MODELING THE INTERACTIONS BETWEEN COMMUTING, HOUSE AND JOB LOCATIONS: EVIDENCE FROM PORTUGUESE INTERCITY RAILWAYS

Guineng Chen (Correspondent Author), PhD Candidate, CESUR, Department of Civil Engineering, Architecture and Georesources, Instituto Superior Técnico, Technical University of Lisbon, Portugal, Email: guineng.chen@civil.ist.utl.pt

João de Abreu e Silva, Assistant Professor, CESUR, Department of Civil Engineering, Architecture and Georesources, Instituto Superior Técnico, Technical University of Lisbon, Portugal, Email: joao.abreu@civil.ist.utl.pt

ABSTRACT

Reduction in travel times between cities brings them “closer” to each other, thus enlarging job search area and increasing house location possibilities. It seems self-evident that the travel patterns are also profoundly related with the residential and job location decisions. The nature of their mutual influences for intercity/interregional commuters is not yet completely understood. To explore the mode choice behavior and the dynamics between intercity commuting patterns and the preferences of house and job locations, we use the stated preference (SP) data collected from the daily commuters from the two conventional railway lines in Portugal, which are Tomar-Lisbon (143km) and Santarém-Lisbon (78km). In the SP survey, we introduced the concept of compound decision, which allows the interviewees to make a relatively more realistic decision that integrates housing location, job location and commuting type. Applying multinomial logit models to the SP data, we then estimated the impacts of travel time and travel cost on the mode choice, and the impacts of the transport, housing and job characteristics on the probabilities of making the following 5 compound decisions: 1) maintain current situation, 2) keep the same job but relocate house to the urban area of Lisbon, 3) keep the same job but relocate house to the suburbs of Lisbon, 4) change job location to a nearby municipality and 5) change job location to the current municipality. The estimated results provide us with the trade-offs between the adopted attributes and the arc elasticity of the mode choice and decision choice probabilities with respect to those attributes.

Keywords: Railway Commuter, Mode Choice, House Location, Job Location.

INTRODUCTION

Long-distance commuters in this paper are referred to the workers who work in one metropolitan area, but reside in different administrative regions frequently beyond the ones that border that area. The geographical distribution of jobs is a very important factor for explaining the intercity or interregional commuting. In Portugal, the capital and the major cities have much more varieties of positions, vacant job opportunities as compared to the rest of the country. High workforce specialization and few jobs within ideal commuting time thus force some people to commute across cities or regions, because it is too costly to change job or move residence (Van Ham, 2001; Van Ham and Hooimeijer, 2009; Sandow and Westin, 2010; Van Ommeren and Rietveld, 2007). Over the past few decades, people have become less prone to migrate, due to the rise in the share of dual-earner and dual-career households, but has become more acceptable towards a longer commute (Van Ham, 2001; Jarvis, 1999). The nature of dual-career family influences the choice of residence, because attention must be paid to the two parties and it is more difficult to combine family and work demands. Commuting tolerance has undoubtedly grown over the past few decades, through faster means of transport (Rouwendal and Rietveld, 1994). Therefore, commuting is becoming a means to balance a geographical mismatch of labor supply and demand , and long-distance daily and weekly commuting are an increasingly important substitute for migration (Green et al., 1999; Lundholm et al., 2004; Lundholm, 2010).

Commuting is considered a key factor to understand changing urban structures (Vickerman, 1984; Clark and Kuijpers-Linde, 1994). Commuting behavior is closely related to residential and job locations, higher commuting distance or longer commuting time tends to make people more willing to change jobs or move residences, and the decision making of household with respect to migration, workplace relocation always involves the change of commuting distance (Wissen and Bonnerman, 1991; Zax and Kain, 1991; Van Ommeren et al., 1997; Van Ommeren et al., 2000). This suggests that labor and residential mobility are mutually dependent and should be simultaneously analyzed (Van Ommeren et al., 2000). It is well recognized and empirically verified that at urban level, transportation development changes the spatial pattern that is accompanied by changes in individual's housing and employment locations. This in turn causes changes in commuting patterns, and in the end in global travel behavior (Alpkokin et al., 2008). The links between urban sprawl, transport network development and travel behavior have been the focus of many researchers in the past few decades (Stead and Marshall, 2001; Oosterhaven and Elhorst, 2003). However, the impacts at intercity or interregional level are much less limited in the research field.

Another motivation of this paper is to set up a preliminary research on the dynamics between the formation of megalopolises along the future high-speed rail (HSR) line from Lisbon to Oporto and the emergence of super-commuting patterns from the potential HSR users. The commuting impact inside a megalopolis generated by HSR is a topic rarely covered in the existing literature. One of the main objectives of the upcoming implementation HSR in Portugal is to shape a Lisbon-Oporto megalopolis, which helps to minimize the negative effects of HSR on small and isolated urban areas and maximize the regional economic gains. With the implementation of HSR, the travel times between different cities will be significantly reduced which brings them "closer" to each other, and thus increase their potential interactions along the HSR line. The regional sprawl favored by the HSR operation, is expected to change the travel behavior of residents, such as the growth of peripheral commutes within this megalopolis. This very long distance commuting is frequently referred as “super-commuting”. The preliminary results will give insightful rules to the potential impact on the “super-commuting” demand for the people who will relocate either job or household locations to become the HSR commuter and for the ones who will move their residences or jobs to stop commuting.

In this paper, we focus on the commuting trips by railway from less populated municipalities to the capital city of Portugal. In this case, commuting to a metropolitan area where better job opportunities exist may produce or maintain a higher household income and an enhanced standard of living. To explore the mode choice behaviors and the dynamics between commuting patterns and the preferences of house and job locations, we use the stated preference (SP) data collected from the daily commuting passengers of the two conventional railway lines in Portugal, which are Lisbon-Tomar (143 km, about 1hour and 50 minutes by train) and Lisbon-Santarém (78 km, around 55 minutes by train). In the SP survey, we introduced the concept of compound decision, which allows the interviewees to make a relatively more realistic decision that integrates housing location, job location and commuting. Applying discrete choice modeling approach to the SP data, we then estimate the impacts of commuting cost, house size, salary level, age, local and social attachment on the probabilities of making the following 5 decisions: 1) maintain the current situation, 2) keep the same job but change house location to the urban area of Lisbon, 3) keep the same job but change house location to the suburbs of Lisbon, 4) maintain the same residence but change job location to a nearby municipality, 5) maintain the same residence and change job location to the same municipality. Besides, the mode choice behavior is also analyzed, which explains the impacts of travel time and cost on their mode choices. The estimated results indicate the trade-offs between the used attributes and the elasticity of the mode choice, residence relocation and job change probabilities with respect to those attributes.

LITERATURE REVIEW

The links between urban sprawl, transport network development and travel behavior have been the focus of many researchers in the past few decades. Travel behavior has often been studied as commuting within one metropolitan area. According to the neoclassical model of urban residential location, in a monocentric urban setting, households maximize their utility subject to their income constraints, and the optimization strategy is reflected by the trade-off between housing prices and commuting cost (Alonso, 1964; Muth, 1969; Mills, 1972). With the decreased transportation costs caused by the technological innovation, households may choose to live further from the city center, the workplace, and commute longer distance to enjoy the lower housing cost and better living condition. This residential location theory provides a basic explanation for commuting behavior.

As the cities get larger, the urban form is expected to diverge from a monocentric city to a more complex spatial pattern of employment clusters. The monocentric model has been criticized that the main assumptions are too restrictive to capture commuters’ behavior properly (Artís et al., 2000). Waddell, (1993) and Boarnet (1994) criticized the important assumption used in monocentric models namely that employment location is exogenous to population location within an urban area. The work of Boarnet (1994) showed that employment changes are endogenous to the population change in a surrounding labor market. The results presented by Waddell (1993) confirmed that a joint choice specification better represents actual choice behavior in a multi-nodal metropolis. Moreover, the assumption from the monocentric model that it presumed a perfect market condition under which workers were fully informed and were always able to choose the optimal amount of commuting distance has also been criticized. Contrarily, the search theory states that commuters continuously search for jobs or houses aiming to improve their situation, due to which commuting distances may change after the costly move of job or residence (Van Ommeren et al., 1997; Rouwendal, 1999; Van Ommeren et al., 2000). From the perspective of a search theory, commuting behavior is determined by the probability of receiving a job or residential offer at a certain distance, a decision-making process, and the decision to accept the offer (Van Ommeren et al., 1997). As a result, commuting behavior explicitly depends on moving behavior in the labor and housing markets. Such model allows us to analyze commuting behavior without making restrictive assumptions on the search process.

However, an individual faced with a lack of suitable job opportunities on the local labor market has to be spatially more flexible to find a job that matches his/her competence. The necessity to be spatially flexible is positively correlated with the number of jobs a worker can reach within acceptable commuting time (Van Ham, 2001; Van Ham and Hooimeijer, 2009). Nowadays, high workforce specialization has given rise to a situation in which labor markets offer few potential jobs within a moderate distance, thus forcing workers to commute across cities or regions. Although workers dislike long commutes and even if it is not fully compensated by higher wages, it is too costly to change job or move residence (Sandow and Westin, 2010; Van Ommeren and Rietveld, 2007).

Research analyzing the long distance commuting at intercity or interregional level has been limited. A common method used for studying commuting across regions is the utilization of regression models to analyze the causal effects of various factors upon the characteristics and choice of long distance commute (Öhman and Lindgren, 2003; Titheridge and Hall, 2006; Sandow and Westin, 2010). Öhman and Lindgren (2003) estimated a binomial logit model to find any possible explanatory differences between the group of long-distance commuters and the group of commuters over shorter distances (choice equal to 1, if the distance between the residence and work place coordinates is 200 km or more, 0 otherwise). The longitudinal micro database contains information about demography, education, household situation, employment, income, and geographic location for the entire Swedish population. They concluded that social ties, individual characteristics, preferences and norms, household composition, etc., all would influence people's choice of longer commute.

The study of Titheridge and Hall (2006) focused on the East Corridor and the North Corridor radiating from London to the periphery of the region, where rail service is available. Six models were created, one for each of the dependent variables, commuting distance and five different commuting modes, for each corridor and the years 1981 and 1991 based on the Census data. They concluded that a lack of job opportunities close to the place of residence was a strong feature of longer commutes. In addition, they found that higher social classes travelled the longest distances, and rail travel was strongly determined by the level of rail access at the workplace. In the study of Sandow (2008), the variables age, education level, income level, employment sector, family status, presence of children in different age groups, population density and employment opportunities were used in a binary logistic regression as explanatory variables for individuals' decisions to have a long (longer than 50 km) or short (shorter than 50 km) commuting distance. The results showed that the local labor market's geographical structure is important. Overall, most individuals commute within their locality of residence and women commute shorter distances than men do.

Van Ham and Hooimeijer (2009) estimated logistic regression models based on the Netherlands Housing Demand Survey data from 2002 to examine the determinants of both long commutes and intentions to migrate for a job. The results further proved the importance of individual and household characteristics to the longer journey to work, and also show that living in the highly urbanized western part of the Netherlands increases the probability that workers opt for long commutes. Living in the more peripheral regions increases the probability that workers think about moving residence. The results further show that workers with long commutes are more likely to have the intention to move residence in the near future than workers with short commutes. Sandow and Westin (2010) carried out multivariate regression analyses based on the register date for the years 1995-2005 covering all long-distance commuters in Sweden to identify effects of different socio-economic, geographic and demographic factors on the duration of long-distance commuting. They found that previous experience of long-distance commuting makes it more likely to have a long duration of long-distance commuting, and the economic incentives are important for continuing to commute long-distance. They concluded that the long-distance commuting can sustain not only gender differences on the labor market but also within households, and long-distance commuting tends to be a strategic mobility choice for households, rather than a short-term solution. Westin and Sandow (2010) conducted a survey of 2,500 individuals in 2004 in six municipalities of northern Sweden and analyzed people's willingness to commute, in terms of travel time and modal choice. The results showed that geographical structure, available infrastructure, and socio-economic factors (such as education, employment, and family situation) are found to restrict women's access to the local labor market to a greater extent than men's. The survey also revealed that the inclination to commute declines rapidly when commuting times exceed 45 minutes, regardless of gender, transport mode, and socio-economic factors.

The existing literature has heavily concentrated on short-distance commuting within urban systems. It is unclear whether the conclusions from short-distance trips can be transposed easily to longer-distance trips given that the latter involves more time and monetary costs. A person undertaking a longer-distance trip should face a different decision situation than an individual making a short-distance trip, and may therefore respond differently. It is important for urban/regional policymakers to understand the main determinants of commuting behavior and their development over time. However, this is a complicated issue because commuting patterns emerge from interaction between housing and labor markets and transport infrastructure. The purpose of this paper is to shed some light on an explanation of this complex interaction, the decision making of workers with respect to housing, employment, and commuting. We do so by analyzing data obtained from a SP experiment of a sample of daily rail commuter respondents.

SURVEY AND DATA

The principal objective of this paper is to explore how travel time and travel cost will influence the choice of modes for the existing railway commuters and how the factors related to job and housing and commuting influence the decision of the respondents in terms of house or job relocation . So in order to investigate these effects, an in-depth computer-based 'face-to-face' survey was carried out in January 2013. This survey was conducted on two conventional railway services: Lisbon-Tomar (143 km, about 1hour and 50 minutes by train) and Lisbon-Santarém (78 km, around 55 minutes by train).A total of 450 passengers in the two intercity services were randomly selected. After cleaning up the data, it leaves us with 400 valid observations. The geographical locations are presented in Figure 1. Tomar is a city of about 20,000 inhabitants and seat of Tomar municipality, which has a total area of 351.0 km² and a total population of 40,674 inhabitants (INE, 2011). Santarém with 29,180 inhabitants is the seat of the same municipality with 560.2 km² and 62,200 inhabitants (INE, 2011). Based on the 2001 census, there were about 432 people commuting from Tomar to work in Lisbon and 1285 people commuting from Santarém to work in Lisbon daily (INE, 2001). This represents an increase of 54% and 58%, respectively when compared to the 1991 census data (see Figure 2). Similar records are not made available yet in the latest Census in 2011.

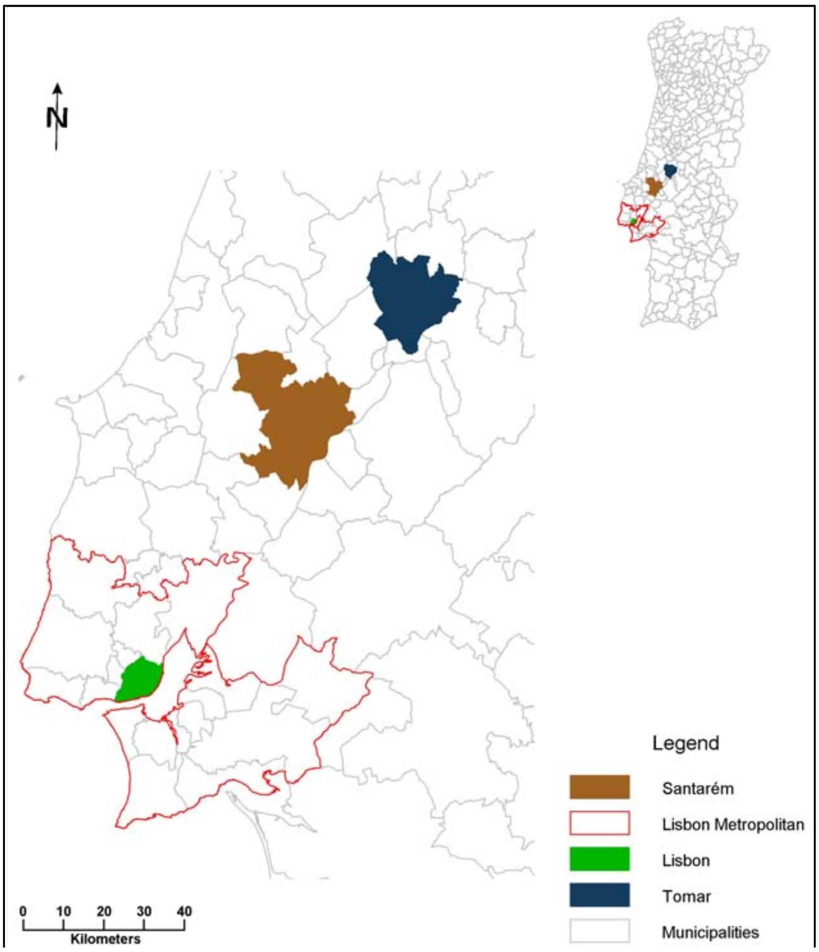

Figure 1 – Study Area

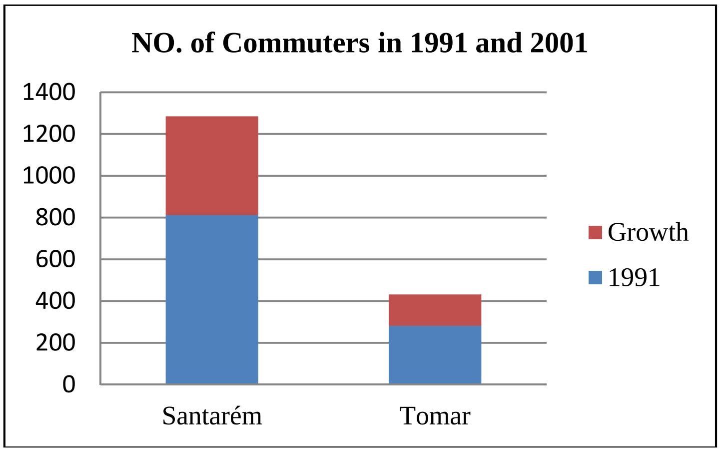

Figure 2 – Number of Commuters in 1991 and 2001

The questionnaire contained two main sections, one for RP and one for SP. The first part asked questions about a respondent's background concerning their personal, household, commuting and financial characteristic, such as age, education level, occupation, marital status, number of children, salary level, rent/mortgage level, housing size, neighborhood type, commuting time and commuting cost, etc. (see Table 1).

Table 1 - Attributes in RP Section

Variable	Explanation	Variable	Explanation
ID	Interviewee ID	**HOS**	House Ownership Status
Age	Age of Interviewee	**HS**	House Size
ED	Education	**NT**	Type of Neighborhoods
MS	Marital Status	**NPS**	Number of Parking Spots
OC	Occupation of Interviewee	**HA**	House Address
WA	Work Address of Interviewee	**TTHT**	Travel Time from Home to Train Station
TRP	Transit Pass Ownership	**MHS**	Mode from Home to Train Station
DL	Driver License Ownership	**TTIT**	TT in Train
NOC	Number of Cars in the House	**TTSW**	TT from Lisbon Station to Work
DCA	Daily Car Access	**MSW**	Mode from Lisbon Station to Work
SN	Support Network	**KR**	Kiss and Ride
NOCH	Number of Children	**TTC**	Total Travel Cost to Work
AOP	Age of Partner	**ETL**	Errand Type in Lisbon
OOP	Occupation of Partner	**EFL**	Errand Frequency in Lisbon
WAOP	Work Address of Partner	**HEX**	Household Expenses per Month
PMTW	Partner Mode to Work	**SL**	Salary Level per Month
PTTW	Partner Travel Time to Work	**ML**	Mortgage Level per Month
AOC	Age of Child	**RL**	Rent Level per Month
OOC	Occupation of Child	**HVL**	Preference of Home over Lisbon
WAOC	Study/Work Address of Child	**IVSN**	Importance of Vicinity to Social Network
CMTW	Child Mode to School/Work	**HSL**	House Satisfaction Level
CTTW	Child Travel Time to School/Work	**NSL**	Neighborhood Satisfaction Level
HT	House Type	**IBSN**	Importance of Benefit from Social Network

Commuting consumes time and money, which could otherwise be used for work, leisure or consumption. Inefficient commute could impost excessive costs in both respects. Moving to a more convenient residence, changing to closer workplaces and switching to a more efficient transport mode are the three typical solutions to substitute or reduce the inconvenience of

commuting. The second part contains the questions about the mode choices provided with hypothetical mode choice situations and the propensity of whether to change job to current municipality or the nearby municipalities of the current residence, or to move residence to Lisbon urban area or to a Lisbon suburb, under the given circumstances. Each interviewee is provided with two different circumstances for mode choice and decision choice respectively.
In the SP survey of mode choices, each respondent was asked to choose between three hypothetical choices, namely new rail, private car and bus, together with the current choice called current rail. In the mode choice SP experiments, each of the alternatives is defined by two attributes, travel time and travel cost, and each attribute exists at three levels, low, medium and high. The definition of each level is presented in Table 2. Applying an orthogonal design (where every attribute varies independently of each other), it allows us to estimate all the main effects whilst dramatically reduce the number of alternatives (Hensher, 1994), thus leaves us with 18 scenarios. Each of the scenarios is unique and contains different combination of the attributes for new rail, car and bus.

Table 2 – SP Experiment Design for Mode Choices

Attributes	**Levels**	**Current Rail**	**New Rail**	**Car**	**Bus**
Travel Time (min)	Low	Current Values	-50%	-30%	-20%
	Med		-35%	-15%	-10%
	High		-25%	-10%	-5%
Travel Cost (€)	Low		20%	15%	5%
	Med		30%	25%	15%
	High		50%	30%	25%
Choices		**[ ]**	**[ ]**	**[ ]**	**[ ]**

The impact on house and job locations may change with the provided circumstances. For example, if the transport service becomes less efficient, it is more likely that households will look for a job closer to their homes to balance out the high travel cost. And, if the housing cost is high and housing size is small near the workplace, longer commuting distance becomes more acceptable, since it is more expensive to relocate closer to work. Or, if the worker is provided with a better job in which is sufficient enough to afford the more costly housing, the decision to move or stay will also vary. Therefore, to analyze the decisions under different circumstances, in the SP survey, we provide different scenarios for the respondents to make the decision accordingly, namely:

- Decision 1 (CUR): Maintain the current situation;
- Decision 2 (LLU): Keep the job, change house location to the city of Lisbon;
- Decision 3 (LLM): Keep the job, change house location to the suburb of Lisbon;
- Decision 4 (WNM): Maintain the house, change job to a closer municipality;
- Decision 5 (WCM): Maintain the house, change job to the current municipality.

Each decision was designed based on their current situations revealed in the RP section. In the decision choice SP experiments, each of the alternative decisions is defined by five attributes, house size, house cost (rent/mortgage level), salary level, commuting time by car and commuting cost by car, and each attribute exists at three levels, low, medium and high (see Table 3). After applying the fully orthogonal design, it reduces the hypothetical alternatives for Decision 2 and Decision 3 to 16, and 9 for decision 4 and decision 5. For each scenario presented to an interviewee, four alternatives are randomly withdrawn respectively from the choice set of each Decision.

Table 3 - Attributes and Levels in SP Section

Attributes	Levels	Decision1	Decision2	Decision3	Decision4	Decision5
House Size (m^2)	Low Med High	Maintain Current Situation	60 100 150	60 100 150	*Same as Current Value*	*Same as Current Value*
House Cost (€/month)	Low Med High		550 900 1500	450 850 1300	*Same as Current Value*	*Same as Current Value*
Neighborhood Type*	Low Med High		Suburb Urban Downtown	Suburb Urban Downtown	*Same as Current Value*	*Same as Current Value*
Salary Level	Low Med High		*Same as Current Value*	*Same as Current Value*	-15% -5% 5%	-15% -5% 5%
Travel Time by Car (min)	Low Med High		10 20 35	20 30 45	15 25 40	10 15 25
Travel Cost by Car (€)	Low Med High		1 2.5 4	3 5 7	2 3 5	0.5 1.5 2
Choices		**[ ]**	**[ ]**	**[ ]**	**[ ]**	**[ ]**

**neighborhood type contains: rural, urban, suburb and downtown;*

MODEL DESIGN

Multinomial Logit Model (MNL) (Train, 2003) have been applied to explain the choice behaviors of the people. Generally, people are considered to choose the mode which gives them highest utility, denoted as U_i^n, meaning the utility of individual n choosing alternative i. It is consisted of two parts, measurable utility (V_i^n) also known as indirect utility and unobservable term (ε_i^n). Measurable utility (V_i^n) depends on the values of all the observable attributes, while unobservable term can help to explain an individual's unexpected choice which is not consistent with utility maximization behavior. The utility (U_i^n) can be expressed as:

$$U_i^n = V_i^n + \varepsilon_i^n$$

The probability of choosing this mode is equal to the probability that alternative i has greater utility than other alternatives in the choice set Ω_n,

$$P_i^n = P\left(V_i^n + \varepsilon_i^n > V_j^n + \varepsilon_j^n\right) \quad i, j \in \Omega_n; i \neq j$$

As indicated earlier, the model structure used in this study for mode choice is the multinomial logit (MNL) model. If the unobserved error terms of each alternative are identically and independently distributed (iid), which in other words means all the alternatives, are irrelevant and independent (IIA). Then the model is an MNL Model. The probability for an individual n to choose alternative i is written as:

$$P_i^n = \frac{e^{V_i^n}}{\sum_j e^{V_j^n}}, i, j \in \Omega_n$$

Mode Choice Model

In the mode choice model, the choice set Ω_n comprehends four different modes, namely current rail, new rail, car and bus, which are denoted as CR, NR, CAR and BUS respectively. Thus, the measurable utilities of all the modes individual n are formulated as:

$$V_{CR}^n = \beta_1 * TT_{CR}^n + \beta_2 * TC_{CR}^n$$

$$V_{NR}^n = ASC_{NR} + \beta_1 * TT_{NR}^n + \beta_2 * TC_{NR}^n$$

$$V_{CAR}^n = ASC_{CAR} + \beta_1 * TT_{CAR}^n + \beta_2 * TC_{CAR}^n$$

$$V_{BUS}^n = ASC_{BUS} + \beta_1 * TT_{BUS}^n + \beta_2 * TC_{Bus}^n$$

Where, ASC is the alternative specific constant introduced for each of the mode choice alternatives to account for the effect of the mean of unobserved modal factors, TT and TC are the travel time and travel cost respectively, and β_1 and β_2 are the coefficients of travel time and travel cost respectively.

Decision Choice Model

In the decision choice model, the respondent is assumed to select one decision out of the choice set, which contains a joint relationship between residential location and work location, so as to maximize its utility. The choice set Ω_n for decisions contains five alternatives, which are explained in the previous chapter as five different decisions, denoted in the following sections as CUR, LLM, LLU, WNM and WCM. The indirect utility of each decision is given by,

$$V_{CUR}^n = \gamma_1 * HS_{CUR}^n + \gamma_2 * TC_{CUR}^n + \gamma_3 * AGE40_{CUR}^n$$

$$V_{LLU}^n = ASC_{LLU} + \gamma_1 * HS_{LLU}^n + \gamma_2 * TC_{LLU}^n + \gamma_4 * ATACH_{LLU}^n$$

$$V_{LLS}^n = ASC_{LLS} + \gamma_1 * HS_{LLS}^n + \gamma_2 * TC_{LLS}^n + \gamma_4 * ATACH_{LLS}^n$$

$$V_{WNM}^n = ASC_{WNM} + \gamma_2 * TC_{WNM}^n + \gamma_5 * SALARY_{WNM}^n$$

$$V_{WCM}^n = ASC_{WCM} + \gamma_2 * TC_{WCM}^n + \gamma_5 * SALARY_{WCM}^n$$

Where, HS is the house size; TC is the travel cost; $AGE40$ is the dummy variable that equals to 1 for age greater or equal to 40, 0 otherwise; $ATACH$ is the computed variable indicating local and social attachment (see Table 4); and γ_1, γ_2, γ_3, γ_4 and γ_5 are the estimated coefficients.
To incorporate the effects of the local and social attachment to the decision choice model, we thus carried out a factor analysis based on the four variables that we have collected concerning their housing satisfaction level, neighborhood satisfaction level, importance of the vicinity to social network, and the importance of being benefit from the social network. The extraction results are presented in the following table. This extracted component is considered as the factor describing the "local and social attachment", denoted as $ATACH$.

Table 4 – Factor Analysis Results

Variable	Factor Loadings
HSL	0,769
NSL	0,776
IVSN	0,650
IBSN	0,596

** Extraction Method: Principal Component Analysis*
KMO=0,632

RESULT ANALYSIS

Table 5 reports the estimation results of MNL Models for the data of Santarém and Tomar respectively. All the t-values of the estimated parameters are significant at a 95% confidence level. These two models fit the data fairly well with rho-squares of 0.528 and 0.432. Moreover, the likelihood ratio test between the model with constants only and the full model shows that both test values are greater than the critical chi-square value with 2 degrees of freedom at 95% significance level, 5.99, so one can reject the hypothesis that these two models are equal, and conclude that the final models have been significantly improved.

Table 5– Estimation Results of Mode Choice

	Santarém		**Tomar**	
Parameter	Value	t-value	Value	t-value
ASC_NR	-1,49	-4,25	-1,15	-2,81
ASC_Car	-3,19	-10,4	-3,26	-6,85
ASC_Bus	-5,39	-7,49	-4,23	-5,80
TT	-0,0389	-2,75	-0,0442	-3,59
TC	-0,242	-3,30	-0,161	-2,06
Value of time	9,65 (€/h)		16,53 (€/h)	
Number of Observations	592		204	
McFadden rho squared	0,528		0,432	
Log-likelihood (Betas)	-387,702		-160,761	
Log-likelihood (zero betas)	-820,686		-282,804	
Log-likelihood (ASC)	-396,768		-169,571	
Degree of Freedom	2		2	
LL-Ratio Test Value	17,62		18,13	
Critical Value at 95%	5,99		5,99	

Furthermore, each of the explanatory variables has the expected sign, such as the negative coefficients for travel time and travel cost indicating the negative correlation with the mode choice utility. It is worth pointing out that the alternative specific constants show the general preferences among the four modes, from which one can conclude that both groups of railway commuters prefer their current rail mode the most, then follow with the new rail, car and bus. The relative magnitude of the coefficient travel time and travel cost reveals the value of time (VOT) for each group of the commuters. For the commuters from Santarém, their VOT is 9.65€/h, lower than 16.53€/h for the people commuting from Tomar. The increasing effects of distance on VOT found in the results is in fact in accordance with a number of existing studies acknowledging the continuous nature of the relationship between the VOT and trip distance (Mackie et al., 2003; Axhausen et al., 2008).
Table 6 presents the sensitivity analysis of the mode choice probability with respect to the variables travel time and travel cost, based on the calculated arc elasticity. Arc elasticity is the ratio of the percentage change of one variable between the two points to the percentage change of the other variable (Sinha and Labi, 2011). In our case, the two points are the ones where the variable values equal to the average values, and the 10% increase of the mean values. Formula for the arc elasticity of the choice probability P with respect to a variable z that enters the utility function is,

$$E_{(P,z)} = \frac{\Delta\%_P}{\Delta\%_z}$$

Where $\Delta\%_\mathrm{P}$ is the percentage change of the alternative choice probability and $\Delta\%_\mathrm{z}$ is the percentage change of the value for attribute z. The cross-elasticity is the same for all the other alternatives. With the calculated elasticities, we thus present the sensitivity analysis of the mode choice probabilities, as in Table 6.

Table 6 – Sensitivity Analysis of Mode Choice Model

Santarém	**% Change of P_CR**	**% Change of P_NR**	**% Change of P_Car**	**% Change of P_Bus**
10% increase in TT_CR	-5,76	17,59	17,59	17,59
10% increase in TC_CR	-4,81	14,68	14,68	14,68
10% increase in TT_NR	2,83	-10,47	2,83	2,83
10% increase in TC_NR	4,88	-18,04	4,88	4,88
10% increase in TT_Car	0,51	0,51	-16,04	0,51
10% increase in TC_Car	0,63	0,63	-19,99	0,63
10% increase in TT_Bus	0,06	0,06	0,06	-17,70
10% increase in TC_Bus	0,07	0,07	0,07	-19,23
Tomar	**% Change of P_CR**	**% Change of P_NR**	**% Change of P_Car**	**% Change of P_Bus**
10% increase in TT_CR	-13,41	19,35	19,35	19,35
10% increase in TC_CR	-6,09	8,78	8,78	8,78
10% increase in TT_NR	7,32	-12,43	7,32	7,32
10% increase in TC_NR	7,07	-12,01	7,07	7,07
10% increase in TT_Car	0,68	0,68	-22,50	0,68
10% increase in TC_Car	0,49	0,49	-16,14	0,49
10% increase in TT_Bus	0,24	0,24	0,24	-24,64
10% increase in TC_Bus	0,15	0,15	0,15	-15,59

Note: CR and NR stand for current rail and new rail respectively

From Table 6, one can see that both groups of commuters from Santarém and Tomar are more sensitive to the change of travel time than to travel cost of the current railway service. However, when it comes to the new transport modes, these two groups have different responses. The respondents from Santarém are more sensitive to the change of travel cost, and on the contrary, the commuters from Tomar are more sensitive to the change of travel time. This difference could suggest that for railway commuters, relatively shorter distance commuters value the cost more than the time of a trip, however, as the commuting distance increases, commuters become more sensitive to the changes in travel time than to travel cost. This effect can be observed by comparing the differences between each pair of own-elasticity for both Santarém case (shorter commuting distance) and Tomar case (longer commuting distance).

For the commuters from Santarém, 10% increase in the travel time of the current rail will decrease its own choice probability by 5.76% and increase the choice probability of switching to other mode by 17.59%, while 10% increase in the travel cost of the current rail will decrease its own probability by 4.81% and increase the mode switch probabilities by 14.68%. The commuters from Tomar are more sensitive to the changes in the travel time and travel cost. 10% increase in the travel time of the current rail will decrease its own choice probability by 13,41% and increase the choice probability of other mode by 19,35%, while 10% increase in the travel cost of the current rail will decrease its own probability by 6,09% and increase other probabilities by 8,78%.

Table 7 presents the estimation results of Decision Choice models for the pooled data of Santarém and Tomar. After removed the incomplete observations, the total number of valid observations for the decision choice model is 690. In the estimated results, the t-values of all the estimated parameters are significant at 95% confidence level. And the model fits the data fairly well with rho-squares of 0.423. And the likelihood ratio test between the model with constants only and the full model shows that the test values are greater than the critical chi-square value with 5 degrees of freedom at 95% significance level, 11.07, so one can conclude that the final model has been significantly improved.

The estimated parameters have the expected sign. The positive sign of house size (HS) indicated the increasing effect of house size on the utility of making the decision. The negative sign of travel cost (TC) shows the negative effect on the corresponding utility. The variable $AGE40$ shows that people who are greater or equal to 40 years old tend to opt to maintain the current situation. The negative sign of the computed local and social attachment variable $ATTACH$ shows that people who are more satisfied with the current housing condition and highly values the vicinity to the social networks prefer living in the current house and work in the nearby or the current municipality to relocating their houses to Lisbon. The coefficient of $SALARY$ means that if the salary level in the nearby municipality or the current municipality is higher, the possibility of changing the job will increase.

The alternative specific constants show that, in general, this group of respondents prefers to live in their current houses but work in a nearby municipality the most. Maintaining the long distance commuting to work in Lisbon is the second option in line. However, it is surprising that the option of working and living in the current municipality is the least preferred option. The possible reason could be that this group of people is clearly aware of the labor market condition in their current municipalities, thus introduced the prejudice to this option and ignored the hypothetical condition that we created for them. In the survey, only three respondents had chosen this option. Relocating the residence to Lisbon is the third preferred decision, in which living in the urban area of Lisbon is more desired than living in the suburb.

Table 7 – Estimation Results of Decision Choice

Parameter	Value	t-value
ASC_LLU	-1,41	-5,99
ASC_ LLS	-1,74	-7,16
ASC_ WNM	0,589	1,99
ASC_ WCM	-3,7	-7,47
HS	0,00251	2,00
TC	-0,0524	-2,42
SALARY	0,00048	2,80
AGE40	0,464	2,53
ATTACH	-0,549	-4,95
Number of Observations	690	
McFadden rho squared	0,423	
Log-likelihood (Betas)	-640,386	
Log-likelihood (zero betas)	-1110,512	
Log-likelihood (ASC)	-667,933	
Degree of Freedom	5	
LL-Ratio Test Value	55,09	
Critical Value at 95%	11,07	

Table 8 presents the elasticity analysis of the changes in decision choice probability with respect to the changes in the variables. If the current travel cost increases by 10%, the probability of maintaining the current situation will decrease by 3.22%. If the housing sizes in the urban and suburban area of Lisbon increase by 10%, the possibility of relocating to the corresponding area will increase by 2.24% and 2.29% respectively. Finally, 10% increase in the salary level of the nearby municipality will increase the probability of job change by 2.39%. And same percentage change in the salary level of the current municipality will increase the possibility of changing the jobs to the current municipality by 6.94%.

Table 8 – Sensitivity Analysis of Decision Choice Model

	% Change of P_CUR	% Change of P_LLU	% Change of P_LLS	% Change of P_WNM	% Change of P_WCM
10% increase in TC_CUR	-3,22	1,07	1,07	1,07	1,07
10% increase in HS_LLU	-0,14	2,24	-0,14	-0,14	-0,14
10% increase in HS_LLS	-0,09	-0,09	2,29	-0,09	-0,09
10% increase in SALARY_WNM	-4,32	-4,32	-4,32	2,39	-4,32
10% increase in SALARY_WCM	-0,07	-0,07	-0,07	-0,07	6,94

To summarize it, travel cost, house size and salary levels are shown to be the three most important factors for house relocation and job changing to happen, which are accompanied by the changes of the mobility strategy. The change of travel cost is seen as critical for the decision of whether to maintain the current situation or not. House size is the most important determinant for the residence relocation decision to Lisbon. And increasing the salary level in the current and nearby municipalities could be the determining factor to attract workers back to the local labor market.

CONCLUSIONS

We have adopted SP survey and discrete choice modeling techniques to estimate the weights to the common factors for transport modes, housing and job conditions, in terms of the ex-ante decision making. These weights were estimated in an ex-ante experiment using repeated hypothetical discrete choices of the provided modes and the predefined house relocation and job changing decisions, together with their current situations. The results revealed respondents' trade-offs between the various attributes by the use of a fractional factorial design. The value of time and elasticities were derived and interpreted.

The mode choice model studies the effects of the travel time and travel cost on their future mode choices. The main conclusions based upon the mode choice model is that generally the railway commuters have the highest preference for their current mode choice, and are less sensitive to the changes of railway service than to the other modes. Their VOT increases as the commuting distance grows. And the sensitivity towards the travel time is also positively correlated with commuting distance. Longer distance commuters are more sensitive to the changes in travel time than travel cost, opposite for the shorter distance commuters. The decision choice model analyzes the impact of housing, job and commuting attributes on their long-term decisions regarding whether to main the current situation, relocate the residence or change the job. An essential feature of the model design is that the respondents who consider a job or residence move also take into account of the future commuting behavior, where commuting time and cost alters after every decision making. The main findings are that the respondents who are over 40 years old have higher tendency of maintaining their current situations. Travel cost, house size and salary level are proven to be the three most important factors to affect their decisions of relocating residences or changing jobs. Moreover, the local and social attachment, such as the satisfaction level towards the house and neighborhood conditions and the importance of being close and having benefit from social network, have also shown a high impact on the residence relocation decisions.

In spite of the impacts concluded above, in practice the provision of highly developed transportation facilities, the dispersal of job opportunities and the flexibility of housing locations have created a much more complex behavioral response to the linkage between work and residence. We have also noticed this complexity while fitting the models. The housing cost and commuting time provided in the SP experiment for decision choice questions were not able to result in a significant impact on the residence and job move decisions. This could be attributed to the irrational responding or the insufficient sample size. However, this research provides us with a rather adequate starting point for a more in-depth research on the interaction between intercity/interregional commuting pattern, residence relocation and work change in the future.

ACKNOWLEDGEMENTS

This research was developed in the framework of the EXPRESS Research Project (MIT/SET/0023/2009) sponsored by the Portuguese national research funds through

FCT/MCTES (PIDDAC) and co-financed by the European Regional Development Fund (ERDF) under the Operational Agenda for Competitiveness Factors – COMPETE. The authors would like to thank REFER (Portuguese Rail network Manager) and CP (Portuguese Rail Operator) for their help in the data collection process.

REFERENCES

Alonso, W., 1964. Location and land use: toward a general theory of land rent. Harvard University Press.
Alpkokin, P., Cheung, C., Black, J., Hayashi, Y., 2008. Dynamics of clustered employment growth and its impacts on commuting patterns in rapidly developing cities. Transportation Research Part A: Policy and Practice 42, 427–444.
Artís, M., Romaní, J., Suriñach, J., 2000. Determinants of Individual Commuting in Catalonia, 1986-91: Theory and Empirical Evidence. Urban Stud 37, 1431–1450.
Axhausen, K.W., Hess, S., K&ouml, nig, A., Abay, G., Bates, J.J., Bierlaire, M., 2008. Income and distance elasticities of values of travel time savings: New Swiss results. Transport Policy 15, 173–185.
Boarnet, M.G., 1994. The Monocentric Model and Employment Location. Journal of Urban Economics 36, 79–97.
Clark, W.A.V., Kuijpers-Linde, M., 1994. Commuting in Restructuring Urban Regions. Urban Stud 31, 465–483.
Green, A.E., Hogarth, T., Shackleton, R.E., 1999. Longer distance commuting as a substitute for migration in Britain: a review of trends, issues and implications. International Journal of Population Geography 5, 49–67.
Hensher, D.A., 1994. Stated preference analysis of travel choices: the state of practice. Transportation 21, 107–133.
INE, 2001. Census Report. Instituto Nacional de Estatística of Portugal.
INE, 2011. Census Report. Instituto Nacional de Estatística of Portugal.
Jarvis, H., 1999. Identifying the relative mobility prospects of a variety of household employment structures, 1981 - 1991. Environment and Planning A 31, 1031 – 1046.
Lundholm, E., 2010. Interregional Migration Propensity and Labour Market Size in Sweden, 1970–2001. Regional Studies 44, 455–464.
Lundholm, E., Garvill, J., Malmberg, G., Westin, K., 2004. Forced or free movers? The motives, voluntariness and selectivity of interregional migration in the Nordic countries. Population, Space and Place 10, 59–72.
Mills, E.S., 1972. Studies in the structure of the urban economy. Johns Hopkins Press, Baltimore, MD.
Muth, R.F., 1969. Cities and Housing : The Spatial Pattern of Urban Residential Land Use. IL: University of Chicago Press, Chicago.
Mackie, P., M. Wardman, A. S. Fowkes, G. Whelan, J. Nellthorp and J. J. Bates (2003) Values of travel time savings in the UK. Institute for Transport studies, University of Leeds, Working Paper 567.
Öhman, M., Lindgren, U., 2003. Who is the long-distance commuter? Patterns and driving forces in Sweden. European Journal of Geography 2–24.
Oosterhaven, J., Elhorst, J.P., 2003. Effects of Transport Improvements on Commuting and Residential Choice (ERSA conference paper No. ersa03p29). European Regional Science Association.
Rouwendal, J., 1999. Spatial job search and commuting distances. Regional Science and Urban Economics 29, 491–517.
Rouwendal, J., Rietveld, P., 1994. Changes in Commuting Distances of Dutch Households. Urban Stud 31, 1545–1557.

Sandow, E., 2008. Commuting behaviour in sparsely populated areas: evidence from northern Sweden. Journal of Transport Geography 16, 14–27.
Sandow, E., Westin, K., 2010. The persevering commuter – Duration of long-distance commuting. Transportation Research Part A: Policy and Practice 44, 433–445.
Sinha, K.C., Labi, S., 2011. Transportation Decision Making: Principles of Project Evaluation and Programming. John Wiley & Sons.
Stead, D., Marshall, S., 2001. The Relationships between Urban Form and Travel Patterns: An International Review and Evaluation. European Journal of Transport and Infrastructure Research 1 (2), 113 – 141.
Titheridge, H., Hall, P., 2006. Changing travel to work patterns in South East England. Journal of Transport Geography 14, 60–75.
Train, K., 2003. Discrete Choice Methods With Simulation. Cambridge University Press.
Van Ham, M., 2001. Workplace mobility and occupational achievement. International Journal of Population Geography 7, 295–306.
Van Ham, M., Hooimeijer, P., 2009. Regional Differences in Spatial Flexibility: Long Commutes and Job Related Migration Intentions in the Netherlands. Appl. Spatial Analysis 2, 129–146.
Van Ommeren, J., Rietveld, P., 2007. Compensation for commuting in imperfect urban markets*. Papers in Regional Science 86, 241–259.
Van Ommeren, J., Rietveld, P., Nijkamp, P., 1997. Commuting: In Search of Jobs and Residences. Journal of Urban Economics 42, 402–421.
Van Ommeren, J., Rietveld, P., Nijkamp, P., 2000. Job mobility, residential mobility and commuting: A theoretical analysis using search theory. Ann Reg Sci 34, 213–232.
Van Wissen, L.J.G., Bonnerman, F., 1991. A dynamic model of simultaneous migration and labour market behaviour (Serie Research Memoranda No. 0020). VU University Amsterdam, Faculty of Economics, Business Administration and Econometrics.
Vickerman, R.W., 1984. Urban and Regional Change, Migration and Commuting — The Dynamics of Workplace, Residence and Transport Choice. Urban Stud 21, 15–29.
Waddell, P., 1993. Exogenous Workplace Choice in Residential Location Models: Is the Assumption Valid? Geographical Analysis 25, 65–82.
Westin, K., Sandow, E., 2010. People’s preferences for commuting in sparsely populated areas: The case of Sweden. Journal of Transport and Land Use 2.
Zax, J.S., Kain, J.F., 1991. Commutes, quits, and moves. Journal of Urban Economics 29, 153–165.