independent samples are not affected by dropout. A major disadvantage, however, is that they do not provide information for the same respondents across time, making it impossible to analyse intra-personal dynamics. A limited number of studies have used repeated cross sectional data from several survey waves to measure the change in factors influencing travel behaviour over time (Feng et al., 2017; Guerra, 2014; McDonald, 2015; Susilo and Maat, 2007; Zegras and Hannan, 2012). The majority of these studies has investigated changes in travel behaviour over two or three time points, by pooling the data sets on households and using interaction with time dummies or the test of preference stability to identify the effect of variables for specific time points. This method retains the individual characteristics and is easy to interpret. However, as each time point contains different observations, the data do not have a longitudinal structure where the same panel units are observed over time.

Alternatively, existing repeated cross-section samples can be restructured to behave as genuine panel data with temporal ordering, where changes within a panel unit and their determinants can be measured over time. This requires the construction of pseudo panels where individuals are grouped into homogenous groups of observations over time. Under certain conditions these groups can be treated as genuine panel units (Van de Coevering et al., 2016). Thus a trade-off is made between keeping individual characteristics and obtaining a panel structure where the same units (here groups of people) are traced over time. While this method entails a loss of individual characteristics, the resulted panel structure satisfies an important condition for causal inference, namely the temporal precedence of cause and effect. In the transport field, this method has been applied to repeated cross-sectional data to mainly model car ownership (Dargay, 2002) and public transport demand (Tsai et al., 2014).

By using such a pseudo panel analysis, this paper investigates the dynamics of daily distances travelled, related to characteristics of the built environment. The study is guided by the research question how travel behaviour has developed from 1980 to 2010 in the Dutch Randstad, in terms of distances travelled by train, car and bicycle, and which factors of the built environment and related policies, consistently or through their change, have influenced this, while controlling for the role of socio-demographic factors. In doing so, we also tested the pseudo panel approach and the best estimation model to answer this question. The study area is the Randstad, the core region of the Netherlands. This region is interesting, as its developments are partly consistent with that of other urban regions in the world, but at the same time it was subject to increasingly stringent policy objectives (see, e.g., Kasraian et al., 2017, for a long-term overview of the land use, transport infrastructure and spatial policy developments in the Randstad). This study is unique as it models a relatively long time period, namely three decades, from 1980 to 2010. In addition to most previous studies, the focus is not only on a single mode, but on train, car and bicycle travel. For this, descriptive and pseudo panel analyses are applied to a series of repeated annual surveys over 30 years, including socio-demographic, residential location and travel behaviour indicators. This study evaluates three frequently used pseudo panel estimation techniques, i.e., the pooled ordinary least squares, fixed effects and random effects. Furthermore, a hybrid estimation is applied and its performance as the best-fitting model is investigated. The results of this study provide policymakers with understanding of the long-term effects of infrastructure investments, urban growth and mitigating policies on travel behaviour.

The next section provides a brief overview of the investigated data and its preparation. We then summarise and compare the estimation techniques applied to pseudo panels and elaborate on the new hybrid method. Subsequently we compare the results of various estimation techniques and the difference between the three modes. The paper ends with reflections on the findings and recommendations for future policy and research.

2. Data

A long-term geo-referenced database was constructed by bringing together various sources. The surveys reported the origin and destination of trips at the municipal level until 2004 and afterwards at the much more detailed level of 4-digit postal codes. Spatial, socio-demographic and travel behaviour data with varying measurements were recoded and converted to the municipal borders of year 2004 (proportional to the area of each year's spatial unit existing within the 2004 municipal border) to generate a consistent dataset for seven time points: 1980, 1985, 1990, 1995, 2000, 2005 and 2010.

Travel behaviour variables were extracted from the Dutch National Travel Surveys (OVG, MON and OViN) which provide reliable travel diary data since 1979 on an annual basis (Statistics Netherlands (1979-2004); Ministry of Infrastructure and Water Management [Rijkswaterstaat, Dienst Verkeer en Scheepvaart] (2011); Statistics Netherlands (2010)). The sample was limited to the Randstad population. As sample sizes varied, they were made comparable between the time points by adding respondents from the previous and proceeding year (e.g. 1984 and 1986 were added to 1985). Respondents younger than 20 years were excluded because of their constrained travel behaviour). We estimated single-mode models for travel by train, car and bicycle. Only respondents who reported at least one trip by train, car or bicycle during the survey day, were included. The sample size per year resulted in 11,066 (1980), 13,348 (1985), 15,107 (1990), 32,596 (1995), 29,007 (2000), 32,858 (2005) and 12,690 (2010) cases.

Table 1 provides an overview of variables used in the analysis, their definitions and sources. Average daily travel kilometres were split into train, car passenger or car driver, and bicycle; multi-modal trips were recoded to the transport mode with the longest leg (in kilometres) of the trip; other modes (e.g. motorcycles, tram, bus, metro) were excluded regarding their smaller share in total distance travelled. Walking trips were left out as they artificially increased over time due to improvements in their measurement in the more recent survey waves.

Socio-demographics are age, gender, educational level, personal income and household car ownership. Residential municipalities were categorised by "daily urban systems", according to Van der Laan (1998) used in several other studies (Schwanen et al., 2001; Van Eck and Snellen, 2006). Though the Randstad and its borders have evolved, its daily urban systems have been relatively stable over time. The three categories are "urban centres", "suburbs" (including medium sized cities in the vicinity of the urban centres) and "rural". Accessibility was