Immobility in a weekly mobility routine: studying the links between mobile and immobile days for employees and retirees

Benjamin Motte-Baumvol, Julie Fen-Chong, Olivier Bonin

This is a postprint of : Motte-Baumvol, B., Fen-Chong, J., & Bonin, O. (2022). Immobility in a weekly mobility routine : Studying the links between mobile and immobile days for employees and retirees. Transportation. https://doi.org/10.1007/s11116-022-10292-x

---

Immobility in a weekly mobility routine: studying the links between mobile and immobile days for employees and retirees

Benjamin Motte-Baumvol (corresponding author), UMR CNRS ThéMA, Université de Bourgogne-Franche-Comté, Dijon, France (21000), benjamin.motte@u-bourgogne.fr, https://orcid.org/0000-0003-4047-4852

Julie Fen-Chong, UMR CNRS ThéMA, Université de Bourgogne-Franche-Comté, Dijon, France (21000), julie.fen-chong@u-bourgogne.fr, https://orcid.org/0000-0002-5152-8054

Olivier Bonin, UMR LVMT, Université Gustave Eiffel, Champs-sur-Marne, France (77447), olivier.bonin@univ-eiffel.fr, https://orcid.org/0000-0002-1487-2323

Abstract

Immobility – i.e. no travel outside the home in a 24-hour day – is an important issue because it concerns a large part of the population and tends to recur frequently, as our results show. Two questions related to immobility have been particularly highlighted in the literature: firstly, whether immobility is an artefact of travel surveys; secondly, whether it corresponds to an extreme form of low mobility. In light of the literature review and levels of immobility observed, these two questions seem to be minor, particularly in relation to the activity of individuals, which remains the main factor in immobility. By using Structural Equation Modeling to process National Travel Survey data, this work has explored the individual variability of trips as a constituent element of immobility for employees and retirees. The link between immobility and variability manifests itself in two ways in our results. Firstly, immobility is associated with activities that are less constrained in time and space, as is the case with the lower frequency of travel for work and support. Secondly, there are rebound effects on mobile days, with more frequent trips for grocery/medical motives in particular, when there is an UK episode of immobility during the week.

Keywords: temporal variability, travel survey, transport poverty, soft refusal, fatigue

Introduction

According to the UK National Travel Survey (NTS), 22.7% of individuals are immobile, i.e. they do not travel outside the home in a 24-hour day, on average on any particular weekday. Cumulatively over a five-weekday period, 52.7% of individuals experience one or more 24-hour periods of immobility.

Immobility over a full day is often associated with transport poverty and/or issues related to the survey methodology that lead to under-reporting of trips, which is referred to as soft refusal in the literature (Madre, Axhausen & Brög, 2007). However, immobility occurs too often and with such marked differences depending on the activity status of individuals for it to correspond to these two determinants alone. This research explores immobility arising from daily variability in travel as a result of less-constrained activity schedules. This could explain why retirees and the non-working population report so many more immobile days than employees do. The activity and travel schedules of individuals with strong time and space constraints (Hägerstrand, 1970a; Schwanen, Kwan & Ren, 2008) like employees mean the intra-personal variability in their travel patterns is low. Conversely, individuals with fewer such constraints exhibit greater intra-personal variability. The absence of information on travel outside the home in the surveys for a given day does not necessarily mean that these individuals never travel, but that they have a less-constrained activity schedule.

In the study of daily mobility, the trips considered are often a snapshot of a typical day of the week. However, the work of Pas & Koppelman (1986) has shown that taking into account a wider range of data-collection days reveals very high intra-person variability. To study immobility as an expression of intra-personal variability, we will look at the recurrence of days of immobility over a seven-day period, based on the NTS, and observe the recurrence of motives for travel over the whole week.

This research, then, addresses the framework of immobility on the basis of three questions. First, are there individual characteristics that contribute to immobility other than activity, i.e. employee or retiree? Second, is immobility necessarily linked to lower mobility on other days? Finally, is immobility linked to fewer activities constrained in space and time?

By using Structural Equation Modeling (SEM), immobility of employees and retirees alone was comprehensively analyzed by combining exogenous variables relating to travel, endogenous variables relating to the characteristics of individuals, and mediation effects in a path analysis approach. Our results show in particular that, for employees, immobility is linked to trips being less constrained and normal mobility on mobile days. This does not hold, however, for retirees for whom immobility is associated with very low mobility on other days and which is rather related to their individual characteristics such as old age, physical difficulties, or not having a car.

The article is structured as follows. First, the literature review enables this research to be set in relation to previous work on immobility. The data and methods section presents the travel-survey data and explains the SEM developed. Results are presented in Section 4 and the final section summarizes the main findings and highlights some lessons that can be drawn for future studies and for transport planners.

Literature review

The question of immobility is the subject of work with approaches and results that sometimes diverge. Two types of approach can be observed. Firstly, immobility is associated with poverty issues in several studies. Secondly, immobility is associated with problems of survey methods in other works. The results obtained with these two approaches only partly explain immobility, with models of low explanatory power, and leave the way open for other types of approach such as the one we propose here, which is based on individual variability of travel, which it is important to understand over an appropriate observation period.

Poverty and immobility

One of the hypotheses explaining low mobility is low household income. Low income results in "transport poverty", a term coined by Lucas (2012) and that expresses the relationship between low mobility and degraded access to social resources. Low income is associated with low access to automobiles and it is this association that is thought to be a key determinant of low mobility (Delbosc & Currie, 2011; Pucher & Renne, 2005; Wixey et al., 2005). However, Lovejoy & Handy (2011) and Motte-Baumvol, Massot & Byrd (2010) have shown that people without access to motorization are not necessarily excluded from car mobility but develop alternative strategies.

Regardless of car ownership, low-income households travel shorter annual distances than other households. In the US, low-income households (<$20 000) travel 18 miles per day, while high-income households (>$100 000) travel 32 miles (Pucher & Renne, 2003). In Great Britain, poorer households limit their travel, including for employment (Wixey et al., 2005). The poorest households limit their travel to work and school. The low mobility associated with poverty is thus low mobility in terms of distance traveled, number of trips, and variety of motives for mobility.

Spatial configurations can accentuate low mobility. The work of Motte-Baumvol & Nassi (2012) in Rio de Janeiro (Brazil) reveals that a large proportion of Rio de Janeiro's immobile inhabitants live in the city's northern working-class neighborhoods and have a low employment rate and little education. Mobility constraints, particularly economic and physical constraints, are all the stronger for residents of outlying or peri-urban neighborhoods, as they do not have access to all possible social resources.

Immobility or low mobility is supposedly, then, the result of certain individuals being unable to cope with the demand to be mobile made by contemporary urban society. Lévy (2000) refers to immobility as disastrous because it allegedly entails for those individuals subject to it a high risk of economic insecurity and marginalization.

Measurement Issues

Beyond transport poverty issues, immobility measured from travel surveys is often addressed as a measurement issue. Hubert et al. (2008) compare travel surveys and time-use surveys in Europe and conclude that immobility measured in travel surveys is greater than that measured in time-use surveys, except in the case of the 2008 French National Travel Survey.

In most travel surveys, such as the UK NTS, immobility is inferred from the absence of travel over the course of a day whereas the 2008 French travel survey contains specific questions on immobility before the questions on travel so as to avoid soft refusal. In the UK survey, the investigator makes a single home visit to respondents at the end of the survey week but makes a follow-up phone call in the course of the week. In France, the investigator makes two home visits before and after the survey day. Investigators play a major part in avoiding soft refusal as shown by Axhausen *et al.* (2007) on the basis of the Mobidrive and Thurgau surveys. Self-administered surveys by internet or telephone have the highest level of low mobility. Other methods can be used to improve survey quality and response rate, such as hybrid methods (Monzon, Julio & Garcia-Martinez, 2020)

Leaving aside differences between the surveys, two factors might account for the higher rate of immobility in the UK NTS. The first is that, unlike the French travel survey, the UK NTS covers a seven-day period and so fatigue becomes an issue. This results in a decline in the quality of responses as the survey days go by. Fatigue is apparent in the survey in the form of increasing soft refusal over time and so comes across by default as immobility. Fatigue is a major limitation on surveys conducted over several days. It may, however, be reduced by more regular follow-up and proper training of investigators (Axhausen et al., 2007).

Activity and mobility

A number of earlier studies have cast light on this debate by showing that immobility cannot be considered exclusively as limited to the financially worst-off individuals. The fact is that the connection between immobility and income is a weak one (Bayart, Bonnel & Havet, 2018; Madre, Axhausen & Brög, 2007; Motte-Baumvol & Bonin, 2018; Motte-Baumvol & Nassi, 2012). Conversely, immobility is closely connected with individuals' employment status. Retirees, homemakers, and the unemployed are the people most prone to immobility, with close on 50% of them experiencing one weekday without travel in the course of a week, whereas the figure is less than 20% among those in employment and students (Motte-Baumvol & Bonin, 2018). It can be inferred from these observations that immobility is no marginal phenomenon but crops up more frequently whenever daily life is not structured by regular activities such as work or study. Immobility may just as easily reflect a situation in which individuals are free to use their time as they wish as it may reflect an inability (physical, material, financial, etc.) to travel.

Immobility is defined in quantitative approaches to mobility as a full day without travelling (Hubert et al., 2008). Even so, a day without travel does not mean a day cut off from the world: individuals may have visitors or have goods delivered, which might become more commonplace with the development of home deliveries and homeworking. Immobility is a major unknown inasmuch as few studies have specifically investigated it.

Temporal variability of travel

Because of the variability of intra-individual travel, one day's immobility does not equate to daily immobility. Pellegrino (2011) views immobility as part of a continuum with respect to mobility. Cresswell (2010) and Ferreira, Bertolini & Næss (2017) present it as a natural

breathing space between travel section. Similarly, Belton-Chevallier (2015) shows that immobility on any given day does not exclude individuals from being mobile, whether on other days or by having others travel for them instead, i.e. running errands or assisting with the escorting of children, or again through immaterial forms of mobility (telephone, internet, etc.). According to the concept of motility, defined as the personal ability to be mobile, hit upon by Kaufmann, Bergman & Joye (2004), individuals' potential mobility is not necessarily transformed into physical travel and immobility is not incompatible with high motility. Immobility is therefore a constituent part of mobility as evidenced by the bracketing of the prefix (im-) (Adey, 2006).

In this light, immobility is not confined to individuals facing exclusion but may also correspond to breaks in less-constrained travel schedules. This highlights the need to take a nuanced, detailed, and precise approach to immobility so as to avoid the pitfall of misinterpreting observations by addressing them solely in terms of inequality or insufficiency. Accordingly, a travel-free day in a schedule of activities, just like a small number of trips, cannot be interpreted solely as an indicator of social inequalities but may alternatively be the sign of diversity in individuals' daily activity schedules.

To understand this, we must place ourselves in the framework of Time Geography (Hägerstrand, 1970b) where individual trips are made for the purpose of performing an activity in a given location at a given time (Schwanen, Kwan & Ren, 2008). Individuals with a time and space constraint due to employment or education make the same trip every day. In contrast, those with fewer daily constraints have greater variability in travel for other purposes (Dharmowijoyo, Susilo & Karlström, 2017). Pas & Koppelman (1986) show that individuals who do not make trips for household purposes, such as grocery shopping or escorting, have more variability in their activity and travel schedules.

Thus, some trip purposes do not require daily travel. Shopping and leisure trips are more irregular (Tarigan & Kitamura, 2009). Mattioli & Anable (2017) show that food procurement mobilities do not occur every day. For some workers even (temping staff, the self-employed, business service providers, telecommuters), weekdays are not all alike and some may not involve travel even for this category of the population.

Non-motorized modes show greater intra-person variability (Li et al., 2018). Some short trips made on foot or by bike are also subject to high daily variability in addition to not necessarily being reported in transportation surveys.

Observation of mobility over a longer period

Last but foremost, these initial observations point up the need to monitor inequalities over a period of several days including both immobile and mobile days. Only observation over such periods can determine the impact of differences in terms of travel and/or immobility on access to social resources that are crucial to individuals. This is particularly the case because as Fol & Gallez (2014) point out, inequality in terms of mobility or travel provides only an imperfect gauge of unequal access: individuals who are not very mobile may have very high access to many resources and even have all resources come to them without ever moving.

Renewing quantitative approaches to immobility involves working on travel observation periods of several days. But quantitative mobility analyses are traditionally conducted on the basis of travel surveys with observation periods of just a single weekday. In most countries, such surveys cannot therefore be used to study how immobile and mobile days hinge together or the diversity and recurrence of purposes for travel (Axhausen et al., 2002; Madre, Axhausen & Brög, 2007). With just a single day's observation, mobility is usually understood on the basis of the "average day", a concept that is reasonably well suited to modelling transport infrastructure flows but is unsuitable for capturing the diversity of lifestyles. Yet, most purposes for making regular trips are not of a daily frequency (Susilo & Axhausen, 2014; Tarigan & Kitamura, 2009). This is particularly so when we are examining the challenges of low mobility for individuals who make few trips in the course of a day. After testing observations over six consecutive weeks, Susilo & Axhausen (2014) conclude it is necessary to have an observation period of travel of at least one and ideally two weeks. We can infer from these references that as there is more variability for week-end days than for weekdays, one week plus the two week-ends could be a good compromise

There is another characteristic of travel surveys that might account for immobility as an artefact (an effect of construction of the model): the observation period is of just a single day, and not necessarily the same day for all the households or individuals surveyed. This observation period provides a distorted picture of travel schedules which are not identical from one day to the next and over the course of the year. Travel patterns are structured on a weekly basis, too, or even over longer periods. Axhausen *et al.* (2002) show that the most relevant time-scale for capturing variance in the set of purposes for travel is two weeks, although a week may prove an acceptable compromise. So one day of immobility is not necessarily a sign of low mobility on the scale of a week (Lucas & Madre, 2018) and may be simply a chance event and/or a sign of variability in travel on different days of the week.

This paper proposes therefore to look at immobility within a wider time-frame so as to put it in perspective on the scale of an observation period that makes more allowance for individuals' travel behavior. This is done using data from the UK national travel survey (NTS) in which the period of observation of travel is seven days, or a sliding week. Using this extended period makes the analyses more robust because it multiplies the number of observations for any one individual and also because it uses a more relevant period in terms of individuals' practices and habits (Susilo & Axhausen, 2014; Tarigan & Kitamura, 2009).

Data and methods

Data

The data used come from the United Kingdom National Travel Survey (NTS) for the period between 2002 and 2017, in order to ensure a healthy sample size of individuals with different numbers of immobile days. The data refer to the travel of English residents within Great Britain. From the NTS, we select only employees and retirees so as to work on homogeneous categories of individuals, while having a large number of individuals for the analysis. Thus, students,

individuals looking after the family/home, the unemployed as well as individuals permanently and temporally sick and injured are omitted. In total, the analysis sample consists of trip records of five consecutive weekdays for 63,859 respondents (Table 1).

In this sample the average proportion of individuals with at least one immobile weekday is about 36%. In fact, our analysis of immobility concerns only the occurrence of immobile days on weekdays, i.e. from Monday to Friday excluding public holidays. We focus our study of immobility on weekdays, because weekend immobility corresponds to specific reasons (Madre et al., 2007) and it seems it should be studied separately or excluded from the scope of analysis. For each individual, we compile the number of immobile weekdays, which is the response variable at the core of the statistical model. Individuals surveyed during a week with public holidays are not included, while individuals with either 4 or 5 non-mobile weekdays are also excluded from the analysis. This is because it proves impossible to study the articulation between non-mobile days and mobile days in this case, and because of the very particular profiles of the individuals concerned.

We therefore work on a population divided into two groups with very different rates of immobility. The two groups are employees and retirees, with weekly immobility rates of 23.6% for employees and 62.2% for retirees. With such different levels, it is unrealistic to treat these two groups together in the statistical modelling. Finally, it is important to note that the definition of an immobile day that we adopt from the NTS data omits short walks, i.e. trips of less than 1 mile on foot. In fact, these trips are only recorded on the seventh day in the NTS, making it methodologically difficult to take them into account in an analysis of all the weekdays. Thus, during an immobile weekday, individuals may in fact walk a short distance. This is why we consider short walks as a dummy variable in the modelling.

Table 1. Characteristics of individuals as a function of the number of mobile weekdays

	Employees		Retirees	
Average immobile weekdays	0.4		1.1	
Immobile weekday(s)	None	1 or +	None	1 or +
# work + escort trips (over 5 weekdays)	6.0	2.7	1.1	0.3
# grocery + medical trips (over 5 weekdays)	0.5	0.5	1.8	1.4
# leisure trip (over 5 weekdays)	2.2	1.7	6.4	2.9
# return home trips (over 5 weekdays)	6.4	3.8	7.4	3.8
# all trips (over 5 weekdays)	15.1	8.7	16.7	8.4
# work + escort trips (average per mobile weekday)	1.2	0.8	0.2	0.1
# grocery + medical trips (average per mobile weekday)	0.1	0.1	0.4	0.4
# leisure trips (average per mobile weekday)	0.4	0.5	1.3	0.9
# return home trips (average per mobile weekday)	1.3	1.1	1.4	1.2
# all trips (average per mobile weekday)	3.0	2.5	3.3	2.6
% Mobility difficulties (dummy)	1.9	2.7	17.4	28.9
% With car & main driver (dummy)	73.2	61.6	68.0	47.2
% Men (dummy)	60.5	57.0	51.6	40.1
Age (mean)	40.2	39.5	70.2	72.6
% Educational qualifications	89.7	88.4	61.2	50.3

% Professional qualifications	4.0	4.4	10.1	9.9
% Higher education diploma	31.2	29.8	14.6	11.1
% Individual income < £25,000	52.0	55.7	86.7	90.0
% Individual income ≥ £50,000	11.3	11.6	3.0	2.0
% Single adult household (dummy)	30.2	32.0	29.2	37.0
% 3rd adult (dummy)	33.5	33.3	9.6	8.4
% One child or more (dummy)	33.2	34.0	1.7	1.4
% Density place of residence (persons / hectare)	29.1	32.4	21.7	22.9
% London	15.1	18.2	9.4	10.4
% Rural	12.8	12.1	15.8	16.7
% Detached house	21.9	20.1	37.7	33.5
% Semi-detached house	34.5	32.9	34.2	33.9
% Short walks (dummy)	12.2	16.6	15.7	15.7
% Holidays (dummy)	3.2	3.3	3.5	3.3
# individuals	32 674	10 101	7 968	13 116
% of row total by group	76.4	23.6	37.8	62.2

Data: National Travel Survey 2002–2017

Among the NTS data, we select a number of exogenous variables considered as determinants of immobility and of motives for trips. These are variables commonly found in analyses of transport poverty, such as gender, age, income level, education level, having a car of which you are the main driver, or mobility difficulties. Added to them are variables concerning household composition, such as living alone, presence of a child or a third adult in the household, and variables on residential location. The description of these variables shows that the profiles of mobile and immobile employees are not very different from each other except for having a car of which you are the main driver and for gender. For retirees, the differences between mobile and immobile individuals are a little more frequent. In addition to having a car of which you are the main driver and to gender, there are differences in terms of educational qualifications and living alone. These differences between employees and retirees reinforce the relevance of a separate analysis of these two groups.

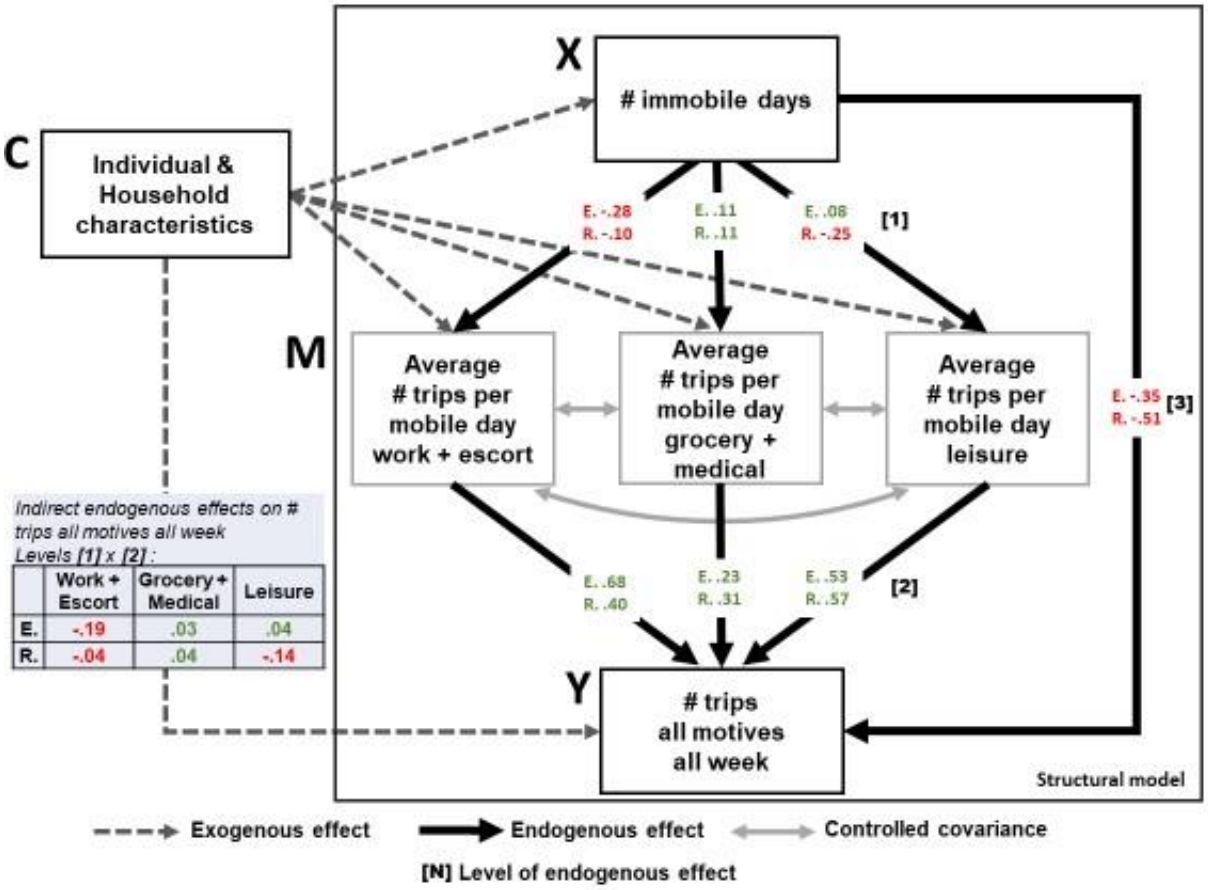
The second type of variable mobilized in this work corresponds to travel indicators used as endogenous variables in the statistical modelling. We select three mobility indicators, i.e. the average number of trips per mobile weekday for three travel motives: work+escort, grocery+medical, and leisure. Although considered, the question of postponement of some trips until the weekend does not appear in this work because it shows no significant results linked to immobility on weekdays.

The three main types of motive are defined according to their constrained nature and frequency. Work+escort is the most frequent and relatively constrained for employees but not for retirees. Trips for grocery+medical are less frequent and less-constrained but nevertheless essential for both categories of individuals, with a higher occurrence for retirees. Finally, leisure trips are the least constrained for both categories of individuals. Table 1 shows the average number of trips for individuals with and without an immobile day, which are very different for the work+escort motive for employees and for leisure for retirees. For the other motives, the differences are minimal. This implies that, for employees, immobility is a sign of lower constraint on making trips, leaving more opportunities for days without trips and therefore for

the temporal variability of trips from one day to another. For retirees, however, it is not the level of trip constraint that explains their temporal variability but rather their lesser involvement in leisure activities, which remains to be explained.

Model framework

Figure 1. Model framework for employees and retirees



We aim to investigate the link between immobility and the total number of trips, that will be negative as observed in the descriptive statistics. To go beyond this negative effect, we choose to introduce mediator variables M between the dependent variable Y, which is the number of trips observed for all motives and during the entire week, and the predictor variable X, which is the number of immobile days. A mediator variable M is a variable on which X has an effect, and which in turn has an effect on Y. Thus, we obtain a mediation model, where we can evaluate the direct effect of X on Y, and the indirect effect, via M. Predictors are chosen according to our research hypotheses. Moreover, we try to control for the effects of individual and household characteristics C on X, M and Y.

As we attempt to identify the effects of immobility on one or more days on mobility on the other days, i.e. the mobile days, we intend to show that immobility is not necessarily associated with low mobility on other days. The mediator variables are therefore the three motives described above, i.e., the average number of trips on a mobile day for selected motives. A mediation model can be thought of as an extension of two-stage least-squares regression, with

mediators replacing instrumental variables and the addition of a direct regression between the dependent variable and the predictor. The flexible framework of SEM enables us to estimate such a model. A very general SEM model can include variables that are either observed (which is our case for all variables) or latent (unobserved). Besides, as in any regression model, variables can be exogenous, such as in our case the individual and household characteristics or the number of immobile days, or endogenous, such as the number of trips for all motives on all days. The SEM framework enables us to properly include the mediators, which are both explained by regressions while being at the same time explanatory factors of other regressions.

The mediation model obtained enables us to differentiate between: (i) the direct effects of immobility ([3] in Figure 1), i.e. the effect of the number of days without travel on the number of weekly trips; (ii) the indirect effects ([1]X[2] in Figure 1), i.e. the effects related to the number of trips on mobile days. To validate the hypothesis of immobility as a result of the variability of trips from one day to the next, the indirect effects would have to be positive or only slightly negative. This would indicate catch-up effects on mobile days to compensate for the absence of travel. If this were not the case and the indirect effects were clearly negative, this would indicate immobility as a result of depressed mobility, which might be a sign of transport poverty.

Thus, the model proposed in Figure 1 is structured around a control model (controlling our predictors X and M) and then a structural model (linking our dependent variable Y to X both directly, and indirectly via M):

- In the control model, we seek to explain the number of immobile weekdays (0–3) and the average number of trips per mobile weekday for the three motives (work+escort, grocery+medical, and leisure) by individual and household characteristics.
- In the structural model, there are two stages. First we study the effect of the number of immobile weekdays on the average number of trips per mobile weekday for the three motives under investigation. Second we study the effect of the number of immobile weekdays on the total number of trips for all weekdays. In this second stage, there are two types of effect: the direct effect [3] and the indirect effects through the mediation of the average number of trips per mobile weekday.

Finally, the model is applied to a population divided into two different groups: employees and retirees. This distinction corresponds to a very different degree of immobility in the weekly travel schedules of these two types of individuals.

Traditionally, path diagrams such as the one in Figure 1 present the more relevant coefficients of the model, with here negative coefficients in red and positive coefficients in green. Without going into details about the interpretation of the results, which will be done in the next section, the model shows that besides the expected result of a direct negative effect of immobility on the total number of trips, this effect can be indirectly decomposed into contrasted effects (in green and in red) when motives are introduced in the analysis, and that moreover these effects vary clearly if we consider employees or retirees.

Results

The model obtained is considered a good model with respect to the three indicators generally used for the purpose (Golob, 2003). The root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR) are both less than 0.05 (**Erreur ! Source du renvoi introuvable.**1), which is judged highly satisfactory. Moreover the comparative fit index (CFI), which compares the proposed model with an unrestricted base model, takes a value of 0.99 (a good model should have a value of more than 0.90). The model is therefore well fitted to the data and has good explanatory power. The results of the control model are presented first and then the results of the structural model.

Determinants of immobility and mobility for employees (control model)

In this section and the next, the results provide some answer to the first question formulated in the introduction on the characteristics of individuals and their households that contribute to immobility other than activity, i.e. employee or retiree. For employees, the individual and household determinants that have a positive effect on the probability of being immobile (table 2) are mobility difficulties, a low level of qualification, a low or a high-income, living in London, having been surveyed during a school holiday period, and finally having taken at least one short walk. The last two determinants have the strongest effects. Conversely, the determinants that have a negative effect on the probability of being immobile are having a car of which you are the main driver, a higher level of qualification, being a man, being older, and belonging to a household that includes a third adult.
Conversely, almost all the determinants that have positive effects on the probability of being immobile have negative effects on the average number of trips for the three motives studied. Similarly, almost all the determinants that have negative effects on the probability of being immobile have positive effects on the number of trips. These rules do not always hold for different trip motives or determinants.

Table 1. Results of the model for employees

	Control Model				Structural Model			
	# immobile weekdays	# work escort trips	# grocery medical trips	# leisure trips	Immobile weekdays indirect [1]*[2]	Average trips per weekday [2]	Immobile weekdays direct [3]	Total
Mobility difficulties (dummy)	0.026 ***	-0.010 *	0.041 ***	0.012 *	-0.012 ***	0.009 *	-0.003 .	
With car & main driver (dummy)	-0.096 ***	0.114 ***	0.082 ***	0.111 ***	0.045 ***	0.156 ***	0.023 ***	0.224 ***
Men (dummy)	-0.016 **	-0.036 ***	-0.103 ***	-0.075 ***	0.008 **	-0.088 ***	0.009 ***	-0.072 ***
Age	-0.011 .	0.023 ***	0.095 ***		0.005 .	0.039 ***	0.012 ***	0.057 ***
Educational qualifications (dummy)	-0.014 *	0.018 **	0.024 ***	0.055 ***	0.007 *	0.047 ***		0.053 ***
Professional qualifications (dummy)				0.013 *		0.012 *		0.012 .
Higher education diploma (dummy)	-0.013 *	0.031 ***		0.009 .	0.006 *	0.025 ***	-0.017 ***	0.014 **
Individual income < £25,000	0.017 **	-0.015 **	0.020 ***	-0.017 **	-0.008 **	-0.015 **	0.017 ***	
Individual income ≥ £50,000	0.014 *		-0.035 ***	-0.017 **	-0.006 *	-0.021 ***	-0.008 ***	-0.035 ***
Single adult household (dummy)		-0.030 ***	-0.021 ***	0.046 ***			-0.008 ***	
3rd adult (dummy)	-0.010 .		-0.024 ***	-0.030 ***	0.005 .	-0.025 ***	0.020 ***	
One child or more (dummy)		0.180 ***	0.016 **	-0.045 ***		0.103 ***	0.018 ***	0.116 ***
Density place of residence (persons / hectare)			-0.019 **					
Residence in London boroughs	0.011 .	-0.019 **	-0.070 ***	-0.071 ***	-0.005 .	-0.067 ***	-0.008 ***	-0.079 ***
Residence in a rural area				0.018 **			-0.012 ***	-0.010 .
Detached House		0.025 ***	-0.024 ***	0.057 ***		0.042 ***		0.040 ***
Semi-detached house				0.018 **		0.008 .	0.008 ***	0.019 **
Short walks (dummy)	0.063 ***	-0.009 *	0.037 ***	0.064 ***	-0.030 ***	0.036 ***	0.004 **	0.010 *
Holidays (dummy)	0.055 ***	-0.096 ***	0.027 ***	0.104 ***	-0.026 ***		-0.006 ***	-0.036 ***

Data: National Travel Survey 2002–2017, Tools: R with the Lavaan package
*Signif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1*
All values of the estimates are standardized and allow comparisons between motives, and between employees and retirees
The missing coefficients correspond to non-significant values, $p < 0.1$, and the modalities/variables were removed from the final computation

Table 2. Results of the model for retirees

	Control Model				Structural Model			
	# immobile weekdays	# work escort trips	# grocery medical trips	# leisure trips	Immobile weekdays indirect [1]*[2]	Average trips per weekday [2]	Immobile weekdays direct [3]	Total
Mobility difficulties (dummy)	0.105 ***		0.094 ***	-0.062 ***	-0.069 ***	-0.072 ***	-0.001 0	-0.142 ***
With car & main driver (dummy)	-0.185 ***	0.147 ***		0.094 ***	0.122 ***	0.237 ***	0.022 ***	0.381 ***
Men (dummy)	-0.028 ***	0.036 ***	-0.016 *	-0.019 **	0.018 ***	0.017 **	0.010 ***	0.045 ***
Age	0.116 ***	-0.080 ***	0.071 ***	-0.115 ***	-0.076 ***	-0.151 ***		-0.228 ***
Educational qualifications (dummy)	-0.053 ***		-0.014 .	0.091 ***	0.035 ***	0.086 ***		0.118 ***
Professional qualifications (dummy)	-0.019 **	0.018 **		0.023 ***	0.013 **	0.033 ***		0.046 ***
Higher education diploma (dummy)		-0.014 *	-0.034 ***	0.047 ***		0.013 *		
Individual income < £25,000		-0.019 **						
Individual income ≥ £50,000	0.046 ***	-0.074 ***	-0.037 ***		-0.030 ***	-0.067 ***		-0.093 ***
Single adult household (dummy)	0.012 .	0.063 ***		-0.028 ***	-0.008 .		0.011 ***	
3rd adult (dummy)		0.105 ***	-0.019 **	-0.029 ***		0.017 **		0.016 .
One child or more (dummy)				-0.024 **		-0.016 *		-0.019 .
Density place of residence (persons / hectare)			-0.038 ***			-0.026 ***	-0.007 **	-0.038 ***
Residence in London boroughs	0.062 ***	-0.023 **			-0.041 ***	-0.046 ***	-0.012 ***	-0.099 ***
Residence in a rural area		-0.014 .		0.064 ***		0.026 **	0.006 *	0.029 *
Detached house		0.022 **		0.025 **		0.020 **	0.006 *	0.023 *
Semi-detached house	0.022 ***		-0.023 ***	0.037 ***	-0.014 ***		0.007 ***	
Short walks (dummy)		-0.041 ***	-0.020 **	0.020 ***				
Holidays (dummy)	0.105 ***		0.094 ***	-0.062 ***	-0.069 ***	-0.072 ***	-0.001 0	-0.142 ***

Data: National Travel Survey 2002–2017, Tools: R with the Lavaan package
*Signif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1*
All values of the estimates are standardized and allow comparisons between motives, and between employees and retirees
The missing coefficients correspond to non-significant values, p < 0.1, and the modalities/variables were removed from the final computation

Determinants of immobility and mobility for retirees (control model)

For retirees, the determinants of immobility (Table 3) are similar to those observed for employees. However, the estimates are much higher, highlighting the greater impact of individual and household characteristics on immobility for retirees. Among the determinants that have a positive effect on the probability of being immobile, we find mobility difficulties, low income, and having taken at least one short walk. However, poor qualifications, living in London, or having been surveyed during a school holiday period do not have a significant effect for retirees. On the other hand, other determinants must be added to the list of positive and significant effects on the probability of being immobile for retirees: age (which has a negative effect for employees), living alone or with a third adult, and living in the countryside. Among the determinants with a negative effect on the probability of being immobile are being the main driver of a car, being male, and educational or professional qualifications.
The effects are generally reversed in the case of average numbers of trips. However, there are several exceptions in the case of retirees, all of which concern *grocery+medical* trips. Thus, having mobility difficulties, being elderly, and being a low income earner are all associated with both a higher probability of being immobile and a higher probability of making *grocery+medical* trips on mobile days.

Contribution to the general number of trips for employees (structural model)

In this section and the next, the results provide some answer to second and the third questions formulated in the introduction that ask whether the immobility is linked to fewer activities constrained in space and time and to lower mobility on other days? First, the effects of immobility on travel on moving days (denoted [1] in Figure 1) are examined. We observe that immobility is not always accompanied by reduced mobility on mobile days. For employees, immobility does indeed display a negative relationship with the average number of work+escort trips on mobile days. On the other hand, it shows a positive link with trips for grocery+medical and leisure. This reflects a form of rebound effect or postponement of trips on mobile days for the latter two reasons. The lower probability of work+escort trips on mobile days can be interpreted in two ways. The first is that it indicates reduced mobility. The second interpretation is that this is a cause of immobility insofar as the constraint of work or escorting is eased for these individuals and allows for a less-constrained and therefore more variable travel schedule.
The second level of interpretation of the structural model concerns the effects of the average number of trips by motive on mobile days on the total number of trips during weekdays (noted [2] in Figure 1). This provides a measure of the contribution of each of the motives to the total number of trips, all other things being equal. Thus, the motive with the largest contribution for employees is unsurprisingly work+escort, ahead of leisure, whose contributions are twice as large as grocery+medical.
Then, by multiplying the [1]x[2] effects (Figure 1), we can measure the indirect effects of immobility on the total number of trips, i.e. the effects of mediation through trips made on mobile days. It can be observed that the indirect contribution of immobility is negative since the work+escort motive makes a strong negative contribution while the other motives make

only a weak positive contribution. The sum of the indirect contributions per motive is -0.12. To this value, we can add the direct effect of immobility (noted [3] in Figure 1) on the total number of trips, which is greater and reaches -0.35. This direct effect corresponds to the effect of one or more days without travel on the total number of trips. In the end, the effect of immobility on the number of employee trips is -0.47, which is significant since it represents 30% of the sum of the effects for the three motives considered according to additional computation.
Table 2 allows us to decompose these effects in the structural model by determinant and to observe that the main effects of immobility on the total number of trips are due to artefacts linked to the effects of school holidays and short walks, which means that the characteristics of employees have very little effect. It should also be noted that the direct and indirect effects of immobility in some cases reinforce and in others weaken the effects of the average number of journeys by motive, but never cancel each other out and have only a very limited modulating effect, whatever the determinant considered. It is just that, for low incomes, the direct and indirect effects of immobility are greater and represent more than 30% of the effects of the average number of trips by reason, according to additional computation.

Contribution to the general number of trips for retirees (structural model)

For retirees, the effects of immobility on travel are mostly negative, both for work+escort and for leisure, while they remain positive for grocery+medical (noted [1] in Figure 1). Immobility for retirees is rather associated with reduced mobility on mobile days, in particular for the leisure motive, which is the primary motive for these individuals and which makes the greatest contribution to the total number of trips (noted [2] in Figure 1). Then, by multiplying the [1]x[2] effects (Figure 1), we can assess the indirect effects of immobility, which amount to -0.14, i.e. slightly more than for employees. If we add this effect to the direct effect [3] (-0.51) we obtain a total of -0.65 as the effect of immobility on the number of weekly trips of retirees, which represents about 50% of the sum of the effects for the three motives considered. Immobility therefore plays a major role in the trip levels of retirees.
Table 3 allows us to decompose the effects by determinant in the structural model. Contrary to what happens for employees, the decomposition shows that for some determinants, immobility has a major effect on the number of trips. In the case of mobility difficulties, the negative effect is entirely due to the effects of immobility. The same is true for age and rural residence. For other determinants, the effects of immobility strongly reinforce the effect of the average number of trips on mobile days. These include low income earners and people living alone. Finally, it should be noted that variables for which immobility is potentially an artefact, such as holidays and short walks, show no significant effect on the total number of trips on mobile days.

Discussion

In the sample of employees and retirees only, the immobility rate is 17.8% during a weekday and 41% of individuals experience at least one day of immobility during a week of five weekdays.
These high values of immobility may be partly explained by the limitations of the survey, such as the partial inclusion of short walks, soft refusal, and respondents' fatigue in the case of an

observation period of a whole week. These effects have been documented in the literature and attempts made to accurately review their scope. However, the very different levels of immobility depending on the employment situation strongly undermine the hypothesis of immobility as an artefact of the survey methods alone. Indeed, there is no evidence of survey methodological problems affecting retirees, with a daily immobility rate of 29.8%, almost three times that of employees with a rate of only 11.4%. These results are consistent with those of Motte-Baumvol and Bonin (2018), who also show a threefold higher immobility rate for retirees than for employees from the French National Survey for 2008. This hypothesis as the only explanation for immobility must therefore be rejected.

Moreover, the explanation for the high values of immobility can only be partially linked to the effects of age, health, or income, which only explain part of the differences observed between retirees and employees (Motte-Baumvol & Bonin, 2018; Madre, Axhausen & Brög, 2007). This is supported by the results of this study, which measure these effects but also highlight the fact that it is the activity status that is the main determinant of immobility. This is why the approach developed in this work is based on what differentiates employees and retirees in terms of activities outside the home. In other words, an activity program that is less-constrained and less structured by commuting is likely to have greater temporal variability depending on the day and therefore likely to leave room for more frequent episodes of immobility.

These results are based on data from the UK NTS, which means immobility can be considered in a longer time perspective because the survey compiles a full week of observations. The results show that for employees, a higher probability of being immobile is associated, as expected, with a lower probability of making constrained trips such as commuting and escorting on mobile days. While immobility is not associated with fewer trips for other motives on mobile days, the opposite even occurs, reflecting a form of rebound effect on mobile days. This would therefore support the hypothesis of immobility as a sign of less-constrained but not necessarily reduced mobility for employees. In the end, immobility is linked to fewer trips on weekdays, but mainly because of days without mobility and not because of reduced mobility on mobile days, except for constrained trips.

For retirees, the picture is different. Firstly, because although immobility is associated with a lower probability of making work+escort trips, the constrained nature of these trips is questionable. Especially since the occurrence of these trips is very low. Secondly, the immobility of retirees is associated with fewer leisure trips on mobile days. Only trips for grocery+medical show a rebound on mobile days. This means that immobility for retirees is linked to reduced mobility on mobile days, with the exception of the only essential trips corresponding to grocery+medical. Finally, for retirees, exogenous determinants have far greater explanatory power for immobility, with variables such as mobility difficulties and age having a major impact on the probability of being immobile and the number of trips made during the week.

Conclusion

In conclusion, working on immobility is an important issue because it concerns a large part of the population and tends to recur frequently, as our results show. Two issues have been

particularly highlighted in the literature. Firstly, whether immobility is an artefact of travel surveys (Lucas & Madre, 2018) that can call into question the current measurement of mobility or secondly whether it corresponds to an extreme form of low mobility that is disastrous for the social life of individuals (Lévy, 2000). In view of the literature review and the values of immobility obtained from the NTS data, these two issues seem to be reduced, particularly in relation to the activity of individuals, which remains the main factor in immobility, but with an explanatory power that is reduced.

The relevance of the study of immobility nevertheless remains high and it is in this sense that this work has explored the individual variability of trips as a constituent element of immobility. The link between immobility and variability manifests itself in two ways in our results. Firstly, immobility is accompanied by activities that are less constrained in time and space, as is the case with the lower representation of travel for work and support. Secondly, there are rebound effects on mobile days, with more frequent trips for grocery/medical motives in particular, when there is an episode of immobility during the week. These results indicate that the practice of including immobility in the calculation of the mean of various individual mobility indicators appears questionable insofar as it takes into account situations that are not primarily related to low mobility per se but to variability in activity schedules. In fact, it offers a misleading result of what is the reality of individual practices. For example, if we do not consider immobile days in the calculation of the average number of trips per day, retirees make as many or more trips than employees, compared with one fewer trip per day on average when immobile episodes are considered.

From a methodological point of view, this paper has used an SEM to process UK NTS data and to study the time element of immobility by analyzing the articulation between immobile and mobile days. In particular, the use of SEM has enabled the development of a comprehensive approach to the phenomena at work in terms of mobility thanks to the articulation of exogenous variables, endogenous variables, and mediation effects in a path analysis type approach.

However, although the results show the relevance of an approach to immobility from the point of view of individual variability, the latter remains poorly explained by socio-economic variables, particularly with regard to employees. This result is consistent with work on the variability of travel (Raux, Ma & Cornelis, 2016; Li et al., 2018).

This means that the factors explaining individual variability are not well taken into account in the surveys. For working people, we can think of work, whose spatial and temporal constraints are not very detailed in the travel surveys, such as the actual working time, its distribution over the various weekdays or the possibility of teleworking. For retired people, information on involvement in associations or their social network or anything that could generate both spatial and temporal constraints could help us to understand the variability of travel and therefore immobility. This work therefore highlights the need to include questions in travel surveys that capture the level of potential variability in individuals' activity schedules. This should lead to a significant gain in the understanding and measurement of individuals' mobility practices.

Authors

All authors whose names appear on the submission

1) made substantial contributions to the conception or design of the work; or the analysis, or interpretation of data;

2) drafted the work or revised it critically for important intellectual content;

3) approved the version to be published;

4) agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

Adey, P. (2006) If Mobility is Everything Then it is Nothing: Towards a Relational Politics of (Im)mobilities. *Mobilities*. 1 (1), 75–94. doi:10.1080/17450100500489080.

Axhausen, K.W., Löchl, M., Schlich, R., Buhl, T. & Widmer, P. (2007) Fatigue in long-duration travel diaries. *Transportation*. 34 (2), 143–160.

Axhausen, K.W., Zimmermann, A., Schönfelder, S., Rindsfüser, G. & Haupt, T. (2002) Observing the rhythms of daily life: A six-week travel diary. *Transportation*. 29 (2), 95–124. doi:10.1023/A:1014247822322.

Bayart, C., Bonnel, P. & Havet, N. (2018) Daily (im)mobility behaviours in France: An application of hurdle models. *Transportation Research Part A: Policy and Practice*. 116, 456–467. doi:10.1016/j.tra.2018.07.003.

Belton-Chevallier, L. (2015) Prendre en compte l'immobilité dans les imaginaires de la mobilité. Illustration à partir de femmes modestes périurbaines. *SociologieS*. http://journals.openedition.org/sociologies/5155.

Cresswell, T. (2010) Towards a Politics of Mobility. *Environment and Planning D: Society and Space*. 28 (1), 17–31. doi:10.1068/d11407.

Delbosc, A. & Currie, G. (2011) The spatial context of transport disadvantage, social exclusion and well-being. *Journal of Transport Geography*. 19 (6), 1130–1137. doi:10.1016/j.jtrangeo.2011.04.005.

Dharmowijoyo, D.B.E., Susilo, Y.O. & Karlström, A. (2017) Analysing the complexity of day-to-day individual activity-travel patterns using a multidimensional sequence alignment model: A case study in the Bandung Metropolitan Area, Indonesia. *Journal of Transport Geography*. 64, 1–12. doi:10.1016/j.jtrangeo.2017.08.001.

Ferreira, A., Bertolini, L. & Næss, P. (2017) Immotility as resilience? A key consideration for transport policy and research. *Applied Mobilities*. 2, 1–16. doi:10.1080/23800127.2017.1283121.

Fol, S. & Gallez, C. (2014) Social inequalities in urban access: better ways of assessing transport improvments. In: *Urban access for the 21st century: Finance and governance models for transport infrastructure*. Routledge. Routledge. pp. 46–86. https://books.google.fr/books?hl=fr&lr=&id=_pD8AgAAQBAJ&oi=fnd&pg=PA46&dq=fol+gallez&ots=WHlt2cR5Zb&sig=zJ2sauO7ALwDklC6EXd52j767cc.

Golob, T.F. (2003) Structural equation modeling for travel behavior research. *Transportation Research Part B: Methodological*. 37 (1), 1–25.
Hägerstrand, T. (1970a) What about people in regional science? *Papers in Regional Science*. 24 (1), 6–21.
Hägerstrand, T. (1970b) What about people in regional science? *Papers in Regional Science*. 24, 7–21.
Hubert, J.-P., Armoogum, J., Axhausen, K.W. & Madre, J.-L. (2008) Immobility and Mobility Seen Through Trip-Based Versus Time-Use Surveys. *Transport Reviews*. 28 (5), 641–658. doi:10.1080/01441640801965722.
Kaufmann, V., Bergman, M.M. & Joye, D. (2004) Motility: mobility as capital. *International Journal of Urban and Regional Research*. 28 (4), 745–756.
Lévy, J. (2000) Les nouveaux espaces de la mobilité. In: M. Bonnet (ed.). *Les territoires de la mobilité*. Presses Universitaires de France. pp. 155–170.
Li, W., Houston, D., Boarnet, M.G. & Park, H. (2018) Intrapersonal day-to-day travel variability and duration of household travel surveys: Moving beyond the one-day convention. *Journal of Transport and Land Use*. 11 (1). doi:10.5198/jtlu.2018.984.
Lovejoy, K. & Handy, S. (2011) Social networks as a source of private-vehicle transportation: The practice of getting rides and borrowing vehicles among Mexican immigrants in California. *Transportation Research Part A: Policy and Practice*. 45 (4), 248–257.
Lucas, K. (2012) Transport and social exclusion: Where are we now? *Transport Policy*. 20, 105–113. doi:10.1016/j.tranpol.2012.01.013.
Lucas, K. & Madre, J.-L. (2018) Workshop Synthesis: Dealing with immobility and survey non-response. *Transportation Research Procedia*. 32, 260–267. doi:10.1016/j.trpro.2018.10.048.
Madre, J.-L., Axhausen, K.W. & Brög, W. (2007) Immobility in travel diary surveys. *Transportation*. 34 (1), 107–128.
Mattioli, G. & Anable, J. (2017) Gross polluters for food shopping travel: An activity-based typology. *Travel Behaviour and Society*. 6, 19–31. doi:10.1016/j.tbs.2016.04.002.
Monzon, A., Julio, R. & Garcia-Martinez, A. (2020) Hybrid methodology for improving response rates and data quality in mobility surveys. *Travel Behaviour and Society*. 20 (0). https://trid.trb.org/view/1696854.
Motte-Baumvol, B. & Bonin, O. (2018) The spatial dimensions of immobility in France. *Transportation*. 45 (5), 1231–1247. doi:10.1007/s11116-017-9763-5.
Motte-Baumvol, B., Massot, M.-H. & Byrd, A.M. (2010) Escaping Car Dependence in the Outer Suburbs of Paris. *Urban Studies*. 47 (3), 604–619. doi:10.1177/0042098009349773.
Motte-Baumvol, B. & Nassi, C.D. (2012) Immobility in Rio de Janeiro, beyond poverty. *Journal of Transport Geography*. 24, 67–76.
Pas, E.I. & Koppelman, F.S. (1986) An examination of the determinants of day-to-day variability in individuals' urban travel behavior. *Transportation*. 13 (2), 183–200. doi:10.1007/BF00165547.
Pellegrino, G. (2011) Introduction: Studying (Im)mobility through a Politics of Proximity. In: *The Politics of Proximity: Mobility and Immobility in Practice*. Ashgate. pp. 1–14. /paper/Introduction%3A-Studying-(Im)mobility-through-a-of-Pellegrino/8bdc507b9d9e73963fa5c97bf2ae05555e4b2c32.
Pucher, J. & Renne, J.L. (2005) Rural mobility and mode choice: Evidence from the 2001 National Household Travel Survey. *Transportation*. 32 (2), 165–186. doi:10.1007/s11116-004-5508-3.
Pucher, J. & Renne, J.L. (2003) Socioeconomics of urban travel: evidence from the 2001 NHTS. *Transportation Quarterly*. 57 (3). https://trid.trb.org/view/662423.

Raux, C., Ma, T.-Y. & Cornelis, E. (2016) Variability in daily activity-travel patterns: the case of a one-week travel diary. *European Transport Research Review*. 8 (4), 1–14. doi:10.1007/s12544-016-0213-9.
Schwanen, T., Kwan, M.P. & Ren, F. (2008) How fixed is fixed? Gendered rigidity of space–time constraints and geographies of everyday activities. *Geoforum*. 39 (6), 2109–2121.
Susilo, Y.O. & Axhausen, K.W. (2014) Repetitions in individual daily activity–travel–location patterns: a study using the Herfindahl–Hirschman Index. *Transportation*. 41 (5), 995–1011. doi:10.1007/s11116-014-9519-4.
Tarigan, A. & Kitamura, R. (2009) Week-to-Week Leisure Trip Frequency and Its Variability. *Transportation Research Record: Journal of the Transportation Research Board*. 2135, 43–51. doi:10.3141/2135-06.
Wixey, S., Jones, P., Lucas, K. & Aldridge, M. (2005) Measuring accessibility as experienced by different socially disadvantaged groups. *Social Research in Transport (SORT) Clearinghouse*.