Doctoral Dissertation

Historical Study of Relationship between Land Use and Transport Service Policies in Gifu City and its Policy Evaluation Using an Integrated Traffic Assignment Model

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Graduate School of Engineering

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ABSTRCT

Rapid urbanization and growing economic prosperity have brought a higher rate of motorization to both developed and developing countries. Motorization causes many problems such as exhaust pollution, traffic congestion. A shift to environmentally friendly and sustainable cities will require a reduction in the unnecessary car use and the use of public transportation and bicycles. The situation in economic and motorization growth is very similar in Japan during 1950s to 1980s and in China during 1980s to 2010s. As a developed country, the experience of policy of urban and transport planning in Japan is very important and referential to developing countries like China.

In order to appraise urban and transport policies of Japan, it is important to identify the relationships among urban planning factors to provide a useful information for future urban and transportation planning. A key issue for sustainable development is a relationship between transport development and land use change. The highly mobile transportation system has affected land use patterns, particularly how people choose to locate their homes and businesses. Conversely, spread out land use patterns further increase the demand for transportation because of greater travel distances.In this study, as first part, we summarizean experience in past 40 years of a typical middle-sized suburbanization and motorization Japan local city, Gifu City, on a relationship between land use and transport.We obtained three major results. First, the demand for urban transport system grew as the city population and economy grew. There is a predictable public opinion for more transportfacilities in urban areas.As described above, we know that the changesof transport system in the Gifu City had animportant impact on urban planning. Second, with high economic growth, the motorization of Gifu City increased continuously, creating a demand for roadnetwork construction. The ring road completed these demands and created the city framework. It also changed land use by industries, commerce, and agriculture. Industrial and commercial land use moved from downtown to the area along the ring road. Third, the public argued that the tram impeded car traffic, which forced the local governmentto give up the tram. This changed the public transport system and exacerbated car traffic. A life style revolving around the automobile enhanced the shift of urban planning into amore caroriented city.

From the analysis of the transport and land use of Gifu City, the strong relationship among them has been confirmed, and especially Gifu City shifted to more car oriented city. On the other hand, in sustainable society, promoting the use of public transportation is a pressing issue. The relationship between land use and transport service is not negligible and therefore a change in the destination choice when transport service changes should be considered. The integration between the spatial location of activities and the use of transport has been a critical planning issue for many years. One way to

estimate wider impacts of transport policies is to develop a model which incorporates the interactions between land use and transport.The second part of this study develops an integrated traffic assignment model which encloses the transport mode and destination choice. We attempt to evaluate the change of destination choice as well as mode choice when land use or transport service is changed. The feature of the proposedmodel is (1) travel time of bus is effected by car traffic congestion, (2) a LOGIT type stochastic choice is applied for route, mode and destination choice and therefore the model is expressed as integrated stochastic user equilibrium (SUE) model, and (3) the destination choice behavior is based on three trip purpose: commuting, business and leisure. We tested the model both on an assimilated and Gifu City network, and evaluated the change of destination as well as mode choice when land use or transport service policy is changed. By considering the delay of buses caused car traffic congestion, the model expressedbus travel time in road network space more precisely. By this integrated model, not only transport measures, land use policy like activation ofCentral Business Districts can also be evaluated. Moreover, since all of choice behavior is formulated as a LOGIT type, a consumer surpluscan be calculated by obtaining log-sum variablesandthis feature enables us to connect this model to cost benefit analysis. Through the analysis, constructing suburban shopping centers raised probability of car use, even though the traffic congestion may get worse around suburban area. On the other hand, increasingan attractiveness of CBD areas and introduction of Bus Rapid Transport system can contribute to improve the traffic situation for the whole city. In conclusion, the developed model can properly express the interaction between transport and land use and thus the effect of varieties of transport as well as land use policies to enhance sustainability of the cities can be evaluated using this model. Such model must be a strong tool for developing countries to develop towards environmentally friendly cities and avoid excessive motorization.

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CHAPTER 1

Introduction

1.1 Research Background

Rapid urbanization and growing economic prosperity have brought a higher rate of motorization to developed and developing countries. Motorization causes many such as exhaust pollution, traffic congestion, and an increase in the number of who cannot drive. A shift to environmentally friendly and sustainable cities will require reduction in unnecessary car use and the use of public transportation and bicycles.

The high economic growth rates achieved by China in the decades following the reforms passed in 1978 are closely linked to the productivity levels of the population. According to National Bureau of Statistics of China, China's nominal GDP by Expenditure surpassed that of Italy in 2000, France in 2002, the United Kingdom in 2006 and that of Germany in 2007, before overtaking Japan in 2009, making China theworld's second largest economy after the United States.From 1979 until 2010, China's average annual GDP growth was 9.91%, reaching an historical high of 15.2% in 1984 and a record low of 3.8% in 1990. Based on the current price, the country's average annual GDP growth in these 32 years was 15.8%, reaching an historical high of 36.41% in 1994 and a record low of 6.25% in 1999.

The Japanese post-war economic miracle is the name given to the historical phenomenon of Japan's record period of economic growth between post-World War II era to the end of Cold War (1954-1973). During the economic boom, Japan was catapulted into the world's second largest economy (after the United States) by the 1980s.

According toJohn Sousanis (2011), the number of vehicles in operation worldwide surpassed the 1 billion-unit mark in 2010 for the first time ever. Global registrations jumped from 980 million units in 2009 to 1.015 billion in 2010.The figures reflect the approximate number of cars, light-, medium- and heavy-duty trucks and buses registered worldwide, but that does not include off-road, heavy-duty vehicles.The 3.6% rise in vehicle population was the largest percentage increase since 2000, while the 35.6 million year-to-year unit increase was the second-biggest increase in overall volume ever.The market explosion in China played a major role in overall vehicle population growth in 2010, with registrations jumping 27.5%. Total vehicles in operation in the country climbed by more than 16.8 million units, to slightly more than 78 million, accounting for nearly half the year’s global increase.The leap in registrations gave China the world’s second-largest vehicle population until 2009, pushing it ahead of Japan, with 73.9 million units, for the first time.About 13.6 million vehicles were sold in 2009, and motor vehicle registrations in 2010 increased to more than 16.8 million units, representing nearly half the world’s fleet increase in 2010.The number of cars and motorcycles in China increased 20 times between 2000 and 2010 (Jonathan Watts, 2011). This explosive growth has allowed China to become the world's largest market for new vehicles overtaking the U.S. in 2009 (Li Y. et al., 2011).

The situation in economic and motorization growth is very similar in Japan during the 1950s to 1980s and in China during the 1980s to 2010s. As a developed country, the experience of policy of urban and transport planning in Japan is very important and referential to developing countries like China. In order to appraise urban and transport policies of Japan, it is important to identify the relationships among urban planning factors to provide useful information for future urban and transportation planning.

When policies were created that attached importance to construction of a road network due to the development of motorization and elimination of the city public transport system, the surrounding suburban area became the focus of land-use development. As a result, local citiesin Japanare plagued by the doughnut phenomenon.In sustainable societies, promoting the use of public transportation is a pressing issue. On the other hand, bus transport servicethat should support citizen’s daily life has been in trouble.

A key issue for sustainable developmentis the relationship between transportation and land use. The relationship between land use and transport service is not negligible in urban growth.If we can summarizethe experience from analyzing the situation in the past 40 years on the relationship of land use and transportation in local Japanese cities, maybe we can give directionality to the developingcountries.

1.2 Research Objectives

As first part, we summarizethe experience in the past 40 years of a typical middle-sized suburbanization and motorization local Japanese city, Gifu City, on the relationship between land use and transport.Gifu City is a typical middle-sizedsuburbanization and motorizationcity.

The relationship between land use and transport service is not negligible and therefore a change in the destination choice when transport service changes should be considered. The integration between the spatial location of activities and the use of transport has been a critical planning issue for many years. One way to estimate wider impacts of transport policies is to develop a model which incorporates the interactions between land use and transport. The second part of this study develops an integrated traffic assignment model which encloses the transport mode and destination choice.We test the model both on an assimilation and Gifu City network, and evaluate the change of destination as well as mode choice when land use or transport service policy is changed.

The objectives of this study are:

- History provides valuable lessons on the interplay of factors that shape urban growth and development.Summarize the lessons of past urban planning and transport planning and their relevancein Gifu City by looking at planning and policy in the past 40 years by using historical maps, population census and socioeconomic statistics data andthe impact of land use planning and transport planning to personal transportation movement with the above data and Personal Trip Survey data.

- Present an integrated traffic assignment model which encloses the transportation mode choice and destination choice. We attempt to evaluate the change of destination choice as well as mode choice when land use or transport service is changed.

1.3 Outline of the Dissertation

The outline of the dissertation is shown in Fig1.1 as follows.

Chapter 1explains the background, the objectives of the study.

Past studies on historical study on urban growth,relationship of land use and transport system and integrated land use and transport model are presented in **Chapter 2**. The hypotheses in this study are presented in last part of this chapter.

Chapter 3 illustrates the database construction that is used in the analysis in this study.

Chapter 4summarizes the lessons of past urban planning and transport planning and their relevance in Gifu City by looking at planning and policy in the past 40 years by using historical maps, population census and socioeconomic statistics data.

Chapter 5 describes the impact of land use planning and transport planning to personal transportation movement with the above data and Personal Trip Survey data.

Chapter6 presents an integrated traffic assignment model which encloses the transportation mode choice and destination choicebased on the following features:

- Travel time of bus is affected by car traffic congestion.
- A LOGIT type stochastic choice is applied for route, mode and destination choice and therefore the model is expressed as integrated stochastic user equilibrium (SUE) mode
- The destination choice behavior is based on three trip purposes: commuting, business and leisure

Chapter 7 uses Gifu city transport network and land use data to demonstrate the impact of public services and land use policies by applying the proposed model.

Chapter 8 closes the dissertation with a conclusion.

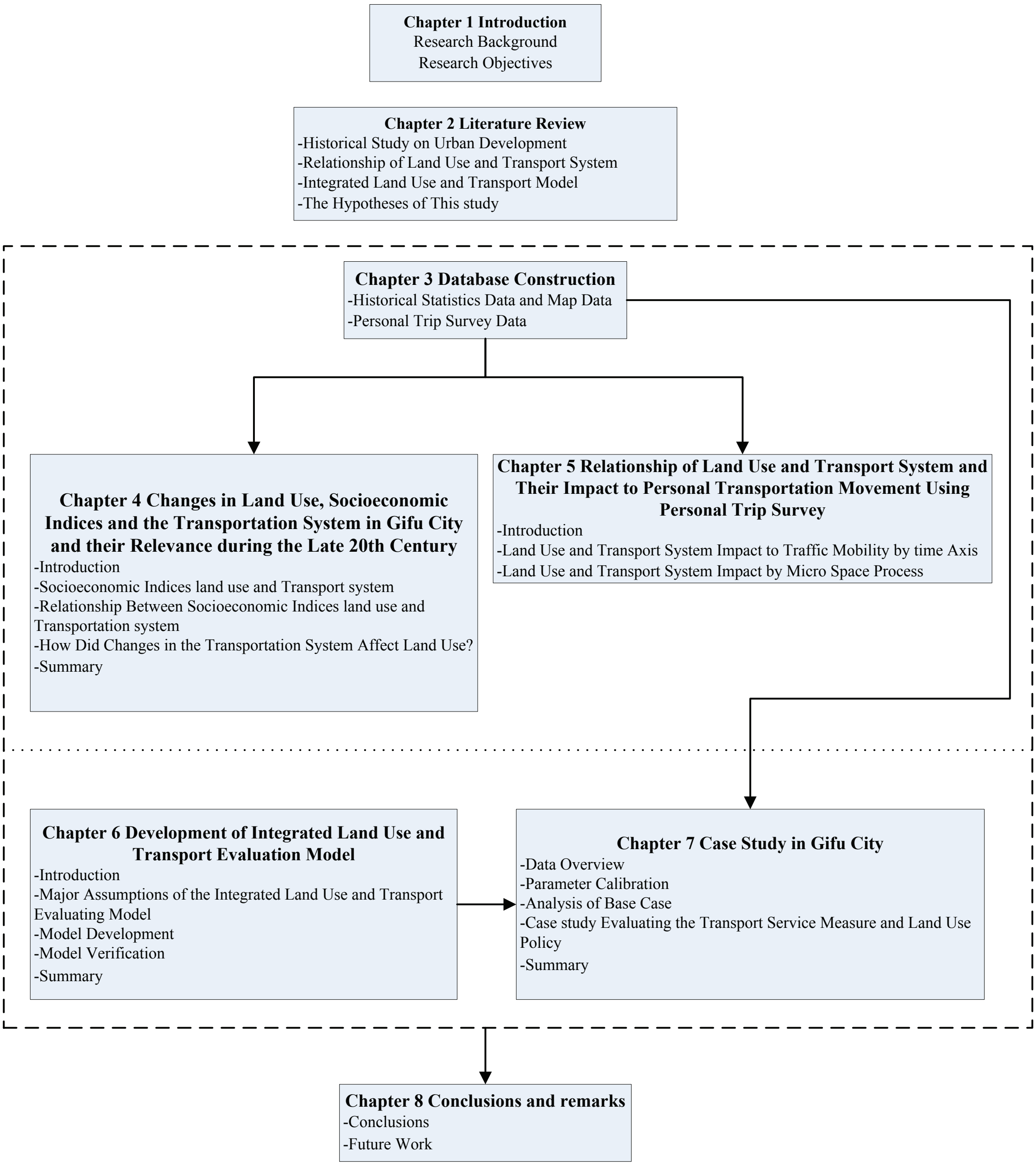


Figure 1.1 Outline of the Dissertation

REFERENCES

John Sousanis (2011-8-15), World Vehicle Population Tops 1 Billion Units, Ward AutoWorld,RetrievedAugust 20th, 2011.

Jonathan Watts (2011-08-24), China's love affair with the car shuns green vehicles, The Guardian, Retrieved 2011-08-24.

Li Yuansheng, Yang Yang, Fu Yanxiao, Xu Xiangyang (2011), Trend Analysis of 2011 China’s Car Sales Volume and Carbon Emissions Based on Rough Set Theory,Emerging Research in Artificial Intelligence and Computational IntelligenceCommunications in Computer and Information Science, Volume 237, pp 582-589.

CHAPTER 2

Literature Review

This chapter provides the literature review of past studies about historical study on urban development, the relationship of land use and transport system and the integrated land use and transport model. Then frameworks and methodologies for analysis the relationship of land use and transport system by using historical data and mathematical model are discussed. Referring to the objectives of this study as well as the finding of the past studies, the hypotheses of this study are presented in the last part of this chapter.

2.1 Historical Study on Urban Growth

History provides valuable lessons on the interplay of factors that shape urban growth and development. Many developed countries have experienced high economic growth and motorization. There are many studies that analyze urban growth by using historical data and maps.

Kishiue, Cal, Amano, and Lidasan(2005) adopted a historical approach to trace urban development in selected urban centers in Asia. In their study, they compared the planning patterns of each study area and conducted historical reviews of development in each area.Willoughby (2001) analyzed Singapore's motorization policies from 1960 to 2000, including fiscal policy, road pricing, transportation and land use, transportation externalities infrastructure, urban development, urban planning, and urban transportation to create a direction for further planning.Black, Cheung,Doust, and Shabtay(2007) gave a case study of metropolitan Sydney on the dynamics of polycentricemployment location and land-use and transport policies that encourage such a spatialformation of jobs. Spatial plans from 1948 to 2005 are reviewed.An historical study of Parramatta, one of the major sub-centres, illustrates theproblems of implementation.Cao Xiao-shu, Yang Fan, Yan Xiao-pei (2000) researched composition of urban transportation and structure of travel pattern from 1978 to 1997 (when the fast pace of economic growth, urban populationgrowth and family-income increase had triggered a boom of car ownership and usage) based on analysis on development and pattern of urban transport inGuangzhou.

C. San-Antonio-Gómez, C. Velilla, F. Manzano-Agugliaro (2014)applied the methodology of georectification to comparehistorical maps with current orthophotos from 2005.They proposedcolor and lines code as usefultools for the analysis of the urban and landscape changes that the town has undergone since the 18thcentury, and they also graphically reconstruct certain former heritage items that no longer exist.Tucci, Giordano, and Ronza (2010) usedhistorical maps dating back to the eighteenth century and a 2005official city map, and they applied methods of spatial analysisand geo-visualization techniques to determine which parts of thecity (Milan) changed the most in the time interval considered.

Computer methodshave been used to analysehistorical urban changesand growth.A geographic information system (GIS) integrates computersoftware with spatial and temporal data for the purposes of organizing,analyzing, and depicting geographically-referenced digitalinformation. GIS technology provides a set of versatile tools thatenable the visualization and interpretation of data in a variety ofways, dramatically enhancing the user's ability to understand andinterpret complicated space and time relationships(ESRI.(2009)).By displayingdata in a way that is quickly understood and easily shared, its useenables us to address a variety of questions and problems. Ho and Shibayama(2009) studied the urban transition in Hanoi in the late 20th century based on GIS/remote-sensing technology.Noam Levin, Ruth Kark and Emir Galilee (2010) scanned and rectified 375 historical maps covering parts or all of the Negev between 1799 and 1948 usingGIS to enable quantitative analysis of their accuracy, and to reveal new insightsinto settlement and sedentarization processes to orporate new methods and demonstrate their application to studies inistorical geography.

2.2 Relationship of Land Use and Transport System

It is important to identify the relationships among urban planning factors to provide for future urban and transportation planning. A key issue for sustainable development (Berke, P. R., & Conroy, M. M., 2000) is the relationship between transportation and land use.The highly mobile transportation system has affected land use patterns, particularly how people choose to locate their homes and businesses. Conversely, spread out land use patterns further increase the demand for transportation because of greater travel distances.

Transport answers to people's desire to participatein different activities (living, working, shopping andrecreating)in different places. Land-use patterns thereforewould seem to have a potentially large impact ontransport. However, even after many years of scientificand policy debate, there is still no consensus aboutthe impact of land use on transport. Some researchersconclude that land use may have a significant impact ontravel behaviour, while others have found no, or hardlyany, impact. Some say influencing travel behaviour vialand-use planning is an illusion, while others say it isa very fundamental way to influence travel behaviour(Banister, 1999).

There are several reasons why some researchers and policy-makers suggest that land should be used as an instrument to affect travel behaviour. Reasons are related mainly to the negative impacts of transport: environmental impacts and congestion. The general idea is that the overall level of travel (expressed in vehicle and person kilometres) may be reduced via land-use planning and that a modal shift from the car to slow transport modes and public transport can be realised. Both effects should reduce the negative impacts of congestion (Bert van Wee., 2002).

Stephen H. Putma (1975)assumes that the general relationship between transportation and land-use may be defined in terms of three primary components: (1) Economic activity (i.e. employment), (2) Demographic activity and (3) Transportation facilities.

2.3 Integrated Land Use and Transport Model

The integration of the location of activities in space and the use of transport has been a theoretical planning issue for many years.One way to estimate the wider impacts of transport policies is to use a computer model which incorporates the both-way interactions between land use and transport.

2.3.1 ILUTM in theWorld

In the 1950s first efforts were made in the USA to study the interrelationship between transportand the spatial development of cities systematically. Hansen (1959) demonstrated forWashington, DC that locations with good accessibility had a higher chance of being developed,and at a higher density, than remote locations ("How accessibility shapes land use").The recognition that trip and location decisions co-determine each other and that thereforetransport and land use planning needed to be coordinated, quickly spread among Americanplanners, and the 'land-use transport feedback cycle' became a commonplace in the Americanplanning literature. The set of relationships implied by this term can be briefly summarized asfollows(Michael Wegener. 2004) (see Figure 2.1):

The first attempt to construct simulation models to forecast land use of metropolitan transportation studies emerged in the early 1960s. One of the first models that gained substantial interest was developed by Lowry (1963, 1964)for the Pittsburgh urban region. He distinguished population, service employment and basic(manufacturing and primary) employment, and these activities correspond to residential,service and industrial land uses. Activities are translated into appropriate land uses by meansof land-use/ activity ratios. The division of employment into service and basic sectors reflectsthe use of the economic base method to generate service employment and population from basicemployment. The model allocates these activities to zones according to the potentials ofzones. Population is allocated in proportion to the population potential of each zone and serviceemployment in proportion to the employment potential of each zone, subject to capacityconstraints on the amount of land use accommodated in each zone. The model ensures thatpopulation located in any zone does not violate a maximum density constraint which is fixedon every zone. In the service sector, a minimum size constraint is placed on each category ofservice employment, and the model does not allow locations of service employment to buildup which are below these thresholds (TimmermansH J P, 2003).

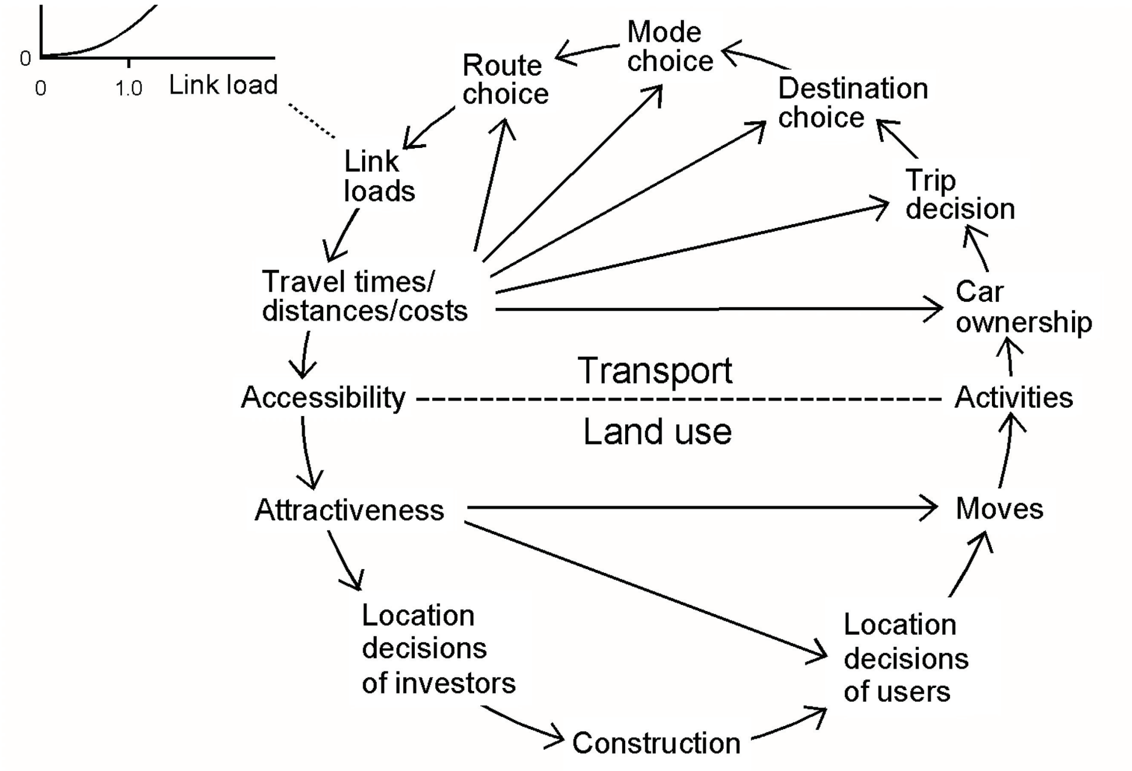


Figure 2.1 The 'land-use transport feedback cycle'(Michael Wegener, 2004)

It was the begging of 1980s that the fully integrated land use and transportation package was proposed,typically theLILT(the Leeds Integrated Land-Use/Transport model developed at the University ofLeeds by Mackett,1983,1990) and MEPLAN(the integrated modelling package developed by MarcialEchenique, 1985, Hunt 1994), there are also researches commentaryabout the models (Mackett, 1991, Miller, 1990).

Miller et al. (1998) presented a matrix in which the past andfuture evolution of urban land-use transport model was charted. The following diagram is an adaptationin which a sixth row L6 was added (Figure 2.2).Each cell in the figure therefore represents a land-use transport modelling combination. Thearrows indicate incremental paths local governments can take to develop their land-use transportmodelling capability(Wegener, 2004).

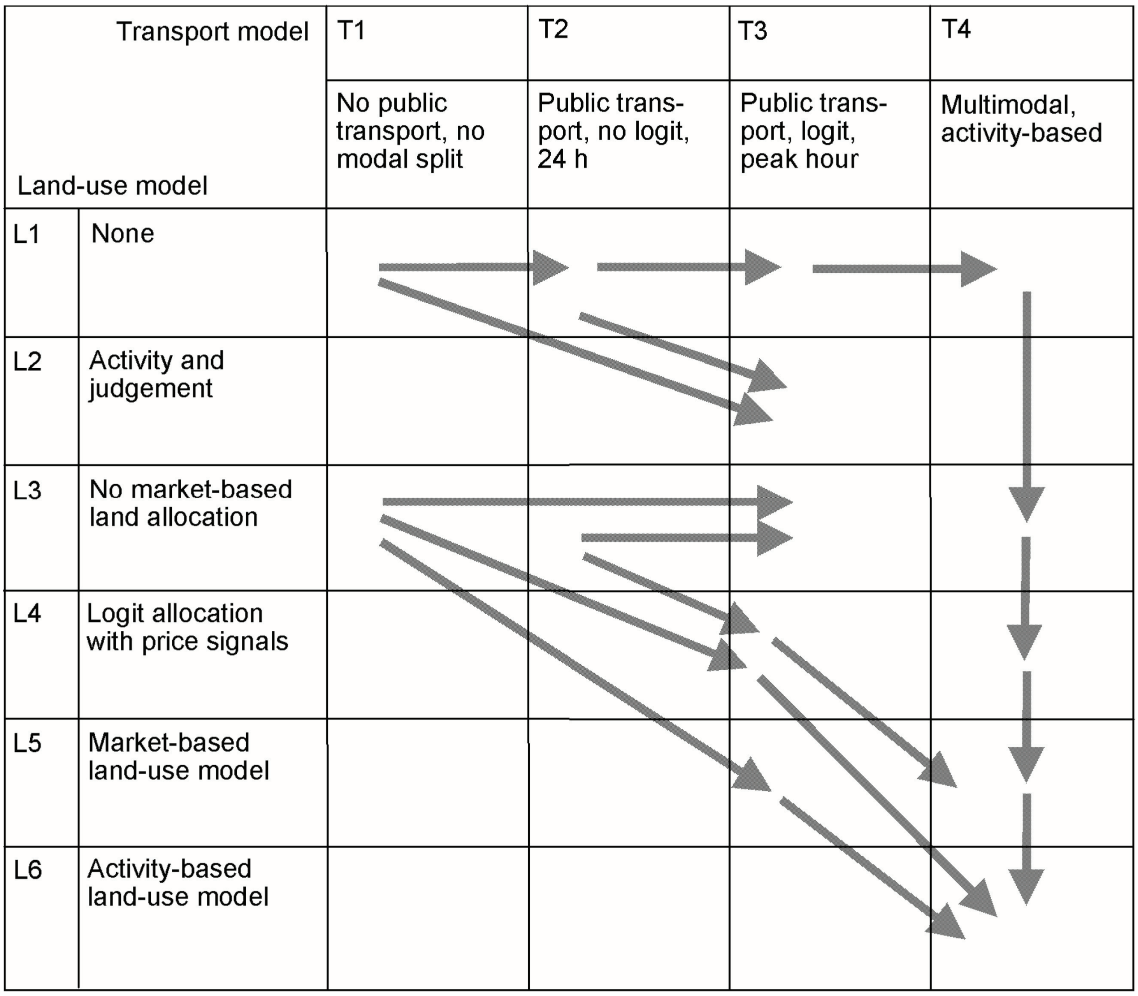


Figure 2.2 Evolution of urban land-use transport models (adapted from Miller et al., 1998)

2.3.2 ILUTM in Japan

ILUTM was also developing in Japan from 1980s. CALUTAS (Computer Aided Land Use Transportation Analysis System (Hidano, 1984)) was one of the models that were inspired by actual planning and policy problems.Miyagi (1989) proposed a combined residential-location and transportation model with formulation of stochastic utility theory inclusion network equilibrium analysisbased on Lowry model.And Miyagiet al. (1995) proposed a mathematical programming approach to the combined land use and travel demand forecasting modelling.The computable urban economic (CUE) model (Ueda et al., 2009)is an advanced form of urban model developed in the tradition of an ILUT model. The CUE model is fully based on microeconomicfoundation so as to overcome these inconsistent features in the LUTI model. The behavior of anyeconomic agent is explicitly formalized as utility-max or profit-max and the interactions both atthe inside and at the outside of markets are modeled as price-adjustment mechanism orexternality (Ueda et al., 2009).

2.4 The Hypothesesof This Study

Land use policy breakthroughs new traffic demand, the traffic demand is causing the congestion phenomenon in the transportation facilities of existing. As summarized above, rather than to predict the other with a fixed one with the traffic demand and land use , integratedland use and transport model is presented to be a predictive model simultaneous congestion effect of traffic on the network such as affect the activity distribution. However, in some cases solve is difficult depending on the setting of the model, it is assumed that congestion is often not to consider in some of the ILUT models. In addition, to handle explicitly traffic network is a feature of ILUTM, it is preferable that considering including all transport system is desirable. However in this case, probability of transportation mode choicebecame a challenge. Models to incorporate traffic network with all transportation mode had been used in research to support urban planning, in order to simplify the problems, the model in transportation is limited to the one transportation mode especially road network in many cases. In this study, to solve these problems, incorporate the transportation choice behaviorto build a model to take into account congestion in road space, by assumption of travel time of transport mode is changed by change in traffic volume. However, in this study, it is possible to evaluate the land use policy by taking the destination choice in the form of attractiveness. It is not incorporatingas the customary land use model that perform location choice of entities(in economic) such as households and businesses.In other words,in this study, form oflocation of activities in the land marketis not applied from the point of view of policy analysis.

To solveabove problem, this study presents an integrated traffic assignment model which encloses the transportation mode choice and destination choice. Transport service level is the most important factor to transportation mode choice behavior. If public transport does not exist ina particular neighborhood, people cannot use it; in the other hand, it if does exist, people don't necessarily useit caused less cost in choice of car.Land use patterns thus impose constraints and offer opportunities for people to conduct theiractivities, resulting in particular activity-travel patterns. Similarly, the choice of destination isoften a key factor for the feasibility of particular functions at particular locations. If peopledecide to start choosing for example other shopping locations, certain stores or shopping centersmay disappear, resulting in a changing land use pattern, which in turn may induce shiftsin travel behavior. Also, exogenous change may result in changing land use patterns andhence changing activity-travel patterns (Timmermans H J P. 2003).We attempt to evaluate the change of destination choice as well as mode choice when land use or transport service is changed. After testingin assumption small scale and middle scale transport network, the proposed model is applying to actual city network with transport network, traffic demand data and land use data in Gifu City.

REFERENCES

Akiko K., Primitivo C. C., Koichi A., Hussein S. L. (2005), The Leading Factors for

The Urban Development in Asian Context—Case Studies of Makita, Cebu, Taipei, and Bangkok, Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 4300–4316.

Benguigui, L. and M. Daoud. (1995), Is the Suburban Railway System a Fractal?,Geog. Analy. 23, 362–368.

Berke, P. R., & Conroy, M. M. (2000), Are we planning for sustainable development?, Journal of the American Planning Association, 66(1), pp.21 – 33.

Bert van Wee. (2002), Land Use and Transport: Research and Policy Challenges, Journal of Transport Geography,Volume 10, Issue 4, pp. 259–271.

C. San-Antonio-Gómez, C. Velilla, F. Manzano-Agugliaro. (2014), Urban and landscape changes through historical maps: The Real Sitio of Aranjuez (1775–2005), a case study, Computers, Environment and Urban Systems, Vol.44, March, pp. 47–58.

C. Willoughby. (2001),Singapore's Motorization Policies 1960–2000, Transport Policy 8, 125 –139.

CAO Xiao-shu., YANG Fan., YAN Xiao-pei. (2000), Studyonthe Urban Transportand Land-use, ChineseGeographical Science Volume 10, Number 2, pp. 144- 150.

D. Banister. (1999),Planning more to Travel Less Land Use and Transport, Town Planning Review, 70 (3), pp. 313‑338.

Echenique, M.H.(1985),The use of integrated land use transportation planning models: the cases of Sao Paulo, Brazil and Bilbao, Spain. In: The Practice of Transportation Planning (M. Florian, ed.) Elsevier, The Hague.

ESRI.(2009),What is GIS? http://www.esri.com/what-is-gis/overview#overview_panel.Accessed April 1.

Hansen, W.G. (1959), How Accessibility Shapes Land Use,Journal of the American Institute ofPlanners, 25, pp. 73-76.

Hunt, J.D. (1994), Calibrating the Naples land-use and transport model, Environment and Planning B: Planning and Design 21, pp.569-90.

Hidano, N. (1984), Outline, Features, Applicability and Direction in Development of CALUTAS (Computer Aided Land Use Transportation Analysis System), Infrastructure Planning and ManagementSymposium, JSCE, Vol.18, pp.125-134. (Japanese).

HoD.D., Shibayama M.(2009),Studies on Hanoi Urban Transition in the Late 20th Century Based on GIS/RS,Southeast Asian Studies,Vol.46,No.4.

Mackett, R.L., (1983),The Leeds Integrated Land-Use Transport Model (LILT), Supplementary Report SR 805 Transport and Road Research Laboratory, Crowthorne, Berkshire.

Mackett, R.L. (1990),The systematic application of the LILT model to Dortmund, Leeds and Tokyo Transport Reviews, 10, pp.323-38.

Mackett, R.L.(1991), LILT and MEPLAN: a comparative analysis of land use and transport policies for Leeds, Transport Review, Vol. 11. No.2. pp.131-154.

Michael Wegener. (2004), Overview of Land-use Transport Models, Chapter 9 in David A. Hensher and Kenneth Button (Eds.): Transport Geography and SpatialSystems. Handbook 5 of the Handbook in Transport,Pergamon/Elsevier Science, Kidlington,UK, 2004, pp. 127-146.

Miller Jr. H.W. (1990),A theoretical frame work for the interactions among models in the integrated transportation and land use package, Environment and Planning A, Vo l. 22. pp. 1355-1373.

Miller, E.J., Kriger, D.S., Hunt, J.D., Badoe, D.A. (1998), Integrated Urban Models for Simulationof Transit and Land-Use Policies, Final Report, TCRP Project H-12. Joint Program ofTransportation, University of Toronto, Toronto.

Miyagi, T. (1989), A Combined Residential-location and Transportation Model, Selected Proceedings of the 5th WCTR, IV, PP.127-137.

Miyagi, T., Okuda, Y., Katoh, H. (1995),A Mathematical Programming Approach tothe Combined Land-useand Travel Demand Forecasting Modelling, Proceedings of JSCE 518, pp.95-105.

Noam Levin, Ruth Kark and Emir Galilee. (2010), Maps and the Settlement of Southern Palestine, 1799–1948: an historical/GISAnalysis, Journal of Historical Geography, 36, pp.1-18.

Stephen H. Putma. (1975), Urban Land Use and Transportation Models a State of the Art Summary,Transportation Research. Vol. 9, pp. 187-202.

Taka Ueda, MoritoTsutsumi, Shinichi Muto, Kiyoshi Yamasaki (2009), Computable Urban Economic Models in Japan, EASTS-Japan Working Paper SeriesNo.09-4.

Timmermans H J P. (2003), The Saga of Integrated Land Use-Transport Modeling: How Many More Dreams Before We Wake Up?, Proceedings of the 10th International Conference on Travel Behavior Research, Lucerne, August, 2003.

Tucci, M.,Giordano, A., &Ronza, R. W. (2010), Using spatial analysis andgeovisualization to reveal urban changes: Milan, Italy, 1737–2005.Cartographica, 45(1), pp.47–63.

CHAPTER 3

Database Construction

3.1 Target Area

The target area was Gifu City in Japan, a typical middle-sized city with a population of 401,769 (Table 3.1).Gifu City is in the center of Japan and is in the north of the third largest city in Japan (Nagoya). The primary access to Gifu is from the south. With fewer bus users in the city, bus companies faced difficulties maintaining services, and three bus companies merged into one. Furthermore, removal of the city tram left buses as the only public transportation within most of the city. Thus, car use has been increasing gradually (Fig.3.2).Furthermore, motorization led to the dispersion of major urban facilities such as shops and public facilities, reducing access to such resources in the central area. As a result, the residential population and the number of shops and workplaces in the central areahave declined over the past several years.

In this study, we used historical documents and maps from the past 40 years to review past urban-planning policies and transportation systems. We analyzed urban changes using the population census and economic statistics and examined changes in the transportation system using transportation-use statistics.

Table 3.1 Essential Statistics of Target City (data in 2005)

Population	401,769	Schooling from the outside	11,772
[Central area]	80,841	Drivers license holders	247,607
[Surrounding area]	156,121	Car owners	279,177
[Suburban area]	164,807	Large size shops	64
Daytime population	426,865	Normal shops	7,585
Families	153,336	Commercial sales [ten thousand yen]	18,918
Elderly persons	73,492	Business sites	25,382
Commuters	279,224	Workers	185,614

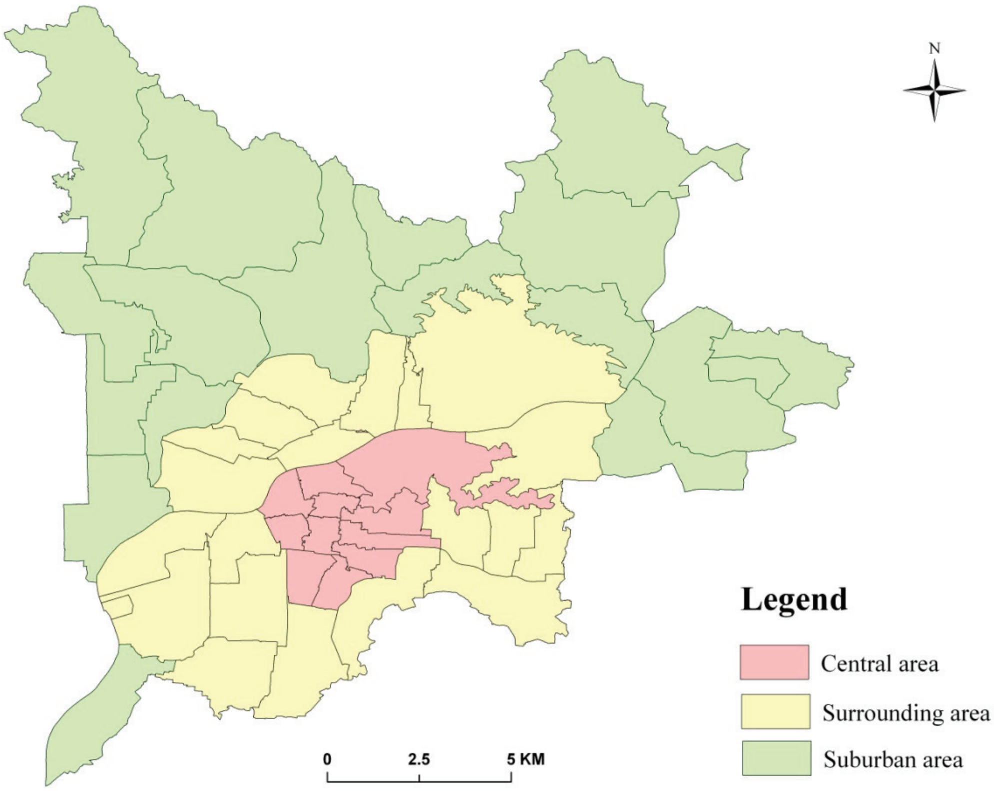


Figure 3.1 Target Area Gifu City

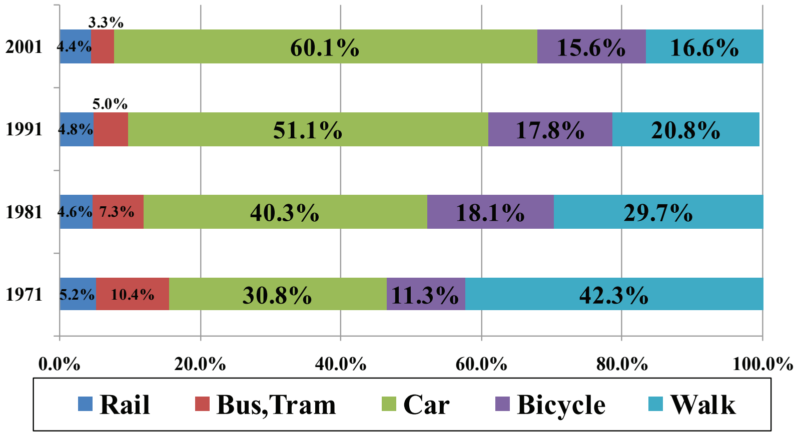


Figure 3.2Mode Share of Trips in Gifu City

3.2 Data Sources

3.2.1 Historical Statistics Data and Map Data

The past 40 years historical data and map collecting was a hard work that cost a lot of time. We collected the documents from Gifu City library, Gifu Prefecture library and

Gifu City hall, made a huge copy work and classified as following:

- Japan National Population and Housing Censuses

Population and housing data from 1950 to 2005 every 5 years

Census data offer a unique insight into small areas and small demographic groups, which sample data, would be unable to capture with precision.

- Statistics Book of Gifu City

Detail population data, socioeconomicdata, transport data and other statistics data from 1970 to 2010 every 10 years

- The Urban Master Plan for Gifu City

First to forth urban planning master plan for Gifu City (1973, 1980, 1986, 1995)

- Gifu History Book

Main reports and news about city planning and construction

- Report of Gifu Regional Integrated Transportation System

Regional transportation system planning and transportation system network (1973, 1974, 1983)

- Old City Maps

Large map collections are available in manycountries, representing great potential for describing and understandingthe development of land use and transportation network through time.

3.2.2 Personal Trip Survey Data

The result of regional trip survey so-called “Personal trip survey (PT)” is an essential database of urban transport planning which has recorded the trips and activities of trip makers dynamically as well as spatially for the target city. PT data can be used to know present mobility situation and to make traffic demand estimation for transport planning, environmental planning, disaster prevention planning and so on.

Comprehensive Urban Transportation Planning Council Chukyo Metropolitan Area helped us to get the Personaltrip survey data in Chukyo area of Japan, first (1971), second (1981), third (1991) and fourth (2001).

3.3 Data Processing

3.3.1 Historical Statistics Data and Map Data

Because of the documents are paper materials, we have to make them to processable data. Statistics data was typed to Excel form data.

Historical maps have their own limitations, which can lead to unreliable virtualreconstructions.Most of historical mapswere created before standardized map projections were beingused. It is almost impossible to perfectly align an old map to moderncoordinate systems (Rumsey & Williams, 2002). Thus, transformationhas been the only option for transforming unprojectedhistorical maps to compare them with projected GIS data layers.

Because land-use changes are difficult to analyze by simply inspecting documents, we used a popular computer GIS method (ArcGIS) to create spatial maps to compare urban changes with spatial-distribution patterns over time.

3.3.2 Personal Trip Survey Data

Personal trip survey data include the personal information that needs to security very well. Personal trip survey data is used popular to know present statesmobility situation and make traffic demand estimation to give suggestion of environment planning (Nitta et al.,2009), transport planning (Miyakawa et al.,2009), disaster prevention planning (Osaragi, 2009)and so on. There are also some researches to focus on the change of activity (Masuya, Shitamura, 2001; Muronaga, Moromizu, 2002) and the relationship of land use, environment and activity (Takahashi,Deguchi, Nishikawa, 2005). Looking in the relationship of changes in land use, transportation system and mobility activity is few.

In this study, we choose traffic demand data in and around Gifu City from the Chukyo metropolitan area PT survey data. By processing the data from text to calculable data, we got traffic trips and activities detail by each transportation mode and each traffic purpose. After zoning Gifu City based on PT zone, OD data was summarized to make traffic activities analysis.

REFERENCES

Rumsey, D., & Williams, M. (2002). Historical maps in GIS. Past Time, Past Place: GISfor History, 1－18.

T. Nitta, S. Sugisaki, S. Okadome, K. Hasegawa, H. Takaguchi. (2009),CO2 emission reduction of transport sector in Local City : Case Study in Honjo City, Summaries of technical papers of Annual Meeting Architectural Institute of Japan. D-1, Environmental engineering I, pp.811-812. (Japanese)

J. Miyakawa, T. Sakamoto, A. Torii, M. Isaka, K. Sai, T.Hada, S. Kose.(2009),Possibility of designs for sustainable communities in the western area of Shizuoka Prefecture, University of Art and Culture bulletin 10, pp.165-172. (Japanese)

T. Osaragi (2009),Spatio-temporal Distribution of Railroad Usersfor Disaster Prevention Planning, Journal of architecture and planning 74(635), pp.137-144. (Japanese)

Y. Muronaga, M. Moromizu (2002),An Empirical Study on Changein Going-out Activities of the Elderly In Kumamoto City, Journal of Architecture, Planning and Environmental Engineering. Transactions of AIJ (553), pp.201-207. (Japanese)

Y. Masuya, Y. Shitamura. (2001),Flow Characteristics of Journey-to-Work Travel based on Cumulative Distribution Function in Sapporo City, Journal of Environmental Science Laboratory 8, pp.327-335. (Japanese)

Takahashi,Deguchi, Nishikawa.(2005), Relationship between Land Useand CO^2 Emittedby Person Trip: Case study of Fukuoka city, Journal of architecture and planning (588), pp.103-109. (Japanese)

Comprehensive Urban Transportation Planning Council Chukyo Metropolitan Area: Person Trip Survey Data in Chukyo Area of Japan, First, Second, Third and Fourth, 1971,1981,1991,2001.

Gifu City Statistics Analysis Department: Statistics Book of Gifu City: Gifu City,1950–2008.

Gifu City Planning Department (1973), The First Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department (1980), The Second Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department (1986), The Third Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department (1995), The Fourth Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Statistics Analysis Department (1978–2008), Statistics Book of Gifu City: Gifu City.

Gifu City, Transportation overall Policy Planning and Evaluation Division (1973),Report of 1973 Gifu Regional Integrated Transportation System, Gifu City.

Gifu City, Transportation overall Policy Planning and Evaluation Division (1974), Report of 1974 Gifu Regional Integrated Transportation System, Gifu City.

Gifu City, Transportation overall Policy Planning and Evaluation Division (1983),

Report of 1983 Gifu Regional Integrated Transportation System, Gifu City.

CHAPTER 4

Changes in Land Use, Socioeconomic Indices, and the Transportation System in Gifu City and their Relevance during the Late 20th Century

4.1 Introduction

Rapid urbanization and growing economic prosperity have brought a higher rate of motorization to developed and developing countries. Motorization causes many problems such as exhaust pollution, traffic congestion, and an increase in the number of individuals who cannot drive. A shift to environmentally friendly and sustainable cities will require a reduction in the unnecessary car use and the use of public transportation and bicycles.

History provides valuable lessons on the interplay of factors that shape urban growth and development. Many developed countries have experienced high economic growth and motorization. Willoughby (2001) analyzed Singapore's motorization policies from 1960 to 2000, including fiscal policy, road pricing, transportation and land use, transportation externalities infrastructure, urban development, urban planning, and urban transportation to create a direction for further planning.

It is important to identify the relationships among urban planning factors to provide for future urban and transportation planning. Kishiue, Cal, Amano, and Lidasan (2005) adopted a historical approach to trace urban development in selected urban centers in Asia. In their study, they compared the planning patterns of each study area and conducted historical reviews of development in each area. Black, Cheung, Doust, and Shabtay (2007) analyzed spatial plans for Sydney from 1984–2031 focusing on metric changes in major employment centers.

Computer methods have been used to analyze urban changes. Ho and Shibayama (2009) studied the urban transition in Hanoi in the late 20th century based on geographic information sensing (GIS)/remote-sensing technology. Because land-use changes are difficult to analyze by simply inspecting documents, we used a popular computer method (ArcGIS) to create spatial maps to compare urban changes with spatial-distribution patterns over time.

In this study, the city was divided into zones according to elementary school districts to analyze land use. Because it is difficult to find land-use information from old maps, zone data were used to make a land-use map with GIS and to analyze the housing population, the number of industries and stores, and commercial and agricultural land use.

4.2 Socioeconomic Indices land use and Transport system

4.2.1 Population Growth

Population growth provides important information on the direction of urban development. The Gifu City population census from 1950 to 2005 was used to analyze population changes in this study. Figure 4.1 illustrates the population growth in the total, central, surrounding, and suburban areas.

A significant increase in the total population occurred along with high economic growth in Japan from 1950 to the early 1960s, but during the 5 years from 1970 to 1975, the population increased just 6%. Then, population growth was almost stagnant, and the population has decreased slightly since 1985. In contrast, the trends show large differences in the populations of particular areas. In the central area, including the heart of the old city center and around the railway station, the population has declined from a peak in 1960–1965. Moreover, the population continues to decline even now. However, when population in this area was beginning to decrease around 1960, the population of the surrounding area increased remarkably. Furthermore, the population increased in the suburban area 10 years later. After 1985, the population in the suburban area became greater than that in the surrounding area, and the central area became depopulated. Based on these data, it appears that suburbanization in Gifu City began in 1965.

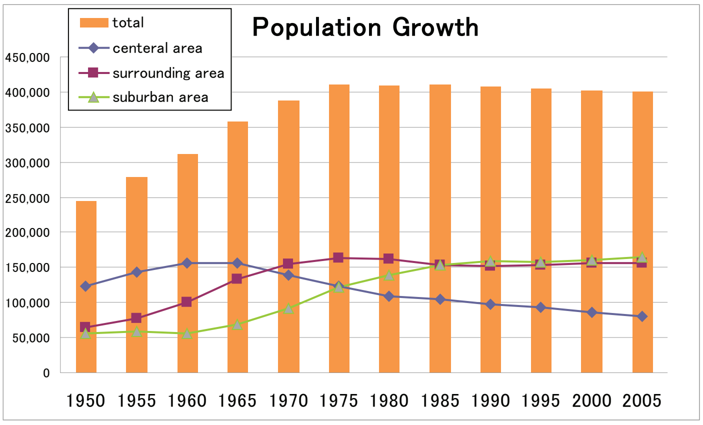
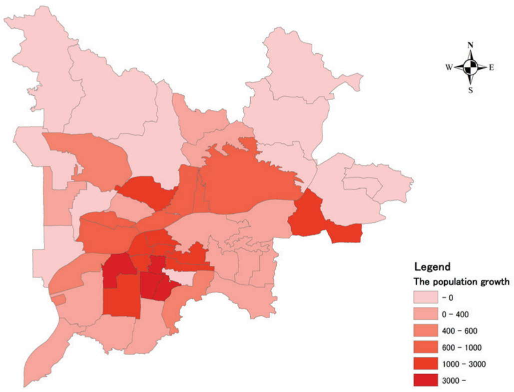
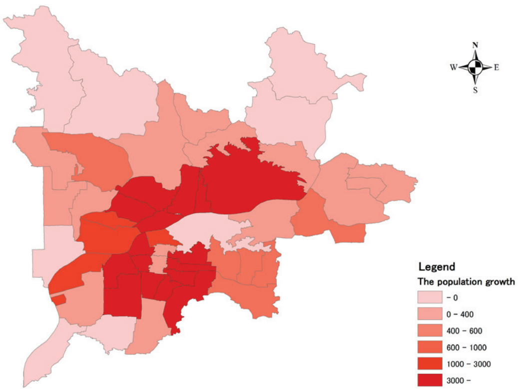


Figure 4.1 Population Growth of Gifu City

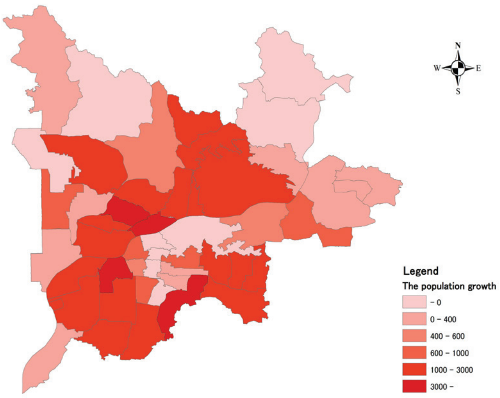
Spatial population growth can be shown using GIS (Fig.4.2). This color-coded figure illustrates population growth by elementary school district every 5 years. The palest red means that the growth number is <0 and the population has decreased. The deepest red means that population in the zone increased significantly (>3,000) during the 5 years. This figure shows that the population has moved from a central area to the surrounding and suburban areas.



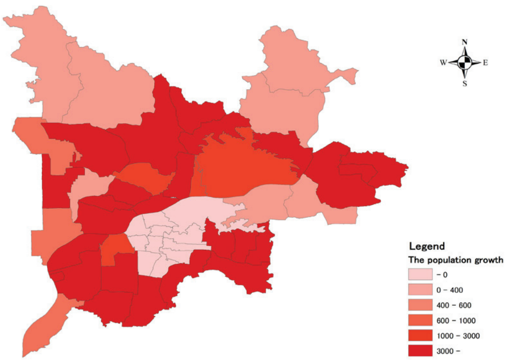
1950~1955



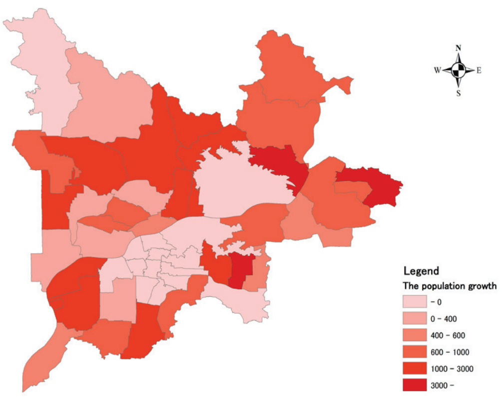
1955~1960



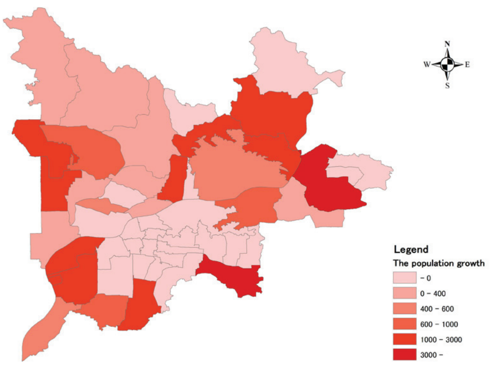
1960~1965



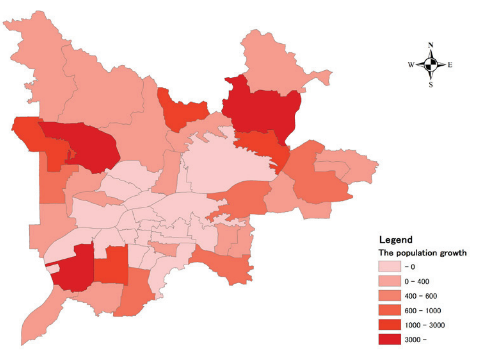
1965~1970

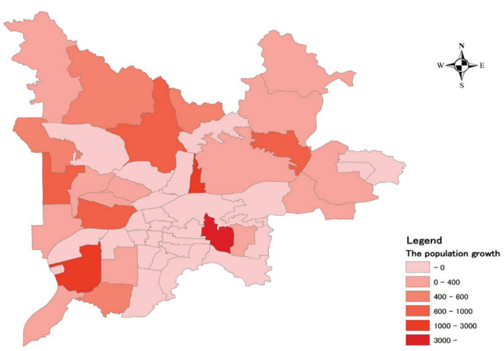


1970~1975



1975~1980





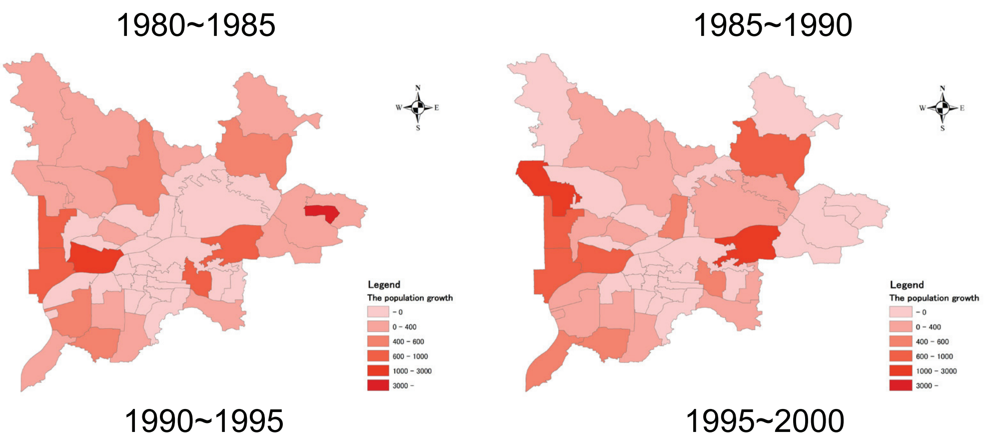


Figure 4.2 Spatial population growth of Gifu City

The rate of aging in the population is shown in Fig.4.3. Aging has advanced around the central city. In 1985, the aged population rate was over 14% only in downtown and in two other zones, but in 2000, all of Gifu City could be considered an aging society, even a super-aging society.

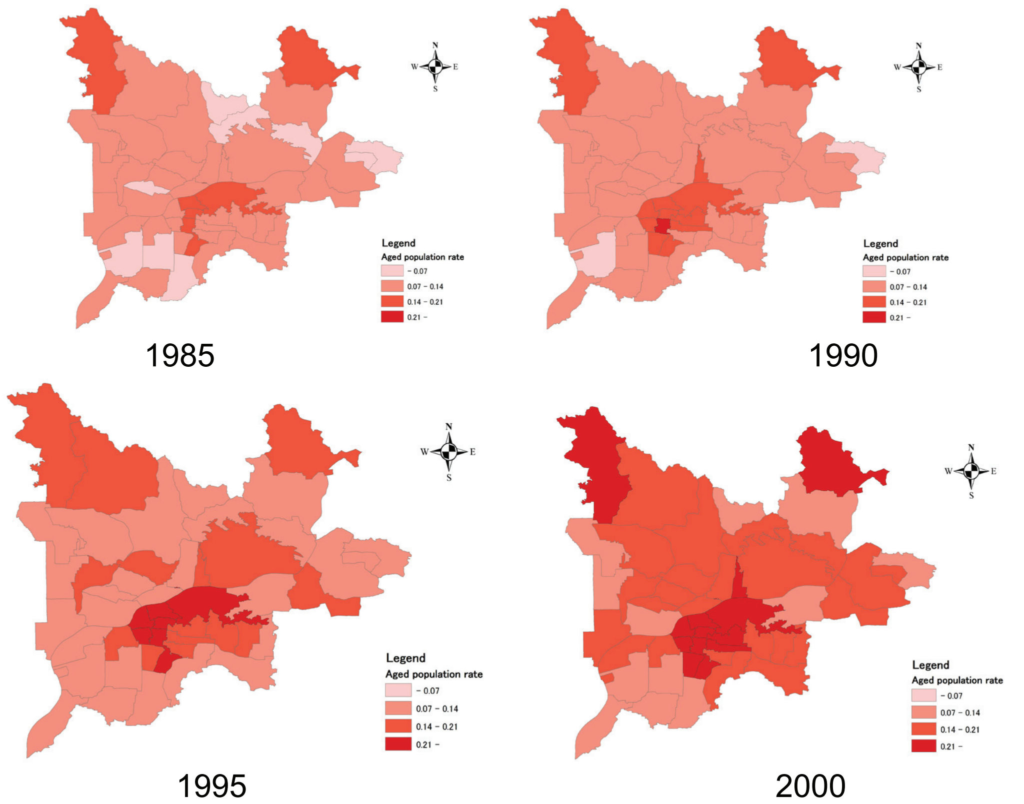


Figure 4.3 Aged Population rate of Gifu City

4.2.2 Industry

Figure 4.4 illustrates the distribution of enterprises in Gifu City. From 1960 to 1975, the number of enterprises increased in each area. However, since 1975, their number has declined continuously in the central and surrounding areas. This period coincides with the time when the ring road was constructed, particularly in the surrounding area to the south. Similar to the population change, the number of enterprises grew in the suburban area before 1995. But after 1995, the number of industrial enterprises has decreased, indicating that construction of the ring road influenced the change in industrial locations. This road also changed the population at the same time.

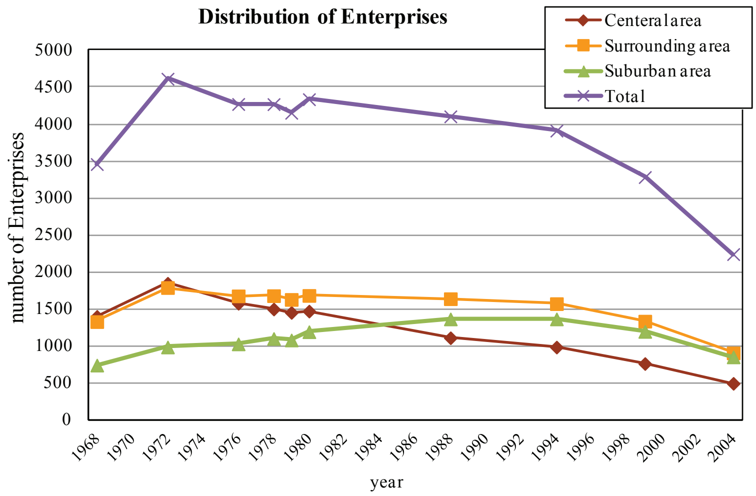
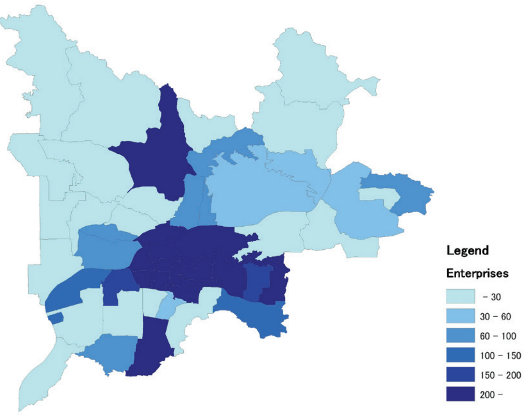
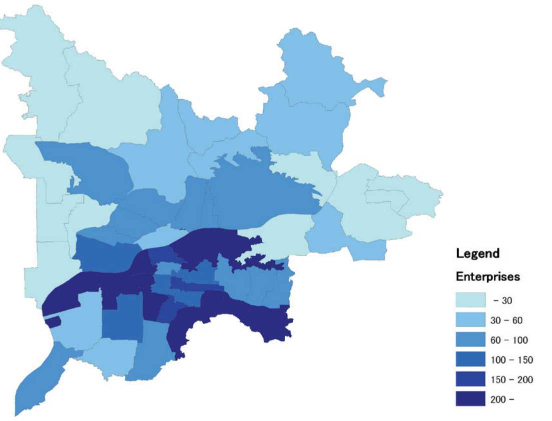


Figure 4.4 Distribution of Enterprises of Gifu City

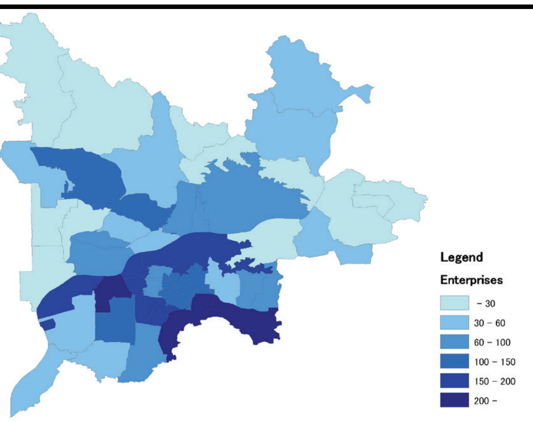
Figure 4.5 shows the spatial and temporal changes in the enterprise locations in 1968, 1972, 1976, 1980, 1988, 1994, 1999, and 2004 using GIS. The figure shows that the main industrial zone has moved from the north central area to the south since 1970.



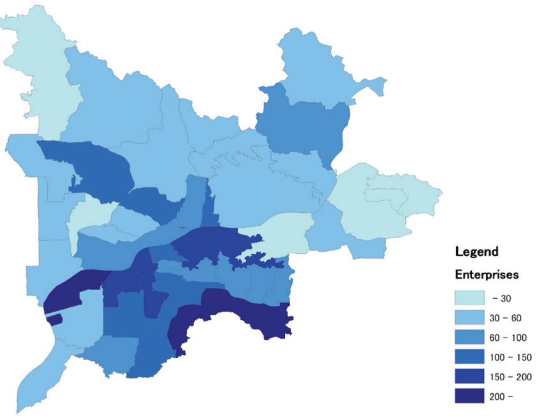
1968



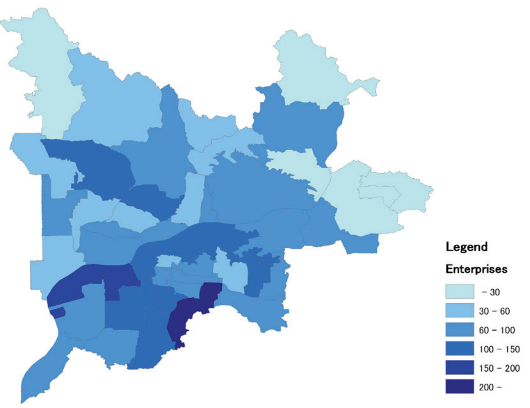
1972



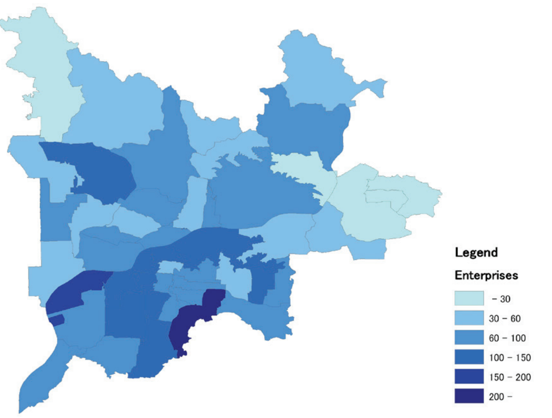
1976



1980



1988



1994

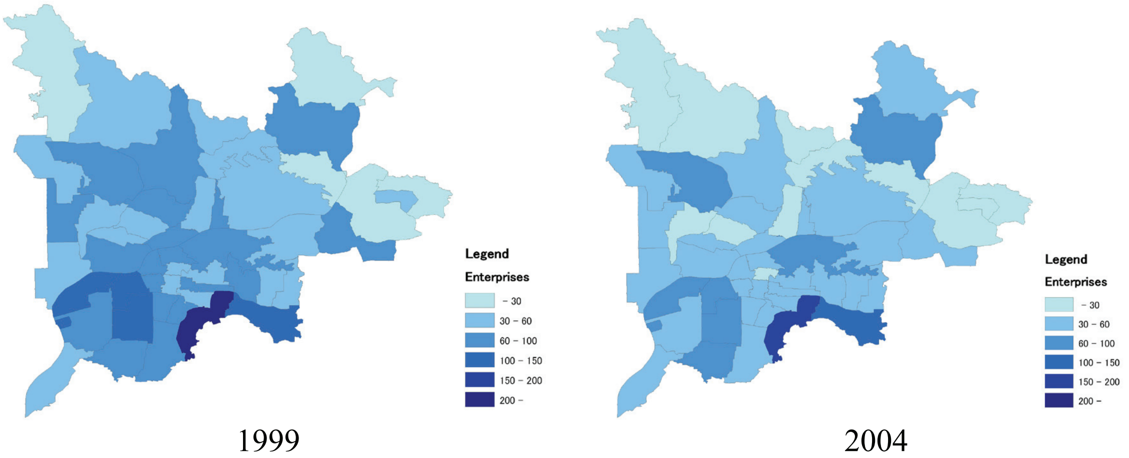


Figure 4.5 Spatial Enterprises Number of Gifu City

4.2.3 Commerce

Figure 4.6 illustrates the distribution of stores in Gifu City, which represents the change in commercial activity. From 1966 to 1974, the number of stores increased continuously in all areas. From 1976 to 1979, many small stores moved from the downtown area because a famous department store opened there, resulting in a rapid decrease in the number of stores during those 3 years. Until 1994, the number of stores was almost the same in all areas. Subsequently, the number of stores began to decrease in the central area year by year. New stores opening along the ring road were one reason that commerce outside the city increased.

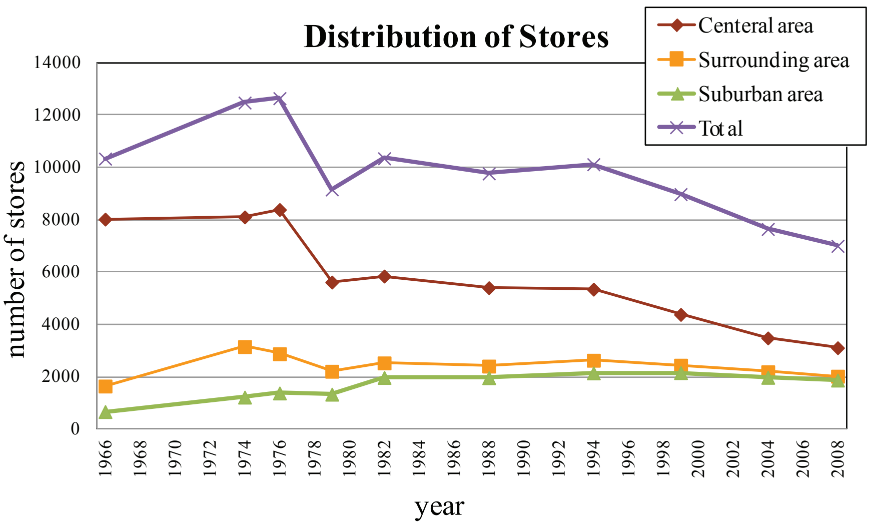
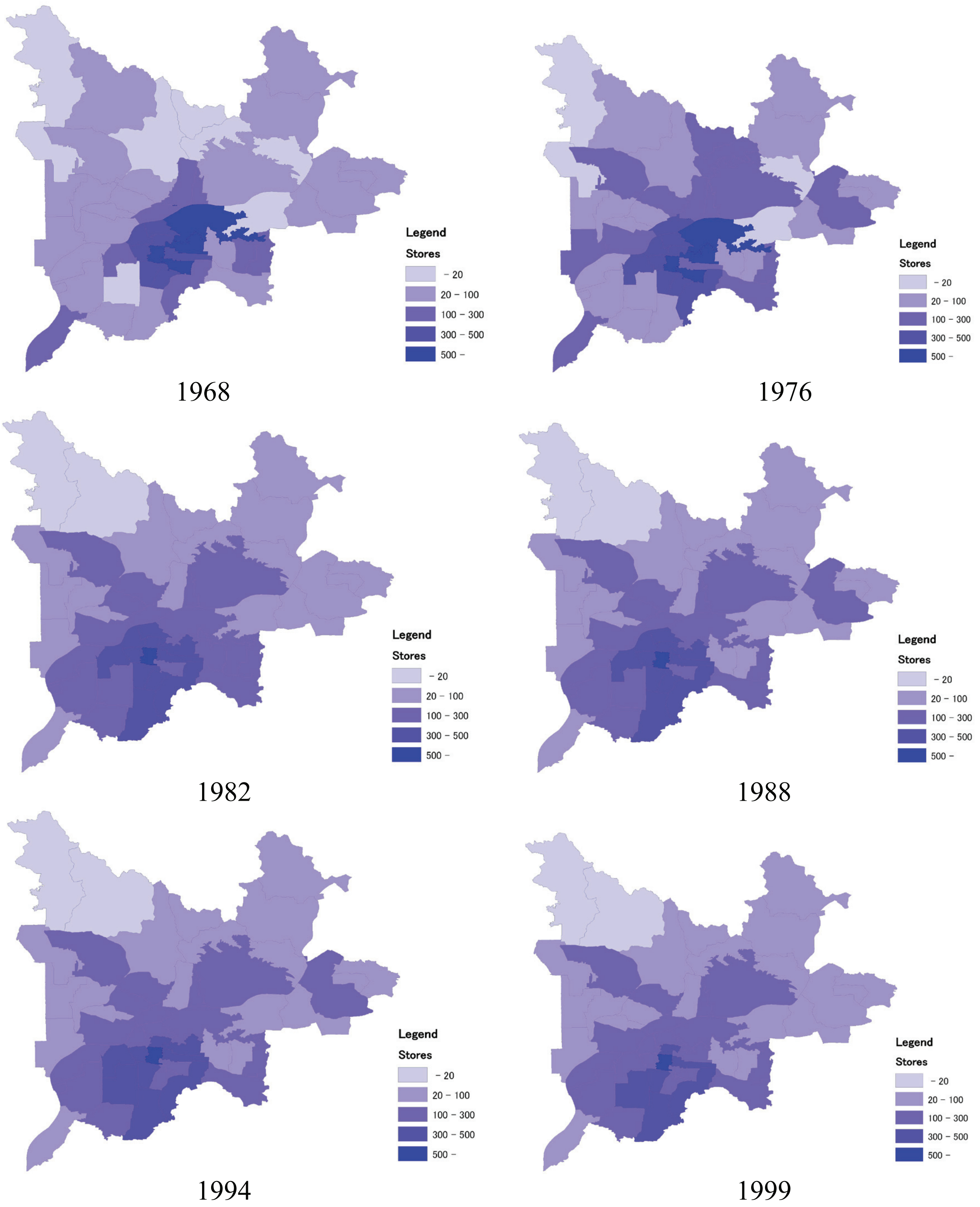
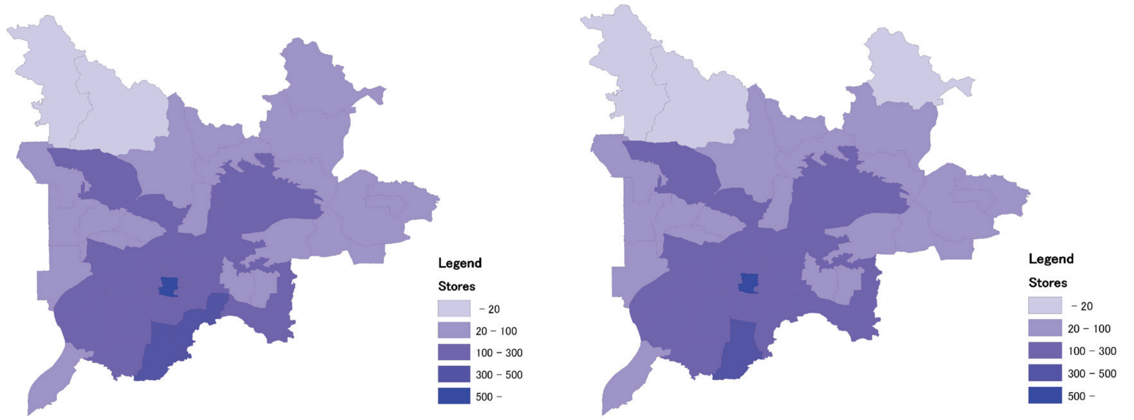


Figure 4.6 Distribution of Stores of Gifu City

Figure 4.7 shows spatial and temporal changes in the number of Gifu City stores in 1968, 1976, 1982, 1988, 1994, 1999, 2004, and 2008. From 1968 to 1976, the number of stores in the central area was constant, while the number increased in the surrounding areas. But after 1976, the number of stores in the central area clearly decreased, whereas the number of stores in the surrounding and suburban areas began to increase.



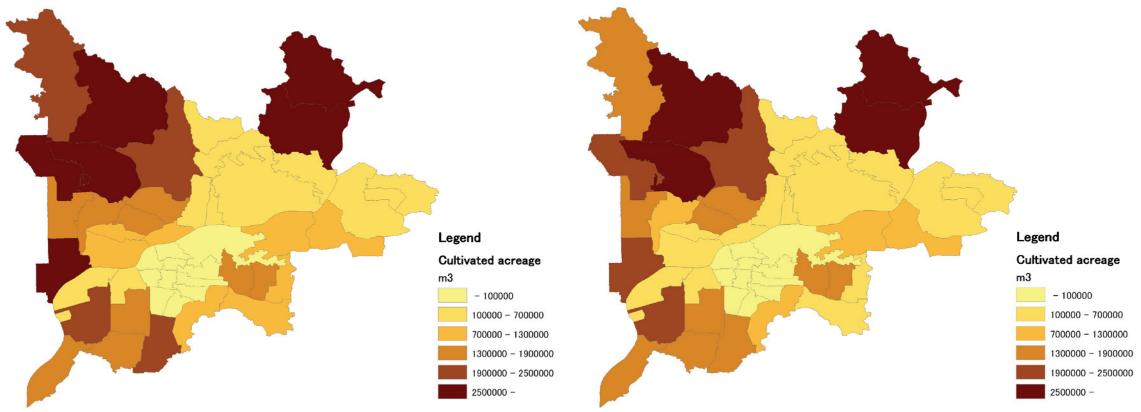


2004 2008

Figure 4.7 Spatial stores number of Gifu City

4.2.4 Agriculture

Data on cultivated acreage were only found for 1975 to 1995. Figure 4.8 shows the spatial extent of cultivated acreage and illustrates the agriculture land-use situation. Cultivated acreage in the surrounding and suburban areas decreased during this time period. Thus, farmland conversion occurred in these areas due to changes in the population, industrial, and commerce zones.



1975 1980

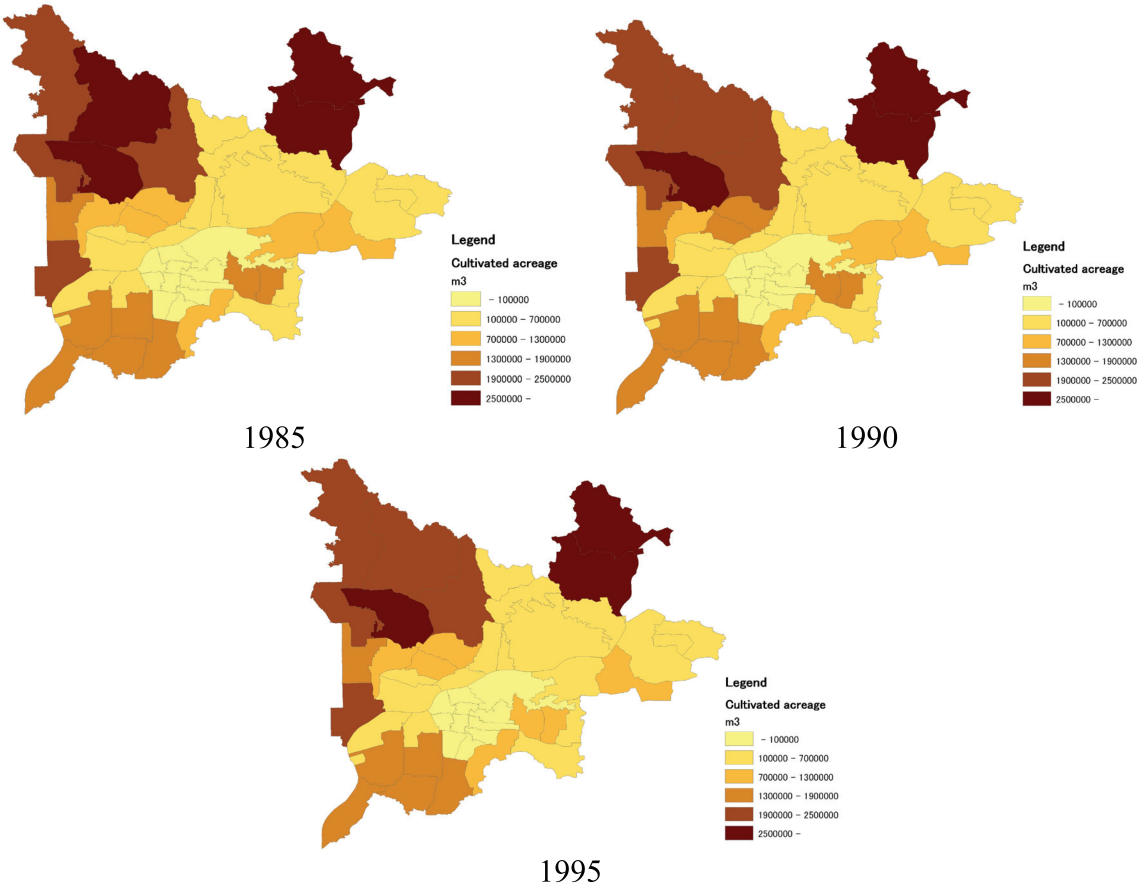


Figure 4.8 Spatial cultivated acreage of Gifu City

4.2.5 Transportation system

Next, we summarize the status of road construction and public rail transportation using historical maps and GIS-based documents. Figure 10 illustrates the road and rail networks during years when major changes occurred: 1964, 1973, 1980, 1984, 1993, and 2005. Construction of the ring road had the largest impact on road maintenance in Gifu City (Fig. 4.9). Construction of the ring road was started in 1965 and completed in 2003. Since then, most of the through traffic within the city center has switched to using the ring road. Construction of the ring road has affected the formation of Gifu City, as commercial establishments such as restaurants and large shops are noticeable along this road, and most of the farmland has been replaced with personal houses.

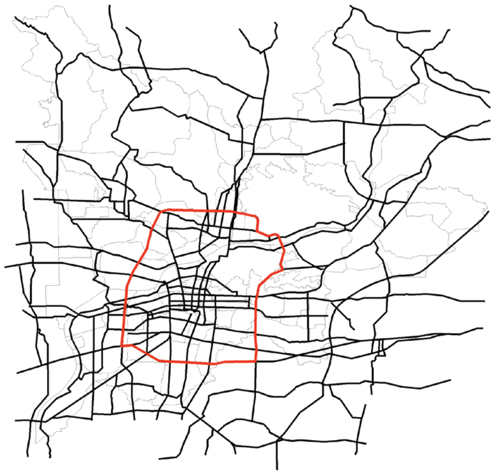
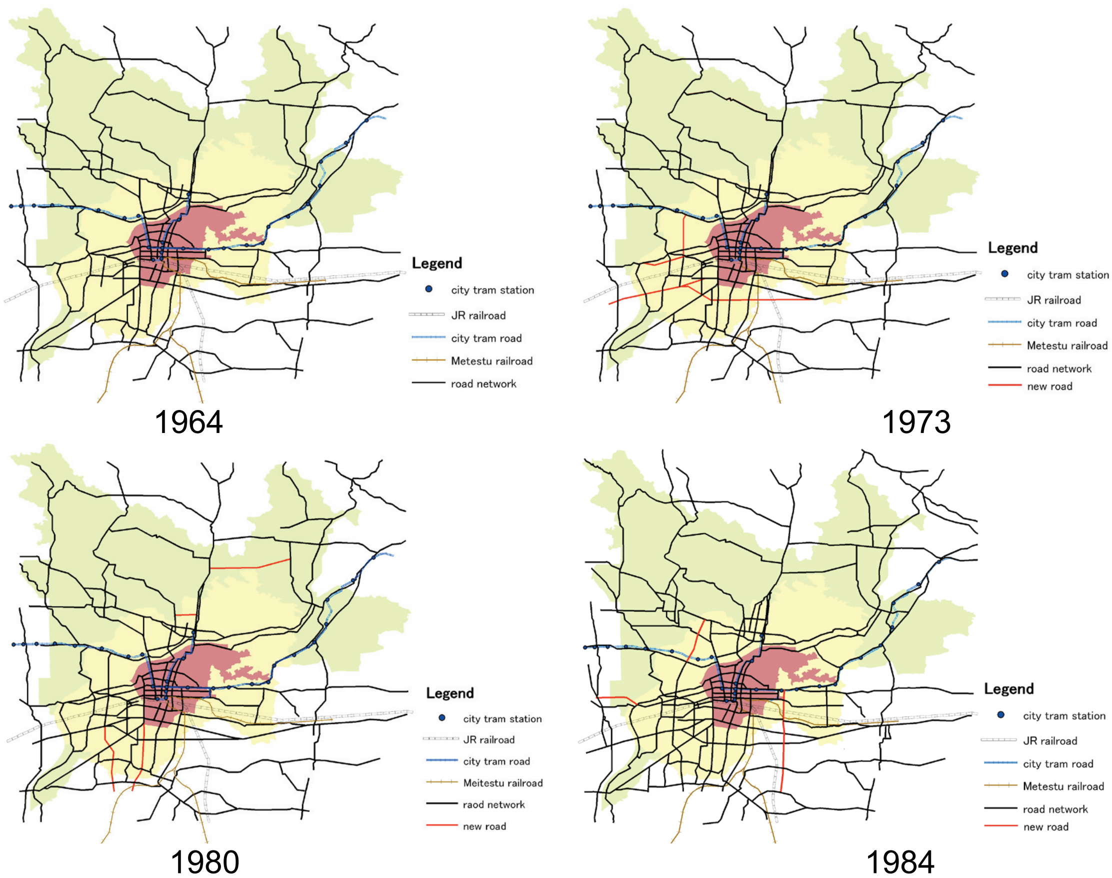


Figure 4.9 The Ring Road in Gifu City

Three major city tram lines were present in Gifu City in 1964, but the north line was terminated in 1993, and all lines were terminated in 2005 (Fig. 4.10). This further enhanced the over-reliance on cars in Gifu City. Industry also changed with construction of the ring road and radial road-network system.



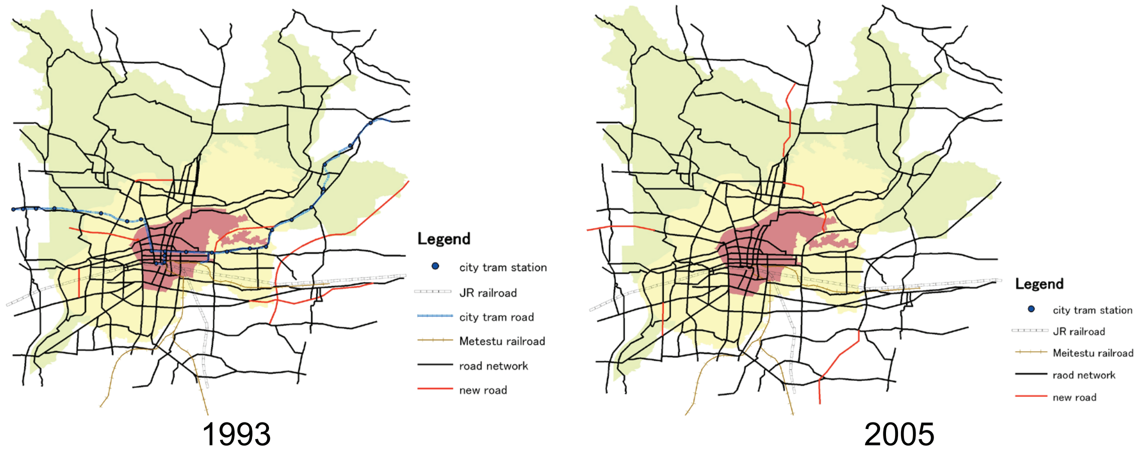


Figure 4.10 Road Construction and Public Rail Transportation in Gifu City

4.3 Relationship Between Socioeconomic Indices land use and Transportation system

As described above, we reviewed changes in the transportation system and population and socioeconomic indices of Gifu City during the late 20th century. Based on a background of high economic growth in Gifu and the development of motorization at the same time as a policy plan was created that attached importance to construction of a road network and elimination of the city tram, land-use development was also focused on the surrounding and suburban areas. As a result, Gifu City was plagued by the doughnut phenomenon. It is important to identify how changes in the transportation system affect urban planning to provide a basis for future urban and transportation planning. In this chapter, we use GIS to show the spatial distribution patterns over time.

4.3.1 Chronology

Table 4.1 summarizes the chronology of events related to facility locations, public-housing construction, planning policy, land-use planning, and public transportation from 1965 to 2005 in Gifu City. During this period, Gifu City created four urban master plans, in 1973, 1980, 1986, and 1995. These plans underpinned important policies for city development, particularly with regard to land-use and transportation-system planning.

Table 4.1 Chronological Table of Gifu City Urban Development

Year	Event (facility)	Public Housing (over 100 households)	Planning Policy, Land-use Planning	City Tram
1966	Gifu Prefecture Office Hall was moved to the surrounding area			
1970				Takatomi Line opened
1971		Mitahora		
1973	Ring-road construction was started		First master plan was created: Clarified land use through urban planning; Land use categorized into city center, industrial zone, housing zone, commercial zone, agriculture zone and green zone; Ring-road construction was planned	
1975		Kamikano		
1976		Ohora		
1977	A new department store was opened in the central area			
1980		Usa	Second master plan was created: Land-use zones were fixed based on the first master plan; Regional highway network with access to other cities was planned; Public transportation was changed to bus; Ring road was a focus	
1981		Kurono		
1982	Gifu University was moved to a suburban area			
1983				
1986	The new JR West Gifu station was opened	Soden	Third master plan was created: Radial ring network was planned to be the major facility construction; Land use was zoned to seven zones such: city center, northeast, north, northwest, west, south, and east; each zone had a detailed delimited land-use class; Integrated transportation system was planned	
1988	A new large shopping mall was opened in the surrounding area			Nagara Line eliminated
1991	A new large sports studio was opened in the surrounding area	Sakuragi		
1993		Shima		
1995	Gifu Prefectural Library was moved to the surrounding area		Fourth master plan was created: The central area was the focus; Surrounding area was planned as industrial and commercial zones; Natural scenery became important; Road construction, such as the radial ring network, was also a focus An integrated transportation system was planned again based on a bus network	
1999	A department store in the central area closed			
2002	Another department store closed in the central area	Nagamori		
2005				All eliminated

Based on the chronology shown in Table 4.1, in the next section, we analyze the urban changes that occurred in 1973, 1980, 1984, 1993, and 2005.

4.3.2 Changes Occurring Around 1973

In 1973, the first master plan was created. This plan classified the south area, particularly the southwest area, as an industrial zone. We compared the number of enterprises before 1973 (1968) and after 1973 (1976). As shown in Fig. 12, the gray-blue map illustrates the changes in enterprise zones using the 1968/1976 data and shows an increase in the number of enterprises. Before the first master plan was made in 1966, the Gifu prefectural hall was moved from the central area to the southwest surrounding area. Subsequently, the number of enterprises started to increase in this area (Fig. 5). After this area was classified as an industrial zone, a large increase in the number of enterprises occurred, showing that the policy made a significant impact from 1968 to 1976 (Fig. 12).

Figure 4.11 shows that the red road was a new road (1973/1964), which traveled into the southwest area. The ring road construction was planned in the first master plan, and construction began from the west. At the same time, a new national road was constructed across the southern area. These new roads attracted area development.

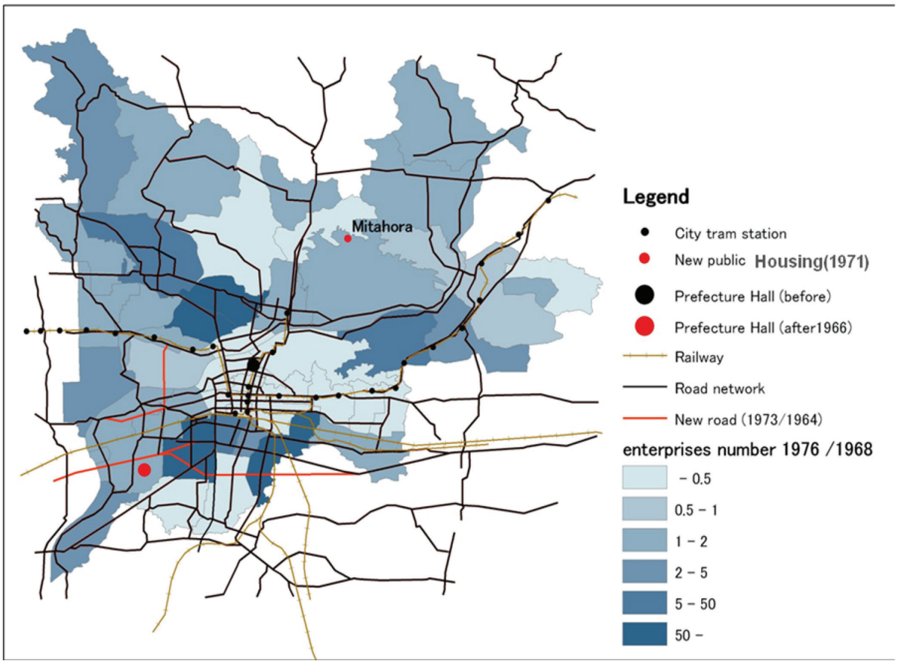


Figure 4.11 Changes Around 1973

4.3.3 Changes Occurring Around 1980

Figure 4.12 illustrates the changes that occurred around 1980, when the second master plan was created. The base map shows the number of store changes from 1976 to 1982. The number of stores increased significantly in the southwest area. During this period, three large public housing developments were built, but only one was in the central area. The housing development, called Usa, was built in 1980 in the southwest near the new prefectural hall. At the same time, two vertical (north to south) roads accessing other cities were built, which also impacted area development. The ring road was also being built in the north at this time. As shown in Fig. 4.1, the population of the surrounding area also increased during these years.

From the 1970s to 1980s, land use changed in the southwest area due to the construction of the road network, housing construction, an increase in the number of public facilities, and increased policy planning.

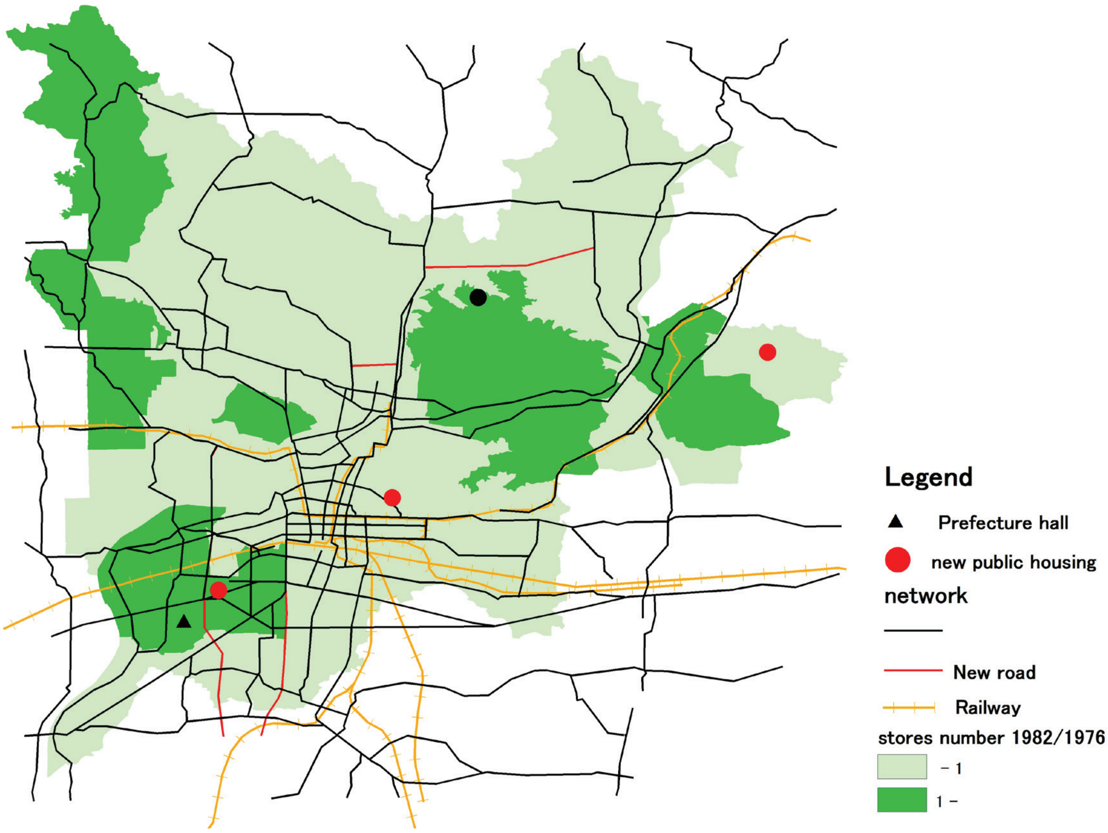


Figure 4.12 Changes Around 1980

4.3.4 Changes Occurring Around 1984

Gifu University, which had been located near the central area, moved to the northwest suburban area in 1982 (Fig. 4.13). At the same time (1981), large public housing was built near the new university campus, which changed the zone population, as shown in section 4.2.1 of Fig. 4.2.

The ring road was built in the western area, as planned in the third master plan in 1986.

Two new roads accessing areas outside the city were also built in the south, leading to a continued increase in the number of stores, as shown in the gray-blue map.

During this period, the doughnut phenomenon was increasing markedly in every index.

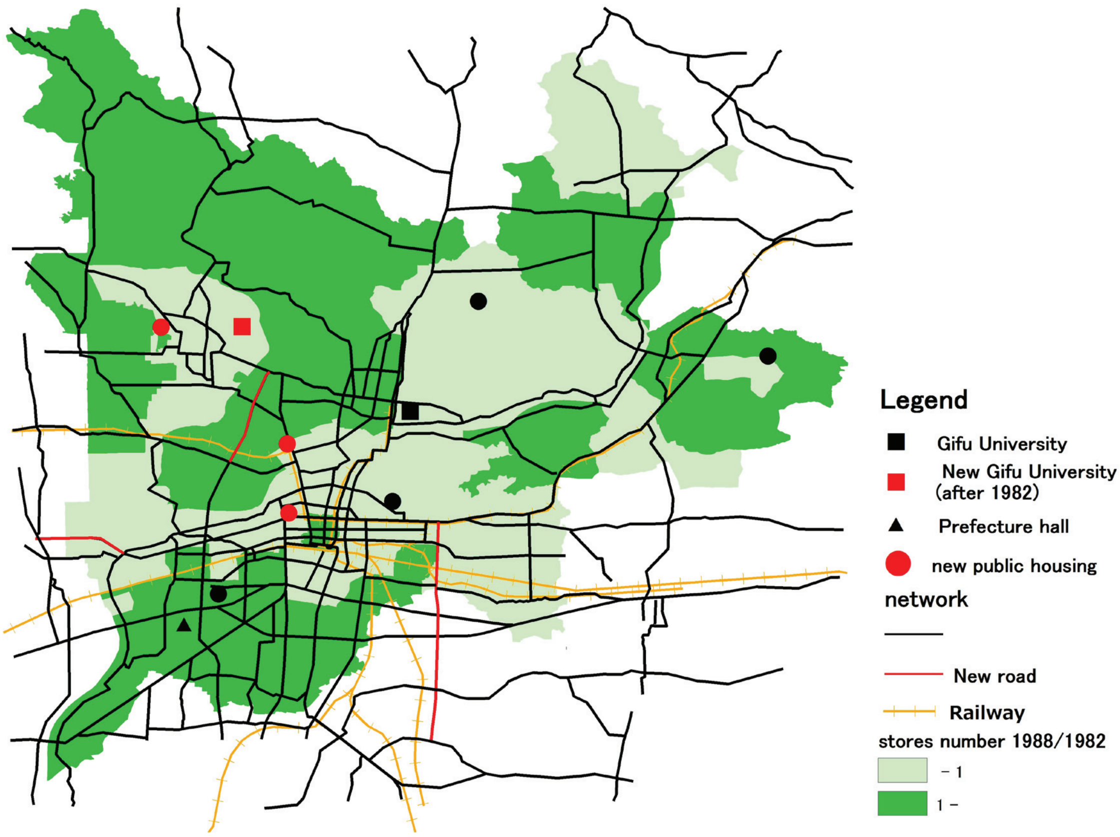


Figure 4.13 Changes Around 1984

4.3.5 Changes Occurring Around 1993

The fourth master plan was created in 1995. Figure 4.14 shows the changes from the late 1980s to the late 1990s around the fourth master plan. The map below also shows the increase in the number of stores (1999/1988).

Many city facilities were built during this period. In 1986, a new JR station (West Gifu) opened, and a new large shopping center opened in the surrounding area in 1988. A new sport studio was built in the surrounding area in 1991 (Fig. 4.14). Four public housing developments were also built from 1986 to 1993 near the central area based on the master plan to reactivate the central area. But due to the ring road and other road construction shown in Fig. 4.14, this plan was difficult to realize. Consequently, the central area has been in a continual decline, as development of the surrounding and suburban areas has progressed. Another important change was elimination of the city tram (Nagara line) in 1988. The transportation system changed significantly in these 10 years, which affected land use more than policy.

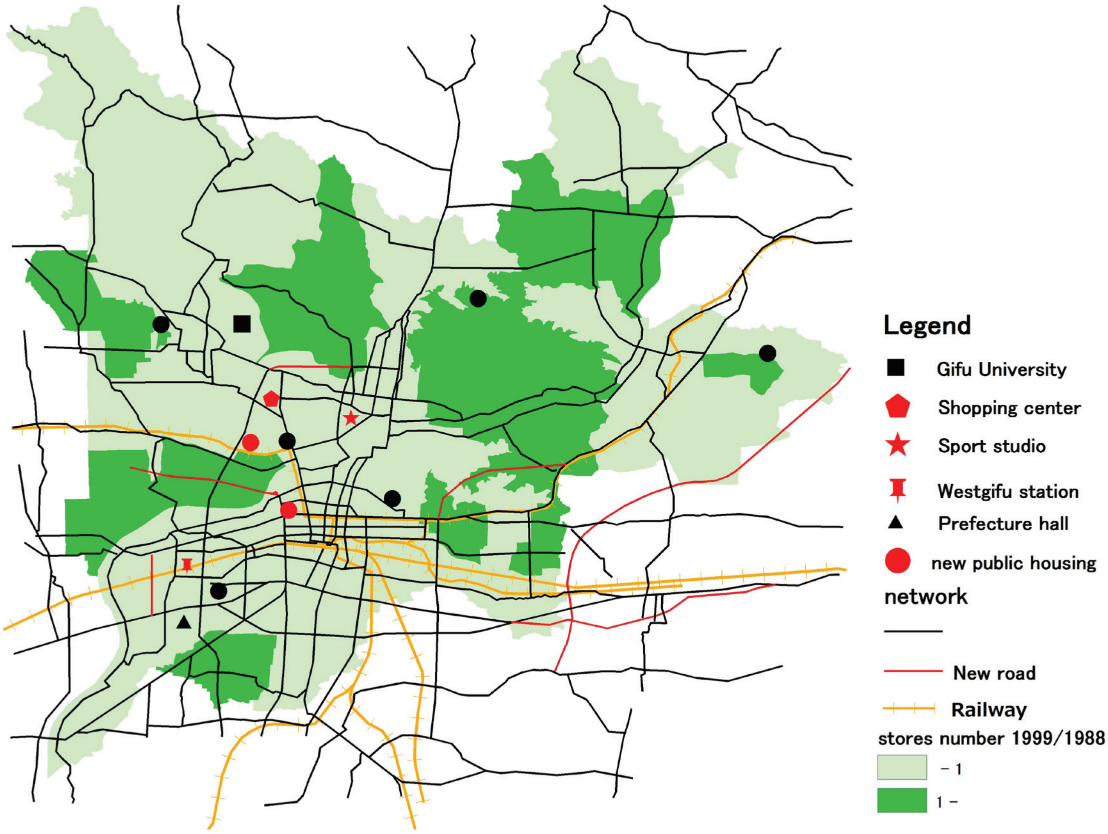


Figure 4.14 Changes Around 1993

4.3.6 Changes Occurring Around 2005

Construction of the ring-road network was completed in 2003, making car access to Gifu City more convenient. Figure 16 shows the changes that occurred around 2005. A new prefectural library and culture hall were built near the prefecture hall and West-Gifu station in 1995, and new public housing was built in the east suburban area in 2002.

Three main roads were built around the outside of Gifu City to access the other regions. With completion of the ring-road network, the formation of a Gifu City road network as a radial-ring network was completed. All of the city tram lines were eliminated in 2005, and buses were the only public transportation system. This accelerated motorization in this region. As a result, Gifu City is now further plagued by the doughnut phenomenon, as shown in the map in Fig. 4.15. Even the total number of stores had decreased, whereas it increased in some suburban areas, particularly along the ring road.

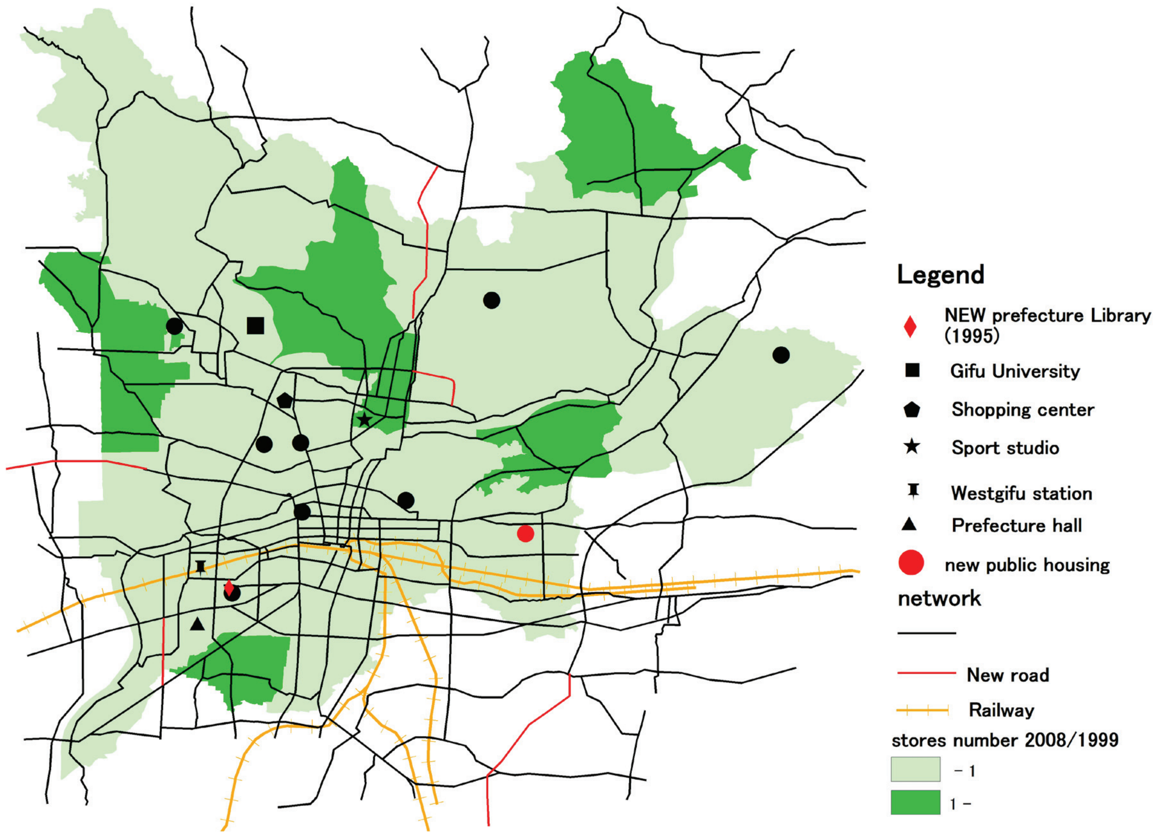


Figure 4.15 Changes Around 2005

4.4 How Did Changes in the Transportation System Affect Land Use?

The demand for urban transportation grew as the city population and economy grew. There is a predictable public voice for more transportation facilities in urban areas. As described above, we know that the changes in the Gifu City transportation system had an important impact on urban planning.

With high economic growth, the motorization of Gifu City increased continuously, creating a demand for road-network construction. The ring road completed these demands and created the city framework. It also changed land use by industries, commerce, and agriculture. Industrial and commercial land use moved from downtown to the area along the ring road.

Furthermore, the public argued that the tram impeded car traffic, which forced the local government to give up the tram. This changed the public transportation system and exacerbated car traffic. A life style revolving around the automobile affects urban planning in a car-oriented city.

4.5 Summary

We have described changes in land use, socioeconomic indices, and the transportation system in Gifu City during the late 20th century using GIS methods, and we have attempted to identify a relationship among urban planning factors. During these years, Gifu City focused on construction of the ring road network, eliminated the city tram, changed city public transportation to the bus, and moved the housing and industrial zones to the surrounding and suburban areas. As a result, commerce moved at the same time. This process was an important cause of the doughnut phenomenon. It is necessary to bring the focus back to public transportation if we are to shift to environmentally friendly and sustainable cities.

REFERENCES

C. Willoughby (2001), Singapore's Motorization Policies 1960–2000, Transport Policy 8, 125 –139.

Akiko K., Primitivo C. C., Koichi A., Hussein S. L. (2005), The Leading Factors for The Urban Development in Asian Context—Case Studies of Makita, Cebu, Taipei, and Bangkok, Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 4300–4316.

Black, J., Cheung, C., Doust, K., and Shabtay, O. (2007b), Metrics of Changes to Major Employment Centres: Analyses of Spatial Plans for Sydney 1984–2031, Journal of the Eastern Asia Society for Transportation Studies Vol. 7, pp.1311–1325.

Ho D. D., Shibayama M.(2009), Studies on Hanoi Urban Transition in the Late 20th Century Based on GIS/RS, Southeast Asian Studies,Vol.46,No.4, March 2009.

The Homepage of Urban Master Plan for Gifu City: http://www.city.gifu.lg.jp/c/40112580/40112580.html.

The Homepage of Statistics Bureau of Ministry of Internal Affairs and Communications: statistics of Regional. mesh, http://www.stat.go.jp/index.htm.

Gifu City Planning Department (1973), The First Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department (1980), The Second Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department (1986), The Third Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department (1995), The Fourth Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Statistics Analysis Department (1978–2008), Statistics Book of Gifu City: Gifu City.

Gifu City, Transportation overall Policy Planning and Evaluation Division (1973), Report of 1973 Gifu Regional Integrated Transportation System, Gifu City.

Gifu City, Transportation overall Policy Planning and Evaluation Division (1974), Report of 1974 Gifu Regional Integrated Transportation System, Gifu City.

Gifu City, Transportation overall Policy Planning and Evaluation Division (1983), Report of 1983 Gifu Regional Integrated Transportation System, Gifu City.

CHAPTER 5

Relationship of Land Use and Transport System and Their Impact to Personal Transportation Movement Using Person Trip Survey

5.1 Introduction

In last chapter, we summarized the lessons of past urban planning and transport planning in Gifu City by looking at planning and policy in the past 40 years by using historical maps, population census and socioeconomic statistics data. Because land-use, transport changes are difficult to analyse by simply inspecting written documents and data, we used a popular computer method, geographical information system (GIS) to create spatial maps to compare urban changes with spatial-distribution patterns over time.

The results of regional "personal trip (PT) surveys" are a database of urban transport planning that contains data on the trips and activities of journey makers for the target city. PT data have been used to determine the mobility situation and to make traffic demand estimation for transport planning (Miyakawa et al., 2009), environmental planning (Nitta et al., 2009) and disaster prevention planning (Osaragi, 2009). Studies have also focused on changes in activities (Masuya and Shitamura, 2001; Muronaga and Moromizu, 2002) and the relationships among land use, environment and activity (Takahashi et al., 2005). Few studies, however, have discussed land use, transport systems and traffic mobility. In this chapter, we investigate the interactions among these three factors using historical maps, socio-economic statistics and PT data.

In order to carry out further analysis about land use change and transport, we use the first to the fourth (1971, 1981, 1991, 2001) PT data in Chukyo Area of Japan. We further divide the city in to 9 zone as Centre, south, east, north, north-west (surrounding), north-west (suburban), north-east (surrounding) and north-east (suburban) inside Gifu city, and from outside, there are 10 direction as Nagoya, Kakamigahara-Aichi, Seki-Mino, Yamagata -Takatomi, Kani, Ogaki, Motosu, Ginan-Hashima, Mizuho and Mie (Fig. 5.1).

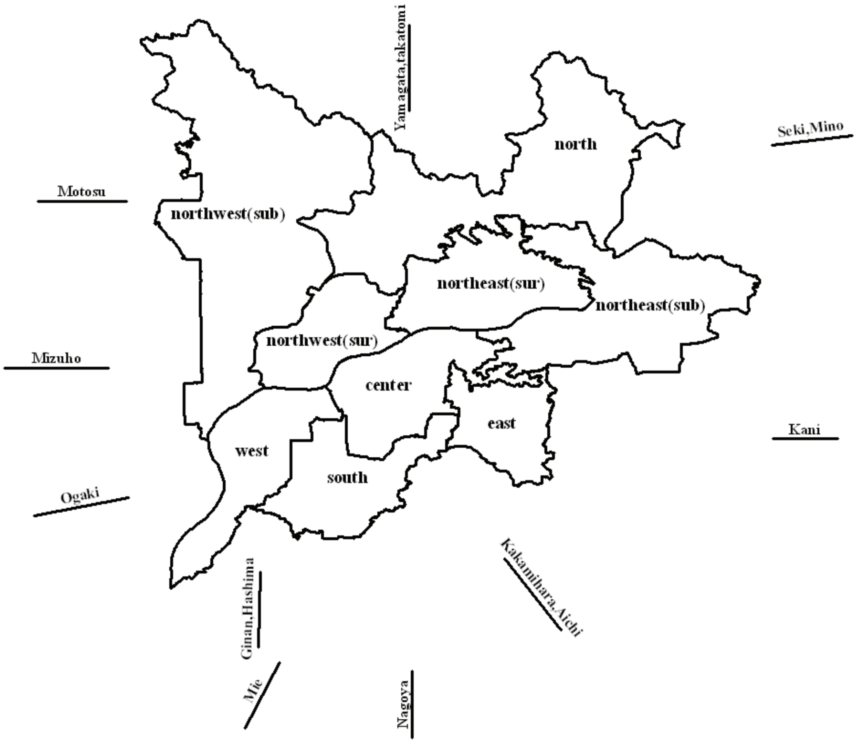


Figure 5.1 Zoning by PT

5.2 Land Use and Transport System Impact to Traffic Mobility by time Axis

Table 5.1 shows the number of population, enterprises, stores as well as trip generation and attraction in the 9 zones from 1970s to 2000s.

In the last chapter, from 1990s to 2000s, the urban structure of Gifu City was forming in motorization suburbanization doughnut city. And looking at table 5.1, trip attraction and trip generation by car was decreased just in the centre and increased in all the other zones. Bus by public transport it was almost decreased in all the zones. This evidence the motorization and suburbanization caused by annular radial road construction and the withdrawal public transport system.

In the next section, we focus on 1970s-1990s that the Gifu City was during the motorization and suburbanization and use the data to analyse the changes in land use, transport system and traffic mobility and there mutual impact.

Table 5.1 Population, enterprise number, store number and trip attraction, trip generation in 9 zones

item	Centre	East	South	West	North	North-west (sur)	North-west (sub)	North-east (sur)	North-east (sub)	Total

Population	1970s	139528	30149	36642	35198	21218	47971	25643	31112	18266	385727
	1980s	109286	32978	41838	39994	29693	49801	35113	34544	37110	410357
	1990s	93991	33448	43191	41347	33329	46327	41232	35182	39829	407876
	2000s	78047	34761	44690	41329	34638	47217	45981	35040	40754	402457
	change 1970s-1980s	-30242	2829	5196	4796	8475	1830	9470	3432	18844	24630
	change 1980s-1990s	-15295	470	1353	1353	3636	-3474	6119	638	2719	-2481
	change 1990s-2000s	-15944	1313	1499	-18	1309	890	4749	-142	925	-5419
Enterprise number	1970s	1845	460	517	537	199	405	216	284	151	4614
	1980s	1320	429	578	522	234	387	471	240	156	4337
	1990s	891	371	612	470	292	375	484	214	203	3912
	2000s	453	226	372	269	203	199	289	112	117	2240
	change 1970s-1980s	-525	-31	61	-15	35	-18	255	-44	5	-277
	change 1980s-1990s	-429	-58	34	-52	58	-12	13	-26	47	-425
	change 1990s-2000s	-438	-145	-240	-201	-89	-176	-195	-102	-86	-1672
Store number	1970s	7641	438	806	1044	253	805	744	458	233	12422
	1980s	5489	532	1003	730	282	780	719	503	313	10351
	1990s	5046	502	1183	751	291	823	678	514	336	10124
	2000s	3265	421	1124	624	250	670	563	430	302	7649
	change 1970s-1980s	-2152	94	197	-314	29	-25	-25	45	80	-2071
	change 1980s-1990s	-443	-30	180	21	9	43	-41	11	23	-227
	change 1990s-2000s	-1781	-81	-59	-127	-41	-153	-115	-84	-34	-2475
Trip attracti	by car1971	79985	29097	13906	29500	8375	20851	13023	15060	6490	216286
	1981	72040	34559	21543	44730	14389	28519	19424	24513	18480	278197

on	1991	75720	40392	26147	68587	40741	42628	42838	31786	28144	396983
	2001	70324	50617	28704	75773	54697	59486	62117	42370	41660	485748
	change 1970s-1980s	-7945	5462	7637	15230	6014	7668	6401	9453	11990	61911
	change 1980s-1990s	3680	5833	4604	23857	26352	14109	23414	7273	9664	118786
	change 1990s-2000s	-5396	10225	2557	7186	13956	16858	19279	10584	13516	88765
	by rail1971	2954	2389	198	688	139	534	2071	335	590	9898
	1981	1554	1660	230	213	45	226	511	234	354	5027
	1991	1441	1285	201	381	63	169	258	96	398	4292
	2001	1085	1164	128	569	29	226	228	86	276	3791
	change 1970s-1980s	-1400	-729	32	-475	-94	-308	-1560	-101	-236	-4871
	change 1980s-1990s	-113	-375	-29	168	18	-57	-253	-138	44	-735
	change 1990s-2000s	-356	-121	-73	188	-34	57	-30	-10	-122	-501
	by bus1971	37821	6779	4273	10035	4304	9803	2661	8006	2753	86436
	1981	25034	4959	2859	6194	2580	6004	2620	7763	2447	60460
	1991	16426	3387	1813	5298	2199	4555	1918	4343	2681	42620
	2001	12439	2081	1408	3179	1516	3429	1220	2930	2316	30518
	change 1970s-1980s	-12787	-1820	-1414	-3841	-1724	-3799	-41	-243	-306	-25976
	change 1980s-1990s	-8608	-1572	-1046	-896	-381	-1449	-702	-3420	234	-17840
	change 1990s-2000s	-3987	-1306	-405	-2119	-683	-1126	-698	-1413	-365	-12102
	total 1971	120760	38265	18377	40223	12818	31188	17755	23400	9833	312620
	1981	98628	41178	24632	51137	17014	34749	22555	32510	21281	343684
	1991	93587	45064	28161	74266	43003	47352	45014	36225	31223	443895
	2001	83848	53862	30240	79521	56242	63141	63565	45386	44252	520057
	change 1970s-1980s	-22132	2913	6255	10914	4196	3561	4800	9110	11448	31064
	change	-5041	3886	3529	23129	25989	12603	22459	3715	9942	100211

	1980s-1990s										
	change 1990s-2000s	-9739	8798	2079	5255	13239	15789	18551	9161	13029	76162
Trip generation	by car1971	83838.1	30051.8	13893.7	29976.7	6714.8	21487.55	10221.26	14794.97	5307.68	216286
	1981	71901	35140	21042	44500	14273	28306	19607	24833	18595	278197
	1991	75894	40335	25536	69594	40564	42051	42979	32230	27800	396983
	2001	69222	50610	29259	75991	54780	59132	62353	42330	42071	485748
	change 1970s-1980s	-11937	5088	7148	14523	7558	6818	9386	10038	13287	61911
	change 1980s-1990s	3993	5195	4494	25094	26291	13745	23372	7397	9205	118786
	change 1990s-2000s	-6672	10275	3723	6397	14216	17081	19374	10100	14271	88765
	by rail1971	3788	2466	366	632	84	906	703	391	562	9898
	1981	1547	1555	187	289	45	258	534	234	378	5027
	1991	1521	1149	151	307	216	103	300	96	449	4292
	2001	1320	387	67	684	77	163	849	218	26	3791
	change 1970s-1980s	-2241	-911	-179	-343	-39	-648	-169	-157	-184	-4871
	change 1980s-1990s	-26	-406	-36	18	171	-155	-234	-138	71	-735
	change 1990s-2000s	-201	-762	-84	377	-139	60	549	122	-423	-501
	by bus1971	38824	6742	4578	10763	2955	10111	2333	8192	1937	86436
	1981	24131	5448	2967	6444	2551	6100	2621	7833	2365	60460
	1991	16603	3248	1823	5412	2184	4399	2016	4271	2664	42620
	2001	12797	2256	1240	3178	1167	3443	1008	3196	2233	30518
	change 1970s-1980s	-14693	-1294	-1611	-4319	-404	-4011	288	-359	428	-25976
	change 1980s-1990s	-7528	-2200	-1144	-1032	-367	-1701	-605	-3562	299	-17840
	change 1990s-2000s	-3806	-992	-583	-2234	-1017	-956	-1008	-1075	-431	-12102
	total 1971	126451	39260	18838	41371	9754	32504	13257	23378	7807	312620

	1981	97579	42143	24196	51233	16869	34664	22762	32900	21338	343684
	1991	94018	44732	27510	75313	42964	46553	45295	36597	30913	443895
	2001	83339	53253	30566	79853	56024	62738	64210	45744	44330	520057
	change 1970s-1980s	-28872	2883	5358	9862	7115	2160	9505	9522	13531	31064
	change 1980s-1990s	-3561	2589	3314	24080	26095	11889	22533	3697	9575	100211
	change 1990s-2000s	-10679	8521	3056	4540	13060	16185	18915	9147	13417	76162

5.2.1 Land Use and Transport System Impact to Traffic Mobility in 1970s-1980s

- Changes in land use and transport system

The first master plan was created in 1973. It clarified land use through urban planning; land use categorized into city center, industrial zone, housing zone, commercial zone, agriculture zone and green zone. The population was decreased in the central area though total population in the city increased. The Ring-road construction was planned and construction was started (Fig.5.2). The motorization was grown fast while car owners/population increased about 12%.

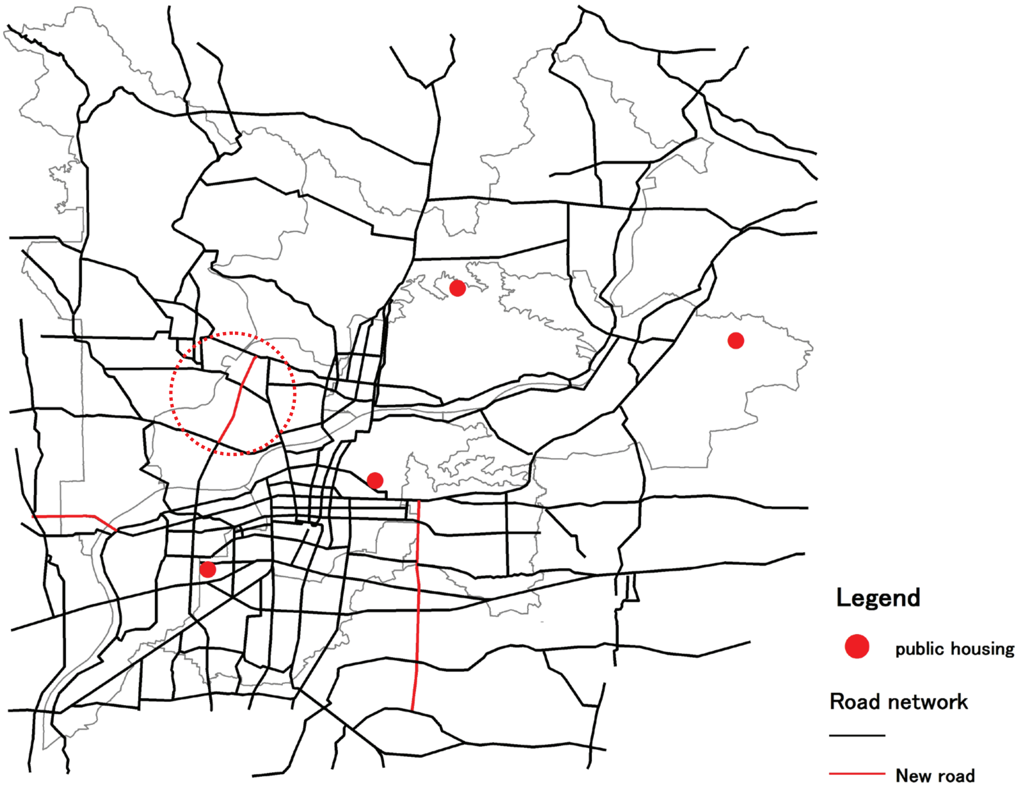


Figure 5.2 Change of the road network (1973-1984)

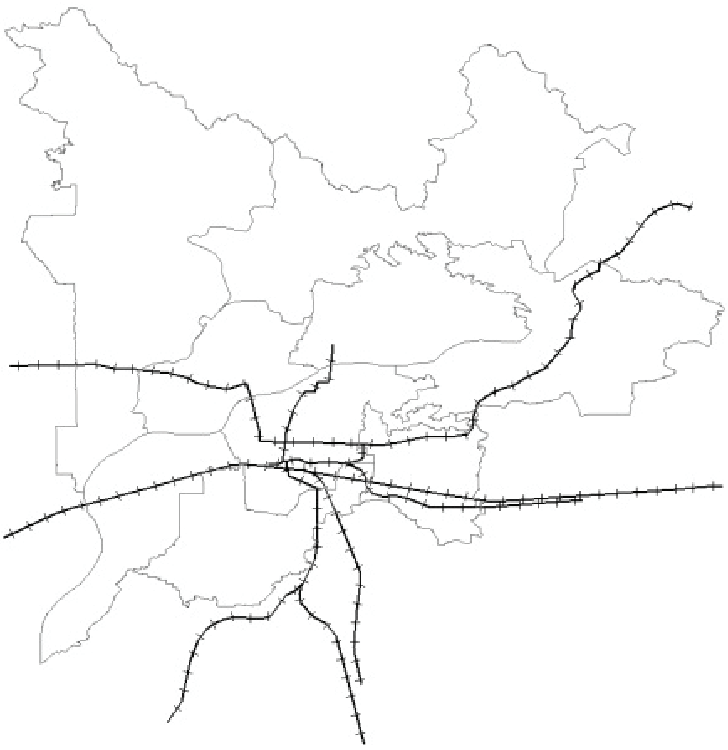


Figure 5.3 The rail network (1980s-1990s)

Figure 5.4 shows the population changes in the 9 zones between 1970 and 1980. The population grew in the surrounding areas and suburban areas but fell in the centre. Figures 5.5 and 5.6 illustrate the changes in the number of enterprises and stores, showing that the locations of enterprises shifted towards the suburban areas. And during this period, stores in centre had not being decreased along the rail network (include city tram) shown in fig.5.3, there were also stores increased.

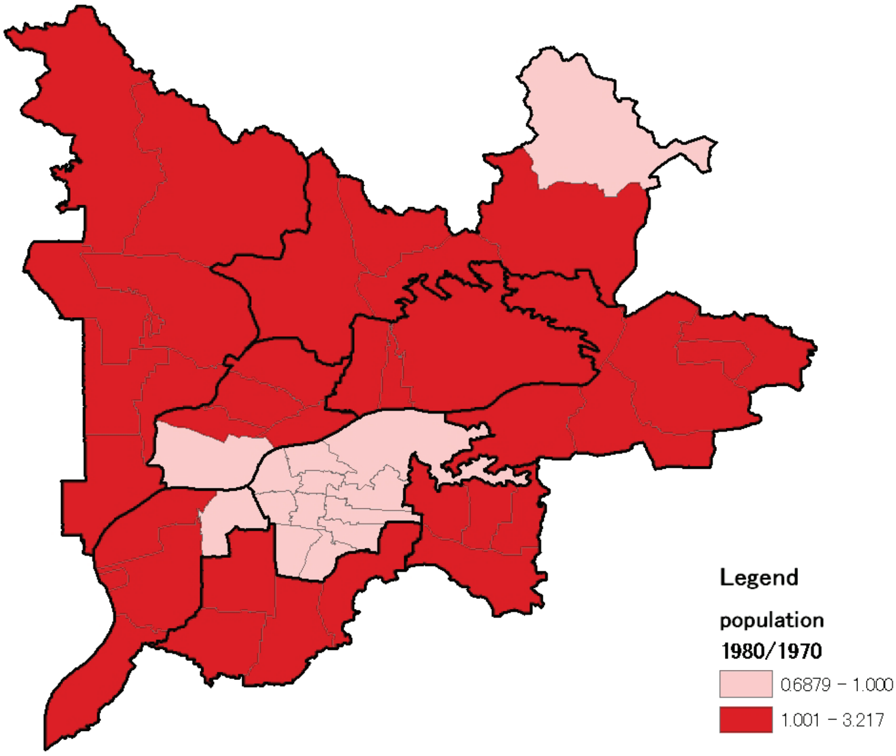


Figure 5.4 Change of population (1970-1980)

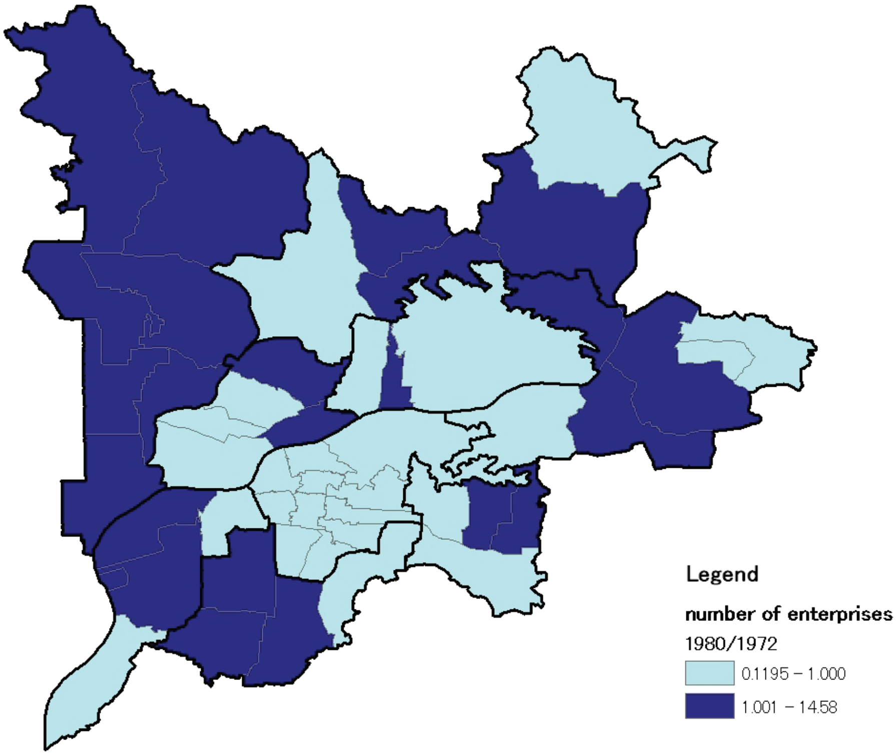


Figure 5.5 Change of the number of enterprises (1972-1980)

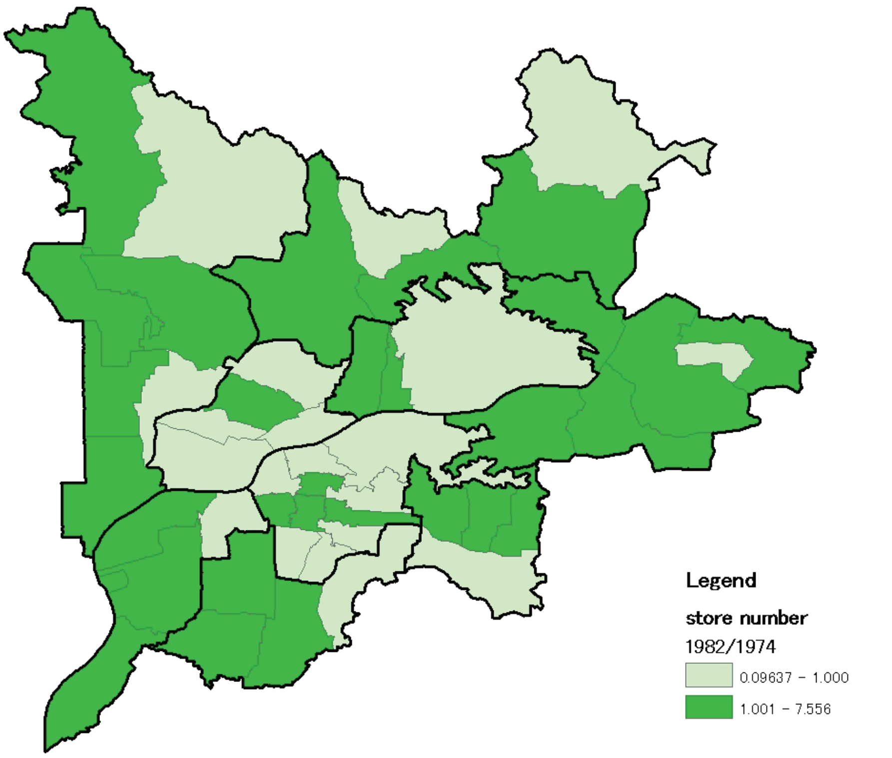


Figure 5.6 Change of store number (1974-1982)

- Changes in Traffic Mobility

From table 5.1, we know that from 1970s to 1980s, trip attraction and trip generation by car began decreased just in the centre and increased in all the other zones. Bus by public transport it was almost decreased in all the zones.

From the changes in land use, we chose south, west and north-west suburban zones which all increased in population, enterprises and store number. Table 5.2 shows the trip attraction to south, west and north-west suburban for commuting by car and public transport. From Table 5.2, it illustrates that except from central zone, the commuting to these three zones was almost same (to south 118%, to west 104% and to north-west suburban 98%). From all the other zones, the trip attraction to these three zones was increased a lot. Especially from the north-west suburban zone and the north-east suburban zone, the trip attraction volume was all over 3 times in the 10 years. The cause could be found in table 5.1 and fig.5.4, we know that the population was increased 18844 in north-east suburban zone and 9470 in the north-west suburban zone, it was number 1 and number 2 in population growth in the city.

Table 5.2 Trip Attraction to South, West and North-west suburban for Commuting (by car and public transport)

origin zone	Destination zone								
	1971			1981			1981/1971		
	south	west	north-east suburban	south	west	north-west suburban	south	west	north-west suburban
centre	1011	1630	307	1197	1687	300	118%	104%	98%
east	422	787	56	781	1408	189	185%	179%	337%
south	393	478	26	725	600	61	184%	126%	236%
west	337	2099	84	598	3032	238	177%	144%	283%
north	112	450	56	500	640	214	445%	142%	381%
north-west surrounding	309	1265	337	558	1131	607	180%	89%	180%
north-west suburban	112	253	309	550	1010	1589	489%	399%	514%
north-east surrounding	337	562	112	434	768	170	129%	137%	151%
north-east suburban	28	309	28	389	1057	166	1384%	342%	590%
total	3062	7831	1316	5731	11332	3534	187%	145%	268%

Next, we follow with interest to the mode share of trip attraction to south, west and north-west suburban for commuting. It is shown in Fig.5.7. Compared to 1971, the share of car increased over 10% in all of the three zones. In the other hand, other mode shares less in 1981 compared to 1971.

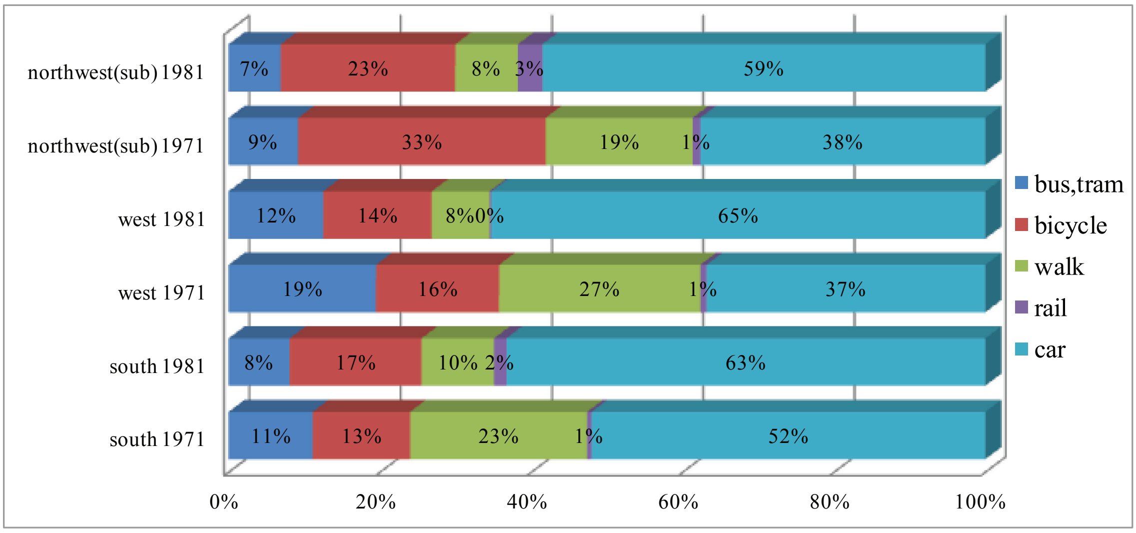


Figure 5.7 mode share of trip attraction to south, west and north-west suburban for commuting

What about the average of shares by car in the city? Table 5.3 shows the detail of share of share of trip attraction to south, west and north-west suburban by car for commuting and the number of average of 9 zones. It illustrates what among that the share of car increased in the entire zone in the ten years. And the number of the three zone was all larger than the average of all the zone. Focus the number, we notice the origin zone from north-west surrounding zone, the increase is substantial. Look back to fig.5.2, there was a new road (shown by the red dotted line) connected the north-east suburban zone to the other zone especially west zone, south zone and north-west suburban zone. The new road pushed the car use a lot obviously.

Table 5.3 Share of Trip Attraction to South, West and North-west suburban by Car for Commuting

car	1971				1981			
origin zone	south	west	north-west(sub)	average of 9 zone	south	west	north-west(sub)	average of 9 zone
center	72%	46%	82%	29%	61%	54%	57%	35%
east	62%	52%	50%	39%	87%	75%	83%	55%
south	24%	70%	100%	42%	35%	74%	100%	53%
west	77%	23%	100%	36%	72%	54%	68%	52%
north	50%	59%	50%	41%	85%	83%	94%	62%
north-west(sur)	46%	43%	67%	37%	76%	69%	80%	55%
north-west(sub)	75%	67%	16%	41%	75%	82%	47%	62%
north-east(sur)	75%	45%	60%	39%	68%	74%	55%	46%

north-east(sub)	50%	91%	100%	57%	74%	86%	76%	70%
total	52%	37%	38%	36%	63%	65%	59%	52%

5.2.2 Land Use and Transport System Impact 1980s-1990s

- Changes in land use and transport system

Table 5.1 shows the population and number of enterprises and stores, as well as trip generation and attraction in the nine zones from 1981 to 1991. The second master plan of Gifu City was drawn up in 1980. Land-use zones remained as described in the first master plan, and a regional highway network with access to other cities was planned. The third master plan was created in 1986, which made the radial ring road network a priority. Motorisation was growing quickly and the number of car owners increased by approximately 30% from 1981 to 1991. During the same period, many facilities were built in the surrounding and suburban areas. Public housing (called kuruno, consisting of approximately 200 households) was built in north-west suburban zone; Gifu University (National University, with a site area of 640000 m² and 7000 students) saw the faculties relocated to a single campus in the north-west suburban area in 1982 (which previously were distributed within Gifu). A new shopping centre (with a site area of 60000 m²) was opened in the north-west surrounding area in 1988, and a new sports stadium was opened in the north-east surrounding area in 1991. The location of these facilities is shown in Figure 5.8.

A new rail station (West Gifu) was opened in west area of the city in 1986, the ring road was extended, and road links to outside areas were also constructed in the west, the north, the north-west surrounding and the north-east suburban zones (Figure 5.8). The Nagara Tramline (shown by the brown line in Figure 5.9) was decommissioned in 1984 and replaced by a bus service.

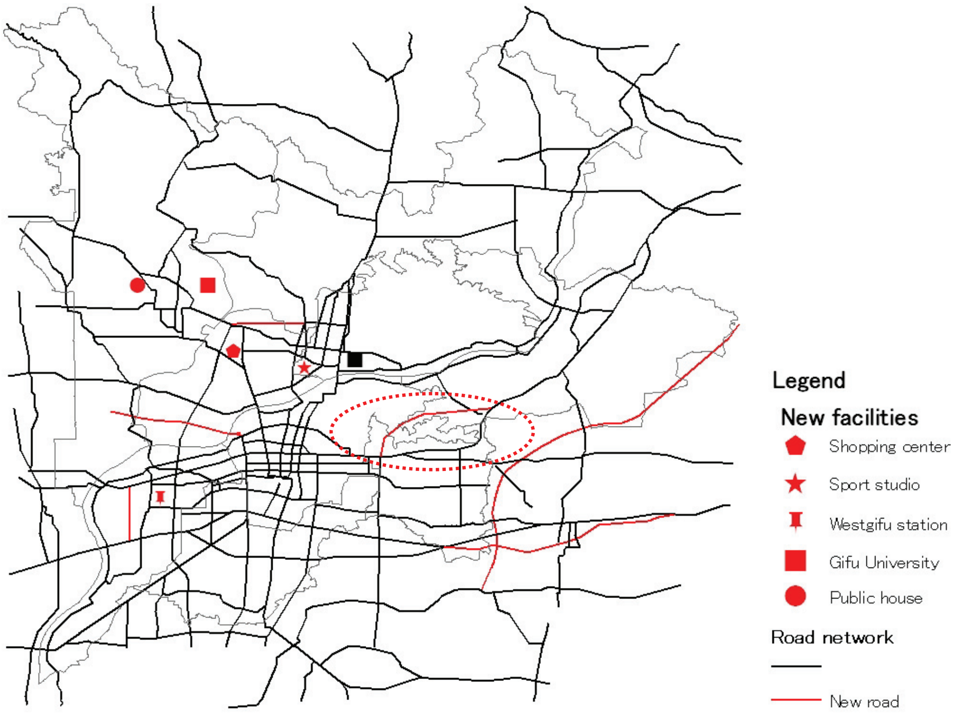


Figure 5.8 change of the road network (1984-1993)

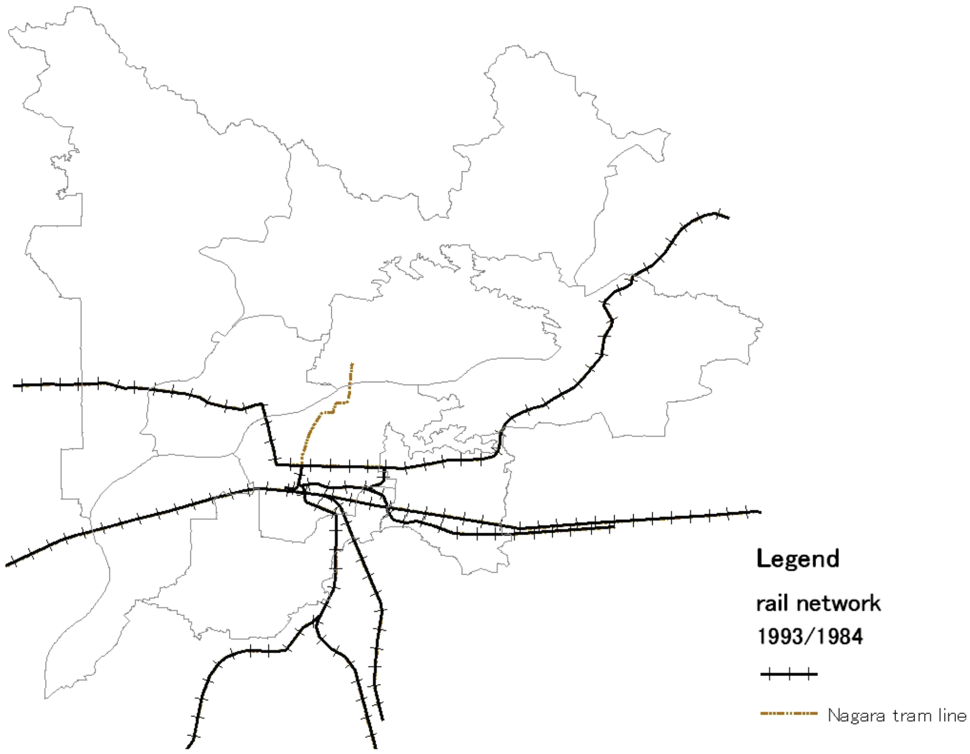


Figure 5.9 change of the rail network (1980s-1990s)

Figure 5.10 shows the population changes in the 9 zones between 1980 and 1990. The population grew in the suburban areas but fell in the centre and most of the surrounding areas. Figures 5.11 and 5.12 illustrate the changes in the number of enterprises and stores, showing that the locations of enterprises and stores shifted towards the suburban areas. When we contrast this with the road network and number of stores shown in Figure 5.12, this illustrates that land use was active where the new ring road was being developed.

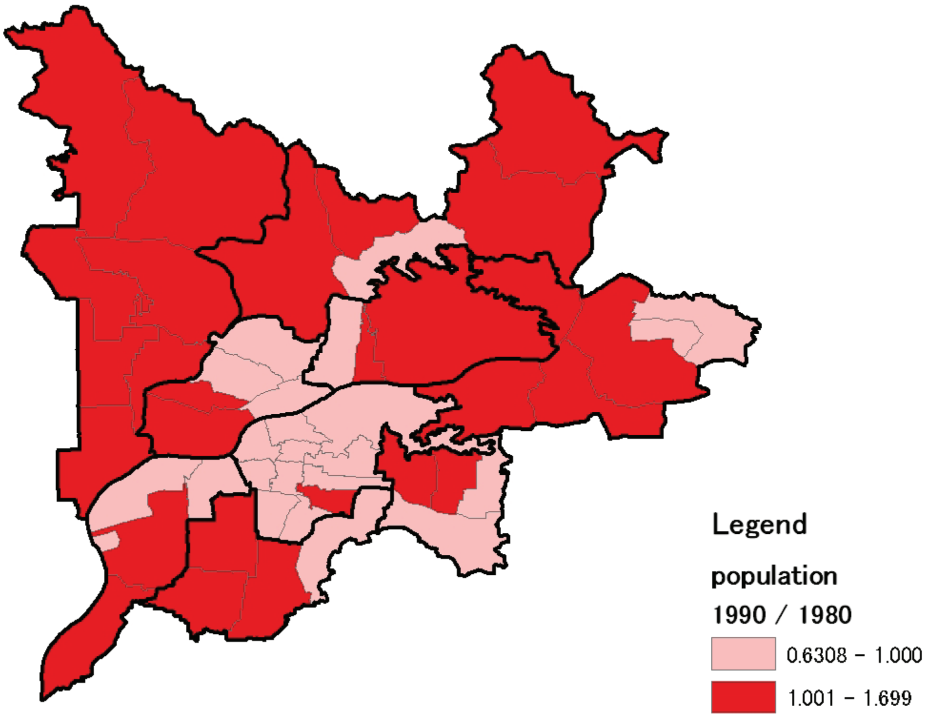


Figure 5.10 change of population (1980-1990)

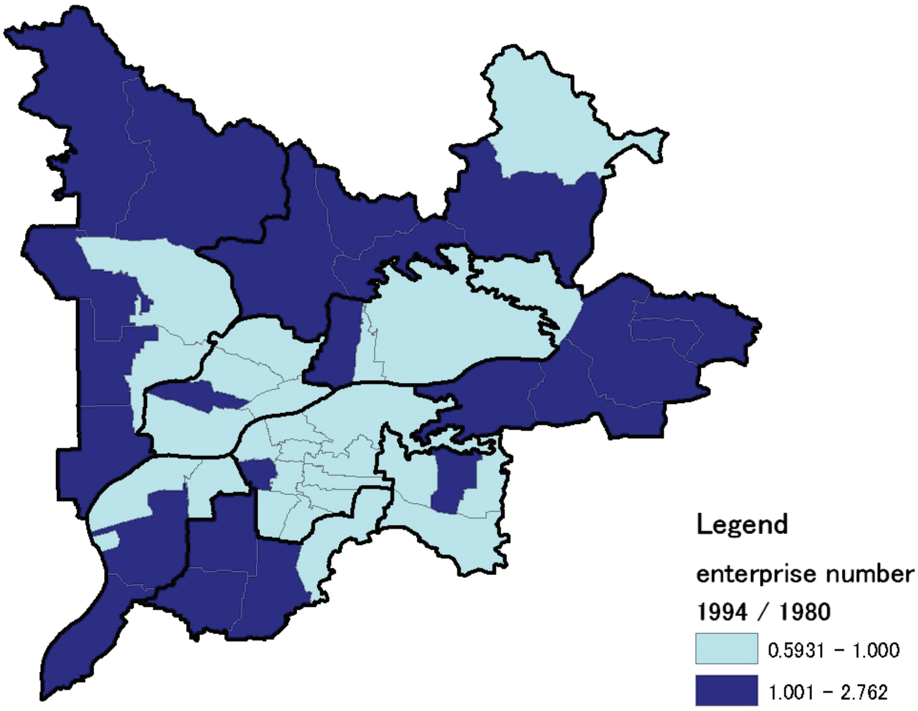


Figure 5.11 change of the number of enterprises (1980-1994)

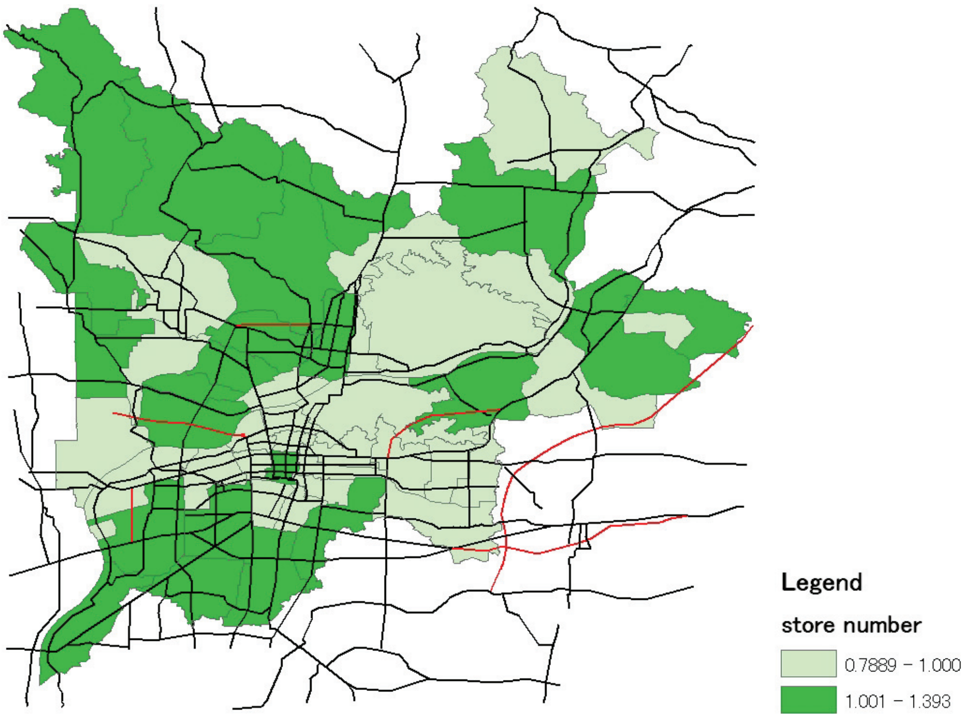


Figure 5.12 change of store number (1982-1994)

Table 5.1 shows that the north-east suburban zone was unique in that the population and number of enterprises and stores all increased, and that the number of journeys by all modes also increased. The reason for this may be large-scale public housing construction in this zone. Starting in the 1970s, approximately 1500 homes were built in a public housing project. Figure 5.8 shows one important new road (shown by the red dotted line) connected the north-east suburban zone to other zones and to the outside of the city. This attracted a large number of people who moved to this zone, leading to growth by all metrics Change in traffic mobility.

- Changes in traffic mobility

We used PT data to determine the number of trips for attractions and generation from 1981 to 1991 (Table 5.1). The number of all trips by car increased during this period. In particular, in the west, north, north-west surrounding and north-west suburban zones, the number of trips by car increased by more than 10000; in this region, the road network was extended by the construction of a new road (Figure 5.8). This is consistent with the growth of the population, and number enterprises and stores. It may affect changes in land-use change and mobility by increasing the convenience of cars, and car usage increased during this period. Figure 5.8 shows that a new road was constructed connecting the north-west surrounding zone to zones including the north and north-west suburban zones.

The new West Gifu rail station that opened in 1986 appears to have led to an increase in the number of journeys from to the west zone, in particular from Aichi, Seki Mino, Ogaki, Hashima and Mizuho (Table 5.4). This new rail station improved the mobility of this area and the number of journeys by rail increased, especially from outside of the city.

Table 5.4 Change of rail trip attraction to west zone (1981-1991)

Origin	Number of trips	Origin	Number of trips
Center	167	Nagoya	64
East	-76	Kakamigahara, Aichi	682
South	-24	Seki, Mino	216
West	0 (0-0)	Yamagata, Takatomi	0 (0-0)
North	0 (0-0)	Kani, Tajimi	35
Northwest (surrounding)	0 (0-0)	Ogaki	143
Northwest(suburban)	42	Motosu	6
Northeast(surrounding)	26	Ginan, Hashima	164
Northeast(suburban)	52	Mizuho	158
		Mie	29

Gifu University opened the new campus in the north-western suburban area in 1982, which was expected to affect the journeys to the north-western suburban area. Figure 5.13 illustrates the changes in the number of journeys in routes to the north-west suburban area. We find that the number of journeys to this area increased from all zones except the centre, south Motosu and north-east surrounding area, and that the number of journeys by rail from Kakamigahara Aichi, Nagoya, west and the north-west suburban all increased. The relocation of Gifu University had a major effect on transport in Gifu City.

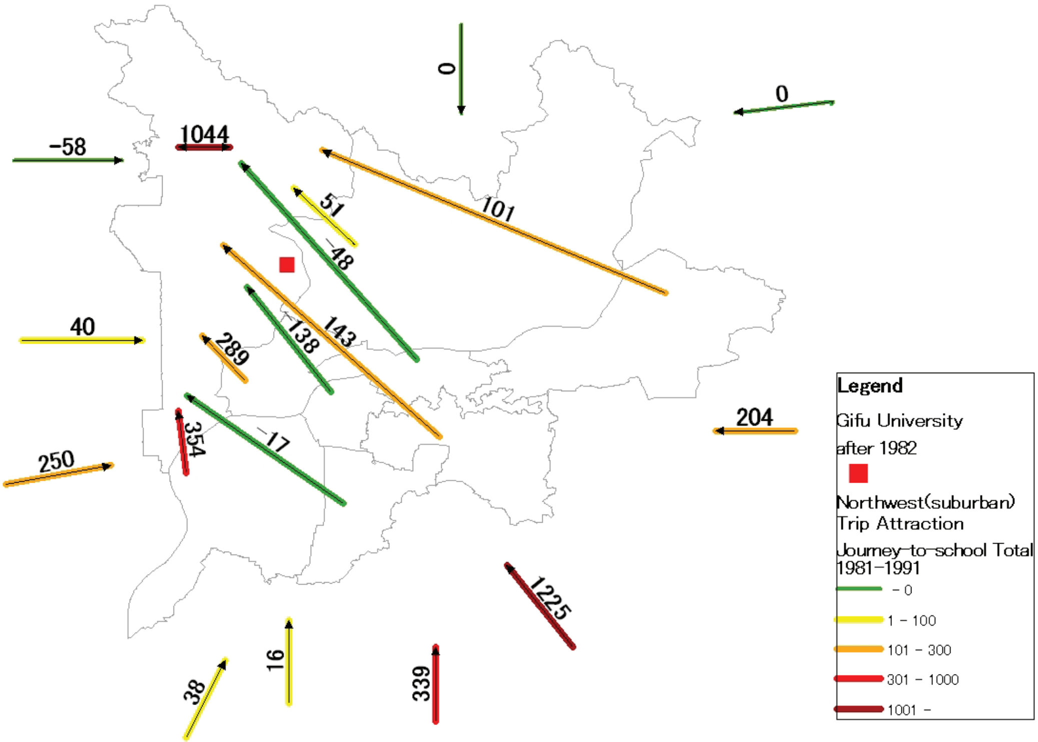


Figure 5.13 change of journey-to-school trip attraction to northwest(suburban) zone (1981-1991)

The biggest change in public transport in this period was one of the city tram line (Nagara Line) was eliminated. Fig.5.14 illustrates the change of public transport system and the trip attraction by bus and tram. The red lines are the new bus line from 1984 to 1993, and the gray line was the eliminated tram line. The bus line was newly designed along the Ring Road in the suburban area. It is shown that in most zones, the trips of bus and tram decreased, especially to central an northwestern (surrounding) areas. It may be caused by the tram eliminated and trip mode may shift to car.

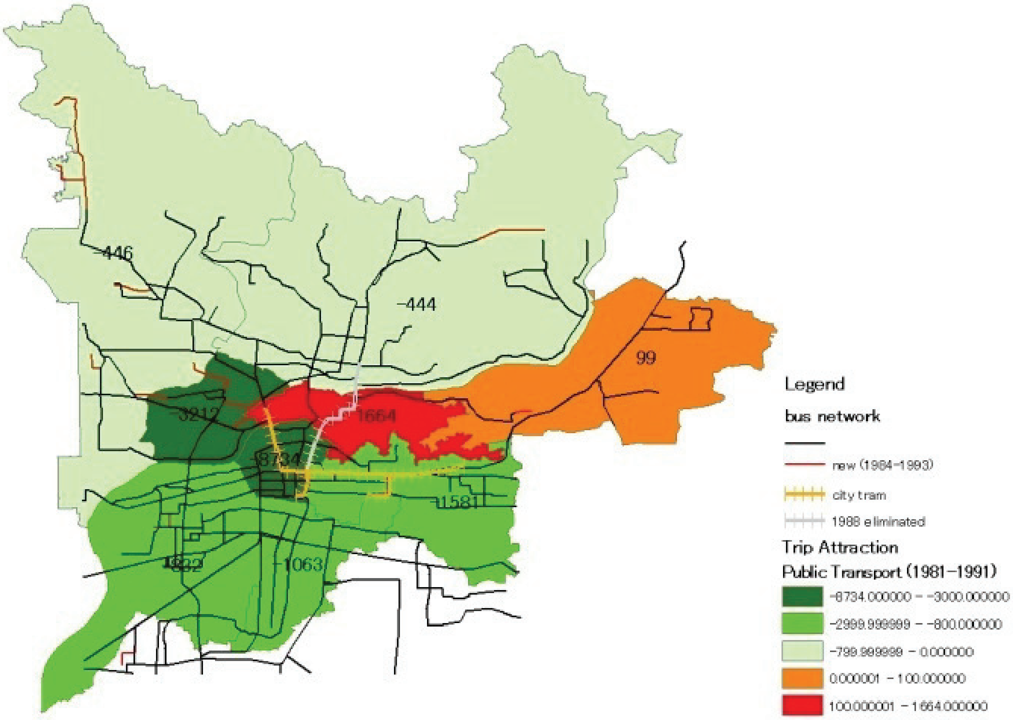


Figure 5.14 Change of Public (Bus and Tram) Trip Attraction (1981-1991)

From above, we can summarise that the road network and public transport system has interaction with land use changes and the facility affect the traffic mobility enormously.

5.3 Land Use and Transport System Impact by Micro Space Process

5.3.1 Land Use and Transport System Impact in North-west(surrounding) Zone

The typical suburban commercial zone is north-west(surrounding) since a new shopping center (site area 60,000m²) was opened. Also from Fig.5.8, the new road was constructed and it connects north-west(surrounding) to other zones like north, north-west(suburban). In this section, we focus on the north-west(surrounding) zone and change in the traffic mobility is explored. Table 5.5 shows the number of trips to and from the north-west surrounding zone in 1981 and 1991. The number of trips from the north and north-west suburban zones doubled from 1981 to 1991. However, the number of trips by rail and bus decreased in most zones. Even the number of car journeys from the centre increased, despite a decrease in the total number of journeys. It could be proved a lot that motorisation pushed on the planning of the road network and at the same time, the developed road network pushed on the motorisation more and more.

Table5.5 Trip attraction to north-west(surrounding)

origin zone	total (car, public transport)			by car		
	1981	1991	1981/1991	1981	1991	1991/1981
center	10632	10295	97%	7291	7449	102%
east	1721	2747	160%	1241	2444	197%
south	1496	1497	100%	1106	1421	128%
west	3278	3825	117%	2787	3579	128%
north	949	2451	258%	931	2272	244%
northwest(sur)	10852	16388	151%	10224	16014	157%
northwest(sub)	2465	5387	219%	2028	4975	245%
northeast(sur)	2891	3702	128%	2478	3489	141%
northeast(sub)	465	1215	261%	433	985	227%
total	34749	47507	137%	28519	42628	149%

Table 5.6 list a breakdown of the journeys to the north-west surrounding zone for leisure (e.g. shopping, dining and amusement) and to the centre. The volume of journeys for leisure to the centre zone is also shown in the table. The appearance of the new shopping centre in the north-west surrounding zone attracted a large number of people (an increase from 4274 to 11185). However, the volume of journeys to the centre zone increased by only 11%. The development of the suburban shopping centre appears to have resulted in a decline in journeys into the city centre.

Table5.6 The Number of Journeys to the North-west Surrounding Zone and to the Centre Zone for Leisure in 1981 and 1991 (shopping, dining, amusement, ex.)

origin zone	for leisure (shopping, dining, amusement, ex.)						Destination zone	for leisure
	northwest(surrounding)			center				
	1981	1991	1991/1981	1981	1991	1991/1981		1991/1981(average)
center	854	1449	170%	6716	7419	110%	center	110%
east	68	497	735%	2845	2654	93%	east	248%
south	91	90	99%	1344	1096	82%	south	150%
west	323	854	265%	2622	3785	144%	west	183%
north	221	494	224%	2135	2801	131%	north	380%
northwest(sur)	1807	4736	262%	2336	2200	94%	northwest(sur)	310%
northwest(sub)	399	1880	471%	1017	944	93%	northwest(sub)	245%
northeast(sur)	461	1005	218%	800	1107	138%	northeast(sur)	166%
northeast(sub)	52	180	349%	1172	1231	105%	northeast(sub)	183%

total	4274	11185	262%	20988	23237	111%	total	220%

5.3.2 Land Use and Transport System Impact in North-east(surrounding) Zone

Another significant change in the public transport network during this period was that one of the city tramlines (the Nagara Line) was decommissioned. From Table 5.1, it is shown that the population was increased over 4000 from 1970-1990. But it was decreased from 1990 to 2000 after the Nagra line was eliminated. The same situation was happened in commercial data (store number).

Table 5.1 shows that the number of journeys by bus and tram decreased significantly, especially in the north-east surrounding zone, where the Nagara Tramline used to run. The decommissioning of the tramline may have led to growth in the number of journeys by car. The north-east surrounding zone is a residential district, and the decommissioning of the tramline may have changed the lifestyle of people living there. Table 5.7 lists the number of journeys from the north-east surrounding zone. The number of journeys to the centre zone by bus and tram decreased by almost half. As a result, in 1991, the number of trips from this zone to the centre decreased to 80% compared with 1981. Considering that the total number of journeys increased by 12% and the increase in the number of journeys by car, which was particularly high in the north, north-west suburban and north-east suburban areas, people who used to visit the centre zone did not appear to change the mode of transport, but rather changed their destination. Note that the changes in the usage of public transport may not only affect the public transport network, but also the destination.

Table 5.7 Trip generation from northeast(surrounding) zone

Destination zone	car			public transport (bus, tram)			total		
	1981	1991	1991/1981	1981	1991	1991/1981	1981	1991	1991/1981
center	5055	5177	102%	4055	2291	56%	9110	7468	82%
east	1059	1317	124%	404	121	30%	1463	1438	98%
south	803	549	68%	448	202	45%	1251	751	60%
west	2146	2635	123%	799	454	57%	2945	3089	105%
north	2490	3930	158%	404	309	76%	2894	4239	146%
northwest(sur)	2478	3489	141%	413	213	52%	2891	3702	128%
northwest(sub)	964	1951	202%	268	133	50%	1232	2084	169%
northeast(sur)	8812	11758	133%	889	296	33%	9701	12054	124%

northeast(sub)	1026	1424	139%	153	252	165%	1179	1676	142%
total	24833	32230	130%	7833	4271	55%	32666	36501	112%

5.4 Summary

We have described changes in land use, socioeconomic indices, the transportation system and traffic mobility in Gifu City during 1980s to 1990s using historical map, census data, PT data and GIS methods. We attempted to identify a relationship among urban planning factors. During these years, Gifu City focused on construction of the Ring Road network, eliminated city tram, changed city public transport to the buses, and moved the housing and industrial zones to the surrounding and suburban areas. As a result, the travel mode moved from public transport to car more and more. This process was an important cause of the doughnut phenomenon. It is necessary to bring the focus back to public transportation if we are to shift to environmentally friendly and sustainable cities. In future studies, we will use an integrated land-use transportation model to create a policy-change simulation using historical data to verify the mathematical method of analysing the relationship among urban-planning factors.

References

Comprehensive Urban Transportation Planning Council Chukyo Metropolitan Area. (1971, 1981, 1991, 2001). Person Trip Survey Data in Chukyo Area of Japan, First, Second, Third and Fourth.

Gifu City. (1983). Transportation Overall Policy Planning and Evaluation Division, Report of 1983 Gifu Regional Integrated Transportation System, Gifu City.

Gifu City. (1994). Transportation Overall Policy Planning and Evaluation Division, Report of 1994 Gifu Regional Integrated Transportation System, Gifu City.

Gifu City Planning Department. (1980). The Second Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Planning Department. (1986). The Third Urban Master Plan for Gifu City: Gifu Literary Publisher.

Gifu City Statistics Analysis Department. (1970–2008). Statistics Book of Gifu City:

Gifu City.

Guo, M. & Kurauchi, F. (2012). Changes in Land Use, Socioeconomic Indices, and the Transportation System in Gifu City and their Relevance during the Late 20th Century, *Open Journal of Civil Engineering*, 2(3), 183-192.

Hosoiri, M., Minamino, A., & Monnai, H. (2009). Analysis of Urban Structure and Mobility using Geographic Information System: A Study on Mobility in the Context of Town, Person and Life in Local Cities Part 1. *Architectural Institute of Japan*, 417-420.

Masuya, Y. & Shitamura, Y. (2001). Flow Characteristics of Journey-to-Work Travel Based on Cumulative Distribution Function in Sapporo City, *Journal of Environmental Science Laboratory*, 8, 327-335.

Miyakawa, J., Sakamoto, T., Torii, A., Isaka, M., Sai, K., Hada, T., & Kose, S. (2009). Possibility of Designs for Sustainable Communities in the Western Area of Shizuoka Prefecture. *University of Art and Culture Bulletin*, 10, 165-172.

Muronaga, Y. & Moromizu, M. (2002). An Empirical Study on Change in Going-Out Activities of the Elderly In Kumamoto City, *Journal of Architecture, Planning and Environmental Engineering. Transactions of AIJ*, 553, 201-207.

Nitta, T., Sugisaki, S., Okadome, S., Hasegawa, K., & Takaguchi, H. (2009). CO_2 Emission Reduction of Transport Sector in Local City: Case Study in Honjo City, *Environmental Engineering*, Summaries of Technical Papers of Annual Meeting Architectural Institute of Japan D-1, I, 811-812.

Osaragi, T. (2009). Spatio-Temporal Distribution of Railroad Users for Disaster Prevention Planning, *Journal of Architecture and Planning*, 74(635), 137-144.

Takahashi, M., Deguchi, A., & Nshikawa, H. (2005). Relationship between Land Use and CO_2 Emitted by Person Trip: Case study of Fukuoka City, *Journal of Architecture and Planning*, 588, 103-109.

CHAPTER 6

Development of Integrated Land Use and Transport Evaluation Model

In a sustainable society, promoting a use of public transport becomes a pressing issue. On the other hand, bus transport servicethat should be an essential supportingservice for citizen's daily life is facing at difficult situation, because of a decrease of its patronage.Moreover, the relationship between land use and transport service is not negligible. To solve this problem, this chapter presentsa development of an integrated traffic assignment modelconsidering both the transport mode and destination choice. We attempt to evaluate the change of destination choice as well as mode choice when land usepoly or transport service measure is applied.

6.1 Introduction

Most of local cities in Japan have attached more importance on road network construction because of quick increase of automobile ownership,and the cities become less centralized and suburban development has been continuing. As a result, most of such local citieshave been plagued by the doughnut phenomenon. In addition, with the improvement of quality of life and diversification of citizens'lifestyle, the needs for transport service have become also diversified and use of automobiles has increased. While enriching people's quality of lives, automobile traffic has caused problems such as traffic congestion, traffic accidents and environmental pollution. Therefore an efficient and effective use of automobiles is required for retaining a society. On the other hand, people do not use buses especially in the rural areas because of longer waiting time, longer travel time, more transfers and other uncontrollablefactors.It can be said however that from the viewpoint of ensuring mobility for everyone including people who do not have their private cars, sophisticated public transport service is needed. Even though a small population may limit the level of public transport services, the publicrequires an acceptable level of service.Other difficulties on bus transport service include diversification of use and reduction of bus users due to depopulation.Tosolve such dilemma, a model to reproduce movementsofautomobiles as well as public transport services such as BRTs (Bus Rapid Transit) and busesare needed and such model should be used for urban planning stage.

Although there are various other factors in urban development, there is no doubt that transport and land use policies have a significant interaction. For example, if there are no shopping places nearby, one needs to travel with long distance.On the contrary, if a new supermarket opens nearby, one starts using it. When selecting a destination, a service level of traffic has a large impact. For example, for commercial premises of suburban area, access by public transport is often inconvenient. Therefore if one does not have access to a car, (s)hemay not have access to such facilities. Furthermore, it can be said that while providing the opportunity for people's activity, land use may as well affect the travel behavior. When choosing a destination, one should consider the attractiveness of a destination.People may decide to visit a further destination and use automobile to access, if one can obtain larger satisfaction at the venue. Therefore,travel patterns and land use are interrelated, and configuration of urban transport network hasa significant impact on the formation of the urban form.

In this study, we aim to build an integrated traffic assignment model capable of evaluating the transport service measures and land use policies.Specifically, the model is developed as an integrated traffic assignment model that includes the destination and transport mode choice andthe model cananalyzethe impact ofdestination choice and transport mode choice by change in the traffic service. The feature of the developed model is summarizedas follows:

(1) the travel time of bus is affected by car traffic congestion,
(2) the model is built as an integrated traffic assignment model that includes the destination and transportmode choice, and
(3) three trip objectives are considered in destination choice behavior; commuting, business and leisure.

6.2 Major Assumptions of the IntegratedLand use and Transport Model

Major assumptions of the developed integratedland use and transport model are summarized as follows:

- The car traffic assignment is assumed to logit-typeStochastic User Equilibrium (SUE).
- Three modes, bus, BRT and cars are considered and the mode choice is expressed by a logitmodel. The BRTruns on dedicated trackanda bus shares roads with automobiles. We assume here that the number of buses is small and does not affect car traffic. Therefore, the travel time of bus is affected only by car traffic congestion. BRT is not affected by car traffic; however, the dedicated track of BRTwhich shares road space decreases the car road spaceas well.
- The travel time of bus is described by the function of car traffic volume. The formulation is based on Miyagi (1985).

6.3 Model Development

6.3.1 Formulation

The Stochastic User Equilibrium (SUE) assignment proposed by Daganzo and Sheffi (1977) and Fisk (1980) is well known as a general model which consistently unifies the concept of the stochastic choice and Wardropian equilibrium. It overcomes the shortcoming of the homogeneous user assumption in the Wardropian equilibrium, andalso includes the random effect of the stochastic assignment problem on a congested road network.SUE is defined as the state in which no traveller believes that his/her perceived travel time can be improved unilaterally by changing routes (Sheffi, 1985).Alot of literature exist about the logit-type SUE assignment (such as Sheffi 1985, Bell and Iida1997). In this study, we use the logit-type SUE assignment following to Bell and Iida(1997) expression.

Let:

t_k^c : acar traffic volumefor OD pair$k$,

h_j : apath traffic volume for route$j$,

g_j : a travel cost for route j $(= \sum_i a_{ij} c_i)$,

a_{ij} : a link-path incidence matrix(=1 if the route j passes link i),

b_{kj} : a OD-path incidencematrix(=1 if route j passes OD k),

θ^c : a dispersion parameter for route choice,

U(k)**:** a set of paths for OD pair k.

At optimum the following relationship must have been established,

$$h_j^c = t_k^c \frac{\exp\left(-\theta^c g_j^c\right)}{\sum_{j \ in \ \mathbf{U}(k)} \exp\left(-\theta^c g_j^c\right)} \quad (1)$$

$$g_j^c = \sum_i a_{ij}^c c_i^c \quad (2)$$

$$v_i^c = \sum_{j \in \mathbf{U}} a_{ij}^c h_j^c \quad (3)$$

Next, to formulate a mode choice,we first assume that there is only one bus and BRT route for every OD pair. We also assume here that there are three classes of traffic demand; demand captured to use automobiles, demand that can choose either automobiles or public transport, and demand captured to use public transport. The first class (class 0)mainly represents traffic from/to outside. The third class (class 2)is considered to express people who cannot drive or who don't have an access to automobiles. Based on these assumptions, at optimum following conditions must have been satisfied as a result of logit-type mode choice. Note that$k_\kappa$represents an OD pair whose origin and destination are exchanged. We assume here that all trips have a single destination and there is a returning trip back to the origin.

$$t_k^c = t_k^0 + t_k^1 \frac{\exp\left(-\theta^m S_k^c\right)}{\exp\left(-\theta^m S_k^c\right) + \exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)} + t_{\kappa_k}^1 \frac{\exp\left(-\theta^m S_{\kappa_k}^c\right)}{\exp\left(-\theta^m S_{\kappa_k}^c\right) + \exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} \quad (4)$$

$$t_k^b = t_k^1 \frac{\exp\left(-\theta^m g_k^b\right)}{\exp\left(-\theta^m S_k^c\right) + \exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)} + t_k^2 \frac{\exp\left(-\theta^m g_k^b\right)}{\exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)} + t_{\kappa_k}^1 \frac{\exp\left(-\theta^m g_{\kappa_k}^b\right)}{\exp\left(-\theta^m S_{\kappa_k}^c\right) + \exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} + t_{\kappa_k}^2 \frac{\exp\left(-\theta^m g_{\kappa_k}^b\right)}{\exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} \quad (5)$$

$$t_k^l = t_k^1 \frac{\exp\left(-\theta^m g_k^l\right)}{\exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)} + t_k^2 \frac{\exp\left(-\theta^m g_k^l\right)}{\exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)} + t_{\kappa_k}^1 \frac{\exp\left(-\theta^m g_{\kappa_k}^l\right)}{\exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} + t_{\kappa_k}^2 \frac{\exp\left(-\theta^m g_{\kappa_k}^l\right)}{\exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} \quad (6)$$

$$g_j^b = \sum_i a_{ij}^b c_i^c(\mathbf{v}^c) + c_j^b \quad (7)$$

$$S_k^c = -\frac{1}{\theta^c} \ln\left(\sum_{j \text{ in } U^c(\mathrm{k})} \exp\left(-\theta^c g_j^c\right)\right) \quad (8)$$

Where:

t_k^0 : the total tripsin OD pair *k* of class0 (class captured to use automobiles)

t_k^1,t_k^2 : the total tripsin OD pair *k* of class1 (demand that can choose either automobiles or public transport) and class2 (class captured to use public transport)

S_k^c : the travel cost by car for OD pair k (Log-sum function)

g_k^b : the total travel cost by bus for OD pair k

a_{ik}^c : OD-bus link incidence matrix(=1 if the bus link i passes OD pair k)

w_k^b : the cost except travel cost by bus for OD pair k (constant)

g_k^l : the cost by BRT for OD pair k (constant)

t_k^b, t_k^l : the trips of bus and BRT for OD pair k

The destination choice probability is assumed to change by the total travel cost and the attractiveness of destinations. We assume three trip purposes here; commuting, on business and on leisure. Each centroid has different attractiveness for each trip purpose, and destination choice probability is calculated separately by trip purposes as a result of logit-type destination choice. As is explained, a travel cost is calculated from the origin to the destination as well as from the destination to the origin, to consider the return trip. Since the available travel mode is different among classes 1 and 2, different log-sum function is defined for different classes.

$$t_k^1 = t_k^{1c} + t_k^{1w} + t_k^{1f} \tag{9}$$
$$t_k^2 = t_k^{2c} + t_k^{2w} + t_k^{2f} \tag{10}$$
$$t_k^{1*} = o_r^{1*} \frac{\exp\left(-\theta^d g_k^{d1*}\right)}{\sum_{k \text{ in } K_r} \exp\left(-\theta^d g_k^{d1*}\right)} \tag{11}$$
$$t_k^{2*} = o_r^{2*} \frac{\exp\left(-\theta^d g_k^{d2*}\right)}{\sum_{k \text{ in } K_r} \exp\left(-\theta^d g_k^{d2*}\right)} \tag{12}$$
$$g_k^{d1*} = S_k^{m1*} + S_{\kappa_k}^{m1*} - w_s^{d*} \tag{13}$$
$$g_k^{d2*} = S_k^{m2*} + S_{\kappa_k}^{m2*} - w_s^{d*} \tag{14}$$
$$S_k^{m1} = -\frac{1}{\theta^m} \ln\left(\exp(-\theta^m S_k^c) + \exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)\right) \tag{15}$$
$$S_k^{m2} = -\frac{1}{\theta^m} \ln\left(\exp\left(-\theta^m g_k^b\right) + \exp\left(-\theta^m g_k^l\right)\right) \tag{16}$$

Where:

o_r^{1*},o_r^{2*} : the number of trips originating from origin *r* of each class and each purpose * (purpose*include$c$(commuting), b(*on business*) *and* l(*on leisure*))

g_k^{d1*},g_k^{d2*} : a cost to destination for each class and each purpose for OD pair *k*

S_k^{m1},S_k^{m2} : a travel cost for each class for OD pair *k*

w_s^d : an attractiveness of destination s(constant)

θ^d : a dispersion parameter for destination choice

Finally, based on the above choice model, the total log-sum; i.e. total utility of travels, is derived as follows;

$$S_r^{d1*} = \frac{1}{\theta^d} \ln\left(\sum_{k \text{ in} K_r} \exp\left(-\theta^d g_k^{d1*}\right)\right) \tag{17}$$
$$S_r^{d2*} = \frac{1}{\theta^d} \ln\left(\sum_{k \text{ in} K_r} \exp\left(-\theta^d g_k^{d2*}\right)\right) \tag{18}$$
$$S = \sum_r \sum_* (S_r^{d1*} o_r^{1*} + S_r^{d2*} o_r^{2*}) + \sum_k S_k^c t_k^0 \tag{19}$$

where,

S_r^{d1*}: Utility of travellers from origin *r* to destination *d* for class 1 and trip purpose *,

S_r^{d2*}: Utility of travellers from origin *r* to destination *d* for class 2 and trip purpose *,

S: Total utility.

6.3.2 Algorithm for Solving the Program

We assumed here that all trips originated within a study area can choose a destination;

i.e., fixed OD traffic volume is not considered here. We also assume here that only one path is consider for each OD pair for BRTand bus. Since logit-type distribution is assumed for car traffic we need to determine a path set. We also assume here that bus can be captured by car traffic congestion. It means that thecost of public transport depends on the car traffic volume. The formulation is similar to the one adopted by Miyagi (1985). It cannot be formulated by Beckmann (1956) type optimization problem. According to Miyagi (1985), the solution can be analytically obtained. In this study, however, to apply to large size network, themethod of successive averages is used to consider this effect. Strictly speaking, the convexity of the problem is not guaranteed in this model. Therefore, the convergence has been checked at the case study.

In stochastic route choice, possible paths should be enumerated in advance, or either Dial's algorithm (1971) or Markov chain algorithm (Akamatsu 1996,1997; Bell, 1995) can avoid path enumeration. Since the choice probability can easily obtained by matrix calculation, we adopt the Bell(1995)'s algorithm. This method doesn't have to solvea shortest path problemand the link use ratios can easily be obtained by matrix calculation. Since a link traffic volume may become infinity when the dispersion parameter $\theta^c$is small with regard to a scale of network, this value should be carefully determined. The algorithm for solving the program based on the method of successive average is summarizedas follows:

Step 1: Initialization

$\mathbf{v} \leftarrow 0$ Link traffic volumesare assigned zero

$\mathbf{c} \leftarrow \mathbf{c}(\mathbf{v})$ Determine the link cost on the basis of the link traffic volumes

$\mathbf{n} \leftarrow 1$ Set n=1

Step 2: Revise the link traffic volumes for each mode

calculate$\mathbf{W}$

$$\mathrm{w}_{\mathrm{mn}} = \begin{cases} \exp(-\theta^c c_{mn}) & if\ a\ link\ connects\ node\ m\ to\ n \\ 0 & otherwise \end{cases}$$

calculate $\mathbf{N} = (\mathbf{I} - \mathbf{W})^{-1} - \mathbf{I}$ Update link use matrix

calculate$\boldsymbol{\Psi}$ Calculating link use ratios

$(\psi_{k(r,s)a(m,n)} = \nu_{rm} \exp(-\theta^c c_{mn}) \nu_{ns} / \nu_{rs})$

calculate$S^c_{k(r,s)}$ Calculating the expected minimum costby car for OD pair $\mathrm{k}(r,s)$ $(S^c_{k(r,s)} = -(1/\theta^c)\ln(\nu_{rs}))$

calculate traffic mode choice probability

$$p_k^{c1} = \frac{\exp(-\theta^m S_k^c)}{\exp(-\theta^m S_k^c) + \exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)}$$

$$p_k^{b1} = \frac{\exp(-\theta^m g_k^b)}{\exp(-\theta^m S_k^c) + \exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)}$$

$$p_k^{l1} = \frac{\exp(-\theta^m g_k^l)}{\exp(-\theta^m S_k^c) + \exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)}$$

$$p_k^{b2} = \frac{\exp(-\theta^m g_k^b)}{\exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)}$$

$$p_k^{l2} = \frac{\exp(-\theta^m g_k^l)}{\exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)}$$

calculate S_k^{m1}, S_k^{m2}

$$S_k^{m1} = \frac{1}{\theta^m}\ln\left(\exp(-\theta^m S_k^c) + \exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)\right)$$

$$S_k^{m2} = \frac{1}{\theta^m}\ln\left(\exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)\right)$$

calculate destination choiceprobability

$$p_r^{k1*} = \frac{\exp\left(-\theta^d g_k^{d1*}\right)}{\sum_{k \text{ in } K_r} \exp\left(-\theta^d g_k^{d1*}\right)}, p_r^{k2*} = \frac{\exp\left(-\theta^d g_k^{d2*}\right)}{\sum_{k \text{ in } K_r} \exp\left(-\theta^d g_k^{d2*}\right)}$$

calculateODtraffic volumes

$$t_k^{1*} = o_r^{1*} \frac{\exp\left(-\theta^d g_k^{d1*}\right)}{\sum_{k \text{ in } K_r} \exp\left(-\theta^d g_k^{d1*}\right)},\ t_k^{2*} = o_r^{2*} \frac{\exp\left(-\theta^d g_k^{d2*}\right)}{\sum_{k \text{ in } K_r} \exp\left(-\theta^d g_k^{d2*}\right)}$$

calculatetraffic volumes of each traffic mode

$$t_k^c = t_k^0 + t_k^1 \frac{\exp(-\theta^m S_k^c)}{\exp(-\theta^m S_k^c) + \exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)} + t_{\kappa_k}^1 \frac{\exp\left(-\theta^m S_{\kappa_k}^c\right)}{\exp\left(-\theta^m S_{\kappa_k}^c\right) + \exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)}$$

$$t_k^b = t_k^1 \frac{\exp\left(-\theta^m g_k^b\right)}{\exp(-\theta^m S_k^c) + \exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)} + t_k^2 \frac{\exp\left(-\theta^m g_k^b\right)}{\exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)} + t_{\kappa_k}^1 \frac{\exp\left(-\theta^m g_{\kappa_k}^b\right)}{\exp\left(-\theta^m S_{\kappa_k}^c\right) + \exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} + t_{\kappa_k}^2 \frac{\exp\left(-\theta^m g_{\kappa_k}^b\right)}{\exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)}$$

$$t_k^l = t_k^1 \frac{\exp\left(-\theta^m g_k^l\right)}{\exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)} + t_k^2 \frac{\exp\left(-\theta^m g_k^l\right)}{\exp(-\theta^m g_k^b) + \exp(-\theta^m g_k^l)} + t_{\kappa_k}^1 \frac{\exp\left(-\theta^m g_{\kappa_k}^l\right)}{\exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)} + t_{\kappa_k}^2 \frac{\exp\left(-\theta^m g_{\kappa_k}^l\right)}{\exp\left(-\theta^m g_{\kappa_k}^b\right) + \exp\left(-\theta^m g_{\kappa_k}^l\right)}$$

Step 3: Method ofSuccessive Average (MSA)

Calculate$\mathbf{v}$

$$\mathbf{v} = (1/n)\mathbf{\Psi}\mathbf{t}^c + (1 - 1/n)\mathbf{v}$$

$$\mathbf{c} \leftarrow \mathbf{c}(\mathbf{v})$$

$$\mathrm{n} \leftarrow \mathrm{n} + 1$$

Step 4: Convergence test

Calculate total cost

$$S^{(n)} = \sum_r \sum_* (S_r^{d1*} o_r^{1*} + S_r^{d2*} o_r^{2*}) + \sum_k S_k^c t_k^0$$

convergence test If $\left|S^{(n)} - S^{(n-1)}\right|/S^{(n)} < \epsilon$ end, otherwise circle to Step 2

6.4 Model Verification

6.4.1 Model Verificationon Small Network

In this section, we discuss the characteristics of the proposed model by applying the calculation on small hypothetical network. The model was applied to the network as shown in Figure 6.1. Here, links in red assumes a four-lane roadand others represent a two-lane road. Further, the input data used for the calculation are shown in Table 6.1. In this calculation, BRT is not implemented.

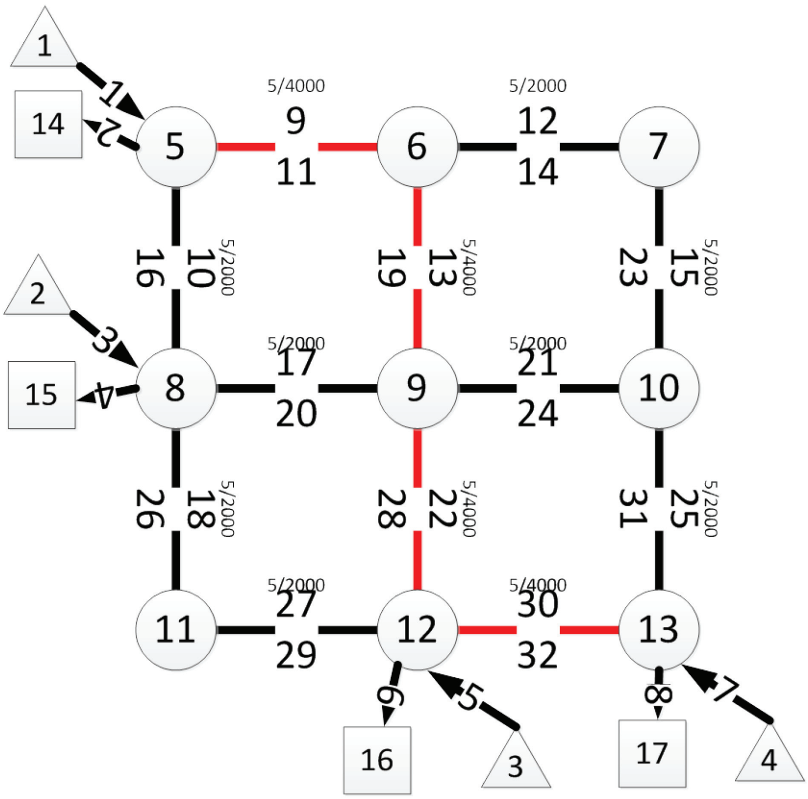


Figure 6.1 Test Network

Table 6.1 Input Data

(a) Parameters

Number of links	Number of nodes	Number of OD pairs	Number of origins	Number of destinations	θ^c	θ^m	θ^d
32	17	12	4	4	1	0.1	0.1

(b) Traffic volumes

OriID	Node	1_Commuting	1_Business	1_ Leisure	2_Commuting	2_Business	2_Leisure

1	1	5000	200	400	1000	100	300
2	2	5000	200	400	1000	100	300
3	3	1000	800	200	200	100	300
4	4	1000	800	200	200	100	300

(c) Destination attractiveness

DesID	Node	Attractiveness for Commuting	Attractiveness for Business	Attractiveness for Leisure
1	14	1	2	2
2	15	1	2	2
3	16	10	5	5
4	17	10	5	5

(d) Traffic mode information

ID	Origin	Dest.	class0	Constant Cost of Bus	Bus links				
1	1	2	0	5					
2	1	3	500	4	9	13	22		
3	1	4	500	4	9	13	22	30	
4	2	1	0	5					
5	2	3	500	4	22				
6	2	4	500	4	22	30			
7	3	1	500	5	28	19	11		
8	3	2	500	5	28				
9	3	4	0	4	30				
10	4	1	500	5	32	28	19	11	
11	4	2	500	5	32	28			
12	4	3	0	4	32				

Numbersnearby links in Figure 6.1 (5/2000) represent the travel time and traffic capacity for each link, respectively. These values are assumed to be identical for both directions. Travel time function is formulated bya following modified BPR function.

$$c_a = c_o\left(1 + 2.62\left(\frac{v_a}{Ca_a}\right)^5\right)$$

where,
c_a: cost of link a,
c_0: a free flow cost of link a,
Ca_a: a link traffic capacity of link a.

Since buses share a road network, they may be captured by car traffic congestion. To consider this we identified car traffic links where each bus route for each OD pair use, and they are called as 'Bus Links' in Table 6.1 (d). For example for the 2nd OD, the bus runs on links 9, 13 and 22, and the travel time of bus is obtained by thecar travel time in these three links. Bus cost should also include the cost caused by waiting time and bus fare. They are considered as an additional constant costs.Cost by bus for the second OD pair is thus the total cost of the three links; 9, 13 and 22, and constant cost of 4. When there is no bus link like for the first OD pair, the bus cost is calculated only by a constant cost. This can be interpreted as congestion-free travel such as walking or cycling.

(a) Convergence Test

In the proposed model, if the assigned link traffic volumeis almost equivalent to the traffic volume calculated by the link choice probability, the convergence reached. Figure 6.2 illustrates the relation betweenassigned traffic volume and the car traffic volume that calculated based on the cost of link. From this figure the convergence has reached.

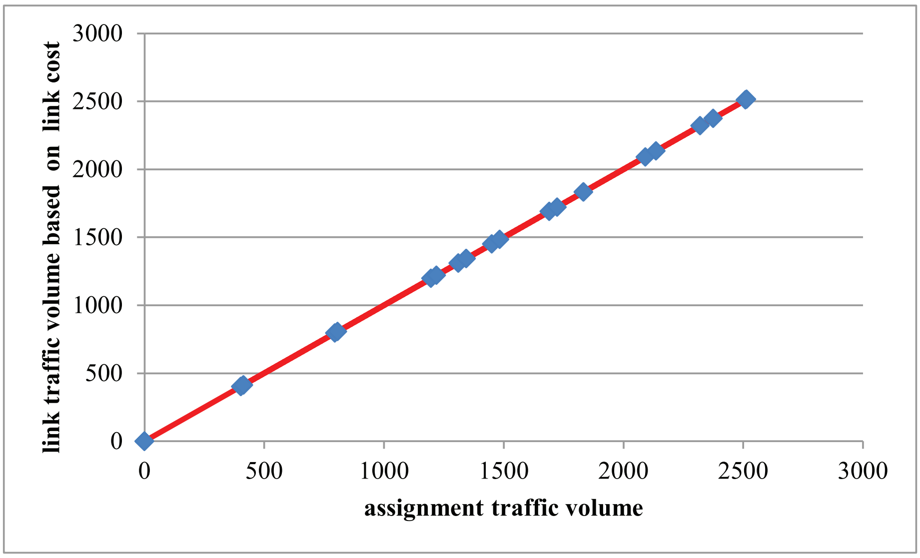


Figure 6.2 Confirmation of the Equilibrium

(b) Effect of the Initial Value

As mentioned above, the proposed method does not guarantee the uniqueness of the solution and there is a risk of obtaining local optimum solutions. Therefore here we started the calculation from different randomized link travel cost and evaluated the convergence by the total utility *S*. Figure 6.3 illustrates the case starting from zero flow as well as 6 other cases started from randomized link traffic cost. In this small network, all cases converged to the same solution after about 20 iterations.

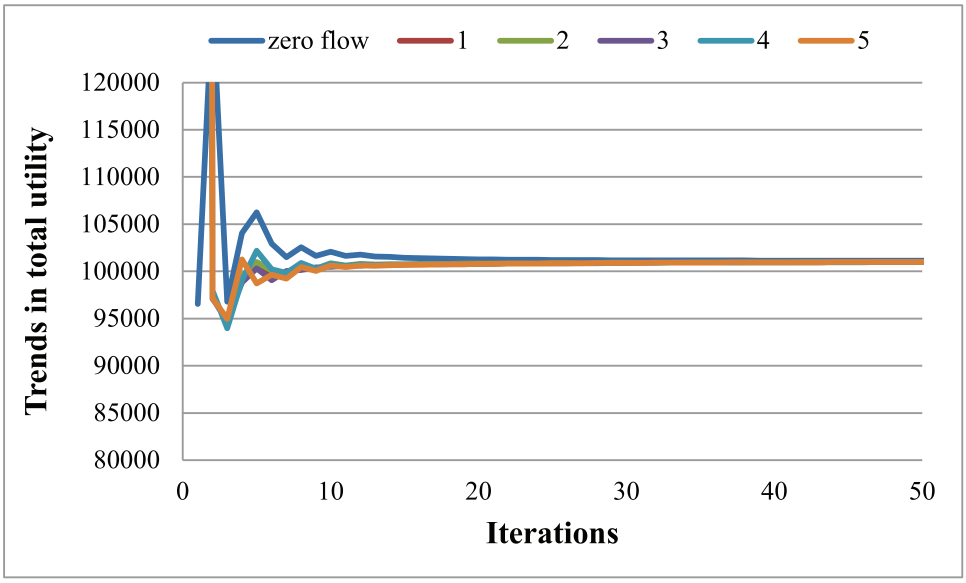


Figure 6.3 Effect of the Initial Value

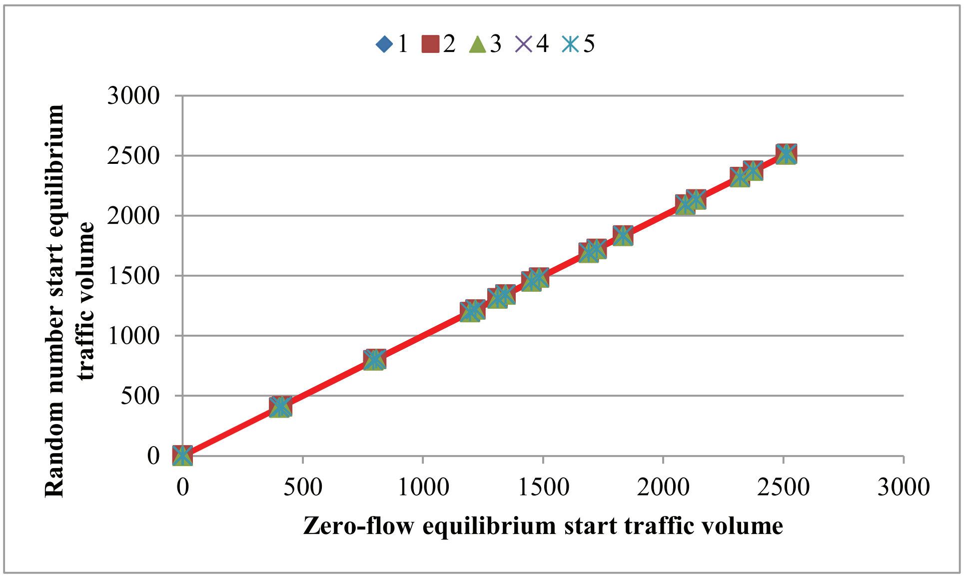


Figure 6.4 Comparison of Link Traffic Volume at Equilibrium

(c) Effect of Considering Bus Travel Time Captured by Car Traffic Congestion

One of the features of the proposed model is that bus travel time is captured by car traffic congestion. To confirm this effect, we compared the case with and without this feature. Table 6.2 shows the traffic volume for each case.

Table 6.2 Comparison of the case of bus not delayed and that delayed by congestion

(a) The case of bus not delayed by congestion

ODID	Ori	Des	Class1 OD	Class2 OD	The cost of travel by car	The cost of travel by bus	Car traffic volume	Bus traffic volume
1	1	2	3829.9	1206.9	12.9	5	1192.4	3844.4
2	1	3	1261.5	141.2	16.6	19	1207.4	695.3
3	1	4	508.6	51.9	20.8	24	795.0	265.5
4	2	1	2004.4	650.8	12.9	5	624.4	2030.7
5	2	3	2653.2	547.7	12.5	9	1598.1	2102.8
6	2	4	942.5	201.5	17.9	14	880.6	763.4
7	3	1	101.9	27.6	16.7	20	559.2	70.3
8	3	2	414.0	204.2	12.9	10	677.6	440.5
9	3	4	1484.1	368.2	6.1	9	847.9	1004.4
10	4	1	49.7	13.6	20.9	25	529.8	33.5
11	4	2	177.9	100.5	18.3	15	574.5	203.9
12	4	3	1772.4	485.9	6.1	9	1012.1	1246.2

(b) The case of bus captured by congestion

ODID	Ori	Des	Class1 OD	Class2 OD	The cost of travel by car	The cost of travel by bus	Traffic volume by car	Traffic volume by bus
1	1	2	3979.2	1262.9	13.5	5.0	1194.2	4047.9
2	1	3	1185.2	106.7	16.5	20.5	1209.6	582.3
3	1	4	435.6	30.4	20.8	26.8	781.2	184.7
4	2	1	2164.0	734.9	13.5	5.0	650.1	2248.8
5	2	3	2632.9	517.6	12.6	9.9	1636.0	2014.5
6	2	4	803.1	147.4	18.1	16.1	861.6	589.0
7	3	1	100.8	25.1	16.7	21.7	562.7	63.2
8	3	2	416.1	214.7	13.0	11.0	686.6	444.2
9	3	4	1483.2	360.2	6.3	10.3	887.9	955.4
10	4	1	45.5	10.2	21.0	28.0	530.5	25.3
11	4	2	156.0	86.9	18.6	17.3	572.9	170.0
12	4	3	1798.4	503.0	6.3	10.3	1076.7	1224.7

First, as can be seen from the comparison of bus travel cost (b) and (a), the bus travel time increases by traffic congestion for the case of (b). As shown in the Table 6.2, the change of car traffic volume is little. It may be because the calculated case did not cause serious congestion. If you look at the amount of car traffic volume, there is no great difference in value. On the other hand, some differences were observed in bus traffic. For example, looking at the data of origin 1, in the case where congestion was considered, the possibility of choice of destination that needs shorter distance is higher for bus traffic. This is because the difference of travel cost is larger when the distance of OD is longer, and thus the OD with shorter travel time is more attractive when congestion is considered. So, the bus travel cost is underestimated when the delay of buses captured by car traffic congestion is not considered. The proposed model is superior in this point. The total travel cost is 90766 in the case of considering congestion and 101,120 in the case of not considering congestion. The underestimation of cost is about 10%.

6.4.2 Model Verification Using Middle Size Network

Next, the proposed model is verified by applying to a middle size network shown in Figure 6.5. There are 28 nodes, 60 links and 6 centroids in the network, which makes the total OD pair to 36. It is assumed that the centroid of node 23 is the CBD of the city, and higher capacity main roads are crossing it (heavy link in figure 6.5). Including the main road, bus runs from node 13 to node 15 (red link in figure 6.5). The bus travel time changes according to the situation of congestion. Table 6.3 shows the origin and destination data. Attractiveness of a centroid 4 (node 23) is setto be the largest that makes the traffic concentrating to the centroid 4. Furthermore, the free travel time of link is set as 10 minutes and the capacity is 4000 for the main road and 2000 for the others. The links from 1 to 12 are dummy links that are set to infinite capacity and 0 travel time. If the origin and the destination is the same centroid (called as 'internal traffic'), the OD travel cost is set to 10 (constant). Finally, the constant cost of bus (Table 6.4) is set to be larger if the travel distance is longer because of the higher fare and lower service frequency. Logit dispersion parameters,$\theta^c, \theta^m, \theta^d$areset as 1, 0.1 and 0.1, respectively. Travel time function is formulated as a following BPR function.

$$c_a = c_o\left(1 + 0.15\left(\frac{v_a}{Ca_a}\right)^4\right)$$

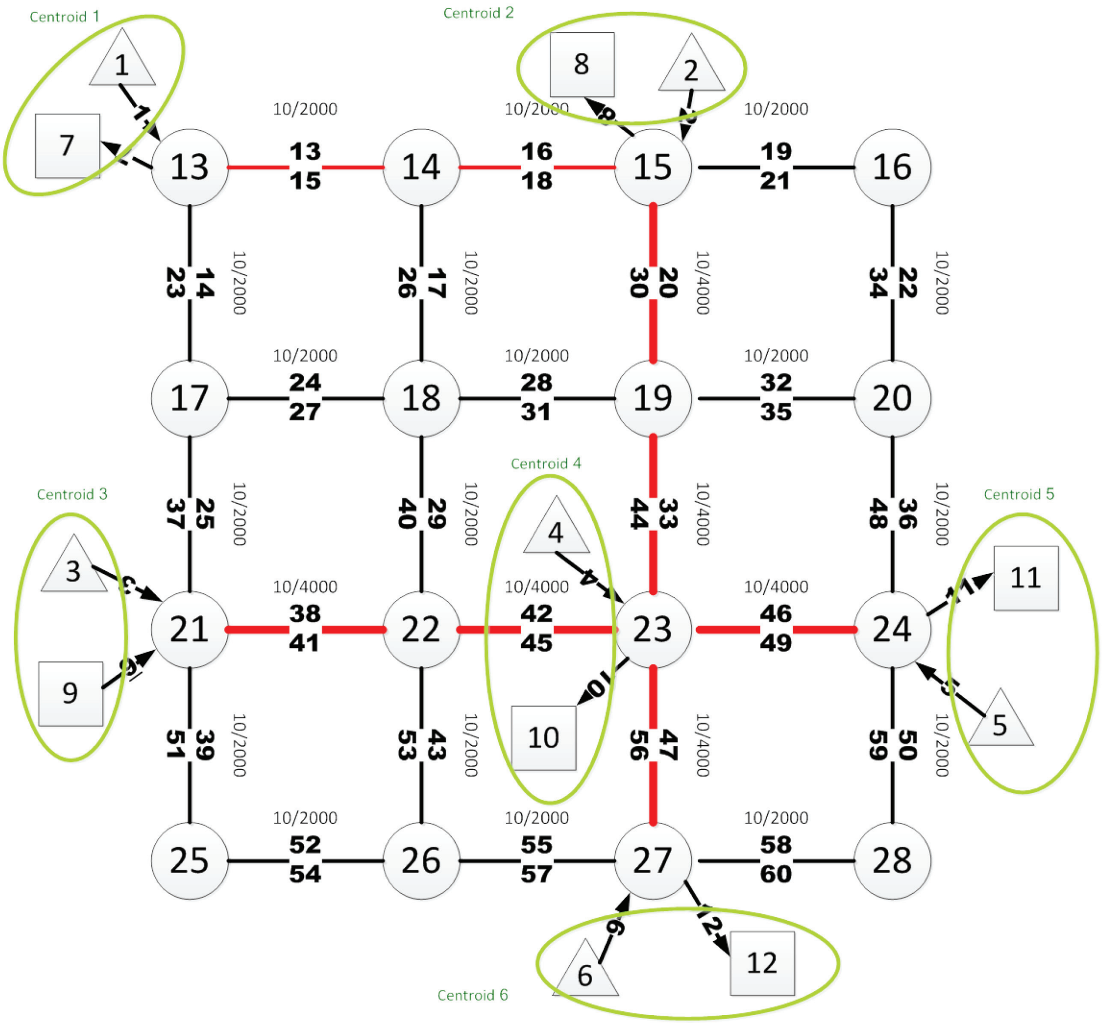


Figure 6.5 Test Network

Table 6.3 Data of Origins and Destinations

(a) Origin Data

		Class1 demand			Class2 demand		
OriID	Node	Commuting	Business	leisure	Commuting	Business	leisure
1	1	3000	1500	1200	2000	400	1000
2	2	8000	3000	1500	2000	400	800
3	3	2000	1200	300	1500	300	150
4	4	10000	8000	800	2000	2500	400
5	5	3000	3000	700	1500	500	300
6	6	3000	1000	1200	1500	100	1000

(b) Destination Data

Des ID	Node	Attractiveness for Commuting	Attractiveness for Business	Attractiveness for Leisure
1	7	100	100	100
2	8	100	100	100

3	9	30	50	50
4	10	500	500	500
5	11	200	300	200
6	12	200	300	200

Table 6.4 Constant Cost of Bus Data

ID	Ori	Des	constant cost	ID	Ori	Des	constant cost
1	1	1	0	19	4	1	40
2	1	2	20	20	4	2	20
3	1	3	60	21	4	3	20
4	1	4	40	22	4	4	0
5	1	5	60	23	4	5	15
6	1	6	50	24	4	6	15
7	2	1	20	25	5	1	60
8	2	2	0	26	5	2	40
9	2	3	40	27	5	3	25
10	2	4	20	28	5	4	15
11	2	5	40	29	5	5	0
12	2	6	30	30	5	6	25
13	3	1	60	31	6	1	50
14	3	2	40	32	6	2	30
15	3	3	0	33	6	3	40
16	3	4	20	34	6	4	15
17	3	5	25	35	6	5	25
18	3	6	40	36	6	6	0

(a) Resultof the Basic Case

Link congestion as a result of calculation is shown in Figure 6.6. The degree of congestion is calculated by the rate of link traffic volume compared with link traffic capacity. From the figure, the congestion is more seriouson links 13, 14, 15 and 23 that are around the centroid 1. Especially on link 14 and 23, the degree of congestion is over 2. Travel time function is formulated by the BPR function, that makes travel time cost 2.57 times when the degree of congestion is 1.8.

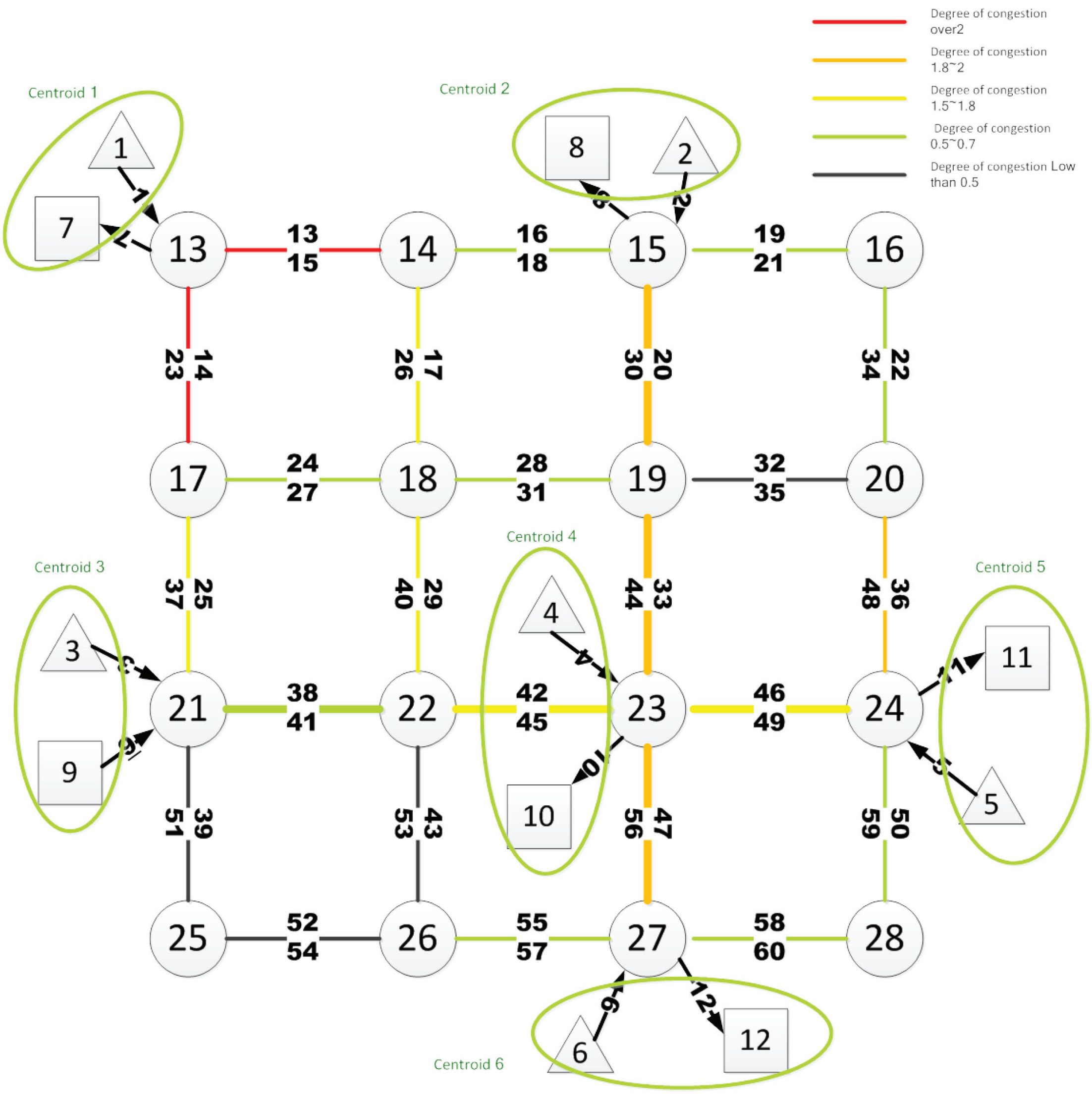


Figure 6.6 Link Congestion Situation

The car traffic assignment is assumedby the SUE model, and the path choice is determined uniquely. By using Markov assignment, although it does not deal explicitly withpaths, the link use ratio can be analyzed to discuss how the paths are used. For example, the link utilization for OD pair (1, 4) is shown in Figure 6.7. Since the centroid 1 is not connected by the main high capacity road, they tend to use other roads.

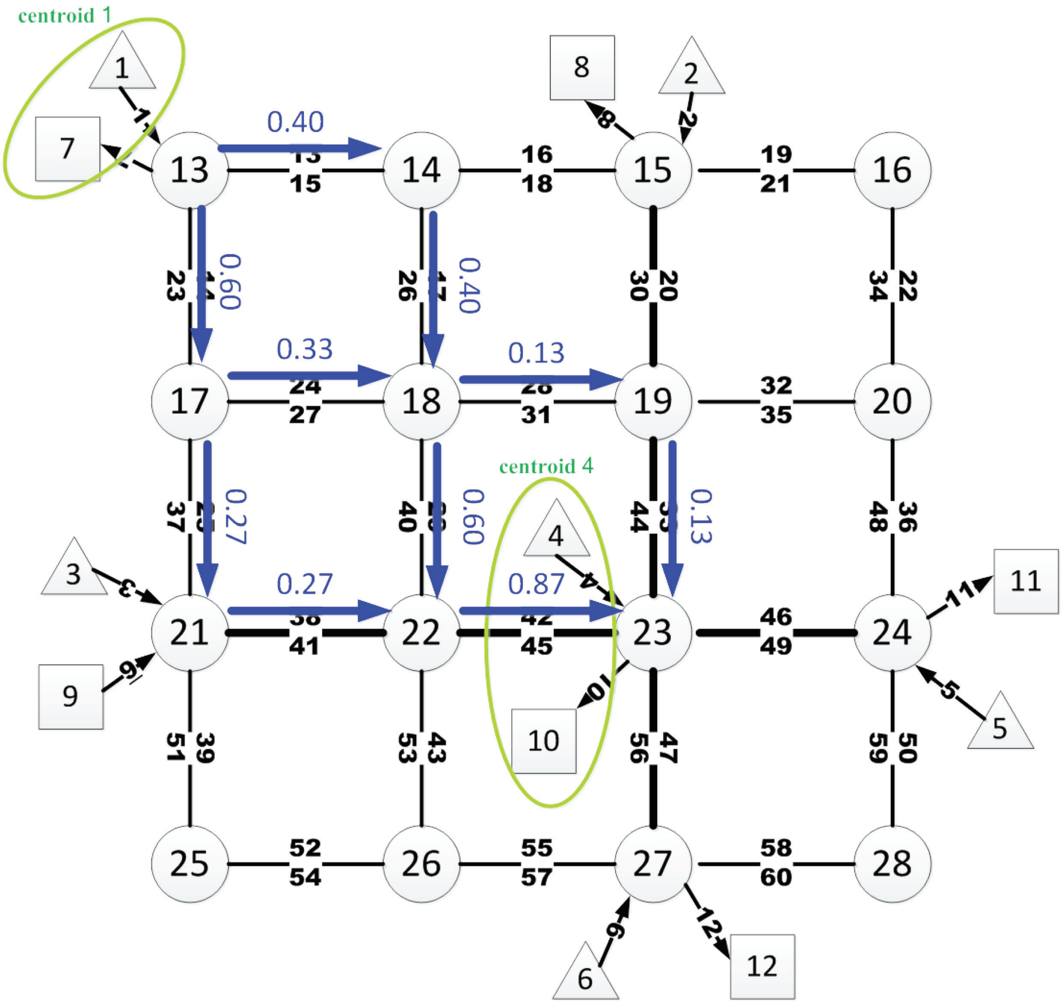
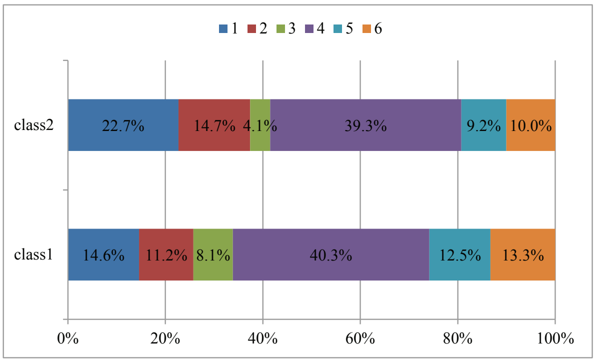


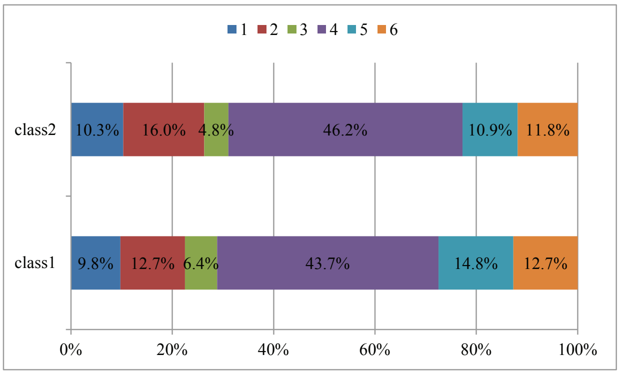
Figure 6.7 Link Utilization in OD Pair (1, 4)

Next, we analyzea destination choice. Figure 6.8 illustrates the destination choice probability for each origin and for each class. Based on the figure, the trafficattraction is concentrated to the centroid 4 which is set to be CBD. Comparing with class1, the concentration ratioto CBD for class2 is higher. The reason could be that all the bus linesare crossed by CBD. It makes bus travel inconvenientfor other OD pairs. In addition, distance of bus travel is longer for the centroid 1. In this case, the internal traffic; i.e. traffic destined to the centroid 1, is larger than others.

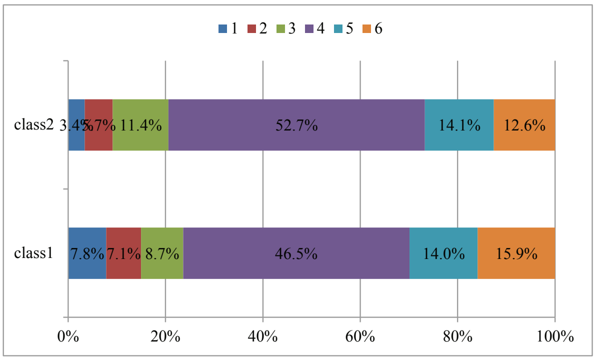
Furthermore, we also compare the result by the purpose. Figure 6.9 illustrates the destination choice probabilityby different purpose from centroid 1. Includinginternal trip, destinations 2 and 4 have better bus service that makes the destination choice probability higher for class2. However, the attractiveness also influences the choice probability. For example, the attractiveness for business is higher in destination 5 and 6.The result of traffic for these destinations is also higher than other purposes. It can be confirmed that this model could be expressed by the movement of each purpose by appropriately setting the values of attractiveness.



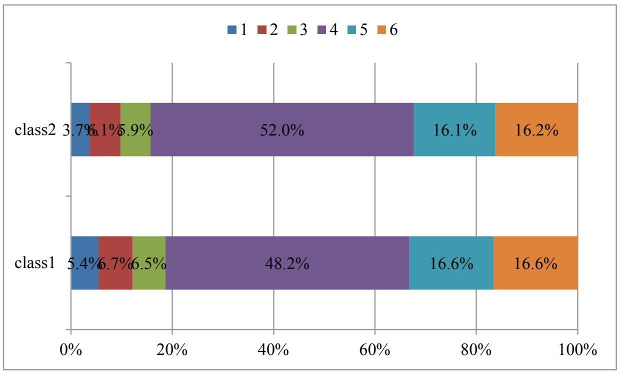
(a) Centroid1



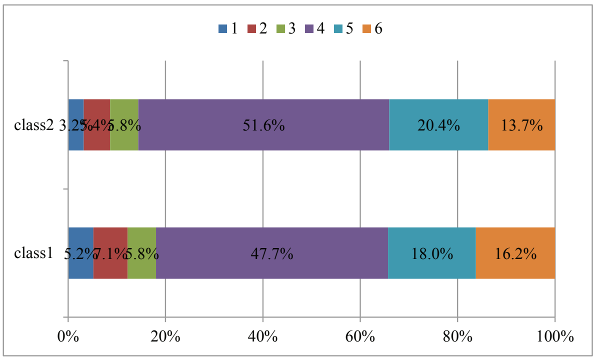
(b) Centroid2



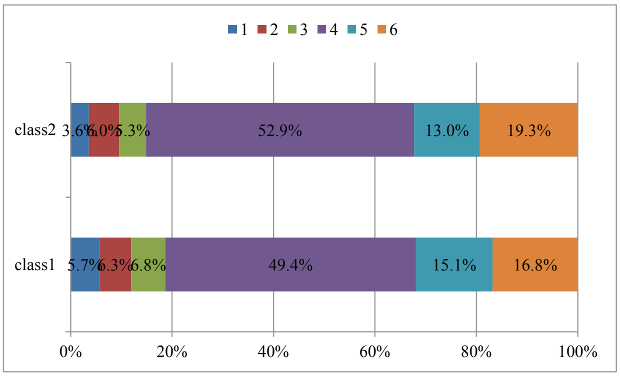
(c) Centroid3



(d)Centroid4



(e) Centroid5



(f) Centroid6

Figure 6.8Destination ChoiceProbabilityfor Each Centroid and For Each Class

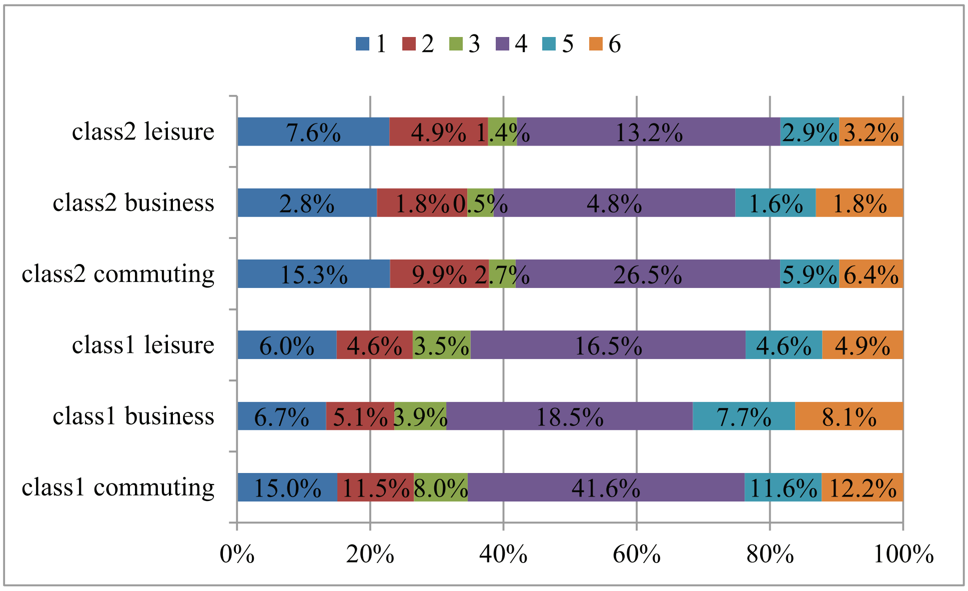


Figure 6.9Destination Choice Probabilityfor Each Trip Purpose (Centroid 1)

In this study, all of the choice behaviorsareformulated by Logittype. The utilitycan therefore be summed up by the log-sum variable. That makes it possible to compare utility of each class by the value of log-sum variables. Here, we analyzethe total utility of each class and each origin. The value is calculated asS_r^{d1*}. Figure 6.10 shows the result. Compared to class1, the utility of class2 is a lot lower. The largest utility is in centroid 4 (CBD). The proposed model can calculate the total utility.

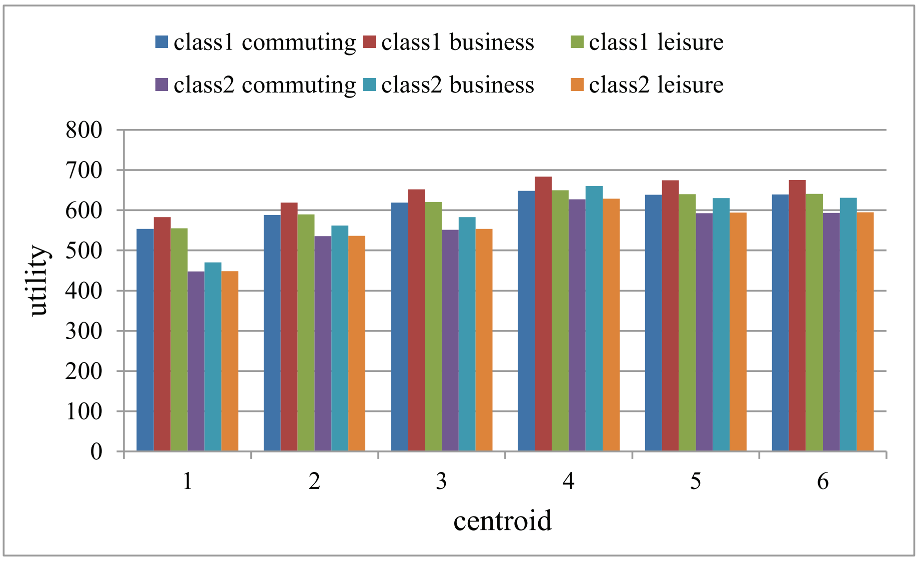


Figure 6.10Utility by Each Trip Purpose and Each Class

Furthermore, the value of log-sum variables can also be calculated to compare cost in different traffic mode and the cost in destination choice. For example, for OD pair (1, 3), the travel cost by car is 53.3 and the travel cost by bus is 193.6. Subtracting the constant cost for bus, 60, there is still a difference of 80. In this OD pair, the large difference may occur since the bus makes a large detour to transfer at centroid 4. As a result, it affects the traffic mode and destination choices.

- Effect of the Initial Value

In the last section, the effect of the initial value was analyzed. The result however maydepend on the network scale. So we make the same analysis on the middle network. Convergence status is shown in Figure 6.11 with different initial values. The convergence is evaluated by the total utility. Compared to small network, the number of iterations is larger until convergence and is around 40, but all of the cases converge to the same value.

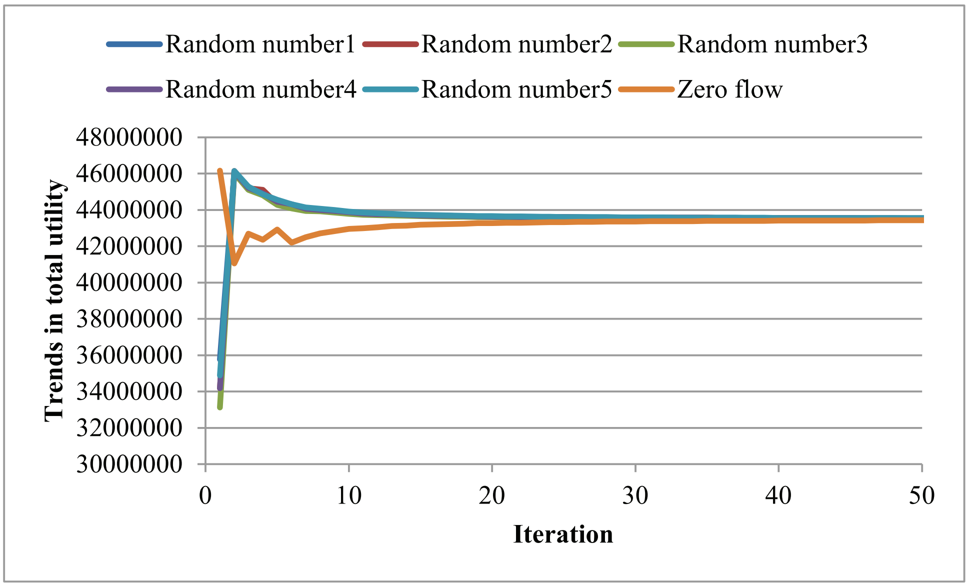


Figure 6.11 Convergence status with Different Initial Value

- Case study Evaluating the TransportService Measure and Land UsePolicy

In this section, we attempt to apply a transport service measure and land use policy on the basic case and evaluate their effects. In particular, transport service measures include ring road construction and Bus Rapid Transit (BRT) service introduction. Land usepolicy includes suburban shoppingcenterconstruction and reactivation of CBD area. The settings of the casesare summarized in Table 6.5.

Table 6.5 Case Setting

Case number	a. Transport Service Measure	b. Land use Policy (commercial facility plan)
00 (basic case)	×	×
10	Ring road	×
01	×	Suburban SC
11	Ring road	Suburban SC
20	BRT	×
02	×	Central Business District (CBD) Reactivation
22	BRT	Central Business District (CBD) Reactivation

- Data Configuration

・ Transport Service Measure

For transport service measure, a ring road construction aims at improving automobile environment and introduction of BRT service is concerned withimprovement of public transport services. Ring road is designed to connect nodes among 13, 16, 28 and 25. We designed the ring road with 4000capacity. BRT is design from nodes 15 to 27. Since travel time of BRT is not affected by car traffic congestion, the travel time is always 10 minutesfor each link. To retain a road space dedicated for BRT, the capacity of car traffic is reduce to 2000 for these links with BRT.

・ Land use Polity

Land usepolicy includes suburban shoppingcenter construction and CBD reactivation. For the first case, a large SC is located in the centroid 3 that makes the attractiveness of business and leisure increasing from 50 to 500. CBD reactivation increases the same amount of attractiveness (450) to the centroid 4 that makes the attractiveness of business and leisure to 950.

Then, we will evaluate the composite effect of transport servicemeasure and land usepolicyby comparing the cases shown in Table 6.5.

- Comparison of Total Travel Time and Total Utility

First, we make a comparison of total travel time and total utility in all the cases. The result is shown in Figure 6.12. About total travel time, Case 22 with BRT implementation and CBD reactivation takes a smallest value. On the other hand, the total travel time is worst in the case 01 with a construction of suburban SC with no road construction. Furthermore, comparing case 10 to case 20, the decrease of total travel time in case 20 is larger than that in case 10. The total travel time decrease with the measure of BRT is larger than the ring road construction. Next, about total utility, the largest value is shown in the case 22. The policy of CBD reactivation contributes to the total utility. In the next section, we will compare with the basic case (case 00), case 11 and case 22 in detail.

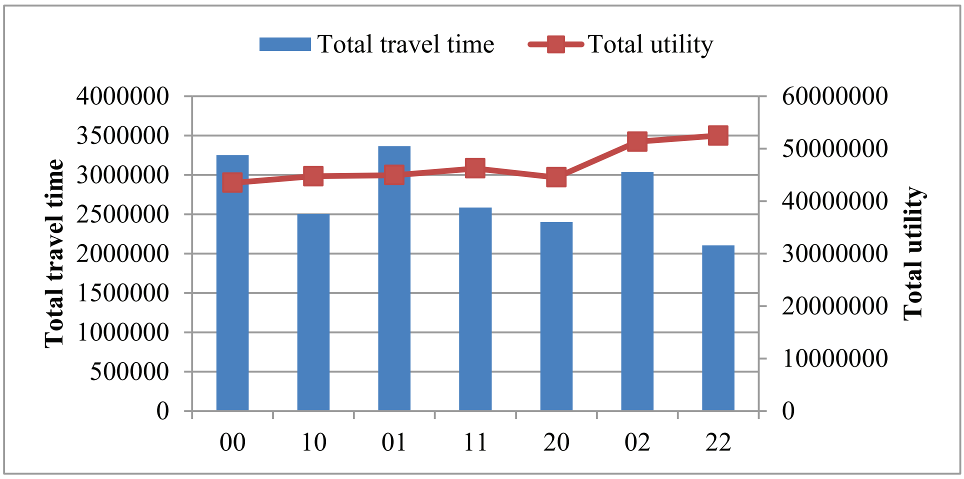


Figure 6.12 Total Travel Time and Total Utility in All the Cases

- Comparison of Case 00, Case 11 and Case 22

Table 6.6 illustrates the destination utilityfor each case and each class. Among the three cases, the destination utility in case 22 is the largest. Specifically, the destination utilities of each purpose are shown in Figure 6.13 to Figure 6.15.Table 6.7 illustrates the values of log-sum variables of mode choice for each case. The decrease of transport cost in case 11 and case 22 is one of the major reasons increasing the destination utility.

Comparing case 11 (Figure 6.14) to case 00 (Figure 6.13), the destination utility of the centroid 3 is the larger in the case 11. By the ring road construction, car becomes more convenient to reach to the centroid3, and with the construction of suburban SC, the attractiveness of this centroid increases. Especially for class 1, the destination utility for leisure increased with the decrease of car transport cost. Comparing case 22 (Figure 6.15) to case 00, with CBD reactivation, the destination utility of the centroid 4 is a lot larger. In the assumed network, by the synergy of implementation of BRT and CBD reactivation, the utility in CBD is improved a lot and the traffic tends to concentrate to the CBD.

Table 6.6 Destination Utilityfor Each Case and for Each Class

	Destination utility of Class 1			Destination utility of Class 2		
Case	Commuting	Business	leisure	Commuting	Business	leisure
00	70.7	80.9	71.1	57.3	65.3	57.6
11	78.1	93.3	112.2	62.6	74.1	86.8
22	91.5	128.1	301.1	79.9	112.4	270.9

Table 6.7 The Values of Log-sum Variables of Mode Choice for Each Case

	Case 00		Case 11		Case 22	
Destination	Class1	Class2	Class1	Class2	Class1	Class2
1	367.7	757.2	232.2	597.3	295.4	549.5
2	301.1	499.6	213.7	420.3	225.0	332.7
3	240.8	548.4	197.7	503.6	211.5	455.1
4	209.9	345.3	167.3	293.9	176.3	252.7
5	244.3	470.3	185.5	413.1	205.3	373.9
6	239.9	463.6	183.6	398.1	201.3	342.7
Total Cost	1603.8	3084.5	1180.0	2626.2	1314.8	2306.5

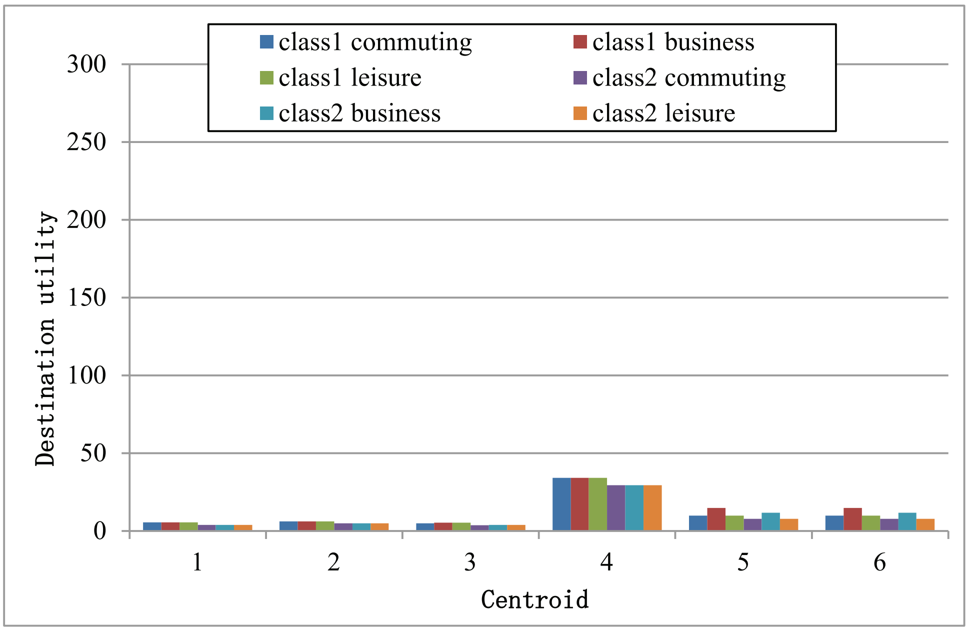


Figure 6.13 Destination Utility of Each Purpose in Case 00

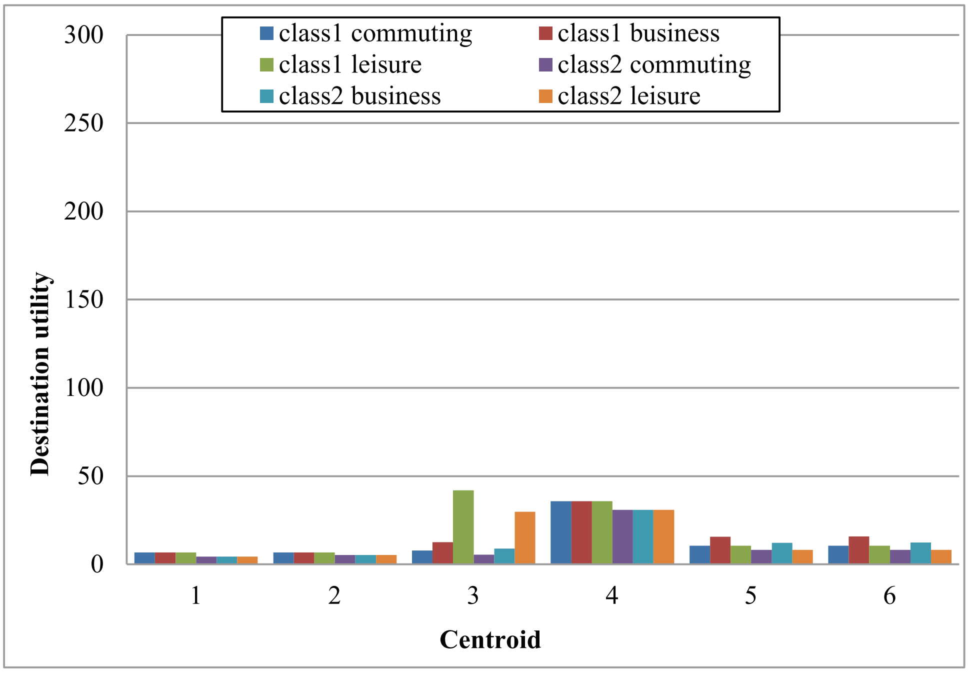


Figure 6.14 Destination Utility of Each Purpose in Case 11

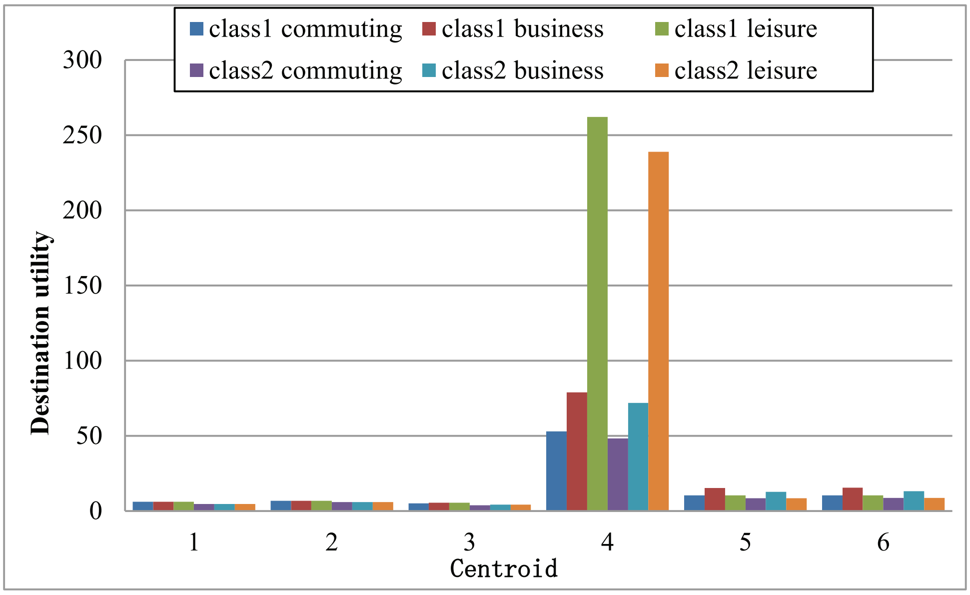


Figure 6.15 Destination Utility of Each Purpose in Case 22

Next, we analysedthe destination choiceprobability. Figure 6.16 to 6.18 show the probability from origin 1 to each centroid for each class. Based on the data setting of case 00 (Figure 6.16), traffic concentrates to centroid 4. However, traffic by bus concentrate more to CBD by class2 compared to class1.The reason could be that all bus service crosses at CBD which made movement of the other OD pair disadvantageous. Furthermore, travel distance by bus in origin centroid 1 is longer than other; as the result, internal traffic ratio is more than the others. In case 11 (Figure 6.17), by the effect of suburban SC construction, the ratio of trip generation to centroid 3 increased a lot. Especiallyfor class1, the destination choice probability by car increased more than two times. The construction of ring road pushed more to use cars. On the other hand, the probability of destination choice by bus for class1 almost unchanged. This is because the bus level of service does not change in implementing ring road. In the case 22 (Figure 6.18), the destination choice probability to the centroid 4 is higher than case 00, especially for the bus users in class1 and class2. Introduction of BRT improved the convenience of using public transport greatly. The traffic destined to CBD increased more than the other cases.

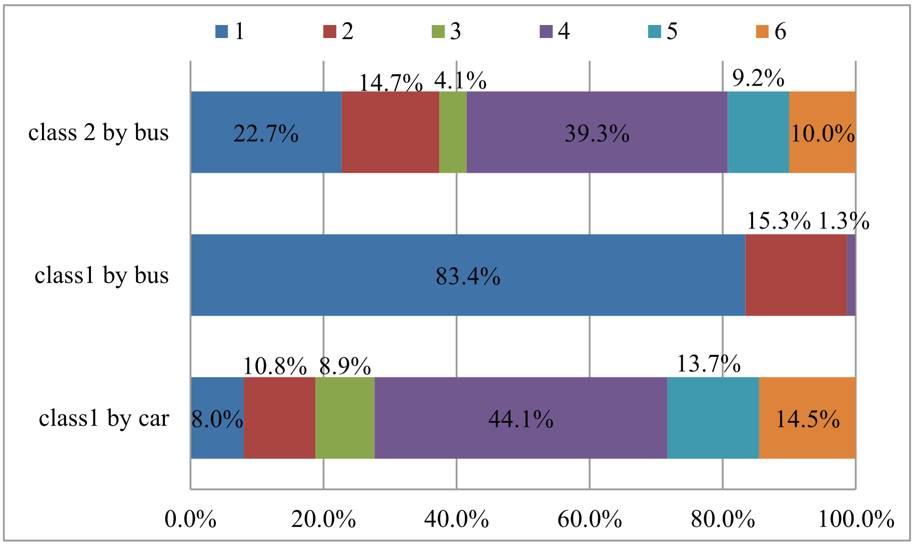


Figure 6.16 Probability of Destination Choice Each Traffic Mode in Case 00 (From Centroid 1)

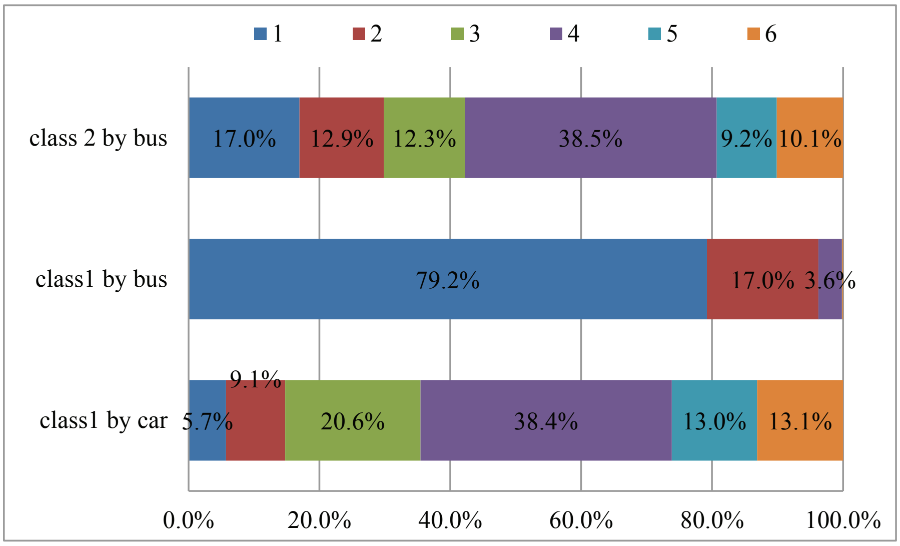


Figure 6.17Probability of Destination Choice Each Traffic Mode in Case 11 (From origin 1)

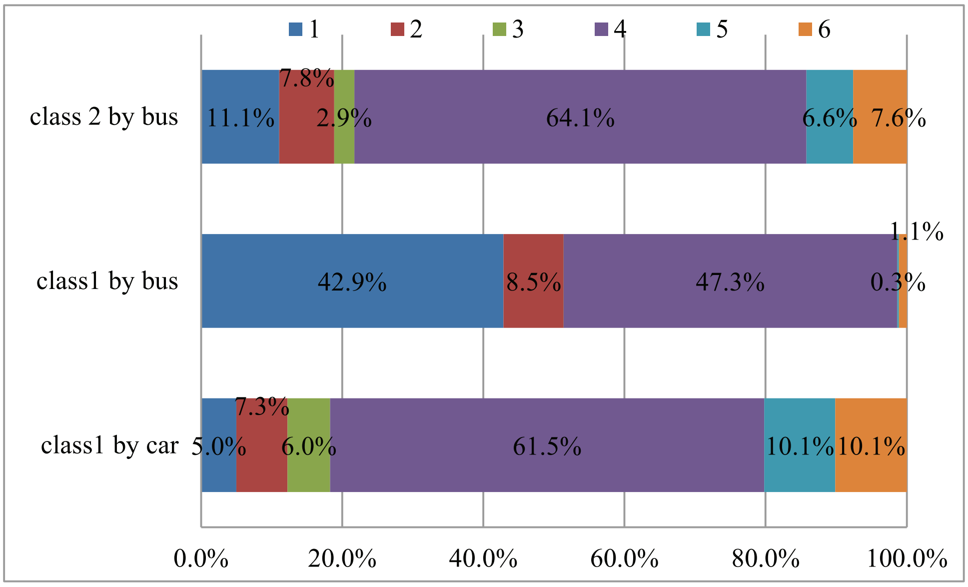


Figure 6.18Probability of Destination Choice Each Traffic Mode in Case 22 (From Centroid 1)

In the formulation of the proposed model, bus may be delayed by longer travel time caused by car traffic congestion. Here we focus on the mode choice probability by class1 in case 00, case 11 and case 22. Figures 6.19 to 6.21 show the mode choice probability from the centroid 2. Comparing case 11 (Figure 6.20) to case 00 (Figure 6.19), probability of car use is larger when the traffic is either to the centroid 3, 4, 5 or 6. This is because the movement by automobiles improves by ring road construction. As shown above, in case 11, suburban development policy that includes transport measure and land use policy accelerated suburbanization and car traffic. As a result, it raised the probability of car choice. On the other hand, case 22 ensures BRT to run without delay. The travel cost by bus decreased by shorter bus travel time. Bus choice probability also raisedwhen the traffic is destined to either centroids 3, 4, 5 or 6. Especially,travel by bus was inconvenientif the traffic is detined to either 4 or 6 in the case 00, but by the introduction of BRT, the probability of bus use raised over 50%.

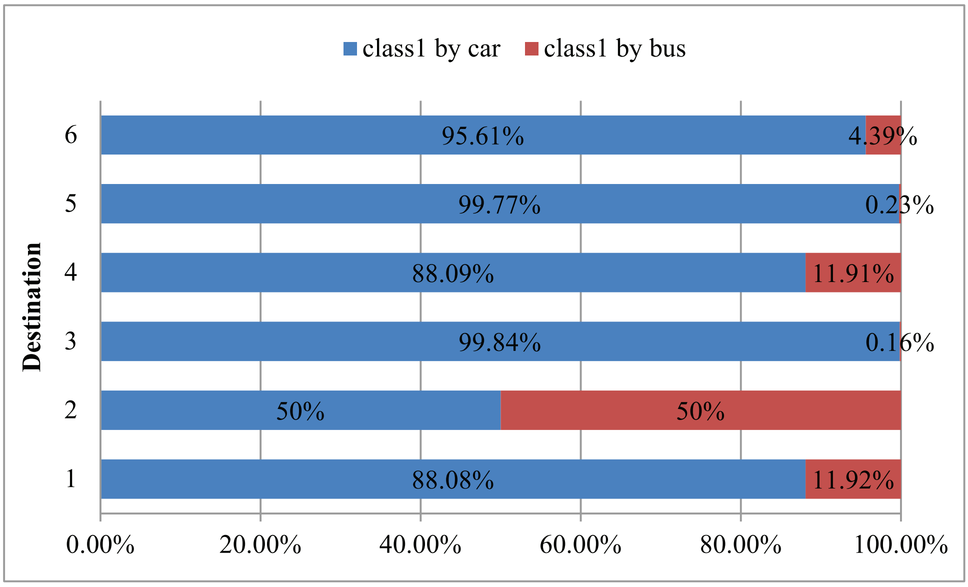


Figure 6.19 Probability of Traffic Mode Choice of Class1 in Case 00 (From Centroid 2)

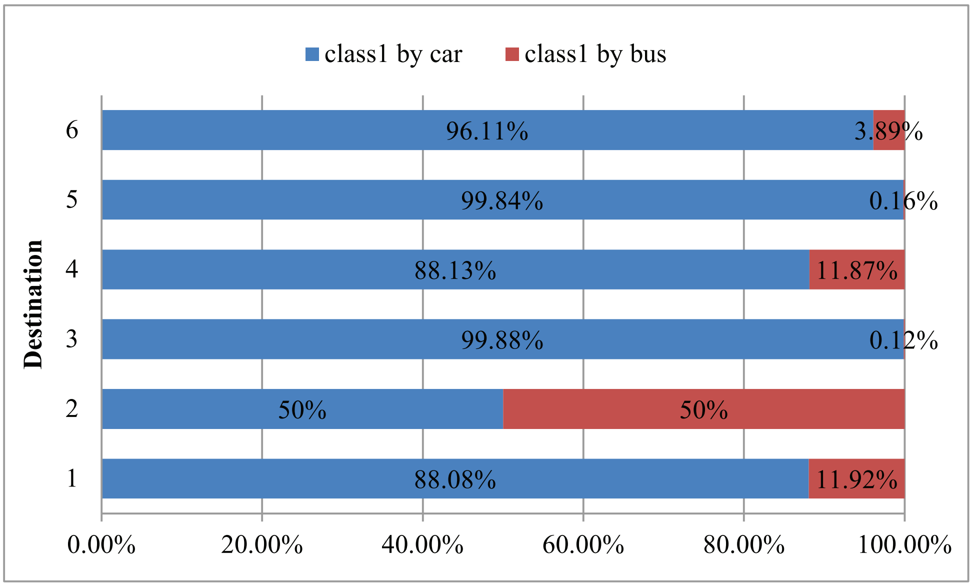


Figure 6.20 Probability of Traffic Mode Choice of Class1 in Case 11 (From Centroid 2)

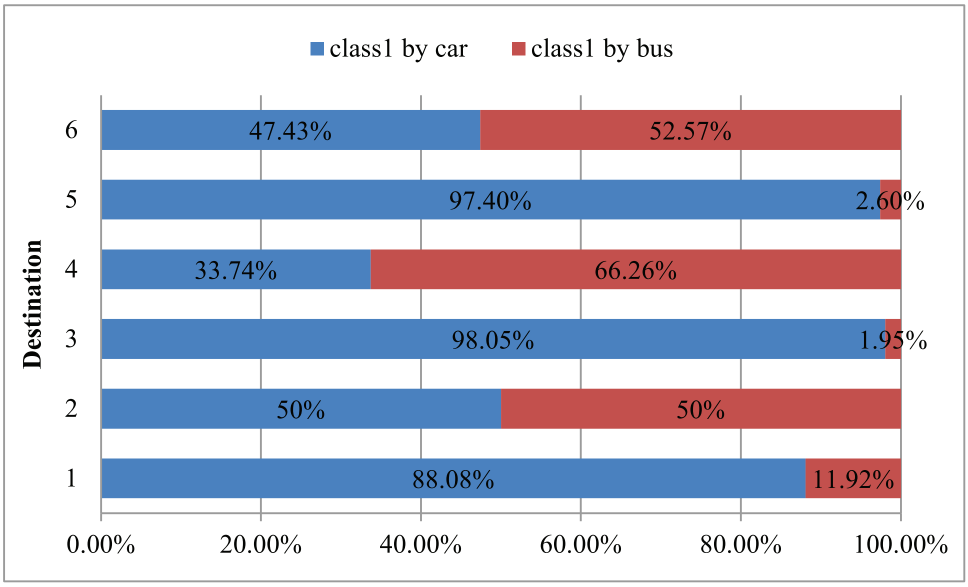


Figure 6.21 Probability of Traffic Mode Choice of Class1 in Case 22 (From Centroid 2)

6.5 Summary

This chapter presented an integrated traffic assignment model which encloses the transport mode and destination choice. With verification on the hypothetical test network, we analyzed the effectby evaluating the change of destination choice as well as mode choice when land use or transport service is changed.By considering the delay caused by car traffic congestion, the model expressedbus travel time in road network space more precisely. As a result, the proposed model showed the structure that the behaviour of destination choice, traffic mode choice and route choice changed by the change of attractiveness of each centroid and the level of transport service. Not only transport measure, but also land use policy like CBD reactivation could also be evaluated by setting properparameters. All choice behaviouris formulated by logittype. Consumer surpluscan be calculated by log-sum variableandconnect the proposed model with cost benefitanalysis. Moreover, by analysis in the test network, the policy of suburban SC construction raised car use probability; eventhough road construction cannot improve the car traffic congestion situation. On the other hand, the policy which increased the attractiveness of CBD and introduction of the BRT contributeto the traffic situation for the whole city.

As described above, there isa limitation in the proposed integrated traffic assignment model which encloses the transport mode and destination choice.First, the relation of cost by increasedregional attractiveness and effect has not been calculated exactly. This leaves achallenge for further study. Second, the proposed model in this study evaluated the impact of transport system and land use change, but did not consider household and firmbehavior which could evaluate land usemarket of the whole city.Finally, not just in the test network, the model should be attemptedto real city transport network. In the next chapter, we will use Gifu city transport network to the proposed modelin order to analyse the transport measure and land use policy.

REFERENCES

Akamatsu, T.(1996), Cyclic flows, Markov processes and stochastic traffic assignment, Transportation Research Part B, Vol.30, pp. 369-386.

Akamatsu, T. (1997), Decomposition of path choice entropy in general transportation networks, Transportation Science, Vol.31, pp. 349-362.

Beckmann, M., McGuire, C. B., & Winsten, C. B. (1956), Studies in the Economics of Transportation, Cowles Commission Monograph, Yale University Press, New Haven, CN.

Bell, M.G.H.(1995), Alternatives to dial's logit assignment algorithm, Transportation Research Part B, Vol.29, pp. 287-296.

Bell, M. G. H. & Iida, Y. (1997), Transportation Network Analysis, John Wiley & Sons, Chichester, U. K.

Daganzo, C. & Sheffi, Y. (1977), On the Stochastic Models of Traffic Assignment, Transportation Science, Vol. 11, No. 3, pp. 253-274.

Dial, R.B. (1971), A probabilistic multipath traffic assignment model which obviates path enumeration, Transportation Research, Vol.5, pp. 83-111.

Fisk, C. (1980), Some Developments in Equilibrium Traffic Assignment, Transportation Research Part B, Vol. 14, No. 3, pp.243-255.

Sheffi, Y. (1985), Urban Transportation Networks: Equilibrium Analysis with Mathematical Programming Methods, Prentice-Hall, Englewood Cliffs, N. J.

Toshihiko Miyagi. (1985), Travel Choice Equilibrium Models: Theory and Algorithms, Journal of JSCE, Infrastructure Planning and Management, No. 2, 1, pp.3-28. (Japanese)

CHAPTER 7

Case Study in Gifu City

In thelast chapter, the integrated land-use and transport model was build and tested on the hypothetical test network.In this chapter, we apply the model onto Gifu City to evaluate an impact of public services and land use policiesby applying the proposed model. Through the case studies, the validity of the proposed model is discussed.

7.1 Data Overview

In this chapter data collected through the analysis in chapter 3 are used. For applyingthe proposed model, it is needed to construct transport network, demand and land use data from them.

7.1.1 Transport Network and Demand Data

The latest PT survey data was carried out in 2001. We therefore use 2001 transport network and PT survey data for zoning and traffic demand data.As is explained in the previous chapters of 4 and 5, construction of Ring Road was almost completed and motorization was exacerbated by land use policies emphasized on automobile transport. Public transport service relies mainly on only buses and their level of service got worse and worse.

Based on the PT survey data, the city is divided into 13 zones, as shown in Figure 7.1. The Mount Kinka locates around the circles place in the figure, and nobody is living around there. Main railway stations of Gifu; JR Gifu Station and Meitetsu Gifu Station arelocated in Zone 1 and CBD of the city is located in zones 1 and 2.Figure 7.2 illustrates a road network.Centroids from 1 to 13 correspond to zonesfrom 1 to 13 within the city, respectively. Capacity of links is set based on Road Traffic Census Data (Gifu Prefecture, 2005), and the link travel time is calculated by dividing the distance by velocity recorded in the census. Centroidsfrom 14 to 20 are set so as to represent traffic movement from/to outside of the city. Traffic demand data for each purpose of commuting, business and leisure is obtained from PT data. We assumed here that 10% of OD traffic volume by car is assumed be captured to car in terms of mode choice and set as class 0 (car only), and 90% of those are set as class 1 (either to use car or public transport). As the ratio of car ownership in 2001 was 0.714 (Gifu City, 2001), class 2 (public transport only) traffic demand is calculated as ((class 0+class1 traffic demand)/ 0.714*(1-0.714)).

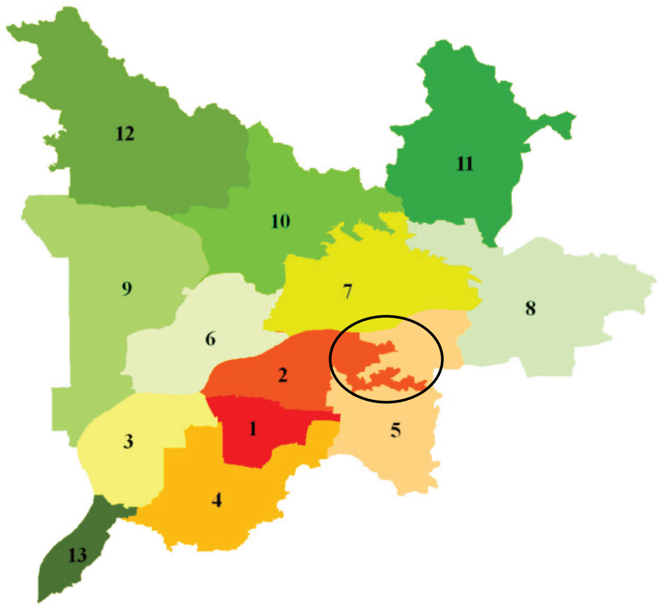


Figure 7.1 Zoning of Gifu City

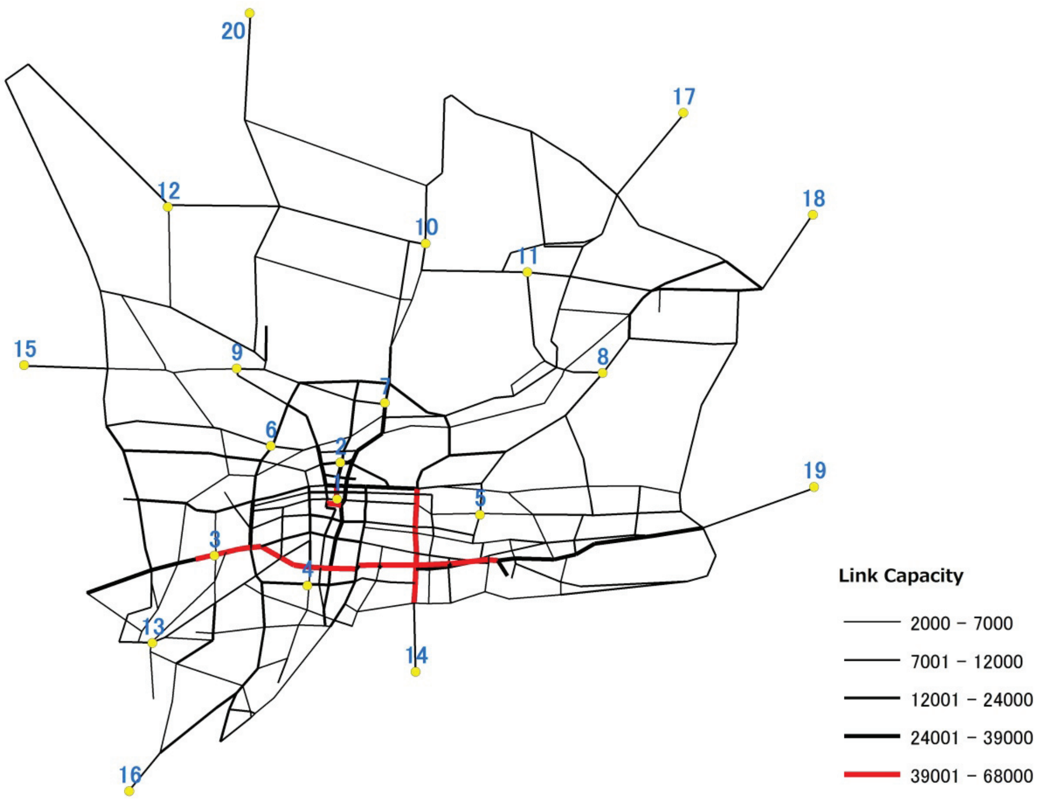


Figure 7.2 Road Network of Gifu City

7.1.2 Land Use Data

Land use data is taken from statistics used in the chapter 4. Data in 2002 is used to unify13 zone data. Table 7.1 shows the land use data in 2002, which includes land use of firmlocation as number of industryenterprise, number of wholesale enterprise and number of retail establishments.

Table 7.1 Land Use Data in 2002

zone	Number of industry enterprise	Number of wholesale enterprise	Number of retail establishments
1	288	917	1230
2	244	236	726
3	252	204	348
4	395	646	433
5	242	111	263
6	229	123	499
7	128	55	333
8	129	34	233
9	224	74	234
10	109	30	136
11	108	9	68
12	42	7	19
13	46	22	13
Total	2436	2468	4535

7.2 Parameter Calibration

The traffic assignment in the proposed modelassumes LOGIT-type SUE assignment.There are route choice parameterθ^c, traffic mode choice parameter θ^m and destination choice parameter θ^dneeded forcalibration. In this study, we carried out the calibrationby following three steps.

7.2.1 Calibration of θ^c

First, route choice traffic assignment is carried out to test route choice parameterθ^c. The link traffic volume obtained as the result of assignment is compared with those of census data obtained from Gifu Prefecture. Travel time function is formulated by next modified BPR function.

$$c_a = c_o\left(1 + 2.62\left(\frac{v_a}{Ca_a}\right)^5\right)$$

By trial and error, the closest result was obtained when $\theta^c = 40$. The average congestion degree is 0.7 for the assignment result and 1.06 as census data.Correlation coefficient with assignment traffic volume and census traffic volumeis 0.49326. Figure 7.3 and 7.4 show the congestion situation of traffic assignment and census data. The value of correlation coefficient is rather low. Judging from the Figures 7.3 and 7.4, this is mainly because for links located around the edge of the network are not efficiently used, because we truncated the network by the area of Gifu City. In reality, such links may have been used by the traffic from outside of the city. Another limitation is the limited number of centroids. Since only 13 centroids are set in the city the traffic therefore tends to concentrate to the links nearby centroids. This phenomenon can be relaxed by preparing more centroids in the city, but it is not easy to prepare more detailed statistics for land-use data. Therefore we use this parameter for the following study, since the result roughly expresses the road congestion, especially in the downtown areas and major trunk roads such as Ring Road.

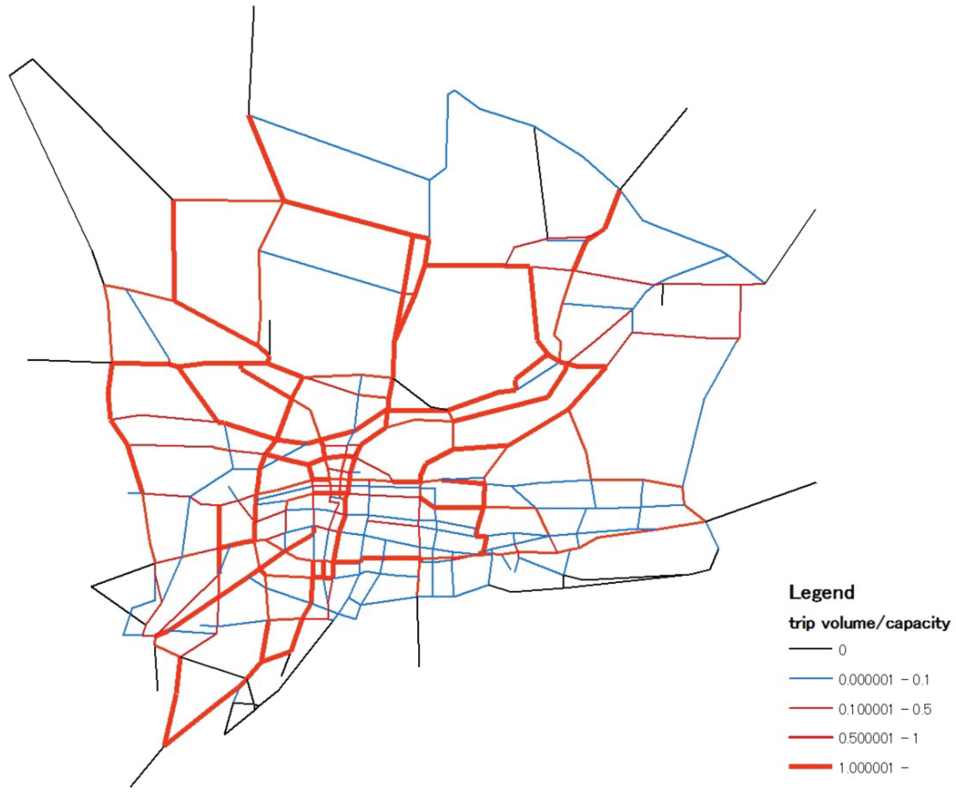


Figure 7.3Result of Congestion Situation of Traffic Assignment

Figure 7.4Result of Congestion Situation of Gifu Prefecture Census

7.2.2 Calibration of θ^m and Constant Bus Cost

Second, traffic assignment with traffic mode choice was carried out to test traffic mode choice parameter θ^m. There is another variable, constant bus cost for each OD pair,which should also be calibrated. As illustrated in the last chapter, traffic mode choice iscalculated based on the log-sum cost of each traffic mode. Since buses are sharing road with car traffic bus travel time was affected by car traffic congestion. Linkswhere buses service is operated are shown in red in Figure 7.5. Each centroid is connected with centroid 1 by bus service and traffic must cross centroid 1 for connecting among all OD pairs.Less cost traffic mode was chosen, The log-sum cost of bus includes travel time and constant bus cost. The constant bus cost is calculated by bus fare obtained from the real bus service data + 100 yen, representing a waiting cost. The probability of traffic mode choice obtained by the model is compared with the probability calculated by PT survey data of each OD pair. By the trial and error, the result fits best when θ^m =0.1.

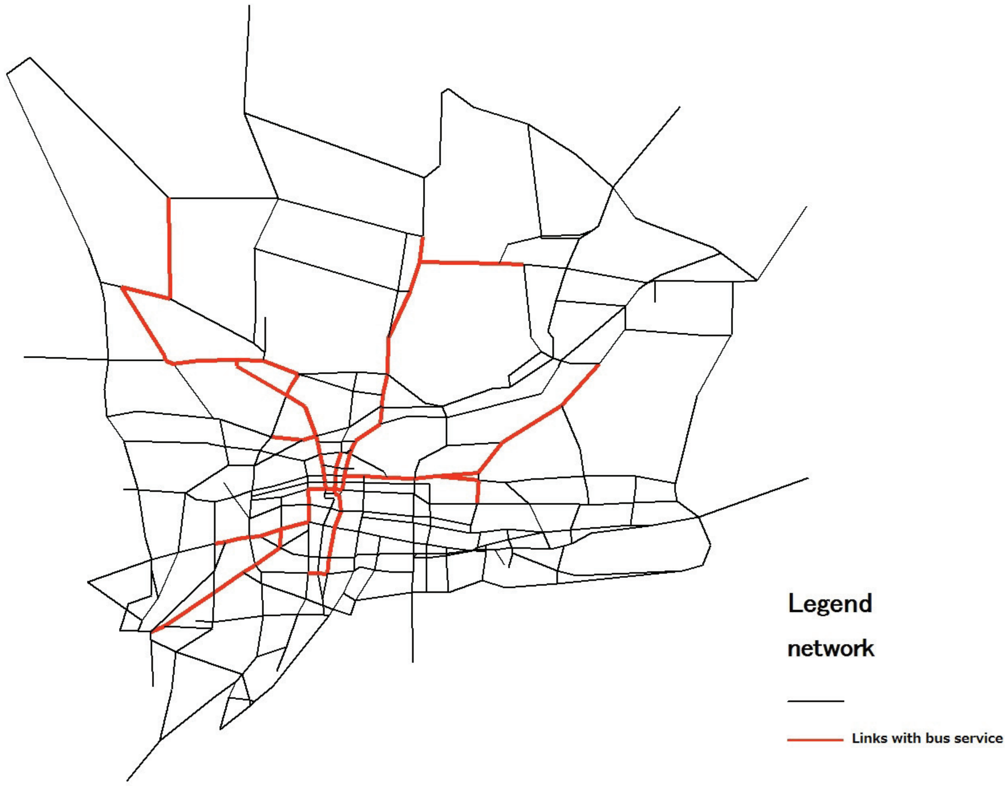


Figure 7.5 Bus Link

Table 7.2ComparisonResult of Traffic ModeChoice
(Assignment Result of and PT Survey)

zone	PT car	PT bus	SUE_m car	SUE_m bus
1	88.39%	11.61%	87.12%	12.88%
2	86.94%	13.06%	89.69%	10.31%
3	96.98%	3.02%	97.75%	2.25%
4	97.48%	2.52%	98.04%	1.96%
5	96.68%	3.32%	97.50%	2.50%
6	97.59%	2.41%	96.70%	3.30%
7	96.86%	3.14%	97.73%	2.27%
8	98.14%	1.86%	97.20%	2.80%
9	97.78%	2.22%	98.34%	1.66%
10	96.39%	3.61%	95.95%	4.05%
11	97.60%	2.40%	97.33%	2.67%
12	100%	0%	96.80%	3.20%
13	100%	0%	98.20%	1.80%
14	100%	0%	100%	0%

15	100%	0%	100%	0%
16	100%	0%	100%	0%
17	100%	0%	100%	0%
18	100%	0%	100%	0%
19	100%	0%	100%	0%
20	100%	0%	100%	0%
Average	95.95%	4.05%	96.08%	3.92%

7.2.3 Calibration of θ^d and Zone Attractiveness

Third, an traffic assignment with traffic mode choice and destination choice is carried out to calibrate destination choice parameter θ^d. As the destination is chosen by its attractiveness for each purpose, θ^d should also beprepared for each three trip purposes;θ^{dc} as commuting choice, θ^{db} as business choice and θ^{dl} as leisure choice.

Table 7.3 Zone Trip Attraction by Each Purpose

Zone	Trip attraction of commuting	Trip attraction of business	Trip attraction of leisure
1	10842	11088	17719
2	9979	9315	12595
3	7523	6745	12935
4	11389	9454	15403
5	4377	3901	7144
6	6553	6790	20986
7	4347	5703	15138
8	3951	3252	12987
9	5320	5458	8119
10	1276	2891	5365
11	878	872	1235
12	999	705	595
13	1230	1915	1161

Attractiveness of zones should depend on land use situation shown in table 7.1 above. To obtain attractiveness of zones, we attempt to explain trip attraction volume for each purpose by land use statistics shown in the Table 7.1. The result of estimation is described in Figures 7.6 to 7.8.

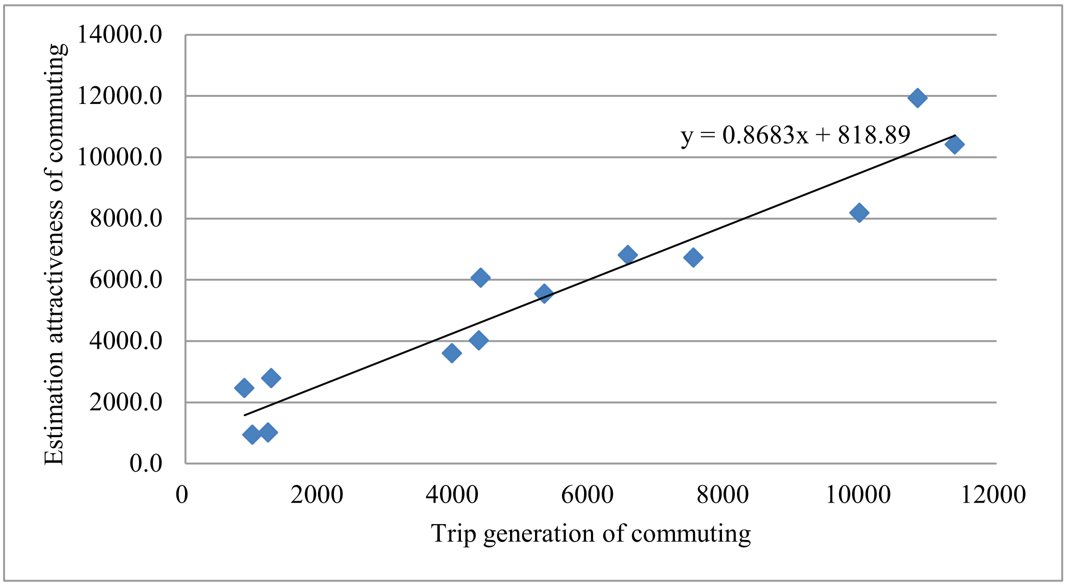


Figure 7.6 Confirmation of theCorrelativity of EstimationAttractiveness of Commuting

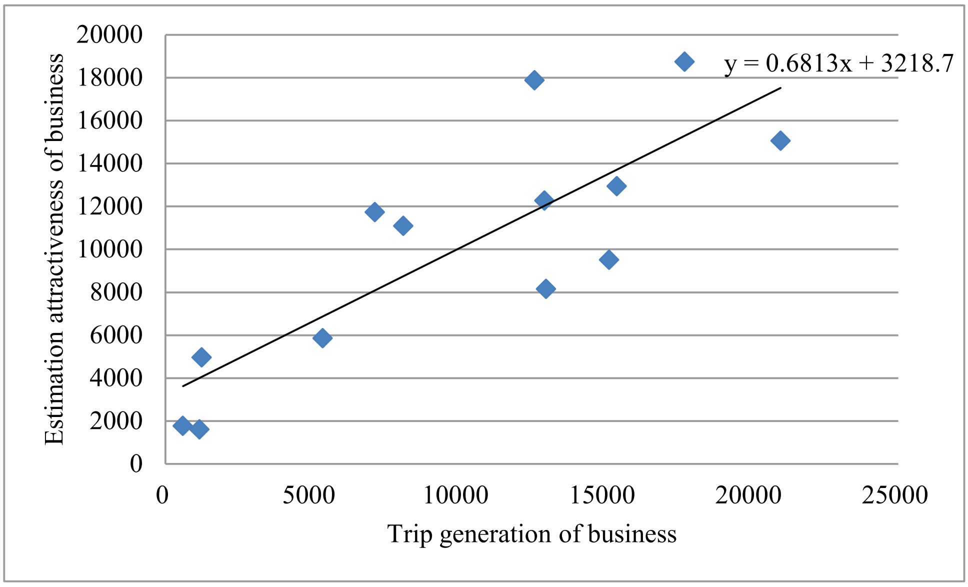


Figure 7.7 Confirmation of theCorrelativity of EstimationAttractiveness of Business

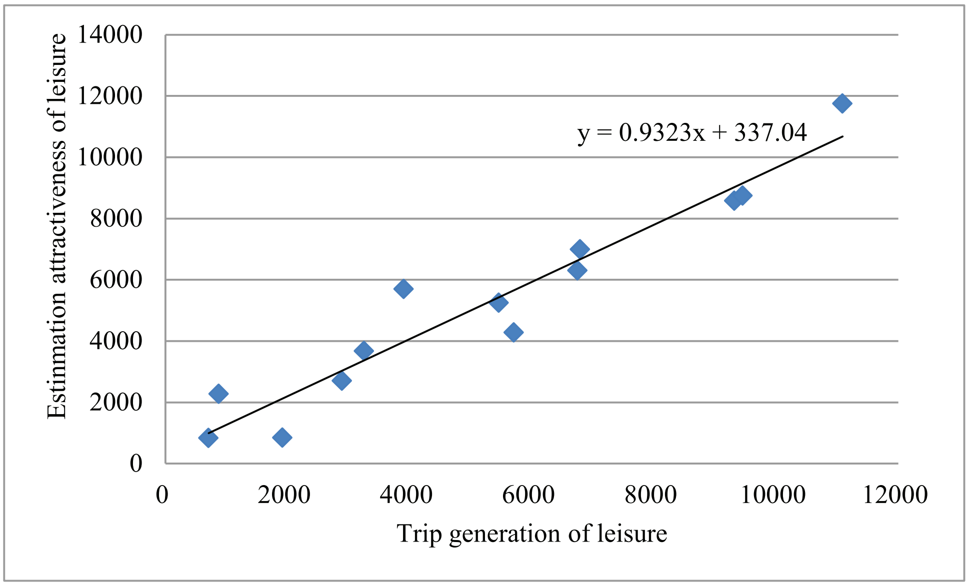


Figure 7.8 Confirmation of theCorrelativity of EstimationAttractiveness of Leisure

As a result, the attractiveness for each purpose can be evaluated by following three equations;

$$A_c = 19.9N_i + 1.1N_w + 4.2N_r$$

$$A_b = 17N_i - 1.24N_w + 6.48N_r$$

$$A_l = 36.4N_i - 13.5N_w + 16.75N_r$$

Where:

A_c: zone attractiveness of commuting for work

A_b: zone attractiveness of business

A_l: zone attractiveness of leisure

N_i: number of industry enterprise

N_w: number of wholesale enterprise

N_r: number of retail establishments

After the estimation by the above formulation, the attractiveness is too large comparedwith travel cost and make an excess impact to destination choice. So a scale parameter to attractiveness was taken to relax the impact. By trial and error, the scale parameter was calibrated to 0.01. The result of estimation zone attractiveness is shown in table 7.4.

Table 7.4Estimation Zone Attractiveness

zone	Attractiveness of commuting	Attractiveness of business	Attractiveness of leisure
1	119.140	117.442	187.181
2	81.662	85.726	178.593
3	67.040	62.986	122.514
4	103.990	87.386	129.201
5	60.448	56.926	117.180
6	67.895	69.858	150.354
7	40.066	42.724	94.953
8	35.836	36.673	81.401
9	55.237	52.437	110.760
10	27.740	27.025	58.414
11	24.455	22.708	49.493
12	9.237	8.305	17.529
13	9.948	8.412	15.957

After trial and error, the final results for destination parameters are θ^{dc} =0.00012, θ^{db} =0.0001 and θ^{db} =0.0001. The comparison of estimated probability by the model with observed probability from PT survey is shown in Table 7.5.

Table7.5Comparison of Destination ChoiceProbability for Each Purpose of SUE Assignment and PT

Zone	Commuting		Business		Leisure	
	SUE	PT	SUE	PT	SUE	PT
1	18%	16%	16%	16%	18%	13%
2	10%	15%	11%	14%	16%	10%
3	8%	11%	8%	10%	8%	10%
4	14%	17%	11%	14%	9%	12%
5	7%	6%	8%	6%	8%	5%
6	8%	10%	9%	10%	11%	16%
7	6%	6%	6%	8%	6%	12%
8	5%	6%	6%	5%	5%	10%
9	7%	8%	7%	8%	7%	6%

10	5%	2%	5%	4%	4%	4%
11	4%	1%	5%	1%	3%	1%
12	3%	1%	4%	1%	2%	0%
13	3%	2%	4%	3%	2%	1%

7.3 Analysis of Base Case

7.3.1 Data Setting

Based on data described in section 7.1 andcalibration in section 7.2, the proposed model is applied in the calculation for Gifu City. There are 378 nodes, 1046 links and 20 centroids in the network, which makes the total OD pair to 400. The centroid 1 and 2represent the CBD of the city. Table 7.6summarizes the origin and destination data. The constant cost of bus is set to the result of calibration in section 7.2.2. Logitdispersion parameters,$\theta^c, \theta^m, \theta^d$ is set to 40, 0.1 and (0.00012, 0.0001, 0.0001). We call this base case as case00, to compare with the other scenarios.

Table 7.6 Input Data

(a) Parameters

Number of link	Number of node	Number of OD pair	Number of origin	Number of destination	θ^c	θ^m	θ^{dc}	θ^{db}	θ^{dl}
1046	378	400	20	20	40	0.1	0.00012	0.0001	0.0001

(b) Data of Origin

OriID	Node	1_Commuting	1_Business	1_ Leisure	2_Commuting	2_Business	2_Leisure
1	339	5562	13392	11484	2383	5739	4921
2	340	4896	11249	11395	2098	4821	4883
3	341	9747	10800	14397	4177	4628	6170
4	342	11364	14728	17692	4870	6312	7582
5	343	7298	5118	9853	3127	2193	4222
6	344	10515	8739	18955	4506	3745	8123
7	345	7623	6894	12941	3267	2954	5546
8	346	11540	5211	15598	4945	2233	6684
9	347	11985	6638	12532	5136	2844	5370
10	348	7941	4214	9480	3403	1806	4062
11	349	293	951	576	125	407	246
12	350	1074	670	2065	460	287	885

13	351	1342	2236	2282	575	958	978
14	352	4410	6892	3475	0	0	0
15	353	22755	14216	20043	0	0	0
16	354	8311	6686	7494	0	0	0
17	355	3242	1542	2803	0	0	0
18	356	777	401	368	0	0	0
19	357	7281	4901	4891	0	0	0
20	358	5031	2433	6907	0	0	0

(c) Data of Destination

DesID	Node	Attractiveness for Commuting	Attractiveness for Business	Attractiveness for Leisure
1	359	119.140	117.442	187.181
2	360	81.662	85.726	178.593
3	361	67.040	62.986	122.514
4	362	103.990	87.386	129.201
5	363	60.448	56.926	117.180
6	364	67.895	69.858	150.354
7	365	40.066	42.724	94.953
8	366	35.836	36.673	81.401
9	367	55.237	52.437	110.760
10	368	27.740	27.025	58.414
11	369	24.455	22.708	49.493
12	370	9.237	8.305	17.529
13	371	9.948	8.412	15.957
14	372	0	0	0
15	373	0	0	0
16	374	0	0	0
17	375	0	0	0
18	376	0	0	0
19	377	0	0	0
20	378	0	0	0

7.3.2 Destination Log-sum Variables of Each Purpose

In this study, all of the choice behavior is formulated by Logittype choice. The utilitycan therefore be summed up to obtain overall utility using log-sum variables. That makes it possible to compare utility of each class based on the value of log-sum variable. Here, we carried out an analysis of total travel utilityfor each class and each origin. The valuesare calculated asS_r^{d1*}. Figure 7.9 shows the result. For the case00, the utility of class2 is lower than that of class1, meaning that people with automobiles can obtain larger utility. This makes sense since class 1 users have an option to use cars, which is more convenient than using buses. By the comparison among nodes, the largest utility can be obtained for traffic originated from node 1, and the utility is lower if the traffic is originated from rather outskirts area like centroids 11, 12 and 13. This also makes sense since travel time from such centroids is longer.

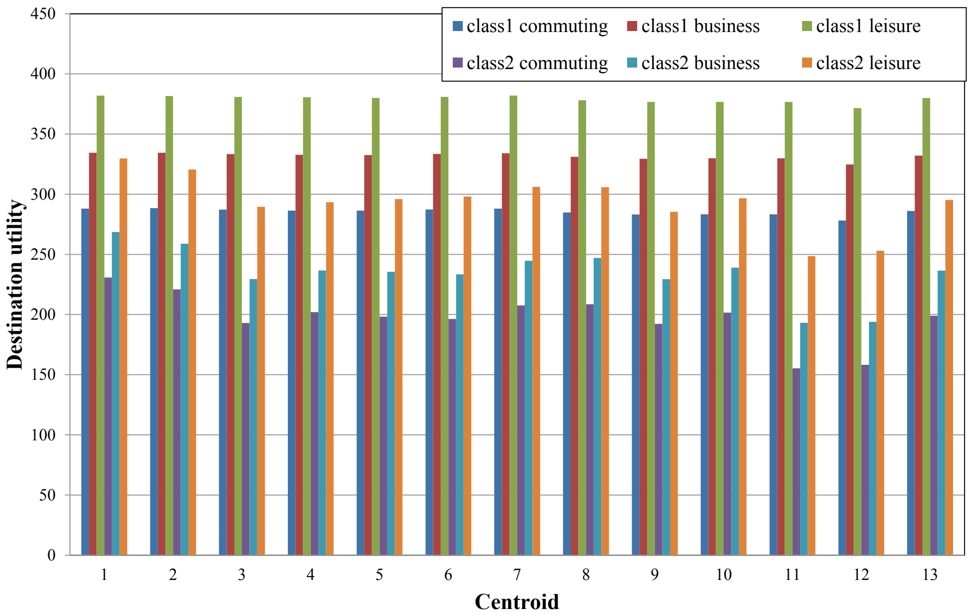
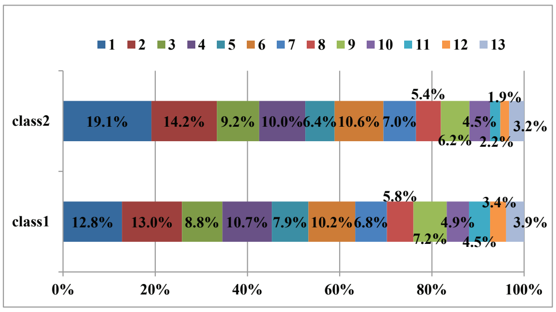


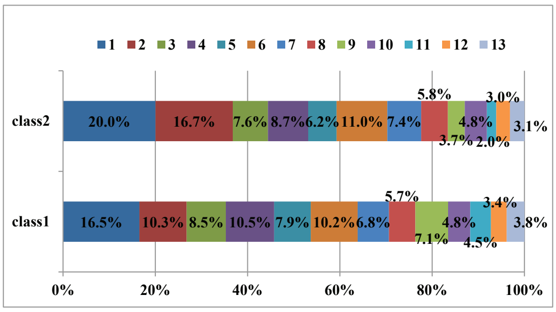
Figure 7.9Utility by Each Trip Purpose and Each Class

7.3.3 Behavior of Destination Choice

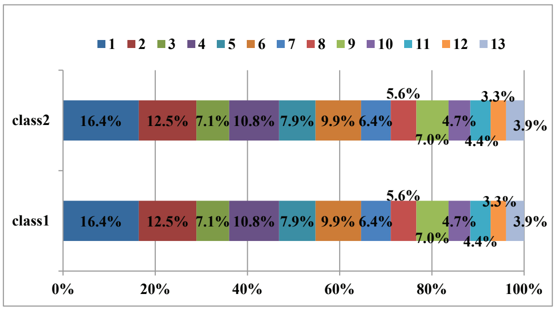
Next, we analyze theprobability of destination choice. Figure 7.10 illustrates the probability of destination choice from each origin for each class. For case00, the traffic attraction is concentrated to centroids1 and 2. However, since the attractiveness is large, destination choice probability for centroid 4 is also high. Therefore, compared to class1, the concentration ratioto CBD of class2 is higher. The main reason is that all the bus services pass centroid 1which makes bus travel inconvenientfor OD pairs not related with centroid 1. In addition,a distance of bus travel is longer in centroids 8, 9, 11, 12 where the inside traffic ratio is larger than others.



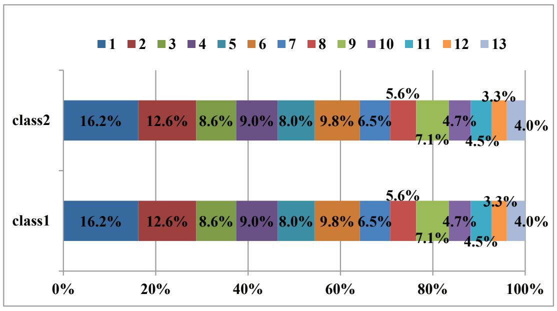
(a) Origin 1



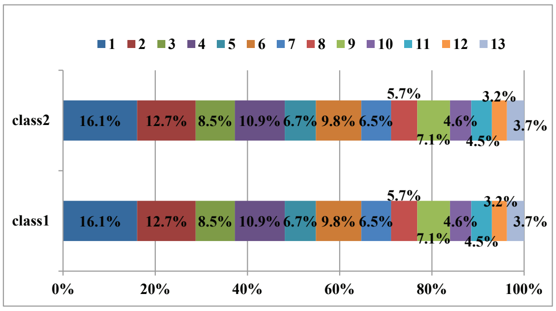
(b) Origin 2



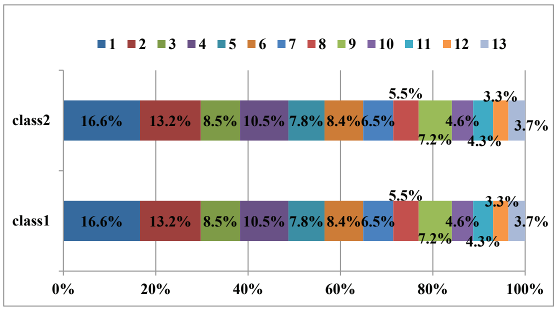
(c) Origin 3



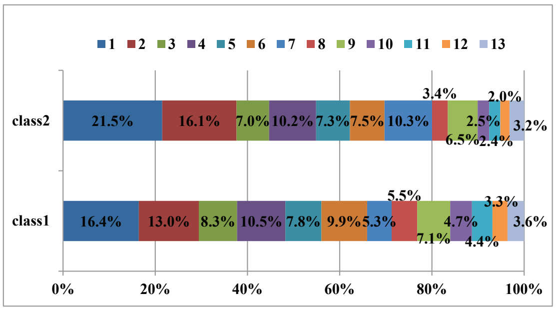
(d) Origin 4



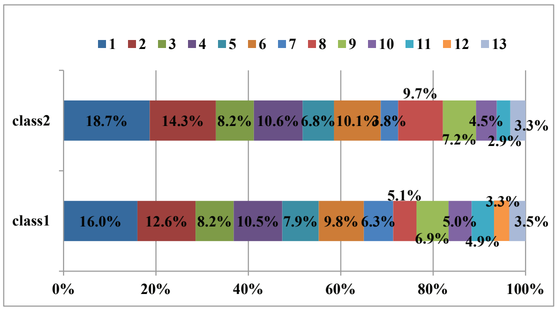
(e) Origin 5



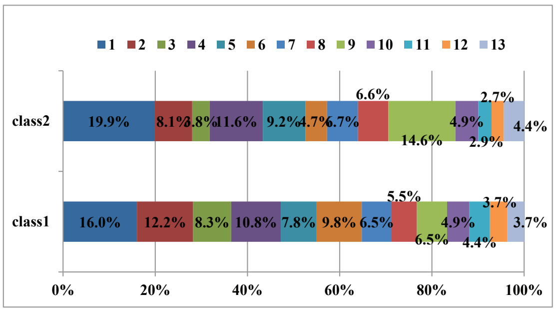
(f) Origin 6



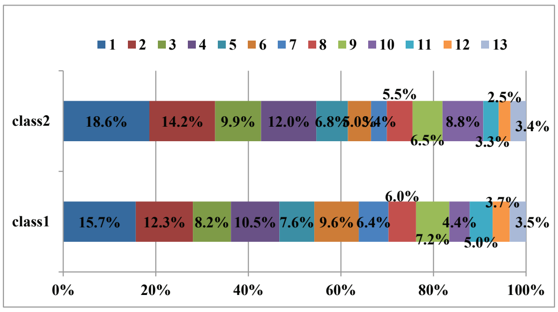
(g) Origin 7



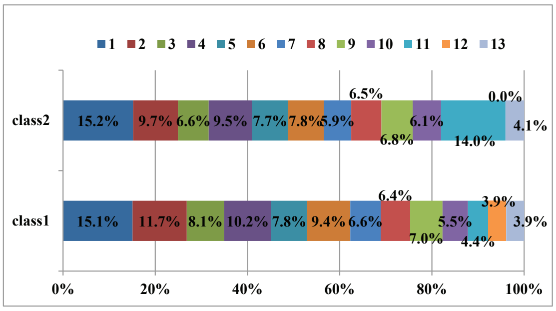
(h) Origin 8



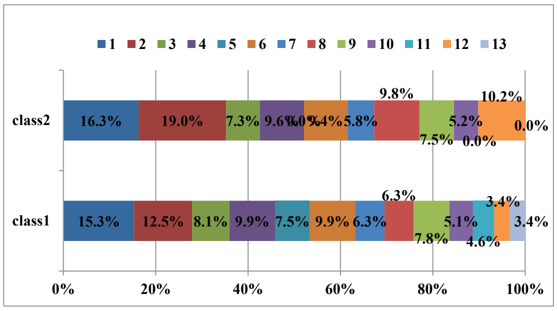
(i) Origin 9



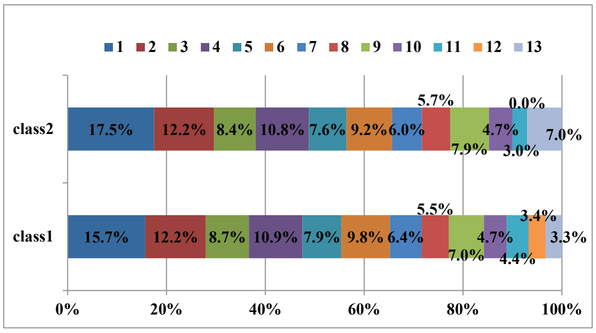
(j) Origin 10



(k) Origin 11



(l) Origin 12



(m) Origin 13

Figure 7.10Destination Choice Probabilityfor Each Class from Each Origin

7.4 Case study Evaluating the Transport Service Measure and Land Use Policy

In this section, we attempt to implement transport service measure and land use policy on base case and evaluate the effect. In particular, Bus Rapid Transit system has been introduced as a transport service measure, and a reactivation of CBD are is selected as a land use policy.

7.4.1 Assumptions of Transport Service Measure and Land Use Policy

The settingof cases is shown in Table 7.7.We will evaluate individual as well as integrated effects of land use and transport schemes. links where dedicated BRT lane is installed are shown in red bold lines Figure 7.11. Gifu City Integrated Transportation

Strategy (2014-2018) is referred to determine the location of BRT service. We assume here that BRT uses exclusive lanes and is free from car traffic congestion. Travel time of BRT is therefore calculated based on free flow link speed. Capacity of links where BRT is installed is decreased 2000 (veh.) to give space of BRT. As for land use policy, we assume that commercial activity in CBD is enhanced, and the number of wholesale enterprise and that of retail establishments in zones 1 and 2 are set 1.5 times more than the base case. Table 7.8 summarizes the statistics. The number of enterprises for other zones is decreased by a uniform rate in order for keeping a total number of enterprises within a city as constant. By the changes of the number of enterprises as is shown in the Table 7.8, the values of attractiveness for each zone for each trip purpose are calculated as Table 7.9.

Table7.7 Case Study Setting

Case No.	a. Transport Policy	b. Commercial Facilities Planning
00 (base case)	×	×
10	BRT	×
01	×	Reactivation of CBD
11	BRT	Reactivation of CBD

Figure 7.11Assumption of BRT Lane Configuration

Table7.8Land Use Data withReactivation of CBD

zone	number of industryenterprise	number of wholesaleenterprise	number of retail establishments
1	288	1375.5	1845
2	244	354	1089
3	252	114.5657795	216.0325708
4	395	362.791635	268.799147
5	242	62.33726236	163.2659946
6	229	69.07642586	309.7708414
7	128	30.8878327	206.720822
8	129	19.09429658	144.6424971
9	224	41.5581749	145.2632803
10	109	16.84790875	84.42652191
11	108	5.054372624	42.21326095
12	42	3.931178707	11.79488174
13	46	12.35513308	8.070182241
Total	2436	2468	4535

Table7.9DestinationAttractiveness with the Reactivation of CBD

DesID	Node	Attractiveness for Commuting	Attractiveness for Business	Attractiveness for Leisure
1	359	150.041	151.613	228.346
2	360	98.204	107.791	223.475
3	361	60.508	55.542	112.474
4	362	93.952	80.259	139.895
5	363	55.723	51.065	107.039
6	364	59.356	58.262	125.934
7	365	34.500	34.838	77.056
8	366	31.964	31.131	68.613
9	367	51.153	47.088	100.273
10	368	25.430	23.846	51.550
11	369	23.329	21.085	45.707
12	370	8.900	7.876	16.736
13	371	9.634	8.212	16.432
14	372	0	0	0
15	373	0	0	0
16	374	0	0	0

17	375	0	0	0
18	376	0	0	0
19	377	0	0	0
20	378	0	0	0

7.4.2 Comparison of Total Travel Time and Total Utility

First, we made a comparison of total travel time and total utility for all the cases. The result is shown in Figure 7.12. The total travel timeis largest in the case 10 with BRT that is caused by capacity decrease of links, and is smallest in the case 01 with reactivation of CBD. Next, about total utility, the largest value is obtained for the case 11. Both the reactivation of CBD and implementation of BRT contributeto the total utility. Even though total travel time is larger in the case 10, the total utility is larger than the base case.

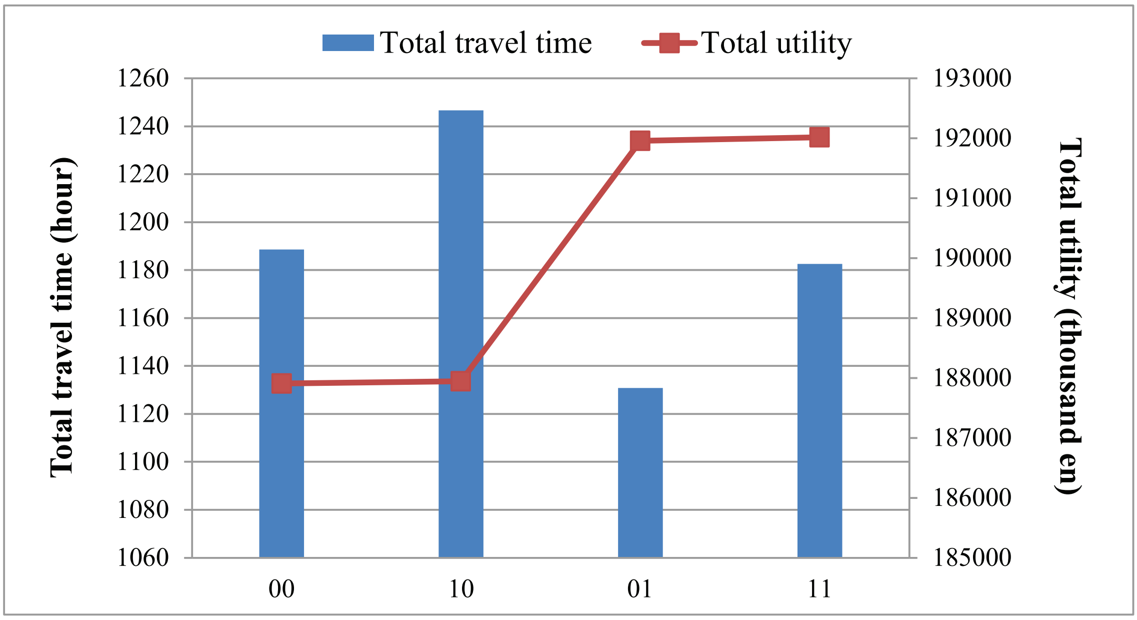


Figure 7.12Utilityfor Each Trip Purpose and Case

7.4.3 Comparison of Destination Log-sum Variables

Second, we make a comparison of destination utility. The result is shown in Figures 7.13to 7.16 for each case, respectively. Comparing case 01 (Figure 7.15) and case 11 (Figure 7.16) to case 00 (Figure 7.13), with policy of reactivation of CBD, the destination utilityof travelers originated from centroids 1 and 2 is largestespeciallyfor the purpose of leisure. On the other hand, comparingthe case 10 (Figure 7.14) with the base case, with longer travel time, utility of class 1 decreased for all of the purposes.

The similar result can be found also for the total travel time. Moreover, the utility of most destinationsincreased except for centroids 11 and 12 where the benefit of BRT cannot be obtained. In the case 11 by the synergy of BRT implementation and reactivation of CBD, the utility in CBD improved a lot.

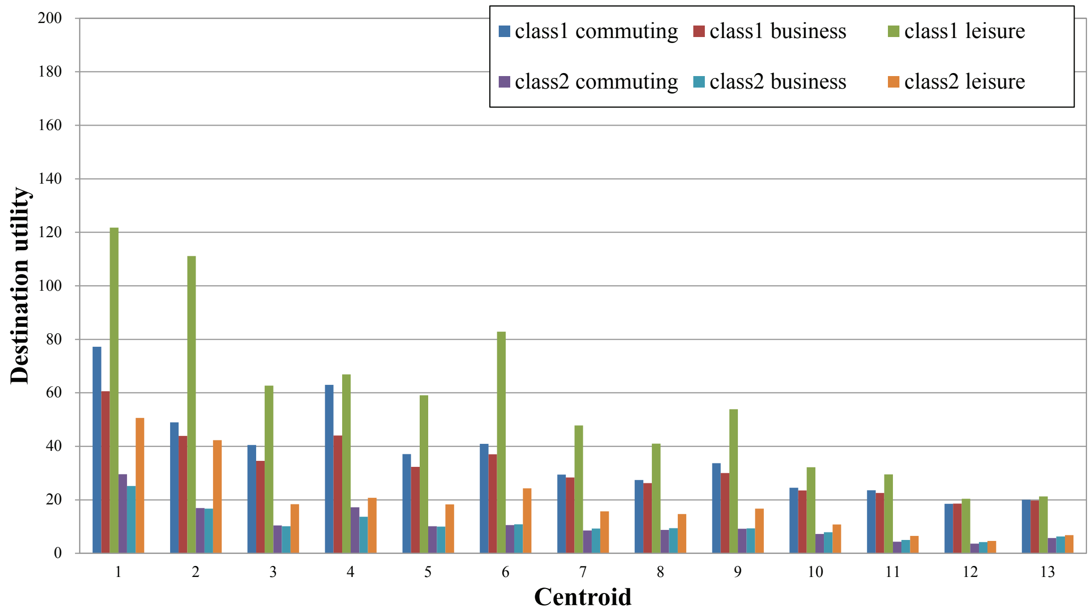


Figure 7.13 Destination Utility of Each Purpose in Case 00

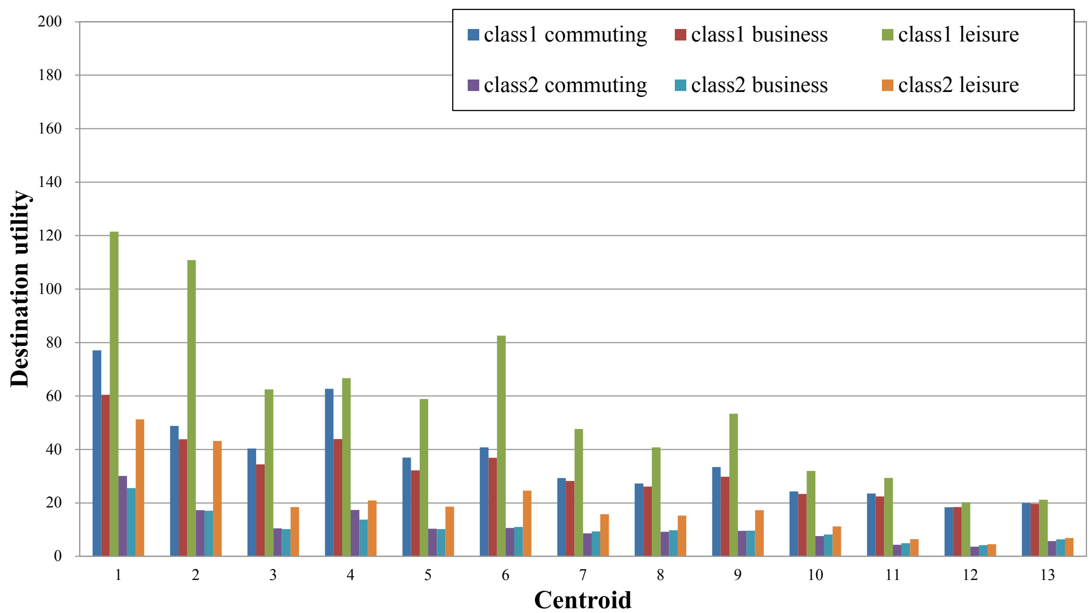


Figure 7.14 Destination Utility of Each Purpose in Case 10

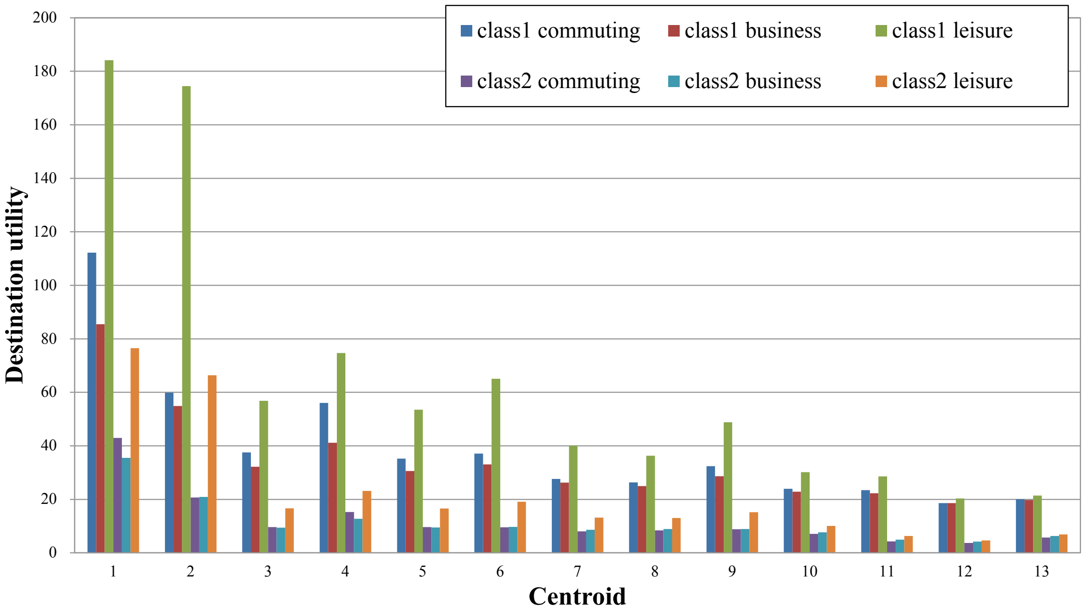


Figure 7.15 Destination Utility of Each Purpose in Case 01

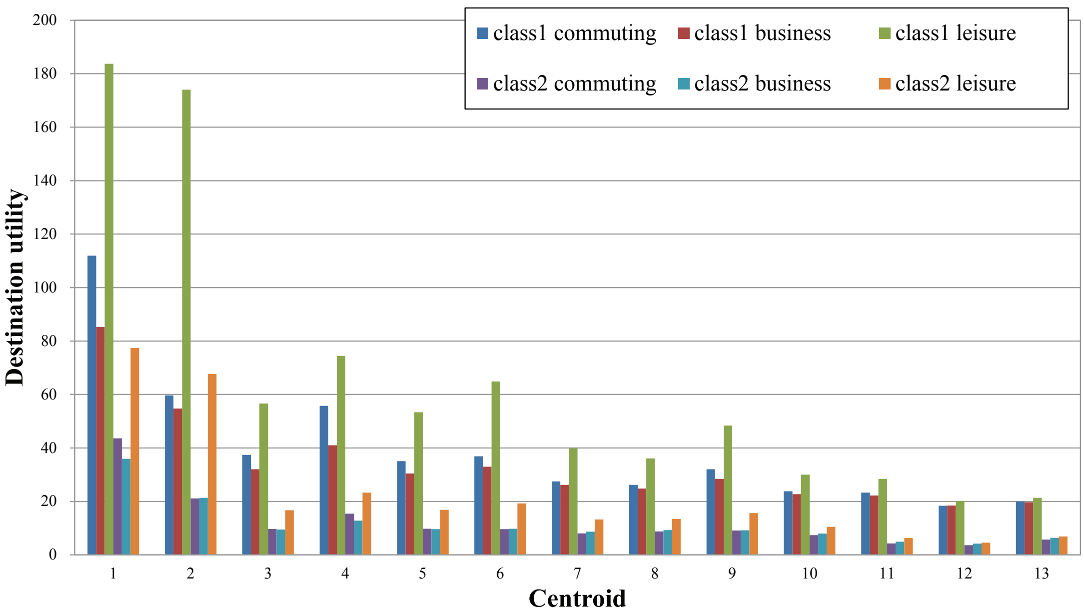


Figure 7.16 Destination Utility of Each Purpose in Case 11

7.4.4 Comparison of Traffic Mode Choice Behavior

Next, we compare traffic mode choice behavior.One of the features of the proposed model is that bus travel time is affected by car assignment traffic congestion. Bus may be delayed caused by car traffic congestion. For analyzing this assimilation, we focus on mode choice probability in class1 for each case. Figuresfrom 7.17 to 7.20 show the mode choice probability for each case from the origin centroid 10whereBRT is implemented. Assimilationof the case 10 makes it possible that BRT runsindependently from car traffic. The cost by public transport decreases because of shorter travel time. Comparingthe case 10 (Figure 7.18) to case 00 (Figure 7.17), the car choice probability is larger in all the centroids for the case 00. By the implementation of BRT that improves connection by public transport especiallyto centroids 1 and 2, the probability of public transport choice increases over 7%. The result of the case 11 (Figure 7.20) is similar to the case 10. On the contrary, for the case 01 car is more used than buses (Figure 7.19). Car choice Probability is a little higher in the case 01 than in the case 00.

Until now we look at the mode choice probability of the centroid 10 that is located in the suburban area. What about the situation in the centroids closer to the CBD? We carried outthe same analysis from the centroid 4. Figuresfrom 7.20 to 7.24 show that mode choice probability from the origin centroid 4. The result is almost the same as the result for the centroid 10; the bus choice probability increases for the cases 10 and 11 whereas it decreases for the case 01. However the changes in the probability is not so large compared to the result of the centroid 10. The effect of BRT implementation is larger for ODs where travel distance is longer. This is understandable since advantages of BRT is larger.

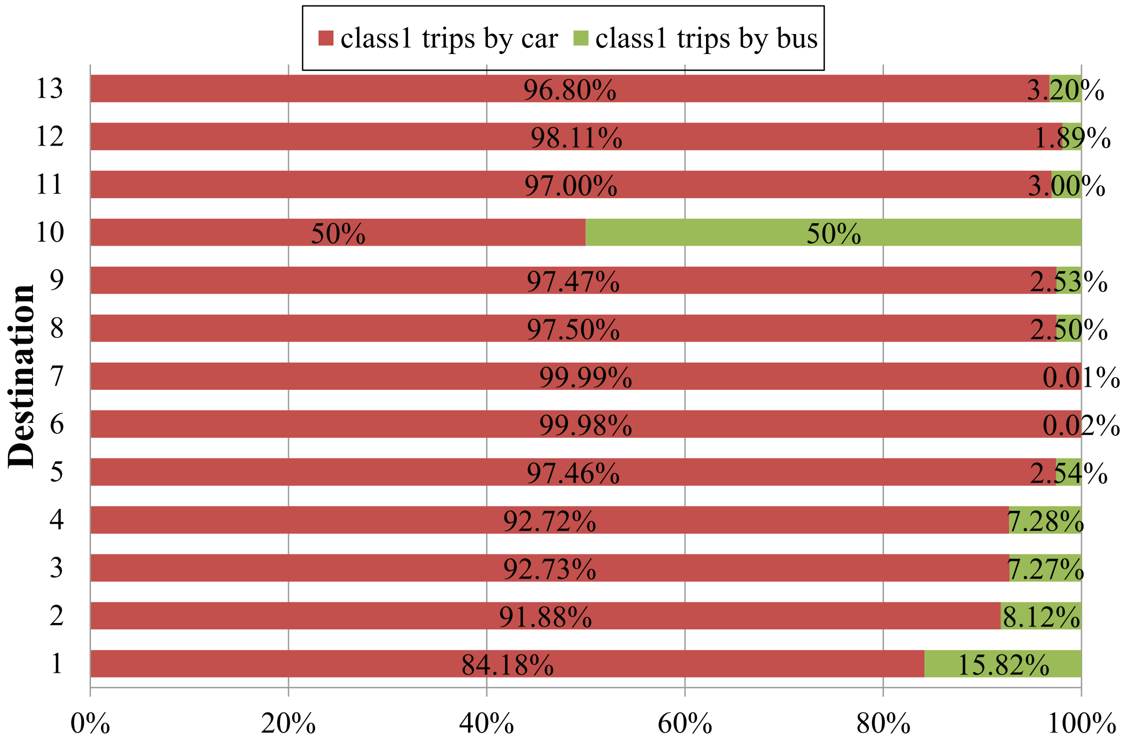


Figure 7.17Probability of Traffic Mode Choice of Class1 in Case 00

(From origin 10)

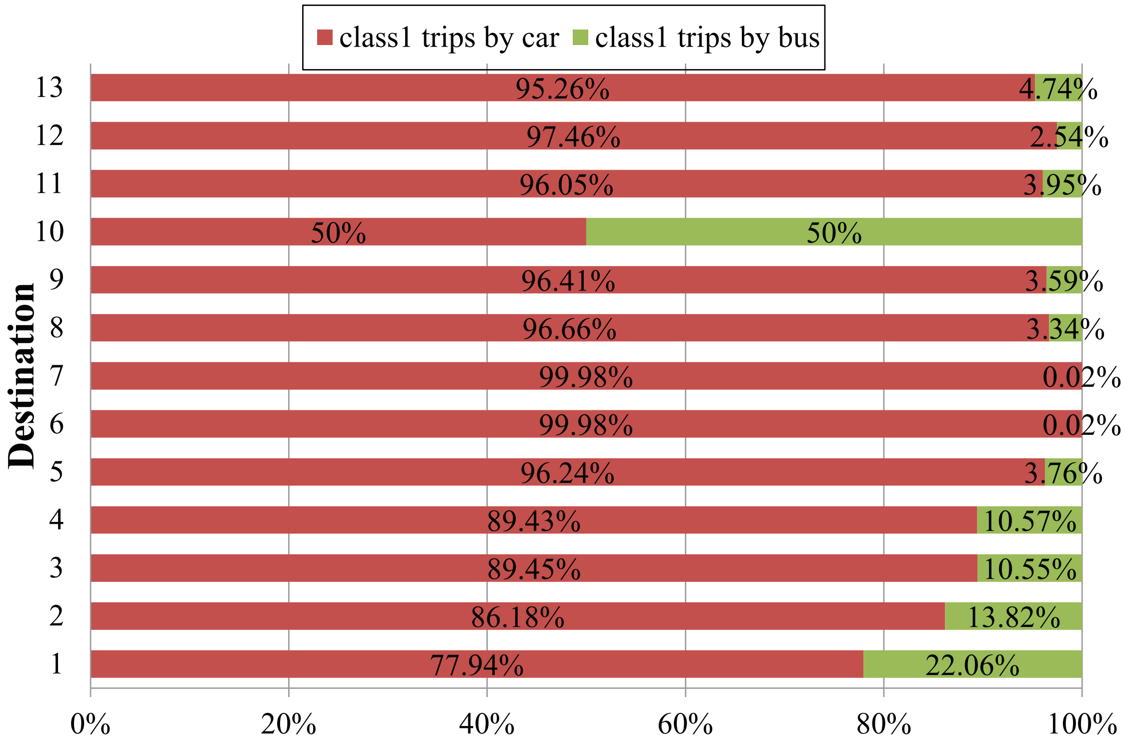


Figure 7.18Probability of Traffic Mode Choice of Class1 in Case 10
(From origin 10)

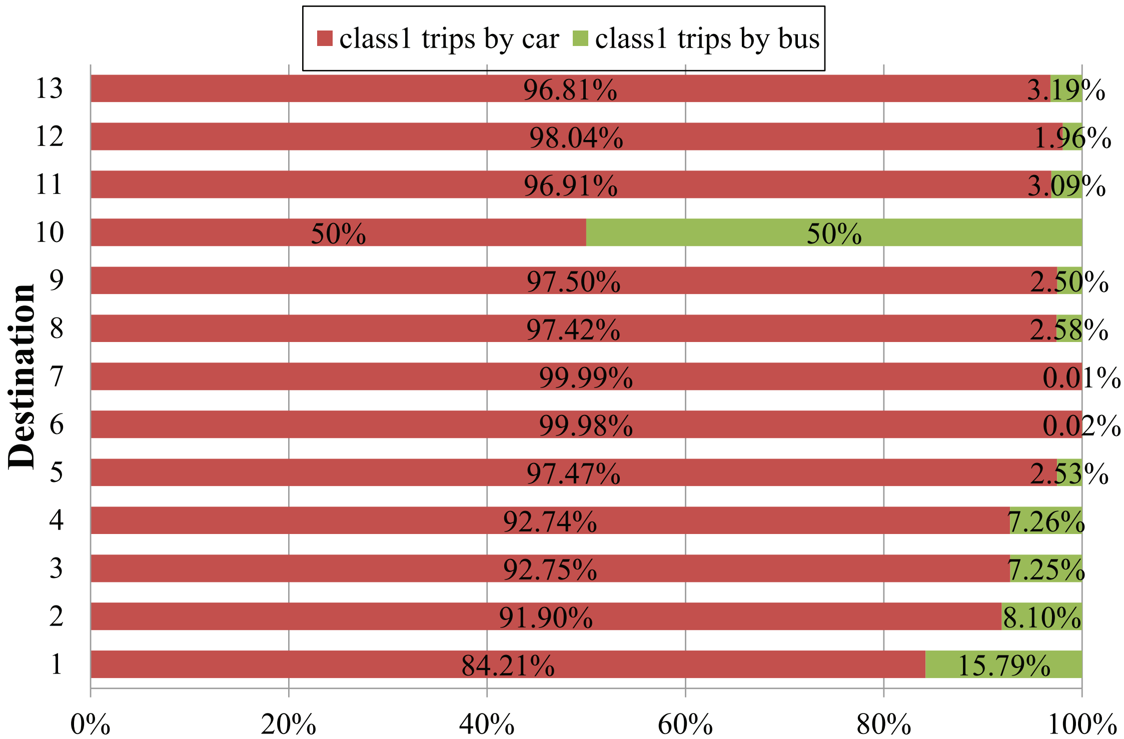


Figure 7.19Probability of Traffic Mode Choice of Class1 in Case 01
(From origin 10)

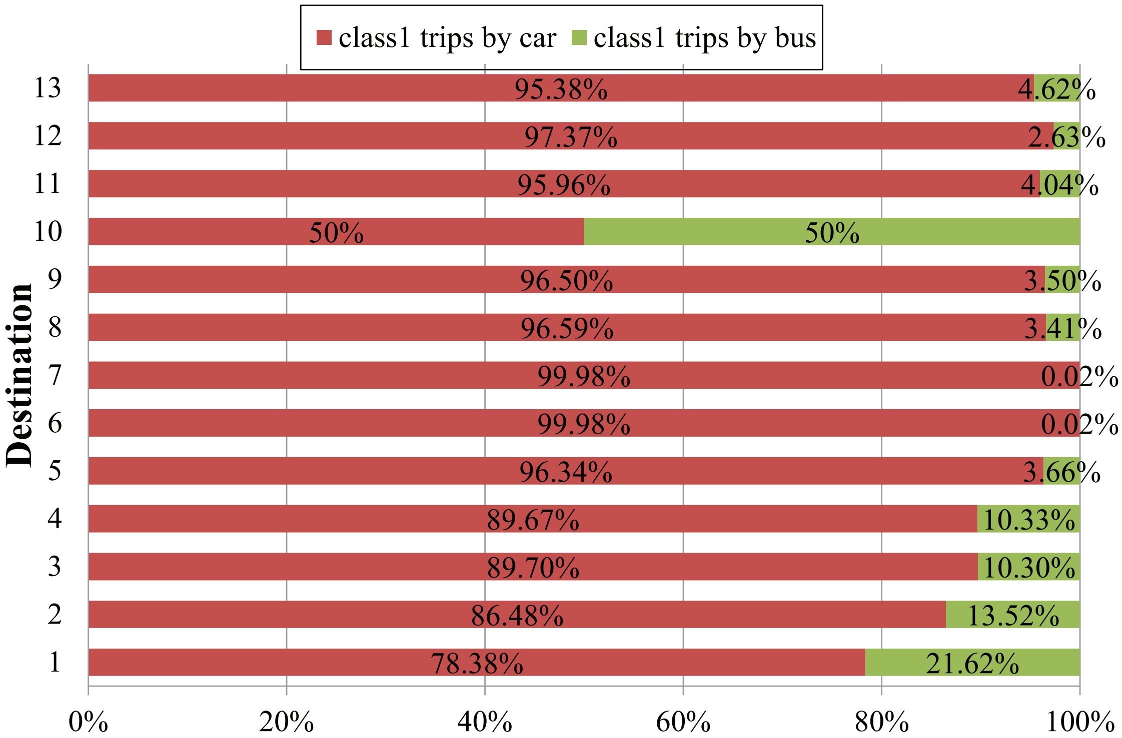


Figure 7.20Probability of Traffic Mode Choice of Class1 in Case 11
(From origin 10)

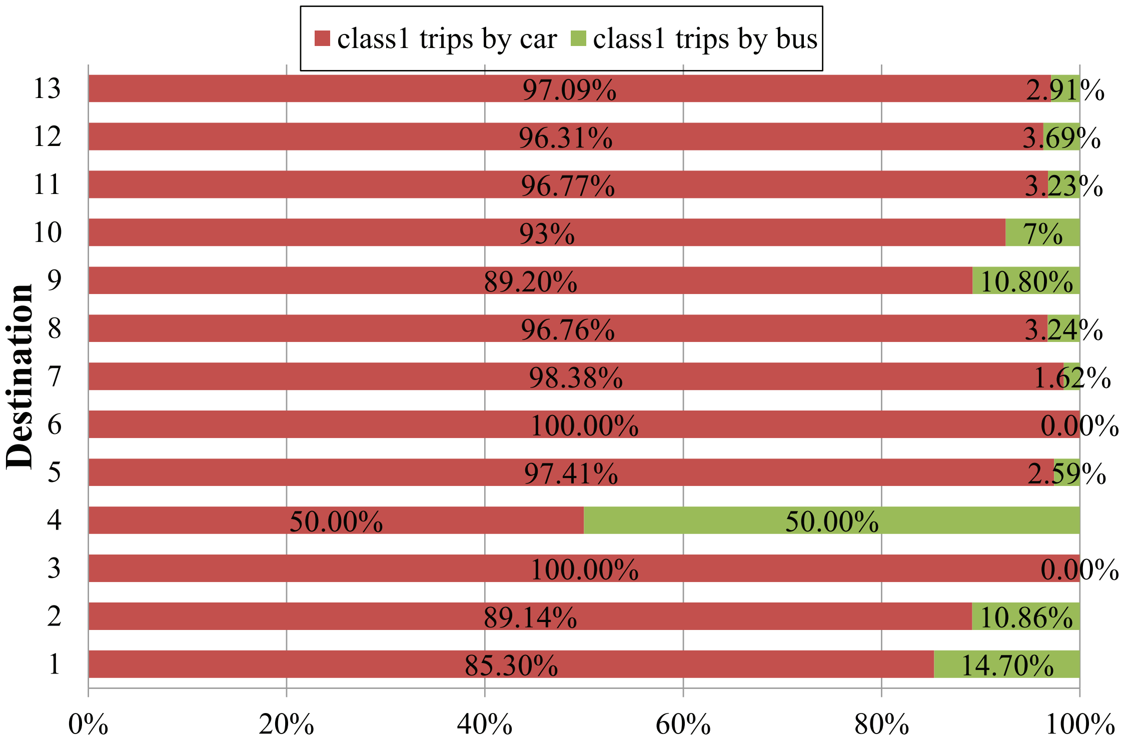


Figure 7.21Probability of Traffic Mode Choice of Class1 in Case 00
(From origin 4)

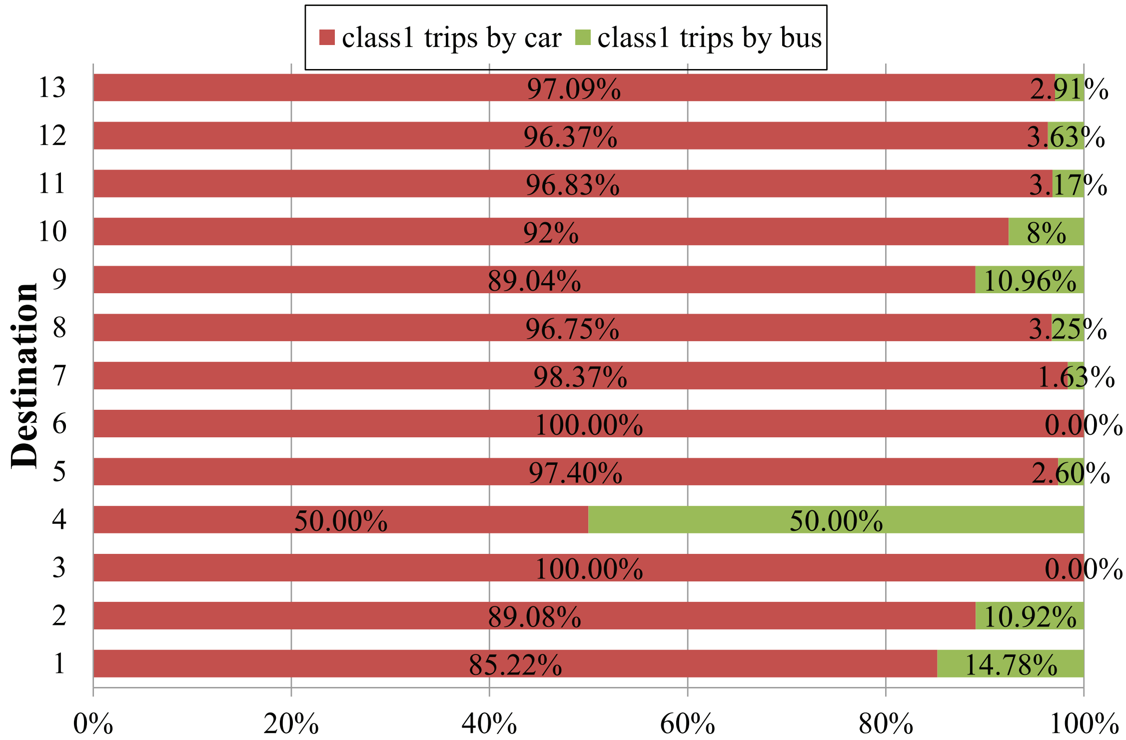


Figure 7.22Probability of Traffic Mode Choice of Class1 in Case 10 (From origin 4)

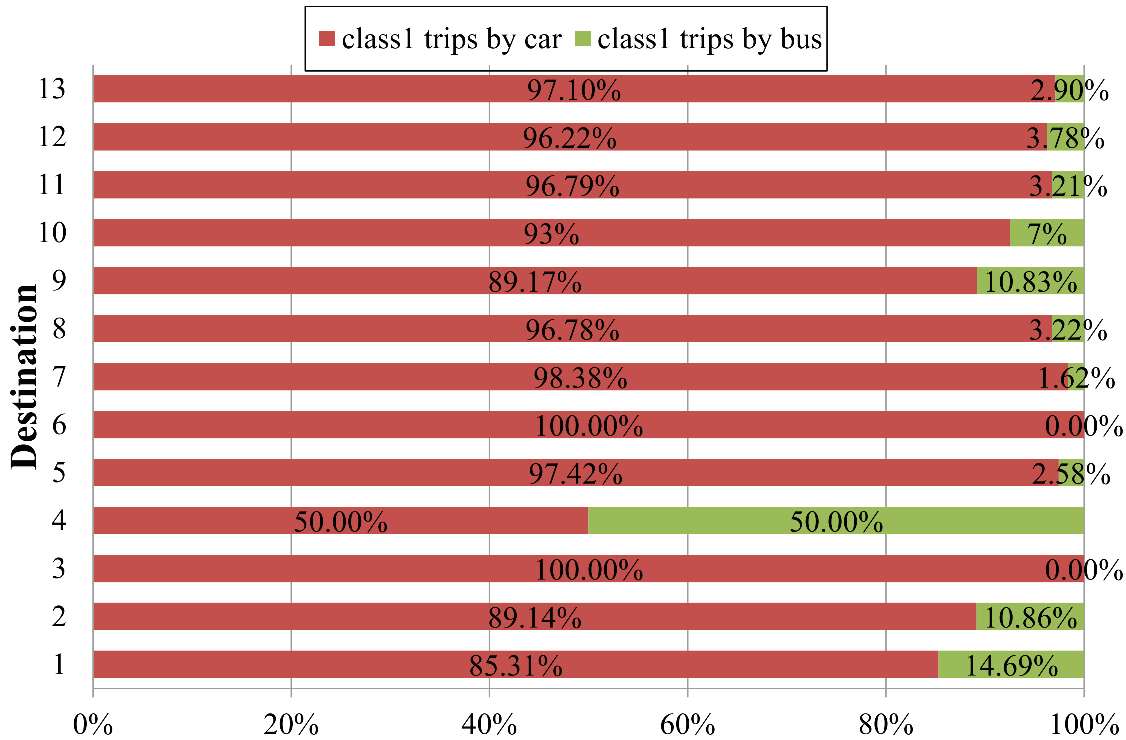


Figure 7.23Probability of Traffic Mode Choice of Class1 in Case 01 (From origin 4)

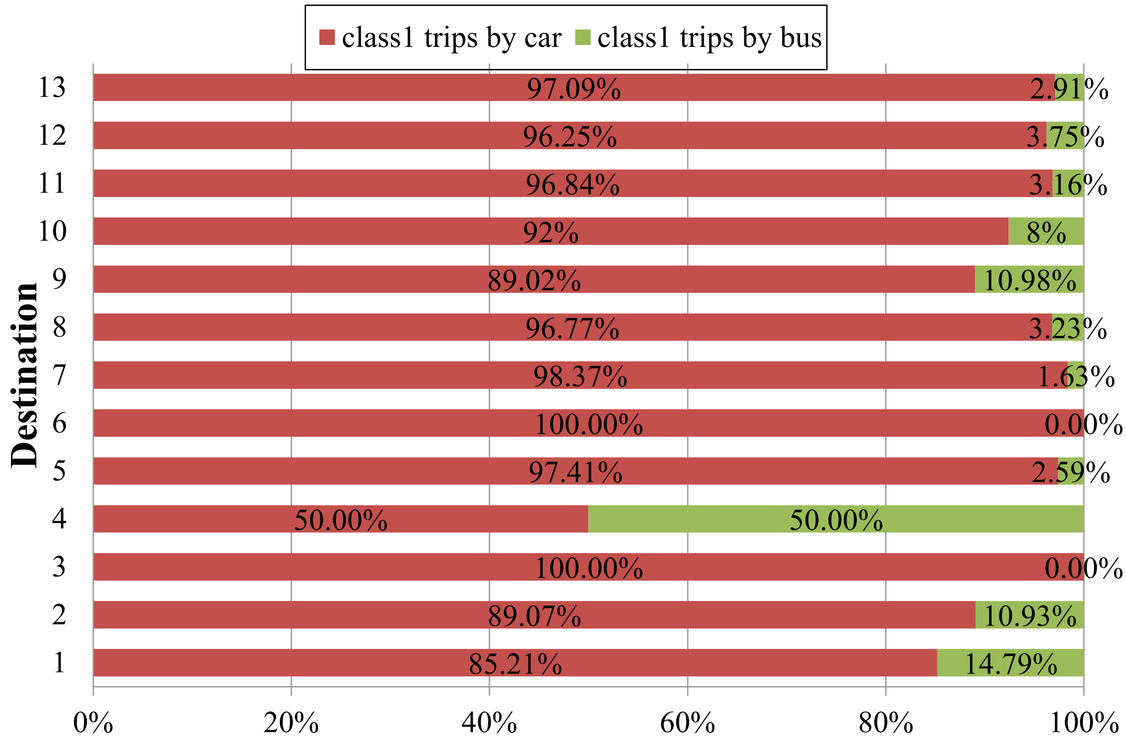


Figure 7.24Probability of Traffic Mode Choice of Class1 in Case 11
(From origin 4)

7.4.5 Comparison of Destination Choice

Finally, we make a comparison of destination choice.Figuresfrom 7.25 to 7.28 show the destination choice probability of each traffic mode from origin centroid 9for each traffic mode and class. Inthe case 00 (Figure 7.29), traffic concentratedto the centroid 1. However, traffic by bus concentrate more to CBD in class2 compared to class1. The reason could be that bus network running through CBD which made movement of the other OD pair a disadvantage. Furthermore, travel distance by bus from the origin centroid 9 is long; as a result, ratio of internal traffic is dominant than those of the other centroids. In the case 10 (Figure 7.30), destination choice probability to centroid 1 is further more for class 1 by bus and class2. BRT made it more convenientto travel by public transport. In the case 01(Figure 7.31), destination choice probabilities to the centroids 1 and 2 increased a lot by the policy of reactivation of CBD. In the case 11 (Figure 7.32), destination choice probability to the centroids 1 and 2 ismuch higher than other cases especially by using public transport in class1 and class2. Concerning the movement from the origin centroid 9, the introduction of BRT improved a convenience of public transport greatly. The traffic designated to CBD increased more than the other cases.Synergy effect of CBD reactivation and BRT implementationdecelerate suburbanization and motorization in the city.

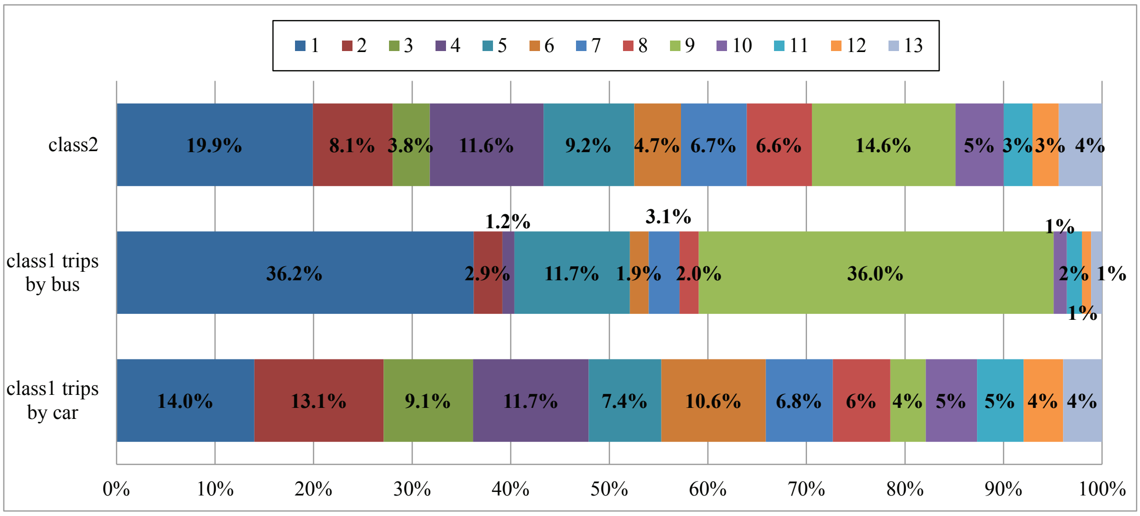


Figure 7.25Probability of Destination Choice Each Traffic Mode in Case 00 (From origin 9)

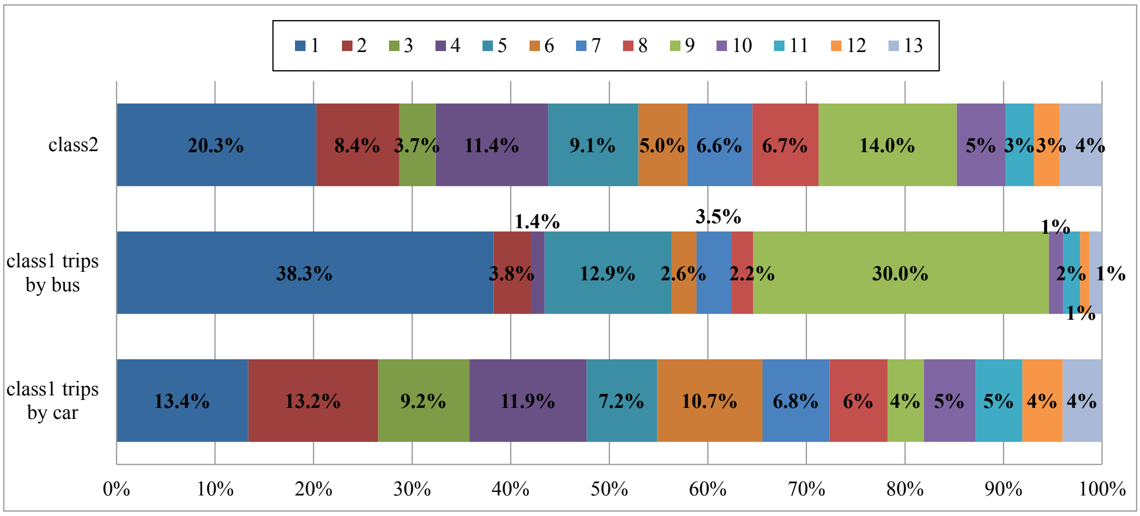


Figure 7.26Probability of Destination Choice Each Traffic Mode in Case 10 (From origin 9)

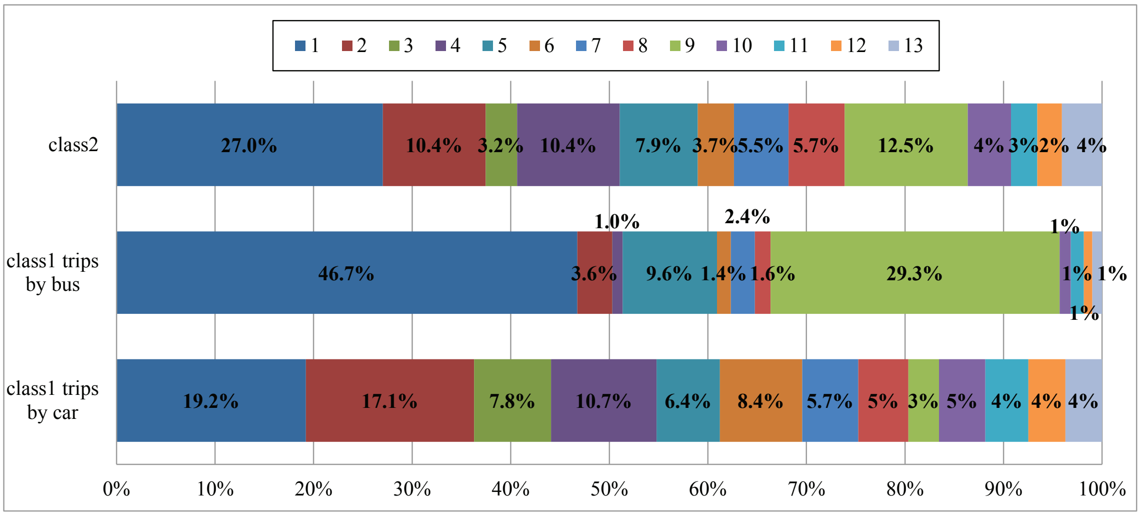


Figure 7.27Probability of Destination Choice Each Traffic Mode in Case 01 (From origin 9)

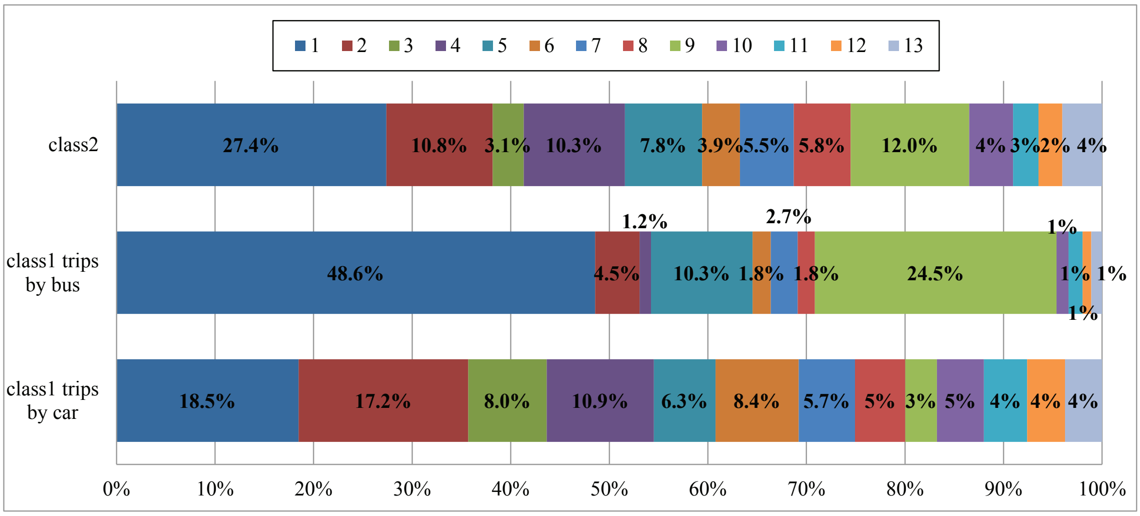


Figure 7.28Probability of Destination Choice Each Traffic Mode in Case 11 (From origin 9)

7.5 Summary

In this chapter, we used Gifu City transport network and land use data to demonstrate the impact of public services and land use policiesby applying the proposed model. As analyzedin chapters 4 and chapter 5, Gifu City is plagued by the issue of suburbanization and motorization. With calibrated parameters for public transport cost and land use attractiveness by real statistics data, we increased the reality of analysis. Based on that, we assumed transport service measure and land use policy on the base case and evaluated their effects. In concrete, introduction of BRT service as transport measure and reactivation of CBD as land use policy are selected. By the analysis of travel mode as well as destination choice behavior, it is confirmed that the synergy effect of two schemes could decelerate the situation of suburbanization and motorization in Gifu City.As the result, the proposed model can calculate the total movement in real network.

REFERENCES

Gifu City, Gifu City Integrated Transportation Strategy (2014-2018), http://www.city.gifu.lg.jp/18821.htm, Accessed April 1st 2014.

Road Traffic Census Data (2005), Gifu Prefecture.

Gifu City Statistics Analysis Department (2001), Statistics Book of Gifu City: Gifu City.

CHAPTER 8

Conclusions and Remarks

8.1 Conclusions

After summarizing the lessons of past urban planning and transport planning and their relevance in Gifu City by looking at planning and policy in the past 40 years using historical maps, population census and socioeconomic statistics data, we gathered the following conditions:

(a) The demand for urban transportation grew as the city population and economy grew. There is a predictable public voice for more transportation facilities in urban areas.As described above, we know that the changesin the Gifu City transportation system had animportant impact on urban planning.

(b) With high economic growth, the motorization of Gifu City increased continuously, creating a demand for road-network construction. The ring road completed these demands and created the city framework. It also changed land use by industries, commerce, and agriculture. Industrial and commercial land use moved from the downtown to the area along the ring road.

(c) Furthermore, the public argued that the tram impeded car traffic, which forced the local governmentto give it up. This changed the public transportation system and exacerbated car traffic. A life style revolving around the automobile affects urban planning in a car-oriented city.

From the analysis of the transport and land use of Gifu City, the strong relationship among them has been confirmed, and especially Gifu City shifted to a more car-oriented city.

This study presented an integrated traffic assignment model which encloses the transportation mode choice and destination choice. We tested the model both on an assimilation and Gifu City network, and evaluated the change of destination as well as mode choice when land use or transport service policy is changed. By considering the delay of buses caused car traffic congestion, the model expressedbus travel time in road network space more precisely. Based on this integrated model, not only transport measures, land use policy like activation of Central Business Districts can also be evaluated. Moreover, since all of choice behavior is formulated as a LOGIT type, a consumer surplus can be calculated by obtaining log-sum variables,and this feature enables us to connect this model to cost benefit analysis. Through the analysis, constructing suburban shopping centers raised probability of car use, even though the traffic congestion may get worse around suburban area. On the other hand, increasing theattractiveness of CBD areas and introduction of Bus Rapid Transport system can contribute to improving the traffic situation for the whole city. In conclusion, the developed model can properly express the interaction between transport and land use and thus the effect of varieties of transport as well as land use policies to enhance sustainability of the cities can be evaluated using this model. Such model can be a strong tool for developing countries to develop towards environmentally friendly cities and avoid excessive motorization.

8.2 Future Work

As described above, there is limitation in the proposed integrated traffic assignment model which encloses the transportation mode choice and destination choice. First, in this case study, the relation of cost by increasedregional attractiveness and effect has not been calculated with certainty. This challenge will be left for further studies. Second, the proposed model in this study evaluated the impact of transport system and land use change, but did not considerhousehold behaviour and firm behaviour which could evaluate land use market of the whole city.