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Economic Evaluation of Transportation Infrastructure Development with Computable Urban Economic Model - A Case of Hanoi, Vietnam

Nguyen Trong Hiep

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Executive Summary

In recent years, integrated land use-transportation modeling have become one of the most useful tool for urban economy analysis. Consequently, it has attracted a great attention of scholars and researchers, especially in developed countries. Among many directions of development, urban computable general equilibrium modeling (called as Computable Urban Economic, or CUE models in Japan) has been transparent and appropriate approach. This type of model, fully based on urban economics and also integrated many updated techniques of traditional transportion models, have proved to be a powerful tool for urban economic analysis. Usually, the models can output an informative set of variables describing real urban economy at equilibrium state, then they can provide rigorous and clear answers to elaborate questions in a systematic way. There are a large number of successful stories by applying this type of model in urban policy evaluation, especially in Japan and United States.

The aim of this paper is to make a comprehensive analysis of the strong relationship between the spatial interaction, represented by transportation infrastructure system, and the spatial development, represented by land-use pattern or spatial structure form of an urban area. The research introduces a general equilibrium framework for a certain urban study area (hereafter called as CUE model), in which the behaviors of economic agents are formulated based on optimized utility or profit functions. The equilibrium conditions are simutaneously set for labor, land, retail commodity and transportation markets. The welfare effect is measured by the expected utility accruing to the workers living and working inside the study area. The research also proposes a computable algorithm so as making the model become "operational" model in practical application.

The operational mechanism behind the model performance can be explicitly explained. The behaviors of economic agents are mathematically formulated as utility/profit functions based on urban economics and discrete choice theories. By maximizing utility/profit under budget or production cost contraints, the aggregate demand and supply in all considered markets in all zones are derived and then put into a general equilibrium framework. In turn, the autonomous adjustment mechanism of "market's invicible hand", urban economy will at geneal equilibrium state will output a set of equilibrium prices and also travel demand among model zones. Next, the travel demand will be converted into modal flows and assigned on transportation network. At equilibrium, the transportation system will send its signal, generalized travel cost, to the urban economy.

The study presented in the paper includes the following main contents: (i) Formulating the mathematic form of computable urban economic (CUE) model with an programmable algorithm for calculation; (ii) Developing a computer program of proposed CUE model for numerical calculation; (iii) Proposing a general framework for pratical application of CUE model in real case studies, including input data preparation, parameter estimation and model calibration. In the beginning stage, the main objective is to estimate the economic benefit of transportation developments; (iv) Verifying and testing the "operational" feature of the CUE model in real world by conducting an empirical calculation for a proposed urban mass rapid transit line (UMRT Line No.3, Nhon-Hanoi Railway Station Section) which will be constructed in Hanoi, Vietnam.

These contents are organized in the thesis as following,

In Chapter 1, general introduction, problem statement are presented. The research objectives and scope of the research are also defined. The main purpose of this chapter is to present the research background and point out why the conventional methodologies for urban management and planning become old fashion and reasons for CUE model development.

Chapter 2 is dedicated for reviewing the profound studies of general equilibrium modeling for urban policy evaluation, both in theory and practical applications.

Chapter 3 provides a review of the historic establishment and development of Hanoi City. The first section of Chapter 3 is to review the historic establishment of Hanoi City. In second part, the economic development, population and land use are presented, for both time before and after the last expansion of Hanoi. In the third section, the current status of transportation infrastructure is briefly showed. In the fourth section, the daily travel demand of Hanoi's inhabitants is analyzed, based on the Person Trip (PT) data surveyed in 2005.

Chapter 4 is to develop the computable urban economic model for urban economy analysis. In the first section, behaviors of economic agents (consumer and firm) are formulated consistent with microeconomic theory. The second section is used to set the general equilibrium conditions on non-wage income, land, commodity and labor markets of each model zone. In the third section is used to discuss on transportation side. The mathematic form of mode choice model is formulated and propose the traffic assignment method is also proposed in this section. In the last section, the programming algorithm for solving the general equilibrium equations formulated in the second section is presented.

The main purpose of Chapter 5 is to estimate the Benchmark CUE model for the case of Hanoi, with available data of 2005. The first section is for suggestions of input data required for model simulation. The second section is to calculate the generalized travel cost among model zones. In the third section, the parameters representing for specification of Hanois economy are estimated and set up. The fourth section is dedicated for proposing model calibration steps. The last section is for sensitive analysis.

Chapter 6 is to apply CUE model for evaluating the economic benefit of a proposal pilot urban mass rapid transit (UMRT) line which will be constructed in Hanoi. The first section is to introduce about the project. In the second section, the mode share with the new UMRT is re-calculated. In the last section, the socioeconomic impacts of the project are analyzed in detail.

The Chapter 7 is dedicated for general conclusions and recommendations for future works.

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Chapter 1

Introduction

1.1 General introduction

Urbanization is one of the main streams of socioeconomic change of the 20th and it has continued in this 21th century. In 2008, first time in history, the world urban population reached 50% and this number is expected to be 72% by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050 [46, 47]. From 1955 til now, Tokyo has been the most populous urban agglomeration in the world. Number of inhabitants of the city was estimated at 37.2 million in 2011. At present time, China has been the world's largest urban nation with more than 600 million urban citizens and projected number could be 900 million by 2050 [30]. For this case, 53 metropolitan regions had contributed about 65% of its total GDP in 2004.

Regarding to the case of Vietnam, after the "Doi Moi" (Reform) policy was introduced in 1986, its planned economy has changed, step by step, to the open-market economy. With the participation of the private business sector, the privatization of many state-owned enterprises (SOE) and foreign direct investment (FDI) flow, the Vietnamese economy has taken-off. Consequently, the urbanization has begun with high growth of urban population. There are two independent and dominant core-periphery urban systems in Vietnam, Hanoi Capital City in the North and Ho Chi Minh City (HCMC) in the South, with high growth rate and industrial concentration within the cities and their surrounding areas [52].

These evidences have shown that, with a little concern regarding to negative impacts, the urbanization nearly has the same meaning with prosperity and increasingly economic development, not only for the urbanized areas themselves but also for the country as the whole. From other perspective, it is clear that urban policies would have critical influences on its inhabitants' welfare and economic growth, specially for the megacities like Tokyo, New York-Newark, Mumbai and so on, where the intensive knowledge and information flows has been continously concentrated, inspiring by increasingly agglomeration economies phenomena.

In real world, the urbanization has continuously induced the urban sprawl or expansion trend and even new appearance of dense cities and metropolitan areas, where a complicated and huge number of socioeconomic activities take place everyday. This phenomenon, along with progressive innovations of transport and communication technologies, have been the main forces affecting strongly on spatial interactions and, therefore, to be the background for establishment of the complex urban structures. From the viewpoint of urban governance, planning or management, many challenges may arise. In which, the harmonious relationship between spatial development, represented by urban land-use pattern, and spatial interaction, embodied by physical transportation system, has been the most important pillar among treatments for keeping the sustainable development of any certain city. In that sense, the mutual interaction between transportation investment, urban economic development and its inhabitants' welfare requires to be treated from a more general and systematic viewpoint so that it can mitigate the negative externalities and enable the positives spreading out.

1.2 Problem Statement

How do travel behavior and transportation system affect urban land-use pattern and vice versa? What is the appropriate way for analyzing and treating this relationship? These questions have become one of the most interesting issues of urban economics for long time, for both scholars, researchers and practioners. With the dynamic and complicated features of the linkage between spatial interaction and spatial development, the influence of investment in urban transport infrastructure on economic development are not always clear. Boarnet, *et. al.* [11] argued that these effects in some cases were clear, but there also existed disminishing effects and even inconsequential causality as evidences in many instances. The authors also pointed out that analyzing influence of urban form or land-use pattern on travel behavior had been the main direction in recent studies. The causal role turned in analysis is subtle but can make an "importantly shifted from *prediction* to *prescription*."

Undoubtedly, the relationship between urban land-use pattern and transportation system is not one-way causality, and the interaction between them is not only complicated but also having strong spillover effects on other aspects of urban socioeconomic conditions. In this context, it is clear that the conventional analytical approach for estimating the economic benefit of transportation infrastructure development becomes "old-fashioned" and inappropriate, especially for large scale projects. Kobayashi, *et. al.* [21], has argued that the "transportation processes," from partial equilibrium point of view, were largely separated from "production and consumption processes." It means that the effects of transportation, from this angle, is only limited in the change of generalized transportation cost but it does not affects to the structure of production and consumption at all. Nevertheless, when transportation improvements are seen from general equilibrium viewpoint, its effects in the economy becomes "more critical and more pervaisive". From perspective of firms or producers, the cheaper, faster and more reliable transportation services may boost the logistical changes which "constitute radical transformations in production systems." From the perspective of households, it is more evident that augmented speed of personal mobility benefited from transportation improvements may incite households locate their home further away from their workplaces and at lower dense areas, and therefore, may trigger "significant shifts in consumption patterns." In the same thinking stream, the author also pointed out another critical limitation of many traditional analyses that they had missed the "network nature of transportation systems," then the transportation investments were identified as "an contributions to an ordinary capital stock rather than as additions to a network." Consequently, they did not realize the congestion or bottleneck effects and/or the network externalities of that investments.

By these reasons, the general equilibrium modeling for urban economy appears to be a modern and suitable suggestion for overcoming the obstacles existing in traditional approach. With a coherent structure, in which the behaviors of economic agents have been formulated consistent with microeconomic theory and integrated with advance archievements in transport models such as modal split and assignment, this type of model has been become a very powerful and informative tool for urban economy analysis. The welfare measure from indirect utility/profit functions is also consistent with benefit measure such as equivalent variation (EV), compensating variation (CV) or consumers surplus in Marshall-Depuit measure [44]. In addition, the model can also provide a set of desirable output variables representing for real urban economy at equilibrium state, therefore, increasing the accountability and transparency of decision making. Conclusively, with a sound theory background and many successful applications in practice, this model type has proved to be a huge potential in applications.

For the case of Hanoi Capital City, from 1976 until now, its administrative boundary was adjusted 3 times. Accompany with these adjustments, the city's area, population, construction master plan and other socioeconomic conditions also changed greatly, time by time. After the last change in 2008, total Ha Tay Province, Me Linh District of Vinh Phuc Province and 4 communes (rural wards) of Hoa Binh Province were merged with Hanoi. The natural area of Hanoi now is 3,344.6 km2, and population (2012) of about 6.8 millions [13]. The high population growth rate, mainly caused by migration, and internal movement of residences from rural area have made a high pressure on the urban infrastructure of the urban center area, especially for the transportation network. Without any other urban mass transit system and low sharing of current bus network, the road network becomes seriously overload and consequently, traffic congestion occur anywhere, at anytime. In order to overcome this situation and to ensure the sustainable development of the City in long term, a new construction master plan was approved in 2011. According to this plan, Hanoi will include urban center and 5 satellites towns, with total projected population of about 10 millions. In the new spatial development plan, the transportation infrastructure system becomes one of the most concentration of investment, with totally new urban mass rapid transit (UMRT) system (mixed light rail-subway) and many new ring and arterial roads.

Evidently, in order to realize these projects, which can make a huge influence on socioeconomic conditions of the city in long term, an appropriate methodology established for social benefit evaluation is necessary. The modern CUE model, with many updated and advanced features and has not been introduced in Vietnam, would be an outstanding and promising option for Hanoi, and also for other urban areas of the whole country, in implementing their ambitious development plans.

1.3 Objectives of Research

The main objectives for development of this paper are to (i) formulate an operational CUE model and then (ii) enable the model to be applied in practical applications. These can be grouped into four separated lines as followings:

- Formulating the mathematic computable urban economic (CUE) model with an programmable algorithm for calculation.
- Programming of the proposed CUE model for numerical calculation.

- Developing a general framework for application of CUE model in real case studies. In the beginning stage, the main attention is for the economic benefit of transportation developments.

- Verifying and testing the “operational” feature of the CUE model in real world by conducting an empirical calculation to estimate the monetary social benefit and also socioeconomic changes for a planned urban mass rapid transit line (UMRT Line No.3), which will be constructed in Hanoi, Vietnam.

1.4 Scope of Research

The scope of the research are documented in this paper as follows:

- The first section of Chapter 3 is to review the historic establishment of Hanoi City. In second part, the economic development, population and land use are presented, for both time before and after the last expansion of Hanoi. In the third section, the current status of transportation infrastructure is briefly showed. In the fourth section, the daily travel demand of Hanoi's inhabitants is analyzed, based on the Person Trip (PT) data surveyed in 2005.

- Chapter 4 is to develop the computable urban economic model for urban economy analysis. In the first section, behaviors of economic agents (consumer and firm) are formulated consistent with microeconomic theory. The second section is used to set the general equilibrium conditions on non-wage income, land, commodity and labor markets of each model zone. In the third section is used to discuss on transportation side. The mathematic form of mode choice model is formulated and propose the traffic assignment method is also proposed in this section. In the last section, the programming algorithm for solving the general equilibrium equations formulated in the second section is presented.

- The main purpose of Chapter 5 is to estimate the Benchmark CUE model for the case of Hanoi, with available data of 2005. The first section is for suggestions of input data required for model simulation. The second section is to calculate the generalized travel cost among model zones. In the third section, the parameters representing for specification of Hanois economy are estimated and set up. The fourth section is dedicated for proposing model calibration steps. The last section is for sensitive analysis.

- Chapter 6 is to apply CUE model for evaluating the economic benefit of a proposal pilot urban mass rapid transit (UMRT) line which will be constructed in Hanoi. The first section is to introduce about the project. In the second section, the mode share with the new UMRT is re-calculated. In the last section, the socioeconomic impacts of the project are analyzed in detail.

- The Chapter 7 is dedicated for general conclusions and recommendations.

1.5 Expected Contribution

After completing the research, it is positively expected that the contents developed in this paper will contribute to some extents as followings:

- The CUE model proposed in Chapter 4, in principle, can be used to quantitatively estimate the social benefit of urban policies related to transportation, land-use or spatial developments. It may also useful for primitive evaluating the production plan of retail sector in the city. With the set of output variables describing the real urban economy at equilibrium state, the model helps decission makers figure out the changes of socioeconomic indicatiors caused by introducing the new policy. In addition, the calculation algorithm proposed in this chapter also offers a "programable" way for realizing "operational" feature of the model in practical applications.

- The contents presented in Chapter 5 proposed a process to estimate the benchmark CUE model for case study of Hanoi. Similarly, the methodology can also be utilized for other cities or urban areas. The data analysis, zoning and model calibration processes shown in this chapter are especially useful for practioners in real application.

- Finally, Chapter 6 of the paper offers an approach using CUE model to evaluate the economic benefit of a new UMRT project. In general, this process can be applied for other transportation improvements. For other type of urban policies, the process can be customized flexibly, case by case.

Chapter 2

Evolution of Land use-Transportation Modeling

2.1 General introduction

In recent years, integrated land use-transportation models have become one of the most useful tool for urban economy analysis. Consequently, they have attracted a great attention of scholars and researchers, especially in developed countries. Among many directions of development, urban computable general equilibrium modeling (called as Computable Urban Economic, or CUE models in Japan) has been transparent and appropriate approach. This type of model, fully based on urban economics and also integrated many updated techniques of traditional transportion models, have proved to be a powerful tool for urban economic analysis.

Routinely, CUE models can output a informative set of variables describing real urban economy at equilibrium state, then they can provide rigorous and clear answers to elaborate questions in a systematic way. There are a large number of successful stories by applying CUE models in urban policy evaluation, especially in Japan and United States. This chapter is to review the profound studies of CUE modeling, in both theory progressive development and practical applications.

2.2 Traditional Land use-Transport Modeling

2.2.1 Urban Transportation Modeling

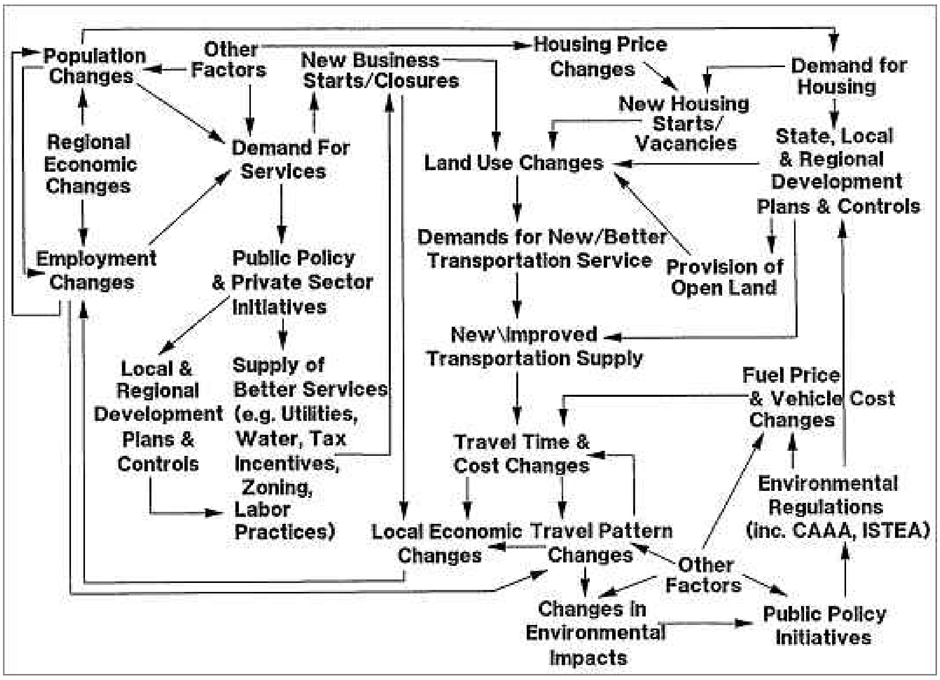
In the mid-1950s, urban transport modeling was officially started in United States. Consequently, from 1960s the traditional four-step and its variants have been widely applied in many metropolitan areas. The original model comprises four consequent sub-models of trip generation (step 1), trip distribution (step 2), mode choice or modal split (step 3) and traffic assignment (step 4). These sub-models are usually estimated separately, utilizing specific theories and calculated as a sequential flow. The main reason of consequent approach is to overcome the difficulty of multicollinearity problems affecting to estimation techniques [36]. The input data for model estimation usually includes travel behavior (person trip, or PT in short), cargo flows, and many related statistic urban socioeconomic indicators, which are usually collected and arranged in terms of *traffic analysis zones (TAZs)*, an appropriate subdivided unit of study area.

Recently, the four-step models, with many evolvements of each sub-models, have been documented as a standard tool for use of transportation planning and other related urban policy analysis in practice (see, for example, [31], [34]).

2.2.2 Linking of Urban Transportation and Land Use Models

Along with the development of the four-step model, the organic and complicated interactions between transportation infrastructure network and other urban systems also has been early recognized by scholars and researchers. From the more general perspective, the most criticised point of the existing four-step transportation models is shined. That is it always deals with activities imposed by a fixed land use pattern in the trip generation phase (step 1). With this limitation, the transportation models do not have the capability in predicting the relative changes of household and employment locations of land users. In turn, as the result of this limitation, even the projection of travel demand in future becomes less reliable, especially in long-term when the lag of the effects are full up.

The traditional land use models are used to describe land users' activities and their competition on land market under a certain urban setting. The land users can be households, firms or retail establishments, who having specific demands for space and access to jobs, schools or markets. The interactions between these activities through transport system are also taken into account inside these models. However, in land use planning, the



Note) Source: Southworth, 1995 [36]

FIGURE 2.1: Complexity of functional linkages in urban system dynamics

transportation network is also supposed to be fixed, while a larger zonal population size or increasing activities might need further transport facility enhancement. In turn, these are not taken into consideration for land use projection.

Evidently, the separated planning framework might give rise to the imbalances between transportation system and land use pattern over time. These phenomina might cause negative externalities in urban development such as traffic congestion, overloaded networks in some part, and under-utilized facilities on the other." [32]

2.2.3 The Development of Integrated Land Use - Transportation Models

The first remarkable effort for establishing a "operational" urban model for a metropolitan belonged to Lowry [22], in his paper "A Model of Metropolis" in 1964 for Pittburgh city. The limitations of available data and theory background, Lowry had to use "crude gravity models with ad hoc equilibration of land use."

Inspired by Lowry's work, many variants of integrated land use-transportation models have been developed in all over the world, especially after the establishment of Geographic Information System (GIS) in 1970s. In order to establish a international discussion forum for researchers pursuing studies in this field, the International Study Group on Land use Transport Interaction (ISGLUTI) was established in 1981. Wegener [49] in a review of better-known and well-documented LUTI models summarized that there were 20 urban models have been developed and spreadly used in practice in the real world. However, from the equilibrium viewpoint of microeconomics, Anas [4, 5] pointed out that most of traditional Land-use/Transportation Interaction (LUTI) models still have "behavioral inconsistency and systemic inconsistency." [44]

2.3 New Approach for Urban Modeling

2.3.1 Urban Computable General Equilibrium Models in U.S

In U.S, Professor Alex Anas is a pioneer scholar who has great contribution in both normative theory development and practical application of the urban computable general equilibrium models in real world. In this section, some of the main and most updated his studies in this academic streamline will be reviewed.

Anas and Kim [6] presented a general equilibrium model to prove the job agglomeration phenomina in policentric urban form. In this paper, authors formulated a computable general equilibrium framework of land use of the study area, in which land will allocated for residential housing, production and road. In this model, the consumers (demand), also to be workers, can freely choose the locations of workplace and home at outer stage, and then the amount of land and commodities can be determined so that utility can be maximized. The inputs factor for zonal production (supply) was described including labor time, land are and intermediate factors. The capacity of the road network was described to be depending on land area used for transportation. In general equilibrium calculation, the land, labor and commodity markets in each model zones were solved simultaneously. The solution of nonlinear equations system represented for the city at equilibrium state. With simulation results obtained from the model, authors found that in case without pre-setting for shopping preferrence, the dispersion phenomenon appears and wage-rate, land-rent and commodity-price would be highest at center of space. In case the scale economies are set for shopping, related to congestion cost, 'the dispersion become unstable.' In additions, authors also provided some intereting conclusions that the stronger agglomeration, the fewer and 'with stronger agglomeration, there are fewer and bigger centers and utility is higher with fewer centers', and 'with higher congestion, the number of centers increases and utility is higher with more centers.' The striking feature of the model is that it were not pointed out in advance the number and also the position of subcenters of the study area while the some other previous studies had done [20, 35, 37, 50, 51].

In order to observe the impacts of congestion tolls on the trends of residences' centralizing and firms' decentralizing in 'dispersed cities', Anas and Xu [8] developed a fully closed computable general equilibrium model in which consumers/workers can freely select the home and workplace zones for housing and job and transportation is integrated to endogenously take into account the congestion effect. The ultimate goal of the paper is to observe 'how the imposition of congestion tolls would modify land use patterns in the dispersed urban form.' The main conclusion of the study is that the influence of congestion tolls on *centralizing effect of residences* is stronger than *decentralizing of firms*. As the results, the dispered city have more 'centralized job and population densities.'

Recently, a remarkable study, with less theoretical testing but high meaningful in practical application, was proposed by Anas and Liu [7]. In this paper, authors formulated a dynamic general equilibrium model in which the regional economy, land-use and transportation (RELU-TRAN) have been considered simultaneously. The study also proposed an algorithm and based on that making a demonstration simulation for Chicago MSA. The modeling approach presented in the paper were flexible, useful and also overcome some limitations in computation, theory and practice of other approaches.

2.3.2 Computable Urban Economic Models in Japan

The computable urban economic (CUE) models have been introduced in Japan in late 1980s and has been widely applied for modeling the real urban economies in practice. According to Ueda[1] *et al.,* [43, 44], this type of model is the advance development of traditional Landuse-Transportation Interaction models, in which the behaviors of main stakeholders have been developed consistent with microeconomic theory. The set of output variables obtained from the models can describe the real urban at an equilibrium state such as the spatial distribution of households and firms, the distribution of land area used for purposes of residential, commercial, manufacturing, business, agricutural or others and also including the land and building price or rent. With integrated transportation models, it can also generated the passenger travel patterns and freight flows in terms of original-destination (OD) matrices for the study area at that state. The authors also asserted the consistency between welfare measurement ouputed from the model and conventional Cost-Benefit analysis.

[1] Prominent Professor of The University of Tokyo Takayuki Ueda passed away on September 19th, 2009, before the great paper [44] submitted

Ueda *et al.,* [43, 44] classified the applied models for urban analysis which can be accounted CUE model. The first one is *Double-Side Discrete Choice Model* (DSDC Model) [17, 18]. The main specifications of this type of model is that the logit model were applied for both location choice behavior of locators and also allocation of land to each locator. It means the demand and supply sides in this model were modeled based on discrete choice model.

The second CUE type is *Discrete-Continuous Land Demand Model* (DCLD Model) [26, 27]. In these models, Morisugi *et al.,* splited the location choice into two stages: at first, the locators will discretely choice a particular zone inside study region (discrete choice) and then determine the size of land lot for their demand (continuous choice). By this way, authors have only considered the tenants' behavior (demand side) and omitted the role of landowners (supply side). These main specifications are the reasons Ueda *et al.,* [43] has classified this type of model as the Discrete-Continuous Land Demand.

The third type is *Random Utility/Rent-Bidding Analysis Model* (RURBAN Model) [23, 24, 25]. In this type of model, the formula were developed based on the random utility and bidding theories simultaneously. However, there was existing an inconsistency in original formulation regarding to price adjustment mechanism in market equilibrium. Therefore, the authors developing RURBAN model proposed provided solutions to overcome the inconsistency.

Ueda *et al.,* [43, 44] grouped their own early CUE models into the fourth type and named *Building Demand-Supply Balancing Model* (BDSB Model) [42, 45]. The main focus of this model type is building market, and used for analyzing the 'emergence of high-raised buildings particularly in a city center,' explicitly.

The fifth type of CUE model is *Continuous-Discrete Land Supply Model* (CDLS Model) [55, 56], in which authors broke the landowners' behavior (supply side) into two stages: at first, the land suppliers will determine the total amount of land are in each zone and then allocate to the tenants by the discrete choice mechanism through logit model.

The last and also newest CUE type was introduced in Japan in early 2000s and leaded by Professor Takayki Ueda. The authors defined their own studies in CUE group sixth, namely *Neo Computable Urban Economic Model Family* (NCUE Model Family). The CUE type is represented by researches of Takagi *et al.,* [38, 39], Muto *et al.,* [28, 29] and Yamasaki *et al.,* [53, 54]. In this type of model, the authors has proposed a group of CUE models which used for analyzing a long list of urban policies, in diversified fields of 'transport, land-use regulation, urban re-development, residential area development, business district reform and so on.' The analyses in practical applications requires the co-working or combination simulation between each model in the family with other particular models such as 'flood, CO2 emission or transport pricing model' to solve out the urban problems taking place in reality.

Ueda *et al.,* [43, 44] has also proposed a 'unified' form for the last type of CUE model in practical application. In this paper, authors has deeply analyzed and compared the mathematic form and in application fields to induce the CUE model development in future. The flexible combination among family's member model and/or expansion to some parts of member model in the family also to be encouraged in solving urban problems in reality. The authors stated that the discovery of efficient calculation algorithms and parameter estimation techniques have been mentioned as the main topics for future perspective development of the CUE models.

2.4 Summary and Conclusion

This chapter has reviewed the evolution of traditional integrated land use-transportation model over time and pointed out their old fashionable features of theory background and its limitations in practical applications. Also, the profound studies on the modern approach of urban computable general equilibrium or computable urban economic (CUE) modeling have been scrutinized.

From theoretical perspective, CUE framework is consistent with microeconomic theory and welfare measurement consistent with conventional cost-benefit analysis. This type of model can output a set of desired variables which represent the urban economy in reality. In addition, by inheriting all advanced feature of general equilibrium models, it can provide decision makers and policy analysts rigorous answers to elaborate questions in systematic way for evaluating urban policy [12].

From practical point of view, CUE models have been customized and widely used in many fields of urban planning and management, in many countries, especially in United States and Japan. However, it seem to be new in developing countries. For the case of Vietnam, the modern and fashionable approach is concrete precious. Therefore, it would be very much promising and meaningful for scholars, researchers and practitioners if this type of model is introduced and spreaded out in both ecademic study and practical application.

Chapter 3

Hanoi Development and Travel Demand

3.1 General introduction

After the introduction of *Doi moi* policy in 1986, Vietnam has changed its economy from planned to open market economy. With the dynamic and active participation of the private business sector, along with privatization of many state-owned enterprises (SOE) and accruing of foreign direct investment (FDI) flows, the Vietnam's economy has taken-off and step by step and stable gone out of economic crisis.

The economy of Hanoi Capital City, one of the two biggest cities of Vietnam, possessing many advantages on population, technology, investment priority, has been growing with a remarkable rate, and harvesting many achievements in commercial, services, production. In addition, the city is also assigned as the dynamic centre for development plans of both regional and national levels. In this context, many infrastructure development plans have been developed aiming to keep the leading position of the city in politics, economics, culture with regarding to the Northern plain region and also the whole country in long term.

The first section of this chapter will introduce the historic development and boundary adjustments of Hanoi Capital City over time. The second section is to present the socioeconomic development of the city in the last decades. The third section will show the urban transportation status at current time. In the fourth section, the Hanoian travel behavior and traffic condition of the city will be analyzed based on the household interview (PT) surveyed in 2005. The last section will be dedicated for introducing the newest construction master plans of the the city.

3.2 Establishment History and Administrative Boundary Adjustment of Hanoi city

3.2.1 Establishment History

The Emperor Ly Cong Uan, a.k.a. Ly Thai To, the founder of Ly dynasty, had made a historic decision by moving the imperial capital of Dai Viet, one of the ancient names of Vietnam, from Hoa Lu to Dai La Citadel in year 1010 AD (year of Canh Tuat in Vietnames Calendar) and renaming the new capital Thang Long (Soaring Dragon). From that time, he has been known as the founder of Hanoi city. Back tracking to Vietnam history, the modern Hanoi has been known more than 2000 years ago. In Au Lac Dynasty, lasted only 50 years, from 257 to 208 BC, the King An Duong Vuong, or Thuc Phan, had built and located his capital in Co Loa Citadel, which now located in the North East of Hanoi, inside Dong Anh District.

After the first time officially chosen as Vietnam capital city, many ruling dynasties had selected Hanoi area as capital of the country, but its name has changed in some periods as presented in Table 3.1.

Table 3.1: Ancient Hanoi served as Capital City through Feudal Dynasties.

Dynasties	Reign Period	Name
Ly	1010 – 1225	Thang Long
Tran	1225 – 1400	Dai La
Le[1]	1428 – 1789	Dong Kinh
Mac[2]	1527 – 1592	Thang Long
Le-Trinh[3]	1592 – 1789	Thang Long
Tay Son	1789 – 1802	Thang Long

Note) [1] sometimes referred as Later Le Dynasty to differentiate with the Le or ealiar Le Dynasty (980-1009); [3] in this period, from 1533, the Le Dynasty had been restored and still competing with Mac Dynasty for governance power; [3] In that period, the Vietnam had been really governed by Trinh Lords for the North, Dang Ngoai, and Nguyen-Lords in the South, Dang Trong, of Vietnam. The Le emperors in that period held no power.

In the year 1802, Gia Long, a.k.a. Nguyen Phuc Anh or Nguyen Anh, a descendant of Nguyen Lords reigning the South of Vietnam under Le dynasty, the founder emperor of Nguyen Dynasty, after defeated Nguyen Hue, had selected Phu Xuan or Hue, located in Central of Vietnam, as the new capital of United Vietnam. Thang Long lost the Capital status but was assigned to be the political, economic centre of Northern Vietnam. In 1831, Emperor Minh Mang, the second progeny of Nguyen Dynasty had renamed Thang

Long by the present name, Hanoi. From the year 1805, Nguyen Dynasty started to reconstructed Hanoi Citadel based on French style urban form.

In August 1858, French - Dai Nam War started and in 1887, French was officially conquered Vietnamese. Again, Hanoi had been served as the capital of French Indochina Union, which was comprised by Vietnam, Laos and Cambodia, in period of 1902-1953. In period 1894-1897, French had replanned and constructed Hanoi as we can see today. Hanoi's population in that time was about 150,000 and until the end of that period, it was never greater than 400,000.

In September 2nd, 1945, the Vietnamese Democratic Republic was officially established by the Declaration of Independent, stated by Ho Chi Minh President. And in 1946, Hanoi was selected as the Capital of the country. After experiencing the Indochina War (1946-1954) and the Vietnam War (1955-1975), from 1976 until now, Hanoi has been the Capital City of the Socialist Republic of Vietnam.

3.2.2 Administrative Boundary Adjustments

Now we review the administrative boundary adjustment for Hanoi city from 1945. In the first period of 1945-1954, there was nearly no change in urban boundary of the city. The core urban area was only about 70km^2 on the right bank of Hong River, comprised Ba Dinh, Hoan Kiem and a part of the current Tay Ho Districts.

In the first national 5-year development plan, 1961-1965, *the first expansion* plan for Hanoi had been approved. The city comprised 4 urban districts Ba Dinh, Hoan Kiem, Dong Da and Hai Ba Trung and 4 rural districts Gia Lam, Dong Anh, Tu Liem and Thanh Tri, with the total area of about 200km^2. The orientation development concentrated on the urban area in the right bank of Hong River but also considered the development of the Northern area (Gia Lam and Dong Anh).

In December 1978, in *the second expansion*, Hanoi was extended toward the North and West of the city, comprised by eight original districts (four urban and four rural districts), Son Tay, Ha Dong Towns and seven other districts Hoai Duc, Phuc Tho, Dang Phuong, Ba Vi and Thach That (Ha Son Binh), and Soc Son, Me Linh (Vinh Phu Province). Total area was 2,130km^2, population was of 2,435,200.

However, because of the limitations in urban planning management, in 1991, the Hanoi administrative boundary was narrowed by returning adminstrative right of Me Linh District to Vinh Phu Province, Son Tay Town and 5 rural districts of Hoai Duc, Phuc Tho, Dang Phuong, Ba Vi and Thach That to Ha Tay Province. After this adjustment,

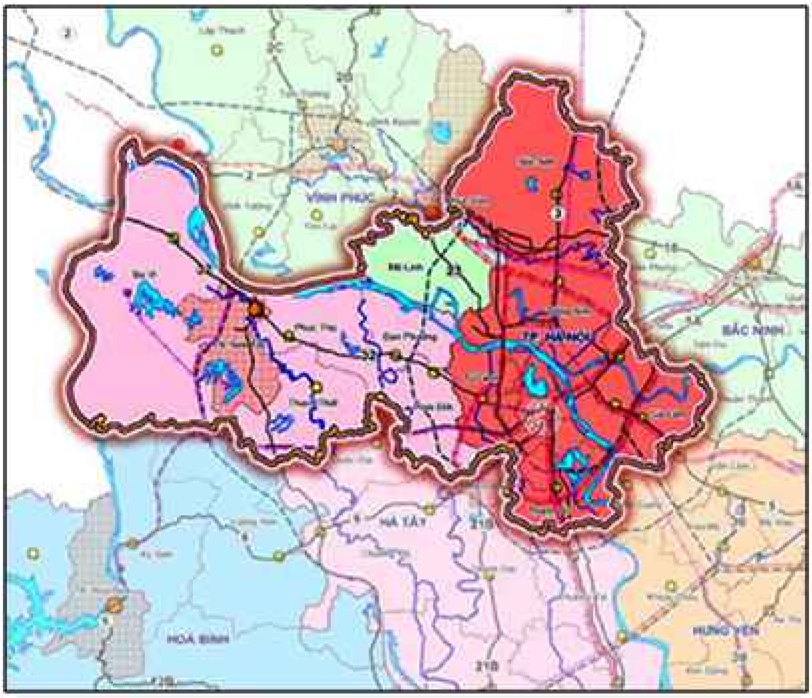


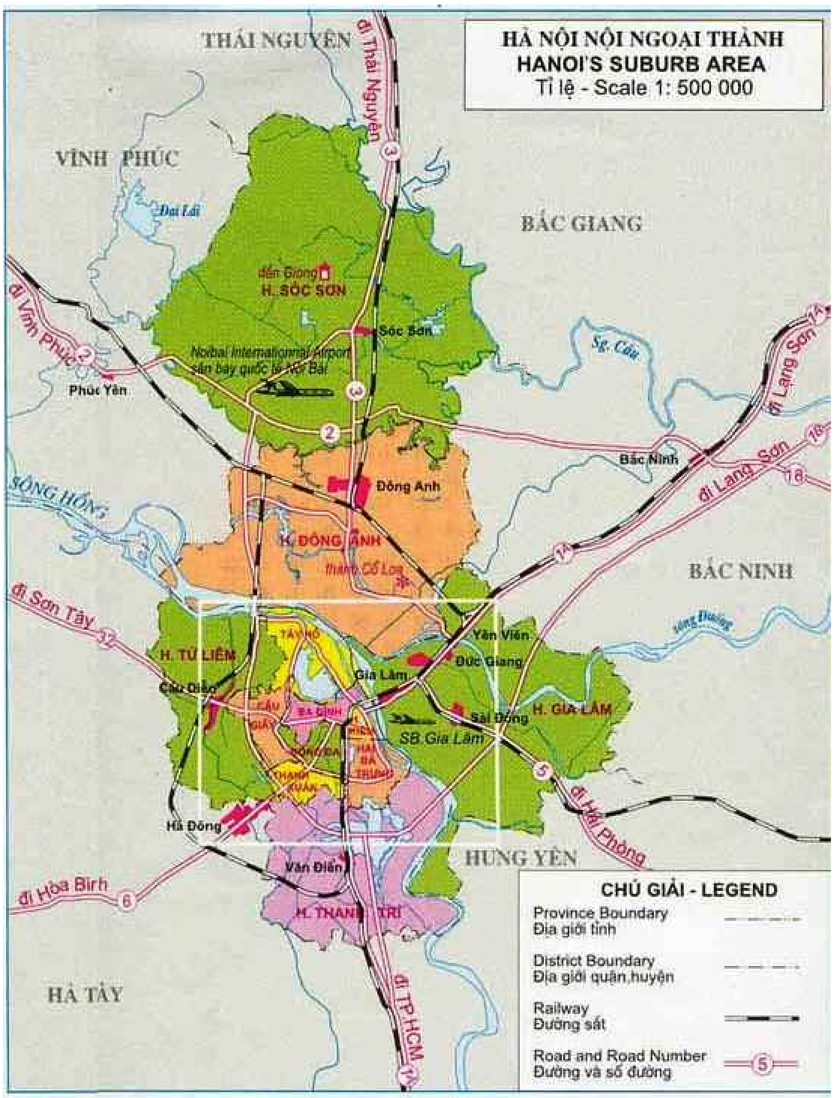
FIGURE 3.1: Hanoi administrative boudary 1978-1991.

total area of Hanoi was 921.8km^2, population of 2,052,000. The city was comprised by 4 rural districts Hoan Kiem, Ba Dinh, Dong Da, Hai Ba Trung and 5 rural districts Soc Son, Dong Anh, Gia Lam, Tu Liem and Thanh Tri.

After the second expansion, the city's boundary adminstrative has fixed until the third expansion in 2008, which will be mentioned in next section. However, the number of districts, wards and/or communes and their boundaries were changed by some adjustment decisions by Hanoi's People Committee (HPC). Until 2005, Hanoi city was comprised by 9 urban districts Ba Dinh, Hoan Kiem, Dong Da, Hai Ba Trung, Tay Ho, Thanh Xuan, Cau Giay, Long Bien, Hoang Mai and 5 suburban districts Soc Son, Dong Anh, Gia Lam, Tu Liem and Thanh Tri.

In Vietnamese Parliament meeting on May 29th 2008, the Resolution on *the third expansion* plan for Hanoi, also to be the last adminstrative boundary adjustment by now, was approved and would be in force from August 1st 2008. According to this document, the natural area of the "New" Hanoi Metropolitan was 3,344.7km^2, comprised by total natural area of the "Old" Hanoi city, Ha Tay Province, Me Linh District of Vinh Phuc Province, and 4 communes of Luong Son District of Hoa Binh Province. The "New" Hanoi Metropolitan was re-arranged and subdevided into 10 urban districts, 1 town and 18 suburban and rural districts. Total population was estimated about 6,232,940[1].

[1]For more detail information of Hanoi Metropolitan, please see on Wikipedia website, http://en.wikipedia.org/wiki/Hanoi

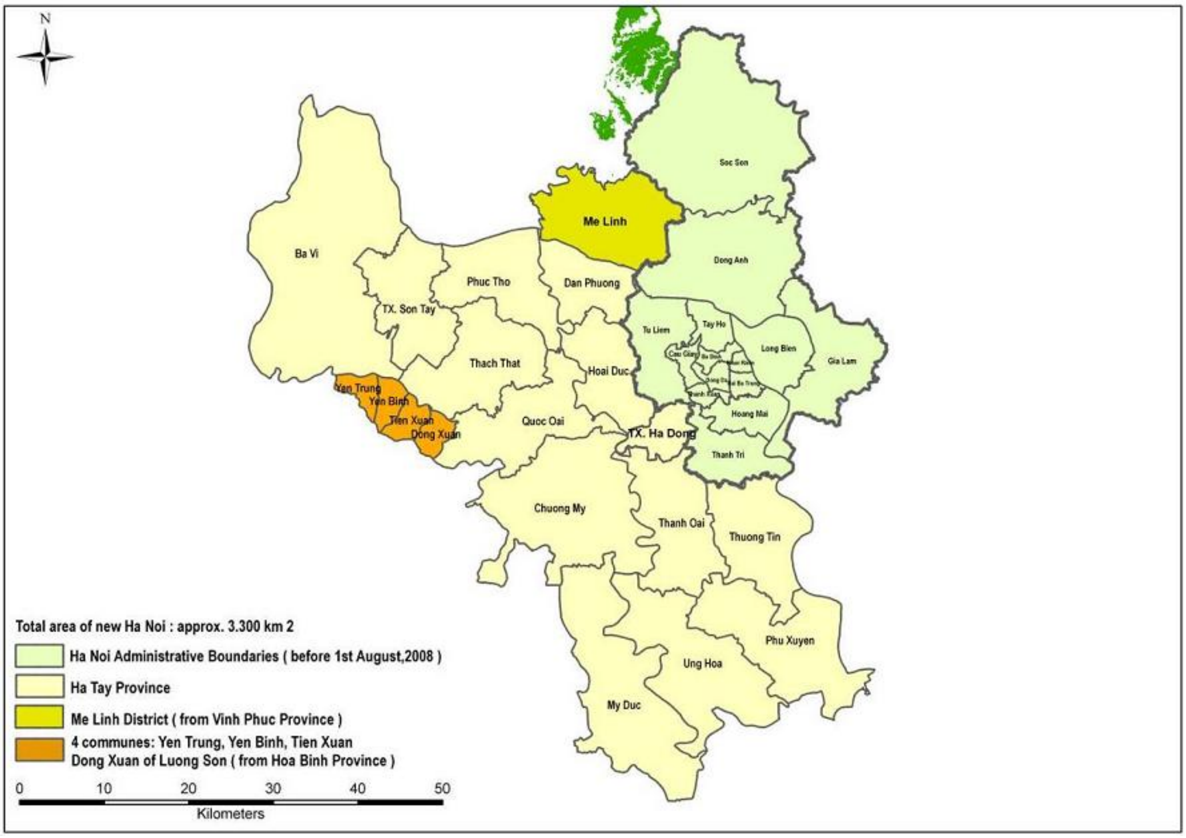


Note) Souce: Master Plan Study, HAIDEP, Final Report, March 2007

FIGURE 3.2: Hanoi administrative boudary 1991-2008.

3.3 Economic Development, Population and Land-use

The economy of Hanoi has been to be one of the two biggest economies of Vietnam, even before the last expansion plan implemented in August 2008. It has been experiencing rapid growth in economic activity, population and transportation system.



Note) Source: Hanoi Light Pilot Light Metro Line, Section Nhon-Hanoi Railway Station, Feasibility Study Report, Final Report

FIGURE 3.3: Hanoi administrative boudary from 2008 by now.

3.3.1 Economic Development

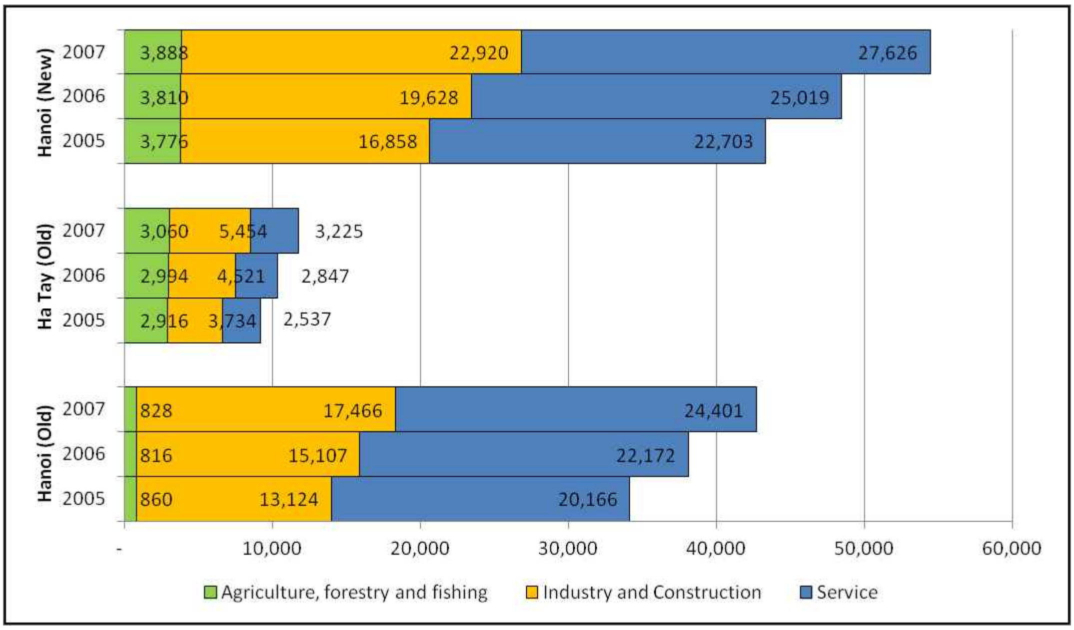
3.3.1.1 Before the third expansion

Before merged with Ha Tay and some other adjacent area, the "Old" Hanoi's economy had been developed rapidly and stably, with the expected growth rate about 10% over the period of 1996-2006. GRDP per capita at 2007 was about 31.8 million VND per year (1870 USD). The structure of economy also have changed with the contribution share of GRDP dominated by Sector 3[2] (more than 50%), and Sector 3 (42.1%). Agricultural activities had played very small role in the city's economy (less than 3% for the last three years before expansion).

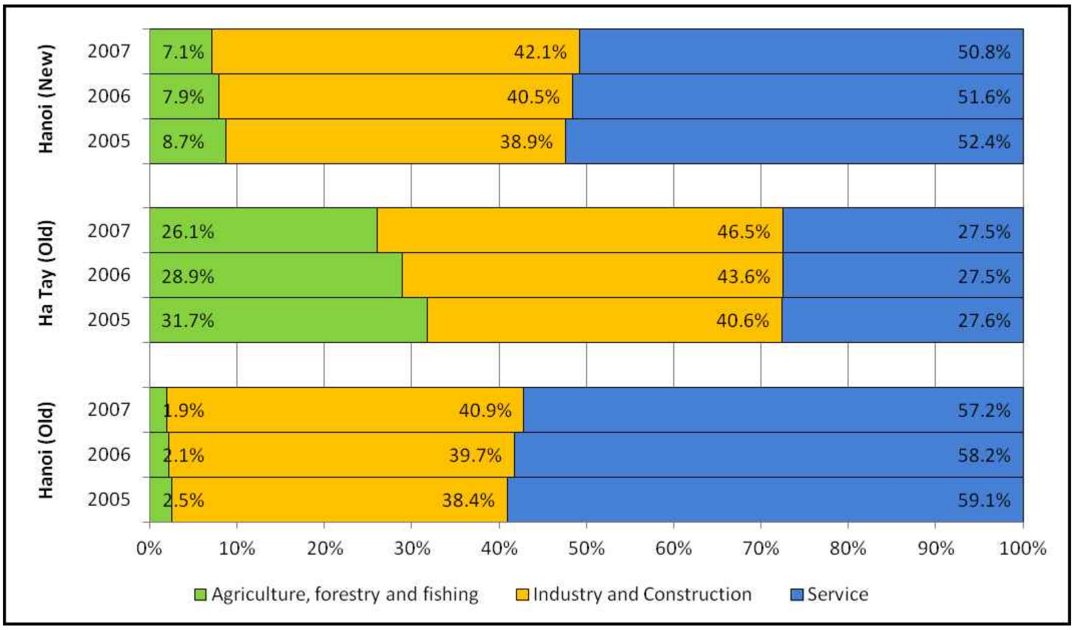
Regarding to the economy of "Old" Ha Tay Province, it also had been experiencing an impressive development after somes districts and towns going back from Hanoi (after

[2]The structure of GRDP is considered by constribution of three sectors: Sector 1, standing for Agriculture, forestry and fishing; Sector 2 standing for Industry and Construction; and Sector 3 standing for Services

1991). Comparing with "Old" Hanoi, the growth rate in two year before merged with Hanoi has been a bit higher but GRDP was about 4 times lower. GDP per capita in 2007 was about 8.3 million VND (490 USD), 3.8 times lower than that of "Old" Hanoi. The Sector 2, industry and construction, had experienced a big leap, with the GRDP contribution about 20% in 1991 to 46.5% in 2007. However, the GRDP structure in the last 3 years before merged with Hanoi shown that the contribution of Sector 3 had not changed and stayed at quite low proportion (about 27%).



(a) GRDP of Hanoi(Old), Ha Tay (Old) and Hanoi (New)(BillionVND)



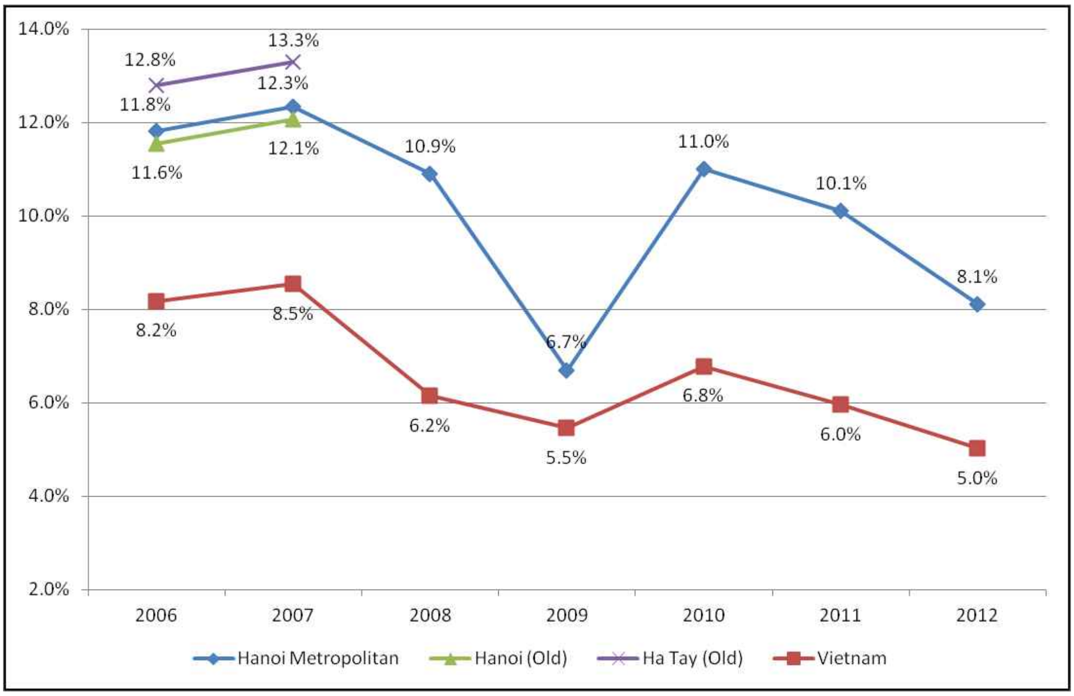
(b) GRDP Structure

Note) Source: Ha Noi and Ha Tay Statistical Year Book; Exchange rate at 2007: 1USD = 17,000VND

FIGURE 3.4: GRDP of Hanoi Metropolitan before 2008.

3.3.1.2 After the third expansion

In 2008, the economic status of the new merged city, Hanoi Metropolitan, was slighly declined comparing with that of the "Old" city since the big gap between the two economies. However, the GRDP per capita of the new city was increase, about 27 million VND comparing with 21.6 million VND in 2007 (proposed that the two economies would have been merged). The economic growth rate of the new city in this year was about 10.9%, lower than previous year but still higher than that of the whole country (6.2%). The GRDP contribution by 3 sectors are 52.2%, 41.3%, and 6.5%, respectively. After 5



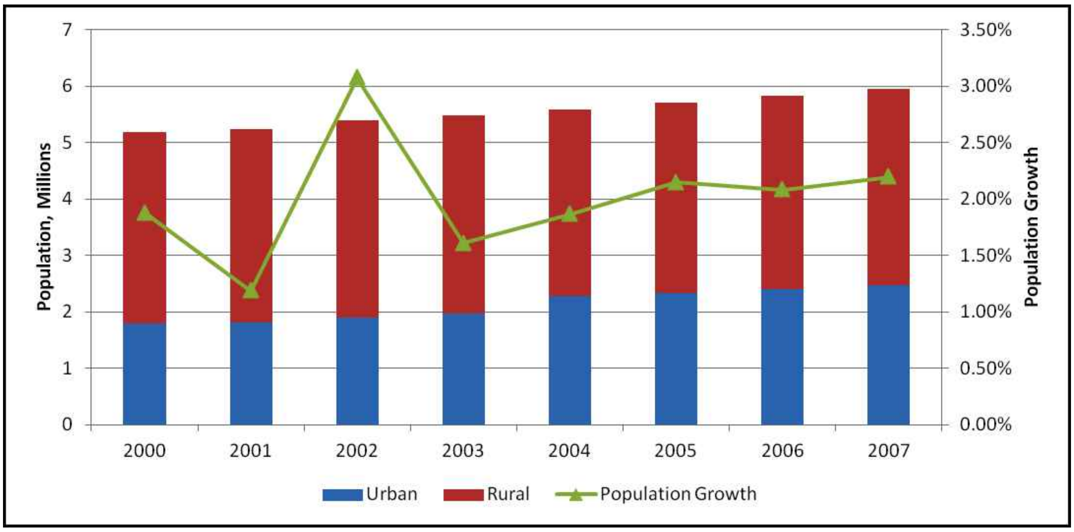
Note) Source: Ha Noi and Ha Tay Statistical Year Book.

FIGURE 3.5: GRDP Growth-rate of Hanoi Metropolitan.

years from the historic expansion, the Hanoi has faced up to many difficuluties in urban management and also economic development. In 2009, since the impacts of global crisis, Hanoi had experiend a serious drop in economic development. The GDP growth was only 6.7% but still higher than that of the whole country (5.5%). The city's economy had returned the growth path in 2 years 2010 and 2011 with growth rate of 11.0% and 10.1%, respectively before experienced an incline in 2012, the time Vietnam economic development was at bottom since the year 2000 (GDP growth was only about 5.0%). The statistic number recorded at the end of 2012 a slight positive change in economy structure comparing that of 2008, represented by increasements of the GDP contribution share of Sector 2 and Sector 3 (GRDP contribution of 3 sectors are 52.6%, 41.8% and 5.6%, respectively).

3.3.2 Population

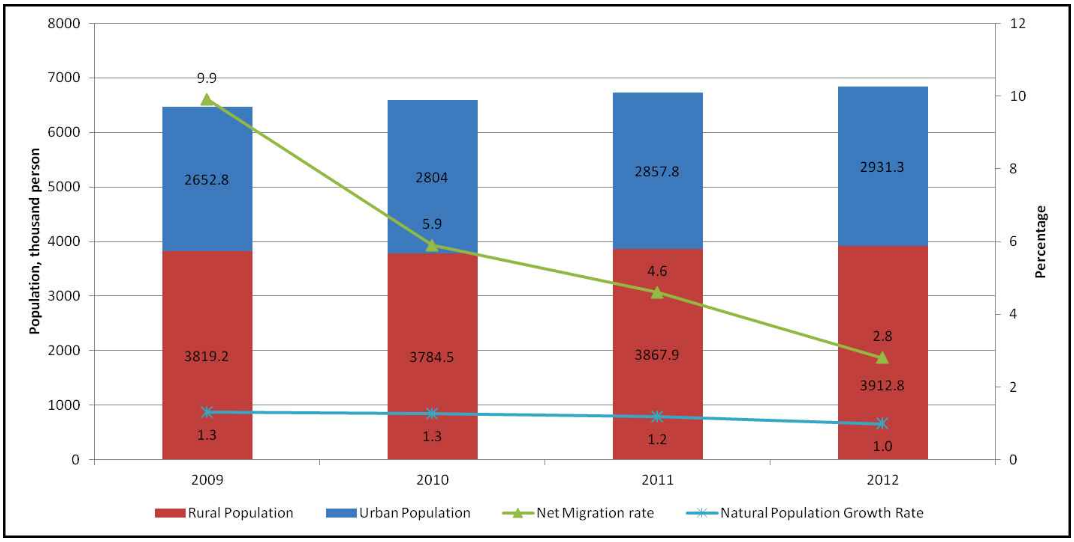
Accompany with economic development, "Old" Hanoi's population has also increased in the last decade, mainly by the immigrations from adjacent provinces of Hong Delta River such as Ha Tay (old), Nam Dinh, Thai Binh, Hung Yen, Hai Duong, Ha Nam . . . and apart from Northern-Central Provinces Thanh Hoa, Nghe An, Ha Tinh . . . In the period of 200-2007, the average annual population growth rate was about 2.80%. In the opposite, the growth rate "Old" Ha Tay Province in the same period was only 0.78% since there was not so much economic incentive, especially lack of promising in urban development, to induce the immigrants from adjacent areas. Now we consider



Note) Source: Ha Noi and Ha Tay Statistical Year Book 2007 [13].

FIGURE 3.6: Population of Hanoi Metropolitan 2000-2007.

the population growth of the two provinces as unified Hanoi metropolitan in the same period of time, 2000-2007. The average growth rate was 1.94%, higher than that of country as the whole (1.3%) but much more lower than growth rate of Ho Chi Minh City (HCMC), 2.8%. However, for the last 3 years before merging, it had been quite stable of about 2.1%, with large contribution of the "Old" Hanoi (3.2%). After the great expansion in 2008, the Hanoi Metropolitan population had increased with the same pace and nearly reached 7 million at 2012 (6.84 million), in which proportion of urban resident was about 42.5, increased about 8% comparing with that of 2007%. The population density of Hanoi Metropolitan in 2008 was about 1,901 person per km^2 but has not been equilly distributed. The average density of Old Hanoi city in 2007 was 3,740 person per km^2 but for urban center area it was about 11,950 person per km^2, 4 times higher than that of the City, while for suburban and rural areas, the number was only 1,763 person per km^2. Regarding to the Old Ha Tay Province, the average density was 1,166 person per km^2. For Ha Dong and Son Tay, the two Towns of the

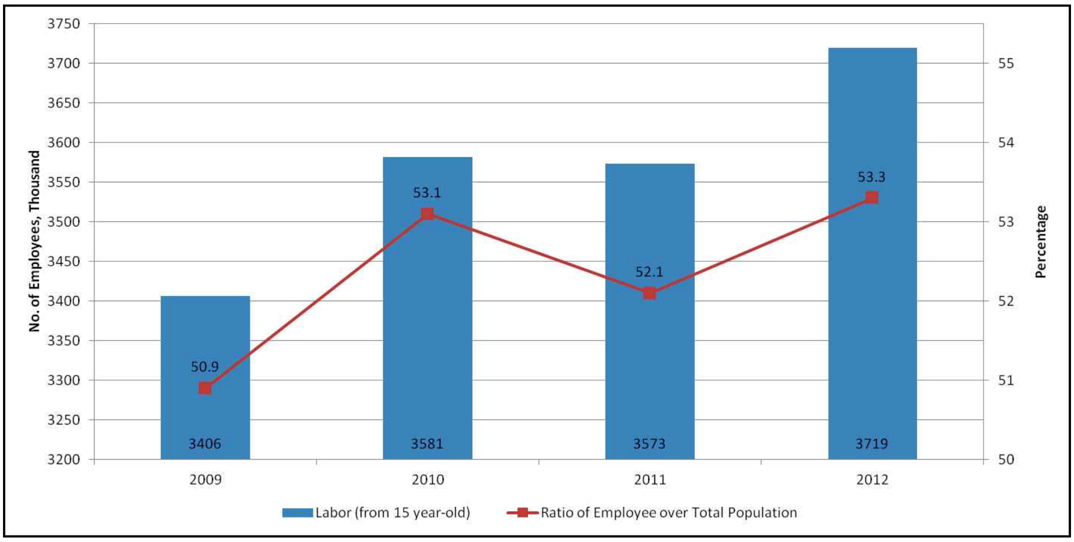


Note) Source: Statistical Year Book 2012 [13].

FIGURE 3.7: Population of Hanoi Metropolitan, 2009-2012.

province, the density were 5,292 and 1,067 person per km^2, respectively, quite high but not so serious like Hanoi. For Me Linh District, an old district of Vinh Phuc Province, the density was 1,300 person per km^2. The population density of Hanoi Metropolitan in 2012 was 2,059 person per km^2.

The overall indicators related to population and labor force of Hanoi Metropolitan after merged is shown in Figure 3.7 and 3.8.



Note) Source: Statistical Year Book 2012 [13].

FIGURE 3.8: Labor Force of Hanoi Metropolitan, 2009-2012.

3.3.3 Land-use

According to the statistic number the source of Ministry of Natural Resources and Environment (MONRE) of Vietnam, the land used by purposes of Hanoi Metropolitan at the establishmetn time was presented in Table 3.5.

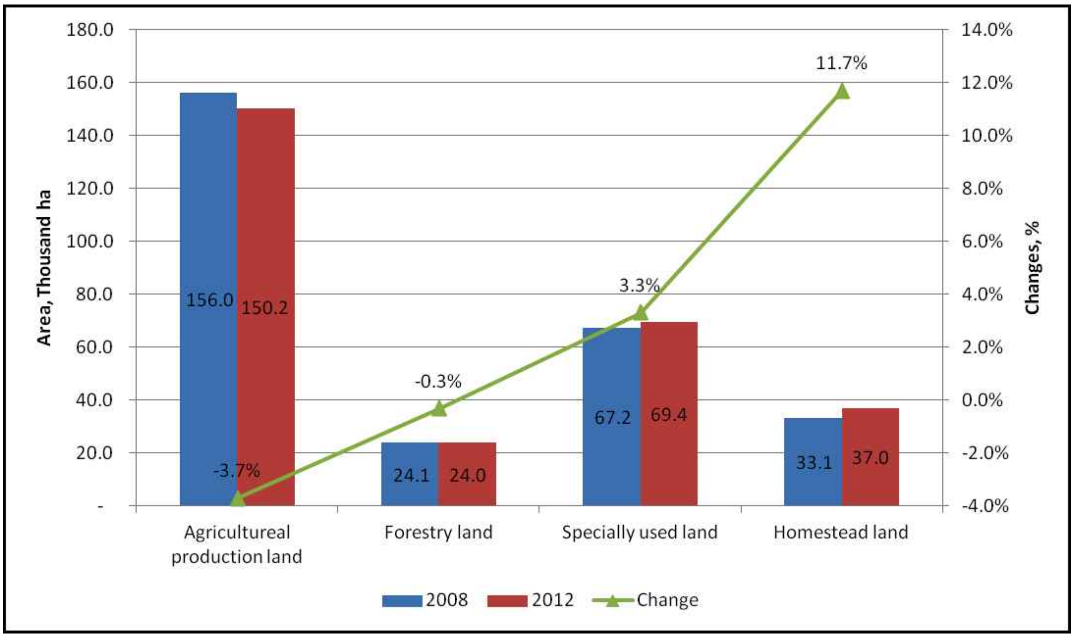
TABLE 3.2: Land-use by Purposes of Hanoi Metropolitan in 2008.

No.	Purposes	Area (ha)	Ratio (%)
I	**Agriculture land**	**192,080.60**	**57.45%**
1	Agricultural production land	155,988.53	46.65%
2	Forestry land	24,080.28	7.20%
3	Water surface land for fishing	10,141.72	3.03%
4	Other agricultural purposes	1,870.07	0.56%
II	**Non-Agricultural land**	**131,615.19**	**39.36%**
1	Homestead land	33,131.20	9.91%
1.1	*Urban*	26,266.02	7.86%
1.2	*Rural*	6,865.20	2.05%
2	Specially used land	67,187.73	20.09%
3	Relicious land	788.67	0.24%
4	Cemetary	2,888.85	0.86%
5	River and specialized water surfaces	27,153.53	8.12%
6	Other non-agricultural purposes	465.21	0.14%
III	**Unused land**	**10,671.69**	**3.19%**
1	Unused flat land	5,052.93	1.51%
2	Unused mountainous land	2,738.40	0.82%
3	Non tree rocky mountain	2,880.36	0.86%
Total		**334,367.48**	**100.00%**

Note) Source: The Hanoi Capital Construction Master Plan to 2030 and Vision to 2050, Appendix for Existing Status of Hanoi, Appraisal Purpose.

In conventional statistic document of land-use data of Vietnam, the land area is subdevided into three main types: *Agriculture land*, *Non-agriculture land* and *Unused land*. For the case of Hanoi, the correspondence percentages for each type are 57.45%, 39.36% and 3.19%, respectively. Regarding to the Non-agriculture land, the share for *Homestead land* and *Specially used land* are dominated with 30% over the total area. The specially used land here includes: *Land used by offices and non-profit agencies*, *Security and Defense land*, *Land for non-agriculture production and business* and *Public land*, which comprising land for fundamental facilities of Transportation, Irrigation, Energy, Post and Telecommunication, Cultural building, Health service, Education and Training building, Sport building, Research building, Social service, Market building and Historic Monument and Lanscape and Disposal and waste treatment.

A comparison between the land-use pattern in 2008 and 2012 by the four main purposes reveals that the area for non-agricultural purposes, particularly for *homestead land* and



Note) Source: Statistical Year Book of Vietnam 2012 [13].

FIGURE 3.9: Land-use changes in four main purposes.

specially used land was increased while for agricutural purposes, *agricultural production* and *forestry*, the area was decreased, especially regarding to the former purpose.

3.4 Status of Urban Transportation Infrastructure

3.4.1 Intercity

3.4.1.1 Road

Hanoi is the most important transportation hub of the country in general and the Hong River Delta in particular. There are many national highways toward the City such as National highways (NH) No. 1, No. 2, No. 3, No. 5, No. 6, No. 18, No. 32, Lang-Hoa Lac and Thang Long-Noi Bai , shaping a radial road network. At present time, there are only NHs No. 1A, No. 5, No. 18 having 4 lanes, and only NH No. 1A and No. 18 approaching the Road Category 1, the other routes are Category 3, with 2 auto lanes. Most of the urban areas and industrial zones around Hanoi are formed and developed along the road and since there are no collecting road to connect these areas to the national highways, therefore, it leads to *streeted national highway*, or national highway become street. Consequently, the capacity and operating speed have been lowering, and traffic safety also very low.

3.4.1.2 Railway

There are five radial railway lines connecting Hanoi with other provinces and there is one Ring-rail line located in the west of the City. Especially, there are two international railway lines: Hanoi-Lang Son line connecting China and Europe, and Hanoi-Lao Cai connecting with Konming, China. However, in general, the Vietnam's railway system is not considered for development at present time and therefore its competition is very low comparing with other transportation means.

3.4.1.3 Waterway

Hanoi located in the center of Hong River Delta, to be confluence of Hong River and Da River, and also to be where the Hong River detaches the largest branch, Duong River, then it has many advantages to develop inland waterway and also mixed river-sea waterway. There are 9 rivers crossing Hanoi (Hong, Duong, Cau, Ca Lo, Da, Day, Tich, Bui and Nhue) with total length of about 300 km. There are 7 ports along Hong River and 10 ports along Duong River located inside Hanoi. However, the share of waterway transportation is low comparing with its potential.

3.4.1.4 Airway

Hanoi has five airports in total, however, there are only two of that being under operation: Noi Bai and Gia Lam. The International Noi Bai Airport has two runway 1A (3,200 m) and 1B (3,800m). According to Internation Civil Aviation Organization (ICAO) regulation, the maximum capacity of Noi Bai is about 10 million passangers per year. The existing T1 Terminal (90,000 m^2)has reached the design capacity (6 million pax/year)and T2 Terminal (90,000 m^2) now being constructed from Japanese ODA fund (about 31 billion JPY).

3.4.2 Urban Transportation Infrastructure and Traffic Conditions

3.4.2.1 Road network in "Old" Hanoi City

At present time, the urban road network of Hanoi has been seriously overloaded since there is big gap between transportation development and socioeconomic growth. The overload state can be represented in many aspects in Table 3.3. At present time, the

TABLE 3.3: Urban Road Network of Hanoi, 2005.

Urban zone	Area[1]	Population	Length	Ratio	Density	Per 000 person
	km^2	(000 person)	(km)	(%)	(km/km^2)	(km/000 person)
Old Urban[2]	31	1,053	138	10.3	4.42	0.13
New Urban	119	827	128	6.3	1.07	0.15
Suburban	130	392	108	4.1	0.84	0.28
Rural	564	250	250	3.4	0.44	0.34
Overal City	844	3,008	624	4.2	0.74	0.21

Note) [1] The area is not included water surface ;[2]including Ba Dinh, Hoan Kiem Hai Ba Trung and Dong Da Districts; Source: The Hanoi Capital Construction Master Plan to 2030 and Vision to 2050, Appendix for Existing Status of Hanoi, Appraisal Purpose.

land used for transportation infrastructure is only about 8% is too low comparing with appropriate value presented in standard (24 – 26%) and law (16 – 26%). In addition, the connectivity of the road network is also main reason for congestion since the bottlenecks and 'missing links' has prevented the effectiveness in distribution of traffic flows. There are recommedations in previous study [14] for enhancing the capacity of urban road network but its still delayed in progress due to the difficulties in implemention coordination, lack of financing source and high cost in land acquisition and resettlement [33].

3.4.2.2 Urban Public Transpit and Road Facilities

By now, only "Bus" plays the role of public transit for the City. The coverage is less than 15% over total travel demand while the target is about 40 – 60%. The recommendations in enhancing the share of public transit has not been implemented.

Regarding to road facilities, total parking area of the city is only about 75,635 m^2 and inequal distributed, especially for the core urban area with average of 544 m^2 per point and smallest point of only 50 m^2 (Hang Trong). The lack of interchanges, pedestrian crossing bridges/tunnel at crowded intersection are also the main reasons for congestion and traffic accidents.

3.4.2.3 Provincial Road Network

The number of provincial road in the Old Hanoi City, Ha Tay Province and Me Linh District (belong to Vinh Phuc Province before merged with Hanoi Metropolitan) are 3, 29 and 3, respectively. The routes are mainly in Category 5 of standard for road design of Vietnam [40], with only 1 – 2 auto lanes and penetration macadam pavement. The road network at rural districts is still small with low paved ratio (about 35-40%).

However, these networks are distributed quite equally and adequate for travel demand generated in these areas.

3.5 Travel Demand Analysis for the Old Hanoi City

The analysis on travel demand and characteristics of Hanoian is based on the Person Trip Survey (PT) Data conducted in 2005 for Hanoi and 5 neighbour districts of "Old" Ha Tay (3 districts) and Vinh Phuc (2 districts) for 'The Comprehensive Urban Development Programme in Hanoi Capital City of the Socialist Republic of Viet Nam' (HAIDEP) [14]. The program was implemented by Japanese Consultans under JICA financing to propose the recommendations for Hanoi sustainable development in future.

3.5.1 Trip Rate

With the population of 3.2 million and total number of trips generated of 8.7 million, on average, a Hanoi's resident made 2.7 trips per day. This rate is slightly lower than that of Ho Chi Minh City (3.0), the biggest city of Vietnam but still higher than some other Asian cities (Tokyo (2.3), Manila (2.2), Bangkok (2.3)) [16]. The trip rate was about 1.9 if the "Walk" trips left out of counting.

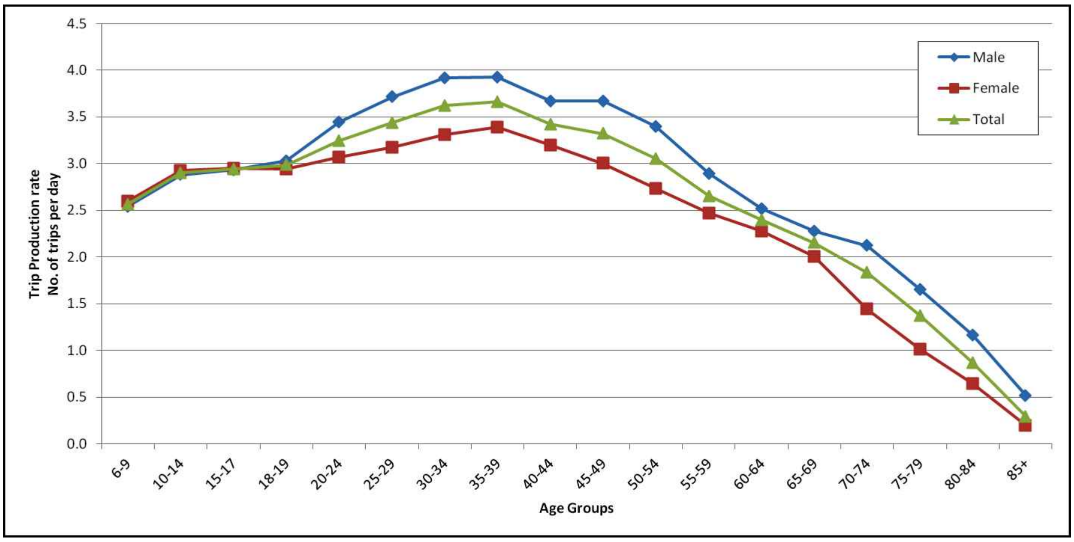
With further analysis on the gender and age of travelers, without Walking trips, in Figure 3.10, the age between $35-39$ had the highest trip rate for both male and female, with 3.9 and 3.4 trips/day respectively. On average, it was 3.7 trips/day for the age having most daily activities.

3.5.2 Trip Purpose and Modal Share

The modal share (excluding Walk) by purposes of Hanoian are shown in Figure 3.11. The motorcycle (MC) was dominated in nearly all purposes, with 75% of "To Work" trips were done by this travel means. The second mode having the large share was bicycle with nearly one half of "To School" purpose.

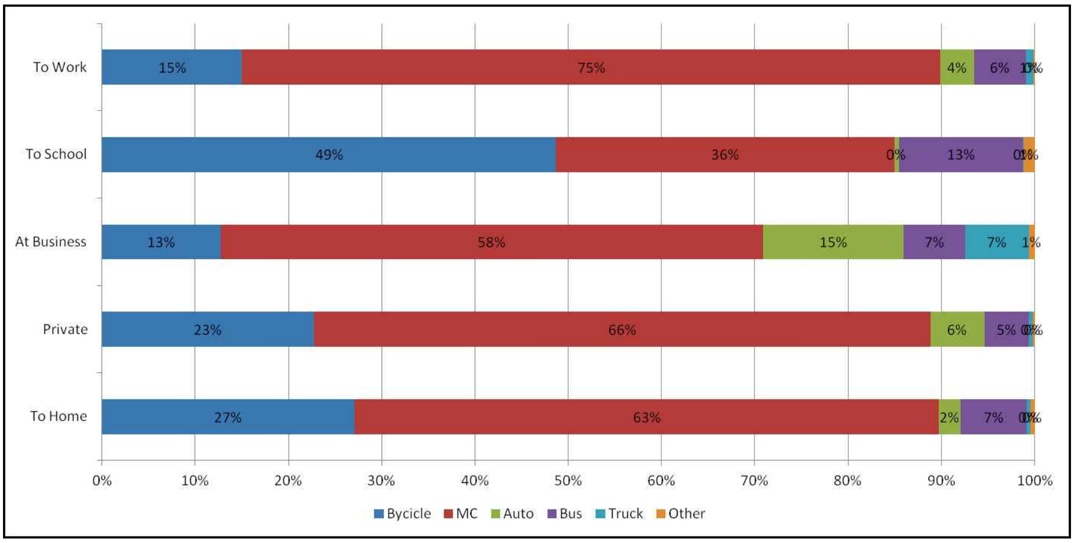
The share of bus, a unique urban public transit at that time, was very minor in traveling market, with only about 7% in total. The considerable value 13% was recorded for "To School" trips.

The auto mode was not widespead used at that time for traveling other than "At Business" purpose with about 15%.



Note) Calculated from Hanoi PT data 2005

FIGURE 3.10: Trip Rate by Gender and Age (Excluding Walk).

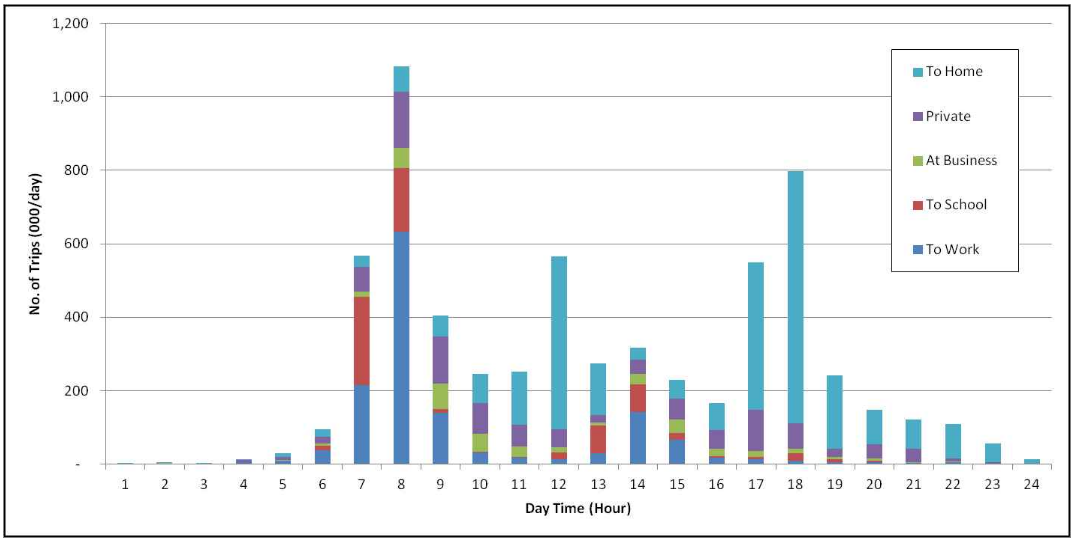


Note) Calculated from Hanoi PT data 2005

FIGURE 3.11: Modal Share by Purposes (Excluding Walk).

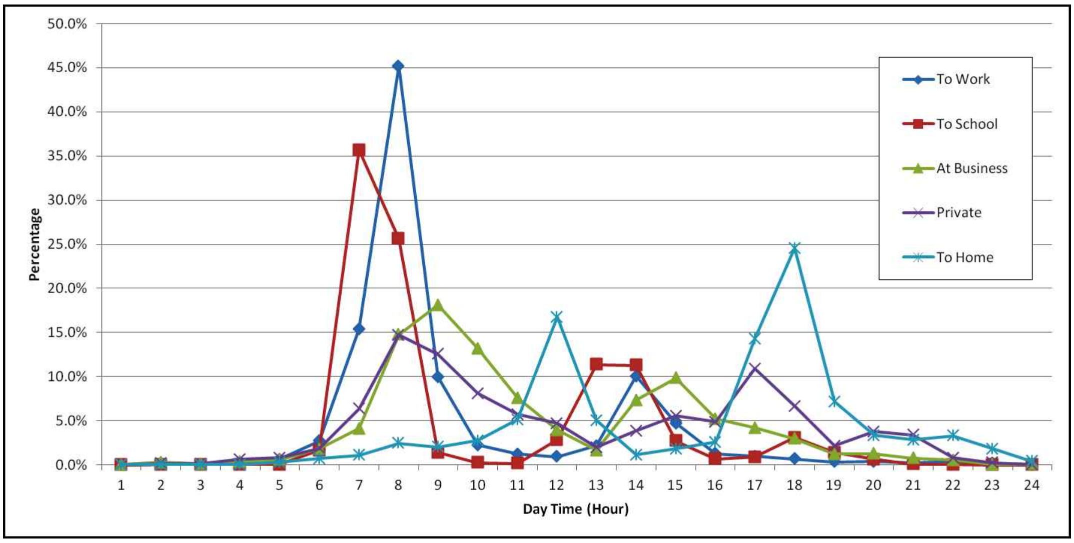
3.5.3 Daily Travel Demand Pattern

The trip (excluding Walk) distribution by time in Figure 3.12 shows that there were three peak-hours in daily travel pattern of Hanoi city. The highest peak hour was in the morning, $7AM - 8AM$, taking about 17% of total daily travel demand, and dominated by "To Work" with nearly 50% over all purposes. The second and third rush hours in a day were $17PM - 18PM$ and $11AM - 12PM$, respectively, with main contribution of "To Home" trips. The total of the three peak hour was about 39% of the total travel demand in a day.



Note) Calculated from Hanoi PT data 2005

FIGURE 3.12: Trip Distribution by Day Time and Purposes (Excluding Walk).

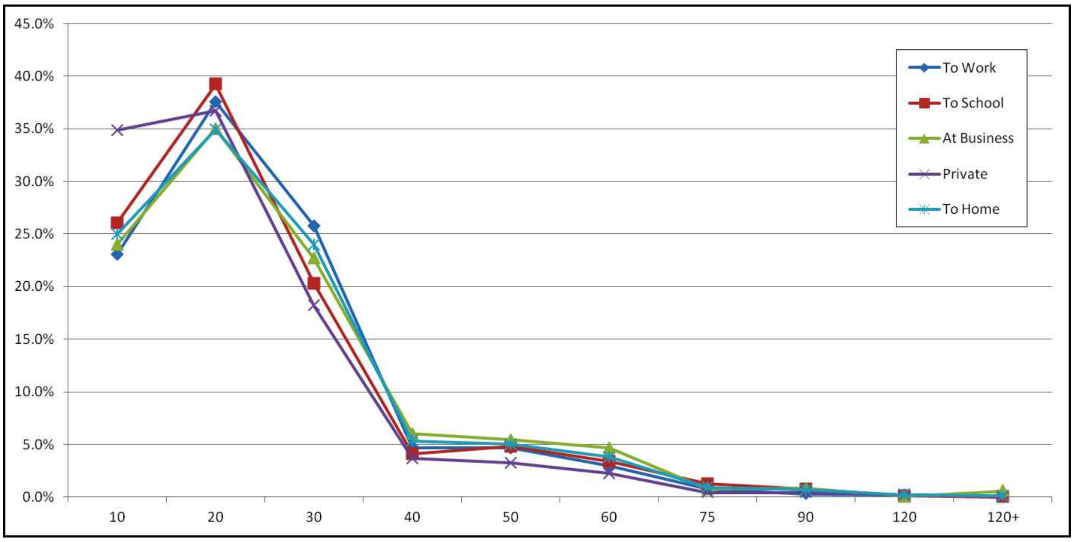


Note) Calculated from Hanoi PT data 2005

FIGURE 3.13: Trip Ratio by Travel Time and Purposes (Excluding Walk).

3.5.4 Travel Time

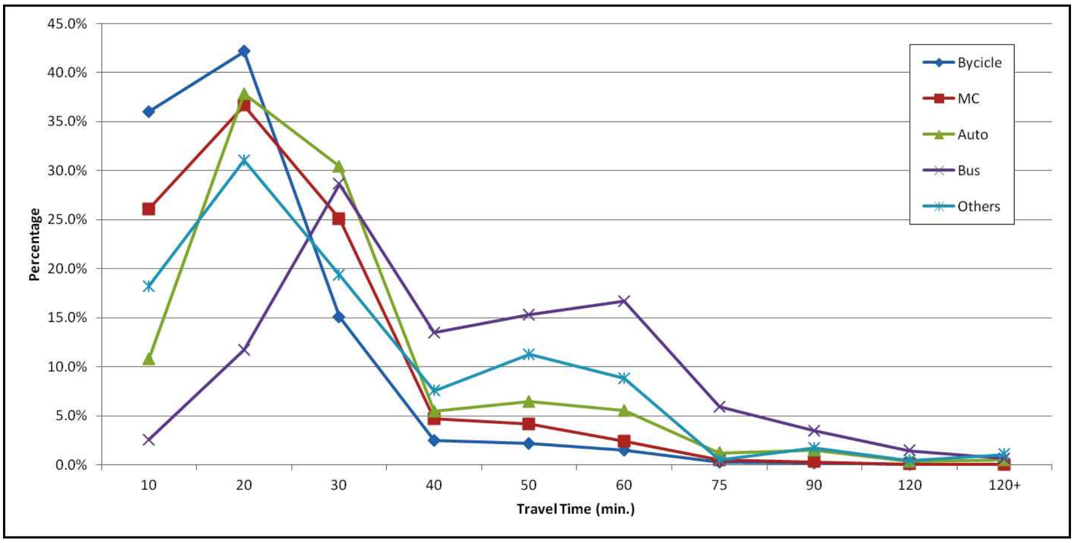
In this section the travel behavior will be analyzed regarding to the travel time aspect. In general, the average travel time for all trips (excluding "Walk") taking place inside the Old Hanoi City was about 22 munites. Let consider the travel time versus travel purposes. Most of trips was in $10-20$ munites bin and varied from $35-40\%$ for all travel purposes. The distribution dropped down quickly with longer trips and just was about 5% for the trips taking more than 40 munites. As shown in Figure 3.14, the distribution of travel time is quite uniform for all purposes in each time bin, just a considerable higher (about 10%) for "Private" trips at time bin $1 - 10$ munites. The distribution of



Note) Calculated from Hanoi PT data 2005

FIGURE 3.14: Trip Distribution by Travel Time and Purposes (Excluding Walk).

trips versus travel modes is shown in Figure 3.15. It seems that nearly all mode was at peak at time bin $10 - 20$ munites, with about 42% of "Bicycle" and more than 35% of "Motorcycle" and "Car" were used in this segment. "Bus" was not popular in this bin with only 12% but at peak at travel time of $50 - 60$ munites. The travel time for inter

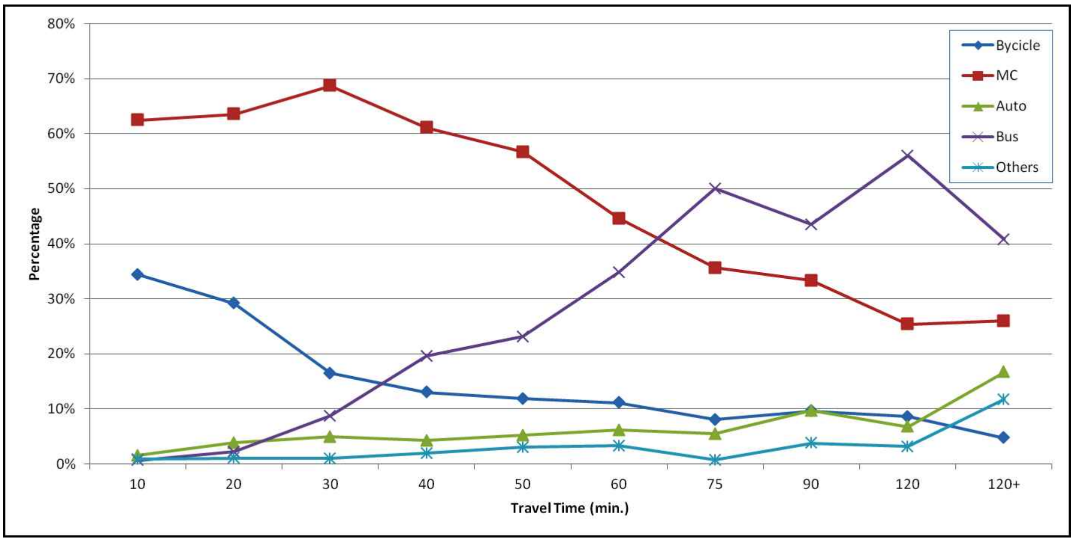


Note) Calculated from Hanoi PT data 2005

FIGURE 3.15: Trip Distribution by Travel Time and Modes.

and intra districts for the Old Hanoi city at the year of 2005 was presented in Table 3.4. The travel time for intra-district trips was quite stable to be less than 20 munites, for all purposes in all districts. For the inter-district trips, the travel was roughly more or less 2 times longer that of intra-district trips and tend to be increased for the suburban or rural districts.

Regarding to the mode share versus the travel time, we can easily find Figure 3.16 that the "Motorcycle" was dominated in all segment less than 60 minutes, and at peak at time bin $20 - 30$minutes with the share of 69%. "Bicycle" was also the main mode for trips less than 30 munites with the peak at $1 - 10$ munites segment. When the travel time was more than 75 minutes, "Bus" became the first choice with the share varied between $40 - 60\%$. The contribution of "Car" and other modes was still low (less than 10%) for nearly all segement less than 120 minutes and tend to be increased with long trips but still lower than "Motocycle".



Note) Calculated from Hanoi PT data 2005

FIGURE 3.16: Trip Ratio by Travel Time and Modes.

TABLE 3.4: Average Travel Time of Intra and Inter District Trips by Purposes (Excluding Walk), Minutes

District		To Work			To School			At Business			Private			To Home			All Purposes		
Type	**Name**	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Center	Ba Dinh	14	26	23	13	25	20	16	31	29	12	27	23	14	27	24	14	27	24
	Hoan Kiem	13	27	25	13	24	20	13	34	31	13	28	25	14	28	26	13	28	25
	Hai Ba Trung	14	29	25	14	31	25	15	39	34	12	29	23	14	32	27	14	31	26
	Dong Da	15	25	23	14	27	22	16	37	33	12	28	23	15	29	25	14	28	24
Fringe	Tay Ho	13	30	26	13	26	20	16	33	27	11	29	21	13	29	23	13	29	23
	Thanh Xuan	14	29	25	15	34	28	14	36	31	13	34	26	15	36	30	14	34	28
	Cau Giay	13	30	26	13	36	28	11	39	33	12	35	25	14	38	30	13	36	28
	Hoang Mai	16	34	28	14	33	25	19	45	39	14	42	31	16	38	29	16	38	30
	Long Bien	16	36	28	15	46	29	15	45	38	15	44	30	16	42	30	16	41	30
Suburb/Rural	Soc Son	15	43	20	19	40	21	17	50	27	16	50	23	17	48	20	17	47	21
	Dong Anh	15	39	19	17	51	19	16	47	23	14	44	17	16	46	20	16	44	19
	Tu Liem	13	36	24	16	38	25	12	48	31	13	41	23	15	42	26	14	41	25
	Thanh Tri	17	34	25	18	34	23	15	41	28	16	39	25	17	36	24	17	36	25
	Gia Lam	15	34	23	17	48	25	14	44	26	15	44	26	16	44	26	16	42	25
Average		14	32	24	15	35	23	15	41	31	13	37	24	15	37	26	15	36	25

Note) (1), (2) standing for the travel time Intra/Inter districs trips, respectively, and (3) represented for Total trips.

3.5.5 Travel Demand by District

The travel demand (total number of trips generated and attracted) of the Old Hanoi City by travel purposes, in district level, are summerized in Table 3.5 and a comparison between trips generation and attraction are presented in Table 3.6. The Table 3.7 shows the ratio of intra districts trips over the total travel demand for all purposes.

The travel demand, both generated and attracted, in the center districts of Hanoi city were larger than that of fringe and suburban/rural districts and total number of attracted trips larger than that of generated in that area. Regarding to the travel purposes, the "To Work" and "Private" trips dominated in both generation and attraction aspects. The total of "To School" and "At Business" trips were just nearly equal to the "Private" trips, and also to be in both generation and attraction aspects.

The information in Table 3.7 said that most of socioeconomic activities in Suburban and Rural districts took place iternally, especially for Soc Son and Dong Anh Districts. The ratio of intra-district trips of Dong Anh was about 83% for "To Work", 90% for "Private" purpose, and attained the highest ratio of near 96% for "To School" trips.

In general, the ratio of Attraction over Generation and the differences between Generation and Attraction in the Table 3.6 tell us that there were a lot of socioeconomic activities taking place in center districts and it attracted that of from other areas of the city. The closed to 1 in the last row in that table also revealed that the trips mostly took place in side the city.

Table 3.5: Trip Generation/Attraction by District (Excluding Walk)

District		**Generation (No. of Trips)**					**Attraction (No. of Trips)**				
Type	**Name**	**Work**	**School**	**Business**	**Private**	**Home**	**Work**	**School**	**Business**	**Private**	**Home**
Center	Ba Dinh (1)	138,264	47,543	44,775	91,710	253,029	143,542	55,691	39,231	107,557	227,386
	Hoan Kiem (3)	110,810	46,229	50,037	101,528	398,050	238,709	39,361	69,820	170,939	166,607
	Hai Ba Trung (4)	170,990	77,189	49,048	131,634	398,809	196,041	111,325	47,998	136,541	313,627
	Dong Da (5)	187,056	76,677	53,889	157,782	336,573	175,084	90,748	47,430	138,530	358,826
	Sub-Total	607,120	247,638	197,749	482,654	1,386,461	753,376	297,125	204,479	553,567	1,066,446
Fringe	Tay Ho (2)	68,896	29,987	20,002	47,846	101,013	46,769	22,066	16,719	45,219	136,870
	Thanh Xuan (6)	93,302	45,469	23,920	73,836	177,404	90,693	56,007	18,757	61,677	188,609
	Cau Giay (7)	84,436	39,542	25,952	68,878	190,318	73,005	71,749	25,693	71,991	159,337
	Hoang Mai (8)	102,909	49,597	27,573	71,328	132,924	65,387	24,549	22,895	52,610	206,952
	Long Bien (9)	115,737	40,967	30,404	67,413	200,587	139,114	23,550	35,997	70,307	209,579
	Sub-Total	465,280	205,562	127,851	329,301	802,246	414,968	197,921	120,061	301,804	901,347
Suburb/Rural	Soc Son (10)	55,935	56,051	14,542	44,241	153,633	60,400	52,774	17,942	44,253	149,474
	Dong Anh (11)	78,946	57,166	26,087	77,576	200,213	71,181	57,624	23,953	76,966	211,045
	Tu Liem (12)	93,001	49,161	29,680	78,828	180,563	78,294	43,220	26,211	66,495	219,189
	Thanh Tri (13)	67,891	32,530	17,698	33,559	97,485	48,839	22,030	14,527	30,124	133,941
	Gia Lam (14)	94,782	37,256	23,808	58,435	163,081	78,643	33,622	20,860	62,772	196,234
	Sub-Total	390,555	232,164	111,815	292,639	794,975	337,357	209,270	103,493	280,610	909,883
Total		1,462,955	685,364	437,415	1,104,594	2,983,682	1,505,701	704,316	428,033	1,135,981	2,877,676

Note) Calculated from Hanoi PT Data 2005; (1) standing for "Average Intrazonal Travel Time", (2) standing for "Average Interzonal Travel Time" and (3) standing for "Average of Inter and Intrazonal Travel Time."

TABLE 3.6: Comparison of Trip Generation/Attraction by District (Excluding Walk)

District		Attraction/Generation (Ratio)					Generation-Attraction (Difference, Trips)				
Type	**Name**	**Work**	**School**	**Business**	**Private**	**Home**	**Work**	**School**	**Business**	**Private**	**Home**
Center	Ba Dinh (1)	1.04	1.17	0.88	1.17	0.90	-5,278	-8,148	5,544	-15,847	25,643
	Hoan Kiem (3)	2.15	0.85	1.40	1.68	0.42	-127,899	6,868	-19,783	-69,411	231,443
	Hai Ba Trung (4)	1.15	1.44	0.98	1.04	0.79	-25,051	-34,136	1,050	-4,907	85,182
	Dong Da (5)	0.94	1.18	0.88	0.88	1.07	11,972	-14,071	6,459	19,252	-22,253
	Sub-Total	0.81	0.83	0.97	0.87	1.30	-146,256	-49,487	-6,730	-70,913	320,015
Fringe	Tay Ho (2)	0.68	0.74	0.84	0.95	1.35	22,127	7,921	3,283	2,627	-35,857
	Thanh Xuan (6)	0.97	1.23	0.78	0.84	1.06	2,609	-10,538	5,163	12,159	-11,205
	Cau Giay (7)	0.86	1.81	0.99	1.05	0.84	11,431	-32,207	259	-3,113	30,981
	Hoang Mai (8)	0.64	0.49	0.83	0.74	1.56	37,522	25,048	4,678	18,718	-74,028
	Long Bien (9)	1.20	0.57	1.18	1.04	1.04	-23,377	17,417	-5,593	-2,894	-8,992
	Sub-Total	1.12	1.04	1.06	1.09	0.89	50,312	7,641	7,790	27,497	-99,101
Suburb/Rural	Soc Son (10)	1.08	0.94	1.23	1.00	0.97	-4,465	3,277	-3,400	-12	4,159
	Dong Anh (11)	0.90	1.01	0.92	0.99	1.05	7,765	-458	2,134	610	-10,832
	Tu Liem (12)	0.84	0.88	0.88	0.84	1.21	14,707	5,941	3,469	12,333	-38,626
	Thanh Tri (13)	0.72	0.68	0.82	0.90	1.37	19,052	10,500	3,171	3,435	-36,456
	Gia Lam (14)	0.83	0.90	0.88	1.07	1.20	16,139	3,634	2,948	-4,337	-33,153
	Sub-Total	1.16	1.11	1.08	1.04	0.87	53,198	22,894	8,322	12,029	-114,908
Total		1.03	1.03	0.98	1.03	0.96	-42,746	-18,952	9,382	-31,387	106,006

Note) The Trip Generation/Attraction here also includes travel demand of the districts of Ha Tay (3) and Vinh Phuc (2) Provinces, which bordering with the Old Hanoi City. It is not included the trips going in/out of that study area.

Table 3.7: Demand Characteristics (Excluding "Walk").

District		**Gen. and Att.**	**Intra Trip Ratio (%)**			
Type	**Name**	**Trips/day**	**Work**	**School**	**Business**	**Private**
Center	Ba Dinh (1)	1,148,728	20.7	35.8	15.4	27.4
	Hoan Kiem (3)	1,392,090	14.7	32.7	13.6	21.2
	Hai Ba Trung (4)	1,633,202	23.8	31.7	18.7	36.6
	Dong Da (5)	1,622,595	20.8	35.9	21.3	31.9
Fringe	Tay Ho (2)	535,387	23.4	46.7	36.9	45.6
	Thanh Xuan (6)	829,674	22.3	32.3	21.9	35.9
	Cau Giay (7)	810,901	23.6	37.0	21.5	41.8
	Hoang Mai (8)	756,724	29.8	44.7	25.2	41.0
	Long Bien (9)	933,655	37.9	54.6	22.6	48.2
Suburb/Rural	Soc Son (10)	649,245	80.5	93.5	69.4	79.9
	Dong Anh (11)	880,757	82.8	96.0	77.7	89.5
	Tu Liem (12)	864,642	55.9	59.5	47.7	62.1
	Thanh Tri (13)	498,624	52.8	70.5	50.4	61.0
	Gia Lam (14)	769,493	57.7	76.1	58.5	63.8

Note) Calculated from Hanoi PT Data 2005.

3.5.6 Travel Demand Distribution

The spatial travel demand distribution is presented in Table 3.8. In general, the travel demand was not equally distributed in the whole city. The main reasons may be the high population density and the difference in development among city's zones.

There was about 1.9 million trips generated and attracted in the urban center area, taking 24% of total travel demand of the City. The largest number of intra district trip recorded was in Hai Ba Trung District, about 240 thousand trips. This trend was still remained for fringe and suburban/rural areas with correspondence percentages about 12% and 17%, respectively. The relationship between the urban center and urban fringe, and between urban center and suburban/rural was declined about 4 times, with corresponding trip percentage in both generation/attraction aspects.

The total travel demand in 2005 Hanoi was about 2.1 time larger than that of 1995 and the highest increasement was recorded for the attraction of suburban area, 4.5 time larger [16].

Table 3.8: Overall Demand Distribution in Hanoi and Neighbour Districts.

Gen.\Attr.	(1)	(2)	(3)	(4)	(5)	∑ Gen.
Hanoi Center (1)	1,909,666	686,375	167,160	53,112	105,309	2,921,622
Hanoi Fringe (2)	668,924	940,513	186,530	38,735	95,538	1,930,240
Hanoi Suburb/Rural (3)	163,245	186,698	1,375,538	41,927	54,740	1,822,148
Neighbour Zones (4)	55,911	34,525	42,865	753,566	47,052	933,919
Outside (5)	77,247	87,990	68,520	46,999	62,246	343,002
∑ Att.	2,874,993	1,936,101	1,840,613	934,339	364,885	*7,950,931*

Ratio to Total (%)	(1)	(2)	(3)	(4)	(5)	∑ Gen.
Hanoi Center (1)	24.0	8.6	2.1	0.7	1.3	36.7
Hanoi Fringe (2)	8.4	11.8	2.3	0.5	1.2	24.3
Hanoi Suburb/Rural (3)	2.1	2.3	17.3	0.5	0.7	22.9
Neighbour Zones (4)	0.7	0.4	0.5	9.5	0.6	11.7
Outside (5)	1.0	1.1	0.9	0.6	0.8	4.3
∑ Att.	36.2	24.4	23.1	11.8	4.6	100.0

Ratio to Total Gen. (%)	(1)	(2)	(3)	(4)	(5)	∑ Gen.
Hanoi Center (1)	65.4	23.5	5.7	1.8	3.6	100.0
Hanoi Fringe (2)	34.7	48.7	9.7	2.0	4.9	100.0
Hanoi Suburb/Rural (3)	9.0	10.2	75.5	2.3	3.0	100.0
Neighbour Zones (4)	6.0	3.7	4.6	80.7	5.0	100.0
Outside (5)	22.5	25.7	20.0	13.7	18.1	100.0
∑ Att.	36.2	24.4	23.1	11.8	4.6	100.0

Ratio to Total Att. (%)	(1)	(2)	(3)	(4)	(5)	∑ Gen.
Hanoi Center (1)	66.4	35.5	9.1	5.7	28.9	36.7
Hanoi Fringe (2)	23.3	48.6	10.1	4.1	26.2	24.3
Hanoi Suburb/Rural (3)	5.7	9.6	74.7	4.5	15.0	22.9
Neighbour Zones (4)	1.9	1.8	2.3	80.7	12.9	11.7
Outside (5)	2.7	4.5	3.7	5.0	17.1	4.3
∑ Att.	100.0	100.0	100.0	100.0	100.0	100.0

Note) Calculated from Hanoi PT Data 2005; The neighbour zones of the Old Hanoi City defined in this PT survey included 3 districts Ha Dong, Dan Phuong, Hoai Duc of Ha Tay Province, and 2 districts Phuc Yen and Me Linh of Vinh Phuc Province.

3.6 The Construction Master Plan of Hanoi by 2030 and Vision to 2050

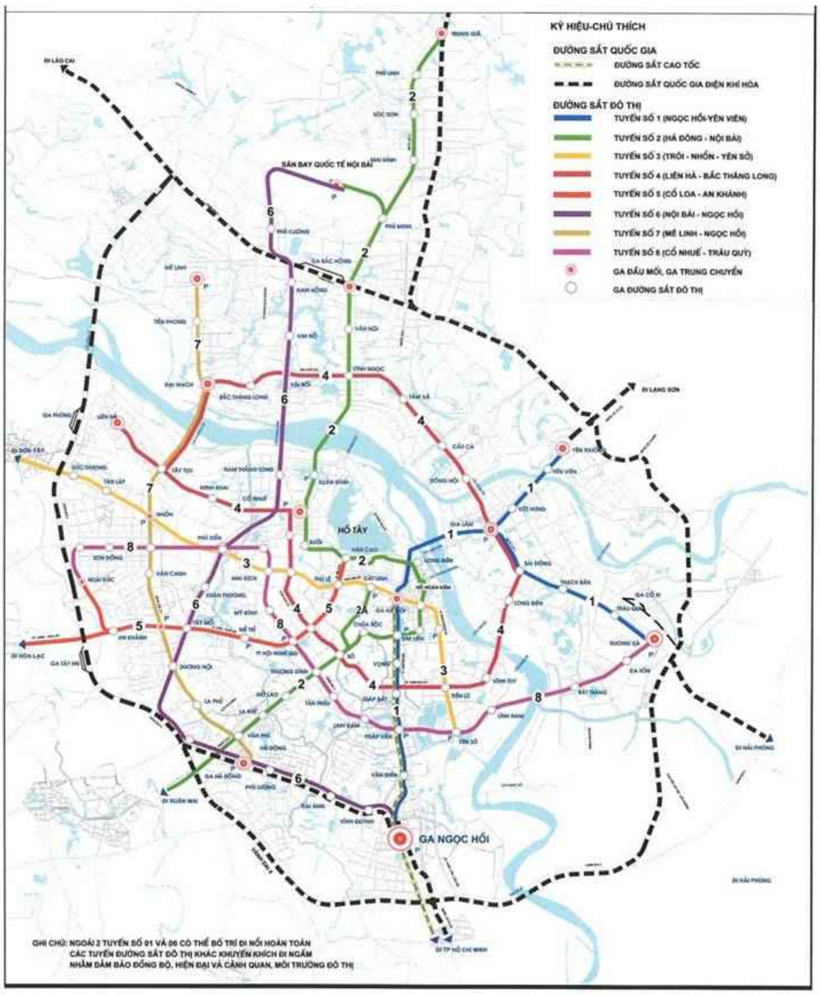
The newest construction master plan 'The Hanoi Capital Construction Master Plan to 2030 and Vision to 2050' was approved by Prime Minister in 2011 [2] and now to be in force. This plan will orient for all urban infrastructure facilities constructed inside Hanoi Metropolitan until the year of 2030 and can be lasted to 2050. According to the key objectives of the plan, Hanoi will be developed in harmonious spatial pattern, with integrated and modern urban infrastructure systems. In this section, the most important contents for spatial development and transportation for the Hanoi City in future will be sumerized in below subsections.

3.6.1 Orientation of Spatial Development

The city will comprise the core urban center and five main satellites urban areas Soc Son, Son Tay, Hoa Lac, Xuan Mai and Phu Xuyen. Between the core center and the satellites will be green corridors (for agriculture, water surface, ecological villages/towns or green space for relaxation) or green belt (for park, water surface or public services).

The urban center area is oriented to play the key roles on polictics, culture, history, service, healthcare, high-quality eduction for the whole country, region and Hanoi City. Its population has been projected to be $4.0 - 4.5$ million. The development boundary of this area will be limited inside the Ring Road No. 4 and development direction will be to the West and the North of Hong River. The core historic urban area will be strictly controlled and to preserve the cultural characteristics and lifestyle of ancient Thong Long. The population will be restrained lower than 0.8 million. A chain of urban zones Dan Phuong, Hoai Duc, Ha Dong, Thanh Tri will be developed along the Ring Road No. 4, embracing the historic core area and separated by green corridor along Nhue River. The urban chain, a part of urban center area but located in the North bank of Hong River, includes urban zones Gia Lam, Long Bien, Dong Anh and Me Linh. Gia Lam-Long Bien will be concentrated on commercial, finance, banking and specialized medical development. Dong Anh will be the internation commercial and hi-tech industry center and also integrated studio and eco-tourism with Co Loa Historic Monument and Van Tri Pond. Me Linh will be green, hi-tech and multi-industrial zone with exhibition center combining with Noi Bai Airport.

In order to support the economic development objectives for the City, the five satellite areas will be developed with specific functions to create jobs and share with the center urban area on housing, high quality education, industrial and urban services. These urban areas will be developed with population size varying from 210 to 750 thousands. *Hoa Lac* will be the science and hi-tech center, attracting the most advanced technologies with intellectural concentration of the whole country. It also will be the high education center for the region and country as the whole. *Son Tay* will be the nuclear to boost up the development of the north-west area of Hanoi. The main direction for economic growth will be eco-tourism, ecological agriculture and handicraft. *Xuan Mai* will be the "University Town" and service for the south-west Gate of the City. Phu Xuyen-Phu Minh located in the south of the City is oriented to be industrial zone integrated with warehouse, transshipment, logistic coordination and agricultural product distribution.



Note) Source: Orientation of public transport planning-The Hanoi capital construction master plan to 2030 and vision to 2050 [2]

FIGURE 3.17: 8 planned routes of Hanoi Public Light Rail and Metro System in Hanoi 2030.

Soc Son located in the north of the City also will be industrial zone integrated with supplying aviation service.

3.6.2 Development Plan of Transportation Infrastructure System

3.6.2.1 Intercity Transportantion

The intercity transportantion system ensuring the passenger and cargo transportation volume between Hanoi and other cities/region has been considered.

For the road network, the primary objectives are to improve and upgrade the existing roads network including national and provincial highways (NH, PH) connecting to the core historic urban center and ring-roads. Some new links which have the parralel alignment with radial routes: Lang-Hoa Lac Road, National highways No. 32, No. 6, No. 1A, No. 1B, No. 5, No. 3 should be constructed to share the overloaded traffic flows. The Ring-road No. 4, the outer bound of center urban area, Ring-road No. 5 and highways along the economic corridors connecting to the counterpart cities of Hanoi should be completed. There are 7 bridges, 1 tunnel crossing Hong River, interchanges should be newly built. The stations, parking areas for road network also should be re-arranged and renovated.

Regarding to the railway network, firstly, the rail line parralel with Ring-road No. 4 will be improved and completed. After that, the five urban light rail-metro lines, which had been formulated and proposed by the Old Hanoi city, will be constructed and connected to the new urban rail system of the new City. This urban railway network will be merged with national railway system at hub stations.

For the airway transportation, the existing Internation Noi Bai Airport will be upgraded to meet the travel demand of 50 million passengers per years. Gia Lam Airport will be mainly used for domestic and short-haul flights.

Related to the waterway transportation, the fairways in Hong River will be improve to utilize for waterways connecting Hanoi and seaport systems in Hai Phong and Quang Ninh Provinces. The Day and Tich Rivers will also be improved to serve for tourism and irrigation of agriculture sector. The river port systems of the Old Hanoi City and Son Tay will be upgraded or newly constructed to connect with that of Vinh Phuc, Hoa Binh, Hung Yen, Hai Duong and Ha Nam Provinces.

3.6.2.2 Urban Transportantion

For the Urban center area, primarily, the main urban road network has to improved reaching the basic road density critera of $3 - 5$ km road per km^2 area, and land for transportation has to be about $20 - 26\%$ total land area. The urban public transport network has to meet the technical ratio of $2.0 - 3.0 km/km^2$ and will cover for the $45 - 55\%$ total travel demand. For existing urban center, at first, Ring-road No. 2 and No. 3 should be completed. For the new urban chain between Ring-road No. 3 and No. 4, a new Ring-road '3.5' connecting the new urban area should be supplemented. The interchange on the urban arterial roads will be constructed and. An appropriate land also will be arranged and controlled for parking purpose. The urban mass rapid transit (UMRT) system will be developed and combined with rapid bus network to make up an efficient and interconnected network. The 8 UMRT lines will be extended to connect the center urban area with the satellite towns.

For the satellite urban areas, a completely new, modern transportation system, unified with the land-use plan, will be customized and established in each satellite town so that it can fit well with the functions and specific characteristics of each. On the other hand, the inter-town transportation network will also be developed to ensure the rapid contact between the satellites and urban center area and also among them. Primarily, the public transport will be enhanced by introducing some shuttle bus routes. In the future, depending on the travel demand of each connection, the network can be upgraded to mass rapid transit type.

3.7 Summary and Recommendations

This chapter has presented the historic establishment, current status and ambitious development plan of Hanoi in long term. The transportation infrastructure system for both intercity and intracity purposes, have been summerized to figure out the main points of current status of the Hanoi at present time. The daily travel behaviors of Hanoian analyzed from PT data 2005 have revealed the daily travel pattern. In general, the transportation system of Hanoi should be improved in both quality and quantity to meet the travel demand generated inside the city. Finally, the construction master plan of Hanoi city to 2030 and vision to 2050 has been introduced.

A comparison between the current status and ambitious development objectives of the city, a long list of projects should be carried out in near future to realize the these targets. Consequently, the socioeconomic benefit of each project should be put in a right context, estimated with a unified and suitable methodology, and judged from an general equilibrium viewpoint. The demand to have a new academic methodology to overcome the limitations of the traditional approach is apparent, in both theory development and practical application. In that sense, the analyzed results from this chapter will be precious information for next chapters in formulating an appropriate framework for economic evaluation of transportation infrastructure development of Hanoi Metropolitan in future.

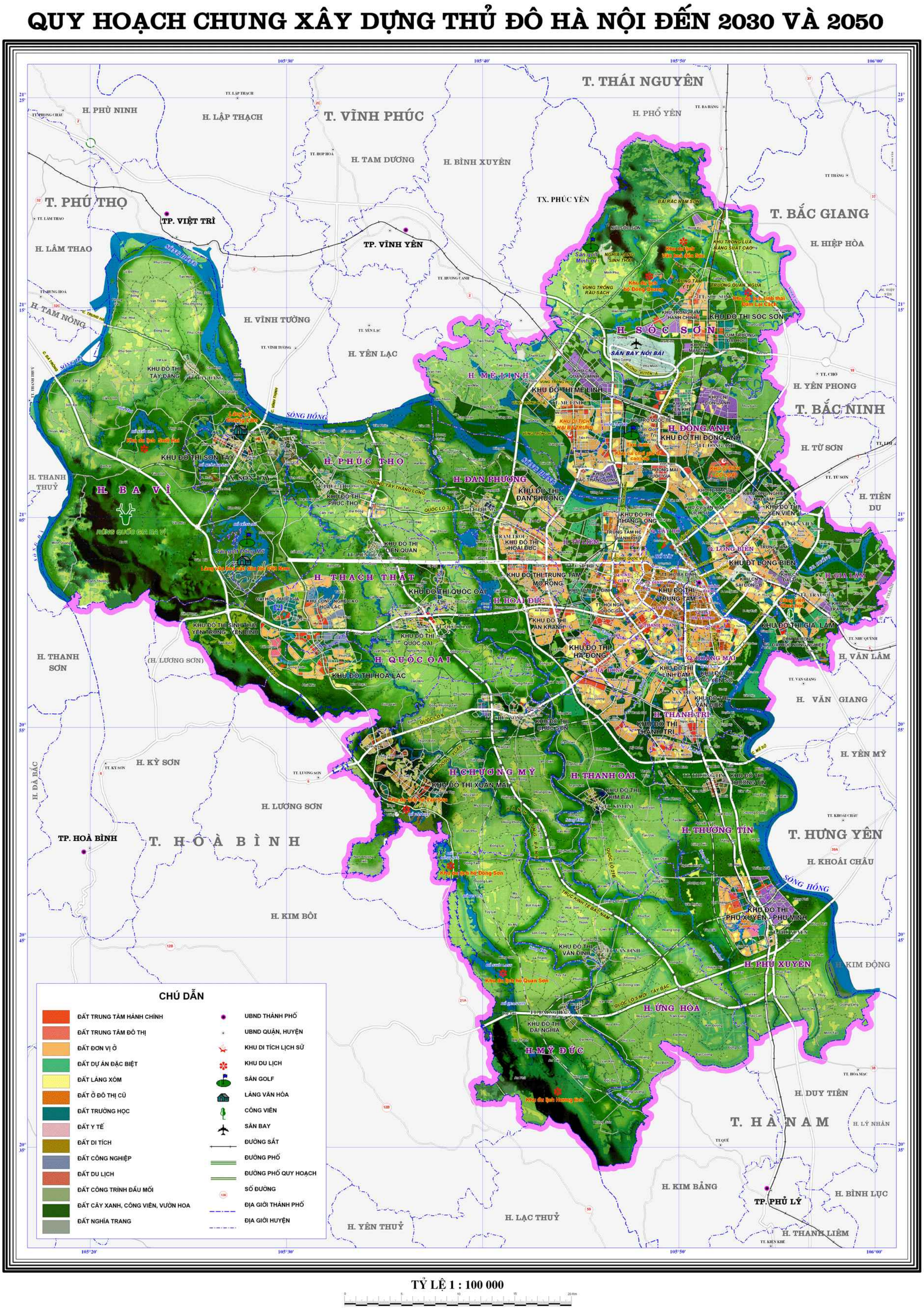


FIGURE 3.18: The Hanoi capital construction master plan to 2030 and vision to 2050.

Chapter 4

Urban Economic Analysis with CUE modeling

4.1 General introduction

The Computable Urban Economic (CUE) Models have proved to be a very powerful tool for urban policy analysis and therefore widely used many other developed countries, especially in Japan and United States of America. This model type is developed consistent with microeconomic theory and welfare measurement in traditional cost benefit analysis. It provides a flexible customization in practical application.

For developing countries, where the urbanization and economic development taking place with high growth rate, the transportation infrastructure also have been expected to develop with the same pace so that it can sastify the increasingly transportation demand. A CUE framework formulation for evaluating the welfare effects of transport infrastructure investment is perfect solution.

4.2 Structure of Computable Urban Economy Model

Before going to model formulation, it is very important to clarify some main hypotheses and assumptions based on the the model can be analyzed. At first, we limit the model in a *closed framework* where only socioeconomic activities taking place inside ZM small zones, which are appropriately subdivided from study region, are considered. The trade between study region and rest of the world is assumed to be absent. Secondly, we suppose that only retail and service sectors in the region economy are considered. Thirdly, we assume that there are only two types of stakeholders, *consumer* and *producer*, to be officially considered in the model. All unemployees and other non-worker inhabitants residing in study region are out of model consideration. There are also other players *landlord* and *transporter* but they are implicitly introduced into the model by supposing that the monetary land rent and transportation cost equally go back to consumer's non-wage income. Finally, as in a typical computable general equilibrium model, this model is developed relied on the two basic economic principles: optimization and equilibrium. Therefore, a trivial but very important hypothesis should be implicitly postulated is that all stakeholders or players under model consideration would behave as *rational decision makers*. It means all players or stakeholders in the model would make socioeconomic activities so that they can maximize their utility or benefit. With these in mind, the players' behaviors are economically constructed in following subsections.

4.2.1 Consumers' Behavior

The consumers, who are also assumed to be potential workers contributing their labor time to regional production, are going to facing with a simultaneous discrete and continueous choices in order to maximize their utitlity. The choice mechanism can be broken down into two consequent stages: 1) at first, the consumer will randomly choose a discrete zonal bundle (i, j) of study region as the places of residence and workplace, respectively; and then, 2) with the given join location choice (i, j), he will decide the amount of retail commodity, land and leisure time to be consumed, in a period of time, to attain the maximum sastisfaction under the budget constraints. The simultaneous discrete-continous choice behavior of each consumer is formulated as a mathematic optimization problem as follows:

$$\max_{\forall Z_z, b, E} U_{ij} = \alpha \ln \left(\sum_{\forall z} \iota_{z|i} \left(Z_{z|ij} \right)^{\eta} \right)^{\frac{1}{\eta}} + \beta \ln b_{ij} + \gamma \ln E_{ij} + WRA_{ij} + \epsilon_{ij} \tag{4.1}$$

subject to

$$\sum_{\forall z} (p_z + a_{ij} g_{iz}) Z_{z|ij} + b_{ij} R_i + dg_{ij} = \left(H - E_{ij} - dG_{ij} - \sum_{\forall z} a_{ij} Z_{z|ij} G_{iz} \right) w_j + M \tag{1a}$$

and $$H - E_{ij} - dG_{ij} - \sum_{\forall z} a_{ij} Z_{z|ij} G_{iz} \geq 0. \tag{1b}$$

In (4.1) U_{ij} is defined as a random utility function which numerically measures the sastisfaction of a consumer who selects zone i to live in and zone j to work for. The systematic or deterministic part of this function is treated as a common Cobb-Douglas form, with the coeficients α, β, $\gamma > 0$, $\alpha + \beta + \gamma = 1$, describing the distribution of disposable income spending on all retail commodity $\sum_{\forall z} Z_{z|ij}$, land b_{ij} and leisure time E_{ij}, respectively. The subutility on all retail commodities is constructed by utilizing the Armington [9] hypothesis[1] and incorporated in the general utility function in terms of nested C.E.S preference structure with $1/(1 - \eta)$, $0 < \eta < 1$, being the elasticity of substitution between any two shopping places where a consumer can go for retail purchasing. The coeficients $\iota_{z|ij}$ introduced into the subutility function to reflect the *shopping inherent attractiveness* of zone z with respect to consumers choosing residence-workplace zones (i, j).

The *residence-workplace inherent attractiveness* constants, $WRA_{ij} \in (-\infty, +\infty)$, are defined as zonal aggregate utility of all other attractive characteristics of residence-workplace join location choice (i, j), to be perceivable accrossing all consumers living and working in study region. To clearly explain the meaning of this term, we can refer to Anas' approach [7], with an active meaning. Suppose tht at very beginning state, a consumer is assumed to face a perfect list of ZM^2 residence-workplace (i, j) choice set where any choice would offer the same utility level. The aggregate utility of all other factors, which are also *common to all consumers* and be effective to consumer's decision making process but not explicitly introduced in utility function, such as green environment, availability of water supply, educational and health care system, . . . now represented in one value of WRA_{ij}. In this case, consequently, which residence-workplace (i, j) choice bundle having highest WRA_{ij} comparing to the all others should be the best option for the consumer. There is another approach mentioned by Morisugi and Ohno [26], with a little passive meaning that a consumer who have already selected (i, j) for residence-workplace. In a certain circumstance, the socioeconomic condition was changed, then suppose there is a motivation that changing his original choice set (i, j) to any other arbitrary choice set, say (m, n), will make him better off. Then, the WRA_{ij} would play as a *threshold*, which can be perceived as aggregate deterrence such as bother of relocating, residential attachments, . . . that the benefit of socioeconomic change has to fill up to stimulate the consumer making a real action of change of his original location choice. From any of the two approaches, active or passive, the introducing of WRA_{ij} constant into the systematic part of utility function is very intuitive, appropriate and meaningful in the sense that it help the model explaining the real decision making better.

The random part of utility function, denoted by ϵ_{ij} term, is to reflect the dispersion of residence-workplace choice behavior accrossing all consumers residing in study region.

[1] Armington assumed that all commodities with the same name but produced in different places are considered imperfect substitutions

In order to clearly distinguish in definition between WRA_{ij} and ϵ_{ij}, we should think of the latter term, ϵ_{ij}, as the heterogeneity in perception and/or evaluation by each consumer, privately, with respect to the exist characteristics of each choice set (i, j). In this paper, the term is treated as an i.i.d Gumbel distribution accross to all consumers living in study region, with the dispersion coeficient λ.

Let's consider the budget constraint equations. The first condition (1a) we assume that total consumer's expenditure equal to total disposable income he or she can earn. The left side represents total expenditure on all retail goods, land, leisure time consumption and also total monetary cost paid for all commuting round trips between home and workplace in a considered time period. The right side shows the total disposable income comprising wage income that each consumer can earn by selling their time endowment on the labor market at any model zone and all other non-wage incomes coming from average land rent and monetary transportation cost. The second condition (1b) is simply to ensure that the sum of time for leisure and travel time for both commuting and shopping trips is less than consumer's time endowment. The notations used in this part are defined in a considered time period as follows: p_z is the price of an aggregate unit of retail commodity sold in zone z; a_{ij} are the number of trips necessary to buy a unit of aggregate retail good; R_i is residential land rent price per one square meter in zone i; w_j is the hourly wage-rate paid for a worker employed in zone j; H is total time endowment of each consumer; d is the number of working days; M is the average monetary nonwage-income, equally distributed to all consumers/workers living in study region; g_{ij} and G_{ij} are expected monetary travel cost and travel time for the round trip between any two zones i and j. In order to derive the mathematic maximization solutions in a more convenient way, the budget constraint is rearranged as follows:

$$\sum_{\forall z} \left[p_z + a_{ij}\left(g_{iz} + w_j G_{iz}\right)\right] Z_{z|ij} + bR_i + w_j E_{ij} = (H - dG_{ij})w_j - dg_{ij} + M. \quad (4.2)$$

Let denote the *full price* that a consumer living in zone i and working in zone j has to face for purchasing one aggregate unit of retail good sold in zone z by:

$$\psi_{z|ij} \equiv p_z + a_{ij}\left(g_{iz} + w_j G_{iz}\right), \quad (4.3)$$

and the disposable *full income* by:

$$\Psi_{ij} \equiv (H - dG_{ij})w_j - dg_{ij} + M. \quad (4.4)$$

By solving mathematic optimization problem in traditional way, the consumer's demands on the amount of aggregate retail, residential land size area and leisure time can be demonstrated in terms of the Marshallian functions as following, respectively:

$$Z_{z|ij} = \frac{\iota_{z|i}^{\frac{1}{1-\eta}} \psi_{z|ij}^{\frac{1}{\eta-1}}}{\sum_{\forall s} \iota_{s|i}^{\frac{1}{1-\eta}} \psi_{s|ij}^{\frac{\eta}{\eta-1}}} \alpha \Psi_{ij}, \tag{4.5}$$

$$b_{ij} = \beta \frac{\Psi_{ij}}{R_i}, \tag{4.6}$$

$$E_{ij} = \gamma \frac{\Psi_{ij}}{w_i}. \tag{4.7}$$

Based on these optimized solutions, the time available for working at zone j of an employee living in zone i can be estimated as follows:

$$H_{ij} = H - E_{ij} - dG_{ij} - \sum_{\forall z} a_{ij} Z_{z|ij} G_{iz} \geq 0. \tag{4.8}$$

The utility now can be expressed in terms of indirect utility function by replacing (4.5), (4.6), (4.7) into the utility function (4.1) as follows:

$$U_{ij}^* = \ln \Psi_{ij} - \beta \ln R_i - \alpha \frac{(\eta - 1)}{\eta} \ln \left(\sum_{\forall z} \psi_{z|ij}^{\frac{\eta}{\eta-1}} \right) - \gamma \ln E_{ij} + WRA_{ij} + \epsilon_{ij}. \tag{4.9}$$

With the assumption on the distribution of ϵ_{ij}, the probability that a consumer or worker chooses the discrete bundle of residence-workplace (i, j) is expressed in terms of multinominal logit choice as follows:

$$P_{ij} = \frac{\exp\left(\lambda U_{ij}^*\right)}{\sum_{\forall (s,t)} \exp\left(\lambda U_{st}^*\right)} \quad \text{with} \quad \sum_{\forall (i,j)} P_{ij} = 1. \tag{4.10}$$

The expected maximized utility or average welfare level that a consumer living in study region can enjoy is evaluated as following expression:

$$W = E(U_{ij}^*) = \frac{1}{\lambda} \ln \sum_{\forall i,j} \exp(\lambda U_{ij}^*). \tag{4.11}$$

4.2.2 Producers' Behavior

As stated in foregoing assumptions, the producers or firms play the role of retailers, who supply all retail commodity or service to meet the iternal final demand from all consumers residing in study region. All firms doing their business in a model zone are represented by a zonal producer who only use labor time L_j and land area S_j for production. In the model, zonal production function is replicated by Cobb-Douglas technology with constant returns to scale as follows:

$$X_j = A_j L_j^{\delta} S_j^{\mu}, \tag{4.12}$$

where X_j is total output of production in zone j. The coefficients δ, $\mu > 0$, $\delta + \mu = 1$ are the cost shares of production input factors, respectively. A_j is zonal productivity, varying among model zones.

With given output X_j at each zone, the zonal production function can be easily transformed into a cost minimization problem as follows:

$$\min_{L,S} C_j = w_j L_j + R_j S_j, \tag{4.13}$$

in that, C_j is generalized production cost that producer has to face off if average hourly wage rate and land rental price per square meter paid for employee and landlord are w_j and R_j, respectively.

The repretative zonal producers are supposed to be perfectly competitive in all input, output markets, and making zero profit at any level of production, the conditional demand function of input factors at any production zone j are represented as follows:

$$L_j^* = \frac{\delta}{w_j} p_j X_j \tag{4.14}$$

$$S_j^* = \frac{\mu}{R_j} p_j X_j \tag{4.15}$$

Replacing (4.14) and (4.15) into (4.13) and considering the zero profit condition of production, the output price produced in zone j can be expressed as following equation:

$$p_j = \frac{w_j^{\delta} R_j^{\mu}}{A_j \delta^{\delta} \mu^{\mu}} \tag{4.16}$$

4.3 General Equilibrium of Urban Economy

In this step, all considered markets are combined and simultaneously solved by put into a general equilibrium framework to represent the urban economy at balance condition. In that state, all markets under model consideration are cleared, all N consumers residing in study region will attain the maximum sastisfaction with their discrete and continuous choice sets, all firms can minimize their generalized production cost with output prices perfectly cover for all input factors.

4.3.1 Non-wage Income

As mentioned in foregoing sections, the non-wage income is equally distributed accross all consumers residing in study region and come from two sources: land rent and monetary of transport expenditure. It is estimated by following equation:

$$M = \frac{\sum\limits_{\forall(i)} R_i Q_i}{N} + \left(d \sum_{\forall i,j} P_{ij} g_{ij} + g_{ij} \sum_{s=1}^{ZA} P_{is} c_{is} Z_{j|is} \right). \tag{4.17}$$

4.3.2 Commodity Market

Total amount of retail commodity and service produced in any model zone i will be cleared by the aggregate final demand of all consumers living in all zone who choose that zone as prefered shopping place. There are ZM such equations:

$$N \sum_{\forall(n,s)} Z_{i|ns} P_{ns} = X_i. \tag{4.18}$$

4.3.3 Land Market

In land market, the aggregate demand with respect to land for residence and production must be equal to the total land resource for that purposes in any model zone i. There are ZM such equations:

$$N \sum_{\forall j} P_{ij} b_{ij} + S_i = Q_i. \tag{4.19}$$

4.3.4 Labor Market

The total amount of labor hours demanded for production in zone j must be equal to total labor time that workers residing in any model zone but employed at that zone. There are ZM such equations:

$$L_j = N \sum_{\forall i} \left(H - dG_{ij} - a_{ij} \sum_{\forall z} G_{iz} Z_{z|ij} \right) P_{ij}. \tag{4.20}$$

4.4 Transportation

One of the most indirect desired result can be derived from urban economy at the equilibrium state is the stable *travel pattern* iternally generated inside the study region. According to assumptions and settings stated in the model, suppose that we just consider the *home-based round trips* for commuting and shopping purposes, and also assume that these trips taking place at the same time of day, the restraint travel pattern can be represented in terms of traditional origin-destination or OD matrix as follows:

$$^{CS}T_{ij} = (NP_{ij}) + \left(\frac{1}{d}\right)\left(N\sum_{s=1}^{ZA} P_{is}c_{is}Z_{j|is}\right). \tag{4.21}$$

As we can see, oviously, the urban economy model will play the role of the first step, *trip generation*, in traditional transportation planning. Of course it is not total travel demand generated in the study region. Trips for other purposes such as business, school, send/pick-up ... and *touch-and-go* trips should be taken into account to reflect the real traffic demand. In that sense, the total travel demand of study region can be expressed as follows:

$$T_{ij} = {}^{CS}T_{ij} + {}^{NR}T_{ij}, \tag{4.22}$$

where T_{ij} is total trips occurred in study region and $^{NR}T_{ij}$ is total *non-retraint* trips as stated before.

Now we turn to analyze the linkage between transportation and urban economy. As we can see in (4.2.1), the capacity and quality of study area's transportation infrastructure system enters the urban economy through *generalized travel cost*, which represented by travel cost and travel time matrices between model zones. Therefore, the target of this part is used to estimate or updat these matrices with congestion in real time. In order to do this task, a mode choice model should be formulated and traffic assignment should implemented in next subsections.

4.4.1 Mode Choice Model

We start to construct the mode choice model with definition of the generalized cost function as follows:

$$c_{ij}^k = \tau m_{ij}^k + \zeta t_{ij}^k, \tag{4.23}$$

in that, m_{ij}^k and t_{ij}^k are one-way travel cost in terms of monetary, and travel time, hours, between zone i and zone j by mode k. τ and ζ are two coefficients, respectively and the τ/ζ should be perceived as *value of time* and assumed to be uniform across all traveler. By defining $C_{ij}^k = c_{ij}^k + c_{ji}^k$ is expected round trip generalized costs of travel per person by mode k from zone i to zone j, a traveler's sub-utility expressed as follows:

$$V_{ij}^k = C_{ij}^k + MA_{ij}^k + \xi_{ij}^k, \tag{4.24}$$

in that, V_{ij}^k is utility of a traveler who want to make a round trip between zone i to zone j by mode k. MA_{ij}^k are the *mode-specific* constants of mode k for traveling between zone i and zone j, common to all traveller, measuring the other attractiveness different from travel cost and travel time. ξ_{ij}^k are defined as i.i.d. Gumbel idiosyncratic constants which vary across travellers with respect to selecting mode k for trips between zone i and zone j.

Now we define the modal choice set. The universal modal choice set is comprised six modes which may usually operate in urban transportation network, namely Motorcycle ($k = 1$), Car ($k = 2$), Bus ($k = 3$), Bike ($k = 4$) and Mass Rapid Transit (MRT) ($k = 5$). The probabilities of selecting mode k for the trip between zone i and zone j are defined by multinominal logit probability expression as follows:

$$\omega_{ij}^k = \frac{\kappa_{ij}^k \exp(V_{ij}^k + MA_{ij}^k)}{\sum_{n=1}^{5} \kappa_{ij}^n \exp\left(V_{ij}^n + MA_{ij}^n\right)}, \tag{4.25}$$

in that, κ_{ij}^k are the indicator variables, receives only two values 0 and 1. $\kappa_{ij}^k = 1$ means that the mode k is available in the traveler's choice set, otherwise, $\kappa_{ij}^k = 0$. The probability ω_{ij}^k can be derived by using the *maximum likelihood method*[2] to estimate τ, ζ and MA_{ij}^k.

4.4.2 Congestion and Traffic Assignment

Applying the mode choice model in section 4.4.1, the traffic demand by purposes are translated into traffic flows by each modes. In order to derive the generalized cost matrix between model zones, a standard stochastic traffic assignment performing these traffic flows on the real transportation infrastructure network is needed. As we know, with respect to mass transit system, the capacity as well as management are usually at very high level, therefore, we can assume that there is no traffic congestion in non-road

[2]The maximum likelihood methodology can be easily found in any statistics document. But for the case of mode choice model, it is convenient to refer to [10] or [41]

network, therefore the travel time and cost matrices are fixed for such kind of network, for example MRT. In the same manner, we can extend to some modals such as Walk or Bycicle or even Bus with seperated line. Adversely, all other modes, especially travel modes operating on road network, we can only estimate the real generalized travel cost with congestion by transforming into standard travel mean unit and assigned on the infrastructure network on which they are operating.

Finally, the expected generalized travel cost, expressed in terms of travel time and cost matrices among model zones, can be estimated as follows:

$$G_{ij} = \sum_{k=1}^{5} \omega_{ij}^{k} \left(t_{ij}^{k} + t_{ji}^{k} \right), \tag{4.26}$$

$$g_{ij} = \sum_{k=1}^{5} \omega_{ij}^{k} \left(m_{ij}^{k} + m_{ji}^{k} \right). \tag{4.27}$$

4.5 Programming Algorithm

4.5.1 Calculation

One of the most important task to make the model become useful in practical application is how to derive the model solution at the general equilibrium state. The general algorithm for this task is presented in Figure 4.1. The process can be broke down into two stages:

- At first, the urban economy represented by land market, labor market, commodity market will be solved by adjusting the endogenous variables land rent (R), wage rate (w) and retail price (p), with given travel time (G) and travel cost (g). At equilibrium state, accompany with set of output variables, the spatial employment and shopping pattern are also derived in terms of OD matrices. These can be seen as an important important segment of the travel demand in transportation market.
- From the spatial distribution of employees and spatial shopping patterns obtained in previous stage, the commuting and shopping trip patterns can be defined. Other trip patterns should be taken into account to make up the total travel demand of the city. In next step, the total travel demand will be translated to ODs by travel modes, by utilizing the mode choice model. And then, these ODs will be brought into the traffic assignment process. The feedback from transportation market,

also at equilibrium state, represented by the expected time and cost for traveling among model zones will be with correspondence values given in previous stage (G, g). If the difference between them are small enough, the model is converged and the calculation process can be stopped and all variables outputted from the model will represent for the city at equilibrium state. Otherwise, the calculation should be continued by going back to stage one, with the new (G, g) replacing for the old one values until the model converged.

4.5.2 Programming Algorithm

At first, it is useful to discussion on traffic assignment. In order to take into account the traffic congestion occurring on the *real* transportation infrastructure network, a traffic assignment should be performed. The point is to take into account the effect in generalized travel cost (G, g). It would be very convenient if this task can be integrated in the model as proposed by Anas and Liu [7]. However, with limited time and other resources, we will focus on the equilibrium treatment for land, labor and commodity markets, and utilize other professional software/package with standard user equilibrium algorithm for transportation side.

The core of calculation process is to find out the solution of the nonlinear system equations formulated in Section 4.3. In this paper, we propose the Newton-Raphson method with "Line seach" algorithm [19]. The programming algorithm based on this methodology with "Fortran95" has performed well and quickly in practical calculation. The detail of programming design based on this method is presented in Appendix A of this document.

4.6 Summary and Conclusions

This chapter has formulated a mathematic form of a CUE model. The behavior of economic agents has been decribed by utility/profit maximization equations which are consistent with microeconomic theory. The final outcome of the model simulation will be a set of endogenous variables representing urban economy at equilibrium state. The employment, land use patterns and all prices will be endogenously generated from model simulation. The welfare measure from indirect utility function is also consistent with traditional cost-benefit analysis. The expected cost and time for traveling among model zones are outputed from equilibrium state of transportation system.

Although the model is developed mainly for evaluating the economic benefit of transportation infrastructure development, it can also be widely used for other relative issues of urban planning and management.

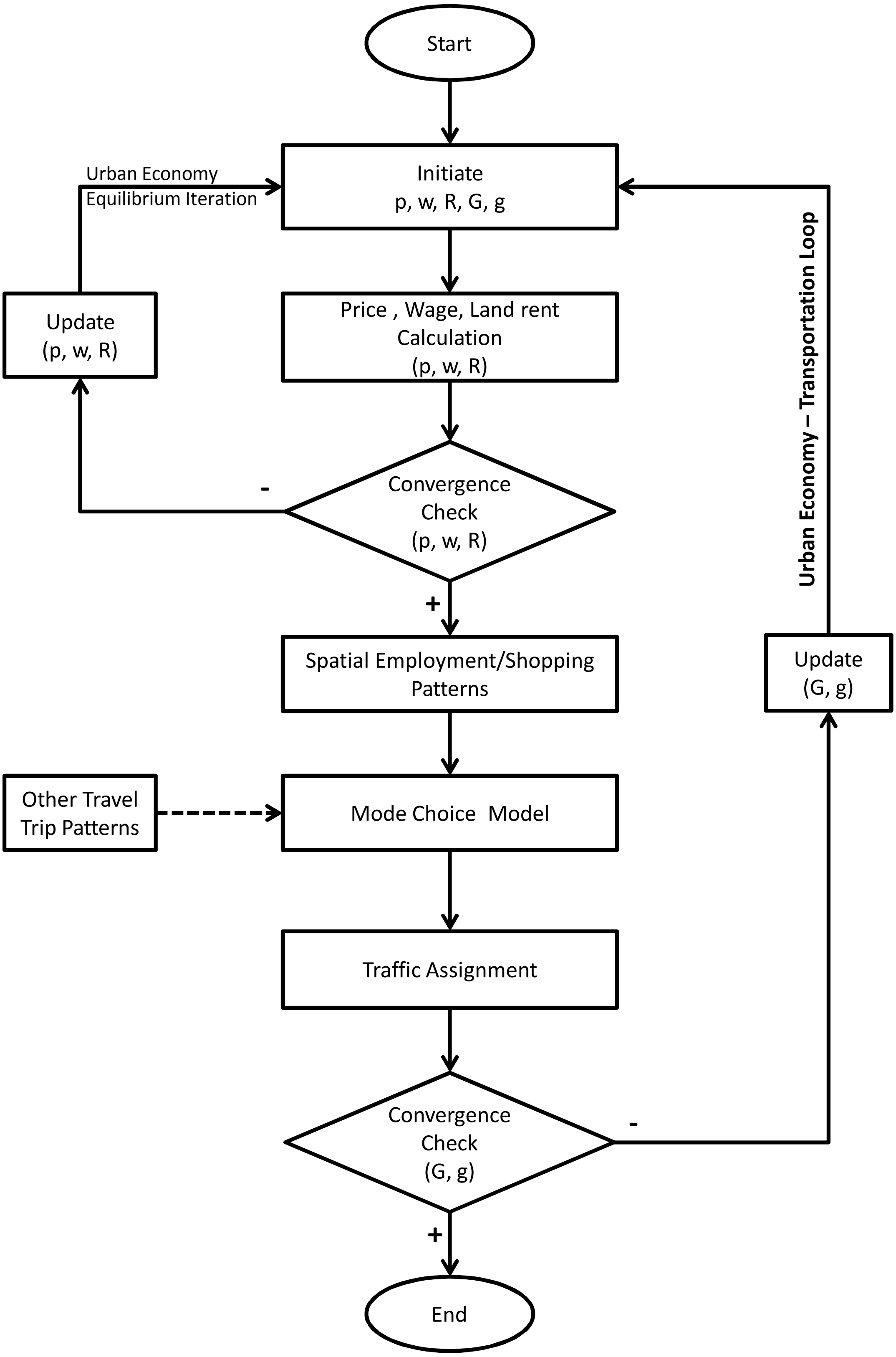


FIGURE 4.1: Programming Algorithm for CUE Model.

Chapter 5

Benchmark CUE Model for Hanoi Case Study

5.1 Introduction

In a review of state of the art of Land use Transport models, Wegener [49] have roughly defined the "operational" models that "they have been implemented, calibrated and used for policy analysis for at least one metropolitan region." The main purpose of this chapter is to turn the theoritical structure developed Chapter 4 into an real "operational" model. The chapter is also designed in a way so that readers can understant how to estimate a CUE model from very beginning step of input database preparation to calibration.

As stated in the chapter title, the selected case study region for simulation is the *Old Hanoi Capital City*[1], with database in the year of 2005. In the first part of this chapter, we will present in general what type of data sets need for CUE model and how the available Hanoi data to be arranged as the input database for the CUE model simulation. In second part, the main model's parameters of Hanoi' economy are estimated based on available Hanoi database extracted in the first part, and also from the other sources. In third part, we analyze civilians travel behavior and evaluate the performance of Hanoi transportation system at that time. In forth part, a calibration process is implemented to estimate a benchmark model for Hanoi case study region with available data and simulation result evaluation.

[1] In this Chapter, Hanoi is mentioned as the Old Hanoi Capital City, before the 2008 expansion

5.2 Data Requirement and Arrangement for Hanoi CUE Model

5.2.1 Input Data Required for CUE Model Estimation

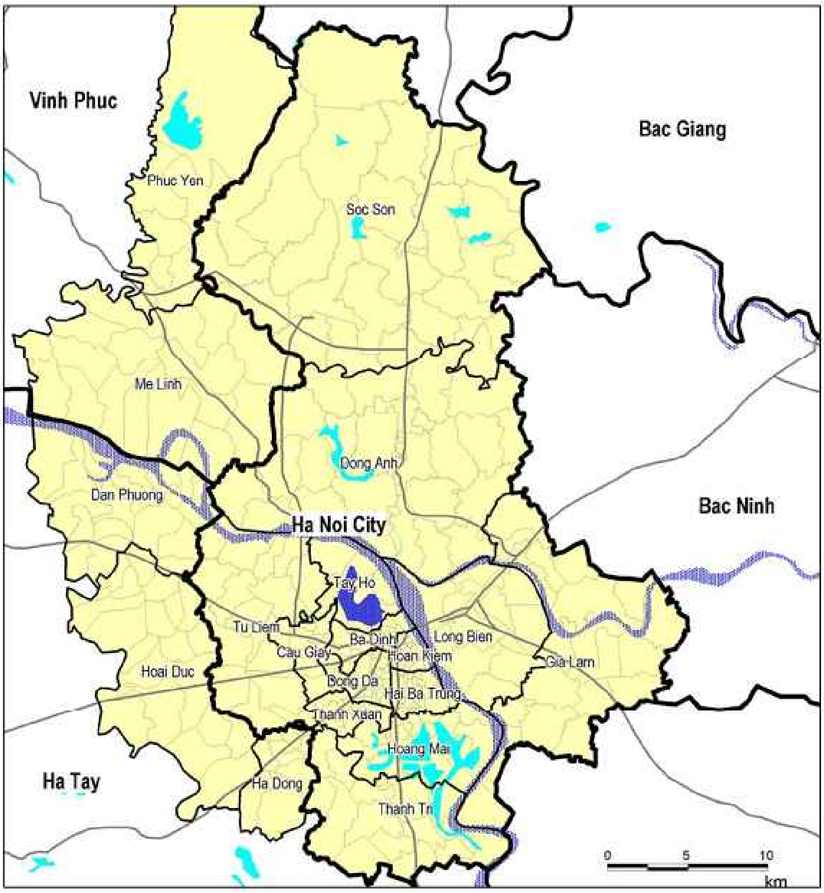
In general, a CUE model is a very flexible and powerful tool for urban policy analysis. It can be customized to meet the desired objectives that modeler aimed at. Therefore, the comprehensive levels and types of input data sets required are also different case by case in application. However, since this kind of model is formulated based on the interaction between transportation and spatial development or land use of urban areas, then land-use, employment and population structure, civilian travel behavior and transportation infrastructure system are the most important input data sets for simulation. In addition, other type of database such as regional economic accounts, logistics data,... will offer a modeler many options in formulating a more comprehensive and/or sound model and also useful for calibration. In next part, we will present what Hanoi's data sets we have at hand and how they are treated and arranged to use as input database for CUE model estimation.

5.2.2 Hanoi's Data Availability

The most important data sets we have for model simulation are *Person Trip*[2] and *Land-Use* data of Hanoi conducted in 2005 for HAIDEP project [15]. For the first type of database, the PT data for short, the surveyed study region included Hanoi city (14 districts, 921 km^2), and adjacent districts, namely Ha Dong, Dan Phuong, and Hoai Duc of Ha Tay Province, and Me Linh and Phuc Yen[3] of Vinh Phuc Province (5 districts, 450 km^2). In the survey, the study region was comprised 301 *traffic zones*, included 228 of Hanoi and 73 of adjacent area, based on administrative boundaries by *ward* for urban areas and *commune* for suburban and rural areas. There are 20,020 household, estimated to be 2.15% of total household in 2005, were interviewed to record the inhabitants' travel behavior and habit in a typical working day and other items of households' information for Hanoi urban strategic development research. The main contents of database include surveyed household information, household member information, and daily activity information or trips information of every household member.

[2]In this Chapter, the PT means Person Trip Survey data of Hanoi, conducted in 2005

[3]Me Linh District was divided into Phuc Yen and Me Linh in 2004



Note) Source Technical Report No.1, HAIDEP Project.

Figure 5.1: Study area for Household Interview Survey in HAIDEP.

Regarding to the second type of data set, Land-use, there are 21 types of land, classified by the purposes of use. It is available for 228 ward/commune or 14 districts of Hanoi city.

Beside these two above database, for transportation infrastructure system, database of road network of Hanoi and the related adjacent areas of PT surveyed, in the year of 2005, is also available. It was comprised by 2,712 links and 2014 nodes with full information of links such as maximum capacity, distance, limit velocity . . . There are many changes in Hanoi road network from that time to present time but new type of public transit has not introduced.

5.2.3 Zone System for Hanoi CUE Model and Data Arrangement for Simulation

Before going to apply the CUE model for a particular region, a natural question may raise that how we define a *model zone*. Consequently, the first issue we have to cope with is that how we divide the study region into smaller zones. In principle, a modeler can freely select a zone system as long as the simulation results based on that system fitting well with the current socioeconomic condition of that area. As we can see, for CUE model, the desirable target that a modeler want to achieve is not only the accuracy in travel pattern but regional economic variables represented for urban economy. According to general transportation planning theory, for daily urban travel demand, the more detail or smaller in zoning task, the better result we get from simulation. On the contrary, for urban economy simulation, the larger zoning the more accuracy macroeconomic indicators we can get.

Let look at the 2005 Hanoi PT data we have at hand, the *traffic zones* are defined as wards or communes, following the lowest official administrative boundary level in Vietnam. Of course, this zone system is good for simulating the traffic condition, but for CUE simulation, traffic zones seem quite small to be an *economy* and therefore they are not much appropriate for transport-economic model like CUE. For these reasons, the mediate administrative zone system based on district administrative boundary is proposed for this case study and zone system for Hanoi CUE model defined by 14 zones, which are also to be 14 districts of Hanoi administrative system.

5.2.4 Travel Behavior and Relative Spatial Economic Activities

As we know, the transport activity is *derived demand* [31], and therefore, except some very special cases, a trip from point A to point B could reveal a *purpose* of which traveler want to obtain beyond that activity. From practical point of view, the information contained in PT data is very useful because it reveal the *travel patterns* of inhabitants living in study region, which will indirectly reveal the regional economic activities. Obviously, for the CUE model application case, *commuting* and *shopping* travel patterns are most desirable since they can represent for the employment and retail/service consumption patterns of regional economy.

Before going to derive these travel patterns, in order to ensure the consistency for model simulation from data preparation step to result analysis, it is very important to assume that *the PT data perfectly refects not only the real traffic condition but also socioeconomic indicators such as population, employment distributions . . . of Hanoi at the survey time.* Based on this assumption, travel patterns are estimated from PT data as in following sections.

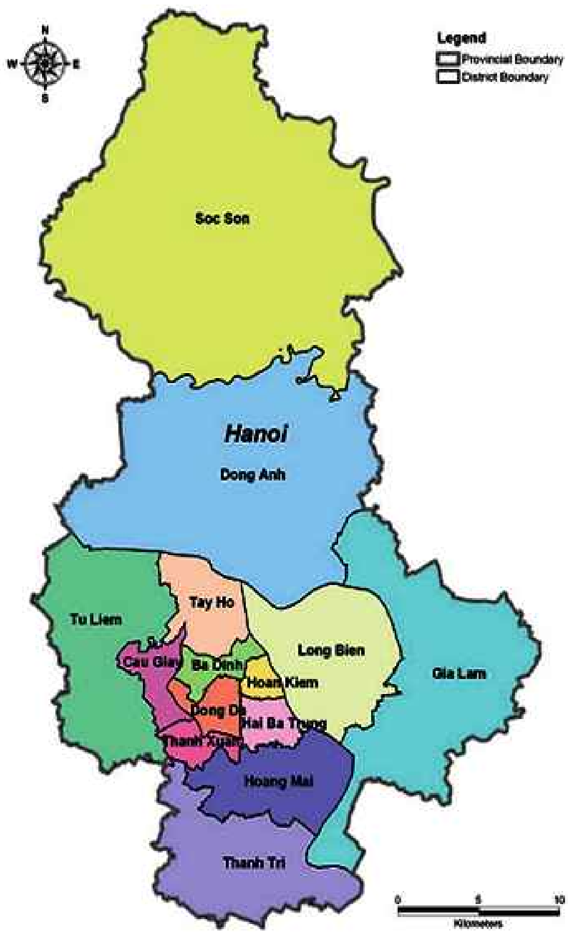


FIGURE 5.2: Hanoi Zone System for CUE Modeling.

5.2.4.1 Spatial Employment Pattern

The employment pattern for CUE simulation is assumed to be represented by the commuting trips in study region in a typical working day. In order to extract the these trips from PT data, there are some assumptions as follows:

- Only the employee who making trip is identified as a valid worker.
- Each employee will make only one round trip between residential zone i to working zone j (home-workplace-home) in a typical working day.
- The origin of *To Work* purpose trip must be the valid home zone.
- The destination of *To Work* purpose trip must be the valid workplace address.

The Employment Pattern of Hanoi study region in 2005 formulated based on PT data is shown in Table 5.1.

Table 5.1: Trip Purpose, Hanoi PT Survey 2005.

2005 Hanoi PT data		**Travel Patterns**	
No.	**Trip Purpose**	**Commuting**	**Shopping**
1	To Home		
2	To Work	O	
3	To School		
4	At Work/Business		
5	To Send/Pick-up other family member or friend		
6	To go Shopping/Market		O
7	To Eat (not at home)		O
8	To have an exercise		O
9	Joy riding		O
10	Social/Recreation/Religious		O
11	Other private purpose		O

Note) Hanoi PT data in 2005, Questioniare Forms.

TABLE 5.2: Spatial Employment Pattern of Hanoi, 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	$\sum$ **S**
1	21,438	3,013	13,575	7,107	11,867	4,189	4,103	1,386	1,835	679	240	1,683	721	239	72,075
2	5,669	7,960	4,986	3,107	3,701	1,375	1,994	505	747	222	177	852	341	156	31,792
3	5,874	1,417	17,756	7,097	6,112	1,494	2,128	832	1,136	170	134	591	62	317	45,120
4	8,245	2,083	17,275	34,637	10,305	4,542	3,463	4,304	1,874	390	240	961	781	386	89,486
5	12,916	1,852	20,635	14,114	30,750	8,065	4,966	2,334	1,979	475	192	1,924	725	333	101,260
6	5,409	1,056	6,488	6,306	10,231	19,010	2,680	1,868	985	201	150	1,132	731	201	56,448
7	7,035	1,422	6,481	3,826	7,698	3,156	15,051	732	1,074	292	245	3,629	147	150	50,938
8	3,309	982	8,606	12,699	5,917	4,016	1,220	18,660	1,026	344	99	1,212	2,033	147	60,270
9	2,025	873	5,108	2,895	2,751	1,062	723	289	34,109	1,019	535	438	191	2,322	54,340
10	375	95	140	46	190	47	94	-	94	92,700	1,698	188	-	93	95,760
11	715	473	996	622	768	430	433	47	1,233	810	57,372	717	95	619	65,330
12	4,341	1,578	3,402	1,724	3,790	3,158	5,410	394	933	296	543	36,271	345	197	62,382
13	1,339	336	1,615	3,877	2,984	2,426	382	4,167	428	47	47	521	25,564	94	43,827
14	1,043	425	2,712	1,232	891	189	285	379	11,239	234	707	282	237	47,523	67,378
$\sum$ **D**	79,733	23,565	109,775	99,289	97,955	53,159	42,932	35,897	58,692	97,879	62,379	50,401	31,973	52,777	*896,406*

Note) Estimated from Hanoi's PT data 2005, HAIDEP.

5.2.4.2 Spatial Shopping Pattern

In order to obtain the "shopping pattern" of inhabitants living in the study area, we embark on PT data analysis with spect to the trip pattern for "shopping" purpose. There are some primitive assumptions are set as follows:

- All trips from any model zone to the model zone j with one of the purposes namely *To go Shopping/Market*, *To Eat (not at home)*, *To have an exercise*, *Joy riding*, *Social/Recreation/Religious* and , *Other private purposes* would be counted as the number of aggregate commodities sold in zone j. From now on, we define these types of trip purpose as *To go Shopping* and it can be perceived as going to purchase any type of physical retail commodities or services such as foods (grocery), PC (electronic shopping mall), go eating out (at restaurant), recreation (at theatre), social (at clinic/hospital for health check, at ward office residential issues).
- A Shopping trip is a round trip from home to shopping place and go back to home (home-shopping place-home)
- In one shopping trip, only one aggregated commodity is purchased: 1 aggregated commodity/1 shopping trip.
- The number of shopping-trip made by consumer, in a day, depends on and budget and time endowment constrains.

Based on these foregoing assumptions, a data processing task is conducted to count the number of trips with widespread meaning "shopping" purpose among study zones. The OD matrix representing this travel pattern is defined as Shopping Pattern for Hanoi City in 2005 shown in Table 5.2.

Table 5.3: Spatial Retail Consumption Pattern of Hanoi, 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	$\sum$ **S**
1	55,762	5,458	13,769	5,384	6,264	1,217	2,060	916	2,630	3	4	1,191	90	262	95,010
2	9,997	42,806	7,670	3,323	2,362	780	2,256	362	398	79	2	718	-	198	70,951
3	10,566	1,610	47,313	5,514	5,761	715	2,548	684	990	74	44	1,425	259	370	77,873
4	8,135	2,033	14,488	95,872	9,897	3,752	3,368	4,248	943	304	9	1,338	450	250	145,087
5	15,839	1,870	31,428	25,357	89,522	4,662	4,759	1,709	4,147	238	1	1,333	766	1,247	182,878
6	3,726	648	8,867	10,291	11,154	49,450	1,877	5,165	2,058	2	403	1,096	885	804	96,426
7	6,453	2,748	7,428	3,171	4,946	1,426	49,148	645	1,090	1	1	2,051	45	-	79,153
8	3,649	1,275	5,750	11,124	6,444	3,026	1,970	43,894	652	1	1,471	314	4,250	203	84,023
9	3,463	1,370	6,047	1,460	3,976	972	576	83	61,524	339	2,185	270	165	1,860	84,290
10	4	-	494	391	2	-	161	-	1,456	52,910	1,383	49	-	47	56,897
11	538	55	1,826	1,015	147	1	211	38	1,218	969	99,289	160	-	2,434	107,901
12	3,565	1,864	5,881	1,324	3,054	1,485	9,096	209	1,415	3	6	68,117	194	229	96,442
13	933	49	2,244	2,142	1,465	1,307	391	1,314	202	-	-	98	33,688	-	43,833
14	2,041	27	1,563	481	639	188	326	542	5,241	223	1,056	-	206	64,196	76,729
$\sum$ **S**	124,671	61,813	154,768	166,849	145,633	68,981	78,747	59,809	83,964	55,146	105,854	78,160	40,998	72,100	*1,297,493*

Note) Estimated from Hanoi's PT data 2005, HAIDEP.

TABLE 5.4: Land-use Pattern for Model Simulation.

Land-use data category by purposes	**Model Land-use Pattern**	
	Residence	**Production**
Commercial and business		O
Education and cultural		
Forest for production		
Government and quasi-public		O
Health and welfare		O
Industrial park/estate		
Industrial(mixed)		
Mixed residential and commercial land	O	O
Other forest		
Park and recreational		O
Religious and cemetery		
Rice field and other agricultural land		
Rural residential land	O	
Security and military		
Transport and service area		
Unused flat land		
Unused mountain land		
Urban residential land	O	
Urban service facilities		
Use for fishery cultivation		
Water surface		

Note) Estimated from Hanoi Land-use data in 2005, HAIDEP.

5.2.5 Land-use Data and Land Patterns for Simulation

According to CUE framework proposed in Chapter 4, there are two types of land-use patterns to be considered as the input for the model: land for *residence* and for retail/service *production*. In order to ensure the unification between the land-use data prepared for simulation and the assumptions for residential and production patterns stated in foregoing sections, each type of land classified by purpose in the statistic 2005 Hanoi land-use data[4] should be considered and selected to formulate the two land-use patterns used in simulation. We propose as presented in Table 5.4. Starting with land area for zonal production, we have assumed that the output of production in the CUE model is defined as aggregate commodity represented for all types of retails and services produced in study region, consequently, the land categories used for these sectors are summed up, zone by zone, for proposed types of land. The land types used for education, agriculture, security and military, industrial production purposes are left out of the list. For residence type, it is simply the sum of all type of land used for all residential

[4]This type of data was collected also for the use in HAIDEP Project.

Table 5.5: Land-use Patterns for Residence and Production of Hanoi, 2005.

No.	Name	Residence	Production	Total
1	Ba Dinh	3,490,013.67	2,112,879.99	5,602,893.66
2	Tay Ho	5,339,795.88	708,239.49	6,048,035.37
3	Hoan Kiem	1,778,457.46	689,908.87	2,468,366.32
4	Hai Ba Trung	5,037,813.98	970,074.62	6,007,888.59
5	Dong Da	5,516,583.36	1,617,001.92	7,133,585.28
6	Thanh Xuan	4,972,865.69	295,617.47	5,268,483.16
7	Cau Giay	5,561,771.40	929,969.32	6,491,740.72
8	Hoang Mai	8,059,842.20	717,000.92	8,776,843.12
9	Long Bien	9,675,430.73	798,604.32	10,474,035.05
10	Soc Son	14,084,690.16	353,439.82	14,438,129.98
11	Dong Anh	16,404,046.09	877,343.40	17,281,389.49
12	Tu Liem	12,645,751.39	1,749,757.74	14,395,509.14
13	Thanh Tri	6,108,775.71	456,484.36	6,565,260.07
14	Gia Lam	12,352,657.69	361,929.96	12,714,587.65
Total	111,028,495.40	12,638,252.20	123,666,747.60	

Note) Prepared from Hanoi Land-use data in 2005, HAIDEP.

purposes. The land-use data prepared in terms of study zone number and purposes for the model simulation is presented in Table 5.5.

5.3 Characteristics of Hanoi's Transportation System

In CUE model framework, the urban economy is connected with urban transportation system throughout the generalized travel cost matrix, which representing for the cost that a person have to pay for moving from any original zone i to destination zone j. This cost is decomposed into monetary travel cost and travel time matrices. The travel time matrix is estimated in order to take into account the time value that a traveler has to give-up for traveling instead working or relaxing at home. This section will present how to estimate these matrices for Hanoi city with 2005 database in conventional way.

As proposed in Chapter 4, Section 4.4, in order to calculate the expected generalized cost for traveling among model zone, at first a modal split model should be estimated to calculate share of each modal in the transportation market, and then the aggregate traffic demand flow by all available modes will be assigned on the transportation network.

Regarding to travel time and monetary travel cost matrices needed to be prepared for benchmark model, we propose that the PT data have truly reflected the real condition of the city and since the ODs matrix by all modes can be extracted directly from the survey data, therefore, the former step could be skipped, only the latter step should be implemented to estimate the travel cost and travel time matrices among model zones. However, in some analyses based on the benchmark model, an iteration calculation could be necessary for attaining equilibrium state in both urban economy and transportation system simultaneously, therefore, a modal split model should be constructed in advance for any further application purpose. In consequent subsections, the calculation procedures presented in more detail for the 2005 PT data of Hanoi City.

5.3.1 Modal share estimation

The utility of traveler who want to start at zone i and terminate at zone j by travel mode k is defined by (5.1) in Chapter 4 as following:

$$V_{ij}^k = C_{ij}^k + MA_{ij}^k + \xi_{ij}^k, \tag{5.1}$$

in that $C_{ij}^k = 2c_{ij}^k = 2(\tau m_{ij}^k + \zeta t_{ij}^k)$ is generalized travel cost. Our objective is to estimate the values τ, ζ and MA_{ij}^k with PT database at hand. For the last kind of parameters, we have also assumed that, at very beginning stage, every worker can freely choose where to live and where to work, therefore, without loosing the generality and also for reducing the burden of calculation, we can just estimate MA^k of mode k for all home-workplace (i, j) choice sets.

Now we embark on parameter estimation work. The methodology selected for this task is maximumlikelihood and it should be conducted following standard consequent steps proposed by Ben-Akiva and Lerman [10]. For practical calculation, we can use any available commercial package or programming to solve by ourself. In this application, we choose Disaggregate Model, a module included in JICA Strada package, a powerful tool, developed by JICA from 1997, designed for traditional transport forecasting. In order to utilize this module for calculation, we need to conduct following steps:

- Define a universal set of modal alternatives which can be available for all travelers in study region.
- Estimate travel cost and travel time of for all valid trips going among model zones.
- Arrange the data in a standard format so that it comprises the main information of the trip: origin/destination, distance, travel cost, travel time, available travel mode, the actual mode choice for that trip.

- Statistically evaluate the estimations and decide whether these values are acceptable or not.

The universal choice set we define here comprising 4 main travel means namely Bicycle ($k = 1$), Motorcycle ($k = 2$), Auto ($k = 3$) and Bus ($k = 4$). The three first modes is consider as private and the last one is only public transit available in Hanoi at that time. The trips made by Walking and other transport service like Xe Om, a type of spread moto-taxi exist in Vietnam, and Taxi are not considered in this research. We also assume that the Hanoi bus network is accessible at any model zone and therefore available for all travelers.

Regarding to trip's cost and time, since these values appear in PT data insuffiently, then we re-estimate trip's cost based on the *average operating cost* including *average parking fee*for trip using private modes and *bus fare* policy applying in Hanoi at that time and trip's time by and *average travel speed* of each travel mean. The travel cost for private modes can be estimated by simple formular 5.2 as following:

$$tc_{ij}^k = \frac{d_{ij} VOC^k + PC^k}{OP^k}, \tag{5.2}$$

where tc_{ij}^k is monetary cost for trip from zone i to zone j; d_{ij} is distance between centroid of zone i and zone i; VOC^k, PC^k, OP^k are Vehicle Operating Cost, Parking Cost and average Occupancy of mode k, respectively. According to the transport survey conducted for HAIDEP [16], the average operating cost and other characteristics of spread travel modes in Hanoi represented in Table 5.6. At that time, the available urban public transit in Hanoi is only bus network. The bus fare is based on the length of route and shown in Table 5.7. The database for Maximumlikelihood estimation process is prepare

TABLE 5.6: Average operating cost by Private Mode, 2005.

Mode	VOC	Parking Cost	Occupancy	Travel Speed
	VND/km	VND/trip	pax/vehicle	km/h
Bicycle	74	656	1.13	8
MC	478	1,296	1.36	25
Auto	1893	7,504	2.02	30

Note) Exchange rate at 2005: 1 USD = 16,000 VND; Source: Traffic Demand Analysis, Technical Report No. 3, HAIDEP.

by eliminating all trips which is not under consideration such as: for purposes other than commuting and shopping, making by other modes (e.g. Truck), the origin/destination located outside study region . . . The result of estimation is summerized in Table 5.13. With these parameters, the modal split model has been established and now we can

TABLE 5.7: Bus fare in Hanoi, 2005

Trip length	**Fare**
km	**VND/trip**
< 25	3,000
$25 - 30$	4,000
> 30	5,000

easily calculate the mode share for travel demand among CUE model zones based on the distances among among model zones in Table 5.9. With the mode share estimated

TABLE 5.8: Estimation Results for Logit Mode-Choice Model, Hanoi PT data 2005.

Variables	**Estimates**	**Standard Error**	**t-value**	**Note**
MA^1	3.51E+00	8.82E-02	3.98E+01	Bike constant
MA^2	4.55E+00	5.79E-02	7.87E+01	MC constant
MA^3	5.12E+00	1.93E-01	2.65E+01	Auto constant
MA^4	0.00E+00	-	-	Bus constant
τ	-2.29E+00	1.27E-01	-1.80E+01	Travel time
ζ	-2.80E-04	2.28E-05	-1.23E+01	Travel cost
Summary Statistics				
Number of observations = 28,911				
$\chi^2 = 35531.63795$				
$\rho^2 = 0.86498$				
$\bar{\rho}^2 = 0.86495$				

Note) Bus constant is set by zero and goes out of estimation since in discrete choice theory, only difference in utility matter, only difference in the alternative-specific constant are relevant, not their absolute levels. In this case, the Bus constant is normalize to be zero [41].

from the modal split model prepared in this section, and travel demand generating from urban economy, we can obtain the travel demand in terms of OD matrices by modes, and then these ODs will be assigned on the real transportation network to derived the travel time and monetary travel cost matrices, which can be used as the input for urban economy.

Table 5.9: Travel Distance on Road Network among Model Zones, 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	1.767	2.382	4.997	5.862	3.718	6.766	2.526	8.394	8.745	31.212	21.041	5.799	12.942	13.305
2	2.382	2.739	7.322	8.187	6.017	8.897	3.642	10.693	10.892	28.830	18.659	6.301	15.241	15.452
3	4.997	7.322	1.294	1.743	2.779	8.336	5.725	4.724	5.665	33.407	23.236	10.057	10.183	10.225
4	5.862	8.187	1.743	1.780	2.494	7.795	5.727	3.195	7.023	34.765	24.594	10.059	8.654	11.583
5	3.718	6.017	2.779	2.494	1.800	5.905	3.837	5.069	7.503	34.847	24.676	8.169	9.617	12.063
6	6.766	8.897	8.336	7.795	5.905	1.723	5.278	7.299	13.060	35.785	25.614	7.542	11.149	17.620
7	2.526	3.642	5.725	5.727	3.837	5.278	1.994	7.843	10.360	31.843	21.672	4.332	12.391	14.920
8	8.394	10.693	4.724	3.195	5.069	7.299	7.843	3.507	9.614	37.356	27.185	12.175	5.459	14.174
9	8.745	10.892	5.665	7.023	7.503	13.060	10.360	9.614	4.383	27.742	17.571	14.512	15.073	4.560
10	31.212	28.830	33.407	34.765	34.847	35.785	31.843	37.356	27.742	9.879	10.171	31.081	42.815	25.038
11	21.041	18.659	23.236	24.594	24.676	25.614	21.672	27.185	17.571	10.171	7.715	20.910	32.644	14.867
12	5.799	6.301	10.057	10.059	8.169	7.542	4.332	12.175	14.512	31.081	20.910	4.949	16.723	19.072
13	12.942	15.241	10.183	8.654	9.617	11.149	12.391	5.459	15.073	42.815	32.644	16.723	4.559	19.633
14	13.305	15.452	10.225	11.583	12.063	17.620	14.920	14.174	4.560	25.038	14.867	19.072	19.633	6.097

Note) The inter-zonal distances are estimated based on shortest route between any two model zones. The intrazonal travel distances are average radius of that zones.

5.3.2 Travel Cost and Travel Time Calculation

The purpose of this part is to estimate the generalized travel cost with congestion effects. In this case, for simplifying in calculation, we also assume that the trip's cost will not be changed due to the congestion, event the driver would decide to change the route connecting original and destination. Only travel time will be effected by traffic congestion and would be changed. In order to perform this task, we propose the traditional User Equilibrium Assignment algorithm based on the first Wardrop's principle, which is widespread used in transportation forecasting [34].

In order to prepare the travel time matrix for Benchmark Hanoi CUE Model, the OD matrices by modes derived from PT surveyed are assumed to be absolutely presented for traffic condition of Hanoi City at that time. Therefore, they will be assigned on the real road network to get the travel time among model zones. In order to perform this task, again we use JICA Strada package, with User Equilibrium Assignment module. The input data for utilizing the software are prepared as following steps:

- Re-arrange the OD matrices by modes in terms of district level from original PT data, including Hanoi City and adjacent areas and traffic catchment point represented for "touch-and-go" passing through the City.
- Prepare road network of the Hanoi City and adjacent areas with links' characteristics such as capacity, limit velocity, number of lanes ...

The final travel time matrix among the model zones prepared as input for Benchmark Hanoi CUE Model demonstration is shown in Table 5.10

Regarding to the monetary travel cost matrix, with above assumption, we can calculate the travel cost among model zones based on the travel distance prepared in Table 5.9 and expected operating cost for each mode presented in Table 5.6 and 5.7. The travel cost between any two model zones would be the expected travel cost for all available modes with each weight coefficient to be the number of drivers who had chosen each available mode. The monetary travel cost matrix for Benchmark Hanoi CUE Model is presented in Table 5.11

TABLE 5.10: Travel Time (Hours) among Model Zones, 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.092	0.270	0.544	0.583	0.403	0.537	0.237	0.648	0.740	1.123	0.845	0.431	0.680	0.974
2	0.270	0.140	0.580	0.630	0.454	0.564	0.266	0.702	0.766	1.010	0.732	0.416	0.734	0.993
3	0.544	0.580	0.067	0.189	0.270	0.633	0.399	0.334	0.386	1.268	0.990	0.694	0.376	0.619
4	0.583	0.630	0.189	0.092	0.304	0.570	0.425	0.275	0.454	1.336	1.058	0.719	0.310	0.687
5	0.403	0.454	0.270	0.304	0.093	0.472	0.243	0.401	0.507	1.243	0.965	0.538	0.432	0.741
6	0.537	0.564	0.633	0.570	0.472	0.089	0.351	0.567	0.863	1.246	0.968	0.509	0.591	1.097
7	0.237	0.266	0.399	0.425	0.243	0.351	0.103	0.468	0.629	1.016	0.738	0.296	0.500	0.863
8	0.648	0.702	0.334	0.275	0.401	0.567	0.468	0.178	0.574	1.451	1.173	0.726	0.221	0.807
9	0.740	0.766	0.386	0.454	0.507	0.863	0.629	0.574	0.221	1.198	0.844	0.924	0.640	0.234
10	1.123	1.010	1.268	1.336	1.243	1.246	1.016	1.451	1.198	0.466	0.354	1.097	1.482	1.060
11	0.845	0.732	0.990	1.058	0.965	0.968	0.738	1.173	0.844	0.354	0.374	0.819	1.205	0.706
12	0.431	0.416	0.694	0.719	0.538	0.509	0.296	0.726	0.924	1.097	0.819	0.248	0.757	1.102
13	0.680	0.734	0.376	0.310	0.432	0.591	0.500	0.221	0.640	1.482	1.205	0.757	0.229	0.873
14	0.974	0.993	0.619	0.687	0.741	1.097	0.863	0.807	0.234	1.060	0.706	1.102	0.873	0.301

Note) The travel time among model zones (hours) were estimated by using user equilibrium assignment 3.5 module of Jica Strada Package. The traffic flow for assignment prepared included traffic of the "Old" Hanoi City and adjacent areas in order to replicate the real traffic condition at that time.

Table 5.11: Travel Cost (VND) among Model Zones, 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	2,654	2,894	3,827	4,109	3,388	4,393	2,949	4,881	4,984	11,520	8,403	4,089	6,163	6,263
2	2,894	3,030	4,563	4,820	4,159	5,028	3,361	5,538	5,594	10,682	7,743	4,248	6,797	6,855
3	3,827	4,563	2,463	2,644	3,045	4,864	4,065	3,736	4,046	12,102	9,004	5,359	5,395	5,406
4	4,109	4,820	2,644	2,659	2,937	4,704	4,066	3,199	4,472	12,442	9,370	5,360	4,957	5,787
5	3,388	4,159	3,045	2,937	2,667	4,123	3,430	3,851	4,617	12,462	9,392	4,815	5,234	5,920
6	4,393	5,028	4,864	4,704	4,123	2,637	3,920	4,556	6,195	12,685	9,800	4,629	5,666	7,455
7	2,949	3,361	4,065	4,066	3,430	3,920	2,744	4,719	5,445	11,691	8,577	3,602	6,010	6,708
8	4,881	5,538	3,736	3,199	3,851	4,556	4,719	3,312	5,233	13,034	10,237	5,951	3,979	6,503
9	4,984	5,594	4,046	4,472	4,617	6,195	5,445	5,233	3,620	10,390	7,441	6,596	6,750	3,680
10	11,520	10,682	12,102	12,442	12,462	12,685	11,691	13,034	10,390	5,309	5,391	11,484	13,953	9,638
11	8,403	7,743	9,004	9,370	9,392	9,800	8,577	10,237	7,441	5,391	4,681	8,367	11,904	6,694
12	4,089	4,248	5,359	5,360	4,815	4,629	3,602	5,951	6,596	11,484	8,367	3,811	7,206	7,858
13	6,163	6,797	5,395	4,957	5,234	5,666	6,010	3,979	6,750	13,953	11,904	7,206	3,680	8,013
14	6,263	6,855	5,406	5,787	5,920	7,455	6,708	6,503	3,680	9,638	6,694	7,858	8,013	4,184

Note) The monetary travel cost among model zones (VND) were calculated based on average operating cost and travel distance.

5.4 Specifications of Hanoi's Economy

By now, we have prepared some input data sets of Hanoi CUE model. They are defined as *exogenous variables* for simulation. Another type of variable should be given before going to simulation is model's parameters. We need to estimate these values from data so that they are closest to the true values. In next subsection, we will effort to estimate the parameters which presenting for specifications of Hanoi economy.

5.4.1 Production cost share and average productivity coeficient

The production of a model zone j proposed in Chapter 4 is presented in Cobb-Douglas form as $X_j = AL_j^{\delta} S_j^{\mu}$, where L_j and S_j are total *labor time* and *land area* required for production, respectively. Since production is assumed to be constant return to scale and zero profit with $\delta + \mu = 1$, the function can be expressed in simplier form as $X_j = AL_j^{\delta} S_j^{1-\delta}$. By taking the logarithm both sides of the function and rearrange, the production function now is represented in a linear form as follow:

$$\ln X_j - \ln S_j = (\ln L_j - \ln S_j)\,\alpha + \ln A. \tag{5.3}$$

Based on this transformation of production function, we formulate a linear regression model in that the regressand or dependent variable would be $\ln X_j - \ln S_j$, regressor or explanatory would be $lnL_j - \ln S_j$; the cost share coeficient α, and the productivity lnA, are estimates of the slope and intercept of the regression line, respectively.

Now we start to discuss about the input data preparation for regression task. At first, the two input factors for production, labor time and land area, can be extracted from the Employment and Land-use patterns proposed in 5.2. The zonal labor time here can be estimated by total amount of working time that all employees live in any model zone i contributing to the production in model zone j where they have been working for. The employee's work-time in one typical day at standard condition, defined in Vietnamese Labor Law 2012, Article 104, Item 1, is 8 hours per day per employee [48]. Therefore, the labor time in each model zone can be estimated by total number of employees multiplying by $8(hour/day)$. The second factor, the land area in terms of square meter required for production in zone j defined and available in the subsection 5.2.5.

Secondly, we turn to estimate the output of zonal production. As in any CGE model, the most important principle is that at general equilibrium state, total output of production

TABLE 5.12: Input factors of zonal production.

Zone		Labor time	Land area	Output
No.	**Name**	(hours)	(m^2)	(Unit)
1	Ba Dinh	637,864.00	2,112,879.99	124,671.00
2	Tay Ho	188,520.00	708,239.49	61,813.00
3	Hoan Kiem	878,200.00	689,908.87	154,768.00
4	Hai Ba Trung	794,312.00	970,074.62	166,849.00
5	Dong Da	783,640.00	1,617,001.92	145,633.00
6	Thanh Xuan	425,272.00	295,617.47	68,981.00
7	Cau Giay	343,456.00	929,969.32	78,747.00
8	Hoang Mai	287,176.00	717,000.92	59,809.00
9	Long Bien	469,536.00	798,604.32	83,964.00
10	Soc Son	783,032.00	353,439.82	55,146.00
11	Dong Anh	499,032.00	877,343.40	105,854.00
12	Tu Liem	403,208.00	1,749,757.74	78,160.00
13	Thanh Tri	255,784.00	456,484.36	40,998.00
14	Gia Lam	422,216.00	361,929.96	72,100.00

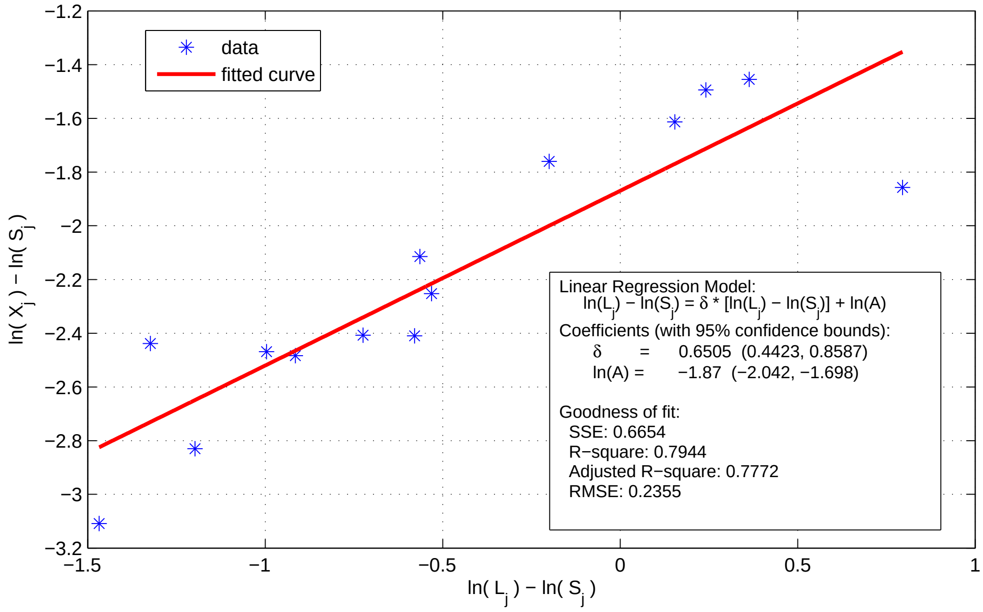
Note) Estimated from Hanoi PT and Land-use data in 2005, HAIDEP.

will be the supply side of the region economy, and they will totally consumed by in the. In this model, we assumed that the amount of aggregate demand of retail commodity at model zone j is represented by total number of trips generated from any model zone accruing to zone j with shopping purpose, and in equilibrium state, it should be equal to the total output produced in that zone. With this in mind, the production output in a model zone is estimated to be the total trips ended at that zone with"shopping" purpose. Also, remember that the "shopping trip" here is defined in a wide meaning as assumed in subsection 5.2.4.2. Based on these arguments, the data for regression is prepared in Table 5.12.

According to regression result shown in Figure 5.3, the value $\delta = 0.6505$ is quite close to the for labor cost share in production [8]. The "goodness-of-fit" $R^2 = 0.7944$ also shows that the data is well-behaved in statistic meaning. The values of δ and $\mu = 1 - \delta$ will be utilized in model simulation. The average productivity of the whole study region are $\overline{A} = 0.1541$

5.4.2 Utility Expenditure Share and Other Coeficients related to Consumers settings

In general, the share coefficients of disposable income should be estimated statistically from official source database or derived from other studies on this issue for the city and can be slightly different case by case.



Note) Source Technical Report No.1, HAIDEP Project.

FIGURE 5.3: Parameter Estimation.

For the case of Hanoi City, the share coefficients of disposable income α, β, γ for retails shopping, land for housing, and leisure time are roughly set as 45%, 15% and 40%, respectively. These values also was proposed by Anas and Xu [8] for Chicago model and it seems quite appropriate with Hanoi City. Therefore, without any related official information for considering study region, we temporarily used these values as default setting for Hanoi case study.

Regarding to the elasticity of substitution between any two shopping places η and Logit dispersion parameter for home-workplace choice λ, without any relevant supplement information from other resource, we also roughly set at neutral values of 0.5 and 1.00, respectively.

5.5 Calibration for the Benchmark Hanoi CUE Model with 2005 Database

The input database prepared for a model simulation includes exogenous variables and parameters. These values are usually considered as given information with regard to the model and collected from other socioeconomic resource. They are assumed to be fixed in model demonstration. However, the output results obtained from the simulation are usually not totally fit with the reality, especially regarding to the type of model which used for replicating simultaneously many socioeconomic indicators like CUE model. In that cases, the calibration process is necessary in order to improve the fitness between simulation output and correspondent real variables, as close as possible.

In this research, the official information from other sources on regional economy is generally not sufficient for all parameter estimations, then at current time, we temporarily postulate that the exogenous variables and parameter estimations prepared in previous part are acceptable and fixed in simulation demonstration. We propose an approach in which the calibration is designed by adjusting the coeficients emphzonal productivity in production function and *Residence-Workplace discrete choice*, *Zonal Attractiveness for Shopping* in utility function. In principle, the general equilibrium root set is derived from simultaneous, complicated interaction among players, and represented by mathematic simultaneous equation system. Designing a mechanism for adjusting all consider parameters at the same time is nearly a burden, or sometime impossible, in calculation. Therefore, in this case we propose the calibration procedure in which each set of considering parameter would be adjusted separately. The calibration process should be implemented into following steps:

- *Step 0:* The parameters represented for the share of disposable income in utility function and the cost share coeficient of production function are fixed as estimated section 5.4.
- *Step 1:* Firstly, the *Zonal Attractiveness for Shopping* coefficients, ι_{ij}, should be set in order to replicate the spatial shopping trend of people living in study region. It would be very precious if we have from a seperate specific research on this issue but in the case these values are roughly calculated based on the shopping patterns extracted from the original database;
- *Step 2:* Secondly, the *Zonal Productivity* coefficients, A_j, should be introduced into the model in order to reflect the level of technology applying in retail production of each model zone. As for the *Zonal Attractiveness for Shopping* coeficients, these parameters should be estimated, or at least consulting from other study or resources in order to minimize the bias. In this case, we just propose a very simple calculation based on PT data.
- *Step 3:* Thirdly, after the two type of above parameters have been set, the *Residence-Workplace discrete choice* coefficients, WRA_{ij}, are adjusted in a way so that the spatial distribution of employees in all zones of the study region fit with original database. Since these values linearly go into the utility function, they could be calculated by an iterative procedure.

The calculation procedure for these coeficients are consequently introduced in following subsection in more detail.

5.5.1 Zonal Productivity of Production

The productivity estimated by least square methodology presented in section 5.4.1 is expected value for the study region as the whole. In this part, the zonal productivity will be re-calculated based on the same database so that it can reflect the effectiveness of using input factors in production of each model zone. We assume that the technology for regional production is unity, it means the cost share coeficients for production between labor time and land, δ and μ, are fixed for all model zones. Now we re-calculate the zonal productivity coeficient A_j for each each zone j by following expression:

$$A_j = \frac{X_j}{L_j^{\delta} S_j^{\mu}}, \tag{5.4}$$

where L_j, S_j and X_j are given labor time, land for production and zonal output of production data sets, respectively, given in Table 5.12. In addition, the values are also adjusted in iterations to ensure that the total regional output is the same with that of input database.

5.5.2 Zonal Attractiveness for Shopping

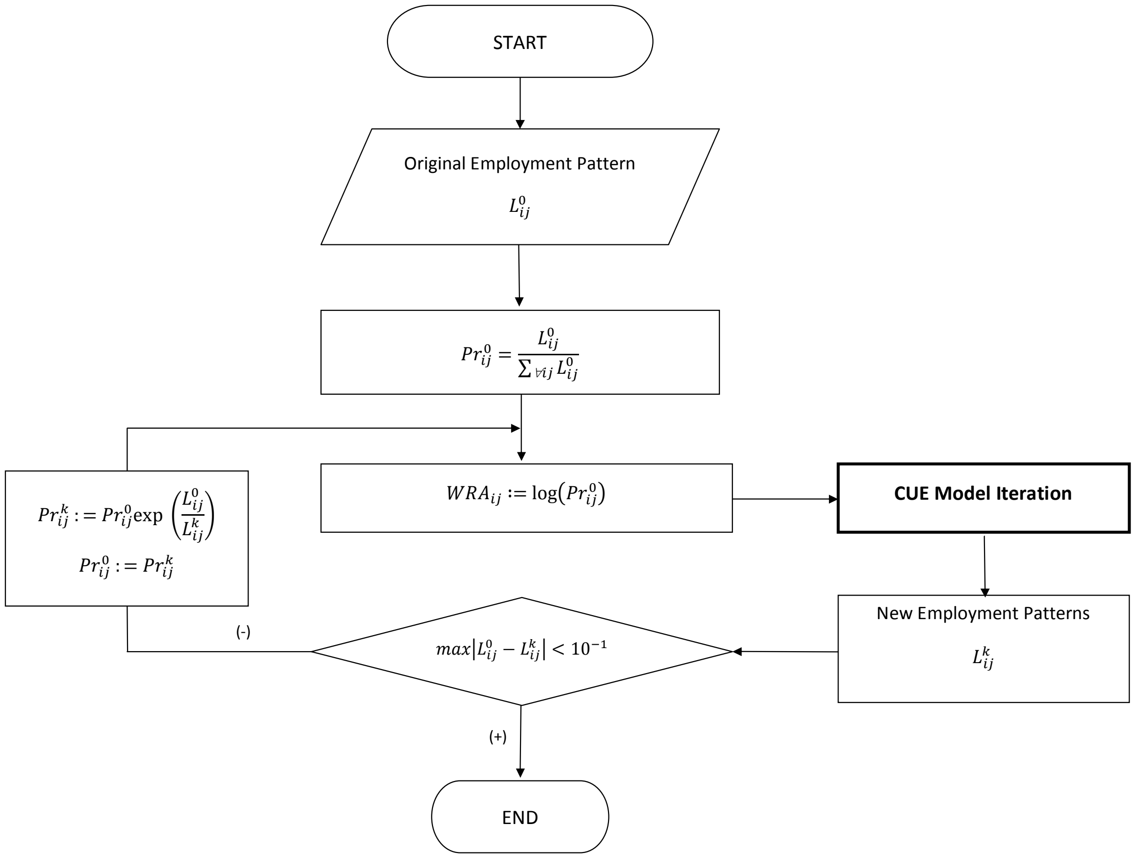
The coefficients are estimated in order to reflect the tendency or preference of people residing in study region on shopping location choice. In this model, they are calculated as the proportions of retail demand of each zone on all other zones by following formula:

$$\iota_{z|i} = \frac{X_{z|i}}{\sum_{\forall z} X_{z|i}}, \tag{5.5}$$

where $X_{z|i}$, $\sum_{\forall j} X_i$ are the amount of retail commodity at zone z demanded by zone i and total demand for retail consumption at zone i, respectively. By this proposal, we could easily find that $\sum_{\forall z} \iota_{z|i} = 1$.

5.5.3 Workplace-Residence Attractiveness

If we postulate that the exogenous input variables for model simulation representing for *an equilibrium state* of study region at that time, it means the benchmarking model should replicate that state by fit the model's output with those correspondent.



Note) The algorithm for solving CUE Model proposed in Chapter **??**. where L_{ij} is the number of employees who would choose zones i and j as home and working zones, respectively. This algorithm has converged quite fast for case of Hanoi.

FIGURE 5.4: Hanoi CUE Model Calibration - WRA_{ij} Iterative Calculation Procedure.

One of the most important pattern which the model simulation should reserved as the original input database is the spatial employment pattern, which reprented for the distribution of employee at home and working zones. The reason is that it will impose on most of other socioeconomic activities taking place inside the study region. In that sense, modeler should give enough effort in order to fit the simulated output pattern with that of input data.

As mentioned in the begining of section 5.5, we propose an adjustment mechanism in which the WRA_{ij} coeficients will be corrected by iterative calculation. The procedure is shown in Figure 5.4.

5.5.4 The "Goodness-of-fit" of Simulation Results and Final Settings for Benchmark Hanoi CUE Model

Check on the "goodness-of-fit" between simulated results outputting from the benchmark model demonstration and original exogenous input data should be conducted in order to decide which the best settings for benchmarking model. The fitness check, represented by the correlation coefficients ρ, is tested for the three most important spatial distribution patterns of employment, consumption and production output in the 5 calibration scenarios, with following settings:

- *Scenario 0:* All calibrated coefficients have been set at defaut values: work-residential attractiveness $WRA_{ij} = 0$, zonal attractiveness for shopping $\iota_{ij} = 1$. The zonal productivity was set at expected value for the whole study region $A_j = \overline{A} = 0.1541$, as presented in Section 5.4.1.
- *Scenario 1:* Only zonal shopping attractiveness coefficients, ι_{ij}, have been introduced into the model; Other type of coefficients was kept as default values.
- *Scenario 2:* Only zonal productivity coefficients, A_j, have been corrected for production in each model zone; Other type of coefficients was kept as default values.
- *Scenario 3:* Only workplace-residence attractiveness coefficients, WRA_{ij}, have been adjusted for location choice behavior of employees living in study region; Other type of coefficients was kept as default values.
- *Scenario 4:* The zonal shopping attractiveness coefficients, ι_{ij} was set as in Scenario 1, after that the workplace-residence attractiveness coefficients, WRA_{ij}, have been adjusted for location choice behavior of employees living in study region; Other type of coefficients was kept as default values.
- *Scenario 5:* The zonal shopping attractiveness coefficients, ι_{ij}, and zonal productivity coefficients, A_j, were set as in Scenario 1 and 2, after that the workplace-residence attractiveness coefficients, WRA_{ij}, have been adjusted for location choice behavior of employees living in study region;

The values of correlation coefficients in each scenario were summarized in Table 5.13. Evidently, the results shown in "combined" scenarios 4 and 5 has dominated the "single" scenarios 1, 2, 3 and especially the "non-calibration" scenario 0. Comparing between Scenario 4 and 5, it is easily to find that the slight adjustment for zonal productivities has improve the fitness of the zonal output production, therefore, the Scenario 5 would

Table 5.13: The correlation between simulated results and original data.

Scenario No.	0[1]	1	2	3	4	5[2]
Employment Pattern	0.19	0.11	0.15	1.00	1.00	1.00
Consumption Pattern	0.27	0.92	0.25	0.33	0.97	0.97
Output Pattern	-0.36	-0.29	0.05	0.38	0.38	0.70

Note) [1] In scenario 0, all adjustment coefficients of work-residential attractiveness WRA_{ij}, zonal attractiveness for shopping ι_{ij} have been set at 1. The zonal productivity was set at expected value for the whole study region as presented in 5.4.1; [2] The settings in this Scenario has been chosen for Benchmark Hanoi CUE Model.

Table 5.14: Simulation Settings for Benchmark Hanoi CUE Model.

No.	Model Inputs	Value	Unit	Note
I	Exogenous Variables			
1	*Population and Labor force*			PT data
	-Population	2,952,035.00	(civilians)	
	-No. of workers	896,406.00	(workers)	
2	*Land-use*			Land-use data
	-Residence	111,028,495.40	(m^2)	
	-Production	12,638,252.20	(m^2)	
3	*Work-time*			Labor Law [48]
	-Number of working day per year	250.00	(days)	
	-Personal Time Endowment	24.00	(hours)	
4	*Transportation Expenditure*			Traffic Assignment Results
	-Travel cost[1]	-	(VND/km)	
	-Travel time[1]	-	(hours)	
II	Parameters			
5	*Consumer's Expenditure share*			
	-Commodity consumption α	0.45	-	
	+CES retail location η	0.50	-	
	-Land for Housing β	0.15	-	
	-Leisure γ	0.40	-	
	-Logit choice dispersion parameter λ	1.00	-	
6	*Producers' expenditure shares of input factors*			PT data estimations
	-Labor δ	0.6505	-	
	-Land for Production μ	0.3495	-	
	-Zonal Productivity[2] A	-	-	

Note) [1]) Travel cost and time matrices among model zones obtained from Traffic Assignment; [2]) Zonal productivity coefficients are recalculated using (5.4)

be the acceptable choice for the establishment of Benchmark Hanoi CUE Model with 2005 database. The final settings of all exogenous variables and parameters for CUE are summerized and shown in the Table 5.14.

The outputs of Benchmark Hanoi CUE Model demonstration based on these settings in Table 5.14 are summerized in Table 5.15 and Figures 5.5- 5.7. The spatial employment and shopping distribution patterns presented 6.12 and 6.13, respectively. These variables output from this benchmark model would be representing for the city's economy at equilibrium state and called *base state* of the city's socioeconomic condition. For any further analysis relying on this CUE framework, these variables will be compared with that of simulation output with the new policy.

Table 5.15: The Hanoi's Socioeconomic Variables resulted from the Benchmark Hanoi CUE Model Demonstration

Zone		**Employment**		**Land-use**		**Output**	**Wage**	**Rent**	**Price**	**Leisure time**		**Working time**	
No.	**Name**	**L(H)**	**L(W)**	**b**	**S**	**X**	**w**	**R**	**p**	**E(H)**	**E(W)**	**WT(H)**	**WT(W)**
1	Ba Dinh	72,075	79,733	2,806,070	2,796,824	78,954	38.6	1,318.6	534.6	13.1	13.7	9.4	8.6
2	Tay Ho	31,792	23,564	3,065,958	2,982,078	63,128	53.0	562.3	304.0	13.1	12.5	9.1	9.7
3	Hoan Kiem	45,120	109,775	980,913	1,487,453	105,538	30.0	2,288.2	369.1	13.1	15.1	9.5	7.4
4	Hai Ba Trung	89,486	99,288	2,813,997	3,193,891	150,644	42.5	1,672.9	406.0	13.1	13.3	9.5	9.0
5	Dong Da	101,260	97,955	3,838,970	3,294,615	107,246	37.9	1,349.8	474.6	13.2	13.9	9.4	8.6
6	Thanh Xuan	56,448	53,159	2,737,850	2,530,633	85,698	41.5	1,081.3	365.5	13.0	13.3	9.2	8.8
7	Cau Giay	50,938	42,932	3,247,212	3,244,528	74,980	48.2	850.9	421.5	13.2	12.9	9.5	9.5
8	Hoang Mai	60,269	35,899	4,659,010	4,117,833	70,397	60.5	745.1	498.8	13.1	12.0	9.2	10.0
9	Long Bien	54,340	58,692	5,284,474	5,189,561	92,069	39.9	535.1	345.2	13.0	13.5	8.9	8.6
10	Soc Son	95,762	97,879	7,334,800	7,103,330	89,707	43.1	703.5	637.6	12.6	12.7	8.4	8.5
11	Dong Anh	65,330	62,379	9,019,620	8,261,769	130,679	46.8	411.5	297.8	12.8	12.7	8.0	9.0
12	Tu Liem	62,382	50,401	7,367,216	7,028,294	78,062	51.8	493.8	508.9	13.0	12.5	9.0	9.5
13	Thanh Tri	43,827	31,974	3,309,507	3,255,753	52,153	61.5	855.8	611.5	13.0	11.9	9.2	10.0
14	Gia Lam	67,378	52,777	6,550,329	6,164,259	118,239	56.8	638.2	380.8	12.9	12.1	8.6	9.7
Total/Average		896,406	896,406	63,015,926	60,650,822	1,297,495	46.6	964.8	439.7	13.0	13.0	9.1	9.1

Note) * The wage-rate at zone No.3, *Hoan Kiem* District is selected as numeraire for simulation. Wage-rate, land-rent and retail price are measured in 000 VND; Leisure and Working time in hours

TABLE 5.16: Simulated Spatial Employment Pattern of Hanoi in 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	$\sum$ **S**
1	21,438	3,013	13,575	7,107	11,867	4,189	4,103	1,386	1,835	679	240	1,683	721	239	72,075
2	5,669	7,960	4,986	3,107	3,701	1,375	1,994	505	747	222	177	852	341	156	31,792
3	5,874	1,417	17,756	7,097	6,112	1,494	2,128	832	1,136	170	134	591	62	317	45,120
4	8,245	2,083	17,275	34,637	10,305	4,542	3,463	4,304	1,874	390	240	961	781	386	89,486
5	12,916	1,852	20,635	14,114	30,750	8,065	4,966	2,334	1,979	475	192	1,924	725	333	101,260
6	5,409	1,056	6,488	6,306	10,231	19,010	2,680	1,868	985	201	150	1,132	731	201	56,448
7	7,035	1,422	6,481	3,826	7,698	3,156	15,051	732	1,074	292	245	3,629	147	150	50,938
8	3,309	982	8,606	12,699	5,917	4,016	1,220	18,660	1,026	344	99	1,212	2,033	147	60,269
9	2,025	873	5,108	2,895	2,751	1,062	723	289	34,109	1,019	535	438	191	2,322	54,340
10	375	95	140	46	190	47	94	1	94	92,700	1,698	188	1	93	95,762
11	715	473	996	622	768	430	433	47	1,233	810	57,372	717	95	619	65,330
12	4,341	1,578	3,402	1,724	3,790	3,158	5,410	394	933	296	543	36,271	345	197	62,382
13	1,339	336	1,615	3,877	2,984	2,426	382	4,167	428	47	47	521	25,564	94	43,827
14	1,043	425	2,712	1,232	891	189	285	379	11,239	234	707	282	237	47,523	67,378
$\sum$ **D**	79,733	23,564	109,775	99,288	97,955	53,159	42,932	35,899	58,692	97,879	62,379	50,401	31,974	52,777	*896,406*

Note) The *Simulated Spatial Employment Pattern* of Hanoi in 2005 was derived by Benchmarking Hanoi CUE Model simulation. The correlation between simulated result perfectly fit with and the original pattern, the Correlation coefficient $\rho = 1.00$.

TABLE 5.17: Simulated Spatial Shopping Pattern of Hanoi in 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	$\sum$ **S**
1	72,062	1,074	1,408	467	2,257	198	748	357	107	0	1	182	42	50	78,954
2	1,881	60,309	87	76	85	16	383	110	43	0	0	137	0	0	63,128
3	7,440	1,092	66,959	3,403	18,570	2,081	1,841	1,953	715	15	22	850	535	63	105,538
4	946	170	721	129,228	10,005	2,436	280	6,340	34	8	6	36	428	5	150,644
5	1,031	70	568	945	99,831	2,248	548	1,510	187	0	0	159	143	7	107,246
6	59	12	12	195	380	84,238	71	491	15	0	0	60	165	1	85,698
7	148	85	132	130	334	83	71,939	169	5	1	0	1,940	12	2	74,980
8	19	1	7	160	30	426	8	69,626	0	0	0	1	116	4	70,397
9	279	3	29	14	327	113	40	25	90,048	146	12	49	4	980	92,069
10	0	0	0	0	0	0	0	0	1	89,702	3	0	0	0	89,707
11	0	0	0	0	0	5	0	115	107	253	130,161	0	0	38	130,679
12	32	6	27	13	17	19	81	3	1	0	0	77,863	0	0	78,062
13	0	0	1	1	4	9	0	434	0	0	0	0	51,703	0	52,153
14	2	1	3	1	23	13	0	2	68	0	43	1	0	118,082	118,239
$\sum$ **D**	83,900	62,823	69,954	134,633	131,863	91,884	75,939	81,134	91,331	90,125	130,249	81,279	53,149	119,232	*1,297,495*

Note) The *Simulated Spatial Shopping Pattern* of Hanoi in 2005 was derived by Benchmarking Hanoi CUE Model simulation. The correlation between simulated result and the original pattern represented by the Correlation coefficient $\rho = 0.97$.

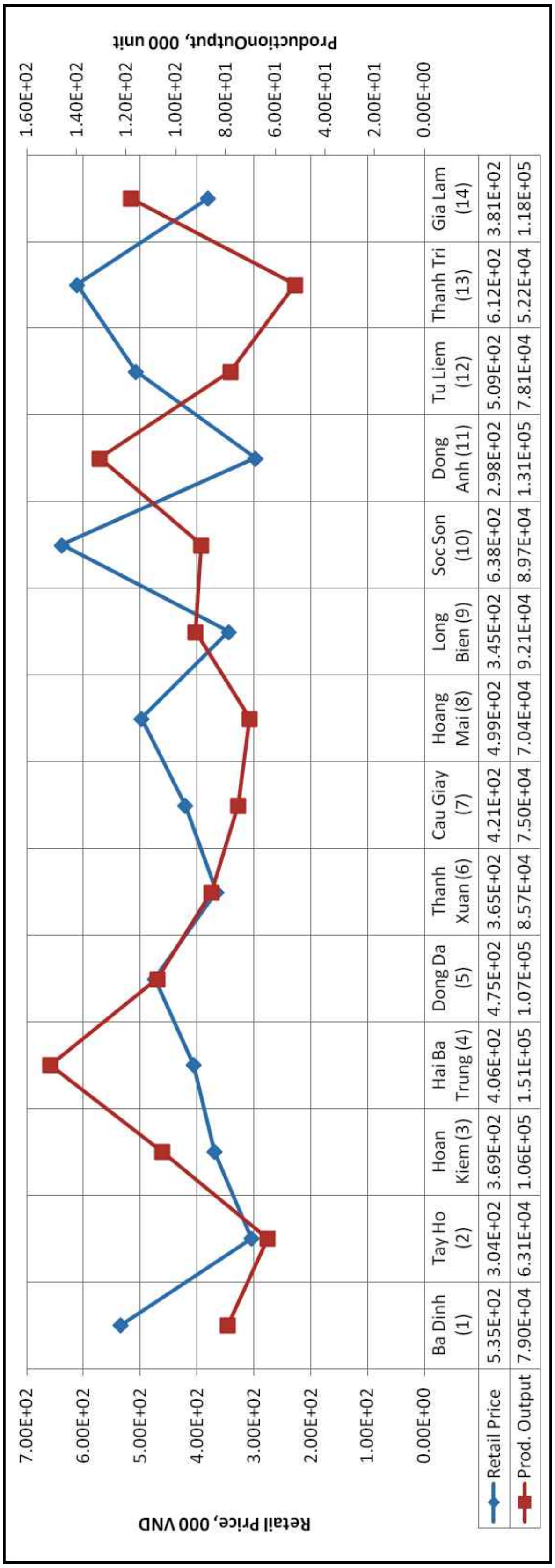


Figure 5.5: Zonal Commodity Price, Production Output.

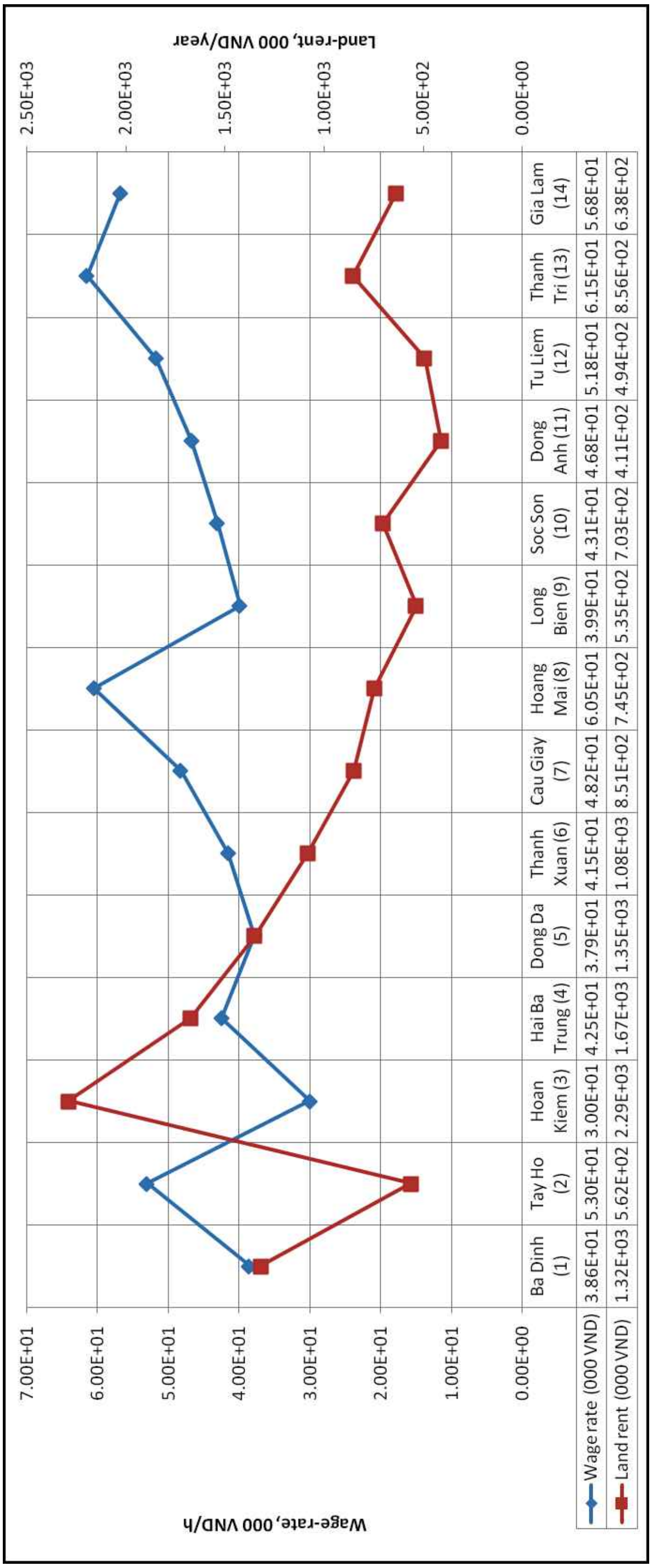
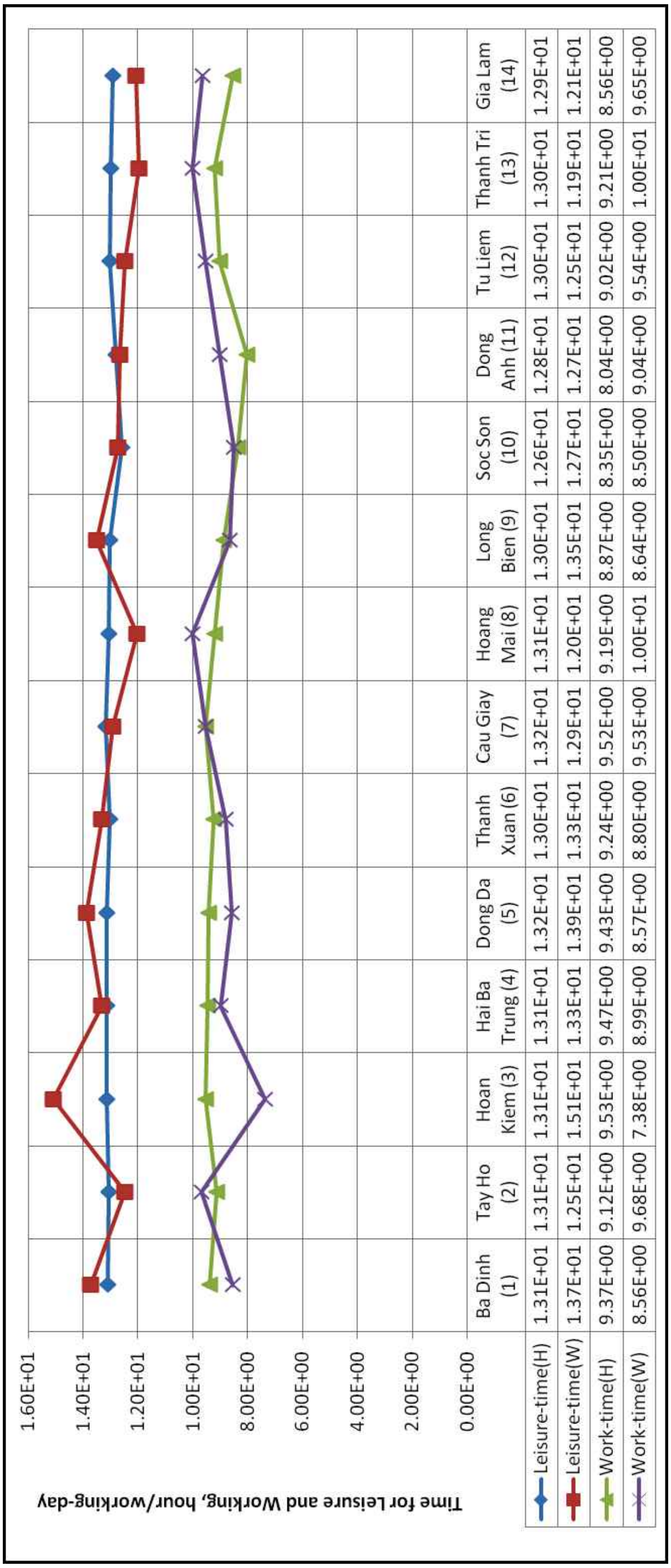


FIGURE 5.6: Zonal Land-rent and Wage-rate.



	Ba Dinh (1)	Tay Ho (2)	Hoan Kiem (3)	Hai Ba Trung (4)	Dong Da (5)	Thanh Xuan (6)	Cau Giay (7)	Hoang Mai (8)	Long Bien (9)	Soc Son (10)	Dong Anh (11)	Tu Liem (12)	Thanh Tri (13)	Gia Lam (14)
Leisure-time(H)	1.31E+01	1.31E+01	1.31E+01	1.31E+01	1.32E+01	1.30E+01	1.32E+01	1.31E+01	1.30E+01	1.26E+01	1.28E+01	1.30E+01	1.30E+01	1.29E+01
Leisure-time(W)	1.37E+01	1.25E+01	1.51E+01	1.33E+01	1.39E+01	1.33E+01	1.29E+01	1.20E+01	1.35E+01	1.27E+01	1.27E+01	1.25E+01	1.19E+01	1.21E+01
Work-time(H)	9.37E+00	9.12E+00	9.53E+00	9.47E+00	9.43E+00	9.24E+00	9.52E+00	9.19E+00	8.87E+00	8.35E+00	8.04E+00	9.02E+00	9.21E+00	8.56E+00
Work-time(W)	8.56E+00	9.68E+00	7.38E+00	8.99E+00	8.57E+00	8.80E+00	9.53E+00	1.00E+01	8.64E+00	8.50E+00	9.04E+00	9.54E+00	1.00E+01	9.65E+00

Figure 5.7: Zonal Leisure and Working Time.

5.6 Summary and Recommendations

In order to demonstrate the "operational" feature of CUE model presented in Chapter 4, an empirical study has been implemented based on PT, Land-use and road network database of Hanoi in 2005. The ultimate objective is to estimate a benchmark CUE model for Hanoi Case Study. In order to realize the purpose, the available databases have been rearranged, analyzed and combined flexibly.

The PT and transport infrastructure network data sketch a picture of traffic condition, and reveal the travel behavior of urban inhabitants. Based on that information, the generalized costs for traveling among model zones are estimated and expressed in terms of travel cost and travel time matrices. They will stand for technical specification of transport system and be exogenously introduced into small iteration but endogenously determined in big loop of calculation.

Regarding to the urban economy, PT and land-use database revealed the production technology and location shopping preference of people living in the city of at that time. In other word, they give us some aspects of demand and supply the urban economy. Based on the assumptions, the employment, land-use (for residence and production) and shopping patterns of Hanoi have been established from the database. They have undertaken two vital roles: firstly, to be exogenous input variables for simulation, and sencondly, help us to estimate some critical parameters for production function.

It is positive to say that the model have been estimated and calibrated quite successfully. The values of variables outputed from simulation have fitted well with correspondent input variables representing by high statistic correlation coefficients. There are some lessons withdrawing from the practical model estimation as follows:

- The benchmark CUE for a certain case study can be estimated from many data sources, in which PT and land use data are vital and indispensable. The other data sources are also important in the complement and/or supportive sense for model estimation and calibration. Further, some type of data can offer the new options for model expansion.
- The parameters should be revised and updated periodically and as closed as possible to the practical application in time. In other words, panel data should be collected for deep analysis over time scale.

Chapter 6

Transport Project Evaluation, An Approach with CUE Modeling

6.1 Introduction

In traditional evaluation of economic benefit of transportation infrastructure, a combination of cost-benefit analysis and travel demand estimation by using four-step model is routinely utilized. However, the conventional methodology would lead to defiencies because of the limited capability of existing four-step. As told in Chapter 2, there are two limited points: (1) the four-step model cannot capture the projection of relative changes of household and employment locations of land users, then leading to (2) even the projection of travel demand in future becomes less reliable, especially in long-term and for project having large influence on socioeconomic condition of the urban area.

In turn, the two limited points give rise to the two consequences: (1) reduce the accountability and transparency and evidence of the new policy since only measure the direct effect of the new project, travel time and cost saving, and (2) create the imbalance between transportation and spatial development, which might lead to congestion or overloaded in some part and under exploited facilities on the others.

CUE model can overcome the deficiencies of the existing four-step model since it has taken into account the "land use-transport feedback cycle." Further, since the model is constructed based on microeconomic theory, and treated under general equilibrium framework of both land use and transportation, the results outputed from simulation are systemic and behavioral consistensy.

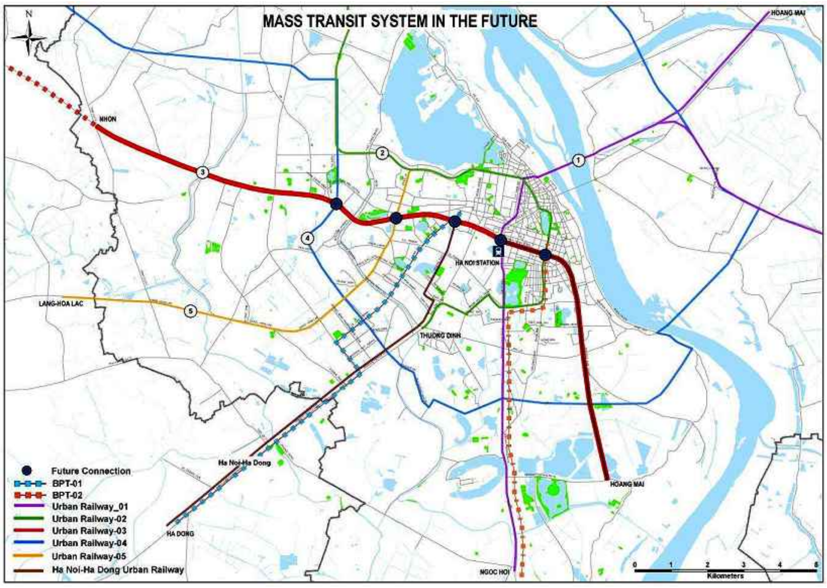
The Benchmark Hanoi CUE model estimated in previous chapter will be used for a real practical application: evaluating the economic benefit of a transport project. The chapter is organized as follows. In the first part of this chapter, we will introduce Hanoi Pilot Light Metro Line, Section Nhon - Hanoi Railway Station, a part of the mixed light rail-metro Line No.3, one of the eight lines of Hanoi urban railway network, planned to be established in Hanoi by the year 2030. In second part, a calculation will be conducted to measure the technical influence of the new UMRT line on transport system of Old Hanoi. In other words, it means the generalized travel cost matrix of Old Hanoi city will be re-estimated with the new transport system, where the new line have been merged with the exist network. And in the last part, the socioeconomic benefit will be estimated by using Hanoi CUE model.

6.2 Hanoi Pilot Light Metro Line, Section Nhon - Hanoi Railway Station

6.2.1 The Long term Plans for Passenger Transport in Hanoi

The urban railway network system for Hanoi city in future is defined by two master plans. The first one is the Transport Development Plan of Hanoi Capital till 2020 [3], issued by Vietnamese Government in 2008. According to this plan, by 2020, the passenger transport system of Hanoi shown in Figure 6.1, includes five main routes as follows:

- The UMRT Line No.1 (Ngoc Hoi - Yen Vien, Nhu Quynh): about 38.7 km long, goes through the Centre City, connects the North-East, the South suburban areas and the City's Centre;
- The UMRT Line No.2 (Noi Bai - City Centre - Thuong Dinh): about 35.2 km long, connects Noi-Bai Airport to new urbanized areas Dong Anh, Tu Liem and Old Streets area of Hanoi;
- The UMRT Hanoi - Ha Dong or Line No.2A: about 14 km long, connected to Line No.2 at Cat-Linh station and passing Hao Nam, La Thanh, Thai Ha, Lang Street, Nga Tu So, going along National Highway No.6 to Thuong Dinh, Ha Dong and ending at Ba La. After 2020, this route would be extended and connected to Xuan Mai.
- The UMRT Line No.3 (Nhon - Hanoi Railway Station - Hoang Mai): about 21 km long, connects the West, the Centre and the South areas of the City. After 2020,



Note) Source: Hanoi Pilot Light Metro Line, Section Nhon - Hanoi Railway Station, Feasibility Study Report

FIGURE 6.1: Transport Development Plan of Hanoi Capital till 2020, Mass Transit System.

the route will be extended toward the Western city and connecting to Son-Tay Town[1];

- The UMRT Line No.4 (Dong Anh - Sai Dong - Vinh Tuy/Hoang Mai - Thanh Xuan - Tu Liem - Thuong Cat - Me Linh): to be a closed or circle line, about 53.1 km long, connects all Lines No.1, No.2, No.3, No.5, and Hanoi - Ha Dong or Line No.2A. Before to be the UMRT line, in near future, it will be developed in terms of rapid bus line;

- The UMRT Line No.5 (South of West Lake - Ngoc Khanh - Lang - Hoa Lac): about 34.5km length, connects City Centre with urban areas developed along Lang - Hoa-Lac Corridor;

In a newer and more general development plan approved in 2011, the Hanoi Capital Construction Master Plan to 2030 and Vision to 2050 [2], there are three lines No.6, No.7 and No.8 adding to Hanoi UMRT as shown in Figure 6.2. Temporarily, according to these documents, we can figure out that the Hanoi UMRT system will be carried out by two stages, at first, the lines namely from No.1 to No.5 (included Line No.2A) will be constructed by 2020 and then, the three additional lines No.6, No.7 and No.8 will be constructed in the period of 2030-2050 to formulate the complete urban railway network for Hanoi. These routes have been defined in the Transport Development Plan

[1]Son Tay Town is a part of Hanoi after expansion, but not in 2005

of Hanoi till 2020 are absolutely coincided with that in the Hanoi Capital Construction Master Plan to 2030 and Vision to 2050.

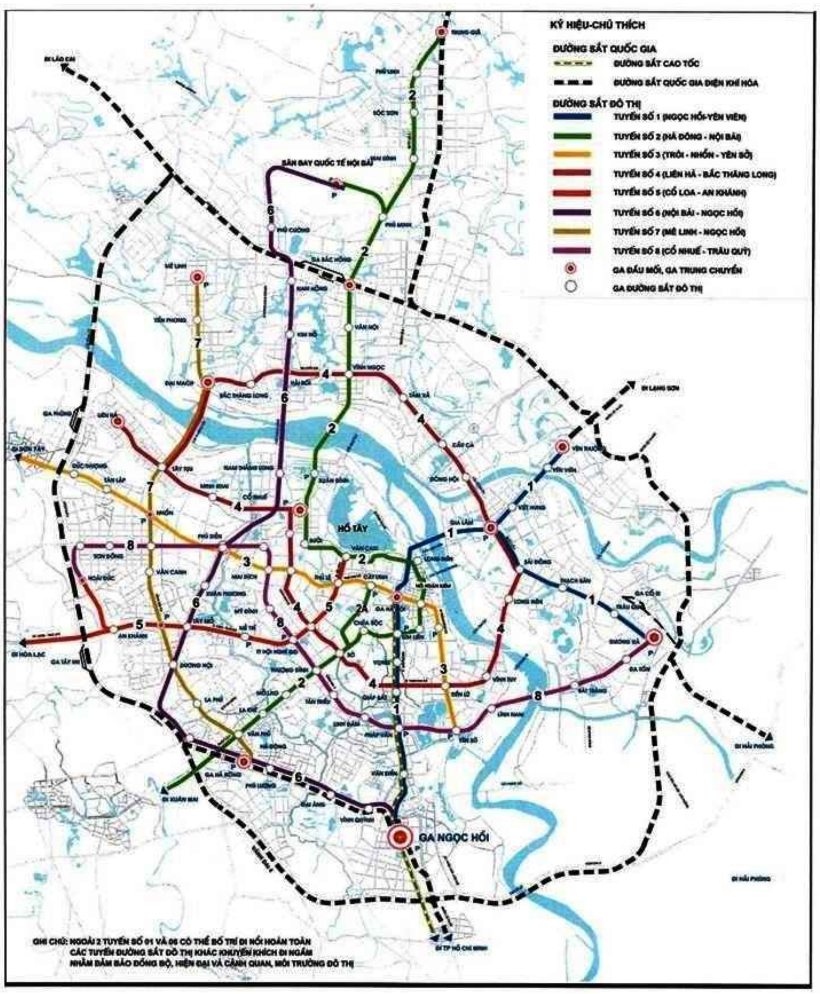
In order to realize the very huge and ambitious plans, a pilot project have been conducted in order to collect the data and experience on contructing, managing and operating the urban railway system in future. The proposed project names *Hanoi Pilot Light Metro Line, section Nhon - Hanoi Raiway Station*, one part of Line No.3 in the transport development master plan. According to the project's feasibility report, the estimation of total investment cost would be about €881.14 millions and starting the maintenance and operation in November 2013. However, by site survey conducted in September 2013, the construction site along this line still has not begun to work.

Although there is a huge lag in the project implementation schedule and real plan, in this chapter, we assume that the project have been finished the construction and the line was being under operation period in year 2005. We will conduct an analysis to calculate the impacts of this project and using Hanoi benchmarking CUE model developed in Chapter 5 to estimate the social benefit and socioeconomic changes by the project introduction in following section.

6.2.2 Project's Location

The new UMRT Line in the pilot project has starting point in Nhon Town and terminates at Hanoi Railway Station (HRS), with total length 12.5 km. The rest section of the whole UMRT Line No.3 (total 21 km length), from HRS to Hoang Mai District, will be completed in next stage. There are 14 stations, including 10 elevated and 4 underground stations, will be arrange along the new route. The location of the UMRT line shown in Figure 6.3 is decribed in detail as follows [1]:

- Section from Nhon to Ring Road 3: to be elevated, inserted in National Route No. 32 (this project is now under construction with planned cross-section of 50m). This section passes through Tay Tuu Commune, Minh Khai District.
- Section from Ring Road 3 to Ring Road 2: to be elevated, inserted in Xuan Thuy - Cau Giay streets constructed with cross-section of about 33m. This section passes through Cau Giay District.
- Section from Ring Road 2 to Daewoo Hotel: transition section from elevated ection to underground section, along Thu Le Lake to Nguyen Chi Thanh-Kim Ma crossing. This section passes through Ba Dinh District.



Note) Source: Orientation of public transport planning-The Hanoi capital construction master plan to 2030 and vision to 2050

FIGURE 6.2: 8 planned routes of Hanoi Public Light Rail and Metro System.

- Section from Daewoo Hotel to HRS: underground section passing by Kim Ma street, Cat Linh street, Quoc Tu Giam street, HRS and ending at beginning of Tran Hung Dao street

The proposed alignment of the new line passes through 4 districts from West to East of Hanoi: *Tu Liem*, *Cau Giay*, *Ba Dinh*, *Dong Da*, and connects to the edge of *Hoan Kiem* District, as presented in Figure 6.4. Projection of the new UMRT location on Hanoi CUE zone map corresponds to the same name of model zones, or 12, 7, 1, 5 and 3, respectively, in numerical system.

Note) After starting at Nhon, the double track elevated line runs to the east along National Road 32, crosses Cau Dien district and pursues its route on Ho Tung Mau where it passes over the 3rd Ring Road. The alignment then continues on Xuan Thuy, Cau Giay, cross over with fly over bridge at Cau Giay Interchange (Ring Road 2) until it reaches the bus transfer station in front of Thu Le Park. At this stage, the line descends underground, follows Kim Ma, passes in front of the Horizon Hotel, continues straight on Cat Linh and Quoc Tu Giam and terminates in Tran Hung Dao at Hanoi main railway station [1]

FIGURE 6.3: URMT No.3 - Section Nhon-HRS on Map.

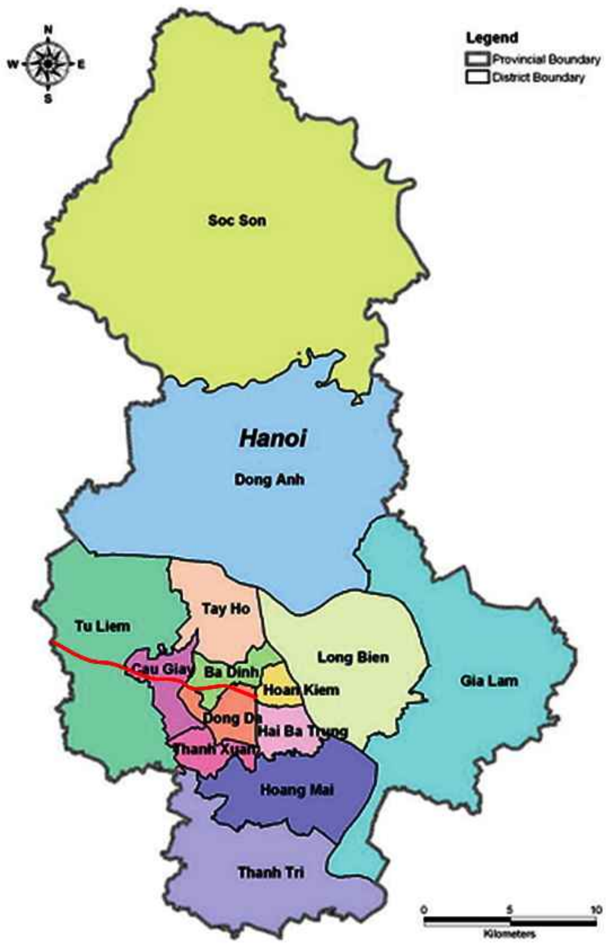
6.3 The Mode Share and New Generalized Travel Cost with New UMRT Line Integration

We assume that the new UMRT line has been already integrated with the transport infrastructure system and fully accessible for it's potential clients. We also suppose that only the new project was introduced, *ceteris pirabus*, all other things existing in the study region in the evaluation period are assumed to be in the same state.

The technical indicators of the new UMRT line such as capacity, velocity, fare, . . . , have been merged with existing urban transport system as the whole. Therefore, the generalized travel cost for traveling among model zones would be changed. As conventional calculation procedure, the geralized travel cost matrix will be decomposed into separate monetary travel cost and travel time matrices for convenience in calculation. For lessen the burden in calculation as proposed in Chapter 5, we also assume that the monetary travel cost matrix will *not* be effected by the congestion but only depend on the distances between any two model zones.

The travel time matrix taking into account the congestion effect will be estimated by the standard user equilibrium assignment algorithm by assigning the demand traffic flow on the new transportation network. In order to perform this task, there are conventional two steps need to be conducted as follows:

1. Estimate the share of available travel modes. In other word, a modal split model should be formulated to estimate the demand share by mode



Note) On Hanoi CUE zone map, the new UMRT line passes through 5 zones Tu Liem (12), Cau Giay (7), Ba Dinh (1), Dong Da (5), and Hoan Kiem (3), from Westen side to the City centre.

Figure 6.4: URMT No.3 - Section Nhon-HRS on Hanoi CUE Zone Map.

2. The traffic flow by modes would be assigned on to the new transportation network to estimate the new travel cost and travel time matrix.

In following subsection, the two steps will be demonstrated in more detail with the new UMRT integration.

6.3.1 The Modal Share with the new UMRT Line Introduction

The purpose of this section is to calculate the share of the available modes on the travel market of the city after the new mode has been integrated with the system. Before going further, some assumptions should be accepted as follows:

- Even the new UMRT line will not go through the centroids of model zones where it goes through, we assume that the new stations along the new UMRT line are very closed to zone centroids. For the case of the new UMRT, we also assume that the new line can effect on both *interzonal* and *intrazonal* generalized travel cost of travelers in 4 model zones Tu Liem, Cau Giay, Ba Dinh, Dong Da, but *only on interzonal* of the *Hoan Kiem* District.

- We assume that the new UMRT line has large capacity and small headways. Therefore, there is no congestion in the new UMRT line.

- The new mode is assumed to be available for all travelers in all zones where it goes through or connected with.

As presented in previous chapter, the mode choice model already established with regard to *four* basic available modes for mobility in Hanoi City. In this model, the travel time, travel cost coeficients are assumed to be unity for that modes. The probability of choosing any available mode for traveling only depends on the modal specific-constants, which represented for aggregate characteristics of each mode. How to set this value for the new introduced mode, UMRT, is really difficult since there were not existance of this type of mode in the past in Hanoi. In this analysis, we suppose it is a very new, convenient and comfortable mode and this value is set the same as *automobile* $MA^{UMRT} = MA^{Auto} = 5.12$. The other coeficients mode choice model formulated in Chapter 5 are preserved. The parameters for mode choice model are presented in the Table 6.3.

TABLE 6.1: Settings of Mode Choice (Logit) model with new integrated UMRT.

Variables	**Estimates**	**Standard Error**	**t-value**	**Note**
MA^1	3.51E+00	8.82E-02	3.98E+01	Bike constant
MA^2	4.55E+00	5.79E-02	7.87E+01	MC constant
MA^3	5.12E+00	1.93E-01	2.65E+01	Auto constant
MA^4	0.00E+00	-	-	Bus constant
MA^5	5.12E+00	-	-	UMRT*
τ	-2.29E+00	1.27E-01	-1.80E+01	Travel time
ζ	-2.80E-04	2.28E-05	-1.23E+01	Travel cost

Note) * New introduced mode UMRT with mode-specific constant$MA^{UMRT} = MA^{Auto} = 5.12$. The other modes are supposed not to be changed by the new mode introduction.

Now, the new mode choice model have been formulated. In next step, we need to prepare the input variables travel cost and travel time to calculate the modal share for traveling among model zones. The travel distance of the new UMRT line is prepare in Table 6.2. In order to calculate travel time for the new UMRT, the operating velocity of the new mode is supposed to be 40 km/h on average. The travel cost is roughly calculated based on the average travel cost proposed by HAIDEP [14], which comprised by *fixed cost* is

TABLE 6.2: Travel Distance on new UMRT lines.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	-	-	4.18	-	2.37	-	1.47	-	-	-	-	5.80	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	4.18	-	-	-	1.81	-	5.65	-	-	-	-	9.98	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	2.37	-	1.81	-	-	-	3.84	-	-	-	-	8.17	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	1.47	-	5.65	-	3.84	-	1.99	-	-	-	-	4.33	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	5.80	-	9.98	-	8.17	-	4.33	-	-	-	-	4.95	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note) Calculated by the author, based on the length of new UMRT line and proposed stations arranged along its route.

TABLE 6.3: Travel Time (Hours) among Model Zones, 2005.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	-	-	0.10	-	0.06	-	0.04	-	-	-	-	0.14	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	0.10	-	-	-	0.05	-	0.14	-	-	-	-	0.25	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	0.06	-	0.05	-	-	-	0.10	-	-	-	-	0.20	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	0.04	-	0.14	-	0.10	-	0.05	-	-	-	-	0.11	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	0.14	-	0.25	-	0.20	-	0.11	-	-	-	-	0.12	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note) UMRT travel time is calculated based on travel distance presented in table 6.2 and the supposed average operating velocity 40 km/h. The time unit represented in the table is *hour*.

3,200 (VND) for all trips having travel distance less than 4 km and *variable cost* is 800 (VND) per km for extra travel distance. The travel time and travel cost for the new UMRT are represented in Table 6.3 and 6.4, respectively.

With the monetary travel cost and time matrices prepared for the new UMRT line and the mode choice model with new introduced UMRT mode, the share of all availble modes in each model zone can be easily calculated. Based on this result, we can obtain

Table 6.4: Travel Cost (VND) among Model Zones, 2005.

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	-	3,347	-	3,200	-	3,200	-	-	-	-	4,639	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	3,347	-	-	-	3,200	-	4,521	-	-	-	-	7,986	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	3,200	-	3,200	-	-	-	3,200	-	-	-	-	6,535	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	3,200	-	4,521	-	3,200	-	3,200	-	-	-	-	3,466	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	4,639	-	7,986	-	6,535	-	3,466	-	-	-	-	3,960	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note) The monetary travel cost among model zones (VND) were calculated based on average operating cost, comprising 2 elements: fixed cost is 3,200 (VND) for all trips having travel length less than 4 km and variable cost is 800 (VND) per km for extra travel distance, and travel distance matrix prepared in Table 6.2.

the new ODs by each mode. It also should be noted that the ODs from Hanoi 2005 PT data comprised some other modes which do not appear in the mode choice model. For these cases, we roughly assumed that the OD by "Walk" will be preserved as original data, and OD by "Truck" will be converted proportional with total OD trip data.

6.3.2 The New Generalized Travel Cost

We have already calculated the modal share for traveling among model zones and also output the ODs by all available modes. In previous sections, we have assumed that there is no congestion on the UMRT line. Therefore, in order to take into account the traffic congestion effect, the all ODs by modes operating on the road network should be assigned on the road network. Also remind that, we have supposed that the monetary travel cost is not effect by traffic congestion, therefore, the final travel cost matrix will be the weighted travel cost for all availble mode in all model zones.

The travel time obtain from traffic assignment would be the expected travel time of all trips by all *on-road* modes assigning on the road network. The final expected travel time matrix will be the weighted average travel time of trips using the new UMRT and travel time outputed from traffic assignment on road network, with weight coeficients will be the ratios of number of travelers who use UMRT and all other modes on road network over total trips.

For conducting the traffic assignment for the modes operating on road network, the traditional user equilibrium assignment algorithm will be utilized. The input data for perform this task include: the road network of Old Hanoi city in year 2005, the ODs by modes, travel mode equivalence coeficients (in order to converted all travel mode into standard passenger car unit (PCU), shown in Table 6.5). The software we used here for traffic assignment is *User Equilibrium Assignment* Program, a module designed based on standard user equilibrium assignment methodology of JICA Strada Package. The new generalized travel cost among model zones expressed in terms of separate travel time and travel cost matrices presented in Table 6.5 and Table 6.6, respectively.

Regarding intrazonal travel cost and time, these values will be average travel cost and time for all mode without consideration of traffic congestion.

TABLE 6.5: Expected Travel Time (Hours) between Model Zones, with new introduced UMRT line (At Initial State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.092	0.238	0.255	0.497	0.187	0.485	0.122	0.579	0.655	1.064	0.790	0.246	0.611	0.890
2	0.238	0.140	0.531	0.605	0.423	0.562	0.263	0.690	0.740	1.000	0.726	0.403	0.723	0.976
3	0.255	0.531	0.067	0.173	0.141	0.590	0.244	0.317	0.372	1.228	0.953	0.443	0.358	0.608
4	0.497	0.605	0.173	0.092	0.282	0.554	0.400	0.273	0.458	1.313	1.040	0.644	0.307	0.694
5	0.187	0.423	0.141	0.282	0.093	0.458	0.154	0.381	0.486	1.193	0.919	0.344	0.414	0.722
6	0.485	0.562	0.590	0.554	0.458	0.089	0.350	0.556	0.854	1.238	0.964	0.472	0.584	1.090
7	0.122	0.263	0.244	0.400	0.154	0.350	0.082	0.450	0.599	1.004	0.729	0.179	0.483	0.835
8	0.579	0.690	0.317	0.273	0.381	0.556	0.450	0.178	0.576	1.430	1.156	0.671	0.221	0.812
9	0.655	0.740	0.372	0.458	0.486	0.854	0.599	0.576	0.221	1.191	0.838	0.844	0.641	0.236
10	1.064	1.000	1.228	1.313	1.193	1.238	1.004	1.430	1.191	0.466	0.354	1.080	1.462	1.051
11	0.790	0.726	0.953	1.040	0.919	0.964	0.729	1.156	0.838	0.354	0.374	0.806	1.188	0.697
12	0.246	0.403	0.443	0.644	0.344	0.472	0.179	0.671	0.844	1.080	0.806	0.189	0.704	1.073
13	0.611	0.723	0.358	0.307	0.414	0.584	0.483	0.221	0.641	1.462	1.188	0.704	0.229	0.878
14	0.890	0.976	0.608	0.694	0.722	1.090	0.835	0.812	0.236	1.051	0.697	1.073	0.878	0.301

Note) The travel time matrix is calculated as expected travel time on road network using User Equilibrium Assignment Module, JICA Strada Package and travel time on the new UMRT line. The traffic congestion has been taken into account in this case.

TABLE 6.6: Expected Travel Cost (VND) between Model Zones, with new introduced UMRT line (At Initial State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	2,654	2,894	3,572	4,109	3,296	4,393	3,057	4,881	4,983	11,618	8,404	4,346	6,163	6,263
2	2,894	3,030	4,563	4,821	4,159	5,027	3,361	5,538	5,593	10,618	7,708	4,248	6,798	6,855
3	3,572	4,563	2,463	2,644	3,113	4,864	4,281	3,736	4,046	12,101	9,003	6,452	5,394	5,406
4	4,109	4,821	2,644	2,659	2,937	4,704	4,066	3,199	4,472	12,441	9,368	5,360	4,958	5,788
5	3,296	4,159	3,113	2,937	2,667	4,123	3,320	3,851	4,617	12,477	9,359	5,568	5,234	5,919
6	4,393	5,027	4,864	4,704	4,123	2,637	3,920	4,556	6,195	12,473	9,833	4,629	5,667	7,453
7	3,057	3,361	4,281	4,066	3,320	3,920	2,922	4,718	5,444	11,721	8,589	3,536	6,011	6,708
8	4,881	5,538	3,736	3,199	3,851	4,556	4,718	3,312	5,234	13,024	10,238	5,951	3,979	6,505
9	4,983	5,593	4,046	4,472	4,617	6,195	5,444	5,234	3,620	10,390	7,442	6,595	6,750	3,680
10	11,618	10,618	12,101	12,441	12,477	12,473	11,721	13,024	10,390	5,309	5,392	11,493	13,935	9,634
11	8,404	7,708	9,003	9,368	9,359	9,833	8,589	10,238	7,442	5,392	4,681	8,338	11,880	6,693
12	4,346	4,248	6,452	5,360	5,568	4,629	3,536	5,951	6,595	11,493	8,338	3,882	7,205	7,856
13	6,163	6,798	5,394	4,958	5,234	5,667	6,011	3,979	6,750	13,935	11,880	7,205	3,680	8,008
14	6,263	6,855	5,406	5,788	5,919	7,453	6,708	6,505	3,680	9,634	6,693	7,856	8,008	4,184

Note) The travel cost matrix is estimated by the expected travel cost of all available modes, without traffic congestion effect.

6.4 Evaluation of the New Project using CUE Model

The new UMRT project is assumed to be alrealdy introduced and integrated with the transportation system. Its effect on transportation system is technically expressed in terms of the expected cost and time matrices for traveling prepared in previous section. With the conventional cost-benefit analysis basing on 4-steps travel demand forecasting, these matrices and traffic flows on transportation network are enough for assessment and calculation preparing for benefit estimation usually can be stopped at this point. However, it is just the effect of the new investment at initial state, and only on travellers, without any feed-back from other agents in real world. In addition, even the travel pattern may also be changed under a new state of socioeconomic condition. Furthermore, at higher level of accountability and transparency, cost-benefit approach can not explain what is the new socioeconomic condition caused by introducing this policy, quantitatively. The analysis based on CUE framework can overcome these difficulties.

In this section, we will use the Benchmark Hanoi CUE Model formulated in Chapter 5 to analyze the impacts of the new UMRT project on the city's socioeconomic indicators. The methodology and calculation results will also presented in detail.

6.4.1 Methodology

The new generalized travel cost with the new UMRT line integration has been estimated in previous section. Now it will be considered as an input of CUE simulation. Since evaluation by CUE model may change the spatial travel pattern due to the change in employment and shopping patterns, then the calculation should be nested in iteration calculation in which the changes in travel time/travel cost or employment/shopping patterns would be the criteria for stop. The procedure for iterative calculation presented in Figure 6.5 can be summerized in following steps:

- *Step 0:* Prepare the new generalized cost for traveling among model zones triggered by the new transport policy, in this case to be the new UMRT Line and add the new UMRT mode to the Mode Choice Model. The new geralized travel cost should be expressed in terms of separate travel time and monetary travel cost matrices, G^0_{ij} and g^0_{ij}.
- *Step 1:* Demonstrate the Benchmark Hanoi CUE Model with the new input travel cost and travel time matrices. All other inputs will be kept as in original condition.

- *Step 2:* Save the output results from CUE performance and convert the Spatial Employment and Shopping Patterns into new Commuting and Shopping Trip Patterns. Other Trip Patterns from PT data also will be converted and merged with Commuting and Shopping Trip Patterns to obtain the travel demand of the city.

- *Step 3:* Perform the Mode Choice Model with added new UMRT mode to obtain the ODs trip by available modes. The OD trip by new UMRT mode and all other ODs by modes operating on road network should be separated for assignment purpose. The monetary travel cost matrix, g^1_{ij} can be calculated in this step.

- *Step 4:* Perform traffic assignment with all ODs by on-road modes to obtain the expected travel time matrix for these modes. The travel time matrix of UMRT can be calculated directly based on distances among model zones and technical specific of UMRT.

- *Step 5:* Calculate the average travel time matrix of all available modes from the two travel time matrices obtained in Step 4. This travel time G^1_{ij} and travel cost g^1_{ij} calculated from Step 3 will be compared with correspond values prepared in Step 0, G^0_{ij} and g^0_{ij}.

- *Step 6:* If the differences of travel time and travel cost smaller than ϵ^G and ϵ^g, the calculation should be terminated and all results obtained from CUE demonstration would be compared with correspondent values of base equilibrium state given in Chapter 5. In case the stop conditions are not sastified, the next iterative calculation is necessary with the new input travel time and travel cost we have obtain from Step 5, G^1_{ij} and g^1_{ij}.

6.4.2 Result Analysis

6.4.2.1 The Changes of Socioeconomic Indicators

At first, we explain about the meaning of status "At Home" and "At Workplace" appearing in some indicators. The reason of these titles is that each worker will choose a couple of zones for his home and workplace (i, j). The indicators with "At Home" title could be translated into the condition with which the all people or the population *living* in that zone can enjoy. On the other hand, the indicators with "At Workplace" status should be understood as the condition with which all workers or employees *working* in that zone can be benefited.

In CUE framework proposed in Chapter 4, the variables represent for socioeconomic condition consist of zonal wage-rate, land rent, leisure time, retail commodity price, production output, and land-use, employment, shopping patterns. The changes of these variables are summerized in Table 6.14 and also represented in more detailed in the graphs from Figure 6.9 to 6.8. Now we relatively explain the mechanism of the interaction of the outcomes resulted from Hanoi CUE simulation.

We start with *direct effects*, the time and cost saving for traveling on transportation network, induced by the new project. In general, the time matrix of traveling between model zones has improved greatly, not only among the zones that the new UMRT line passes throgh but also all other interzonal linkages. It is understandable since the network effect has responded positively. Look on the Table 6.11, the generalized cost for traveling among model zones has been reduced at all linkages accepting a very small increment (0.19%) of intrazonal travel cost at zone 7 (Cau Giay). Simply, this can be explained by the dominance of travel time over monetary travel cost. In more detail, as represented in Table 6.10, the travel time of all interzonal traffic links has been reduced. The greatest improvements of travel time have been recorded at the links having the direct share of the new UMRT line. The greatest value is about 58% on the link connecting zone 1 and zone 3.

Now we turn to analyze the *indirect effects* of the project on urban economy. In general, it is positive to find that nearly all socioeconomic indicators of Hanoi have been improved. It is also easy to understand that the magnitude of changes of nearly all indicators of the zones where the new UMRT going through, Ba Dinh (1), Hoan Kiem (3), Dong Da (5), Cau Giay (7) and Tu Liem (12) have been wider than that of other zones. Intuitively, we begin with the distribution of saving time resulted from reduction of travel time on working and leisure time. Look at Figure 6.6, it is positive to find that the working and leisure time in all zones has increased, in both "at home" and "at workplace," and the largest values occur at the zones that the new UMRT line going through. The highest value of about 3% has been recored in zone 12.

Next, let's look at Figure 6.8 to see how the labor market responses to these changes. It is easy to find that wage-rates in almost zones have decreased, except the slight increments in zone 10 (0.22%), zone 11 (0.25%) and zone 14 (0.19%). It can be roughly explained by the fact that the increments of individual working time, as presented in Figure 6.6, leading to the increasing of labor supply. In turn, the "invicible hand" of market have been activated and then given rise to the zonal wage-rates going down. The exception cases of zones 10, 11 and 14 can be interpreted as the dominance of local deficit of total labor supply causing by the number of workers withdrawing from their labor markets as shown in Figure 6.9.

Now we change to consider the retail production respond to the increment of one of its input factors, labor time, and also the reaction of commodity market. From the Figure 6.7, we find that the zonal outputs have increased in 10 zones and slightly decreased in 4 zones. The highest increasing rates are also recorded at 5 zones that the new UMRT passing through, and the remarkable rates occuring at Hoan Kiem (3) and Tu Liem (12). The zonal retail markets seem to be well-behaved: the more outputs are produced, the lower its prices are. The exceptions occur at zone 3, 9 (both output and price increase) and 13 (both decrease). The phenomina can be explained by the dominances of demand and supply may occur at that zones.

Continuously, we observe the zonal changes of the employment pattern presented in Figure 6.9. At new equilibrium state, the zonal labor demands have increased at zones 1, 3, 12 but decreased in zones 3, 5 and all other zones, in which the highest change, in both absolute and relative values, would occur at zone 3, with about 466 (0.42%) workers would choose this zone as new workplace. Zone 10 (Soc Son), one among zones where the new UMRT line would not go through, would be lost about 118 (0.12%) workers from its labor market and also to be highest number among zones lost their labor force. Regarding to the home zone choice, or zonal population change, zones 1, 5, 7, 12 would increase their population, and zone 1 (Ba Dinh) would be the most new attractive destination for living, with 327 (0.45%) workers wanting to move their home to that zone. And Soc Son (10), again, would see the largest number of its workers moving their home to other zones (148, 0.15%). But it is just the absolute number, the highest relative value is 0.23% (105), at Hoan Kiem (3), a zone that new UMRT going through.

Finally, let's consider the land use pattern change and response of zonal land market in long term. The allocation of land to residence and production purpose, or land-use pattern, is presented in Figure 6.10. The magnitudes of changes in land-use by the two purposes are more clear in the zones where the new UMRT line going through and they tend to behave likely of employment distributions in most model zones. It mean that the more labor time demanded, the more land for production needed. It is consistent with the constant return to scale implying in production function (4.12) formulated in Chapter 4. However, in some zones where the number of new workers choosen as home and workplace are both possitive, the *tug-of-war* may occur and then the dominant trend would be the winner. Another special result should be considered in this case is that the largest percentages of land-use changes by purposes are recorded at Hoan Kiem (3) and Tu Liem (12). It can be roughly explained because they are the two ends of the new UMRT line, then they are mostly benefited from the new investment among the others. Let's look at Figure 6.8 to see how land market responses to the changes. The zonal land rent prices increase at 11 zones and it is easy and understandable to find that highest rates occuring at 5 zones where the new UMRT line located and remarkable values, again, recorded at the two end points of the new line, Hoan Kiem (3) and Tu Liem (12). However, the land prices slightly decreased in zones 6, 8 and 13. They are the zones where demand of land for both residence and production purposes seem decreased but production output still increased. In addition, the output price 6.7 also decreased, then the input factors of production should be decreased.

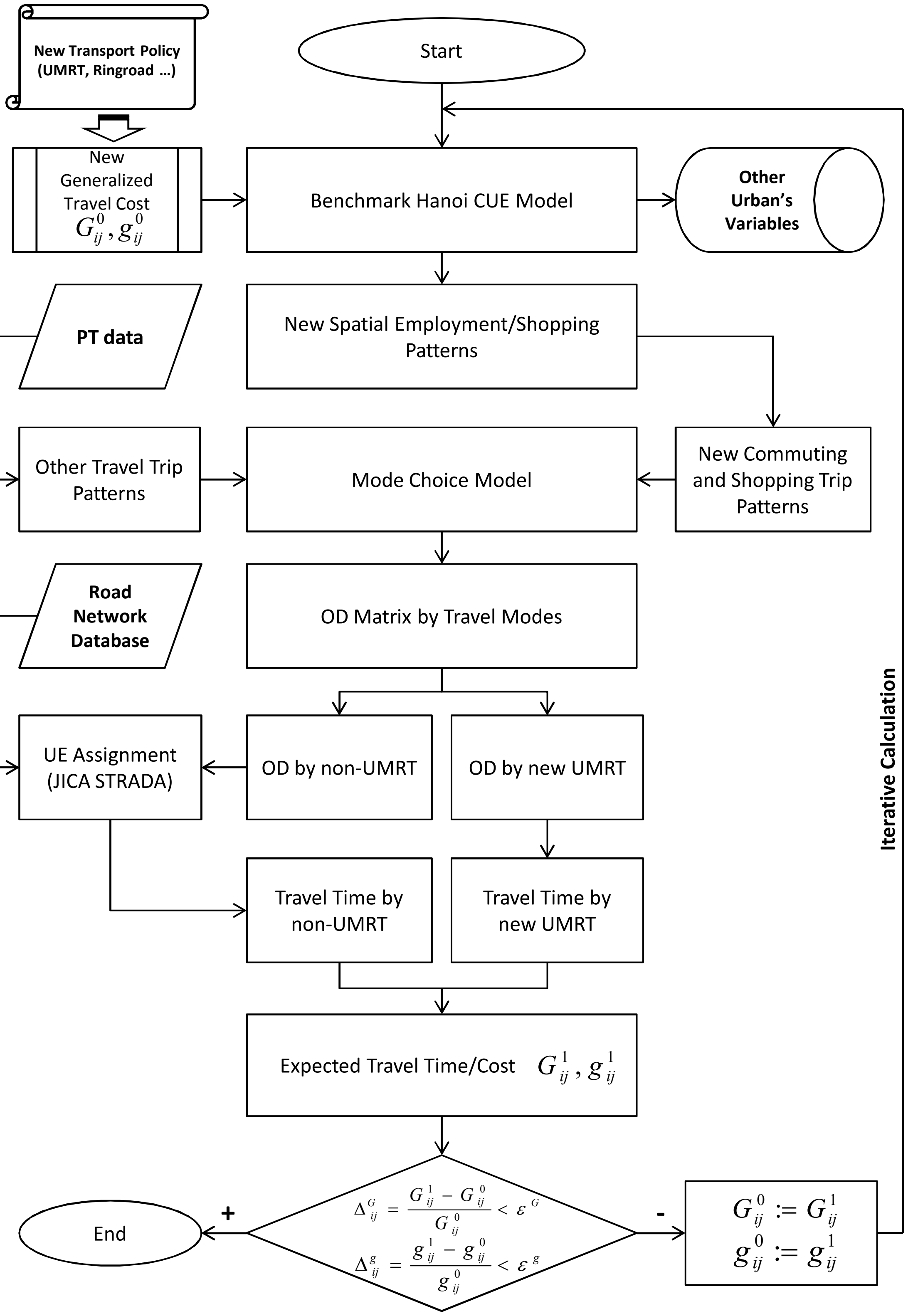


Figure 6.5: Flowchart of Economic Evaluation of a new UMRT Line.

Table 6.7: Travel Time (Hours) among Model Zones, with new introduced UMRT line (At Equilibrium State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.092	0.202	0.229	0.438	0.172	0.462	0.113	0.528	0.550	1.030	0.761	0.236	0.566	0.762
2	0.202	0.140	0.457	0.530	0.377	0.528	0.231	0.624	0.620	0.958	0.689	0.378	0.662	0.832
3	0.229	0.457	0.067	0.154	0.123	0.539	0.224	0.301	0.311	1.170	0.901	0.415	0.346	0.523
4	0.438	0.530	0.154	0.092	0.242	0.507	0.358	0.252	0.390	1.249	0.980	0.593	0.291	0.602
5	0.172	0.377	0.123	0.242	0.093	0.430	0.149	0.347	0.409	1.153	0.885	0.332	0.386	0.621
6	0.462	0.528	0.539	0.507	0.430	0.089	0.342	0.512	0.759	1.202	0.934	0.456	0.550	0.971
7	0.113	0.231	0.224	0.358	0.149	0.342	0.082	0.414	0.516	0.975	0.707	0.173	0.452	0.729
8	0.528	0.624	0.301	0.252	0.347	0.512	0.414	0.178	0.511	1.370	1.102	0.632	0.209	0.723
9	0.550	0.620	0.311	0.390	0.409	0.759	0.516	0.511	0.221	1.020	0.700	0.751	0.581	0.212
10	1.030	0.958	1.170	1.249	1.153	1.202	0.975	1.370	1.020	0.466	0.320	1.052	1.411	0.894
11	0.761	0.689	0.901	0.980	0.885	0.934	0.707	1.102	0.700	0.320	0.374	0.784	1.143	0.574
12	0.236	0.378	0.415	0.593	0.332	0.456	0.173	0.632	0.751	1.052	0.784	0.189	0.670	0.963
13	0.566	0.662	0.346	0.291	0.386	0.550	0.452	0.209	0.581	1.411	1.143	0.670	0.229	0.793
14	0.762	0.832	0.523	0.602	0.621	0.971	0.729	0.723	0.212	0.894	0.574	0.963	0.793	0.301

Note) The travel time matrix estimated by using User Equilibrium Assignment Module, JICA Strada Package. The traffic congestion was considered in this case.

TABLE 6.8: Travel Cost (VND) among Model Zones, with new introduced UMRT line (At Equilibrium State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	2,654	2,894	3,572	4,109	3,296	4,393	3,057	4,881	4,984	11,521	8,401	4,346	6,163	6,261
2	2,894	3,030	4,563	4,820	4,159	5,028	3,361	5,538	5,593	10,694	7,746	4,248	6,801	6,854
3	3,572	4,563	2,463	2,644	3,113	4,864	4,280	3,736	4,046	12,107	9,005	6,451	5,394	5,407
4	4,109	4,820	2,644	2,659	2,937	4,704	4,066	3,199	4,472	12,452	9,371	5,359	4,957	5,787
5	3,296	4,159	3,113	2,937	2,667	4,123	3,320	3,851	4,617	12,470	9,390	5,567	5,234	5,921
6	4,393	5,028	4,864	4,704	4,123	2,637	3,920	4,556	6,195	12,642	9,791	4,629	5,666	7,452
7	3,057	3,361	4,280	4,066	3,320	3,920	2,922	4,718	5,444	11,693	8,564	3,536	6,008	6,709
8	4,881	5,538	3,736	3,199	3,851	4,556	4,718	3,312	5,232	13,030	10,227	5,950	3,979	6,505
9	4,984	5,593	4,046	4,472	4,617	6,195	5,444	5,232	3,620	10,387	7,440	6,595	6,753	3,680
10	11,521	10,694	12,107	12,452	12,470	12,642	11,693	13,030	10,387	5,309	5,390	11,469	13,882	9,631
11	8,401	7,746	9,005	9,371	9,390	9,791	8,564	10,227	7,440	5,390	4,681	8,367	11,905	6,693
12	4,346	4,248	6,451	5,359	5,567	4,629	3,536	5,950	6,595	11,469	8,367	3,882	7,208	7,861
13	6,163	6,801	5,394	4,957	5,234	5,666	6,008	3,979	6,753	13,882	11,905	7,208	3,680	8,004
14	6,261	6,854	5,407	5,787	5,921	7,452	6,709	6,505	3,680	9,631	6,693	7,861	8,004	4,184

Note) The travel cost matrix is estimated by the expected travel cost of all available modes.

TABLE 6.9: The change of travel time (%) among Model Zones, with new introduced UMRT line (At Equilibrium State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.00	-25.19	-57.90	-24.87	-57.32	-13.97	-52.32	-18.52	-25.68	-8.28	-9.94	-45.24	-16.76	-21.77
2	-25.19	0.00	-21.21	-15.87	-16.96	-6.38	-13.16	-11.11	-19.06	-5.15	-5.87	-9.13	-9.81	-16.21
3	-57.90	-21.21	0.00	-18.52	-54.44	-14.85	-43.86	-9.88	-19.43	-7.73	-8.99	-40.20	-7.98	-15.51
4	-24.87	-15.87	-18.52	0.00	-20.39	-11.05	-15.76	-8.36	-14.10	-6.51	-7.37	-17.52	-6.13	-12.37
5	-57.32	-16.96	-54.44	-20.39	0.00	-8.90	-38.68	-13.47	-19.33	-7.24	-8.29	-38.29	-10.65	-16.19
6	-13.97	-6.38	-14.85	-11.05	-8.90	0.00	-2.56	-9.70	-12.05	-3.53	-3.51	-10.41	-6.94	-11.49
7	-52.32	-13.16	-43.86	-15.76	-38.68	-2.56	-20.39	-11.54	-17.97	-4.04	-4.20	-41.55	-9.60	-15.53
8	-18.52	-11.11	-9.88	-8.36	-13.47	-9.70	-11.54	0.00	-10.98	-5.58	-6.05	-12.95	-5.43	-10.41
9	-25.68	-19.06	-19.43	-14.10	-19.33	-12.05	-17.97	-10.98	0.00	-14.86	-17.06	-18.72	-9.22	-9.40
10	-8.28	-5.15	-7.73	-6.51	-7.24	-3.53	-4.04	-5.58	-14.86	0.00	-9.60	-4.10	-4.79	-15.66
11	-9.94	-5.87	-8.99	-7.37	-8.29	-3.51	-4.20	-6.05	-17.06	-9.60	0.00	-4.27	-5.15	-18.70
12	-45.24	-9.13	-40.20	-17.52	-38.29	-10.41	-41.55	-12.95	-18.72	-4.10	-4.27	-23.79	-11.49	-12.61
13	-16.76	-9.81	-7.98	-6.13	-10.65	-6.94	-9.60	-5.43	-9.22	-4.79	-5.15	-11.49	0.00	-9.16
14	-21.77	-16.21	-15.51	-12.37	-16.19	-11.49	-15.53	-10.41	-9.40	-15.66	-18.70	-12.61	-9.16	0.00

TABLE 6.10: The change of travel cost (%) among Model Zones, with new introduced UMRT line (At Equilibrium State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.00	0.00	-6.66	0.00	-2.72	0.00	3.66	0.00	0.00	0.01	-0.02	6.29	0.00	-0.03
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.11	0.04	0.00	0.06	-0.01
3	-6.66	0.00	0.00	0.00	2.23	0.00	5.29	0.00	0.00	0.04	0.01	20.38	-0.02	0.02
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.01	-0.02	0.00	0.00
5	-2.72	0.00	2.23	0.00	0.00	0.00	-3.21	0.00	0.00	0.06	-0.02	15.62	0.00	0.02
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.34	-0.09	0.00	0.00	-0.04
7	3.66	0.00	5.29	0.00	-3.21	0.00	6.49	-0.02	-0.02	0.02	-0.15	-1.83	-0.03	0.01
8	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	-0.02	-0.03	-0.10	-0.02	0.00	0.03
9	0.00	-0.02	0.00	0.00	0.00	0.00	-0.02	-0.02	0.00	-0.03	-0.01	-0.02	0.04	0.00
10	0.01	0.11	0.04	0.08	0.06	-0.34	0.02	-0.03	-0.03	0.00	-0.02	-0.13	-0.51	-0.07
11	-0.02	0.04	0.01	0.01	-0.02	-0.09	-0.15	-0.10	-0.01	-0.02	0.00	0.00	0.01	-0.01
12	6.29	0.00	20.38	-0.02	15.62	0.00	-1.83	-0.02	-0.02	-0.13	0.00	1.86	0.03	0.04
13	0.00	0.06	-0.02	0.00	0.00	0.00	-0.03	0.00	0.04	-0.51	0.01	0.03	0.00	-0.11
14	-0.03	-0.01	0.02	0.00	0.02	-0.04	0.01	0.03	0.00	-0.07	-0.01	0.04	-0.11	0.00

TABLE 6.11: The change of generalized travel cost (%) among Model Zones, with new introduced UMRT line (At Equilibrium State).

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.00	-10.88	-34.16	-13.34	-29.59	-6.97	-18.49	-9.62	-14.06	-3.66	-4.49	-17.52	-7.94	-12.18
2	-10.88	0.00	-10.79	-8.19	-7.98	-3.05	-5.16	-5.65	-10.06	-2.18	-2.53	-4.05	-4.56	-8.78
3	-34.16	-10.79	0.00	-6.82	-21.54	-7.64	-16.55	-4.16	-8.50	-3.54	-4.24	-10.73	-2.90	-7.48
4	-13.34	-8.19	-6.82	0.00	-9.33	-5.49	-7.25	-3.45	-6.38	-3.00	-3.53	-9.16	-2.07	-6.08
5	-29.59	-7.98	-21.54	-9.33	0.00	-4.29	-16.19	-6.18	-9.13	-3.21	-3.79	-10.07	-4.28	-8.17
6	-6.97	-3.05	-7.64	-5.49	-4.29	0.00	-1.08	-4.88	-6.41	-1.76	-1.62	-4.92	-3.19	-6.28
7	-18.49	-5.16	-16.55	-7.25	-16.19	-1.08	0.19	-5.17	-8.72	-1.66	-1.82	-17.76	-3.90	-7.94
8	-9.62	-5.65	-4.16	-3.45	-6.18	-4.88	-5.17	0.00	-5.19	-2.67	-2.97	-6.46	-1.69	-5.22
9	-14.06	-10.06	-8.50	-6.38	-9.13	-6.41	-8.72	-5.19	0.00	-7.21	-8.20	-9.99	-3.99	-3.21
10	-3.66	-2.18	-3.54	-3.00	-3.21	-1.76	-1.66	-2.67	-7.21	0.00	-3.36	-1.87	-2.50	-7.44
11	-4.49	-2.53	-4.24	-3.53	-3.79	-1.62	-1.82	-2.97	-8.20	-3.36	0.00	-1.90	-2.32	-8.65
12	-17.52	-4.05	-10.73	-9.16	-10.07	-4.92	-17.76	-6.46	-9.99	-1.87	-1.90	-7.03	-5.29	-6.71
13	-7.94	-4.56	-2.90	-2.07	-4.28	-3.19	-3.90	-1.69	-3.99	-2.50	-2.32	-5.29	0.00	-4.37
14	-12.18	-8.78	-7.48	-6.08	-8.17	-6.28	-7.94	-5.22	-3.21	-7.44	-8.65	-6.71	-4.37	0.00

Note) The generalized travel cost among model zones have been calculated basing on travel time, travel cost and time-value of traveling.

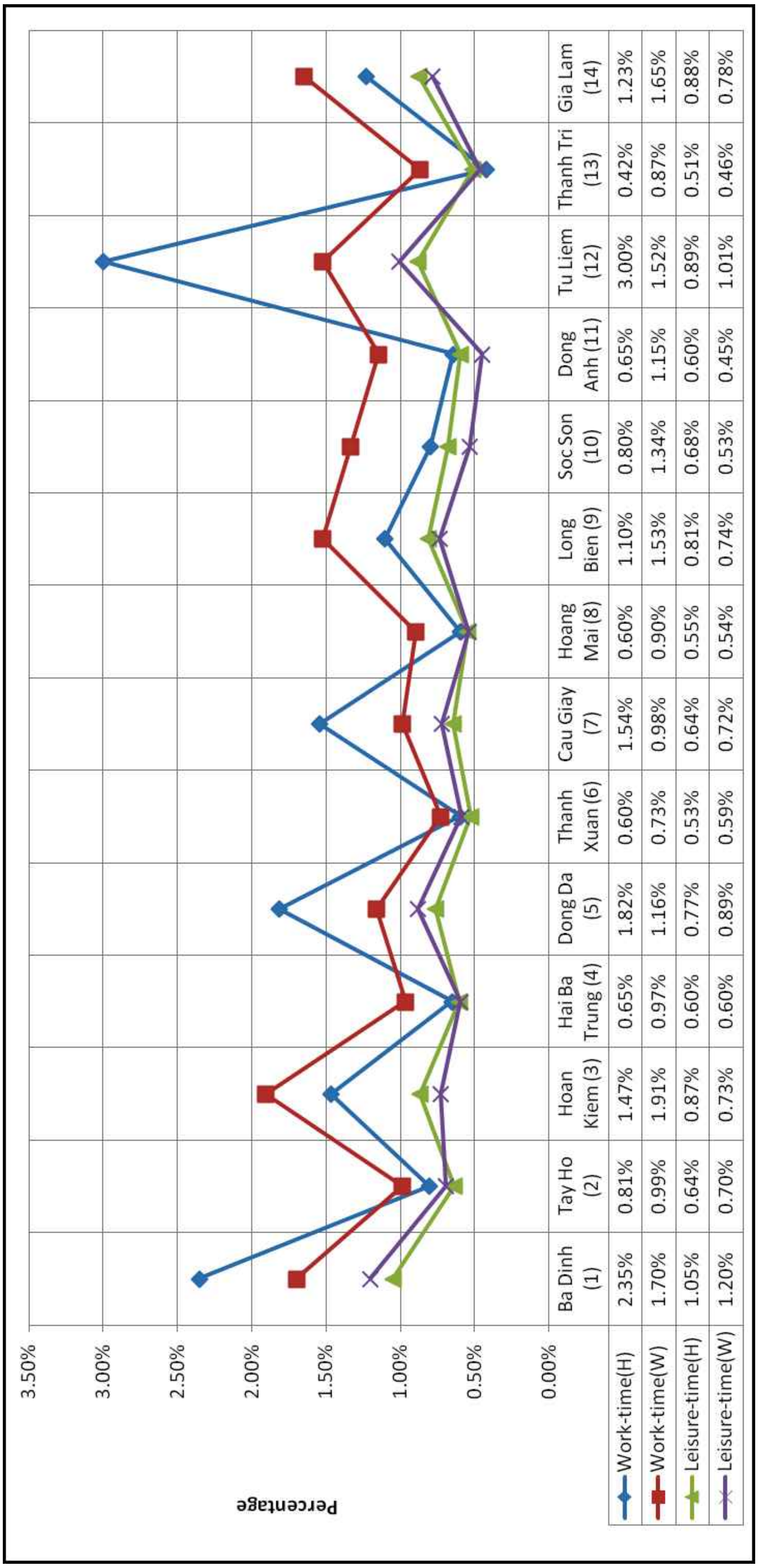


FIGURE 6.6: Expected zonal working and leisure time.

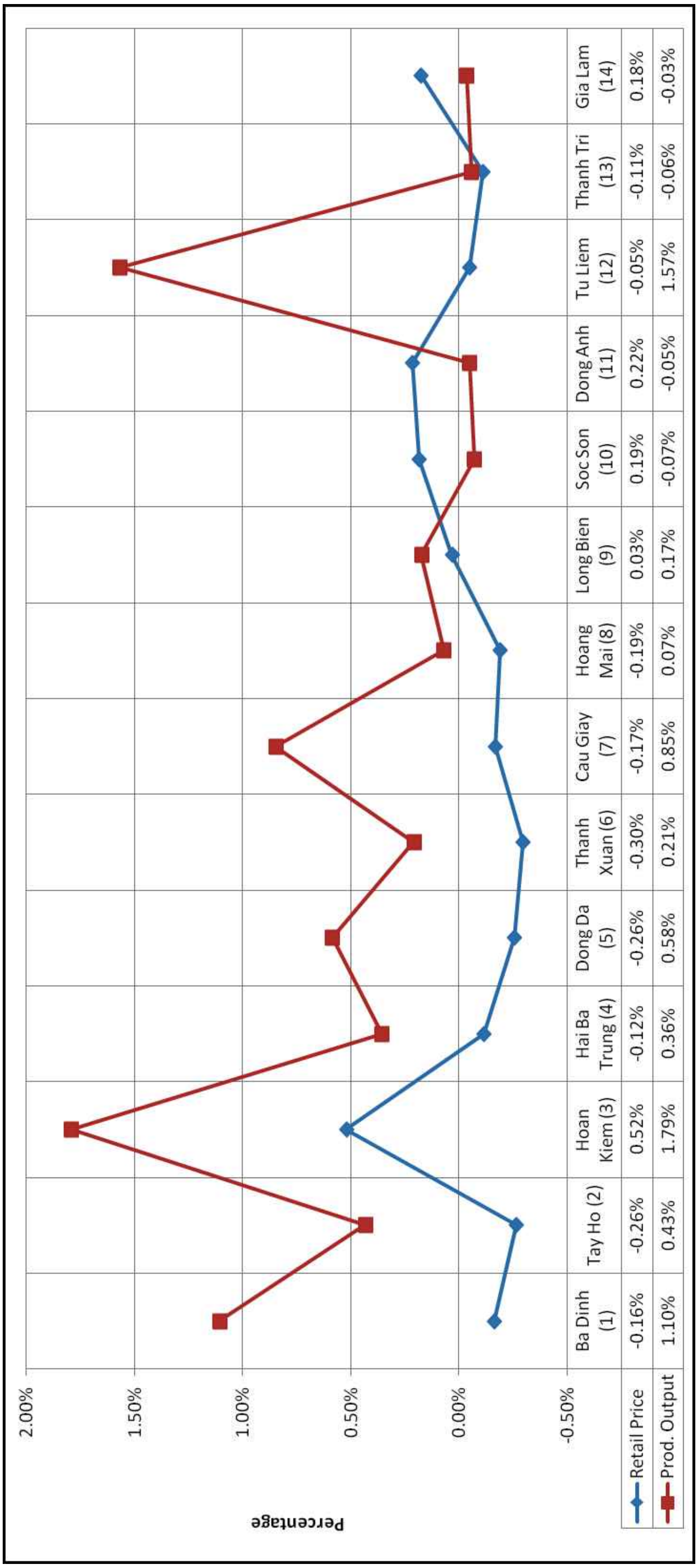


Figure 6.7: Zonal Commodity Price and Production Output Change.

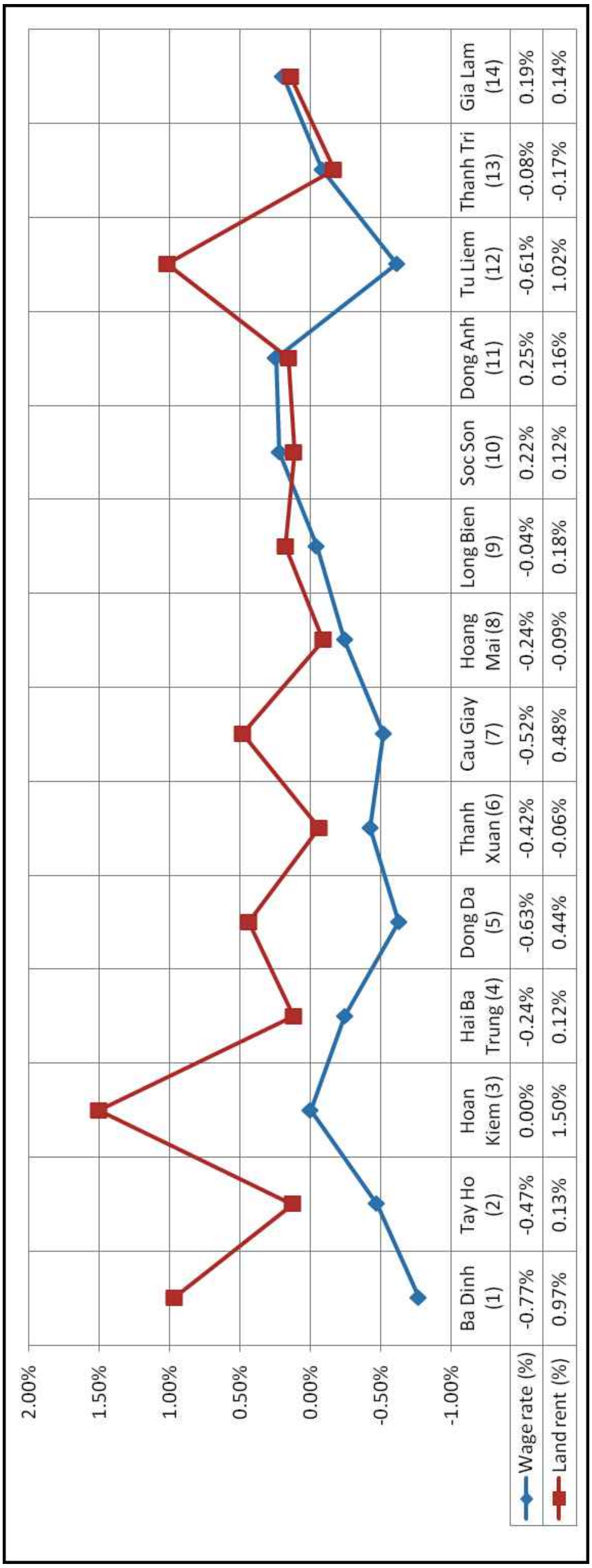
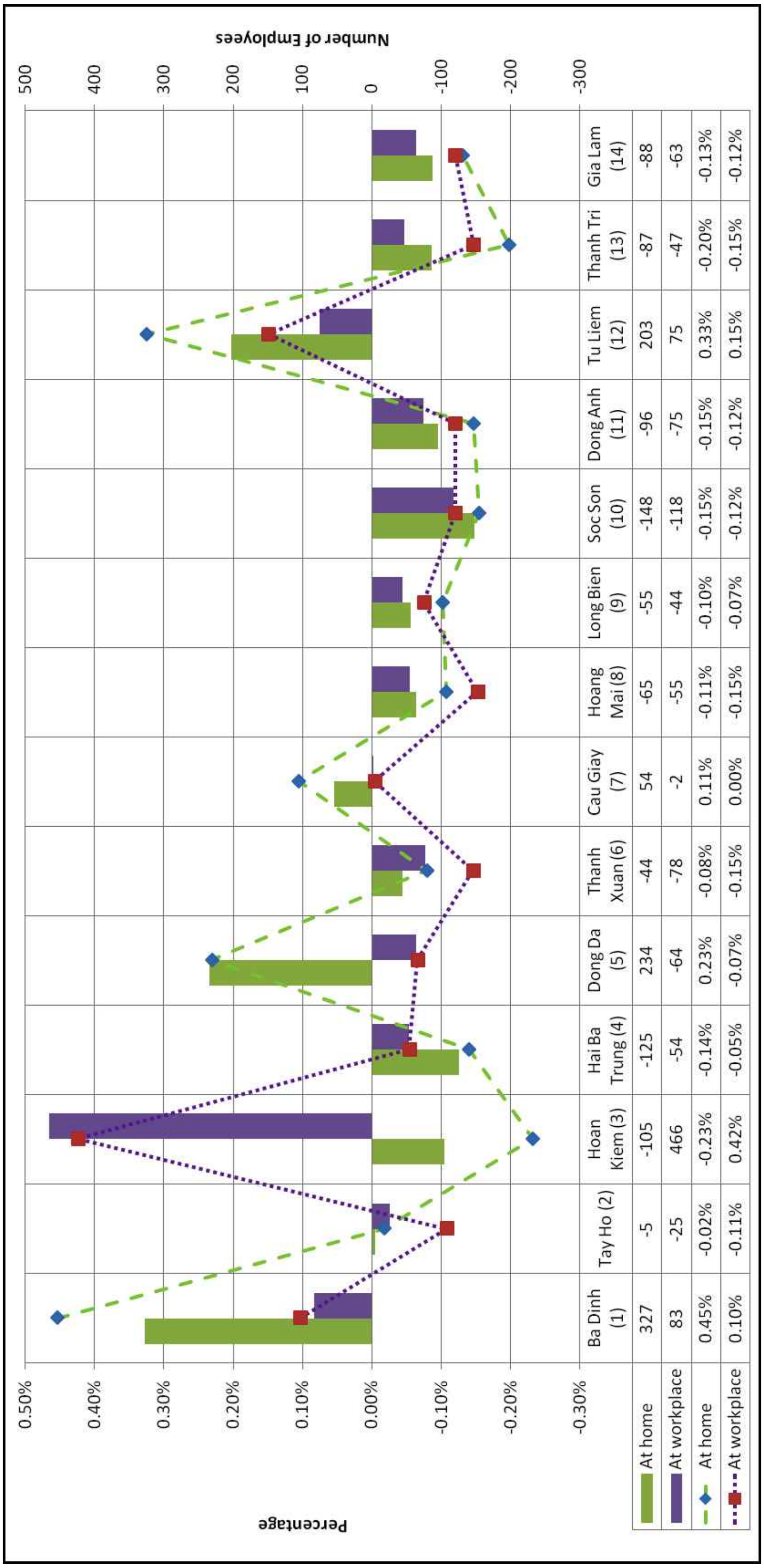
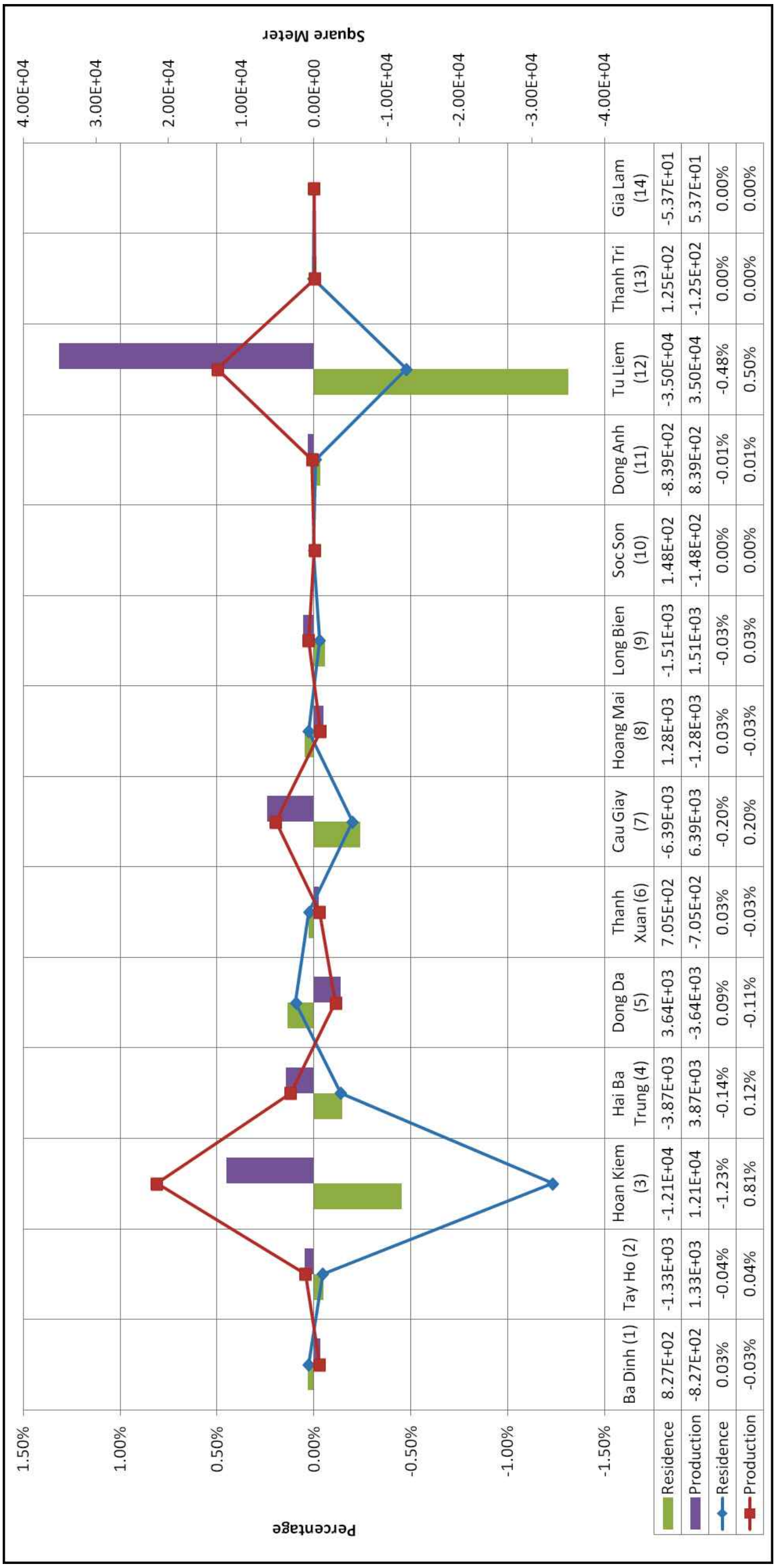


Figure 6.8: Zonal Wage-rate and Land-rent Change.



	Ba Dinh (1)	Tay Ho (2)	Hoan Kiem (3)	Hai Ba Trung (4)	Dong Da (5)	Thanh Xuan (6)	Cau Giay (7)	Hoang Mai (8)	Long Bien (9)	Soc Son (10)	Dong Anh (11)	Tu Liem (12)	Thanh Tri (13)	Gia Lam (14)
At home	327	-5	-105	-125	234	-44	54	-65	-55	-148	-96	203	-87	-88
At workplace	83	-25	466	-54	-64	-78	-2	-55	-44	-118	-75	75	-47	-63
At home	0.45%	-0.02%	-0.23%	-0.14%	0.23%	-0.08%	0.11%	-0.11%	-0.10%	-0.15%	-0.15%	0.33%	-0.20%	-0.13%
At workplace	0.10%	-0.11%	0.42%	-0.05%	-0.07%	-0.15%	0.00%	-0.15%	-0.07%	-0.12%	-0.12%	0.15%	-0.15%	-0.12%

Figure 6.9: Spatial Employment Pattern Change.



	Ba Dinh (1)	Tay Ho (2)	Hoan Kiem (3)	Hai Ba Trung (4)	Dong Da (5)	Thanh Xuan (6)	Cau Giay (7)	Hoang Mai (8)	Long Bien (9)	Soc Son (10)	Dong Anh (11)	Tu Liem (12)	Thanh Tri (13)	Gia Lam (14)
Residence	8.27E+02	-1.33E+03	-1.21E+04	-3.87E+03	3.64E+03	7.05E+02	-6.39E+03	1.28E+03	-1.51E+03	1.48E+02	-8.39E+02	-3.50E+04	1.25E+02	-5.37E+01
Production	-8.27E+02	1.33E+03	1.21E+04	3.87E+03	-3.64E+03	-7.05E+02	6.39E+03	-1.28E+03	1.51E+03	-1.48E+02	8.39E+02	3.50E+04	-1.25E+02	5.37E+01
Residence	0.03%	-0.04%	-1.23%	-0.14%	0.09%	0.03%	-0.20%	0.03%	-0.03%	0.00%	-0.01%	-0.48%	0.00%	0.00%
Production	-0.03%	0.04%	0.81%	0.12%	-0.11%	-0.03%	0.20%	-0.03%	0.03%	0.00%	0.01%	0.50%	0.00%	0.00%

FIGURE 6.10: Zonal Land-use Pattern Change.

TABLE 6.12: New Spatial Employment Pattern of Hanoi, with New UMRT.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	$\sum$ **S**
1	21,317	3,015	13,796	7,154	11,969	4,194	4,117	1,395	1,854	684	242	1,695	726	243	72,402
2	5,658	7,925	5,015	3,118	3,699	1,373	1,989	506	753	223	178	850	342	158	31,787
3	5,920	1,415	17,657	7,060	6,102	1,490	2,131	828	1,134	170	134	595	62	318	45,015
4	8,259	2,085	17,281	34,520	10,282	4,538	3,459	4,295	1,877	392	241	963	780	388	89,361
5	13,025	1,856	20,788	14,147	30,627	8,064	4,980	2,340	1,990	479	193	1,940	728	336	101,494
6	5,404	1,054	6,519	6,317	10,211	18,949	2,671	1,871	991	202	151	1,130	732	203	56,403
7	7,045	1,420	6,534	3,834	7,705	3,148	15,011	734	1,081	293	246	3,641	147	152	50,992
8	3,313	983	8,614	12,683	5,906	4,014	1,218	18,607	1,029	346	100	1,213	2,031	148	60,205
9	2,033	876	5,117	2,894	2,749	1,063	724	289	34,017	1,030	539	440	191	2,322	54,284
10	374	95	140	46	190	47	94	1	95	92,552	1,699	187	1	94	95,614
11	713	471	998	622	766	428	431	47	1,239	810	57,277	713	95	623	65,235
12	4,369	1,579	3,446	1,736	3,817	3,162	5,439	397	943	298	546	36,305	348	200	62,585
13	1,339	336	1,616	3,870	2,976	2,422	381	4,156	429	47	47	521	25,506	94	43,741
14	1,048	427	2,718	1,233	891	189	286	379	11,216	236	712	282	237	47,435	67,290
$\sum$ **D**	79,816	23,539	110,241	99,234	97,891	53,081	42,930	35,845	58,648	97,761	62,304	50,476	31,927	52,714	*896,406*

Table 6.13: New Spatial Shopping Pattern of Hanoi, with New UMRT.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	$\sum$ **S**
1	72,521	1,098	1,548	488	2,415	202	777	371	113	0	1	194	44	54	79,827
2	1,961	60,471	93	80	89	16	391	114	46	0	0	140	0	0	63,402
3	8,395	1,137	66,646	3,416	19,483	2,131	1,955	1,959	731	15	23	938	538	65	107,431
4	1,002	177	736	129,320	10,248	2,488	287	6,400	35	8	6	38	432	5	151,182
5	1,121	72	600	968	100,204	2,281	568	1,543	194	0	0	170	146	7	107,873
6	61	12	13	201	388	84,380	71	504	16	0	0	62	169	1	85,878
7	156	87	141	133	347	83	72,436	173	5	1	0	2,040	12	2	75,616
8	19	1	7	161	30	433	8	69,664	0	0	0	1	116	4	70,447
9	302	3	30	15	339	118	42	26	90,135	156	13	53	4	994	92,229
10	0	0	0	0	0	0	0	0	1	89,638	3	0	0	0	89,644
11	0	0	0	0	0	5	0	119	114	257	130,082	0	0	41	130,617
12	34	6	29	14	18	19	84	3	1	0	0	79,078	1	0	79,285
13	0	0	1	1	4	9	0	435	0	0	0	0	51,672	0	52,123
14	2	1	3	1	23	14	0	2	69	0	46	1	0	118,037	118,198
$\sum$ **D**	85,574	63,064	69,846	134,797	133,589	92,179	76,620	81,313	91,459	90,076	130,174	82,715	53,133	119,211	*1,303,751*

TABLE 6.14: The changes of Hanoi Socioeconomic Indicators by the effects of the new project

Zone		**Employment**		**Land-use**		**Output**	**Wage**	**Rent**	**Price**	**Leisure time**		**Working time**	
No.	**Name**	**L(H)**	**L(W)**	**b**	**S**	**X**	**w**	**R**	**p**	**E(H)**	**E(W)**	**WT(H)**	**WT(W)**
1	*Ba Dinh*	0.45%	0.10%	0.03%	-0.03%	1.10%	-0.77%	0.97%	-0.16%	1.05%	1.20%	2.35%	1.70%
2	Tay Ho	-0.02%	-0.11%	-0.04%	0.04%	0.43%	-0.47%	0.13%	-0.26%	0.64%	0.70%	0.81%	0.99%
3	*Hoan Kiem*	-0.23%	0.42%	-1.23%	0.81%	1.79%	0.00%	1.50%	0.52%	0.87%	0.73%	1.47%	1.91%
4	Hai Ba Trung	-0.14%	-0.05%	-0.14%	0.12%	0.36%	-0.24%	0.12%	-0.12%	0.60%	0.60%	0.65%	0.97%
5	*Dong Da*	0.23%	-0.07%	0.09%	-0.11%	0.58%	-0.63%	0.44%	-0.26%	0.77%	0.89%	1.82%	1.16%
6	Thanh Xuan	-0.08%	-0.15%	0.03%	-0.03%	0.21%	-0.42%	-0.06%	-0.30%	0.53%	0.59%	0.60%	0.73%
7	*Cau Giay*	0.11%	0.00%	-0.20%	0.20%	0.85%	-0.52%	0.48%	-0.17%	0.64%	0.72%	1.54%	0.98%
8	Hoang Mai	-0.11%	-0.15%	0.03%	-0.03%	0.07%	-0.24%	-0.09%	-0.19%	0.55%	0.54%	0.60%	0.90%
9	Long Bien	-0.10%	-0.07%	-0.03%	0.03%	0.17%	-0.04%	0.18%	0.03%	0.81%	0.74%	1.10%	1.53%
10	Soc Son	-0.15%	-0.12%	0.00%	0.00%	-0.07%	0.22%	0.12%	0.19%	0.68%	0.53%	0.80%	1.34%
11	Dong Anh	-0.15%	-0.12%	-0.01%	0.01%	-0.05%	0.25%	0.16%	0.22%	0.60%	0.45%	0.65%	1.15%
12	*Tu Liem*	0.33%	0.15%	-0.48%	0.50%	1.57%	-0.61%	1.02%	-0.05%	0.89%	1.01%	3.00%	1.52%
13	Thanh Tri	-0.20%	-0.15%	0.00%	0.00%	-0.06%	-0.08%	-0.17%	-0.11%	0.51%	0.46%	0.42%	0.87%
14	Gia Lam	-0.13%	-0.12%	0.00%	0.00%	-0.03%	0.19%	0.14%	0.18%	0.88%	0.78%	1.23%	1.65%

Note) * The wage-rate at zone No.3, *Hoan Kiem* District, is selected as numeraire for simulation. In this case, we assumed that the numeraire had not changed between the two scenarios.

6.4.2.2 Monetary Social Benefit Estimation

In previous section 6.4, we can see the change in urban socioeconomic indicators. In this section, we will measure the aggregate monetary benefit which generated by the new introduced policy. This value will be calculated indirectly based on the change of expected utility and total income of study region in the base year 2005. The monetary benefit generated by the new project in 1 fiscal year show in Table 6.15.

TABLE 6.15: Economic benefit generated by the new project in one year.

Items	Value	Unit
Total Income at Base State 2005	3.2735E+11	(000 VND)
Expected Utility at state 0, $W_0 = E(U^0_{ij})$	16.09697007	-
Expected Utility at state 1, $W_1 = E(U^1_{ij})$	16.10026051	-
Expected Utility change, $\Delta(W)$	0.003290436	-
Monetary Social Benefit	66,915,332	(000 VND)
	4,182.208	(000 USD)
Total Income Changes	0.23	(%)

Note) The average exchange rate in 2005: 1 USD = 16,000 VND. W_0 and W_1 are expected utility for all people living in study region, resulted from without, or benchmarking model running, and with proposed project.

6.5 Summary and Conclusion

In this chapter, a pilot UMRT project, one part of the urban light-metro network which will be constructed in Hanoi, have been evaluated by utilizing the Benchmark Hanoi CUE model estimated in Chapter 5. In order to realize this work, a method for evaluating a type of transportation infrastructure construction (UMRT) has been designed. The results outputed from model simulation have been shown in diagrams and tables and the mechanism of the interaction among variables have been explained coherently in a systematic way thanking to microeconomics theory.

The economic benefit estimated from this model, of course, is not total social benefit that the project can generate. It should be taken into account other factors such as CO2 emission, traffic accidents, noisy and so on to exhaust the other effects from some other positive/negative externalities. These works can be done by explicitly integrating the CUE model with other sub-models in future when their input data becomes available. Further, freight transportation also could be taken into account if urban logistic data are collected.

Chapter 7

Conclusions and Recommendations

7.1 Brief Summary

This study has pursued an approach of computable urban economic or urban economic computable general equilibrium modeling for urban economy analysis. The reason is that CUE model has been a modern model with many advanced features. It is also that CUE model possesses a huge capability in practical applications. In the research, there are 3 main missions have been accomplished.

In the first mission, a solid mathematic structure of CUE model, in which the agents' behaviors are model consistent with microeconomic theory, has been formulated. It also included an sound programable algorithm for calculation.

In the second mission, a methodology of using CUE model in practical application has been established, with simple and standard input database. It included data preparation, model estimation and model calibration to develop a benchmark CUE model for application. Hanoi has been selected as the case study for CUE model estimation. A FORTRAN computer program also has been developed in this mission for numerical calculation.

In the third mission, the benchmark Hanoi CUE has been used to evaluate the economic benefit of a new transportation infrastructure project, an new UMRT line which is planned to be added to current transportation network.

7.2 Conclusions

Brief conclusive points are highlighted as follows,

- Integrated Land use - Transportation (ILUT) models have been continuously developed, updated, customized and widely use in real world. Derivative models in this streamline could be capable for various types of urban policies related to transportation and spatial development.
- Computable Urban Economic (CUE) model is advanced variant of ILUT model. Structure of CUE model are fully based on microeconomic theory then it can overcome the inconsistent features of ILUT model. The indirect utility is consistent with benefit measurement then urban policies evaluated by CUE model is consistent with cost-benefit analysis. CUE model can output an informative set of variables describing real urban economy at equilibrium state, then they can provide rigorous and clear answers to elaborate questions in a systematic way (Chapter 4).
- CUE model is absolutely an "operational" urban model in the sense that it can be estimated, calibrated and applicable for urban policy analysis. Moreover, the input data set for model estimation is simple and standard database (Chapter 5).
- Using CUE model for evaluating economic benefit of transportation infrastructure development is a modern and suitable approach in the sense that it can help decision maker inreasing the accountability and transparency of considered policy (Chapter 6).

7.3 Recommendations for Future Works

The CUE framework formulated in Chapter 4 is mainly inspired by utilizating of the two standard available database of Hanoi city at 2005, person trip and land use. The major objective in begining stage is oriented for evaluating the economic benefit of transportation developed in the city. In some extents, the model can be expanded or integrated with other models in order to widen the analysis scope it can cover as follows:

- Loosing the boundary of location choice by assumption of open city: worker can freely choose the location for housing and working inside or outside of city boudary; take into account of import/export.

- Explicitly introducing of other players: developer (housing market), landlord (land market), government (taxes, road pricing).
- Introduction of basic sectors (agriculture, manufacturing) in production.
- Integrated with environmental model: CO2 emission.

The above works, however, along with evident benefits the model can bring to user, also could make the output results become costly in terms of calculation time, and also in the means that richer database should be collected and prepared for calculation.

In practical application, CUE models have a thick fruitful profile in many metropolitans areas such as Nagoya, Gifu, Sapporo, Hiroshima, Kyoto, Tokyo (Japan), Chicago (U.S.),... in various types of urban policy such as transportation improvement (road network, urban railway new development/improvement, road pricing, railway fare, guideway systems), land-use, housing, flood control,... Therefore, they also would be a good solution for developing countries, where the urbanization have been indispensable trend in future.

For the case of Hanoi, with an ambitious construction plan toward 2030 and vision 2050, CUE model is a good offer for urban planning and management in general. In beginning stage, a long list of large scale projects in transportation infrastructure development planned to carry out in near future would be the first priority that CUE model aims at. For other type of urban policies or other cities/metropolitans such as Ho Chi Minh City, Hai Phong or Da Nang,... a derivative, extended or even absolutely new version of CUE model also can be promising candidate.

Appendix A

Numerical Algorithm for Solving Non-linear System Equations

This appendix is to present the use of Newton-Raphson for solving non-linear system equations. The contents are mainly based on or partly extracted from Chapter 11 of the book *Dynamic General Equilibrium Modeling: Computational Methods and Applications*, written by Burkhard Heer and Alfred Maußner [19].

A.1 Newton-Raphson Method

A.1.1 The Method

The original idea in Newton-Raphson method is to find successively better approximations to the root or zero value of a real value function. For the case of simultaneous equations, the method also can be applied. The common problem that we are usually facing off is how to solve for n equations with n variables as following:

$$\begin{cases} f^1(\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n) = 0, \\ f^2(\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n) = 0, \\ \ldots \\ f^n(\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n) = 0. \end{cases} \tag{A.1}$$

Let's denote variables as a vector, $\mathbf{x} = [x_1, x_2, \ldots, x_n]$ and $g(\mathbf{x})$ is linear approximation of $f(\mathbf{x})$ at point begin point$\mathbf{x}_s$, the problem can be rewritten as following:

$g(\mathbf{x}) = f(\mathbf{x}^s) + J(\mathbf{x}^s)w,.$

in which, $w = (\mathbf{x} - \mathbf{x}^s)$ is called as Newton step and J is the Jacobian matrix, defined as following:

$$J = \begin{bmatrix} f_1^1(\mathbf{x}) & f_2^1(\mathbf{x}) & \dots & f_n^1(\mathbf{x}) \\ f_1^2(\mathbf{x}) & f_2^1(\mathbf{x}) & \dots & f_n^1(\mathbf{x}) \\ \vdots & \vdots & \ddots & \vdots \\ f_1^n(\mathbf{x}) & f_2^n(\mathbf{x}) & \dots & f_n^n(\mathbf{x}) \end{bmatrix} \tag{A.2}$$

By setting $g(\mathbf{x}^{s+1}) = 0$, we can derive the equation to approximate value of $\mathbf{x}$ at step $s + 1$ as following:

$$\mathbf{x}^{(s+1)} = \mathbf{x}^s - J(\mathbf{x}^s)^{-1} f(\mathbf{x}^s) \tag{A.3}$$

A.1.2 Algorithm

The original numerical algorithm based on Newton-Raphson method for solving system equations are summerized as following steps [19]:

- *Step 1:* initialize the starting value of $\mathbf{x}^0[\underline{\mathbf{x}}, \overline{\mathbf{x}}]$,
- *Step 2:* calculate the Jacobian matrix $J(\mathbf{x}^0)$ of f at $\mathbf{x}^0$, and then solve $J(\mathbf{x}^0)w = -f(\mathbf{x}^0)$. If $\mathbf{x}^1 = \mathbf{x}^0 + w \notin [\underline{\mathbf{x}}, \overline{\mathbf{x}}]$ then we need to randomly choose $\lambda \in (0, 1)$ so that $\mathbf{x}^2 = \mathbf{x}^0 + \lambda w \in [\underline{\mathbf{x}}, \overline{\mathbf{x}}]$, and after that set $\mathbf{x}^1 = \mathbf{x}^2$,
- *Step 3:* check for convergence: if $\|f(\mathbf{x}^1)\|_\infty < \epsilon$ and/or $|\mathbf{x}_i^1 - \mathbf{x}_i^0|/(1 + |\mathbf{x}_i^0|) \leq \epsilon \forall i$ for a given tolerance $\epsilon \in \mathbb{R}_{++}$ then the iterative calculation can be stopped, if not, set $\mathbf{x}^0 = \mathbf{x}^1$ and return to the step 2.

A.2 Line Search Algorithm

The original algorithm usually can be used in case the initial guess value of $\mathbf{x}^0$ is closed to the real final solution and function $\mathbf{f}$ is well-behaved in its domain. In this case, usually $\lambda = 1$. However, in some circumstances where the next approximation of $\mathbf{x}^1$ goes out of its boundary, choosing an appropriate and effective value of λ becomes critical but not easy task. This algorithm show us a common appoach to overcome this obstacle[1].

The algorithm is presented in Figures A.1 and A.2:

[1]You can easily find out this content at page 617 in great book of Heer and Maußner [19]

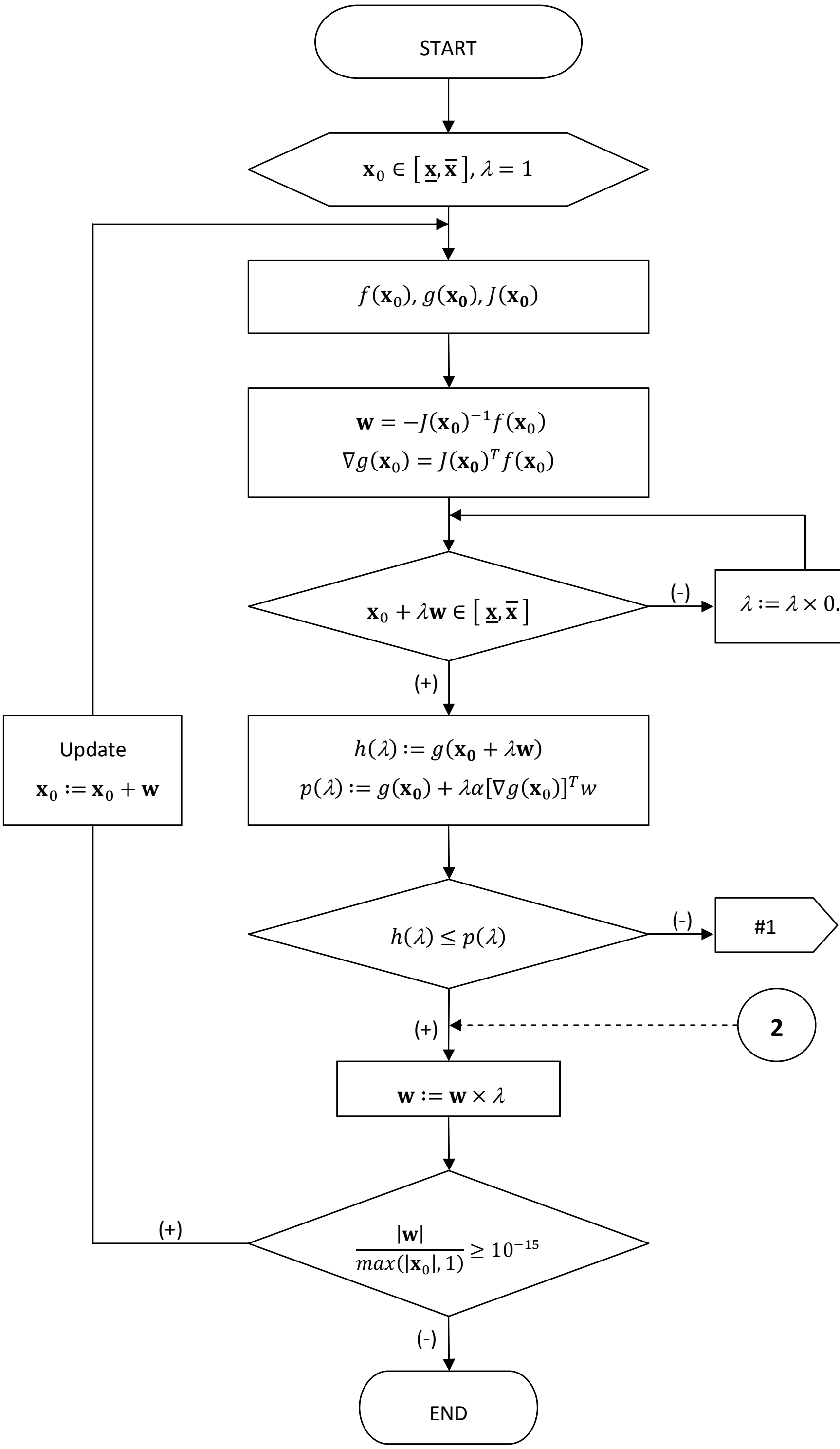


FIGURE A.1: Line search algorithm for Programming.

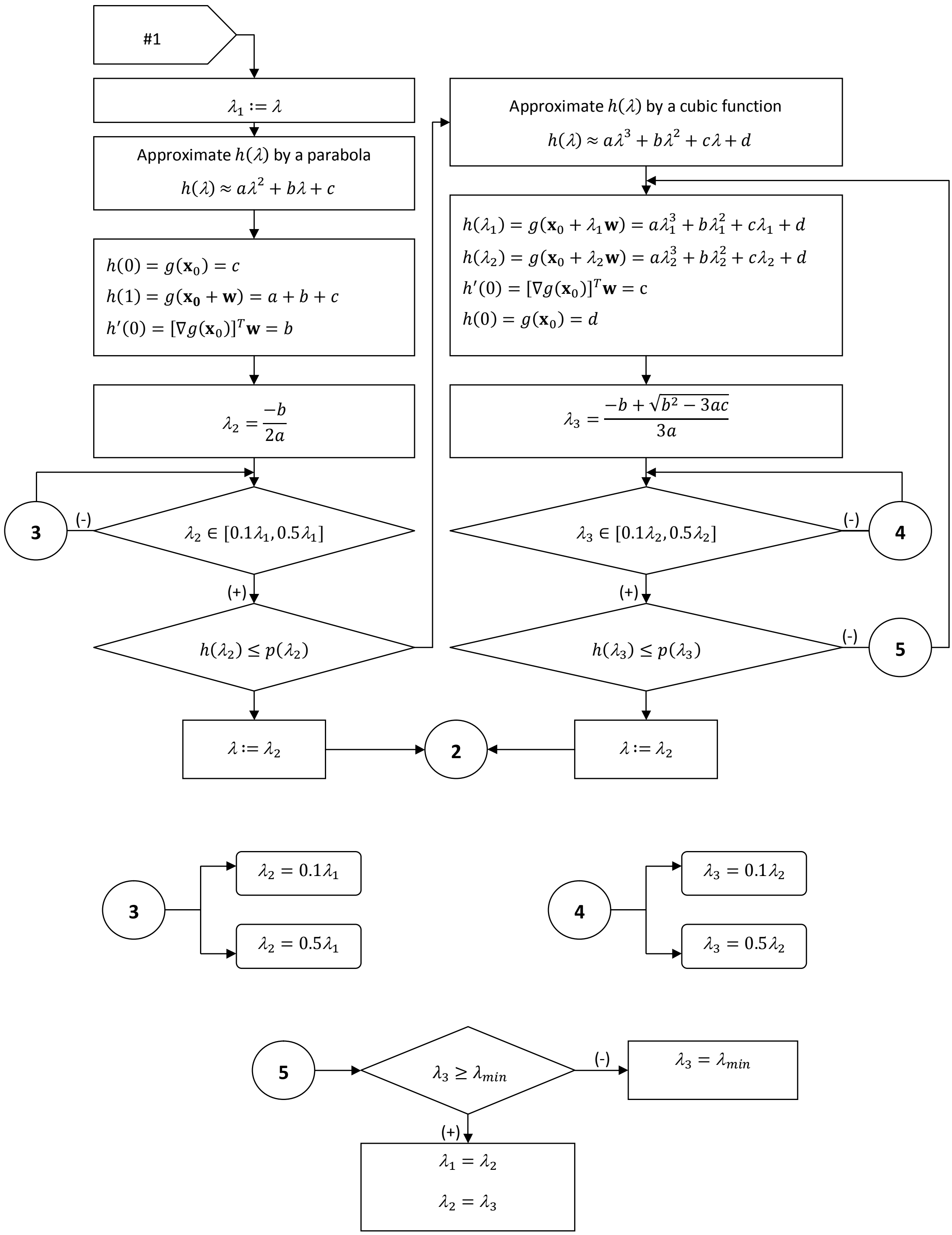


Figure A.2: Line search algorithm for Programming (cont.)

Bibliography

[1] (2008). Hanoi pilot light metro line, section nhon-hanoi railway station, feasibility study report, final report. Technical report, Hanoi Metropolitan Rail Transport Project Board.

[2] 1259/QD-TTg (2011). The hanoi capital construction master plan to 2030 and vision to 2050. Vietnamese Government.

[3] 90/2008/QD-TTg (July, 2008). Decision on approval of transport development plan for hanoi capital city to 2020. Vietnamese Government.

[4] Anas, A. (1982). *Residential Location Markets and Urban Transportation: Economic Theory, Econometrics and Policy Analysis with Discrete Choice Models*. New York Academic Press.

[5] Anas, A. (1987). *Modeling in urban and regional economics - Fundamentals of pure and applied economics*. Harwood Academic Publishers, London.

[6] Anas, A. and Kim, I. (1996). General equilibrium models of polycentric urban land use with endogenous congestion and job agglomeration. *Journal of Urban Economics*, 40(0031):232–256.

[7] Anas, A. and Liu, Y. (2007). A regional economy, land use, and transportation model (relu-tran): Formulation, algorithm design, and testing. *Journal of Regional Science*, 47(3):415–455.

[8] Anas, A. and Xu, R. (1999). Congestion, land use, and job dispersion: A general equilibrium model. *Journal of Urban Economics*, 45(3):451–473.

[9] Armington, P. (1969). A theory of demand for products distinguished by place of production. *International Monetary Fund Staff Papers*, Vol. 16(1):159–178.

[10] Ben-Akiva, M. and Lerman, S. R. (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand*. The MIT Press.

[11] Boarnet, M. G. and Crane, R. (2001). *Travel by design: The influence of Urban form on travel*. Oxford University Press.

[12] Borges, A. M. (1986). Applied general equilibrium models: An assessment of their usefulness for policy analysis. *OECD journal: economic studies*, 7:7–43.

[13] General-Statistics-Office (2012). *Statistical Yearbook of Vietnam 2007, 2012*. Statistical Publishing House.

[14] Hanoi-People's-Committee and JICA (March, 2007a). The comprehensive urban development programme in hanoi capital city of the socialist republic of vietnam (haidep). Technical report, Hanoi-People's-Committee and JICA.

[15] Hanoi-People's-Committee and JICA (March, 2007b). Technical report no.1, household interview survey. Technical report, The Comprehensive Urban Development Programme in Hanoi Capital City of the Socialist Republic of Vietnam (HAIDEP).

[16] Hanoi-People's-Committee and JICA (March, 2007c). Technical report no.3, traffic demand analysis. Technical report, The Comprehensive Urban Development Programme in Hanoi Capital City of the Socialist Republic of Vietnam (HAIDEP).

[17] Hayashi, Y. and Doi, K. (1989). A model for analysing the imputation of commuters' benefits to land property values. In *Selected Proceedings of the 5th World Conference on Transport Research*, pages 303–317.

[18] Hayashi, Y. and Tomita, Y. (1989). A micro-analytic residential mobility model for assessing the effects of transport improvement. In *Selected Proceedings of the 5th World Conference on Transport Research*, pages 91–105.

[19] Heer, B. and Maußner, A. (2009). *Dynamic General Equilibrium Modeling: Computational Methods and Applications*. Springer, second edition.

[20] Helsley, R. W. and Sullivan, A. M. (1991). Urban subcenter formation. *Regional Science and Urban Economics*, 21(2):255–275.

[21] Kobayashi, K., Lakshmanan, T., and Anderson, W. P. (2006). *Structural Change in Transportation and Communications in the Knowledge Society*. Edward Elga Publishing Limited.

[22] Lowry, I. S. (1964). A model of metropolis. Technical Report RM-4035-RC, The RAND Corporation, Santa Monica CA.

[23] Miyamoto, K. and Kitazume, K. (1990). A land use model based on random utility/rent-bidding analysis (rurban). In *Selected Proceedings of the 5th World Conference on Transport Research*, volume Vol. 4, pages 107–121.

[24] Miyamoto, K., Noami, T., Kuwata, Y., and Yokozawa, K. (1993). An evaluation method of transport projects with the aid of rurban model. In *Selected Proceedings of the 6th World Conference on Transport Research*, volume Vol. 1, pages 55–66.

[25] Miyamoto, K., Vichiensan, V., Sugiki, N., and Kitazume, K. (2007). Applications of rurban integrated with a transport model in detailed zone system. In *Proceedings of the 11th World Conference on Transport Research*, volume CD-ROM.

[26] Morisugi, H. and Ohno, E. (1992). A benefit incidence matrix for urban transport improvement. *The Journal of Regional Science Association Internation*, Vol. 71(1):53–70.

[27] Morisugi, H., Ohno, E., and Miyagi, T. (1993). Benefit incidence of urban ring road - theory and case study of the gifu ring road. *Transportation*, Vol. 20(1):285–303.

[28] Muto, S., Takagi, A., and Ueda, T. (2003). The benefit evaluation of transport network improvement with computable urban economic model. In *Selected Proceedings of the 9th World Conference on Transport Research*. Elsevier Science, CD-ROM, No.6218.

[29] Muto, S., Ueda, T., Yamaguchi, K., and Yamasaki, K. (2004). Evaluation of environmental pollutions occurred by transport infrastructure project at tokyo metropolitan area. In *Selected Proceedings of the 10th World Conference on Transport Research*. CD-ROM, No.1152.

[30] OECD-CDRF (2010). Trends in urbanisation and urban policies in oecd countries: What lessons for china? Technical report, OECD-CDRF.

[31] Ortúzar, J. d. D. and Willumsen, L. G. (2011). *Modelling Transport*. John Wiley and Sons, fourth edition.

[32] Oryani, K. and Harris, B. (1996). Review of land use model and recommended model for dvrpc. Technical Report ORNL-6881, U.S. Department of Energy.

[33] Phin, D. T. and Dotson, E. (2013). Urban transport institutions and governance and integrated land use and transport, hanoi, vietnam. Case Study.

[34] Sheffi, Y. (1985). *Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods*. Printice-Hall.

[35] Sivitanidou, R. and Wheaton, W. C. (1992). Wage and rent capitalization in the commercial real estate market. *Journal of Urban Economics*, 31(2):206–229.

[36] Southworth, F. (1995). A technical review of urban land use-transportation models as tool for evaluating vehicle travel reduction strategies. Technical Report ORNL-6881, U.S. Department of Energy.

[37] Sullivan, A. M. (1986). A general equilibrium model with agglomerative economies and decentralized employment. *Journal of Urban Economics*, 20(1):55–74.

[38] Takagi, A., Muto, S., and Ueda, T. (1999). The benefit evaluation of urban transportation improvements with computable urban economic model. In *Shanghai International Symposium on Urban Transportation Proceedings*, CD-ROM.

[39] Takagi, A. and Ueda, T. (2001). Evaluation of flood mitigation countermeasures considering the interdependence between flood risk and land use. In *First Annual IIASA-DPRI Meeting*, pages 87–99.

[40] TCVN (March, 2005). Highway - specifications for design. Technical report, Vietnam.

[41] Train, K. E. (2012). *Discrete Choice Methods with Simulation.* John Wiley and Sons, second edition.

[42] Ueda, T., Hiratani, K., and Tsutsumi, M. (1993). Landuse model based on the general equilibrium of land and building markets. In *Proceedings of International Conference on Land Problem and Urban Policy, Kyoto*, pages 183–198, Kyoto.

[43] Ueda, T., Tsutsumi, M., Muto, S., and Yamasaki, K. (2009). Computable urban economic models in japan. In *Research Show Window: EASTS-Japan Working Paper Series*. No.09-4.

[44] Ueda, T., Tsutsumi, M., Muto, S., and Yamasaki, K. (2012). Unified computable urban economic model. *The Annals of Regional Science*, Vol. 50:341–362.

[45] Ueda, T., Tsutsumi, M., and Nakamura, H. (1995). An urban transport and activity location model for the evaluation of commuting rail improvement. In *The 7th World Conference of Transportation Research, Sydney, Australia, 16-21 July, 1995*, Sydney, Australia.

[46] United-Nations (2007). World urbanization prospects. Technical report, UN.

[47] United-Nations (2011). World urbanization prospects. Technical report, UN.

[48] Vietnamese-Parliament (March, 2013). Vietnamese labor law. Technical report, Vietnam.

[49] Wegener, M. (2003). Overview of land-use transport models. In *Proceedings of CUPUM '03 Sendai*, pages 20–40.

[50] White, M. J. (1988). Location choice and commuting behaviour in cities with decentralized employment. *Journal of Urban Economics*, 24(2):129–152.

[51] Wieand, K. F. (1987). An extension of the monocentric urban spatial equilibrium model to a multicenter setting: The case of the two-center city. *Journal of Urban Economics*, 21(3):259–271.

[52] World-Bank (2011). Vietnam urbanization review. Technical report, World Bank.

[53] Yamasaki, K., Ueda, T., and Muto, S. (2007). The evaluation of the tokyo-metropolitan area policy by computable urban economic model (cue). In *Selected Proceedings of the 11th World Conference on Transport Research*. University of California Berkeley, CD-ROM, No.734.

[54] Yamasaki, K., Ueda, T., and Muto, S. (2008). Impacts of transport infrastructure policies in population-declining metropolitan area, business productivity and quality of urban life in tokyo. In *11th Uddevalla Symposium 2008*. Kyoto, Japan.

[55] Yoon, J., Aoyama, Y., Nakagawa, D., and Matsunaka, R. (2000). A practical land use-transport interaction model considering changes in population and industrial activities. In *Proceedings of International Symposium on City Planning*, pages 381–390, Kobe.

[56] Yoon, J., Aoyama, Y., Nakagawa, D., and Matsunaka, R. (2003). An evaluation of urban and transport policy using a land-use/transport interaction model. In *Selected Proceedings of the 9th World Conference on Transport Research*, CD-ROM.

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