EVALUATING THE EFFECTS OF A TRANSPORT INFRASTRUCTURE IMPROVEMENT ON HETEROGENOUS HOUSEHOLD GROUPS USING AN URBAN CGE MODEL

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ABSTRACT

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This study evaluates the economic effects of urban transportation policies on different household groups utilizing a CGE model integrated with a discrete choice model and a traffic model. The London Travel Demand Survey (2004) data is utilized basically in this study and two alternative transport policies which are an improvement in public transportation infrastructure and a price increase in the congestion charge are examined. Households are heterogenized according to their living locations, working places, income groups, transport modes and additionally some characteristics of themselves such as having one or more school children or one or more retired persons. Results show that the heterogenization of the households may give crucial insights to the policy makers. Contrary to the general trends, some sub-groups may be affected in different ways as a result of the policy actions.

Keywords: Computable General Equilibrium, Applied General Equilibrium, Discrete Choice Models

ÖZ

ULAŞIM ALTYAPISI İYİLEŞTİRMELERİNİN KENTSEL BİR CGE MODELİ KULLANILARAK HETEROJEN HANEHALKI GRUPLARI ÜZERİNDEKİ ETKİLERİNİN DEĞERLENDİRİLMESİ

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Bu çalışma, bir ayrık seçim modeli ve ulaşım modeli ile entegre edilmiş kentsel bir CGE modeli kullanarak, ulaşım politikalarının farklı hanehalkı grupları üzerindeki ekonomik etkilerini değerlendirmektedir. Bu çalışmada temel olarak London Travel Demand Survey (2014) verisinden yararlanılmış ve muhtemel iki alternatif ulaşım politikasının etkileri incelenmiştir. Bu politikalardan ilki toplu ulaşım altyapısında topyekün bir iyileştirme, ikincisi ise kent merkezi yollarda uygulanan trafik yoğunluğu ücretinde bir artırım olarak düşünülmüştür. Hanehalkları yerleşim bölgeleri, çalışma bölgeleri, gelir grupları, tercih ettikleri ulaşım yöntemleri ve evde okul çaocuğu bulunup bulunmaması gibi ekstra bir özelliklerine heterojenize edilmiştir. Sonuçlar hanehalklarını altgruplara ayrıştırarak yapılan incelemelerin politika yapıcılara önemli öngörüler sağlayabileceğini göstermektedir. Genel eğilimlerin aksine, kimi hanehalkı grupları politika eylemlerinin sonuçlarından farklı biçimde etkilenebilmektedir.

Anahtar Kelimeler: Hesaplanabilir Genel Denge, Uygulamalı Genel Denge, Ayrık Seçim Modelleri

To My Family

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CHAPTER 1

INTRODUCTION

One of the most important problems of the major cities in all over the world is the traffic congestion. The TomTom Traffic Index provides information about congestion levels in cities across 56 countries.[1] The index compares the travel times during peak hours with those from non-congested periods. According to the 2018 list, Mumbai is the most suffering city with a level of 65%. Bogota and Lima follow it with 63% and 58% of congestion levels respectively. The major cities from all the continents face the congestion problem with levels more than 30%. The traffic congestion causes health problems, waste of time and monetary losses. In addition, the reduced traffic speeds lead to increases in fuel consumption, consequently worsening the air pollution and global warming (Hopkins & McKay, 2018).

Local authorities must struggle against the traffic congestion and other traffic related problems especially in the major cities all around the world. In this process, to predict the possible outcomes of the concerned policy actions can help policy makers a lot. The economic outcomes of the possible policy actions may be predicted by the help of the Computable General Equilibrium (CGE) models.

[1] See https://www.tomtom.com/en_gb/traffic-index/about

A Computable General Equilibrium model describes an entire economy, taking into account both macroeconomic constraints and the individual microeconomic behaviours. CGE models are also convenient tools for modelling economic and transportation interactions (Shahraki and Bachmann, 2018).

While regional CGE models generally address the trade-related issues, the urban CGE models often focuses on the urban scale problems such as the transportation system of the city. These models also include the discrete choices that the households face, like residential or working location choices. Anas's Regional Economy, Land Use and Transportation model (RELU-TRAN) is an important example of such models which evaluate the impacts of transport policies on the urban economy with contributions of several scholars [Anas and Kim(1996), Anas and Xu (1999), Anas and Liu (2007), Anas and Hiramatsu (2012), Anas (2013a), Anas (2013b), Anas and Hiramatsu (2013)]. RELU-TRAN model is calibrated and used for the Chicago MSA and for the Greater Los Angeles metropolitan area. There are other contributors to the literature, such as Horridge (1994) with an urban CGE model calibrated and utilized for Melbourne, Sato and Hino (2005) for Tokyo, Rutherford and Van Nieuwkoop (2011) for Zurich and, Truong and Hensher (2012) for Sydney.

Yılmaz (2018) develops a CGE model integrated with a Household Discrete Choice Model and a Traffic Model to evaluate the effects of Crossrail 2 Project which is a railway project in the North-South direction of London. The primary goal of his work is to analyse impacts of urban transport policies on different household groups.

Here, in this thesis, I extend his model to enhance its explaining power and further heterogenize the households to utilize the data more. By doing that, I intend to display impacts of the policy actions on household groups in a more detailed way. I improve the explaining power of the model making the choice mechanism of the households more realistic.

The London Travel Demand Survey (2014) data is utilized basically in this study and two alternative transport policies which are an improvement in public transportation infrastructure and a price increase in the congestion charge are examined. Both policies are considered as possible actions to fight against the traffic congestion problem of the city. Households are further heterogenized according to some characteristics of themselves such as having one or more school children or one or more retired persons. Results show that the extension of the model provides a more detailed picture about the behaviours of the household groups.

The organisation of the thesis is as follows:

Following the Introduction chapter, Chapter 2 describes the model explaining the specifications for households and firms. The household choice model and the traffic model which are utilized in an integrated framework with the computable general equilibrium model are explained in this chapter.

Chapter 3 describes the data utilized in this study and briefly explains the calibration procedure. Afterwards, the results of the simulations are evaluated in terms of their effects on household groups.

Chapter 4 concludes the thesis and makes suggestions for future studies on the issue.

CHAPTER 2

MODEL

2.1 Introduction

This thesis intends to explore the role of heterogeneity in investigating the effects of alternative transport policies in urban models. To this end, the model introduced and utilized in this thesis extends Yılmaz (2018) to account for representation of different household groups. With this purpose, the model utilized in this thesis modifies slightly that of Yılmaz (2018).

Households maximize their utilities in a framework taking into account the consumption of commodities and housing space, the commuting options and the neighbourhoods' attractiveness. Commuting can be by private or public transport and the commuting times and costs are considered in the utility maximization process. While in Yılmaz's study the attractiveness level of a neighbourhood is same for each household group, this study heterogenizes the attractiveness levels of the boroughs for different household groups. The major contribution of this thesis to the framework designed in Yilmaz (2018) is taking into account the fact that each household may be attracted to a neighbourhood by different levels due to the different needs of different groups of households. For instance, a household with a school pupil may be concerned about the access to the school or if there is an old person in a household the existence of a health centre may make one particular region more attractive. To include this reality and to add an additional criterion to the residential place choice mechanism of the households, the neighbourhood attractiveness term is also heterogenized for each household category. Thus, the households are assumed to choose their living places also considering their peculiar needs apart from the commuting conditions and consumption opportunities.

Following Yılmaz (2018), the model is an integration of a discrete choice model, a traffic model and a macroeconomic general equilibrium model. The discrete choice model determines the choice behaviour of households among alternative living places and transport modes. The traffic model determines the routes used by the private transport users and calculates the commuting times between the boroughs. The macroeconomic general equilibrium model complements the overall modelling framework with the optimization problems of the economic agents, namely the households and firms. Households maximize their utility deciding on how much to spend on housing and commodity consumption. Households also decide on where to live and which transport mode to use for commuting. Firms minimize their costs deciding on the amount of production factors. Firm locations are assumed to be fixed. The economy has one type of commodity produced and consumed.

2.2 Households

The model defines each household with a quintet of indices. Here, i stands for the living location, w stands for the working location, g for the social grade of the household, t for the transport mode used for commuting and s for the additional categorization of the households according to their some peculiar properties (having a school pupil or retired person, size of the household etc.). The transport mode is divided into two categories: (i) private and (ii) public transport modes. The social grade is divided into three categories: (i) high income group, (ii) middle income group and (iii) low income group. The households can change their living locations and transport modes, but the other properties are assumed to remain fixed.

Households' utility function is defined as the summation of three terms, each referring to a different component of household preferences.[2] The first component of representative household utility is a constant elasticity of substitution (CES) function which includes housing space consumption and commodity consumption. The second term is the disutility stemming from commuting time. The last component is the neighbourhood attractiveness term which is heterogenized for each household category as explained before.

The household's problem is defined as follows:

$$\max\ U_{iwsgt}(c,d) = \left(\alpha_{iwsgt} c_{iwsgt}^{\rho} + \alpha_{iwsgt}^{h} d_{iwsgt}^{\rho}\right)^{1/\rho} - \gamma\tau_{iw} + \Psi_{iwsgt} \quad (1)$$

$$\text{s.t.} \qquad r_i d_{iwsgt} + p c_{iwsgt} + \kappa_{iw} \le M_{iwsgt} \quad (2)$$

$$\text{with} \qquad M_{iwsgt} = \omega e_{iwsgt}^{L} + \delta e_{iwsgt}^{K} + \sum_{i'} r_{i'} e_{iwsgt}^{H}(i') \quad (3)$$

where, c and d are commodity consumption and housing space consumption respectively. The CES shares of the commodity and the housing space are represented by α and α^h. While τ_{iw} stands for the commuting time between boroughs *i* and *w*, γ is the coefficient of commuting time disutility. The neighbourhood attractiveness term

[2] These types of urban CGE models generally use a utility function including the elements of "utility of neighborhood" and "disutility of travelling" (Anas and Liu, 2007, and Anas and Hiramatsu, 2013, cited in Yılmaz, 2018, p. 18).

is Ψ_{iwsgt}, which was indexed only with *i* in Yılmaz (2018).[3] Here, Ψ_{iwsgt} stands for the attractiveness level of borough i for the household working in borough w, having the social grade g, belonging to the category *s* and using the transport mode *t*. M stands for the income of household and it is composed of the wage income and rent from the holdings of capital and housing endowments. While ω is the real wage rate, δ is the capital price, r is the price of housing space and p is the price of the commodity which is taken to be the numeraire of the model. Commuting also has a cost represented by κ_{iw} depending on the living and working locations. When the public transport is preferred the commuting costs are taken from Transport for London (TfL) Oyster Card Prices (2014). For the private transport, following Treiber (2008) the calculation of the commuting cost is defined as follows:

$$\kappa_{iw} = \left[C^f + \frac{\tau_{iw}}{\tau_{iw}^f}\frac{t_{100}^f}{t_{100}^c}(C^c - C^f)\right] D_{iw} p^f \left(\frac{2*365}{100}\right) \tag{4}$$

Here, C^f is the fuel consumption per distance when there is zero congestion on the road, C^c is the fuel consumption per distance for a reference congestion level, τ_{iw} is the commuting time between boroughs i and w, τ_{iw}^f is the commuting time between boroughs *i* and *w* when there is no congestion, t_{100}^f is a reference travel time for passing a 100 km distance when there is no congestion, t_{100}^c is a reference travel time for passing a 100 km distance when there is congestion on the road, D_{iw} is the distance between boroughs i and w, and p^f is the price of the fuel. The fuel consumption per distance increases due to increasing level of traffic congestion by this formulation.

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[3] Yılmaz's study (2018) treats the attractiveness of a neighbourhood as the same for all types of households. Therefore, the neighbourhood attractiveness parameter is indexed only by i (Ψ_i). However, this study approaches different households with different characteristics as being attracted by neighbourhoods in different levels.

The first order conditions of the representative household's maximization problem provide one with the following conditions:

$$\left(\alpha_{iwsgt}c_{iwsgt}^{\rho} + \alpha_{iwsgt}^{h}d_{iwsgt}^{\rho}\right)^{\frac{1-\rho}{\rho}}\alpha_{iwsgt}c_{iwsgt}^{\rho-1} - \lambda p = 0 \tag{5}$$

$$\left(\alpha_{iwsgt}c_{iwsgt}^{\rho} + \alpha_{iwsgt}^{h}d_{iwsgt}^{\rho}\right)^{\frac{1-\rho}{\rho}}\alpha_{iwsgt}^{h}d_{iwsgt}^{\rho-1} - \lambda r_i = 0 \tag{6}$$

$$M_{iwsgt} - r_i d_{iwsgt} - pc_{iwsgt} - \kappa_{iw} = 0 \tag{7}$$

which allows one to determine the housing space demand, relative to commodity consumption demand. Making use of the budget constraint, we can determine the demand functions for commodity consumption and the housing consumption:

$$c_{iwsgt} = \left(\frac{\alpha_{iwsgt}}{p}\right)^{\sigma}\frac{M_{iwsgt}-\kappa_{iw}}{\alpha_{iwsgt}{}^{\sigma}p^{1-\sigma}+\alpha_{iwsgt}^{h}{}^{\sigma}r_i{}^{1-\sigma}} \tag{8}$$

$$d_{iwsgt} = \left(\frac{\alpha_{iwsgt}^{h}}{r_i}\right)^{\sigma}\frac{M_{iwsgt}-\kappa_{iw}}{\alpha_{iwsgt}{}^{\sigma}p^{1-\sigma}+\alpha_{iwsgt}^{h}{}^{\sigma}r_i{}^{1-\sigma}} \tag{9}$$

2.2.1 Discrete choice model

The CES component of the utility maximization determines the choices of the representative household on commodity consumption and housing demands. On the other hand, a "Discrete Choice Model" is utilized to explain the households' choice behaviour among living places and transport modes.

Different from the standard consumption models in which the quantity of each good consumed is taken to be a continuous variable, discrete choice models which are generally based on Multinomial Logit (MNL) describes choices between two or more discrete alternatives.[4] The decision makers maximize their utilities while deciding on their choices. In these models, the utilities of the decision makers are assumed to have a random component. Then, the utility function takes the following form (Train, 2009):

$$U_{ni} = V_{ni} + \varepsilon_{ni} \qquad (i = 1,2,3,\dots,J) \tag{10}$$

Here, V_{ni} stands for the observed part of the utility by the researcher and ε_{ni} represents the unobserved and random component of the utility. The decision maker *n*, facing *J* alternatives, chooses the alternative *i*, if the condition $U_{ni} > U_{nj}\ \forall j \neq i$ holds. Then, the probability of choosing alternative *i* can be expressed as follows:

$$P_{ni} = prob[U_{ni} > U_{nj}, \forall j \neq i] \tag{11}$$

Here, we assume that the random component of the utility (ε_{ni}) has a Gumbel distribution:

$$\varepsilon_{iwsgt} \sim Gumbel(0, \mu) \tag{12}$$

Then, it becomes possible to define the probability of choosing an alternative among the others as described in Train (2009)[5]:

$$P_n(i) = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}} \tag{13}$$

The representative household in our model makes two different discrete choices: (i) living location and (ii) transport mode. Thus, the probability for living location and

[4] See Lerman (1975), McFadden (1977)

[5] The intermediate steps are explained in detail by Train (2009).

transport mode choices of the representative household working in borough w, having social grade g and belonging to category s can be expressed as follows:

$$P_{wsg}(i,t) = P_{wsg}(i) \cdot P_{wsg}(t|i) \tag{14}$$

Where,

$$P_{wsg}(i) = \frac{\sum_{t'} e^{V_{iwsgt'}}}{\sum_j \sum_{t'} e^{V_{jwsgt'}}} \tag{15}$$

$$P_{wsg}(t|i) = \frac{e^{V_{iwsgt}}}{\sum_{t'} e^{V_{iwsgt'}}} \tag{16}$$

Afterwards, putting equations (15) and (16) into the equation (14), we get the following expression:

$$P_{wsg}(i,t) = \frac{\sum_{t'} e^{V_{iwsgt'}}}{\sum_j \sum_{t'} e^{V_{jwsgt'}}} \cdot \frac{e^{V_{iwsgt}}}{\sum_{t'} e^{V_{iwsgt'}}} = \frac{e^{V_{iwsgt}}}{\sum_j \sum_{t'} e^{V_{jwsgt'}}} \tag{17}$$

The probability for residential location and transport mode choices of a household working in location w, having a social grade g and belonging to the category s:

$$P_{wsg}(i,t) = \frac{exp\left[\left(\alpha_{iwsgt} c^{\rho}_{iwsgt} + \alpha^{h}_{iwsgt} d^{\rho}_{iwsgt}\right)^{1/\rho} - \gamma\tau_{iw} + \Psi_{iwsgt}\right]}{\sum_j \sum_{t'} exp\left[\left(\alpha_{jwsgt'} c^{\rho}_{jwsgt'} + \alpha^{h}_{jwsgt'} d^{\rho}_{jwsgt'}\right)^{1/\rho} - \gamma\tau_{jw} + \Psi_{jwsgt'}\right]} \tag{18}$$

The working location (w), the social grade (g) and the type of household (s) are assumed fix. However, households choose their living location (i) and transport mode (t) themselves. Using the probability of choosing the alternative *i* and *t* given above, we can calculate the number of households live in borough *i* and using the transport mode *t* ($N_{wsg}(i,t)$).

$$N_{wsg}(i,t) = P_{wsg}(i,t)N_{wsg} \tag{19}$$

$$N_{wsg}(i,t) = \frac{exp\left[\left(\alpha_{iwsgt}c^{\rho}_{iwsgt}+\alpha^{h}_{iwsgt}d^{\rho}_{iwsgt}\right)^{1/\rho}-\gamma\tau_{iw}+\Psi_{iwsgt}\right]}{\sum_j \sum_{t'} exp\left[\left(\alpha_{jwsgt'}c^{\rho}_{jwsgt'}+\alpha^{h}_{jwsgt'}d^{\rho}_{jwsgt'}\right)^{1/\rho}-\gamma\tau_{jw}+\Psi_{jwsgt'}\right]} N_{wsg} \tag{20}$$

2.2.3 Traffic model

The last module of the integrated framework employed in this thesis is used to determine the travel times needs between the residential and working location of each household. It is the traffic model that provides the other two modules with the travel times. The module takes the travel demand between the boroughs (number of households commuting between i and w) as its input and provides the travel times, which then serve as inputs to the CGE model. The traffic model chosen to be employed in this thesis is based on Wardrop's First Principle (1952). That is in the equilibrium state there is no driver who has an alternative route with a shorter travel time. Accordingly, the equilibrium state can be determined minimizing the sum of the travel times of all the links in the city. The model is formulated by Yılmaz (2018) using travel time function of Le Blanc et al. (1975) as follows:

$$\min z(x) = \sum_a t_a(x)dx \qquad where \quad t_a(x) = A_a + B_a\left[\frac{x_a}{Q_a}\right]^4 \tag{21}$$

$$s.t.\;\; (1) \sum_{path} f^{iw}_{p} = N_{iw} \tag{22}$$

$$(2) x_a = \sum_i \sum_w \sum_p f^{iw}_{p}\, \Delta^{iw}_{a,p} \tag{23}$$

Where, "a" stands for the links which are used by private transporters and "t_a" is the needed time to pass that link which is a function of the flow on that link, x_a. While,

Q_a stands for the capacity of the link, B_a is the traffic congestion coefficient and A_a is the time needed to pass the link a when there is no congestion on that link.

In equations 21-23 above, the first condition (equation 22) implies the equality between the travel demand from borough i to borough w, N_{iw}, and the sum of the traffic flows on all the alternative paths stemming from the travel demand from *i* to *w*, where *p* stands for the paths and f_p^{iw} stands for the traffic flow on path *p* starting from borough i and reaching borough w. In other words, the total travel demand from borough i to borough w is distributed among the alternative paths starting from borough *i* and ending in borough *w*. The second condition (equation 23) means that the flow on a link is the summation of all the flows between boroughs which use that link, where $\Delta_{a,p}^{iw}$ is a binary variable which takes value 1 if the link a belongs to the path *p* starting from *i* and ending in *w*.

When the travel demands between the boroughs are given exogenously, this model determines the which routes are used for travelling between boroughs and how much time is needed to travel across all the links in the city. However, integrating the traffic model into the CGE model with the discrete choice model is not practical. Instead of an optimization problem, a set of simultaneous equations is easier to solve. Thus, to integrate the traffic model into the CGE model, the traffic model is modified by Yılmaz (2018) as follows:

$$\sum_{path} f_p^{iw} = N_{iw} \tag{24}$$

$$x_a = \sum_i \sum_w \sum_p f_p^{iw} \Delta_{a,p}^{iw} \tag{25}$$

$$t_a = A_a + B_a \left[\frac{x_a}{Q_a}\right]^4 \tag{26}$$

$$t_p^{iw} = \sum_a t_a \Delta_{a,p}^{iw} \tag{27}$$

$$t^{iw}_{p=1} = \sum_p \frac{t^{iw}_p}{\pi_{iw}} \quad (28)$$

If the paths minimizing the total travel time of the travellers are known and given to the modified model, the same durations to pass the links can be calculated by this set of equations. That means the Δ parameters are not endogenous anymore. Therefore, as a solution strategy, first the total, integrated model is solved with the existing paths between the boroughs, the travel demands between the boroughs are calculated, then with the calculated travel demands the minimization problem is solved and the new paths are determined. This process is repeated until the paths determined by the minimization problem are same with the ones used in the total model.

2.3 Firms

There is only one commodity produced in the economy. It is consumed by the households and also the transportation cost is defined in terms of the same one-good. It is the firms that supply the only good demanded in this model economy. Firms operate under a CET type production function. There are two production factors: labour and capital. Both factors are owned and supplied by the households. The representative firm's problem can be formulated as the following:

$$\min \quad \mathrm{C(K, L)} = \delta K + \omega L \quad (29)$$

$$\text{s.t.} \quad y = [\beta K^{\rho} + (1-\beta) L^{\rho}]^{1/\rho} \quad (30)$$

Following the first-order conditions, one can find the factor demand functions of the representative firm:

$$L = y[\beta^{\sigma}\delta^{1-\sigma} + (1-\beta)^{\sigma}\omega^{1-\sigma}]^{\frac{\sigma}{\sigma-1}}(1-\beta)^{\sigma}\omega^{-\sigma} \quad (31)$$

$$K = y[\beta^{\sigma}\delta^{1-\sigma} + (1-\beta)^{\sigma}\omega^{1-\sigma}]^{\frac{\sigma}{\sigma-1}}\beta^{\sigma}\delta^{-\sigma} \tag{32}$$

2.4 Market clearing conditions

The model is closed via several market clearing/equilibrium conditions. First, one has to define the market clearing condition for the commodity supply/demand:

$$y = \sum_i \sum_w \sum_s \sum_g \sum_t N_{wsg}(i,t)\left(c_{iwsgt} + \kappa_{iw}\right) \tag{33}$$

As mentioned before the cost of the transportation is treated as commodity consumption.

The next condition defines the equality between the capital demand of firms and the capital supply of the households:

$$K = \sum_i \sum_w \sum_s \sum_g \sum_t N_{wsg}(i,t) e^{K}_{iwsgt} \tag{34}$$

The third condition equates the labour demand of firms to the labour supplied by the households:

$$L = \sum_i \sum_w \sum_s \sum_g \sum_t N_{wsg}(i,t) e^{L}_{iwsgt} \tag{35}$$

Finally, the last condition implies the equality between the total housing space demanded and supplied in all the boroughs.

$$\sum_w \sum_s \sum_g \sum_t N_{wsg}(i',t) d_{i'wsgt} = \sum_i \sum_w \sum_s \sum_g \sum_t e^{H}_{iwsgt}(i') \quad \forall i' \tag{36}$$

CHAPTER 3

EVALUATING THE EFFECTS OF POLICY SHOCKS ON THE HOUSEHOLD GROUPS

3.1 Introduction

The aim of this chapter is to analyse the effects of a policy change related with the transportation infrastructure of the city on different household groups. To this aim, the effects of two different policy actions which are considered as possible in London are examined using the model stated in Chapter 2. These policy actions are an overall improvement in public transport infrastructure and a price increase in usage of the congestion charge zone. These two policy changes may be attributed to the widely debated issues on transportation in the British public sphere. Improving public transport is one of the primary policy goals for local authorities of London.[6] Price policy of the congestion charge zone is still also a matter of debate among the public since its beginning in 2005.[7] Therefore, in this study an improvement of public

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[6] In the *Mayor's Transport Strategy* document (2019) of the Greater London Authority, improving public transport is mentioned strongly.

[7] See https://www.theguardian.com/politics/2019/jan/05/london-ultra-low-emission-zone

transport infrastructure and a possible price increase in the congestion charge are simulated as two alternative policy actions.

First, the model is calibrated using the data of the initial equilibrium. Then, the calibrated model is used to calculate the new equilibria after the policy actions. In section 3.2, the data sources and the necessary assumptions made are given in detail. Section 3.3 describes the calibration part. Then, section 3.4 explains the policy actions in detail and describes the final equilibria after applying the mentioned policy actions.

3.2 Data

This study primarily uses the London Travel Demand Survey (LTDS) 2014 data. LTDS is a household survey repeated every year since 2005. It covers the London boroughs as well as the area outside Greater London. LTDS gives information about the household characteristics such as income, housing tenure and vehicle ownership as well as the personal information of the individuals including working status, use of transport modes and details of driving licences and public transport tickets held. It also captures data on all daily trips made by the residents in the household. Although sometimes other data sources are needed, mostly LTDS data is used in this study. The other data sources are Census 2011 for households' social grades, Google Maps for commuting times and distances, Valuation Office Agency (VOA) Private Rental Market Statistics (2014) for house rental rates and Transport for London (TfL) Oyster Card Prices (2014) for public transport costs.

LTDS data includes information about households, persons belonging to these households and their daily trips. The number of residents in the households, the income group of the households and their living places are taken from the *household* table of LTDS. This table also gives an expansion number for the households included in the survey which tells how many households are represented by that particular household that attended the survey. The data aggregation procedure is based on this expansion number value. The *person data* table of LTDS is utilized to get the working status information of the persons. Using this data, further heterogenization of the households is possible. For this study, the information of existence of a school pupil or a retired person is used to categorize households into different sub-groups. In addition, I have also used the number of residents to generate further heterogenization of households.

The *trip* table of LTDS provides the starting and ending boroughs, the transportation modes and the purposes of all the trips made by the residents. Looking at the data given in the *trip* table, the households which don't have a resident who makes a trip for commuting reason and commutes to a borough which is inside the Greater London Area are excluded. Additionally, if there are more than one commuting person in the household, the commuting trip which has the largest commuting duration is accepted the commuting trip of this household.

To determine the social grades of the households Census 2011 data is utilized. It gives the percentages of the households which belongs to high, middle and low income groups in the boroughs. Using the income information of LTDS and the social grade percentages from Census 2011 together, the households are aggregated to three social groups which are namely the high, the middle and the low income groups. After the aggregation procedure we get a household table in which the households are categorized according to their living and working places, the existence of a school pupil in the household, their social grade and transport mode. Their income and expansion numbers are also given in the table. A small part of the table to illustrate the data used is given in Appendix A.

In total, there are 1045074 commuting households in the city according to the data and they are categorized in 13068 sub-groups. The index s represents whether the household has a school pupil or not. However, the index s is also used to divide the households into sub-groups according to whether they have a retired person or whether the resident number of households is two or less, or not. Additionally, a simulation is made for each policy actions without dividing the households into sub-groups according to their characteristics.

3.3 Calibration

Calibrated parameters are the CES shares of the utility function (α_{iwsgt} and α^{h}_{iwsgt}) and the neighbourhood attractiveness parameters (Ψ_{iwsgt}). While these ones are calibrated according to the data, some other parameters are taken as given. The parameters assumed as given are the elasticity of substitution (σ), the disutility coefficient of the travel times (γ) and the CES share of production function (β). The reasonable values are assigned to them.

As can be seen in Appendix A, the incomes of each household are known. The number of rooms per household in boroughs from Census 2011 are assumed as the housing space consumption of the households. Thus, I assume that each household living in the same borough consumes the same amount of housing space. The rental rates are taken from the Valuation Office Agency (VOA) Private Rental Market Statistics (2014) as mentioned before. Therefore, we have housing expenditures and transport costs of the households. That means the remaining part is the expenditure for commodities. The price of the only commodity in the economy is taken as one as a numeraire good. Then, the CES shares of the utility function are calibrated with that information. The only unknowns in the demand functions given below are the CES shares.

$$c_{iwsgt} = \left(\frac{\alpha_{iwsgt}}{p}\right)^{\sigma} \frac{M_{iwsgt} - \kappa_{iw}}{\alpha_{iwsgt}{}^{\sigma} p^{1-\sigma} + \alpha_{iwsgt}^{h}{}^{\sigma} r_i{}^{1-\sigma}} \tag{37}$$

$$d_{iwsgt} = \left(\frac{\alpha_{iwsgt}^{h}}{r_i}\right)^{\sigma} \frac{M_{iwsgt} - \kappa_{iw}}{\alpha_{iwsgt}{}^{\sigma} p^{1-\sigma} + \alpha_{iwsgt}^{h}{}^{\sigma} r_i{}^{1-\sigma}} \tag{38}$$

Then, the neighbourhood attractiveness parameters are calibrated using the probability function of choosing a living place and transport mode pair.

$$N_{wsg}(i,t) = \frac{exp\left[\left(\alpha_{iwsgt} c_{iwsgt}^{\rho} + \alpha_{iwsgt}^{h} d_{iwsgt}^{\rho}\right)^{1/\rho} - \gamma\tau_{iw} + \Psi_{iwsgt}\right]}{\sum_j \sum_r exp\left[\left(\alpha_{jwsgr} c_{jwsgr}^{\rho} + \alpha_{jwsgr}^{h} d_{jwsgr}^{\rho}\right)^{1/\rho} - \gamma\tau_{jw} + \Psi_{jwsgr}\right]} N_{wsg} \tag{39}$$

In the calibration procedure of the traffic model, a different method is applied. Remember the travel time function:

$$t_a = A_a + B_a \left[\frac{x_a}{Q_a}\right]^4 \tag{40}$$

While, t_a represents the needed time to pass link “a”, which is a function of the flow on that link, x_a, Q_a stands for the capacity of the link, B_a is the traffic congestion coefficient and A_a is the time needed to pass the link a when there is no congestion on that link.

Instead of calibrating the parameters A_a, B_a and Q_a according to the initial equilibrium, the reasonable values are assigned to these parameters and the values of the variables belonging to the traffic model are calculated. Then, the real durations for the travels between the boroughs are taken from Google Maps and a calibration matrix is created taking the difference between the calculated times and real values. This calibration matrix is added on the calculated time values in the simulations. Thus, the real travel times between the boroughs are utilized in the simulation procedure.

3.4 Evaluating the effects of alternative transport policies

Here, I provide analyses of two alternative policy scenarios. The first scenario that I study is an improvement in the overall public transport infrastructure, which, I assume, is represented via a twenty percent decrease in transportation times between all the boroughs. The second scenario is doubling the price of usage of the roads belonging to the congestion charge zone. Since the both being widely discussed issues in the public sphere in London, these two policy actions are chosen to be studied.

A map of London which shows the boroughs as defined and utilized in this thesis is given below.

Figure 3.1– London Boroughs

Before the examination of the policy actions, the initial equilibrium is described with its some prominent aspects. Then, the effects of the considered policy actions are evaluated separately.

3.4.1 Defining initial equilibrium: An illustration of the data

It is crucial to have a look at the data (which also serve as the components of initial equilibrium for the integrated modelling framework of the thesis) from several perspectives. One important attribute of the spatial data utilized in this thesis is the population density.

Figure 3.1 shows the number of households living in the boroughs. The figure clearly illustrates that the central boroughs of Tower Hamlets, Southwark, Lambeth and Wandsworth and the peripheral boroughs including Ealing, Brent, Barnet and Croydon are the most crowded ones. On the other hand, Richmond upon Thames is the least crowded borough according to the data used for this study.

Note that City of London is shown as having zero residents. It is highly a business district; hence it is unsurprising that the borough hosts a small number of residents. In addition, our data only includes the households which are commuting into the Greater London Area. The City of London is a small area and the data representing the area is not sufficient in the data source. However, due to the relative smallness of the region this lack of data is not considered as an important problem in terms of the overall analysis.

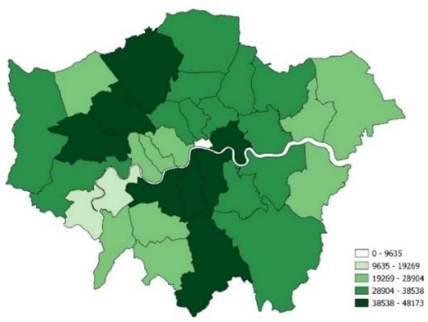

Figure 3.2– Number of resident households in boroughs

Figure 3.3 shows the working/resident population ratio in the boroughs. The share is high mostly in the central boroughs as expected in a typical metropolis.

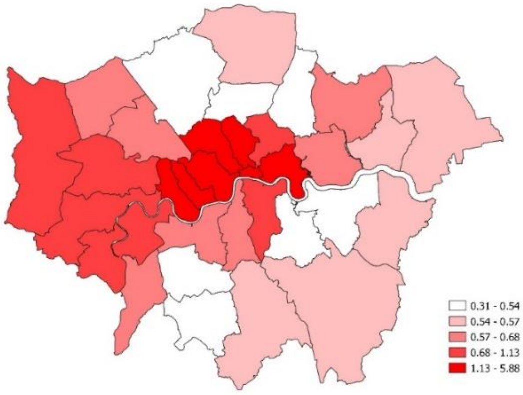

Figure 3.3–Working/resident population ratio in boroughs

Figure 3.4 and Figure 3.5 show the share of utilization of public and private transport in the boroughs respectively. As expected, in the central boroughs mostly the public transport is preferred, but in the periphery private transport usage is more common.

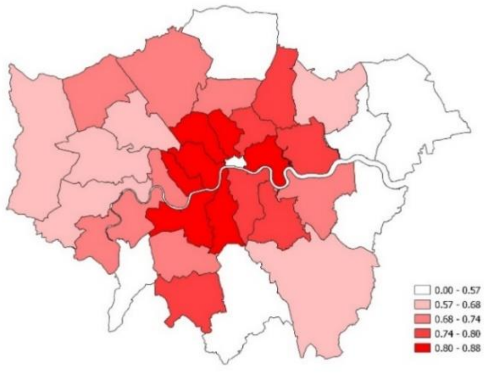

Figure 3.4– Share of households using public transport

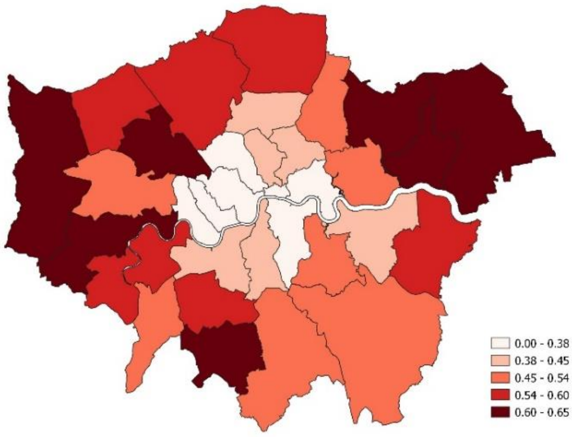

Figure 3.5– Share of households using private transport

Figure 3.6 and Figure 3.7 display the number and share of households with school pupils in boroughs respectively. The highest number is seen in Enfield with a 27% share. In addition, the households with school pupils in Enfield mostly belong to the low-income group with a 48% share. The numbers and the share of income groups of households with school pupils in each borough are given in Appendix B. As can be seen in Appendix B, in the boroughs where the households with children mostly agglomerate, the large part of these families belongs to middle-income group. On the other hand, the lowest number seems in Merton. The shares vary between 9% and 27%. One can observe that there is a significant variation in the shares of households with children going to school. Therefore, one might suppose that some boroughs attract the households with school pupils more than the others. This may stem from the differences in the accessibilities of schools in the boroughs or some other features of the boroughs can make these places more advantageous for that type of households.

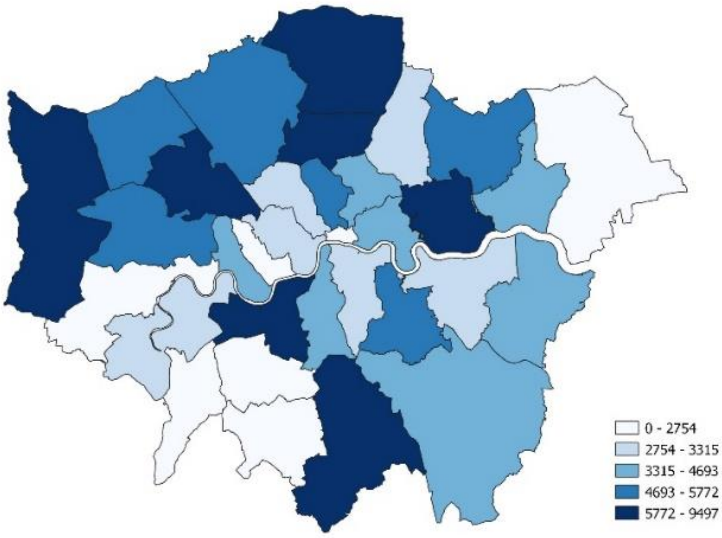

Figure 3.6– Number of households with school pupils in boroughs

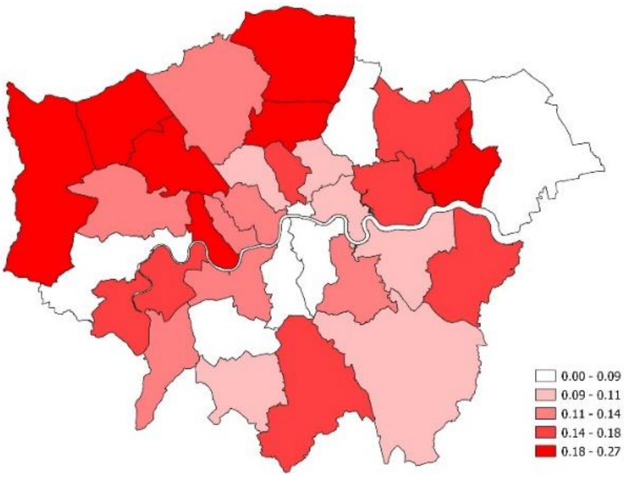

Figure 3.7– Share of households with school pupils in boroughs

Figure 3.8 and Figure 3.9 display the number and share of households with retired persons in boroughs respectively. The highest number of households with retired persons live in Ealing and the lowest amount is observed in Richmond upon Thames. The shares vary between 20% and 1%. Besides, the households with retired persons mostly belong to the middle-income level with a level of 52%. The numbers and the share of income groups of households with retired persons in each borough are given in Appendix C. Again, the variation among the boroughs may be considered as there are differences in boroughs in terms of attracting the households with retired persons. A reason may be the differences in the accessibilities of the health centres in the boroughs or the lifestyle in some boroughs may be more appropriate for the old and retired people.

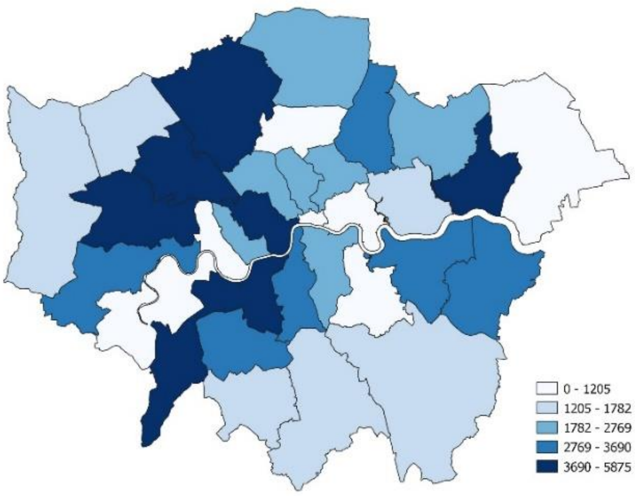

Figure 3.8– Number of households with retired individuals in boroughs

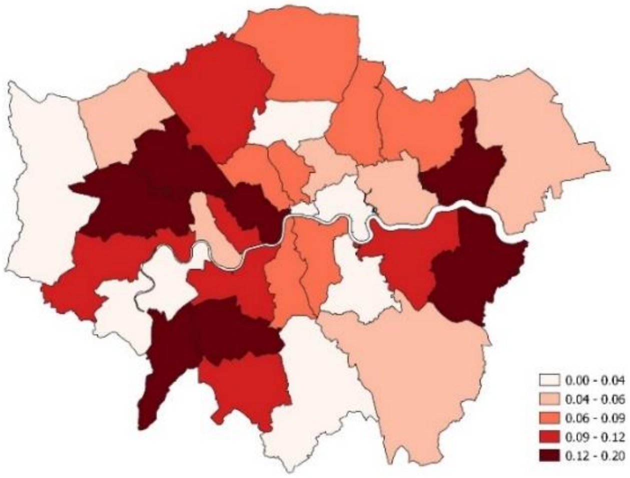

Figure 3.9– Share of households with retired individuals in borough

Another criterion to distinguish households used in this thesis is the household size. One can naturally argue that large households would have different preferences in their residential location choice compared to households with smaller number of members. Hence, the size of the families may create different concerns in choosing a residential region. Figure 3.10 and Figure 3.11 show the number and share of households with two or less residents respectively. Looking at shares it can easily be said that the central regions are preferred more by the small numbered households. The shares vary between the 64% and 34%. Thus, it can be considered that the boroughs' attractions change according to the size of households. Additionally, the households with retired persons mostly belong to the middle-income level with a level of 47%. The numbers and the share of income groups of households with two or less residents in each borough are given in Appendix D.

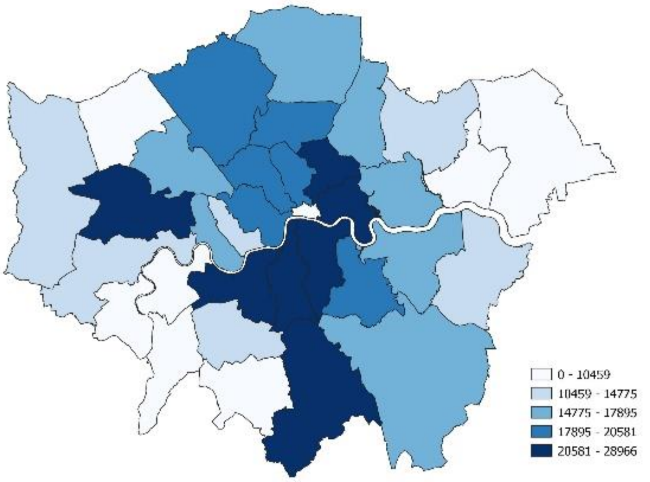

Figure 3.10– Number of households with two or less residents

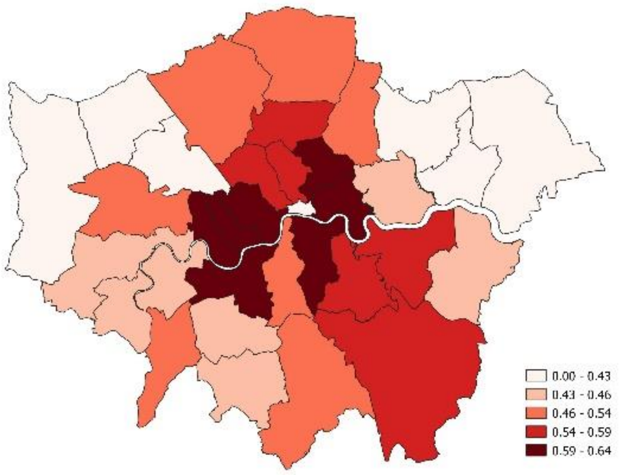

Figure 3.11– Share of households with two or less residents

3.4.2 Evaluating the effect of an improvement in the overall public transport infrastructure

This section presents the results of the simulation analysis which looks into an overall improvement in public transport system in GLA. To this end, I study a reduction in public transportation times between boroughs. The present commuting times with public transportation are given in Appendix E. As a consequence of this policy action, I assume that all the transportation times of public transport services between the boroughs decrease by 20 per cent. These new public transport times are fed into the model as a shock and the new equilibrium values are calculated. Here, the results are presented for four different cases in which s index represents different criteria. Remember that the households are divided into five categories with respect to their living place, working place, social grade, transport mode and one more extra criterion which provides extra information about the households. The last attribute (s) generates three different categories which are, the existence of a school pupil in the household, the existence of a retired person in the household and whether the number of residents is two or less, or not. These three cases are simulated separately. However, initially an extra simulation is made without using index s, which means I do not divide households into sub-groups according to their mentioned characteristics. The results of these four simulations are given below. First, I provide the results for the case where all households are treated equally with respect to the neighbourhood attractiveness parameter (Ψ_{iwgt}). Then, I compare these results with the cases where the location attractiveness parameter is differentiated with respect to (i) households with school pupils, (ii)households with retired persons and (iii)households with resident number equals to or less than two.

When one considers the case with a homogenous attractiveness parameter for each household, a 20 percent reduction in public transport times display the following results w.r.t major variables (share of public transport, number of households in each borough, housing prices in each borough, number of sub-grouped households in each borough) of the integrated modelling framework. As expected, the share of public transport use increases in each simulation case, as shown in Figure 3.12.

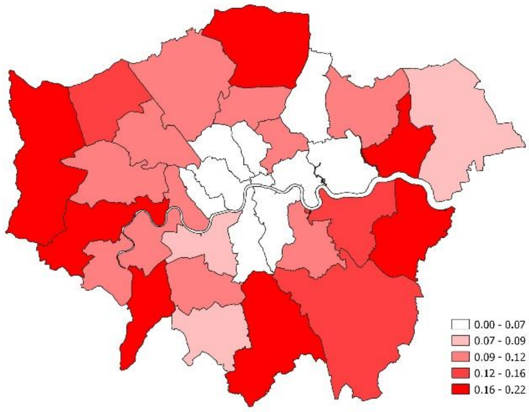

Figure 3.12– Percentage change in usage of public transport

The highest change occurs in Barking and Dagenham with a 22% increase. Moreover, significant increases generally occur in the peripheral boroughs with 20% in Bexley, 19% in Hillingdon, 19% in Kingston upon Thames, 18% in Hounslow, 17% in Croydon, 16% in Enfield. These results are somewhat expected because a homogeneous decrease in the overall public transport times effects these regions more due to their higher public transport time values. For instance, Barking and Dagenham having one of the highest public transportation times before the improvement (56 minutes to City of London, 65 minutes to Camden, 61 minutes to Westminster, 86 minutes to Lambeth etc.[8]) experiences large amount of decreases in travelling times with public services.

[8] See the whole list in Appendix E.

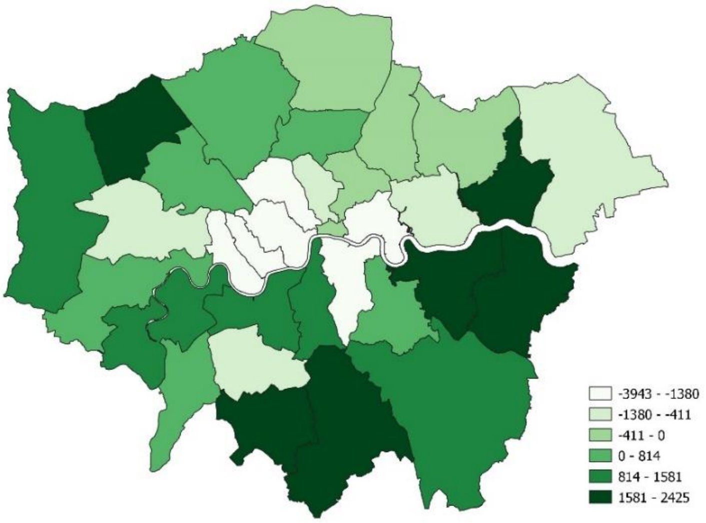

Figure 3.13– Changes in the number of resident households in boroughs

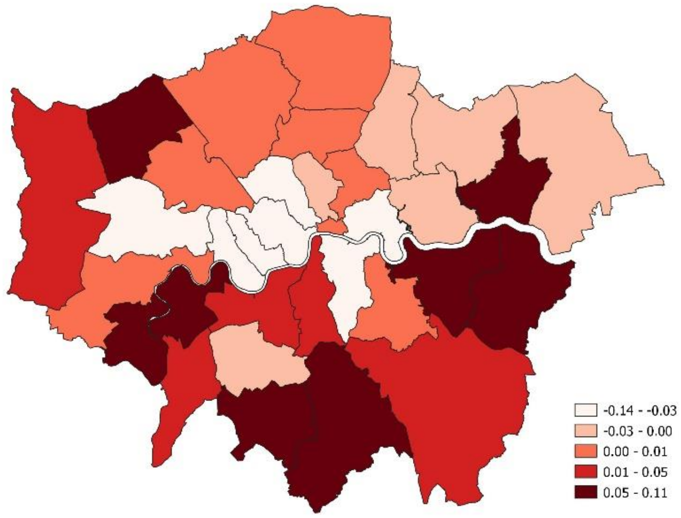

Figure 3.14– Percentage changes in the number of resident households

Figure 3.13 and Figure 3.14 illustrates the amount of changes and the percentage changes in the number of resident households respectively. Here, we observe that, with the improvement of public transport system, more households prefer to move to peripheral boroughs thanks to higher decreases in public transport times in these regions.

As a result of the increase in residential demand in the peripheral boroughs such as Sutton, Croydon, Greenwich, Bexley, Barking and Dagenham and Harrow, and the decrease in residential demand in the central boroughs such as Southwark, Tower Hamlets, Camden, Westminster, Kensington and Chelsea and Hammersmith and Fulham the housing prices are affected. Figure 3.15 shows the price increases and decreases in the boroughs.

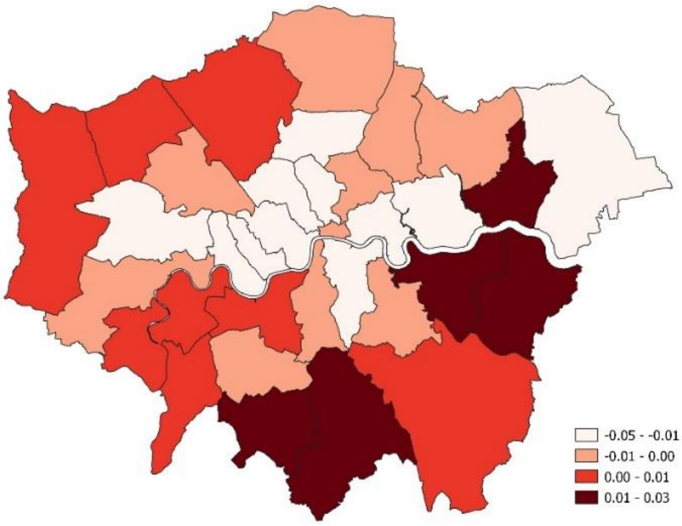

Figure 3.15– Percentage change in the housing prices

Additionally, to understand the effect of the mentioned policy action on the social welfare, the total utility level of the households in the economy can be focused on. As a result of the improvement in the public transport infrastructure the total utility level of the households increases by 147% according to the simulation results.

3.4.2.1 Evaluating the effect of an improvement in the overall public transport infrastructure: Households with school pupils

Here, I repeat the same analysis (of an improvement in public transport times) under the differentiation of households into two categories of the last attribute as explained in Section 3.4.2. In this case, the attractiveness parameter is allowed to change for households with one or more school pupils. First the effect of this differentiation on the whole solution is evaluated. Afterwards, the effects of the improvement in overall public transport on the households with school pupils are examined.

Figure 3.16 shows the percentage change in public transport use in the boroughs. The result is similar with the previous case. There is an increase in each borough, but the peripheral ones are more prominent.

However, the increases are less than the simulation of homogeneous neighbourhood attractiveness parameter. One reason for why we observe smaller changes in the share of households moving to public transportation is that the neighbourhood attractiveness parameters are calibrated for each household sub-groups separately and making an extra categorization for households with school pupils decreases the mobility of households among the alternative transport modes and living location choice pairs. The households with school pupils tend to stay at their current position more, because with the heterogenization of the neighbourhood attractiveness parameter we create an additional motive for their current pair of living location and transport mode choices.

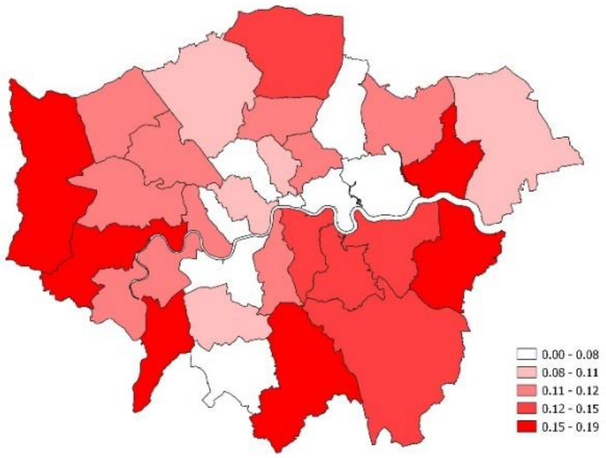

Figure 3.16– Percentage change in usage of public transport

Figure 3.17 gives the changes in resident households in boroughs. The result is similar with the previous analysis, again with slightly different values.

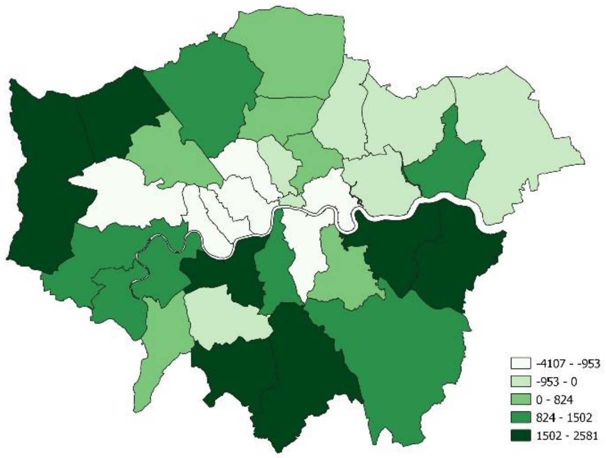

Figure 3.17– Changes in the number of resident households

To understand the reason creating that difference, the household mobility should be examined in detail. As mentioned before the households are divided into five categories and $N_{wsg}(i,t)$ stands for the number of households who live in borough i, work in borough w, belong to social grade g, use the transport mode t, and s is the last category which shows either having a school pupil or a retired individual or having two or less residents. In the model, the households are allowed to choose their living places and transport mode, but the other properties are assumed fixed. Thus, the problem is to place the fixed number of households who work in *w*, have a social grade g, and belong to category s to a living place *i* and transport mode *t* pair. Because, for the initial equilibrium it is impossible to calibrate the parameters for a non-existent category (*i*,*w*,*s*,g,*t* quintet), I assume that if a residential location and a transport mode pair is not chosen by any household, this pair is not allowed to be chosen in the new equilibria. This makes sense because if a pair of a living place and a transport mode is not chosen by even one household, it is reasonable to suppose that no household will consider placing itself in that combination when a new equilibrium arises in the economy.

N_{wsg} stands for the number of households belonging to category (*w*,*s*,g). Table 3.1 displays how a fixed number of households, for instance, belonging to category (29,1,1) is distributed among alternative living place and transport mode categories in the initial equilibrium. Note that these numbers are from the analysis with homogeneous neighbourhood attractiveness parameter. Thus, s index can only take value one. As can be seen in the table, mentioned fixed number of households are distributed into four alternative categories. That means they are allowed to be redistributed among the same alternatives when a disturbance applied to the initial equilibrium. Initial and after shock values can be compared from the table.

Table 3.1 – Distribution of the households belonging to category (29,1,1) at the initial equilibrium and after the shock

Nfixed(29,1,1) 1782			
N_init(28,29,1,1,1) 459	N_init(32,29,1,1,1) 728	N_init(20,29,1,1,2) 209	N_init(29,29,1,1,2) 386
N_final(28,29,1,1,1) 405.2638	N_final(32,29,1,1,1) 535.035	N_final(20,29,1,1,2) 381.7648	N_final(29,29,1,1,2) 459.9364

Next, Table 3.2 gives the same values for the heterogenized neighbourhood attractiveness parameter case. The index s stands for having a school pupil now. If s is two this means that there is a school pupil in the household. If it is one, no school pupil. As the table shows, the category (29,1,1) is now divided into (29,1,1) and (29,2,1). Our new fixed number sub-categories are distributed into their own possible choices now. That means a household belonging to the category (29,2,1) cannot choose to live in borough 28 or 32 anymore. It also can not choose the private transport as a transportation mode. That changes the story. By doing this, I assume that if no household with a school pupil, working in borough 29 and belonging to social grade 1 considers living in borough 28 or 32 in the initial case, there will be no household from that category which consider living in borough 28 or 32 in a new equilibrium.

Therefore, when I make an extra categorization, I expect the total picture that my model draws changes through the mechanism explained above. As a result, the mobility of the households decreases but the model tells more about the household behaviour.

Table 3.2 – Distribution of the households belonging to category (29,1,1) and (29,2,1) at the initial equilibrium and after the shock

Nfixed(29,1,1) 1187		Nfixed(29,2,1) 595	
N_init(28,29,1,1,1) 459	N_init(32,29,1,1,1) 728	N_init(20,29,2,1,2) 209	N_init(29,29,2,1,2) 386
N_final(28,29,1,1,1) 519.9179	N_final(32,29,1,1,1) 667.0821	N_final(20,29,2,1,2) 268.8989	N_final(29,29,2,1,2) 326.1011

Figure 3.18 shows the changes in the number of households with school pupils. When these values are compared with ones shown in Figure 3.17, it can be seen that in the north-west regions there are decreases in the numbers of households with school pupils contrarily to the general trend.

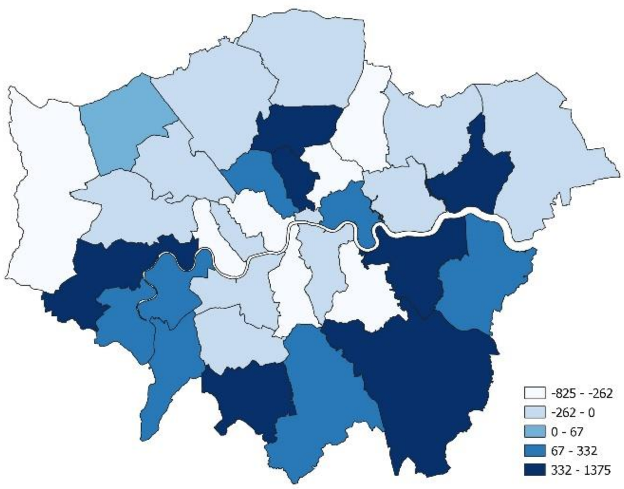

Figure 3.18– Change in the number of households with school pupils in boroughs

Additionally, the total increase in the utility level of all the households is 185%. However, the share of the households with school pupils in that increase is only 12%. The remaining 88% of the increase in the total utility level belongs to the households which do not have school children. Therefore, we can interpret that the households which have school children benefit less from the mentioned public transport improvement less than the other parts of the society.

3.4.2.2 Evaluating the effect of an improvement in the overall public transport infrastructure: Households with retired persons

Here, the same analysis is repeated under the differentiation of households according to the presence of a retired person in households. The index s stands for whether a retired person belongs to the household or not. If there is no retired person in the household the index s takes the value 1, otherwise, the index s takes the value 2.

The results of the simulation are given below. Then, the effects of the improvement in overall public transport on the households with retired persons are evaluated.

Figure 3.19 displays percentage change in the usage of public transport in boroughs. Similarly, an increase is observed in all boroughs, but with slightly less values than the homogenous neighbourhood attractiveness case.

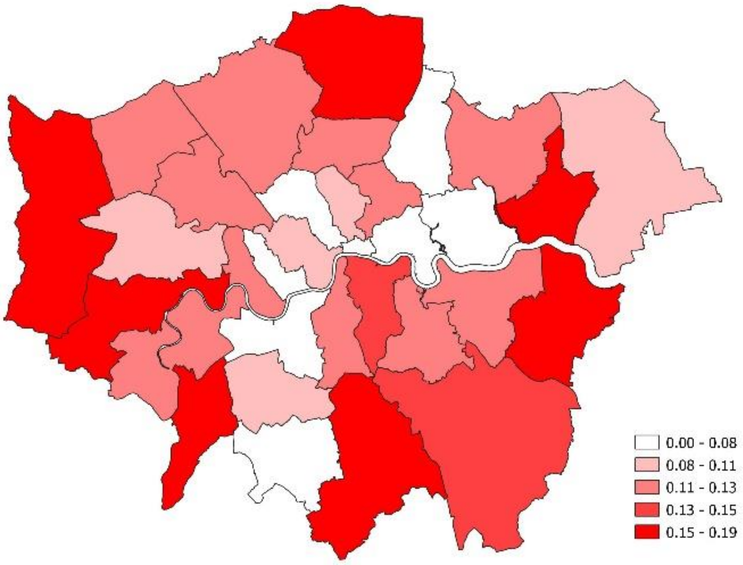

Figure 3.19– Percentage change in usage of public transport

Figure 3.20 and Figure 3.21 show the changes in the number of all households and the changes in the number of households with retired persons respectively. As can be seen in the figures, there are counter movements of the households with retired persons against the general trend. For instance, there is an overall increase in Barking and Dagenham with 1590 new households living in the city. However, the change in the number of households with retired persons is negative with a value of 368 in that borough. This means that the rival boroughs of Barking and Dagenham are more attractive to the retired people.

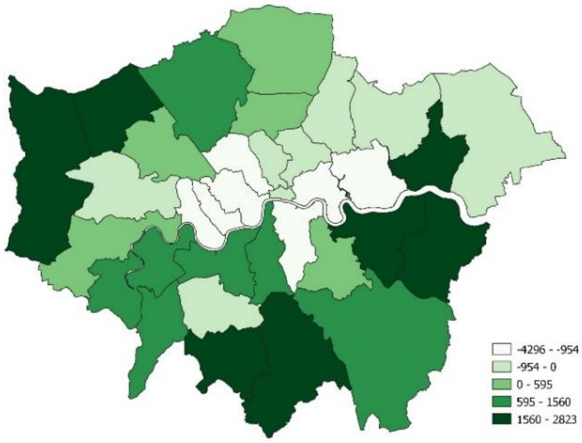

Figure 3.20– Changes in the number of resident households in boroughs

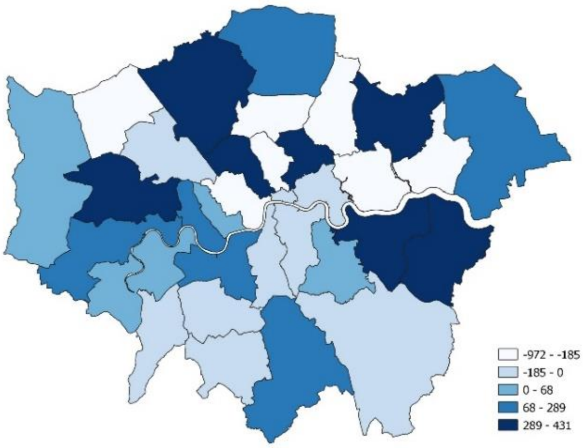

Figure 3.21– Change in the number of households with retired persons

Additionally, the total increase in the utility level of all the households is 168% according to the results of this simulation. The share of the households with retired persons in that increase is only 6%. On the other hand, the remaining 94% of the increase in the total utility level belongs to the households which do not have retired persons.

As mentioned before, the households with retired persons mostly belong to the middle and low income groups and like in the school children case, we see that the households belonging to the lower income groups benefit from the public transport improvement less than the higher income groups.

3.4.2.3 Evaluating the effect of an improvement in the overall public transport infrastructure: Households with two or less residents

Finally, the same analysis is repeated under the differentiation of households according to their sizes. The index s stands for whether the number of residents in the household is equal to or less than two or not. If the number is more than two the index s takes the value 2, otherwise, the index s takes the value 1.

The results of the simulation are given below. Then, the effects of the improvement in overall public transport on the households with resident number equal to or less than two are examined.

As can be seen in Figure 3.22, the increases in the percentages of public transport use are a little bit different than the homogeneous neighbourhood attractiveness case. The maximum change is 20% while that is 22% in the homogeneous neighbourhood attractiveness case.

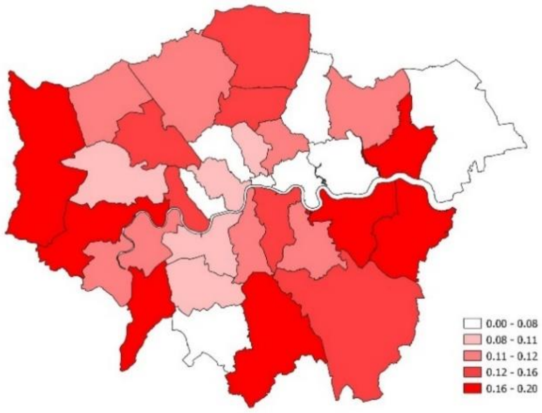

Figure 3.22– Percentage change in usage of public transport

As seen in Figure 3.23 and Figure 3.24 the general trends and the movement of the households with two or less residents are frequently in the same direction. However, there are also counter movements in this case. While the population increases in Hillington, Richmond upon Thames and Croydon there are decreases in the number of big households in these boroughs.

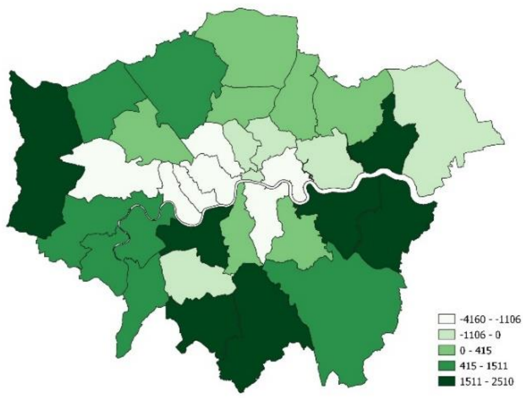

Figure 3.23– Changes in the number of resident households in boroughs

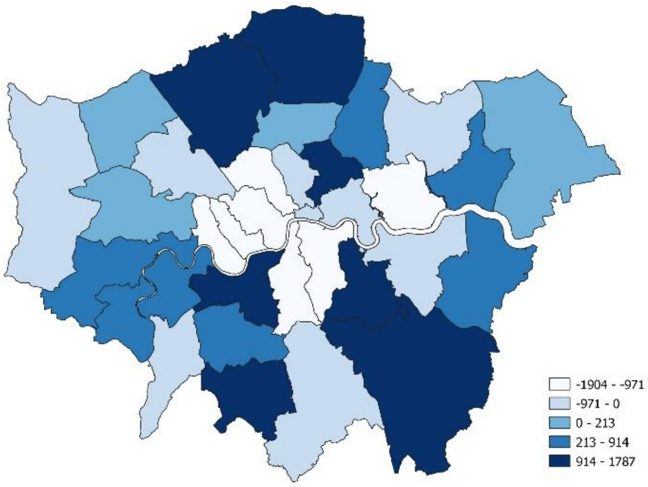

Figure 3.24– Change in the number of households with two or less residents

Finally, the total increase in the utility level of all the households is 150% according to the results of the simulation. The share of the households with two or less residents in that increase is 48%. Therefore, we can say that they benefit a lot from the public transport improvement because almost half of the utility increase in the overall economy belongs to this group.

3.4.3 Evaluating the effect of doubling the price of usage of the roads belonging to the congestion charge zone

London has a congestion charge zone in the centre of the city.[9] The zone is displayed in the figure below. Some parts of the City of London, Westminster, Lambeth, and

[9] See Transport for London website, retrieved from https://tfl.gov.uk/modes/driving/congestion-charge/congestion-charge-zone

Southwark are in the charge zone. In this section the effect of doubling the price of usage of the roads belonging to the congestion charge zone is examined. The results are given below for the same simulation cases with the previous policy action.

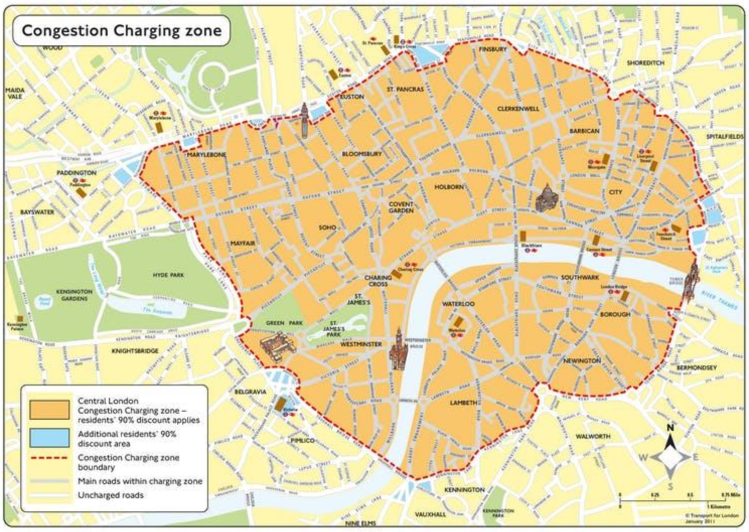

Figure 3.25– Congestion charge zone[10]

First, the results for the case where the neighbourhood attractiveness parameter is homogeneous among each type of households are given. Afterwards, I compare the results with the cases where the parameter is differentiated with respect to households with school pupils, with retired persons and with two or less residents.

Doubling the congestion charges has less influence upon the economy than the overall improvement in the public transport infrastructure which is examined before. This is quite normal because a little part of the households, who live in the congestion charge zone or pass through it for their daily trips, are subjected to mentioned price increase.

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[10] The map of congestion charge zone. Retrieved from https://www.citymetric.com/transport/london-congestion-charge-has-been-huge-success-it-s-time-change-it-3751

Others are only indirectly affected. Therefore, there are very little changes observed mostly in the central regions.

As can be seen in Figure 3.26, the highest change in the public transport usage is in Southwark with a 11% increase. It is followed by the boroughs which are either in the congestion charge zone or very close to it. Also, the south-east region of the city seems to be affected by the policy change with about a 4% increase in public transport. On the other side in the remaining parts of the city there are only negligible changes.

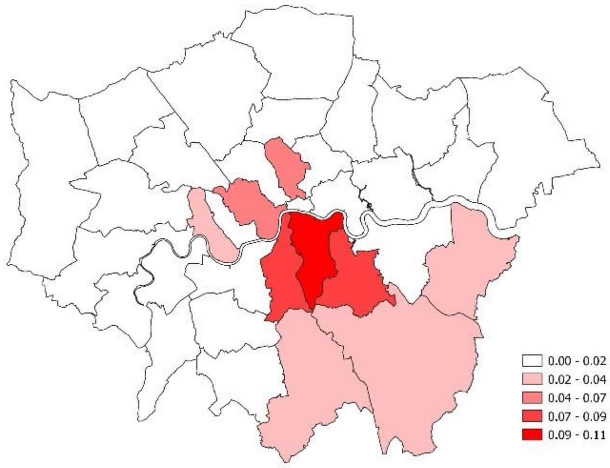

Figure 3.26– Percentage change in usage of public transport

The household mobility seems rather limited. As displayed in Figure 3.27, Southwark is the region which loses the highest number of households with a decrease of 919. The highest increases are in Newham and Kensington and Chelsea which are central boroughs but not in the congestion charge zone. Farther regions like Hillingdon or Barking and Dagenham also seem to encounter with a population increase. However, note that these household movements are very lower than the case with an overall public transport improvement, which is quite normal as explained above. The housing price changes are also negligible as can be seen form Figure 3.28. Additionally, the total increase in the utility level of all the households is 27%.

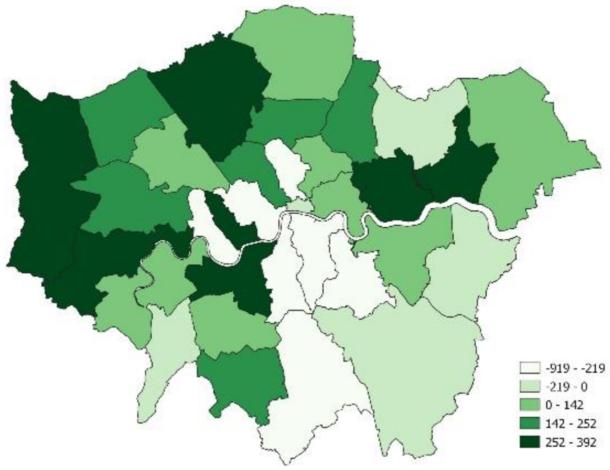

Figure 3.27– Changes in the number of resident households in boroughs

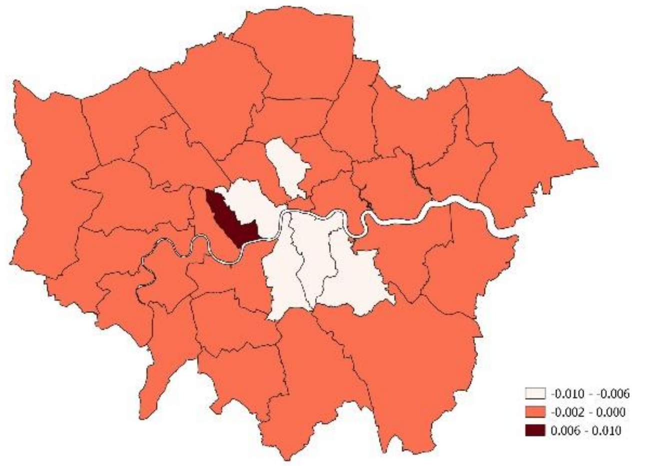

Figure 3.28– Percentage change in the housing prices in the boroughs

3.4.3.1 Evaluating the effect of doubling the congestion charge: Households with school pupils

Here, the same analysis is repeated under the differentiation of households according to the presence of one or more school pupils in households.

The results are very similar. Public transport usage increases mostly in the central boroughs. The highest rise is observed again in Southwark with a value of 17%.

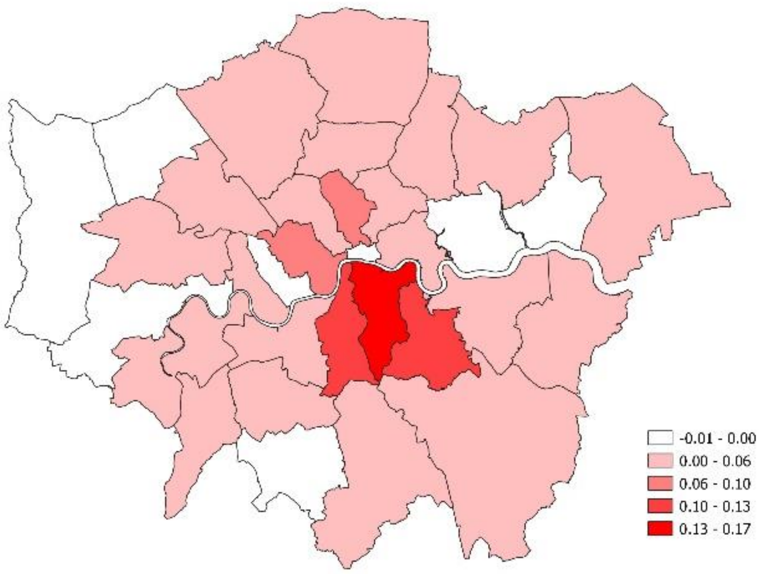

Figure 3.29– Percentage change in usage of public transport

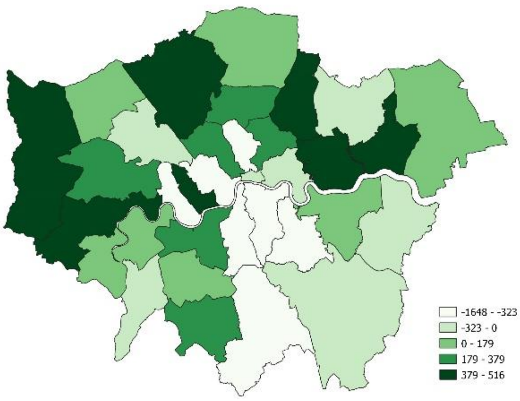

Figure 3.30– Changes in the number of resident households in boroughs

The total household movements are also similar as displayed in Figure 3.30. Figure 3.31 displays the movements of households with school pupils. There are counter movements against the total trend. For instance, Bromley and Croydon's total populations decrease but there are increases in the number of families having a school pupil.

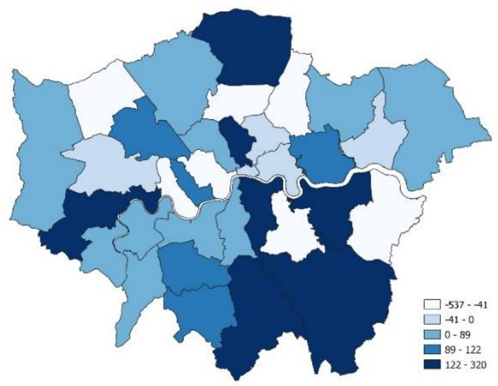

Figure 3.31– Change in the number of households with school pupils in boroughs

Finally, the total increase in the utility level of all the households is 32% according to the results of this simulation. Again, the share of the households with school pupils in that increase is small with a value of 14%, which is similar with the public transport improvement simulation.

3.4.3.2 Evaluating the effect of doubling the congestion charge: Households with retired persons

Here, the same analysis is repeated under the differentiation of households according to the presence of a retired person in households. The general trends do not seem to change significantly. Again, there is an increase in the public transport usage and a decrease in the number of households in central boroughs which belong to the congestion charge zone as expected.

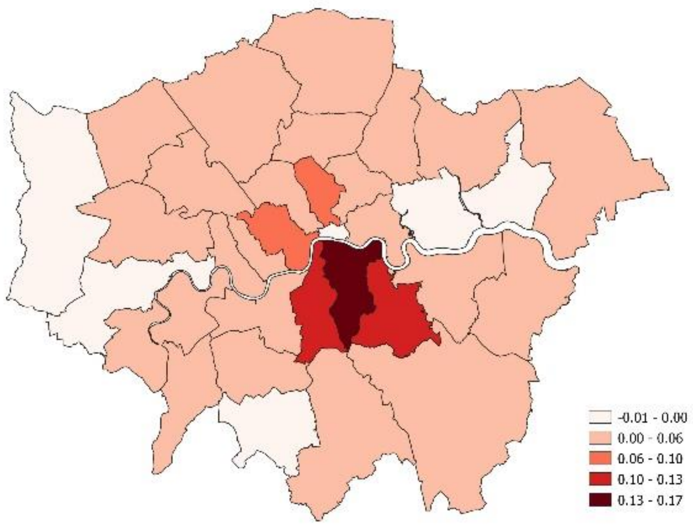

Figure 3.32– Percentage change in usage of public transport

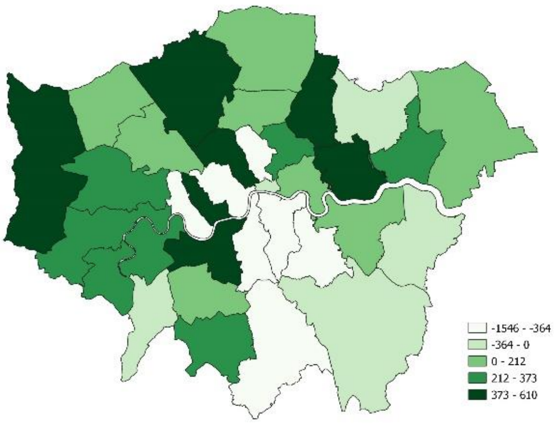

Figure 3.33– Changes in the number of resident households in boroughs

The movements of the household with retired persons can be seen Figure 3.34. The most prominent result is the rise in Lambeth. Although the total change in the number of households is negative in Lambeth, it seems that the borough's attractiveness is high for the retired people.

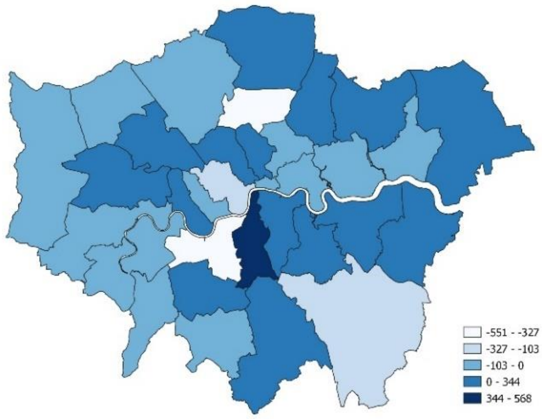

Figure 3.34– Change in the number of households with retired persons in boroughs

Additionally, the total increase in the utility level of all the households is 30% according to the results of this simulation. The share of the households with retired persons in that increase is 6%.

3.4.3.3 Evaluating the effect of doubling the congestion charge: Households with two or less residents

Finally, the same analysis is repeated under the differentiation of households according to their sizes. The index s stands for whether the number of residents in the household is equal to or less than two, or not. If the number is more than two the index s takes the value 2, otherwise, the index s takes the value 1. The general trends are very similar. The public transport usage increases in central boroughs and the change is negative in the number of households in these regions.

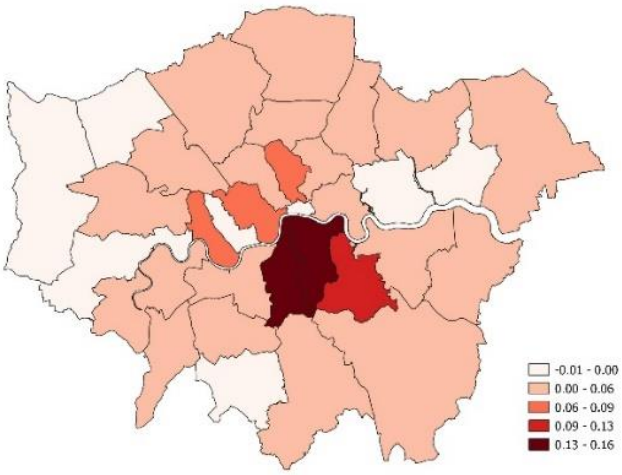

Figure 3.35– Percentage change in usage of public transport

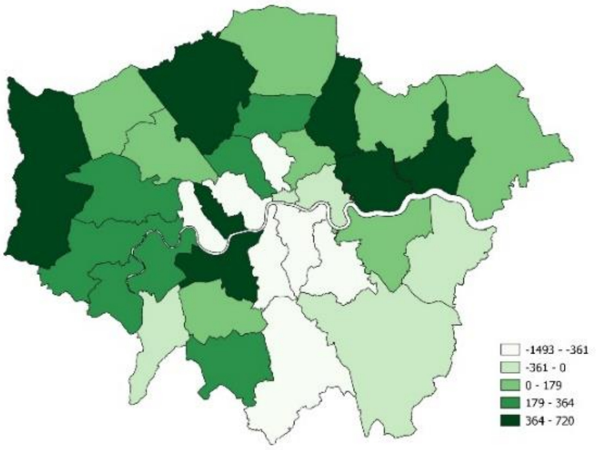

Figure 3.36– Changes in the number of resident households in boroughs

As can be seen in Figure 3.37, the movements of the households with two or less residents are compatible with the general trends.

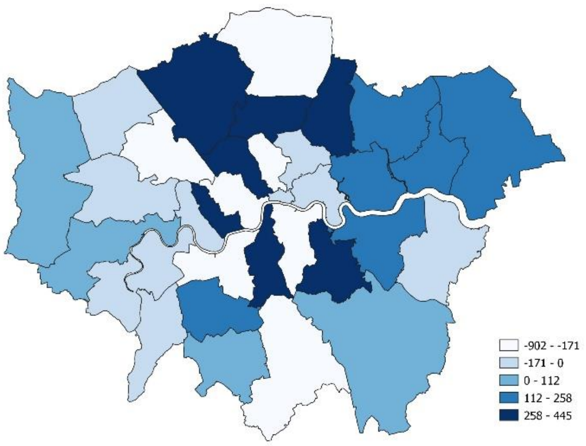

Figure 3.37– Change in the number of households with two or less resident in boroughs

Finally, the total increase in the utility level of all the households is 25% according to the results of this simulation. The share of the households with two or less residents in that increase is 54%, which is similar with the public transport improvement simulation.

3.4.4 Conclusion

Thanks to the heterogenization of the neighbourhood attractiveness parameter with respect to all the household categories, I add a new dimension to the decision-making process of the households. Without a heterogenized neighbourhood attractiveness according to all the household categories, the effect of this parameter is very limited on choice behaviour among discrete alternatives. The parameter which is indexed only by the neighbourhood numbers (Ψ_i) cannot make a determinant impact on the discrete choice mechanism. The impact of the mentioned modification can be seen in the simulation results.

Further heterogenization of the households make them more attracted to their initial positions. Therefore, their movements are more limited in comparison with the homogeneous neighbourhood attractiveness cases. The total trends are similar, however it is observed that the households are less mobile among the alternative discrete choices when their attractiveness levels to the neighbourhoods are calibrated in a differentiated manner. This differentiation of the results is more apparent in the improvement of the public transport case. On the other hand, in the price doubling simulation the effects of the further heterogenization of the neighbourhood attractiveness parameter with respect to the household characteristics are seem insignificant, because the shock applied to the model in this case is weaker in comparison with the public transport improvement.

Additionally, the further heterogenization of the households and the neighbourhood attractiveness parameters accordingly enables us to see the reactions of the sub-groups of households to the policy shocks separately. Some counter-movements of the sub-groups occur against the general trends as can be observed in the previous sections. Thus, I have a more detailed picture about the household behaviours.

Policy makers may deduce a set of interpretations looking at these results. For instance, in the initial equilibrium the households with school pupils mostly live in the peripheral regions. One can consider that these regions are more attractive for this type of households thanks to the qualities specific to their peculiar needs. After the public transport improvement shock, it is observed that a general tendency to these regions occurs due to the sharp decreases in travel times. As a consequence, the housing prices increase in peripheral regions. Although, a movement of households to the peripheral regions seems as a positive phenomenon in terms of a possible decrease in the traffic congestion levels in the central regions, this may be a negative situation for the households with school pupils who already live in the periphery. It is known that they generally belong to the low and middle income groups, hence increases in the housing prices resulting from the housing space demand rises in the peripheral regions may affect them negatively. Accordingly, a counter movement of the households with school pupils occurs outwards in peripheral regions in spite of the general trend. As a result, it can be considered that the model utilized in this thesis can help the policy makers to foresee the negative impacts of such a policy action on some specific household groups.

CHAPTER 4

CONCLUSION

Urban CGE models can provide useful insights to the policy makers as being convenient tools for modelling economic and transportation interactions. Urban CGE models may be functional in the decision-making processes in various fields such as city and regional planning, designing large infrastructural projects and determining local government strategies.

In this Thesis, an urban CGE model integrated with a traffic and a household choice model is utilized to assess the potential negative and positive effects of two alternative transport policy actions in London. The model is taken from Yılmaz's study (2018) and extended to capture a more detailed picture about the effects of the policy actions on different household groups.

After a brief introduction about the thesis and a review on the existing literature on the field in Chapter 1, the Chapter 2 describes the model utilized in this thesis. The specifications for households and firms are given in this chapter and additionally, the discrete choice model and the traffic model utilized in an integrated framework with the CGE model are explained in detail.

In Chapter 3, the data utilized in this study is explained in detail. Then, the calibration procedure is described. Afterwards, the evaluation of the policy actions is carried out and their impacts on the different household groups are examined. As a result, it is interpreted that the model utilized in this work gives useful insights about the possible effects of mentioned policy actions on specific household groups.

This study reveals that the heterogenization of the neighbourhood attractiveness parameter and further heterogenization of the households provides useful information about the possible effects of policy actions such as an overall improvement in public transportation infrastructure and a price increase in the congestion charge zone on specific household groups. For instance, the negative effects of an improvement in transport infrastructure are revealed thanks to the mentioned modification of the model. Additionally, by such an extension of the model it is evaluated that the results of the simulation become more realistic, because the fact that different regions attract different household groups in changing levels is included to the simulations.

Due to the lack of necessary data, the home ownership information of the households could not be involved in this study. However, if it could be involved, the household behaviour can be depicted in a more realistic manner.

To enhance the explanatory capacity of this work, as a further study, the access to the public services can be added directly to the utility function of the representative household instead of trying to see their effects in the neighbourhood attractiveness parameter. By this way, a more advanced model can be obtained, and the policy makers can have comprehensive insights about the policies related with the public services.

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APPENDICES

A. A SAMPLE OF THE HOUSEHOLD TABLE

Home	Work	School Pupil	Social Grade	Transport Mode	Income	Expansion Number
Barking and Dagenham	Camden	1	C	1	45327	651
Barking and Dagenham	Hackney	1	AB	1	81404	622
Barking and Dagenham	Hackney	1	AB	2	81404	1192
Barking and Dagenham	Newham	1	C	1	28361	1894
Barking and Dagenham	Newham	1	C	2	28361	1295
Barking and Dagenham	Newham	1	AB	1	74984	464
Barking and Dagenham	Tower Hamlets	2	DE	2	17371	1357
Barking and Dagenham	Tower Hamlets	1	C	1	39182	702
Barking and Dagenham	Tower Hamlets	1	C	2	39182	784
Barking and Dagenham	Westminster	1	C	2	41644	1294
Barking and Dagenham	Westminster	1	AB	2	91874	1041
Barking and Dagenham	Barking and Dagenham	2	DE	1	12500	749
Barking and Dagenham	Barking and Dagenham	1	DE	2	23964	427
Barking and Dagenham	Barking and Dagenham	1	C	1	43796	668
Barking and Dagenham	Barking and Dagenham	1	AB	1	95442	2173
Barking and Dagenham	Barking and Dagenham	2	AB	1	125000	693
Barking and Dagenham	Brent	1	C	1	32023	721
Barking and Dagenham	Havering	1	DE	2	15566	594
Barking and Dagenham	Havering	1	C	1	45144	1745

B. INCOME SHARES OF HOUSEHOLDS WITH SCHOOL PUPILS

Borough	Count	High income	Middle income	Low income
Enfield	9497	0.19	0.33	0.48
Brent	8078	0.17	0.59	0.24
Hillingdon	6650	0.06	0.59	0.36
Croydon	6449	0.38	0.42	0.2
Haringey	6136	0.13	0.62	0.24
Newham	6133	0.16	0.3	0.55
Wandsworth	5972	0.4	0.55	0.05
Harrow	5472	0.51	0.42	0.07
Redbridge	5456	0.32	0.39	0.29
Barnet	5348	0.08	0.82	0.1
Islington	5187	0.04	0.37	0.58
Ealing	5062	0.19	0.74	0.07
Lewisham	4743	0.18	0.45	0.37
Barking and Dagenham	4681	0.26	0	0.74
Tower Hamlets	4496	0	0	1
Hammersmith and Fulham	4218	0.19	0.27	0.54
Bexley	4122	0.17	0.45	0.38
Hackney	3986	0.13	0.87	0
Lambeth	3438	0.09	0.58	0.33
Bromley	3317	0.43	0.57	0
Westminster	3307	0	0.56	0.44
Waltham Forest	2961	0	0.55	0.45
Richmond upon Thames	2956	0.12	0.71	0.17
Southwark	2940	0	0.16	0.84
Greenwich	2897	0	0.53	0.47
Camden	2758	0	0.11	0.89
Kensington and Chelsea	2752	0.28	0.72	0
Kingston upon Thames	2180	0.23	0.63	0.14
Hounslow	2128	0.35	0.65	0
Havering	1904	0.22	0.42	0.36
Sutton	1897	0	1	0
Merton	1632	0.24	0.53	0.23
City of London	0	0	0	0

C. INCOME SHARES OF HOUSEHOLDS WITH RETIRED PERSONS

Borough	Count	High income	Middle income	Low income
Ealing	5875	0.27	0.56	0.17
Brent	5411	0.15	0.77	0.08
Wandsworth	4546	0.29	0.43	0.28
Barking and Dagenham	4433	0.65	0.35	0
Westminster	4293	0	0.43	0.57
Barnet	3934	0.14	0.38	0.48
Kingston upon Thames	3822	0.56	0.44	0
Hounslow	3493	0.28	0.59	0.13
Lambeth	3468	0	0.37	0.63
Merton	3396	0.08	0.92	0
Bexley	2946	0.24	0.76	0
Waltham Forest	2846	0.14	0.52	0.34
Greenwich	2806	0.2	0.35	0.45
Redbridge	2760	0.39	0.35	0.26
Southwark	2607	0	0.15	0.85
Islington	2465	0	1	0
Enfield	2033	0.61	0.39	0
Camden	1984	0	0.82	0.18
Kensington and Chelsea	1843	0.21	0.79	0
Hackney	1788	0.28	0.22	0.5
Sutton	1757	0.56	0.2	0.24
Newham	1649	0.31	0.36	0.33
Bromley	1590	0	0.62	0.38
Croydon	1373	0.69	0.31	0
Harrow	1345	0.28	0.72	0
Hillingdon	1318	0.41	0.59	0
Haringey	1130	0.38	0.62	0
Hammersmith and Fulham	1042	0.37	0.63	0
Havering	991	0	0.73	0.27
Lewisham	835	0.47	0.53	0
Tower Hamlets	450	0	0	1
Richmond upon Thames	261	0	1	0
City of London	0	0	0	0

D. INCOME SHARES OF HOUSEHOLDS WITH TWO OR LESS RESIDENTS

Borough	Count	High income	Middle income	Low income
Brent	25038	0.25	0.5	0.25
Barnet	24842	0.23	0.61	0.16
Redbridge	23127	0.39	0.4	0.21
Croydon	23073	0.49	0.35	0.17
Hillingdon	22206	0.29	0.58	0.13
Ealing	21496	0.34	0.51	0.15
Lambeth	21117	0.25	0.53	0.22
Enfield	20493	0.36	0.39	0.25
Newham	19734	0.13	0.42	0.45
Hounslow	18583	0.51	0.43	0.06
Wandsworth	18582	0.4	0.39	0.2
Lewisham	17105	0.26	0.38	0.36
Waltham Forest	17034	0.35	0.48	0.17
Bromley	16752	0.41	0.44	0.15
Merton	16006	0.21	0.64	0.15
Barking and Dagenham	15309	0.38	0.31	0.31
Tower Hamlets	14881	0.2	0.4	0.4
Hackney	14838	0.12	0.55	0.33
Havering	14443	0.18	0.49	0.33
Harrow	14369	0.43	0.43	0.14
Southwark	14279	0.22	0.56	0.22
Bexley	14104	0.2	0.59	0.2
Haringey	13945	0.25	0.54	0.2
Islington	13158	0.4	0.37	0.23
Sutton	12979	0.46	0.43	0.1
Greenwich	12801	0.15	0.66	0.19
Camden	11589	0.12	0.4	0.48
Kingston upon Thames	9960	0.14	0.56	0.3
Richmond upon Thames	9787	0.2	0.53	0.27
Westminster	9164	0.3	0.39	0.3
Hammersmith and Fulham	8009	0.29	0.51	0.2
Kensington and Chelsea	6411	0.52	0.41	0.07
City of London	0	0	0	0

E. PUBLIC TRANSPORT TIMES

		1	2	3	4	5	6	7	8	9	10	11
Camden	1	10	29	37	35	43	22	43	35	47	40	29
City of London	2	33	10	32	38	35	43	38	44	31	30	15
Hackney	3	37	31	10	67	53	40	67	51	55	47	40
Hammersmith & Fulham	4	39	39	59	10	63	47	23	45	61	51	41
Haringey	5	38	38	49	65	10	30	64	52	77	65	43
Islington	6	36	39	36	55	31	10	44	44	57	60	34
Kensington & Chelsea	7	33	34	67	21	60	44	10	31	45	43	29
Lambeth	8	37	35	49	50	55	44	51	10	68	53	38
Lewisham	9	45	31	52	63	66	65	66	72	10	46	41
Newham	10	38	31	48	46	68	54	50	53	50	10	27
Southwark	11	28	16	35	48	45	39	45	31	27	33	10
Tower Hamlets	12	39	24	43	54	59	48	55	56	30	16	29
Wandsworth	13	49	44	63	22	63	52	40	39	57	60	49
Westminster	14	18	20	38	32	42	32	28	29	45	35	24
Barking & Dagenham	15	65	56	64	82	76	71	81	86	86	51	56
Barnet	16	41	45	64	62	32	46	56	54	78	62	46
Bexley	17	75	56	82	87	95	88	87	93	40	66	58
Brent	18	17	50	52	49	58	59	40	54	65	56	45
Bromley	19	48	48	64	55	71	57	48	39	42	65	48
Croydon	20	55	55	61	52	76	61	66	65	43	57	49
Ealing	21	43	42	64	42	67	55	32	56	73	58	49
Enfield	22	63	52	44	78	35	42	77	66	80	85	57
Greenwich	23	65	50	72	91	92	76	86	80	38	39	59
Harrow	24	27	56	69	57	78	62	53	69	79	67	53
Havering	25	46	32	38	67	55	44	63	64	58	33	45
Hillingdon	26	49	71	91	69	92	76	62	88	89	87	73
Hounslow	27	50	71	85	29	90	70	53	41	58	97	45
Kingston upon Thames	28	72	75	82	53	75	68	53	52	66	80	65
Merton	29	52	36	63	42	64	57	55	33	59	54	30
Redbridge	30	50	35	50	69	71	52	59	60	58	34	37
Richmond upon Thames	31	54	59	88	47	75	60	34	40	55	55	46
Sutton	32	54	58	72	48	76	67	48	55	60	73	46
Waltham Forest	33	40	34	26	52	34	20	53	44	59	58	34

		12	13	14	15	16	17	18	19	20	21	22
Camden	1	42	39	18	64	48	78	19	46	52	40	59
City of London	2	22	41	21	48	56	57	50	49	50	45	50
Hackney	3	40	72	39	61	65	84	53	70	70	66	47
Hammersmith & Fulham	4	54	24	35	82	78	88	61	54	59	44	74
Haringey	5	61	67	40	80	29	97	54	73	73	72	36
Islington	6	49	65	30	72	41	84	52	65	68	45	52
Kensington & Chelsea	7	57	42	30	88	61	73	32	44	51	28	74
Lambeth	8	52	36	28	83	65	81	54	38	66	48	67
Lewisham	9	28	67	44	70	77	40	74	41	43	67	76
Newham	10	18	45	34	39	75	66	56	57	44	61	74
Southwark	11	31	56	22	59	56	53	49	51	42	59	57
Tower Hamlets	12	10	52	35	54	73	64	63	76	52	62	71
Wandsworth	13	59	10	54	83	74	91	64	58	43	58	78
Westminster	14	38	38	10	57	61	75	39	40	50	34	57
Barking & Dagenham	15	63	79	61	20	105	95	95	95	96	86	95
Barnet	16	65	63	52	90	20	97	60	67	79	67	40
Bexley	17	62	89	71	94	106	20	103	64	79	96	99
Brent	18	58	57	40	90	58	92	10	80	54	35	70
Bromley	19	80	52	47	94	75	66	69	20	50	67	79
Croydon	20	60	58	49	84	87	95	57	56	20	89	89
Ealing	21	60	47	33	83	77	100	29	75	64	10	81
Enfield	22	83	76	54	83	54	111	80	76	86	83	20
Greenwich	23	39	83	60	73	101	51	87	66	74	90	104
Harrow	24	66	67	41	91	61	108	29	83	77	57	93
Havering	25	37	68	43	30	86	93	63	89	74	66	67
Hillingdon	26	86	86	61	115	91	119	68	95	96	60	99
Hounslow	27	59	40	57	115	91	89	49	80	44	35	100
Kingston upon Thames	28	82	45	50	110	88	93	57	62	52	54	88
Merton	29	54	28	39	78	73	83	71	63	40	67	74
Redbridge	30	39	70	44	65	77	84	69	70	73	65	82
Richmond upon Thames	31	56	19	46	99	87	82	48	51	42	55	96
Sutton	32	70	41	49	99	86	98	53	62	26	64	90
Waltham Forest	33	56	53	31	45	48	88	53	55	60	46	45

		23	24	25	26	27	28	29	30	31	32	33
Camden	1	56	34	63	48	50	56	39	46	47	76	36
City of London	2	46	52	41	68	68	51	36	33	43	47	34
Hackney	3	68	70	49	97	85	72	61	42	61	87	26
Hammersmith & Fulham	4	77	70	77	66	48	41	40	64	32	47	52
Haringey	5	90	79	71	88	93	73	55	55	69	78	30
Islington	6	70	68	66	75	72	73	56	56	59	72	26
Kensington & Chelsea	7	67	49	63	70	53	58	54	61	40	52	58
Lambeth	8	79	67	74	85	62	54	28	60	42	39	43
Lewisham	9	34	87	67	87	92	74	52	56	67	71	66
Newham	10	33	58	35	85	75	70	41	31	46	73	58
Southwark	11	56	56	52	71	65	51	29	42	41	52	40
Tower Hamlets	12	35	66	49	84	83	62	48	40	53	71	49
Wandsworth	13	76	72	51	92	41	33	29	71	19	41	51
Westminster	14	49	45	54	57	62	51	33	42	40	44	31
Barking & Dagenham	15	64	99	28	115	120	94	80	60	79	101	50
Barnet	16	86	68	80	77	84	81	67	71	65	83	47
Bexley	17	47	120	91	120	111	103	83	86	100	110	87
Brent	18	81	28	74	73	48	62	62	73	44	72	51
Bromley	19	57	81	87	92	82	73	57	73	53	66	55
Croydon	20	80	74	79	105	65	48	38	75	41	26	63
Ealing	21	80	52	79	55	30	60	70	69	47	73	55
Enfield	22	100	78	79	113	107	90	78	74	85	98	37
Greenwich	23	20	92	71	109	105	87	80	63	82	91	82
Harrow	24	89	20	83	43	59	76	75	84	57	83	69
Havering	25	53	81	25	92	99	82	63	34	77	90	45
Hillingdon	26	110	43	100	25	80	102	95	97	81	116	80
Hounslow	27	81	66	106	76	20	64	42	93	41	49	75
Kingston upon Thames	28	93	73	108	59	66	25	38	86	28	45	66
Merton	29	75	85	71	90	65	40	10	62	40	45	53
Redbridge	30	55	87	55	94	99	90	59	20	69	81	36
Richmond upon Thames	31	93	62	82	62	38	38	43	81	10	54	65
Sutton	32	99	76	89	109	62	39	36	80	48	20	63
Waltham Forest	33	65	61	52	77	87	63	50	30	54	66	10

F. TURKISH SUMMARY / TÜRKÇE ÖZET

GİRİŞ

Trafik sıkışıklığı dünyanın her yerinde büyük kentlerde yaşanan önemli sorunlardan bir tanesidir. TomTom trafik indeksi 56 ülkedeki şehirlerde görülen sıkışıklık seviyeleri hakkında bilgi vermekterdir. Indeks trafiğin en sıkışık olduğu saatlerdeki seyahat süreleriyle trafik yoğunluğu gözlenmeyen saatlerdeki süreleri karşılaştırmaktadır. 2018 verilerine göre, Mumbai %65'lik trafik sıkışıklığı seviyesi ile bu sorundan en çok muzdarip olan kent olarak görülmektedir. Bütün kıtalardan büyük şehirler %30'dan yüksek seviylerle trafik sıkışıklığı problemi yaşamaktadır. Trafik sıkışıklığı sağlık problemlerine, zaman ve kaynak israfına yol açmakta, düşük trafik hızları yakıt tüketimini artırmakta ve iklim değişikliği üzerinde olumsuz etkiye yol açmaktadır (Hopkins and McKay, 2018).

Yerel otoriteler bu sorunlarla mücadele etmek için politikalar geliştirmek durumundadır ve bu süreçte olası projelerin muhtemel etkilerini öngörmek son derece faydalı olacaktır. Olası politika eylemlerinin ekonomik etkileri Hesaplanabilir Genel Denge (HDG) modelleri kullanılarak tahmin edilebilmektedir.

Hesaplanabilir Genel Denge modelleri makroekonomik kısıtları ve bireysel mikroekonomik davranışları hesaba katarak bütün bir ekonomiyi tarif etmektedir. Ayrıca bu modeller ekonomi ve ulaşım etkileşimini incelemek açısından elverişli araçlardır (Shahraki and Bachmann, 2018).

Bölgesel Genel Denge modelleri çoğunluka ticaretle ilgili sorunları incelemek için kullanılırkan, kent ölçeğindeki sorunları incelemek için kent ölçekli Hesaplanabilir

Genel Denge modellerinden faydalanılmaktadır. Kent ölçekli Genel Denge modelleri ekonomik aktörlerin yerleşim bölgesi veya çalışma bölgesi seçimi gibi ayrık seçim problemlerini de içermektedirler. Anas'ın Bölgesel Ekonomi, Arazi Kullanımı ve Ulaşım modeli (RELU-TRAN) ulaşım politikalarının kent ekonomisi üzerindeki etkilerini inceleyen modellere önemli bir örnek teşkil etmektedir [Anas and Kim(1996), Anas and Xu (1999), Anas and Liu (2007), Anas and Hiramatsu (2012), Anas (2013a), Anas (2013b), Anas and Hiramatsu (2013)]. RELU-TRAN modeli Chicago Los Angeles için kalibre edilmiştir ve kullanılmaktadır. Melbourne'e uygulanmış Horridge (1994) modeli, Tokyo'ya uygulanan Sato ve Hino (2005) modeli, Zurih'e uygulanan Rutherford ve Van Nieuwkoop (2011) modeli ve Sydney'e uygulanan Turong ve Hensher (2012) modelleri literatüre katkı yapan diğer modellere örnek olarak sayılabilir.

Yılmaz (2018) Londra'nın kuzey-güney hattında hayata geçirilecek olan Crossrail 2 tren yolu projesinin etkilerini incelemek için Hanehalkı Ayrık Seçim modeli ve Ulaşım modeli ile entegre çalışan bir Hesaplamalı Genel Denge modeli geliştirmiştir. Yılmaz'ın (2018) çalışmanın temel amacı kentsel ulaşım politikalarının farklı hanehalkı grupları üzerindeki etkilerini analiz etmektir.

Bu tez kapsamında, Yılmaz'ın (2018) modeli açıklayıcı gücünün artırılması ve hanehalklarının daha detaylı alt gruplara ayrılması hedeflenerek geliştirilmiştir. Hanehalklarının yerleşim bölgesi seçim mekanizmasının daha gerçekçi bir hale getirilmesi amaçlanmıştır.

Bu çalışmada temel olarak London Travel Demand Survey (2014) verisinden yararlanılmış ve iki alternatif muhtemel ulaşım politikasının etkileri incelenmiştir. Bu politikalardan ilki toplu ulaşım altyapısında topyekün bir iyileştirme, ikincisi ise Londra kent merkezindeki kimi yollar için uygulanan trafik yoğunluğu ücretinde bir artırım olarak düşünülmüştür. İki politika da trafik yoğunluğu ile mücadele etmek için hayata geçirilebilecek olası politikalar olarak değerlendirilmektedir. Hanehalkları hanede okul çocuğu bulunup bulunmaması, evde yaşlı birey bulunup bulunmaması gibi veriler kullanılarak daha da ayrıştırılmıştır. Analiz sonuçları Yılmaz'ın (2018) modelinin geliştirilmesi ile elde edilen modelin hanehalkı gruplarının davranışları açısından daha detaylı bir tablo ortaya çıkardığını göstermektedir.

MODEL

Bu çalışmada kullanılan model çerçevesinde hanehalkları faydalarını maksimize etmek amacı ile oturma alanı ve mal tüketim miktarlarına ve hangi ilçeyi yerleşim bölgesi olarak seçeceklerine karar vermektedirler. İşe gidiş dönüş zaman ve maliyeti de karar alma süreçlerini etkileyen etmenlerdir. İşe gidiş dönüş toplu ulaşımla veya özel araçla sağlanabilmektedir. Yılmaz'ın (2018) modelinde ilçelerin cazibe seviyeleri bütün hanehalkı gruplarına aynı görünmekteyken, bu çalışmada ilgili terim bütün alt gruplar için heterojenize edilmiştir. Bu çalışmanın esas katkısı ilçelerin cazibe seviyelerinin hanehalkları için değişkenlik gösterebileceği olgusunun modele dahil edilmiş olmasıdır. Örneğin, bünyesinde okul çocuğu bulunduran bir hane için okula erişim kolaylığı bir bölgeyi diğerlerine göre daha çekici hale getirebilir. İlçelerin cazibe seviyelerinin hanehalkı alt grupları için heterojenize edilmesi sayesinde bahsedilen durum hanelerin yerleşim bölgesi seçimi mekanizmalarına dahil edilmiş olmaktadır.

Yılmaz'ın (2018) çalışmasında olduğu gibi bu çalışmada kullanılan model de bir ayrık seçim modeli, ulaşım modeli ve genel denge modelinin entegre edilmesi ile elde edilmiştir. Ayrık seçim modeli hanehalklarının yerleşim bölgeleri ve ulaşım yöntemleri arasından yapacakları seçimleri belirlemekte, ulaşım modeli ise özel araç kullanıcısı hanelerin işe gidiş geliş için kullanacağı rotaları ve işe gidiş geliş sürelerini hesaplamaktadır. Genel denge modeli, hanehalkları ve firmaların optimizasyon problemlerini dahil ederek modeli tamamlamaktadır.

Hanehalklarının optimizasyon problemi aşağıdaki denklemlerle tanımlanmaktadır:

$$\max\ U_{iwsgt}(c,d) = \left(\alpha_{iwsgt} c_{iwsgt}^{\rho} + \alpha_{iwsgt}^{h} d_{iwsgt}^{\rho}\right)^{1/\rho} - \gamma\tau_{iw} + \Psi_{iwsgt} \quad (1)$$

$$\text{s.t.} \qquad r_i d_{iwsgt} + p c_{iwsgt} + \kappa_{iw} \leq M_{iwsgt} \quad (2)$$

$$\text{with} \qquad M_{iwsgt} = \omega e_{iwsgt}^{L} + \delta e_{iwsgt}^{K} + \sum_{i'} r_{i'} e_{iwsgt}^{H}(i') \quad (3)$$

Hanehalkı fayda fonksiyonu ($U_{iwsgt}(c,d)$), üç bileşenin toplamından oluşmaktadır. İlk bileşen mal tüketimi (c_{iwsgt}^{ρ}) ve oturma alanı tüketimi (d_{iwsgt}^{ρ}) değişkenlerini içermektedir. α_{iwsgt} ve α_{iwsgt}^{h} parametreleri başlangıç dengesi verileri kullanılarak kalibre edilmiştir. İkinci bileşen işe gidiş geliş süresinden (τ_{iw}) kaynaklı negative faydayı temsil etmektedir. Üçüncü bileşen ise ilçe cazibe seviyesini (Ψ_{iwsgt}) göstermektedir. Hanehalkları beş index kullanılarak alt gruplara ayrılmıştır. Burada, *i* yerleşim bölgesini, *w* çalışılan bölgeyi, *g* gelir grubunu, *t* ulaşım yöntemini, *s* ise hanede okul çocuğu bulunup bulunmaması gibi ekstra bir özelliği ifade etmektedir. Hanehalkı geliri (M_{iwsgt}), maaş geliri (ω), sermaye kira geliri (δ) ve konut kira gelirlerinden (r_i) oluşmaktadır. Özel araçla yapılan seyahatin maliyeti (κ_{iw}) aşağıdaki gibi hesaplanmaktadır (Treiber, 2008):

$$\kappa_{iw} = \left[C^f + \frac{\tau_{iw}}{\tau_{iw}^{f}} \frac{t_{100}^{f}}{t_{100}^{c}} (C^c - C^f)\right] D_{iw} p^f \left(\frac{2*365}{100}\right) \quad (4)$$

Burada, D_{iw} bölgeler arasındaki mesafeyi, p^f ise yakıt ücretini temsil etmektedir.

Hanehalklarının yerleşim bölgesi ve ulaşım yöntemi seçimleri "Ayrık Seçim Modeli" kullanılarak belirlenmektedir. Ayrık seçim modelleri malların tüketim miktarlarının sürekli kabul edildiği standart tüketim modellerinden farklı olarak, iki veya daha fazla ayrık alternative arasında yapılacak seçimleri tarif etmektedir. Karar alıcının seçim yaparken faydasını maksimize ettiği kabul edilir ve fayda fonksiyonuna gözlemci tarafından gözlemlenemeyen etkenleri temsil etmesi amacıyla bir rasgele bileşen dahil edilir (Train, 2009):

$$U_{ni} = V_{ni} + \varepsilon_{ni} \qquad (i = 1,2,3, \ldots., J) \tag{5}$$

Rasgele değişkenin (ε_{ni}) Gumbel dağılımına sahip olduğu varsayımı ile bütün alternatifler arasından bir alternatifin seçilme olasılığı aşağıdaki formülle hesaplanabilir (Train,2009):

$$P_n(i) = \frac{e^{V_{ni}}}{\sum_{j=1}^{J} e^{V_{nj}}} \tag{6}$$

Böylece, w ilçesinde çalışan, g gelir grubuna ve s kategorisine ait olan bir hanehalkının bir yerleşim bölgesi ve ulaşım metodu çiftini seçme olasılığı aşağıdaki gibi hesaplanabilir:

$$P_{wsg}(i,t) = \frac{exp\left[\left(\alpha_{iwsgt} c_{iwsgt}^{\rho} + \alpha_{iwsgt}^{h} d_{iwsgt}^{\rho}\right)^{1/\rho} - \gamma\tau_{iw} + \Psi_{iwsgt}\right]}{\sum_j \sum_{t'} exp\left[\left(\alpha_{jwsgt'} c_{jwsgt'}^{\rho} + \alpha_{jwsgt'}^{h} d_{jwsgt'}^{\rho}\right)^{1/\rho} - \gamma\tau_{jw} + \Psi_{jwsgt'}\right]} \tag{7}$$

Ulaşım modeli Wardrop'un birinci ilkesine (1952) dayanarak tasarlanmıştır. Wardrop'un birinci ilkesi trafikte denge durumunda hiçbir sürücü için halihazırda kullandığından daha az zaman alacak alternative bir rota bulunmadığını ifade eder. Model, Yılmaz (2018) tarafından Le Blanc'ın (1975) seyahat süresi formulasyonu kullanılarak aşağıdaki denklemlerle ifade edilmiştir:

$$\min z(x) = \sum_a t_a(x)dx \qquad where \quad t_a(x) = A_a + B_a \left[\frac{x_a}{Q_a}\right]^4 \tag{8}$$

$$s.t.\ \ (1)\sum_{path} f_p^{iw} = N_{iw} \tag{9}$$

$$(2) x_a = \sum_i \sum_w \sum_p f_p^{iw}\, \Delta_{a,p}^{iw} \tag{10}$$

Burada, “a” iki ilçe arasındaki bağlantı yolunu ifade etmektedir. Bir bağlantı yolunu geçmek için harcanan zaman t_a, yol üzerindeki trafik akışı miktarı x_a ile ifade edilmiştir. Q_a yolun kapasitesini, B_a trafik sıkışıklığı katsayısını, A_a ise yol üzerinde herhangi bir trafik yoğunluğu yokken yolu geçmek için gereken zamanı ifade etmektedir. Trafikte denge hali bütün yollar üzerinde geçirilen sürelerin toplamı minimize edilerek elde edilir. Denklem 9, iki ilçe arasındaki seyahat talebinin (N_{iw}) bu bölgeler arasındaki alternative rotalar üzerindeki akış miktarlarının (f_p^{iw}) toplamına eşit olduğunu ifade eder. Denklem 10 bir yol üzerindeki toplam akışın, farklı bölgeler arasında seyahat etmek için bu yolu kullanan sürücülerin oluşturduğu akışların toplamına eşitliğini ifade etmektedir. $\Delta_{a,p}^{iw}$, i ilçesinden w ilçesine p rotasını kullanarak seyahat edenler a yolunu kullanıyor ise 1 değerini alan ikili bir değişkendir.

Bölgeler arasındaki seyahat talebi miktarları egzojen olarak verildiğinde yukarıda verilen ulaşım modeli, bu seyahatler için kullanılacak rotaları ve trafikte denge durumunda bütün yolların seyahat sürelerini hesaplamaktadır. Fakat, bir optimizasyon problemini çözen bu ulaşım modelini mevcut haliyle CGE modeline entegre ederek kullanmak pratik bir yöntem olmamaktadır. Bir denklem setini simültane olarak çözmek, bir optimizasyon problemini çözmekten daha kolaydır. Bu yüzden CGE modeli ile entegre kullanılacak ulaşım modeli modifiye aşağıdaki gibi modeifiye edlmiştir:

$$\sum_{path} f_p^{iw} = N_{iw} \tag{11}$$

$$x_a = \sum_i \sum_w \sum_p f_p^{iw}\, \Delta_{a,p}^{iw} \tag{12}$$

$$t_a = A_a + B_a \left[\frac{x_a}{Q_a}\right]^4 \quad (13)$$

$$t_p^{iw} = \sum_a t_a \Delta_{a,p}^{iw} \quad (14)$$

$$t_{p=1}^{iw} = \sum_p \frac{t_p^{iw}}{\pi_{iw}} \quad (15)$$

Eğer bütün yolculuklar için toplam seyahat süresini minimize rotalar biliniyorsa ve modifiye edilmiş modele girdi olarak verilirse yolların seyahat süreleri bu denklem seti çözülerek hesaplanabilmektedir. Bu $\Delta_{a,p}^{iw}$ parametrelerinin artık endojen olmaması anlamına gelmektedir. Bu durumda başlangıç ekonomik dengesine bir şok uygulandığında, bir çözüm prosedürü stratejisi olarak, ilk önce başlangıç durumundaki rotalar verili kabul edilerel entegre edilmiş model çözülmekte ve ilçeler arasındaki yeni seyahat talebi miktarları belirlenmektedir. Sonrasında bu seyahat talebi miktarları kullanılarak ulaşım optimizasyon problemi çözülür ve yeni rotalar elde edilir. Bu süreç optimizasyon problemi sonucu elde edilen rotalar değişmez hale gelene kadar iteratif bir biçimde çözülmektedir.

Modellenen kent ekonomisinde yalnızca bir adet malın üretildiği varsayılmaktadır. Üretim firmalar tarafından iki üretim faktörü kullanılarak yapılmaktadır. Bunlar emek (L) ve sermayedir (K). Temsili firmanın optimizasyon problemi aşağıda verildiği gibidir:

$$\min \quad \mathrm{C(K, L)} = \delta K + \omega L \quad (16)$$

$$\mathrm{s.t.} \quad y = [\beta K^\rho + (1-\beta) L^\rho]^{1/\rho} \quad (17)$$

Burada, $\mathrm{C(K, L)}$ firmanın üretim maliyetini, y üretim miktarını temsil etmektedir. Firmalar belli bir miktar malı üretirken maliyetlerini minimize etmektedirler.

Model aşağıda verilen piyasa dengesi denklemleri ile kapanmaktadır:

$$y = \sum_i \sum_w \sum_s \sum_g \sum_t N_{wsg}(i,t)\left(c_{iwsgt} + \kappa_{iw}\right) \quad (18)$$

$$K = \sum_i \sum_w \sum_s \sum_g \sum_t N_{wsg}(i,t) e^K_{iwsgt} \quad (19)$$

$$L = \sum_i \sum_w \sum_s \sum_g \sum_t N_{wsg}(i,t) e^L_{iwsgt} \quad (20)$$

$$\sum_w \sum_s \sum_g \sum_t N_{wsg}(i',t) d_{i'wsgt} = \sum_i \sum_w \sum_s \sum_g \sum_t e^H_{iwsgt}(i') \quad \forall i' \quad (21)$$

Burada dikkat edilmesi gereken bir husus ulaşım maliyetinin ekonomide üretilen tek tip mal cinsinden kabul edildiği varsayımıdır. Ayrıca, e^K_{iwsgt}, e^L_{iwsgt} ve $e^H_{iwsgt}(i')$ hanelerin sahip olduğu emek, sermaye ve oturma alanı miktarlarını temsil etmektedir.

SİMÜLASYON SONUÇLARININ DEĞERLENDİRİLMESİ

Bir önceki bölümde verilen model London Travel Demand Survey (LTDS) 2014, Census 2011, Google Maps, Valuation Office Agency (VOA) Private Rental Market Statistics (2014) ve Transport for London (TfL) Oyster Card Prices (2014) verileri kullanılarak kalibre edilmiş ve ardından politika şokları uygulanarak olası politika eylemlerinin ekonomik etkileri simüle edilmiştir.

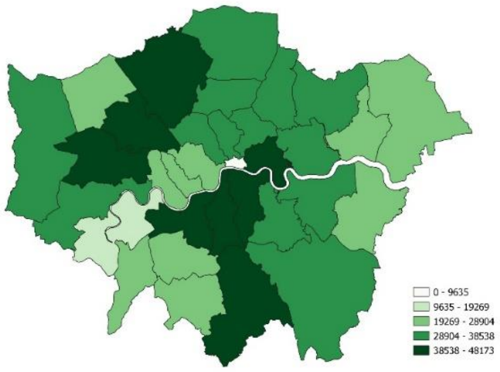
Kalibre edilen parametreler, hanelerin fayda fonksiyonlarının mal ve oturma alanı tüketimi terimlerini içeren bileşendeki α_{iwsgt} ve α^h_{iwsgt} parametreleri ve ilçe cazibe seviyelerini temsil eden Ψ_{iwsgt} parametreleridir. Bunlar eldeki başlangıç dengesi verileri kullanılarak kalibre edilirken, modelde varolan diğer parametre değerleri verili kabul edilmiştir. Verili kabul edilen parametreler ikame esnekliği parametresi (σ), seyahat sürelerinden kaynaklanan olumsuz fayda katsayı parametresi (γ), ve temsili firmanın üretim fonsiyonunda yer alan β parametresidir. Bunlara makul değerler atanmıştır.

Ulaşım modeli parametrelerinin kalibrasyonunda ise farklı bir yol izlenmiştir. A_a, B_a ve Q_a parametrelirini kalibre etmek yerine bunlara makul değerler atanmış ve modeldeki değişkenlerin değerleri hesaplanmıştır. Sonrasında, ilçeler arasındaki gerçek seyahat süreleri Google Maps'ten alınmış ve gerçek sürelerle hesaplanan sürelerin farkını gösteren bir kalibrasyon matrisi hazırlanmıştır. Simülasyonlar yapılırken hesaplanan entegre model içinde hesaplanan seyahat süreleri bu matristeki değerler üzerlerine eklenerek kullanılmıştır. Böylece simülasyon sürecinde, ilçeler arası yoların gerçek seyahat sürelerinden faydalanılmış olmaktadır.

Bu bölümde öncelikle başlangıç denge durumu görseller aracılığı ile tarif edilmiş, ardından trafik altyapısının tamamında yapılacak ve bütün ilçeler arasındaki toplu ulaşım sürelerini %20 azaltacak bir iyileştirmenin farklı hanehalkı grupları üzerindeki etkileri Londra haritası üzerinde görselleştirilerek verilmiştir.

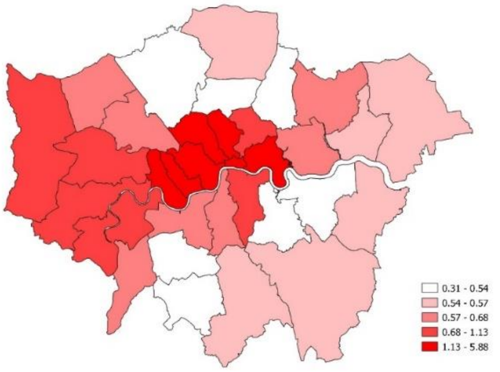
Şekil 1 Londra'nın ilçelerinde ikamet eden hanehalkı sayılarını vermektedir. Merkez ilçeler çoğunlukla daha kalabalık görünmektedir, fakat çevre ilçelerde de nüfus yoğunluğu görülebilmektedir.

City of London ilçesinde yerleşik hanehalkı sayısı sıfır görünmektedir. Bu hem ilgili ilçeyle ilgili hanehalkı verisi yetersizliğinden hem de data işleme sürecinde kimi kriterleri karşılamayan hanelerin hesaplamaya dahil edilmemesinden kaynaklanmaktadır. İlçe yerleşimci hane sayısı açısından son derece küçük olduğundan bu durumun bir sorun teşkil etmeyeceği değerlendirilmiştir.



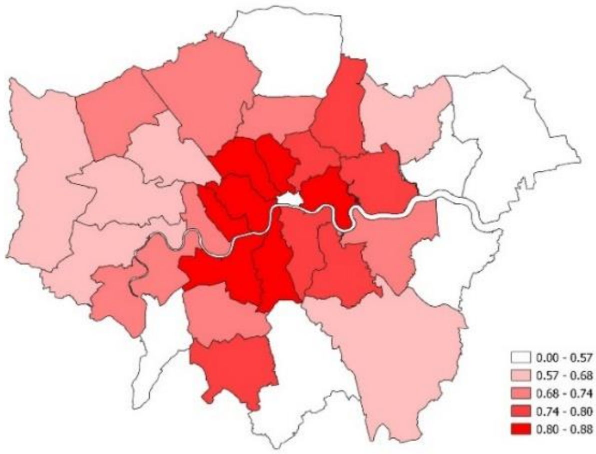
Şekil 1 – İlçelerde yerleşik hanehalkı sayısı

Şekil 2, ilçelerdeki çalışan/yerleşik nüfus oranını göstermektedir. Beklendiği gibi kent merkezindeki ilçelerde bu oranın yüksek olduğu görülmektedir.



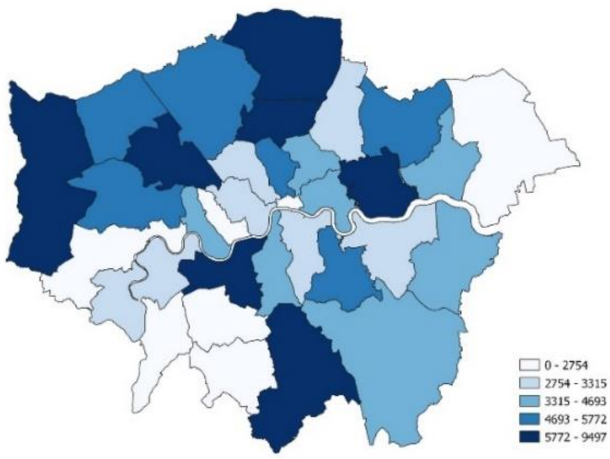
Şekil 2 – Çalışan/yerleşik nüfus oranı

Şekil 3'te ilçelerdeki toplu taşıma kullanıcılarının oranı verilmektedir. Görüldüğü gibi merkez ilçelerde işe gidiş geliş amaçlı seyahatlerde toplu taşıma kullanımının özel araç kullanımına oranı son derece yüksektir. Çevre ilçelerde ise özel araç kullanımının tercih edildiği görülmektedir.

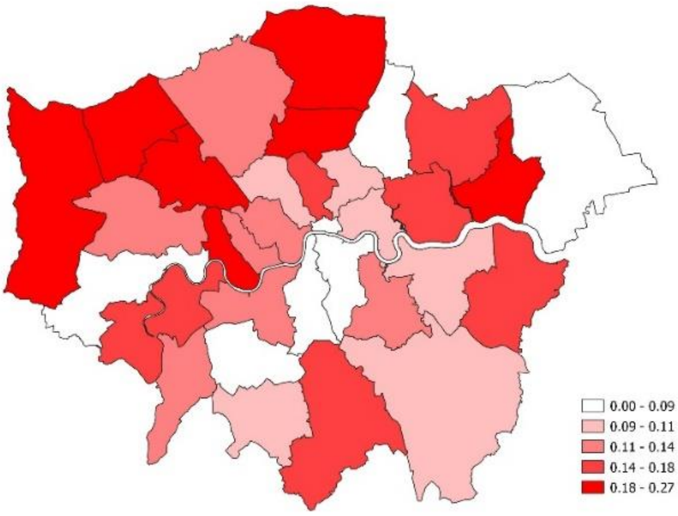


Şekil 3 – Toplu taşıma tercih edenlerin oranları

Ayrıca alt hanehalkı gruplandırmasına örnek olarak, bünyesinde okul çocuğu bulunduran hanelerin sayıları ve oranları Şekil 4 ve 5'te görülmektedir.



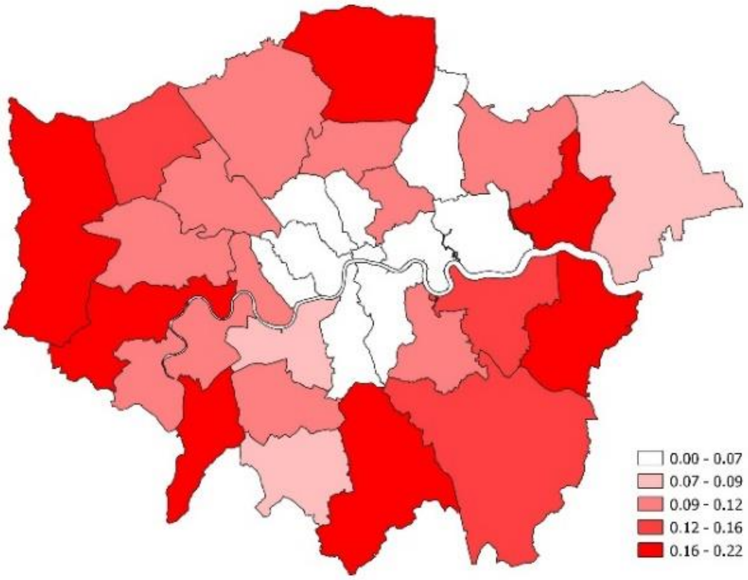
Şekil 4 – Okul çocuğu bulunduran hanelerin sayısı



Şekil 5 – Okul çocuğu bulunduran hanelerin oranı

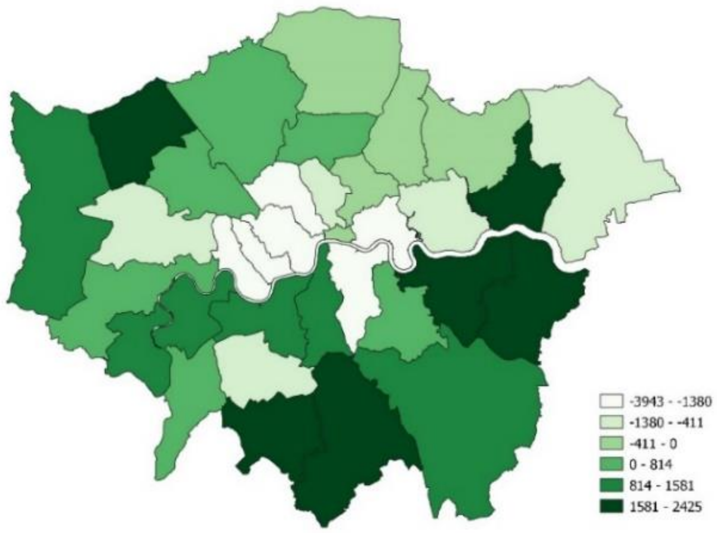
Mevcut başlangıç dengesine politika şoku olarak toplu ulaşım altyapısında toplu bir iyileştirmeyi temsilen bütün ilçeler arasındaki toplu ulaşım seyahat sürelerinde %20’lik bir azalma uygulanmıştır. Simülasyon ilk olarak hanehalklarını yerleşim bölgesi, çalışılan ilçe, ulaşım yöntemi ve gelir gruplarına göre kategorize ederek yapılmıştır. Ardından hanehalkarı evde okul çocuğu bulunup bulunmamasına göre daha da ayrıştırılarak simülasyon tekrarlanımştır. Bu iki simülasyonun sonuçları karşılaştırılarak hanehalkları ve ilçe cazibe seviyelerinin heterojenize edilmesinin sonuçlara nasıl etkilerde bulunduğu araştırılmıştır. Sonuçlar hanehalklarını ayrıştırmanın ve ilçe cazibe seviyelerinin bu ayrıştırılmış hanehalkı grupları için heterojenize edilmesinin hanehalkı davranışlarında öncesinde görülemeyen detayların ortaya çıktığını göstermektedir.

Şekil 6, uygulanan politika eylemi neticesinde toplu taşım kullanımındaki yüzde değişimleri göstermektedir. Beklenildiği gibi toplu taşım kullanımı her ilçede artış göstermiştir. Uygulanan yüzde değişim yüksek seyahat sürelerine sahip bölgeler için daha fazla süre kazanımı anlamına geldiğinden, yüksek seyahat sürelerine sahip çevre ilçelerde toplu taşım kullanım artışı merkez ilçelere göre gözle görülür biçimde fazladır.

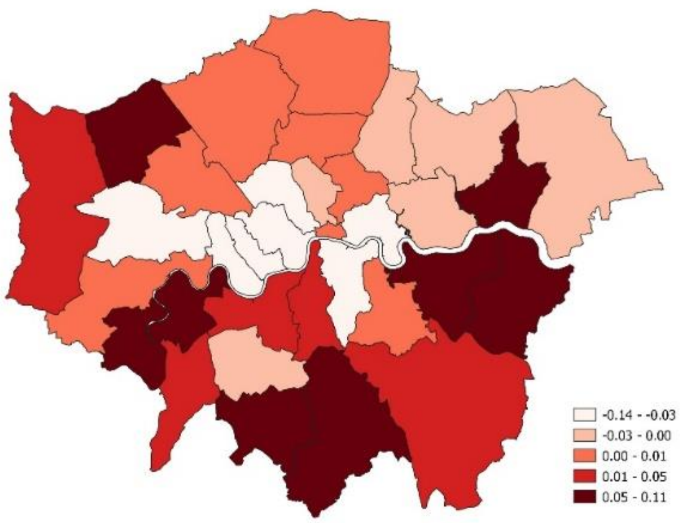


Şekil 6 – Toplu taşım kullanımında yüzde değişim

Uygulanan politika neticesinde çevre ilçelerin önceki durumlarına göre daha avantajlı hale gelmesi bu ilçelere doğru bir nüfus hareketine sebep olmuştur. Şekil 7'de de görüldüğü gibi çoğunlukla merkez ilçelerde negatif, çevre ilçelerde ise pozitif nüfus değişimi gözlenmektedir. Bu durumun bir sonucu olarak konut fiyatları çevre ilçelerde artmış, merkezde azalmıştır. Şekil 8'de konut fiyatlarındaki yüzde değişimler görülmektedir.

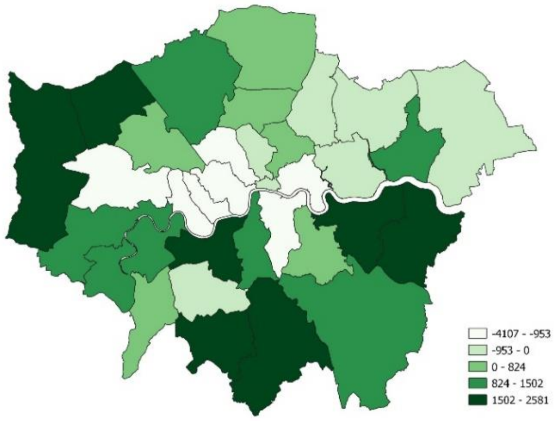


Şekil 7 – Yerleşik hanehalkı sayılarındaki değişim

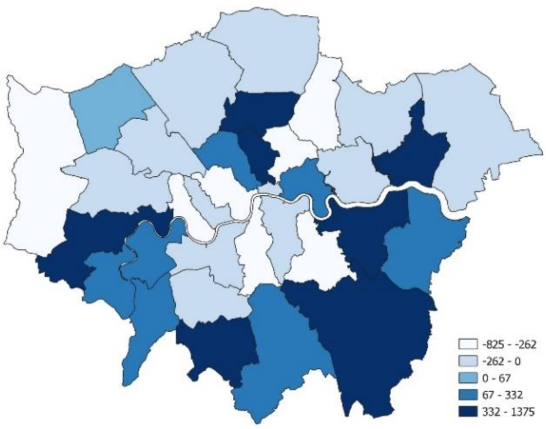


Şekil 8 – Konut fiyatlarında yüzde değişim

Sonrasında hanehalkları hanede okul çocuğu bulunup bulunmamasına göre daha da heterojenize edilerek simülasyon tekrar edilmiştir. Şekil 9 ve 10 sırasıyla ilçelerdeki toplam hanehalkı sayısı değişimini ve ilçelerdeki okul çocuklu hanehalkı sayılarındaki değişimi vermektedir.



Şekil 9 - Yerleşik hanehalkı sayılarındaki değişim



Şekil 10 – Okul çocuğu bulunduran hanelerin sayısındaki değişim

Şekil 9'da görüldüğü gibi daha önceki simülasyon sonucuna benzer biçimde burada da merkez ilçelerden çevre ilçelere doğru bir nüfus hareketi görülmektedir. Toplu taşıma sürelerinde meydana gelen %20 azalma çevre ilçeler için daha yüksek seyahat süresi azalmalarına tekabül etmektedir. Bu yüzden bu bölgeler başlangıç durumunlarına göre göreli olarak daha avantajlı hale gelmişlerdir. Fakat ilçelerdeki hanehalkı sayısı değişimi bir önceki simülasyon sonuçlarına yakın olsa da değerler tam olarak aynı değildir. Bu durum aşağıdaki tablolarla açıklanacak mekanizmadan kaynaklanmaktadır.

Table 1 – (29,1,1) kategorisine ait hanehalklarının başlangıç denge drumuunda ve şok uygulandıktan sonraki dağılımları

Nfixed(29,1,1) 1782			
N_init(28,29,1,1,1) 459	N_init(32,29,1,1,1) 728	N_init(20,29,1,1,2) 209	N_init(29,29,1,1,2) 386
N_final(28,29,1,1,1) 405.2638	N_final(32,29,1,1,1) 535.035	N_final(20,29,1,1,2) 381.7648	N_final(29,29,1,1,2) 459.9364

Table 2 – (29,1,1) ve (29,2,1) kategorisine ait hanehalklarının başlangıç denge drumuunda ve şok uygulandıktan sonraki dağılımları

Nfixed(29,1,1) 1187		Nfixed(29,2,1) 595	
N_init(28,29,1,1,1) 459	N_init(32,29,1,1,1) 728	N_init(20,29,2,1,2) 209	N_init(29,29,2,1,2) 386
N_final(28,29,1,1,1) 519.9179	N_final(32,29,1,1,1) 667.0821	N_final(20,29,2,1,2) 268.8989	N_final(29,29,2,1,2) 326.1011

Tablo 1'de ilçe 29'da çalışan ve yüksek gelir grubuna ait hanelerin, evlerinde okul çocuğu bulunup bulunmadğına göre kategorize edilmedikleri durumda hangi yaşama bölgesi (i) ve ulaşım modu (t) seçeneklerine dağıldıkları görülmektedir. Burada önemli bir kabul yapılmış, hanehalkı gruplarının başlangıç dengesinde hiç tercih etmedikleri ayrık seçim çiftlerini, şok uygulandıktan sonra da tercih etmeyecekleri varsayılmıştır. Tablo 1'de ilçe 29'da çalışan ve yüksek gelir grubuna ait hanelerin yalnızca dört farklı yerleşim bölgesi ve ulaşım modu çiftini tercih ettikleri ve bu seçeneklere dağıldıkları görülmektedir. Uygulanan şoktan sonra da mevcut dört ayrık seçim çifti alternatifine yeni koşullar altında yeniden dağılmışlardır. Tablo 2, ilçe 29'da çalışan ve yüksek gelir grubuna ait hanelerin bir de hanede okul çocuğu bulunup bulunmamasına göre ayrıştırlarak yapılan simülasyona ait değerleri vermektedir. İlk durumda 1782 hane sayısına sahip ilçe 29'da çalışan ve yüksek gelir grubuna ait hanelerin ikinci durumda 1187 hane çocuksuz ve 595 hane çocuklu olmak üzere iki alt gruba ayrıldığı görülmektedir. Bu iki alt grup da kendi içlerinde ikişer yerleşim bölgesi ve ulaşım mode ayrık seçim çiftlerine dağılmıştır. Yukarıda yapılan kabul burada çocuklu ailelerin şok uygulandıktan sonra yine bu iki ayrık seçim alternatifine dağılacakları anlamına gelmektedir. Çocuksuz haneler içinde aynı durum geçerlidir. Görüldüğü gibi ilk durumda şok uygulandıktan sonra 1782 hanenin tamamı dört farklı ayrık seçim çifti arasında tercih yaparken, yapılan ayrıştırma neticesinde 1187 hanelik ilk grup iki seçeneğe, 595 haneli ikinci grup da yine iki seçeneğe kısıtlanmış durumdadır. Burada örneğin çocuklu ailelerin başlangıç durumunda hiç tercih etmedikleri ayrık seçim çiftlerini oluşacak yeni denge durumunda da tercih etmeyecekleri varsayılmaktadır. Çünkü ilk durumda yaptıkları tercihlerin tüketim olanakları ve işe gidiş dönüş süre ve maliyetleri dışında, yerleştikleri bölgenin bu hanelerin başka ihtiyaçlarına hitap eden özgün birtakım özelliklerinden de kaynaklandığı düşünülmüştür. Örneğin başlangıç durumunda ilçe 29'da çalışan ve yüksek gelir grubuna ait olan hiç bir okul çocuklu aile ilçe 28'i yerleşmeyi tercih etmediğine göre evlerinde okul çocuğu bulunmasından kaynaklı ihtiyaçlarını ilçe 28'in karşılamadığı ve bu yüzden yeni durumda da bu ilçeye yerleşmeyecekleri düşünülmektedir. Görüldüğü gibi haneleri alt gruplara ayrıştırmak onların seçeneklerini daraltmaktadır. Bu durum haneleri bir alt gruba daha ayırarak yapılan simülasyon sonuçlarının bu kategorizasyon yapılmadan gerçekleştirilen simülasyon sonuçlarından farklı olmasına yol açmaktadır.

Şekil 10'da görülen okul çocuklu hanelerin hareketleri de çevre ilçeleri doğru hareket etme genel eğilimiyle çoğunlukla uyumludur. Burada dikkat edilmesi gereken nokta kimi ilçelerde toplam değişime bakıldığında hanehalkı sayısında bir artış görülmesine rağmen, okul çocuklu hanelerin sayısında bir azalma gözlenmesidir. Bu durum başlangıç durumunda okul çocuğuna sahip aileler için cazip olan kimi ilçelerin toplu taşıma sisteminde yapılan iyileştirme sonucunda bütün hanehalkı grupları için daha avantajlı hale gelmesi sonucu bölgedeki konut talebi ve fiyatı artışından kaynaklanmaktadır. Başlangıçta seyahat süreleri ve maliyetlerinin yüksekliği sebebiyle genel olarak hanehalkları açsından dezavantajlı görülen bir ilçe, belki de okul sayısının fazlalığından ötürü okul çocuklu aileler için cazip olabilmektedir. İlçenin bu özelliğinin avantajından faydalanan hanehalkları, toplu ulaşım altyapısı iyileştirmesi sonucu bütün hanelerin ortak kriterleri açısından da (seyahat süreleri) eskisine göre daha avantajlı hale gelen bu ilçede yaşanacak talep ve konut fiyatı artışından olumsuz etkilenmekte ve belki de ilçeyi terk etmektedir. Sonuç olarak alt gruplarda genel eğilimlerin aksine davranışlar görülebilmekte, bu da politika yapıcıların bu alt grupların özgün ihtiyaçlarını da hesaba katarak politika geliştirmeleri gerekebileceğini ortaya koymaktadır. Başlangıçta bir alt gruba, o grubun özgün ihtiyaçlarını karşıladığı için cazip gelen bir ilçenin bütün gruplar için avantajlı hale gelmesi bölgedeki yaşamı daha maliyetli hale getirerek söz konusu alt grubun bölgeyi terk etmesine sebep olabilir. Bu durumda örneğin okul çocuklu aileler için okula erişimin bütün ilçelerde artırılması gibi politika önlemleri düşünülebilir.

SONUÇ

Bu tezde kent ölçeğinde çalışan entegre bir Hesaplamalı Genel Denge modeli kullanılarak, toplu taşıma altyapısında yapılacak bir iyileştirmenin hanehalkı grupları üzerindeki ekonomi etkileri incelenmiştir. Yılmaz'ın (2018) modeli geliştirilerek açıklayıcı gücünün artırılması ve hanehalkları davranışları ile ilgili daha detaylı bir tablo elde edilmesi amaçlanmıştır.

Elde edilen sonuçlar, ilçe cazibe seviyelerinin tüm hanehalkı gruplarına göre heterojenize edilmesi ve hanehalklarının alt gruplara ayrıştırılmasının söz konusu politika eylemlerinin olası etkileri hakkında daha detaylı bir tablo edilebileceğini göstermektedir. Dahası, yapılan geliştirme sonucunda kimi hanehalkı gruplarında genel eğilimlerin aksine etkilerin ortaya çıktığı gözlemlenmiş, politika yapıcıların politika geliştirirken bu olguyu da hesaba katabilecekleri belirtilmiştir. Başlangıçta kendi özgün ihtiyaçlarından ötürü, hanehalklarının büyük kesimlerine cazip görünmeyen bir bölgede toplanan kimi haneler için, kentte yapılan bir altyapı iyileştirmesi sonucu bu bölgenin her gruba hitap edecek şekilde gelişme kaydetmesi bölgeye olan talebi artırıp konut fiyatlarını yükselterek olumsuz sonuçlar doğurabilmektedir. Öncesinde özgün kimi avantajlarından ötürü yalnızca kendilerine cazip görünen bölgenin faydasını yaşayan özellikle düşük gelirli kimi gruplar, çoğunluğun faydası anlamına gelen bir gelişmeden zarar görebilmektedir. Bu durumda politika yapıcılar bu grupların durumlarını da hesaba katarak ek politikalar geliştirmeyi düşünebilir.

Bu çalışmada veri yetersizliğinden ötürü hanelerin evsahipliği bilgisinden faydalanılamamıştır. Eğer bu verilere de sahip olunsaydı hanehalkı davranışları, kiracılar ve evsahipleri açısından farklı eğilimlere sahip olunabileceği gerçeğinden ötürü daha gerçekçi bir biçimde resmedilebilirdi.

Mevcut modelin, hanehalkarının fayda fonksiyonuna kimi kamu hizmetlerine erişimin (okul, hastane vb.) dahil edilmesiyle, yerleşim bölgesi seçim mekanizmasının daha gerçekçi hale getirilerek geliştirilebileceği değerlendirilmektedir. Böylece daha gelişkin bir model elde edilebilir ve politika yapıcılar hanelerin söz konusu kamu hizmetlerine erişim ihtiyaçları hakkında daha isabetli öngörülere sahip olabilir.

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<u>**TEZİN ADI /** TITLE OF THE THESIS</u> (**İngilizce** / English) : EVALUATING THE EFFECTS OF A TRANSPORT INFRASTRUCURE IMPROVEMENT ON HETEROGENOUS HOUSEHOLD GROUPS USING AN URBAN CGE MODEL

<u>**TEZİN TÜRÜ**</u> **/** <u>DEGREE**:**</u> **Yüksek Lisans** / Master ■ **Doktora** / PhD ☐

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