# A Study on Factor Decomposition for $CO_2$ Emission Generation and its Causal Mechanisms in Urban Transport —A Comparison between Shanghai and Tokyo—

# (都市交通における $CO_2$ 排出の原因要素分解と因果メカニズムに関する研究 —上海と東京の比較—)

LUO, Xiao

（駱　暁）

# Summary


As the biggest developing country, China has experienced quick economic development since the policy of “Open and Revolution”, the GDP increase rate in China kept for higher than 8% averagely, and China is now the second biggest economic body in the world. The quickly developing economy stimulates the travel demand of people, especially in mega cities, the traffic demand of people increased in a very high speed. Moreover, more and more family has the ability to own a car, the quick increased in car ownership and car use has caused lots of problems in cites, the government has burden high pressure on traffic congestion, high investment of infrastructure, the environmental degradation and global warming that caused by $CO_2$ emission increase. Hence, to provide a sustainable transport system that emitter less $CO_2$ and reduce the financial cost and environmental load of the passenger transport system became a very important issue.

The objective of this research is: (1) take Shanghai and Tokyo as case cities, find out the crucial factors that affect passenger transport system; (2) find the relationship between these factors and conclude the good experience both in Tokyo and Shanghai; (3) based on the experience and the investigation in Shanghai and Tokyo, design a series of policies that based on a policy framework called CUTE matrix, and examine the performance of different scenarios, give proper policy suggestion for the future development of passenger transport system for mega cities.

The paper is organized as follows:

Chapter 1 introduces the background of this research. It shows that there is big presser on developing cites, to have a whole insight of the transport system to solve current problem is very important. In different cities, there are different causes for the increase of the environmental burden. Therefore, to investigate different causes in different cities would be very important and the developing cities can provide good experience to the developing cities, to find out the correct direction of development.

Chapter 2 reviewed the methodology of decomposition and the practice of decomposition in transport sector all over the world, after that, the individual policy practice and integrated framework and case studies aiming at low carbon transport are reviewed. Firstly, the decomposition is reviewed and finds that the LMDI (Log Mean Divisia Index method) is the best decomposition method for this study, and this method was seldom used for comparing different urban passenger transport sector $CO_2$ emission, hence this research can fill the gap. Then, the individual integrated transport policy aiming at low carbon transport are reviewed, the case study of low carbon transport policy is also reviewed. And the author finds that there are less researches focus on the integrated low carbon transport policy framework in Asian developing cities, this research will also fill this gap.

Chapter 3 examined the historical tendency and policy changes of population, economic growth, land use change and transport system development of Shanghai and Tokyo. The author finds that: Shanghai is now in the stage of high speed of suburbanization, the population in Shanghai will constantly increase and traffic demand and transport infrastructure will also increase very quickly in the next 10 years. Shanghai now has big potential to change its land use system and transport system to a more sustainable way.

Chapter 4 carries a decomposition analysis in Shanghai's passenger transport system, population, trip generation rate, mode shift, travel distance, load effect show strong effect on the $CO_2$ emission increase. From 1986 to 1995, mode shift effect shows the strongest positive effect, contribute to 73% of the total change. From 1995 to 2004, mode shift also shows the strongest positive effect, it contribute 56% of the total change, trip generation rate and population contribute 15% and 19% to the total change respectively. From 2004 to 2009, mode shift also shows the strongest positive effect, it contribute 52% of the total change, trip generation rate and population contribute 14% and 18% to the total change respectively. While the fuel efficiency constantly contribute negative to the $CO_2$ emission, the contribution in the period of 1986 to 1995, 1995 to 2004, 2004 to 2009 are respectively -0.1%, -3% and -6%. The same decomposition analysis has also been made in Tokyo transport system. From 1968 to 1978, population, trip rate and mode shift contribute positive to the $CO_2$ emission increase, travel distance contribute negative to the $CO_2$ emission. From 1978 to 1988, the population, mode shift, travel distance contribute positive effect, while the trip generation rate, load effect and the fuel efficiency contribute negatively. From 1988 to 1998, population, mode shift, travel distance and fuel efficiency contribute positively, only the load effect shows negatively effect. From 1998 to 2008, only population and trip rate effect shows positive effect, mode shift, travel distance and fuel efficiency shows the strong negative effects. Totally, population constantly shows positive effect, mode shift and fuel efficiency is very sensitive factor to the $CO_2$ emission change. The causality map was also made based on the decomposition analysis.

Chapter 5 examines a series policy package to achieve low carbon transport system. CUTE MATRIX is used to design the policy package. From the performance of the different scenarios, we find that: TOD development contribute a lot to the control of travel distance and mode shift to railway. Strict car parking policy on car and high usage fee of car, together with the high service level of rail make the car use manner in a very eco-friendly way, namely shorter travel distance and less use ratio. And the recent policy on redevelop the railway station make the population increased 1.88 million around railway stations in Tokyo, which also contribute to the mode shift to railway. The fuel efficiency change contributes a lot to improvement, the main reason is the improvement of the engine technology and tax policy changed to preference of the low emission cars.

Finally, chapter 6 concludes the main findings and the contribution of this research, and looks forward to the future possible works.

# CONTENTS

# Chapter 1 Introduction

## 1.1 Background

Our world is now more and more affected by the threats of natural environment that caused by climate change, such as big storms, floods and the heat waves. To handle with these problems, many countries set targets to reduce environmental emissions. One of the key strategies is to make cities more low carbon and more sustainable on an urban scale.

Transport sector is biggest and the quickest increasing department that consuming oil, it's also the quickest $CO_2$ increasing department. Based on the research of IEA[1], by the year of 2009, the oil consumption of transport department all over the world occupied 61.7%, the total amount achieve 2.14 billion-t. In the year of 2009, $CO_2$ emission of transport sector is 6.54 billion-t, it occupy 23% of $CO_2$ emission of all the energy source $CO_2$ emission, it is the second biggest department just after electricity and warm supplying. From 1970 to 2008, the $CO_2$ emission increase 136%, both in developed and developing countries, the transport sector $CO_2$ emission is increasing, the biggest contributor is road sector. In the year of 2009, road transport sector contribute 4.88 billion-t $CO_2$, it occupy 74.5% $CO_2$ emission. In the scenario of IEA, by 2020, transport sector $CO_2$ emission all over the world will be 7.2 billion-t. In the year of 2035, it will decrease to 6.9 billion-t. The research of IEA shows that, the potential of $CO_2$ emission in transport sector will be higher and higher, and then to be the biggest contributor of $CO_2$ emission, the ratio of transport sector will be 37% in the year of 2050(IEA)[2].Just as described by Dargay[3], Haddock and Jullens[4], in 2006, China surpass America and then became the world's biggest $CO_2$ emitter. After three years, China became the world's biggest new car market, while China was only regarded to have just achieved the income level of growth acceleration of car ownership.

At present, China is the biggest emitter of $CO_2$ emission in the world, so it is facing high pressure of $CO_2$ mitigation. In 2009, Chinese government declared that China would reduce its $CO_2$ emission intensity by 40% to 45% by the year of 2020.As described by Annual review of Low-carbon development in China (2010)[5], the transport sector $CO_2$ emission in China increased by 8.6% annually, it reached 630 million-ton in 2008, and increased 93.2% compared with the energy consumption in 2000. The energy consumption in 2000 is 147 Mtec, and in 2008 is 288 Mtec, China is facing big pressure in energy saving and $CO_2$ mitigation pressure in the future.

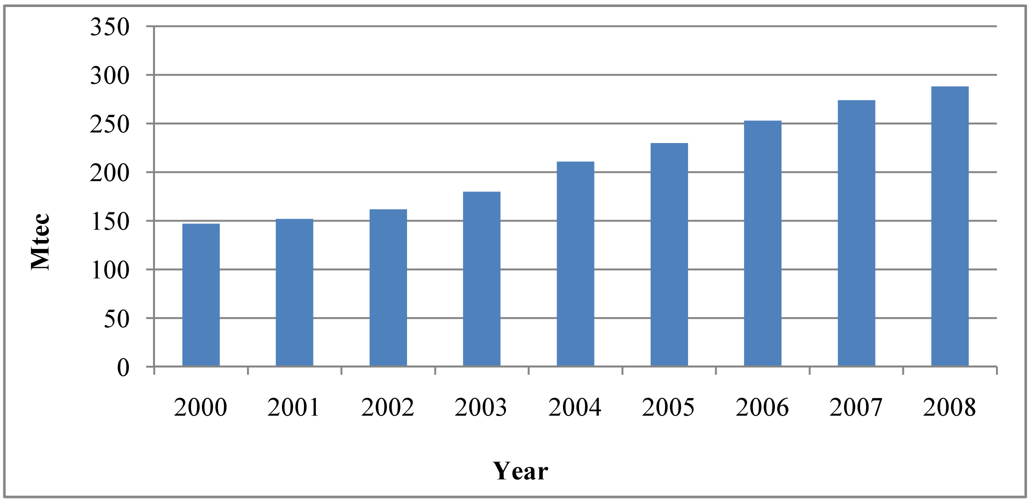



Fig 1.1 China transport sector energy consumption

(Source: Annual review of Low-carbon development in China[5])

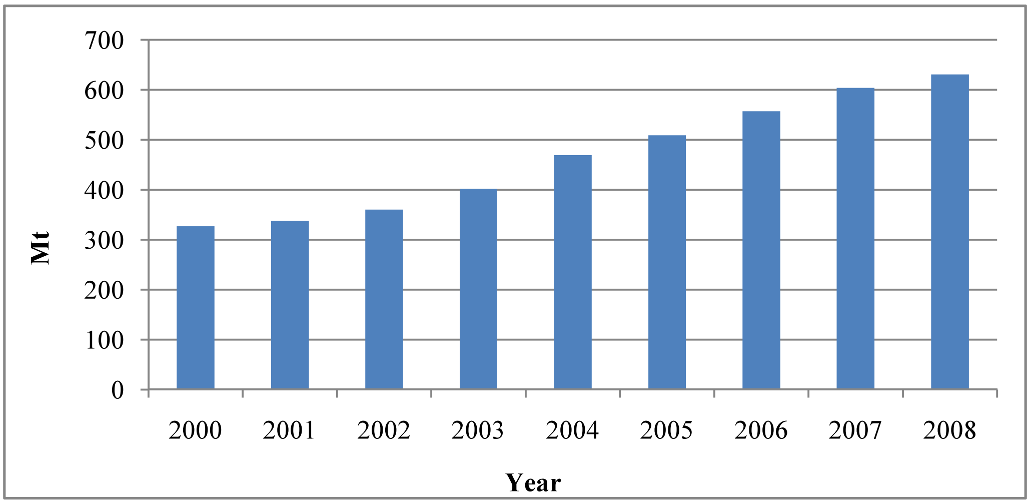



Fig 1.2 China transport sector $CO_2$ emission

(Source: Annual review of Low-carbon development in China[5])

Most of the transport activities happen in urban because of high developed economy and the quickly increased service and the according demand on transport. Now, in China, urbanization is now progressing quickly, more and more people rush into cities for better chance for work and higher quality of life. One of their key strategies is to make cities low-carbonized and more sustainable on an urban scale. In low-carbon cities, transport systems are expected to play key roles. Therefore, the development for transport was previously more and more focusing on minimizing travel time, but it's now pay more attention on the environmental and social cost to improve sustainability with the certain financial budgets (Banister, 2008)[6].

Especially, in mega cities, because of the population movement and the development of economy, the trend of motorization is increasing quickly, especially in Asian developing cities, they are facing a conflict of increasing travel demand and limiting transport supply and that caused a serious problem, such as traffic congestion, increasing traffic related injured and increasing transported related air pollution such as PM 2.5 and transport energy consumption. And the experience form developed cities can give some lessons to developing cites, the experience (both good and bad) of developed cities should be concluded and let the developing cities can achieve a leap-frog with the early policy making.

Concern should be paid to how to make people use the transport system more efficient and use less energy and emit less $CO_2$. The problem that the city meets can be described as Fig1.3.

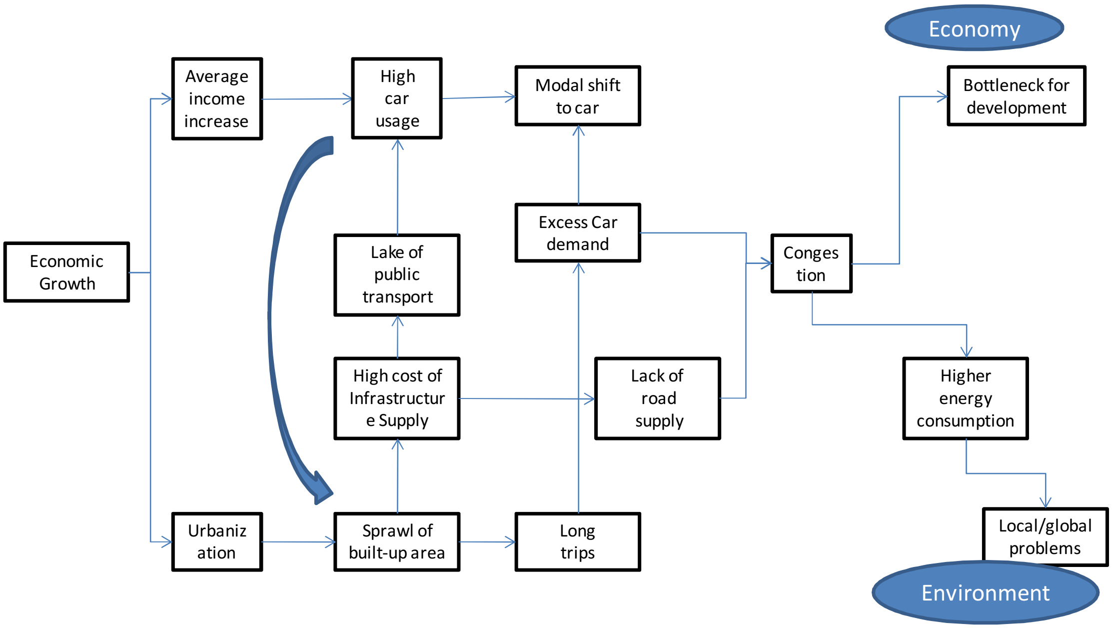



Fig 1.3 Problem in developing mega cities

(Source: Hayashi[7], 1996)

Just as Hayashi[7] described, the relationship between transport and environment are extremely complicated. There is no doubt that the effort of drawing overall picture to use policies to deal with the transport related environment issues is better than the effort to use the individual policy initiatives.

Hence, firstly to find out the relationship between the urban transport sector $CO_2$ emission and corresponding factors and the relation between these factors is important, and secondly to design systematically organized policy initiatives for more efficient and environmental friendly transport system is necessary.

## 1.2 Motivation

Shanghai is a developing mega city, it's facing great conflict of traffic demand and traffic supply. While Tokyo is a developed city, it has experienced high speed economic development and socio-economic change from 1950s to 1980s, in the developing stages, Tokyo also experience the similar conflict of traffic demand and traffic supply, but Tokyo has successfully overcome the dilemma, Tokyo is now famous for its public transport system, especially its railway system. Hence, it is necessary to find out the deeper reason of the experience of Tokyo, and find useful policies in Tokyo and combine these experience with the local situation of Shanghai to find a proper policy system make the transport system more sustainable in Shanghai.

In this research, the total transport activities are taken as integration. As show in Fig 1.4. The transport activities can be divided into 3 parts: (1) Trip generation, it is affected by the urban area, concentration of urban activity and trip rate. The related policy AVOID, it includes TOD development, job-housing unbalancing, control of sprawl, tele-working and so on. (2) Mode shift, it is affected by the car ownership, access to public transport, access to road. The related policy is SHIFT, it includes: improvement of bus/rail system, encourage of bicycle, ITS, parking regulation, integrated transport system. (3) Improve fuel efficiency, it is affected by average engine technology level of car fleets, car occupancy rate and so on. The related policy is IMPROVE, it includes, encourage e-cars, use renewable energy, regulate emission standard, introduce fuel tax, and subsidy for LEVs.

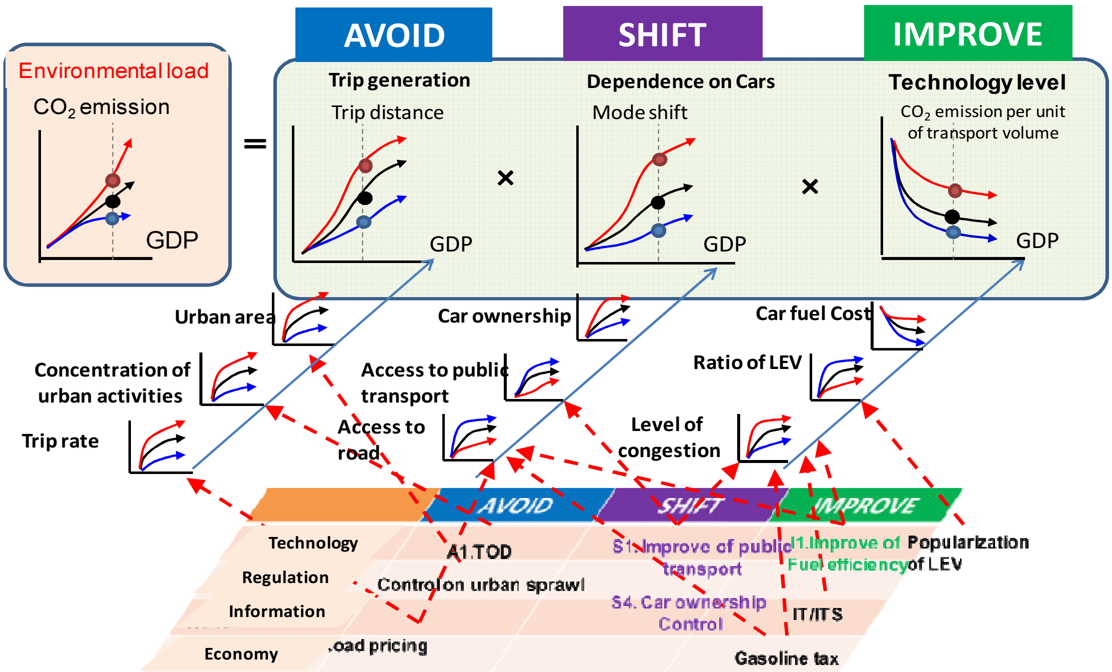



Fig 1.4 Dynamic tracking of transport related emission mechanism

(Source: Professor Hayashi's Lecture)

## 1.3 Objectives

Research has been concentrated on advance in different individual areas of analysis such as vehicle ownership, travel behavior, traffic demand management, energy consumption, environmental tax, urban planning regulation and so on.[7] But he research on the contribution of factors and inter-factor mechanism and the relationship between policies has not yet been done, especially in developing mega cities. What's more, the effect of systematically organized policies to future transport system has not been done. Hence, this paper tries to fill the gap in the research.

The main objective of this research is to find the factors that affect urban transport $CO_2$ emission and find the inter-factor mechanisms between factors. And base on that, by applying the policy generation system, name CUTE matrix (Hayashi, 2004), design a policy package to achieve the target of low carbon and high efficient transport.

The main factors of this paper are as follows:

(1) Identify the contributions of factors that affecting $CO_2$ emissions in urban passenger transport.

(2) Find the causality of urban transport $CO_2$ emission, find inter-factor mechanisms.

(3) Design different scenario to analysis the future development of Cities on 3 levels: (a) Transport demand: population allocation, land use; (b) Modal shift: which kinds of transport that people use; (c) Efficiency improvement: improve each kind's of transport mode.

(4) Based on (1), (2) and (3), build a model to asset how different transport policy package affect urban passenger transport environmental impact.

(5)Take mega city- shanghai as an example, proposal a design of policy for low-carbon transport system in different development scenario.

Originality is:

(1) Find the causality of urban transport $CO_2$ emission, find inter-factor mechanisms in Asian cities.

(2) Design a policy framework to achieve urban transport $CO_2$ mitigation target.

## 1.4 Dissertation Structure

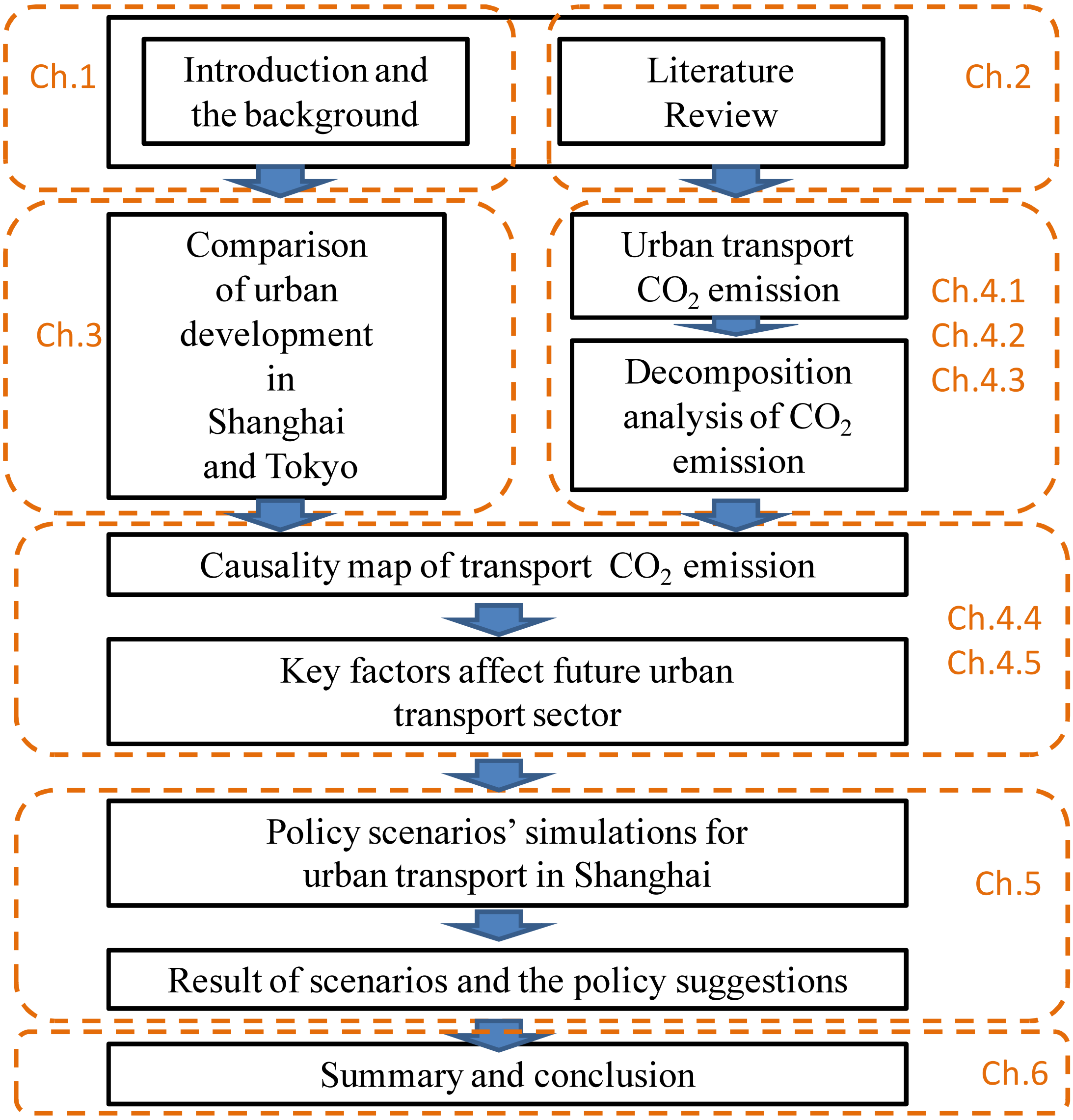



Fig1.5 Dissertation Structure

This dissertation is organized as follows: Chapter 1 gives the introduction, illustrate the reason and the meaning of the research, gives the objective and the goal of this dissertation. Chapter 2 is focus on the review of the related research.

Chapter 3 described the urban development and urban transport $CO_2$ in Shanghai and Tokyo, and then calculated the $CO_2$ emission in Shanghai and Tokyo.

Chapter 4 give a decomposition analysis of Shanghai and Tokyo passenger transport $CO_2$ emission, shows the contribution of the factors to the passenger transport $CO_2$ emission. The contribution of the factors can be divided into 3 levels: AVOID, SHIFT and IMPROVE. The results show the contribution of each factor. After the decomposition, the factors that affect the contributor and the relation between them are checked and the characteristic of Shanghai and Tokyo are obtained. The inter-factor mechanisms are also examined, the key factors that affect $CO_2$ emission are picked out. Based on these works, the causality maps that describe the transport system behavior in Shanghai and Tokyo are obtained.

Chapter 5 describes the methodology of modeling the transport related policies. The transport policies can be divided into 3 stages: AVOID, SHIFT and IMPROVE. Based on the analysis on Chapter 4, policy aiming to solve the problem that Shanghai faced and the good practice that Tokyo done are combined, how these transport policy affect the final traffic allocation in the future is modeled in the model and the $CO_2$ emission and the related infrastructure construction cost is also estimated in the model. Taking Shanghai as the case study city, based on the key factor that affect $CO_2$ emission found in Chapter 4, different scenario is designed in this chapter. The policy package and measures are classified into 2 axes: "strategies" and "Instrument", according to ASIF is modeled in 3 steps: Avoid, shift, and improve[32]: 1) Reducing unnecessary travel demand (AVIOD); 2) Shifting travel to lower-carbon modes (SHIFT); 3) improving intensity of transport-oriented emission (IMPROVE). In the CUTE matrix, each instruments is further classified into (a)technology; (b)regulation; (c)information; (d)economy. Based on scenarios' result, we suggest proper policies for future transport development in Shanghai.

Chapter 6 draws conclusions on the major findings and contribution to literature and practices, and gives the prospect for future studies.

# Chapter 2 Literature Review and Positioning of the Research

This chapter firstly introduces the decomposition method, and then reviews the decomposition method used in transport sector. After that, the integrated low carbon transport policies and some of the case studies are examined. Furthermore, the individual transport policy on avoiding transport demand, shifting to eco-friendly and improving transport efficiency is examined individually. At last, the gap in these studies has been pointed out and proposes the effort of this research.

## 2.1 Review on decomposition analysis

### 2.1.1 Method of decomposition

The index decomposition method was firstly used to solve some economic problem, such as how the change in the production and of goods affects the enterprise sales. Form 1970s, the oil crisis made developed countries stated to research on the energy consumption, the researchers tried to researched the inner mechanism, in another word, how the industry structure affect the total energy consumption, then the decomposition method is generally used in the energy related research.(AngBW[8]., 1995)

The basic thought of index decomposition method is to decompose one aim variable into the combination of many factors, and then judge how much each factor affect the result, namely the contribution rate. In terms of the data availability, we decomposed the factors, and differentiate the contribution rate of each factor. Till now, there are many decomposition methods, the Laspcyres and Divisia decomposition method are the mostly commonly used method. In the developing of these methods, Sun(1998)[9]provided fully Laspeyres decomposition method, Ang(1997, 1999)[10,11] amply described the LMDI method (Log Mean Divisia Index method), this method efficiently solve the problem of redundancy, Ang(1997, 1998) suggested to use a very small positive number to alternative the "0" value, he also researched the negative number problem in Divisia decomposition, it makes the Divisia decomposition method can be used for every situation.

In the applying the decomposition method, the LMDI (Log Mean Divisia Index method) is used mostly, because they do not have redundancy. Hereafter, generally introduction of LMDI decomposition method:

The Y can be the sum of many sectors, namely $Y=\sum_{i=1}^{m} Y_i$, and if $V_i$ can be expressed as

$$Y_i = x_{1i} \times x_{2i} \times .... \times x_{ni} \tag{2-1}$$

$$Y^0 = \sum_{i=1}^{m} x_{1i}^0 \times x_{2i}^0 \times ... x_{ni}^0 \tag{2-2}$$

$$Y^t = \sum_{i=1}^{m} x_{1i}^t \times x_{2i}^t \times ... x_{ni}^t \tag{2-3}$$

$$D_{tot} = \frac{Y^t}{Y^0} = D_{x1} \times D_{x2} \times ... \times D_{xn} \tag{2-4}$$

If we decomposed it as additive LMDI,

$$\Delta Y_{tot} = Y^t - Y^0 = \Delta Y_{x1} + \Delta Y_{x1} + ... + \Delta Y_{xn} \tag{2-5}$$

The subscript "tot" stand for total changes, and the $D_{xk}$ can be expressed as

$$D_{xk}=\exp(\sum_{i=1}^{m}\frac{L(Y_i^t,Y_i^0)}{L(Y^t,Y^0)}Ln(\frac{x_{ki}^t}{x_{ki}^0})) \qquad (2\text{-}6)$$

$$\Delta Y_{xk}=\sum_{i=1}^{m}L(Y_i^t,Y_i^0)Ln(\frac{x_{ki}^t}{x_{ki}^0}) \qquad (2\text{-}7)$$

Where, $L(a,b)=(a-b)/(Lna-Lnb)$ (2-8)

Nowadays, the decomposition is more and more used in transport related energy consumption research, the related research is shown in the following sections.

Decomposition analysis is wildly use in the analysis of energy uses. In literatures, two decomposition tools, SDA and IDA were broadly used to obtain the driving factors. The former is on the basis of I-O model, while the latter carry the index number concept in decomposition. Lots methods of index decomposition analysis are compared, the result indicate that the LMDI was better, that's because of it has a very good theoretical bases, flexibility and easy to be explained.

In the 1970s, this method was employed to research the influence of transform on energy consumption in different industries. Around 200 papers have done many works on the area, among these researchs, five main applications are conclude as follows: (1) the supply and demand of energy part; (2) energy related emissions; (3) material flow setting; (4) national energy efficiency measurement; (5) compare between nation and regions. In the 1980s, most scholars adapts methods related with the Laspeyres index. The Divisia index method started only in the early 1990s. From the 1995 to 2005, the related researches adapted the 2 methods were equal in number.

LMDI method consists of two kinds, one of which is additive LMDI method and the other is multiplicative LMDI method. Essentially, these two methods are similar.

However, the results of additive LMDI method can be compared with each other more conveniently, because they are absolute values. However, the results of multiplicative LMDI result are relative values so that they can hardly be compared in different cases. What's more, to capture annual changes of factors from 2001 to 2010, additive LMDI can be used to provide more meaningful result for comparison.

In the transport sector, a few studies regarding examining factors that affect emissions growth have been conducted over the past few years. Generally, those studies can be classified into types: one is international comparative study, the other is national-wide study. Jiyong Eoma[15] and Lee Schipper decompose the passenger transport of South Korean between 1986 to 2007 into transport activity, modal structure, energy intensity; Marı´a Mendiluce and Lee Schipper[18] take the passenger and freight transport sector energy consumption in Spain from 1990 to 2008 as example, decompose the factors into traffic volume, energy intensity, carbon intensity and structure; Tae-Hyeong Kwon[19] used LMDI method researched the car travel in UK, they decompose the factor into population, vehicle trip distance, occupancy rate, fuel efficiency and fuel structure; Katerina Papagiannakiand Danae Diakoulaki[24] take passenger cars in Greece and Denmark as example, decompose the factors into car ownership, energy mix, travel distance, engine capability, engine technology. Scholl, Schipper and Kiang[20] compared the $CO_2$ emissions growth of passenger transport in some OECD countries between 1973 and 1992 from activity, modal shift and energy related intensity perspectives; Lu, Lin, Sue and Lewis[23] researched the changes in highway vehicles $CO_2$ emissions in Japan, Germany, South Korea and Taiwan between 1990 and 2002, they decomposed the factors into emission ratio, fuel intensity, car ownership, population coefficient and economic growth; Govinda[17] uses LMDI method analysis $CO_2$ emissions in the whole transport sectors in different Asian countries and found different driving forces of $CO_2$ emissions in these countries. Lakshmanan and Han disassembled the change in transport sector $CO_2$ emissions in the US between 1970 and 1991, and found that the growths in people's willing to travel, population increase and GDP increase were the important driving forces; Zhang, Li[26] identified the relationships between transport sector energy consumption and the changes of transport mode, passenger-freight share, energy intensity and transport activity in China between 1980 and 2006.

### 2.1.2 The use of decomposition method in transport sector

There are many study carried out in the area of transport energy use, the following table show recent research on transport related energy using decomposition research.

Table 2.1 decomposition analysis in freight transport sector

| Author and year | Objective year | region | Method | Factor | Result |
|---|---|---|---|---|---|
| Lee Schipper [12](1996) | 1973-1992 | Freight transport in 10 INDUSTRIALIZED COUNTRIES: | No decomposition method | Freight activity<br>Modal energy intensity<br>Fuel mix | |
| Fatumata Kamakat Lee Schipper(2009)[13] | 1973 to 2005 | truck freight transport in selected OECD countries | Laspeyres decomposition | Intensity effect<br>Structure effect<br>Activity effect | |
| W.W. Wang(2011) [14] | 1985 to 2009 | Inter-city freight transport and passenger transport in China as a whole | Additive LMDI | Population<br>Economic<br>Transportation intensity<br>Modal services share coefficient effect | |
| Jiyong Eoma, , Lee Schipper(2012)[15] | | Freight transport in 11 IEA countries | IPAT-type analyses | Population<br>affluence<br>Technology | |

| | | | | | |
|---|---|---|---|---|---|
| Tianyi Wang , Hongqi Li[16] | 1995-2006 | China's Road Freight Transport | Laspeyres complete decomposition approach | carbon intensity<br>level of vehicle technology<br>vehicle load<br>scale of road freight companies<br>numbers of road freight companies<br>distance<br>level of industrialization<br>economic grow | PLSR approach (4 factors: urbanization, road freight volume, total GDP and GDP in industry sector,） |
| Govinda R. Timilsina, Ashish Shrestha[17] | 1980-2004 | Transport sector $CO_2$ of 12 Asian countries during the 1980–2005 | LMDI approach of Ang | $CO_2$ intensity of a fuel<br>fuel mix<br>modal mix<br>transportation energy intensity<br>economic activity | |
| Marı´a Mendiluce, , Lee Schipper[18] | 1990-2008 | passenger transport and freight energy use in spain | LMDI | Activity<br>Structure<br>Energy intensity<br>Carbon intensity | |

Table 2.2 decomposition analysis in passenger transport sector

| Author and year | Objective year | region | Method | Factor | Result |
|---|---|---|---|---|---|
| Tae-Hyeong Kwon[19] | 1978–2000 | car travel in Great Britain | Log-mean Divisia index decomposition method | Population<br>Occupancy rate<br>Fuel efficiency<br>Fuel structure<br>$CO_2$ emission factor<br>Car travel distance | |
| Lynn Scholl, Lee Schipper and Nancy Kiang[20] | 1973-1992 | international | No Decomposition Method | Activity<br>Modal structure<br>$CO_2$ intensity<br>Energy intensity<br>Fuel mix | |
| Jiyong Eoma, ,Lee Schipper[21] | 1986-2007 | Passenger transport of South Korean | | Activity<br>modal structure<br>energy intensity | |

| | | | | | |
|---|---|---|---|---|---|
| V. Andreoni, S. Galmarini[22] | 2001-2008 | water and aviation transport sectors in , Norway and EU27. | Refined Laspeyres extension | $CO_2$ intensity effect<br>Energy intensity effect<br>Structural changes effect<br>Economic activity growth effect | Rapid growths of economy, vehicle ownership is the most important factors to $CO_2$ emissions increase, population intensity contributed a lot to emission decrease. |
| I.J. Lua , Sue J. Lin[23] | 1990–2002 | highway transportation in Taiwan, Germany, Japan and South Korea | Simple Average Divisia index Method | emission coefficient; vehicle fuel intensity; vehicle owner-ship; population expansion; economic productivity | Taiwan should pay attention to improving the operation and energy use by using ITS and with this method to manage the traffic demand, and they should build an integrated feeder transport, and encourage people to use the eco-friendly transport tools. |
| Marı´a Mendiluce , , Lee Schipper[12] | 1990-2008 | passenger transport and freight energy use in Spain | LMDI | Activity; Structure; Energy intensity; Carbon intensity | |
| Katerina Papagiannaki, Danae Diakoulaki[24] | 1990-2005 | passenger cars in Greece and Denmark | LMDI | fuel mix; engine size; yearly travel distance; engine technology of vehicles; car ownership | How these factors are affected the change of $CO_2$ emissions are shown in the comparative study in the two countries. |

| | | | | | |
|---|---|---|---|---|---|
| Becky P.Y. Loon, Linna Li[25] | 1949-2007 | China passenger transport | LMDI | Population<br>Income<br>Travel willingness<br>Diversity of travel purpose<br>Modal energy factor<br>Fuel mix | At the provincial level, great regional disparity was remarkable. Moreover, income growth was the biggest contributor to the passenger transport $CO_2$ emissions from 1949–2009 periods. The second biggest contributor was transport intensity and mode shift. The main factor contributed to emission decrease was the reduced emission intensity, even the influence was weak. |
| Ming Zhang, Huanan Li[26] | 1980-2006 | China freight and passenger | LMDI | transportation mode effect<br>The passenger–freight share effect<br>the energy intensity effect<br>The transportation activity effect | The transport related energy consumption in 2006 increased by 7.63 times compared with that of 1980. In 2006, the oil consumed in transport sector hold 49.6% of the total oil consumption in the entire nation. The efficiency of energy utilization was decreasing generally. The transport volume is the biggest contributor to the increase of the energy consumption, and the energy intensity shows the strongest negative effect to the energy consumption. |

But, to the best knowledge of the author, there is not paper on the urban level transport $CO_2$ emission analysis, especially in 2 mega city, namely, Tokyo and Shanghai, This research will fill the gap.

## 2.2 Review on integrated low-carbon transport policies and case studies

Tony May[27](1995)'s research shows that the integrated policy packages that integrated the infrastructure pricing and management measure can obviously alleviate the urban transport problem, in the research he also give the guideline for the integrated transport policy. And furthermore, in 2012, May[28] provide a generation tool on providing integrated policy packages, namely KonSULT. As the research shows, some policy will be very effective in fulfill a certain set of objectives. While the policy package is not necessary to give benefits as the sum of their ingredient. The useful policy package design should consider the composition of the policy instrument and how the policies are organized.

David A Hensher(2008)[29] applied THESIS, an integrated transport-land use environmental strategy impact simulation program in Sydney. The result suggests that the combining of technology and economic measure such as carbon tax or user charge is a sustainable way to use fossil energy. They think that technological solutions (improvement in engine efficiency) are somewhat more flexible the carbon tax, because the pass of carbon needs strong negotiation in congress.

Xiaoyan Zhang[30](2006) present a method to design optimal transport policy package and test the model in 6 cities. By adapting TRL strategic transport related policy model, namely TPM, taking total welfare of social system as the objective function, sensitive test of each individual policy and optimization of package of transport policies are carried out. The result shows that it is very important for the cities to control the fares policies in public transport system, the result also shows that they need continual revenue support.

As Hayashi proposed a CUTE matrix[31] in 2003, it provided a integrated policy system to achieving low carbon transport system as shown in Table 2.3

Table 2.3 CUTE Matrix

| | Avoid | Shift | Improve |
|---|---|---|---|
| Technology | TOD; Multi-center development | High speed bus/rail system; Feeder transport improvement | e-cars; renewable energy; smart grid |
| Regulation | Control of sprawl | Encourage of bicycle; parking regulation; | Emission standard |
| Information | Tel-working; Internet shopping; change of life style | ITS system for public transport | Eco-driving; traffic flow management system |
| economy | Economic subsidy for relocation to railway station | Park and Ride; integrated transport system | Fuel tax; Carbon tax; low tax for LEV |

Source: Hayashi[31]

Kazuki Nakamura and Yoshitugu Hayashi[32] (2013) review the strategies and instruments for low-carbon urban transport system. They summarized the trends and effects of low-carbon transport measure, and it has showed how they differ on development stages and the types of urban land-use transport system. The paths for

AVOID and SHIFT are significantly influenced by types of land-use system, and this shows the process between the measure implementation and the system development. To use proper policies in the early-stage is more useful especially for developing cities, while the use of the later-stage policies (such as fuel efficiency improvement) is more useful for the developed nations. For cities that have low density and high dependency on cars, IMPROVE would be more effective, and author also described the importance of the policy package to reach the target of carbon dioxide reduction. Early consideration of the implementation is a key factor on achieving leap-frog especially for developing cites that developing quickly. There should be enough consideration on the economy and the social welfare benefits, namely the infrastructure cost, mobility and QOL (Quality of life) for the policy makers. The economic measurement and the traveler's change in lifestyle and vale should also be taken consideration.

After examining 41 different cities, Louis de Grange[33] (2012) found that a measure on spreading rail networks can encourage people to use the public transport system. Averagely, 10% extension of rail length could bring a growth in user in transit around 3%, at the same time, there are 2% reduction in the user of private cars. Furthermore, the author make an assumption that the control of car use and other policies such as road user charge and related taxes on car users also can promote the use of the public transport system. In practice, in the cities that regulated the car use the car usage reduced by 20 to 30 percentages, and the user of the public transport system increased. And the fare subsidies are not found to be useful to stimulate people to use more public transport system. This means that this policy cannot reduce the usage of cars. The finds means that the fund should be more put on expanding the public transport system but not to reduce the public traffic fares.

The city of Dalian was taken as the case study city by Rui Mu[34](2012), the integrated policies system for public transport was assessed by the author. Three scenarios are designed, and the average time consuming, passenger cost, safety, comfort, system operating cost, profit and the environmental cost are calculated in the model. The result suggests that the Dalian should decrease the fragmentation of the public transport system to increase the service level of the public transport system. Another researcher, Tao Feng[35] (2012) also did a research on Dalian. He developed a model to maximize the mobility, and the restriction is the environmental load and the transport system's capacity. The parameter in the model is: population, land use, land use pattern and the change of network. The conclusion suggests that, an integrated model is helpful for the government to discover the relationship between land use and transport system and the environmental load.

London was taken as a case study city by Robin Hickman[36](2010), he designed 12 policies packages to simulate possible performance in the city. The model (TC-SIM) is designed to model transport and carbon emission at the same time. Policy such as LEV, fuels alternative, pricing, public transport improvement, walking and cycling, local urban design, IT technology and communication technologies, smarter choices, eco-driving, long distance travel substitution, freight transport and international transport are considered. The conclusion suggest that the $CO_2$ emission mitigation goals are very ambitious, the government need more effort on a border range of policy packages with full application to reach the goal(60% decrease in carbon dioxide by the year of 2025, compared with that of 1990). The author reminds that the QOL (quality of life) and border range of sustainability should also be achieved simultaneously.

Christopher Yang[37](2009) did a back casting research on California transport system, the goal is to reduce the greenhouse gas emission 80% by 2050(compared with that of 1990). Kaya equation is use to decomposes GHG into many factors, namely population, transport intensity, energy intensity and carbon intensity. The results shows that, even the goal of California's is ambitious, the task could be finished by changing the travel behavior and improve the vehicle efficiency.

Philippe Barla[38] take Quebec City as the case study, the researcher find out the causes of the urban transport system, he also investigated that the influence of people's socio-economic preference, land use pattern and the transport supply characteristics around house and working place. The result suggests that the emission is different in different gender, age, family structure, income level and the day of a week. The elasticity of $CO_2$ emission to the residential density (as deputy of land use and public transport supply) is very small.

Above all, there is no framework that can contain all the works that to solve the problem for Asian developing mega-cities.

## 2.3 Review on individual policies on low carbon related transport system

To investigate the factor that affect urban transport sector more precisely, the effect of the policy in each stage are examined individually, namely avoid, shift and improve.

### 2.3.1 Review on avoiding unnecessary traffic demand

In the Avoid stage, the researches mainly focus on the urban form and telecommunication to reduce the transport demand.

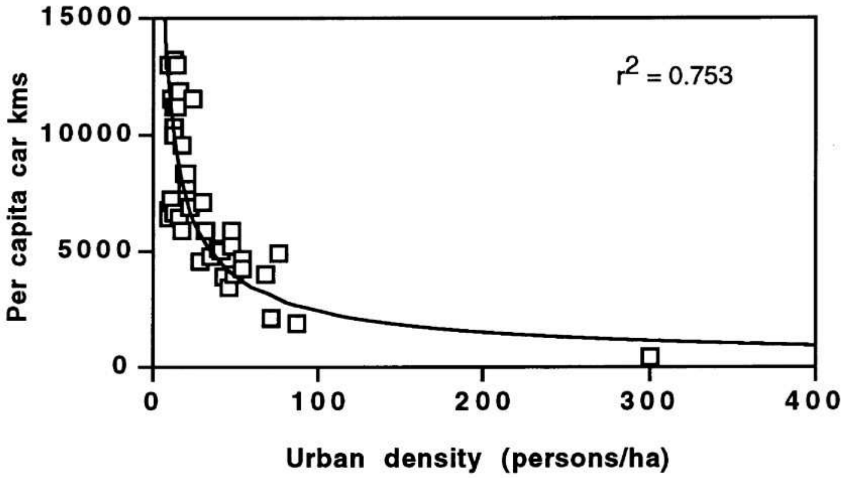



Fig2.1 Urban density and car use in developed cities, 1990
(source: J.R. Kenworthy[39])

The research of Newman and J.R. Kenworthy[39] (1989) provide a famous research shown in Fig 2.1, this picture shows the relationship between urban density and car use in different cities, the bigger the density, the bigger relation of car use. It shows that, high density can reduce car use and related energy consumption

Robert Cervero[40] (1997) give suggestion, 3Ds, density diversity and design, he examined how the 3Ds affect trip rates, mode choice in the San Francisco Bay area. The research concluded that density, land diversity and people friendly designs can gradually decrease trio rate and encourage eco-friendly travel mode. The result shows that the combination of compact, land diversity and people friendly designs can influence how Americans' travel behavior.

Reena Tiwari[41] (2011) use the 3Ds (density, diversity and design) principal and ASIF(avoid, shift, improve and finance) modeled the transport performance in Bentley Technology Precinct. The output is evaluated by taking an audit for place-making, vehicle travel distance and $CO_2$ decrease. The result shows that the combined framework can efficiently reduce the $CO_2$ emission.

Take Baltimore metropolitan area as case study, Chao Liu[42] (2011) measures the influences of urban land-use on travel pattern and transport sector energy consumption. The results show that built environment measure has big effect on transport performance. With SEM(structural equation model), they concluded that the urban form do not directly affect vehicle travel distance. While, the household socio-economic characteristic have strong relationship between vehicle travel distance and energy consumption.

By setting the target of reducing energy consumption in transport sector, Atsushi Akisawa[43] (1998) made an optimization in urban land use system. Two kinds of models are developed, one of the model is to minimize the total travel distance with the control of constant congestion. The other is to minimize fuel consumption directly where congestion is taken in to endogenously. The result shows that the business area should be located in the city center while the residential areas should be in the suburban areas. This is similar to the actual land use just as observed generally. The result is as shown in Fig2.2.

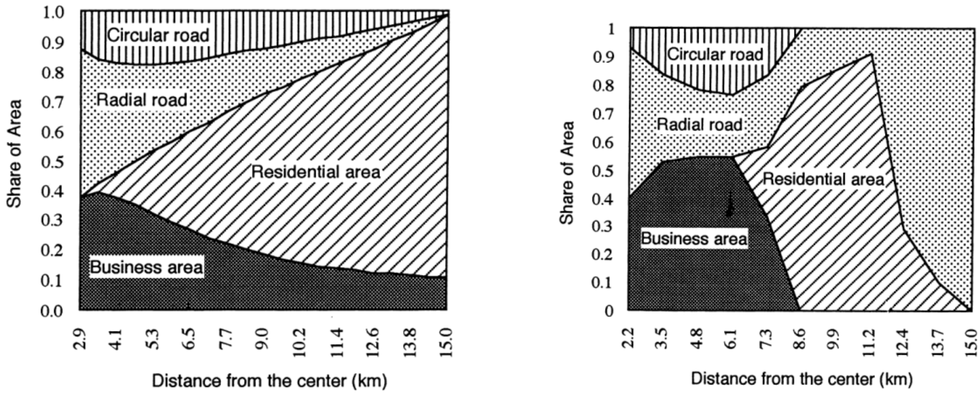



Fig2.2 Mode share VS distance to city center
(Source: Atsushi Akisawa [43])

By regarding relation between sustainability, transport, design and energy use, James Cooper[44](2001) develops methodologies for the city of Belfast. With the simulation in 3 scenarios is considered. The result show that the public transport improvement along corrodes has negative effect on energy consumption, and the existing models can give a cost effective method to analyze the energy consumption and its related influence.

James Keirste [45] (2011) developed "Green Move", with the objective to design and test a vehicle-sharing system, with different categories of electric vehicles. The se rvice will have the following characteristics: multi-ownership, allowing single users, p rivate companies, and associations to join the service both using vehicles provided by the service itself and sharing their personal electric car or fleet, this represents an appl ication of a peer2peer approach in the field of sustainable mobility.The design of a ful l scale service for the city of Milano will be carried out by a multi-criteria assessment of a wide number of possible alternative options in order to identify the most feasible and effective one.

A trial to test the operating modes and the service efficiency will be carried out with electric vehicles and docking stations in a specific area of Milan, establishing a connection with the present traditional electric car sharing service owned by the Region. The performance of the service in term of accessibility and usability will be measured with a specific monitoring system.

### 2.3.2 Review on shifting to more eco-friendly mode

The mitigation of congestion and carbon emission is considered as an important purpose to promote a mode shift from car usage to cycling and walking. Generally, as main congestion management policies, congestion pricing or tax measures are usually taken to suppress car usage, at the same time policies such as transit subsidies and dedicated bus or cycle lanes are reinforced to promote the usage of transport friendly modes. By applying a quantitative analysis which can support a freedom for users to choose any traffic mode (car, bus or the others) and allow optimizing the usage of each mode, Leonardo J. Basso[46] (2011) compares policies such as congestion pricing, dedicated bus lanes and transit subsidization and figures out advantages or disadvantages of each policy or its combination. Due to the result, it is clear that dedicated bus lanes measure can function well independently, while transit subsidies are usually enormous and inefficient and congestion pricing would negatively affect consumer surplus. In addition, only dedicated bus lanes could help optimize the bus system service efficiency and both of transit subsidies and this could escape from a kickback of opposition. However, appropriate assignment of congestion pricing income to bus system and transit subsidies is indicated to be economic.

On the other hand, there are also various studies that focus on such one typical available measure. For instance, congestion pricing is well discussed by Zheng Li[47]'s (2012) research. He summarizes a wide range of cases including 20 published studies which respectively investigate the efficacy and acceptability of pricing policy in different regions. In general, congestion pricing policies are confirmed that they indeed lead to a behavior transition such as mode shift, resident or work place change, etc. Furthermore, focusing on tax measure, Miao Fu[48] (2012) compares different outcomes brought from fuel based carbon tax, VRT and motor tax which would affect car ownership and its usage. As a result, fuel based carbon tax is found much more effective than the others by comparing the tax income, reduced quantity of $CO_2$ emission even the social welfare, but it decreased more household utility and production cost than the others. However, policy package of all three measures is proved to be able to result the highest carbon emission reduction, furthermore the revenues also could be used by governor to improve the quality of social welfare.

The researches above have indicated that policy making has availability to promote mode shift in urban transportation. In fact, there are several social-economic reasons or critical factors influencing the result brought from those policies; this means people with different properties will have different reactions to policies. Tina Gehlert[49](2011) investigates several socioeconomic factors regarding car usage and their responses to road pricing policies. The method is to classify experimenters who have similar situation into three groups named young families, suburban families, and singles and couples. The result obviously shows differences among three groups in car usage and preferred revenues use responding to road pricing. All of them decreased their car usage a lot especially young families took the largest reduction than singles, couples and suburban families. Finally, according to each group's response characters, several methods are thought out for suppressing the car usage.

Otherwise, by using stated-preference method, Kian Ahmadi Azari[50] (2013) directly took interviews in CBD district of Mashhad City to investigate drivers' sensitivity towards traffic modes. Then after applying to a multinomial logit model considering mode and parking choices, the result comes out that drivers pay much more attention to cordon charge than to parking fees or the other factors. But they seem to be more likely to pay parking fees than cordon tolls. Many similar studies support that the efficiency of policies is actually subtly interacting with specific people even individually. It indicates a necessity to carry out more detailed specific policies in addition to common ones. Bharat P. Bhatta[51] (2011) researches the effect brought from measurement biases on policy making. It is found that initial errors and parameter errors could cause a negative effect to policy making so that the result may greatly departure from policy targets. Several remedial methods are considered to solve this problem, but still there should be more numerical and structure analyses to make clear the mechanism theoretically and practically.

Different from the studies mentioned above, some studies do not directly focus on forming a mode shift by powerful policies, but consider the benefit of optimizing the usage of the other traffic modes to strengthen their competitiveness towards car use. Graham Currie [52](2011) investigates the factors influencing the fascination of BRT system in Australian. More than seventy BRT and non-BRT routes are analyzed by regression model in which many explanatory variables are included such as right of way, service quality, residential density, infrastructures and so on. Generally, it is supported that service quality finally has the strongest efficiency to increase usage, but right of way or other infrastructures treatments could also greatly make effect on the ridership of BRT. These studies show us an operative improvement to traffic system beyond pricing or tax policies.

Not only for bus system, but also for cycling and walking there are some typical researches focusing on. One of them is Ari Rabl[53]'s (2012) study which tries to evaluate the effects on people's health from the shift of car usage towards cycling and walking. As a result, due to a shift from car using to cycling and walking, there is an improvement not only in ambient air quality surrounding both car users and all the other residents that improves their health, but also in reducing accident risk. In some cases such as Paris and Amsterdam, accident risk increased with the shift to cycling, but the increment is quite affected from the local conditions and the loss of accidents is actually much smaller than the benefits of improving health. This is quite important because both public and personal benefits are made clear to compare with costs so that it could be an assured reason to encourage mode shift at micro level and evaluate the impacts quantitatively. Specially, with consideration of air condition, Yunlong Zhang[54](2010) tries to supply a methodology to allocate transportation from a sight of networking. Travel costs and emissions are main factors limiting the optimization schemes in this study. But in fact, due to the result in general, although it could be pointed out that car emissions are decentralized to improve the air quality at some serious places, the total emission does not change too much, somewhere travel distance/time may increase a little. This oppositely proved the critical importance of mode shift in emission reduction.

Beside objective researches mentioned above, some studies dedicate to research on mode preference from a subjective sight. For instance, in Serge Pahaut's[55] (2003) research, British government's policies and the implementing impacts are discussed as a case study for promoting the shift to walking and cycling. The character of the research is the method that is to estimate local authorities' efforts by questionnaire survey. A special index is created by the author to evaluate the activeness of local authorities so that it could be compared with the outcomes of mode shift. At last, the result shows the different situations of policy implementation would affect the reality of shifting to cycling and walking and some factors could be figured out critical to bring out expected outcomes. In addition, Brian Caulfield[56](2012) attends to research the factors of infrastructures which affect preferences of the people using cycles in Dublin. By stated preference survey it is indicated that cyclists would have different preferences towards different situation of infrastructures. Separated infrastructures from the traffic are the preferred form for cyclists, followed by the through streets in resident and park area. These studies indicate mode shift is indeed related to various complex factors, not only political or social-economic processes but also infrastructure development or environmental improvement.

Furthermore, some researches probe into mode shift issue in a way of observation of specific colony, for example, the commuters. Since commuting to workplace or school is the main part of traffic demand, to shift its car usage to more transport friendly mode is quite significant. To find out the main factors related to commuters' mode choice, Ryoichi Sakano[57](2011) tests the mode choice decision making of commuters (especially against the commuter rail) in the Piedmont Triad region of North Carolina by a group of structural equations. In general, commuters' decision preference is confirmed to be firstly effected by destination activities. But as times go by, the mode choice preference of commuting activities turns to be similar with non-commuting activities if they have various modes could be chosen. Another interesting research is done by Maya Abou-Zeid[58] (2012) who did an experiment on customary car users in Switzerland to observe the feedback from their mode shift to public traffic. All the car users were differentiated into two groups, in one group they shifted to use public transport and in another one they did not. By comparing variables such as satisfaction and treatment before and after, a polarization phenomenon appeared that in the shifted group, they became more likely to prefer public transportation and more conscious about its cost and service level, while in another group non-shifted car users used private cars more and became much more satisfied. This result indicates the importance of changing people's traffic custom especially promoting car users to try public transport, not only to limit their car usage by powerful policies.

Finally, some researches try to discuss on commonsensible issues and usually bring a deeper understand. Alexander Y. Bigazzi[59] (2012) finds that there is no absolute conclusion that mitigating congestion would indeed decrease the emission brought from car usage. He uses aggregate US congestion and vehicle fleet condition data and found the real outcome is more likely to be affected by traffic demand and vehicle efficiency. Pollutants, congestion degree and vehicle composition are figured out as the critical factors. However, since traffic demand management and vehicle efficiency improvement may encourage more vehicle usage, this research also proves the importance of mode shift promotion from a side face.

### 2.3.3 Review on improving transport mode efficiency

#### (1) Eco-car

Promoting the utilization of eco-cars is considered as the most direct policy for improving transport mode efficiency. There have been a large amount of researches focusing on this topic.  Some of them study from a policy maker's sight at macro-level, while the others pay attention to the personal preference and receptivity against the policies. A study taken by Michiels hans[60](2012) is a typical one which simulates policy outcomes of promoting clean vehicle utilization as a case study of Belgium. Using indices such as total quantity and composition of proportion, kilometers and emissions differentiated by vehicle category, an integrated indicator called "Ecoscore" is developed to estimate the efficiency of assumed policies. As a result, it is indicated that policies such as charging by distance, car replacement subsidies and introduction of well to wheel index could much more efficiently promote a transformation of vehicle technologies and improve the environmental efficiency of vehicles. It means an advanced drive force is necessary for exporting expected outcome.

On the other hand, some researches take a consumer’s view towards eco-car promotion policies. One of them is Brian Caulfield[61]’s (2010) research, which tries to find out consumer’s attitude to environmental efficient vehicles. In general, it is found that towards Hybrid Electric Vehicles (HEV) and Alternatively Fuelled Vehicles (AFV), consumers indeed show a preference to them, but not briefly because of the better environmental efficiency or vehicle registration tax. The most critical factors are their physical performance such as reliability and safety and economic performance like fuel consumption and the price. In one word, for a long-term use, eco vehicles are considered more economic and environmental efficient than the others. Therefore, policies for eco cars should take both political and market factors into consideration and connect them organically.

**(2) Eco-driving**

Another method for improving transport mode efficiency is eco-driving. Michael Sivak[62](2012) comprehensively investigates the facts of eco-driving and show a great potential to reduce carbon emission. As a result, drivers are indeed found as eligible decision makers who could react with vehicle attributes such as on-road fuel efficiency. Their decisions are differentiated into three levels by the author. That clearly indicates that considering a long-term use, drivers would strategically purchase efficient vehicles and pay attention to the maintenance. Then regarding the way of usage they would notice to find out the best route and load, even change driving habit themselves. Due to the study, a case of the U.S.A is emphasized that the efficiency of the best available car is 9 times better than the worst. It means drivers' eco-driving activities have so enormous a quantity of emission reduction. Furthermore, another study published by Timon H. Stasko[63](2010) could be listed which discusses three methods for realize a reduction of emission by eco-driving. They are mentioned as retrofits, replacements and usage changes. He recommends a combination of all three methods so that an integrated strategy could be set up to bring out a long-term reduction.

**(3) Car sharing**

Except for eco-car and eco-driving, car sharing is also considered as an efficient way to improve transport mode efficiency. A research taken by Ulrike Huwer[64](2004) confirmed the feasibility and efficiency of car-sharing policy. As a research project in Germany, an experimental introduction of car-sharing system and its integration with public transport is taken into urban transportation system. They observed the facts including users' adoption, usage behavior and satisfaction with car sharing system and found generally car-sharing system has a compatibility with public traffic and is suitable to be generalized. However, in some different cases, it is also affirmed that car-sharing policy may have its limitation. For instance, a case study in China made by Rui Wang[65] (2011) tries to analyze car sharing policy and compare it with the others. The result shows that indeed car sharing policy could increase road service, but non-motorized users are more likely to become car-sharers. It means in fact the total car utilization would increase although efficiency is increasing. At last, car sharing subsidies are considered inefficient and unequal, even also dedicated bus lane is recommended rather than high occupancy vehicle (HOV) lane. Regarding that it is a case in China, local environmental factors may affect policy implementation a lot.

Thus investigation on environmental/social-economic factors is necessary to estimate validity and feasibility. Brian Caulfield[66] (2009) uses a model called "COPERT4" to analyze car-sharing development in Dublin. Census data of Ireland are utilized to interpret car-sharing traffic patterns and evaluate emission reduction and vehicle kilometers travelled. In general, the result indicates that personal attributes including gender, occupation, age and family and so on, are important factors affecting car-sharing facts. Although females and couples take a large proportion of car-sharing users, the most significant factor is thought to be occupation that professional workers and managers squint towards car-sharing mostly. In addition, young people also show a preference towards car-sharing. Against it, Jörg Firnkorn[67]'s (2011) study focuses on the environmental factors and found free-floating car-sharing system is a recommendable thought better than traditional system. In this study, a car sharing system named "CAR2GO" is observed as an original experimentation. The characteristic of the new system is the freedom for users to begin and end sharing travel anywhere in city range while this is unable in old car-sharing system. According to a survey and modeling for evaluating its environmental effect, it is indicated that a reduction of emission could be realized because of the transition of car purchasing will, so that a part of potential car consumption would be mitigated. However, as a necessary condition, the system should be confirmed to be operated stably for a long time.

In addition to the estimation of car-sharing impacts and the factor analyses, there are several significant researches focusing on the operation and industrial development of car-sharing operators. For example, Susan A. Shaheen[68] (2012) paid attention to explore the development of individual car-sharing operators located in North America. While taking indicators such as business models, market opportunities, and service barriers into consideration, an affirmative conclusion is supported that car-sharing enterprises have very great potential to impact on car ownership and be a supplement to public transport. For sustainably development, availability and integration with other modes should be solved well in advance. Furthermore, some researches try to deepen this sight and investigate one specific business model of car-sharing. As one typical study, Gonçalo Correia[69](2011) discusses a case of car-sharing club in Lisbon, which could not only supply a traditional service for compatible sharer groups by a basic trust system, but also support chances for users to create temporary trips and match to different groups. By using a web-based survey and stated preference method, several preconditions and critical factors are figured out for a deeper analysis by Binary Logit Discrete Choice Model. In general, income is found to be the most important factor so that most of the users are belonging to low income class. This also reveals the limitation of car-sharing system as mentioned above, therefore car-sharing enterprises need to pay more efforts on sustained trust construction and improve the flexibility of service.

## 2.4 Conclusion and positioning of this research

After review we did above, we can see that the gaps in the previous research is shown as follows:

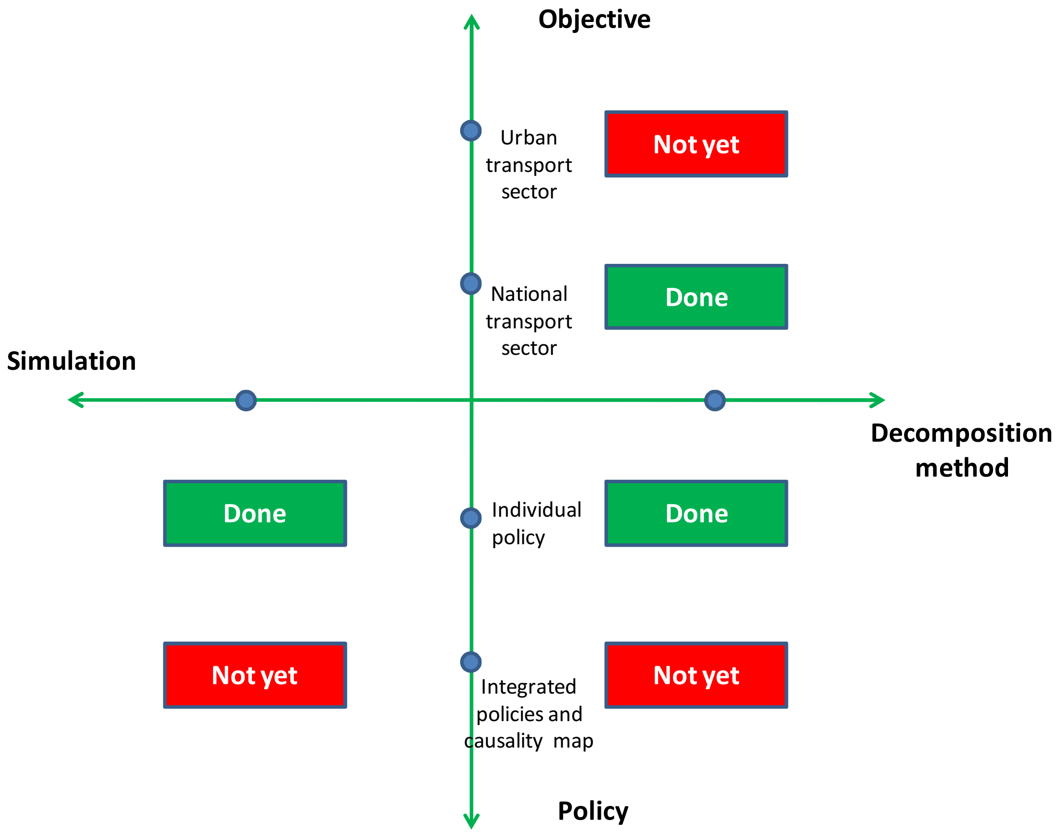



Fig 2.3 Gaps in current researches

We can see form Fig 2.3, the research on the combination of decomposition and urban transport sector has not yet been done, the research on integrated policies and furthermore causality map has not yet been done, and the simulation on the integration of policies has not yet been done.There are seldom research do research on counting out the feature and make a full causality map for the reason that causing the urban transport $CO_2$ emission in developing cities. So this research would like to fill this gap with the comparison of a mature city Tokyo and a developing city in china.

And then to make different simulation in different kinds of policy package to check which policy is more available.

# Chapter 3 Urban development of Shanghai and Tokyo

This chapter mainly focuses on the introduction of the social-economic change and urban development of Shanghai and Tokyo. The chapter first compares the difference and similarity of Shanghai and Tokyo. Section 3.1 introduces the population growth and economic development of Shanghai and Tokyo, section 3.2 introduces the land use system, section 3.3 introduces the traffic situation, section 3.4 finally makes a conclusion.

## 3.1 Population growth and economic development in Shanghai and Tokyo metropolitan area

### 3.1.1 Total population growth

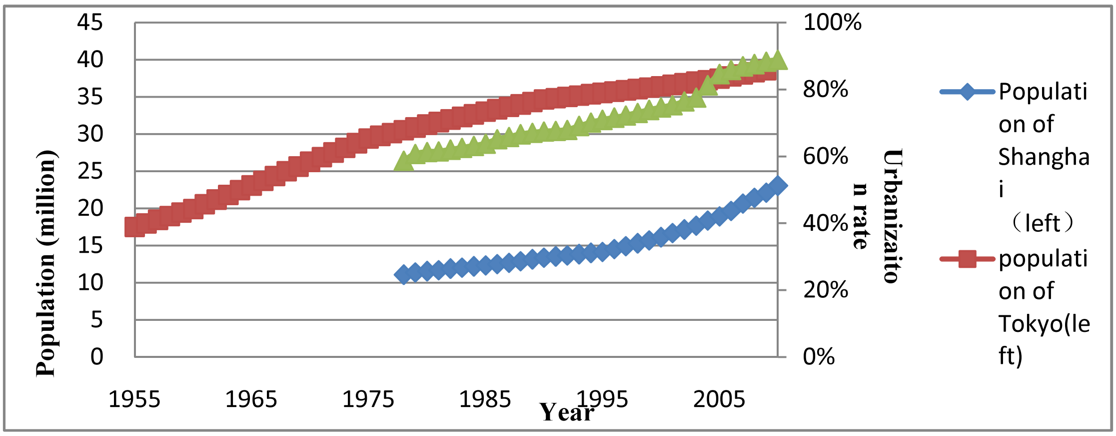



Fig 3.1 population growth and urbanization in Shanghai and Tokyo metropolitan area (Source: Shanghai statistical yearbook, statistical yearbook of Japan; Definition of urbanization rate: in Shanghai, the residence who are register as urban population/ total population)

The total population in Shanghai increased constantly, the main reason for the population growth is the immigration of the population, and people move from the other part of China to Shanghai for working opportunities and higher quality of life. The total population increase trend can be seen from Fig 3.1. The population grew quiet quick, from 1978 to 2011, the population grew from 11.04 million in 1978 to 23.47 million in 2011, with an annual growth rate of 2.3%[70], as we can see from the Fig 3.1, the population increase is now accelerating. At the same time, the population more and more non-agriculture population, the urbanization rate increased from 59% in 1978 to 89% in 2011[71].

The population in Tokyo metropolitan areas also increased quickly, from 20million from 1968 to 34 million in 2008[72]. But he age structure changed a little bit, with the progressing of aging, the natural population increase rate decrease constantly, the population is keeping the trend of increase, but he speed decreased. We can see that the total population increase was very quick, from 1995 to 2009, the total population increased from 17.4 million to 38.5 million, the total increase rate was 120%,the annual increase rate was 1.4% per year. The population increase in Tokyo was not quick from 1970 to 2000, that's mainly because of its high land value. While the population increase in Saitama-ken, Chiba-ken and Kanagawa-ken was very quick, the population increased 220%, 180% and 310%, the population increase in Ibaraki-ken and Tokyo was 40% and 60%. Actually it is a distinct suburbanization, the population increase mainly happened in the suburban areas.

### 3.1.2 Population distribution

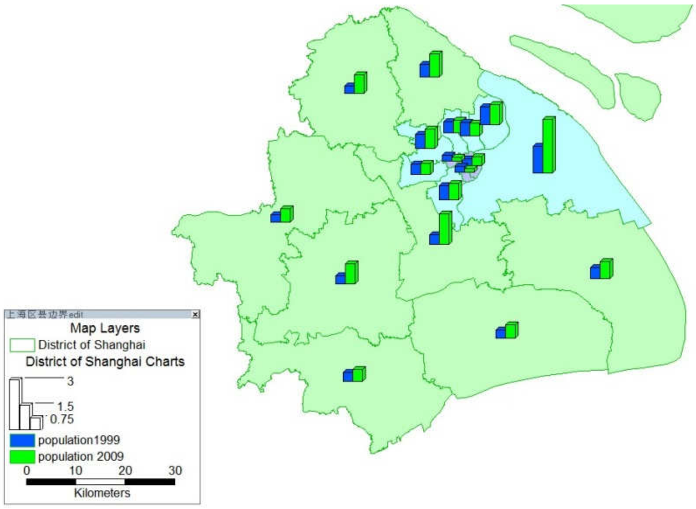



Fig 3.2 Population change from 1999-2009 in Shanghai

(Source: Population data is from Shanghai statistical yearbook)

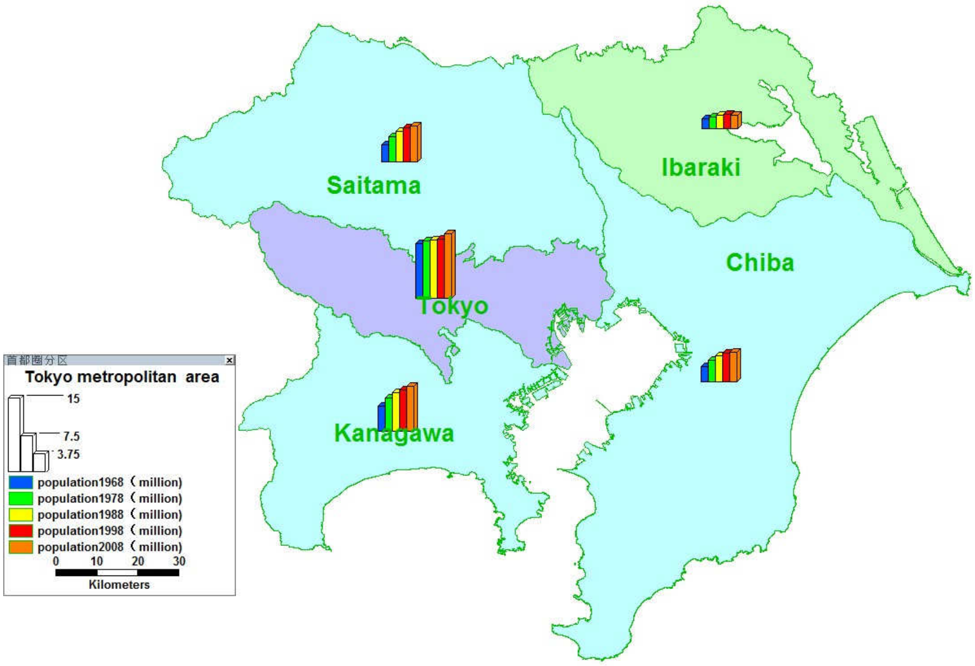



Fig 3.3 Population change from 1968-2008 in Tokyo metropolitan area

(Source: Statistical yearbook of Japan)

As shown in Fig 3.2, the population distribution in 1999 is mainly in the city center, but Shanghai is now experiencing quick suburbanization, the population growth in mainly in the city suburban areas. The population in the city center in 1980s was very high, in some districts, it nearly reached 60000 persons/m$^2$. With the land use adjustment, the people in the city center generally move out of the city center, and the population generally moves out of the city center, especially in the 2000s, the population generally start move to the suburban areas. We can clearly see that, the population mostly increased in the suburban area, and the population city center constantly decreased. Especially after the building of bridges and tunnels across Pudong district, the population generally move to Pudong district, the population started after 1990s after the policy of developing Pudong district. We can see that, from 1990 to 2000, the population growth is mainly within the outer ring road, but after the 2000s, the population generally went to the outer ring areas because of limited land use in the city center and the transport infrastructure construction supply to the outer ring of Shanghai. Even the population density in the city center decreased, they are still the most density area with a density of 35000 persons/km$^2$.

Tokyo is surrounded by many cities including Yokohama, Kawasaki, Chiba, etc. Many inhabitants of these cities commute to workplace in Tokyo each day, and these cities are closely connected to Tokyo in terms of commercial activities. So, when considering the transport of Tokyo, Tokyo and the surrounding cities should be considered as integration, and it can be called Tokyo metropolitan area. From Fig 3.3, in the city of Tokyo, it has the largest population, because the population is so dense, the population is generally moving to the suburban area. We can see from Fig 3.3, from 1968 to 2008, the populations increase is distinct in Kanagawa-ken, Saitama-ken and Chiba-ken. The main reason for these changes is the high raised land price and well built public system in Tokyo that can evacuate people to the suburban areas or surround kens.

### 3.1.3 Economic development and economic structure

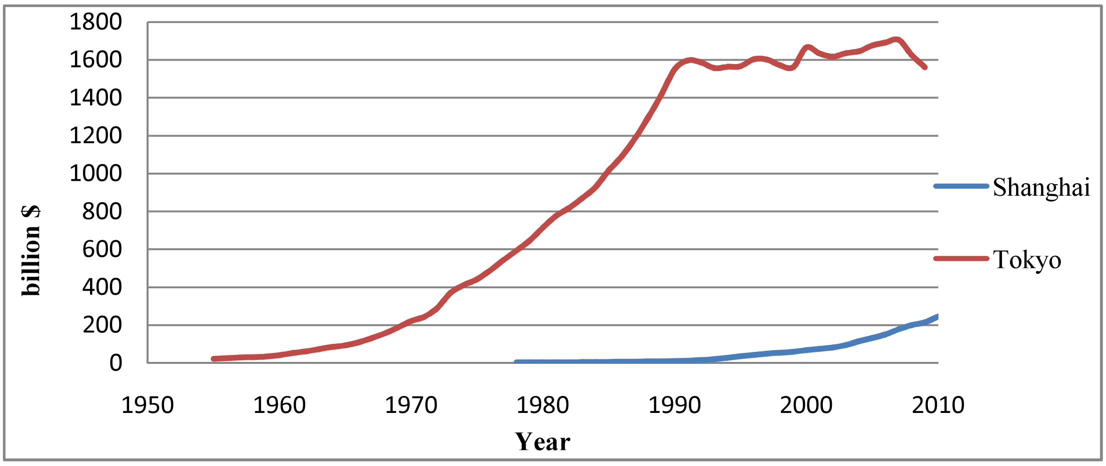



Fig 3.4 Total GDP of Shanghai and Tokyo metropolitan area

(Source: Shanghai statistical yearbook, statistical yearbook of Japan)

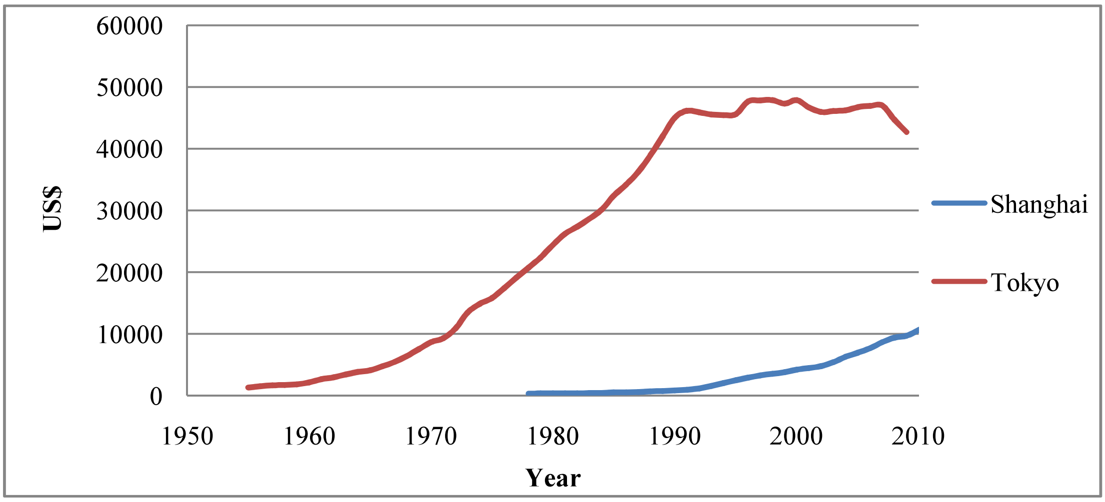



Fig 3.5 Per capita GDP of Shanghai and Tokyo metropolitan area

(Source: Shanghai statistical yearbook, statistical yearbook of Japan)

Shanghai experienced 30 years of rapid economic development since the policy of opening and reformation in 1978. As the frontier of economic development, and its history of connecting with foreign countries, Shanghai became the headquarter of many international companies, and attract lots of investment from all over the world. With the effect of economies of agglomeration, Shanghai attracts more resources and became the financial center, port center and culture center of China. This trend continues with the opening of World EXPO in 2010. Fig 3.3 shows the Gross Domestic Product (GDP) of Shanghai reached 274 billion US$ till 2011, with an annual growth rate of 13.7%.

The GDP annual growth rate in Shanghai of 1978-1989, 1990-1999,2000-2011 keep a very high level with a value of 8.8%, 19%, 13%. In the first period (1978-1990), the increase of the industry was very quick, the share of tertiary industry started to increase, and the share of the first industry achieved its peak. In the second period (1990-2000), Shanghai start the development of Pudong district, the increase of tertiary industry start to speed up, because the government pay more attention to the development the tertiary industry rather than heavy industry, and because of the trend of urbanization, the share of first industry constantly decreased, in the year of 2000, the share of tertiary industry was 52%, and the share of first industry became 1.6%. In the tertiary stage (2000-2011), the total GDP continually increase, the industry part and the tertiary industry part keep high speed increase. The share of tertiary industry increased a little to 58%.

Tokyo developed quickly since the Second World War, after 1945, it's one of the largest cities and agglomeration and economics with per capita GDP around 40000 us dollar. From 1965 to 2005, the employment in Tokyo increased from 5.0 million to 8.5 million, where the largest increase was in the suburban area, from 8% to 15%. While the center decreased a lot. We can see that the economy developed very quick from 1955 to 1990, the GDP increased with annual increase rate of 12.7% in 35 years, after that the economic growth seems stopped, that's mainly because of the bursting of the housing bubble.

In terms of per capita GDP, it also increased very fast from 1955 to 1990, the per capita GDP increase rate was 10.6% in 35 years, after 1990, per capita GDP kept a stable value and decreased a little since 2008 because of the financial crisis. Within all the regions, Tokyo was the highest, it has a value of 100% higher than the other areas, because most the headquarters of 500 biggest company accumulated within Tokyo.

In terms of GDP and per capita GDP, Shanghai is much lower than that of Tokyo, Shanghai is now equivalent to the Tokyo's level in 1970s'. Tokyo is now in a very stable economic status, but the tendency of Shanghai economy development is now very quick, just like the economic golden quick development era in Tokyo in 1970s and 1980s.

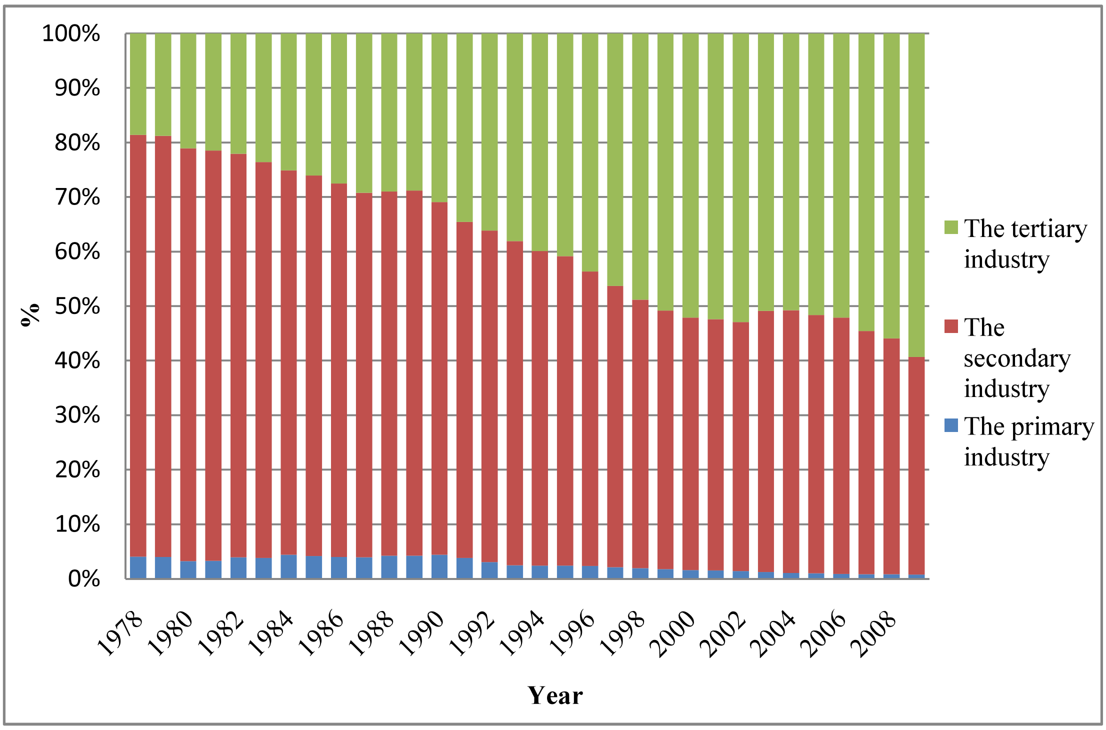



Fig 3.6 Industry share of Shanghai

(Source: Shanghai statistical yearbook)

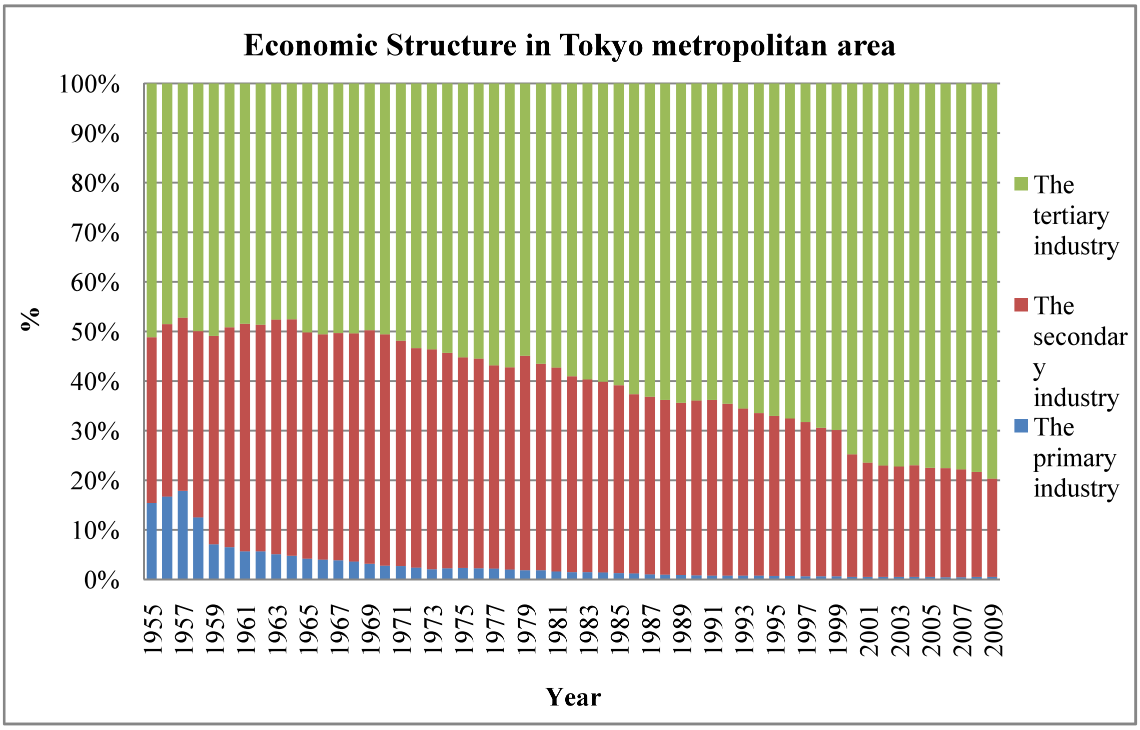



Fig 3.7 Industry share of Tokyo metropolitan area

(Source: Statistical yearbook of Japan)

From Fig3.6 we can see that, the share of share of tertiary industry increased constantly from 1978 to 2009, the second industry decreased quickly, and the first industry decreased a lot, till 2009, the share of the first industry was nearly 0%.

From Fig3.7 we can see that the share of tertiary industry increased constantly from 1955 to 2009, while the second industry decreased quickly and the first industry decreased a lot, till 2009, the share of the first industry was nearly 0%

Compare with the economic structure of Shanghai and Tokyo, the share of the tertiary industry of Tokyo is much higher than that of shanghai, in both cities, the share of the tertiary industry increase; the share of the second industry of Shanghai is much higher than that of Tokyo, in both cities, the share of the second industry decrease; the primary industry in both cities decrease constantly and can be omitted now.

## 3.2 Land use in Shanghai and Tokyo metropolitan area

### 3.2.1 Land use and urban planning in Shanghai

Based on the Comprehensive plan of Shanghai (1999-2020)[73], the development of land use system for valuable consideration has became a powerful lever for regulating function of urban land use. The process of redeveloping shack-dwellers and adjustment of industrial arrangement have been speed up. Urban industrial structure and spatial arrangement have had significant changes. The land use planning from 1999-2020 is shown as follows:

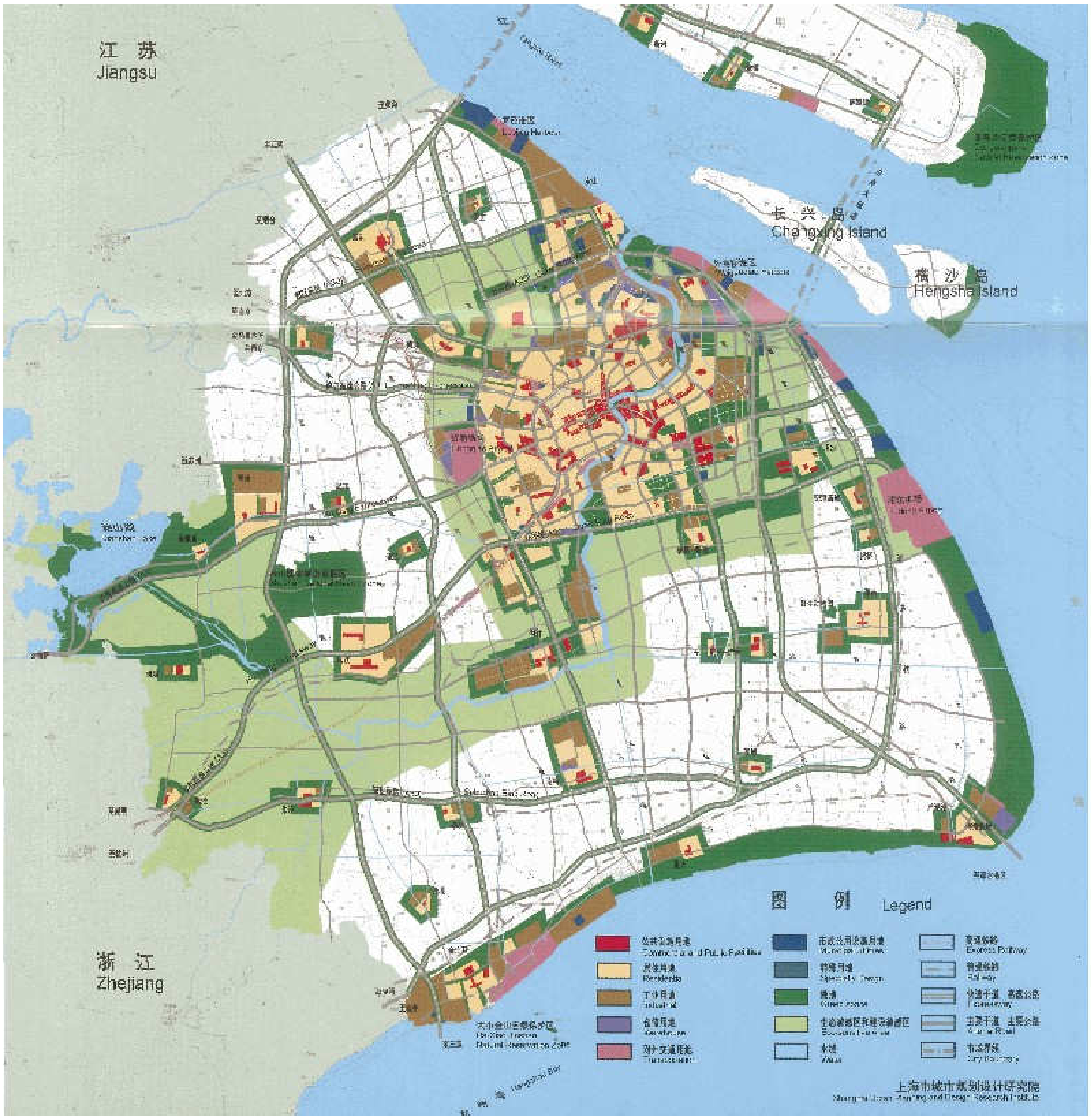



Fig 3.8 Land use planning from 1999-2020 in Shanghai

(Source: The Comprehensive Planning of Shanghai 1999-2020)

In accordance with the guideline on integration and coordinated development of the urban and rural areas with the Central City as a major part, a "multi-axes, multi-levels and multi-centers" urban spatial structure will be formed. Multi-center is mainly composed of the central city and 11 new cities as shown in Fig 3.9.


Fig 3.9 New towns in Shanghai

(Source: The Comprehensive Planning of Shanghai 1999-2020)

Central town is surrounded by outer ring road, it's the political, economic and culture center of Shanghai. The central city is planned to adopt the "multi-centric and opening" layout structure, the CBD area consists of XiaoLujizaui and Bund in Puxi, The planned area is about 3 km$^2$, CBD is the integration of finance, trade, information shopping, culture, recreation, tourism and business, with moderate amount of residential buildings. The main public activity centers are referred to civic and sub civic centers, the civic center is centered with People's Square, there are four sub-civic centers: Xujiahui, Huamu, Jiangwan-Wujiaochang and Zhenru.

### 3.2.2 Land use and urban planning in Tokyo

Since the first comprehensive plan for national and capital region development was established, mono-centric structure and associated high stress and congestion on the city center has been successfully mitigated and now became an efficient multi-centric development by polycentric spatial restructuring. The sub center is now attracting many people and became very import. The function of each sub center is shown as follows:

(1) Central area of Tokyo: Land for agriculture and forest constantly decreasing; Residential, business land increased, the land for industry keep constant and have a slight trend of decrease;

(2) Tama area: Area around 1160km$^2$, with the population of 4 million, is now the concentration of high-tech industry;

(3) Kanagawa: Agglomeration of industry and international port;

(4)Saitama: For government, residential, life, business, sub center;

(5) South of Ibaraki: Concentration of R-S department and university;

(6) Chiba-ken: International airport, bay, industry.

## 3.3 Transport development in Shanghai and Tokyo metropolitan area

### 3.3.1 The traffic system challenge of Shanghai

Now, the traffic congestion in shanghai is very serious, the traffic is mainly concentrate in the city center, especially with in the inner ring, the transport in volume occupy 58% of the total volume of the transport volume in total Shanghai city. The congestion is also very serious, especially in the period of morning and evening rush hours.

According to the 4$^{th}$ Shanghai comprehensive traffic investigation, in 2009, the average travel speed of cars was decreasing constantly, the average speed in morning rush hours is around 20 km/h. The time consumption of each trip that use bus mode and rail mode is respectively 55 min and 70 min. The total average travel distance increase from 4.3 km in 1986, 4.5km in 1995, and 6.5km in 2009.

**(1) Conflict of traffic supply and demand**

The investment in transport infrastructure of Shanghai increased a lot, the supply level of transport infrastructure increased, but with the restriction of land use control and the frame of urban planning, the total increase of road infrastructure increased slowly, the road length increase rate was 8% from 1995 to 2009, but the urban road increase very slow, it increased from 3674 km in 2000 to 4400 in 2009, the increase rate is only 2%.

The traffic demand increase very quick, the trip generation rate of residential people increase from 1.7 in 1986 to 2.45 in 2009, the total population also increased from 12 million in 1986 to 23 million in 2009. The car ownership also increased very quickly, the detail amount can be seen from Table 3.1as follows.

Table 3.1 the change of registration of vehicle ownership (unit: million)

| Year | 1986 | 1995 | 2004 | 2009 |
|---|---|---|---|---|
| Number of vehicle | 0.16 | 0.56 | 2.11 | 2.43 |

Source: Shanghai statistical yearbook, 1978-2010

Job-housing unbalance is also very serious, the residential population is generally moved out from the city center, and the job is concentrating in the city center. According to the 4th Shanghai comprehensive traffic investigation, the population decrease 10% in the city center, while the job increased 2%.

**(2) Competition between public transport and private transport**

a) As shown in Table 3.2, public transport ratio is low, in the mode share of 2009, the ratio of public transport (bus, rail and taxi) is only 25.2%, while the ratio of private transport (private car, motor cycle) was 20%, the ratio of slow transport was 54.8%.

b) The increase of public transport share was very slow, while the increase of private transport quick. From 1995 to 2009, the public transport share only increased from 20% to 25.2%, while the share of private transport increased from 7.9% to 20%, that's mainly because of the quick car ownership increase as shown in Table 3.1. Slow transport share decreased from 69.1% to 54.8%. Fortunately, the share of the rail increased very quickly, that's because of the quick increase of operation rail length increase, but the ratio of rail transport is still very low. In term of rail service area of 600m's service radius of rail station, the coverage area is only 9% and the population coverage is only 16%, compared with the current situation of Tokyo, it's still need to be greatly improved.

### 3.3.2 Transport system development in Tokyo

Tokyo is the capital of Japan, the Tokyo metropolitan area includes Ibaraki-ken, Saitama-ken, Chiba-ken, and Kanagawa-ken ken, it has a area of 19651 $km^2$, the total population of 36.4 million in 2008, the population is 1853 person/km2. In the Tokyo 23 ward, it has a population of 8 million, within the 23 ward, it has 58% of the headquarter of big company, 47% of the financial department, 84% foreign company. The total job within 23 wards is 6.7 million, it means that most of the job is in the city center, while most people lived in the periphery area. Hence, the trip can be very frequent, the volume will also be big, and the trip is mainly concerned in the city center.

**(1) Rail development of Tokyo**

After Japan-Russia war, with the progress of industrialization, population moved to Tokyo, from the year of 1912, people started move to the suburban areas, this kind of tendency became more obvious after Kando-earthquake, after the earthquake, the population in the suburban area increased 2 to 6 times. Lot of the private railway company takes quick reflection to these changes, they realized the house price increase along the railway station, and then they developed a mode to jointly develop the house and the railway. They tried to provide high quality house and environment, and make the people live near the railway can arrive to the city center within 1 hour. And in the big interchange station, the business center and big shopping mall also opened.

In the 1920s, the city center and the suburban area are well connected by private railway, national railway and city train way. In the exchange station, such as Shinjuku, Shibuya, Ikebukuro, there are now agglomeration of business and office.

Tokyo's TOD development is started from private company, most of the Japan railway company searching for the other merchant chance and other business, the most profitable business of Japan is the real estate beside the railway station. As private company, they are perusing for biggest benefit, it include 2 parts: (1) max the land value of the railway station, (2) improve the efficiency of railway, to attract more population, and the high volume railway project generate more business center ,and the land value increase more. And at the same time, the real estate concentrated to the railway station, the nearer with the station, the higher the development density. And this situation became more advantage to the operation of railway.

To increase the value of railway, the railway company also attracts school, hospital, post office, library and other public facilities. These institutions not only increase the value of house, but also can provide passenger in non-peak hour. Because of these, the railway station became the local community center. And in the station, there are good walk system and bus route that cooperate with the time schedule of the railway.

**(2) The government attitude to TOD policy**

After second world, the Tokyo 23 ward's pop density increased a lot, the traffic congestion became a major problem for the society, and the development of auto increased the tendency, the rail became more and more congested, the longer congestion time, an the pollution and energy shortage, and the increase of the land price. On considering that, to develop new town beside Tokyo became a major policy for the government to reduce the traffic intensity and alleviate the traffic congestion. The development of Tokyo population is that: firstly, the population concentrated in the city center of Tokyo, till the population scale achieves some degree, the population started to spillover the 23 ward, the population was absorbed by the Tama district. In total, the population continually moves to Tokyo, and within Tokyo, the population generally moved from inner part to the outer side part.

At the same time, the motorization of the auto was developing quickly. The quick development of car was firstly in the Tokyo city, and then spill over to the outer areas. But the city transport policy and public transport infrastructure and service level slow down the development of the cars. Till 1990s, the car ownership of Tokyo 23 ward was obvious lower than the other area of Tokyo metropolitan area. In the outer part, because of the low service level of public transport, people relied more on the private transport, the car ownership became higher.

With the concentration of the population and the increase of the tendency of the motorization, the conflict of the road demand and the supply became more and more serious. In the starting period of motorization, the main way to solve it is to enlarge the road capacity. But the result was that, with the increasing of road, the improvement of road system, but the increase of road infrastructure of road cannot catch up with the increase of cars, the increased capacity was occupied by the increased car travel demand, the conflict of road supply and demand became worse.

To improve the attractiveness of public transport, in the Third national comprehensive development planning, Japan proposed that, there should be enough integrate in the road infrastructure and the land development. Tokyo had a high density development, they controlled the land development and integrated with the development with the transport infrastructure. In the planning of transport infrastructure, they firstly consider the demand of the rail transport, and then develop the other transport infrastructure. They use the high speed railway transport system connected the whole metropolitan area into a multi-center urban form.

Tokyo also paid special attention to the interchange and systematically organized the railway, bus, car parking and the bicycle parking and shops. That decreased the interchange time, and stimulates the business development. Besides that, from 1970s, Tokyo also developed the new transport mode and propose new planning concept, such as walking street, public bus Business Street, and air corridor and so on.

With these strategies and measures, in the 1990s, Tokyo has already built well organized public transport system, especially the railway system, the railway system became a quick cheap and on time mode, it connect the new city and Tokyo center, use the railway supported the highly developed and industrialized area with limited land.

### 3.4 Summary of comparison analysis of Shanghai and Tokyo

#### (1) Population

According to the review on Tokyo's population increase, the population distribution in Tokyo was more in the manner of TOD, DID areas in Tokyo was mainly around the railway, for the convenience in travel and the government's promotion of the development of the railway station. From 1998 to 2008, the population around railway station in Tokyo metropolitan area increased 1.88 million.

The population increase in Shanghai will keep a high speed, and the population will mainly spread to the suburban areas, because the land price is now very high in the central areas. Allocate increased to the suburban areas will be helpful for the improvement of the QOL (Quality of Life). So the control and the policy on the future population distribution especially in suburban areas will be very important to the urban development.

**(2) Economy**

In Tokyo metropolitan area is a global economic center, the economy kept a very stable status from 1990, but the economic structure was changing constantly, the share of the tertiary industry continually grew, it's now reached nearly 80%, the share of the second industry decreased, while the first industry can nearly be omitted.

In Shanghai ,the total economy grew very quick, the increase rate kept more than 8%, and the share of the tertiary industry was also increasing very quick, in 2010, the share of the tertiary industry was 50%, and the share of second industry decreased, the share of the first industry can nearly be omitted. The share of tertiary industry will continually grow and the growth of the tertiary industry will attract more and more people all over the country even the world to go to Shanghai for the work opportunities.

**(3) Transport and Land use system**

In transport system, the Tokyo's case can be a very good lesson and can be a very good experience for the integration land use and transport development. Especially the rail system development in Tokyo, the land around railway attract the majority of the population, it provided the most efficient method to develop a transport in a very high density and huge population. And the connection of the transport system and the city center contribute a lot to the development and the agglomeration of economy a lot.

The land use in shanghai is now changing very quickly, the quick increasing population will cause suburbanization, and the transport system that connect the suburban areas has not yet well built. In the urban planning of Shanghai, there are 9 new satellite cities, and there is not rail or the other high speed and efficient connection. Hence, the allocation should be well design or controlled to high efficiently use the land and strengthen the connection between the suburban areas and the city center.

# Chapter 4 Decomposition analysis of Shanghai and Tokyo inner-city passenger transport emission

This chapter first introduces the decomposition method, and then applies this method in urban transport sector in Shanghai and Tokyo to capture the main factor that affect $CO_2$ emission change. Based on the analysis, we get the causality diagram of Shanghai and Tokyo in different periods, and then make a conclusion.

## 4.1 Introduction

As we stated before, the amount of energy consumption in the transport sector is affected by many factors such as the energy intensity of vehicles, travel distance and so on. Therefore, there is a certain relationship between the change of energy consumption and the changes of these factors mathematically. That is to say, the amount of change of each factor decides the amount of total change. Decomposition analysis mainly focuses on the decomposition of the change in total amount and distributes the change into the effects of its factors under certain rules.

It mainly deals with the issues whose total amount can be expressed by the factors multiplied together. By the done studies, the index decomposition analysis is currently broadly used as tool for policy maker to use on the national energy and environmental issues. With the development of the method, a lot of mathematics algorithms are applied to the calculation of the decomposition. Scanning over the studies done by various researchers in recent years, we could find that the most widely used decomposition methods are apparently the Laspeyres method and the Divisia method, which are able to give decomposition results easily and reasonably. But the trouble these two initial methods may bring in is that a factor left unexplained always exists, and this unexplained factor could be beyond imagination and lead to improper results. Consequently, two other methods were developed separately to achieve perfect decomposition. At present, most of the decomposition studies are based on these improved methods. In this section, we show the results of decomposing a three-factor case, for the sake of simplicity, by the two methods discussed by Ang,B.W et al. in 2003. Under the principle of these methods, the decomposition with more factors can be done in the similar way.

There are various kinds of decomposition analysis could be used to measure the influences of different facts on $CO_2$ emission. In literatures, two widely used method, namely SDA and IDA, were widely used to measure the driving factors[74]. The former is on the basis of I-O model, while the latter uses index number concept in decomposition. Ang compared lots of index decomposition method, the result suggested that LMDI was better because it has good theoretical base, it can adapt with many situation and it's also very easy to use and easy to interpret.[14]

LMDI method consists of two kinds, one of which is additive LMDI method and the other is multiplicative LMDI method. Essentially, these two methods are similar. However, the results of additive LMDI method can be compared with each other more conveniently, because they are absolute values. However, the results of multiplicative

LMDI result are relative values so that they can hardly be compared in different cases.

Although there are some scholars who have used decomposition technique to carry out studies on $CO_2$ emission of the transport sector, for example, Govinda used LMDI method to analyze $CO_2$ emission in the whole transport sectors of Asian countries and found different driving forces for $CO_2$ emission in these countries, the decomposition methods are seldom applied to researches on $CO_2$ emission of the freight transport sector. Especially in developing passenger transport sector.

Undoubtedly, urban passenger transport is one of the most important parts in transport sector. With the development of economy and the configuration of economy sector, income and activities of goods movement have been changing. To find out the causes, index decomposition method is employed in this study.

## 4.2 $CO_2$ emission and decomposition of Shanghai urban transport

Shanghai, one of the most urbanized metropolitan areas of China over the past 30 years, is experiencing rapid urban sprawl and motorization. Shanghai is divided into 3 areas: inner city, peripheral area and suburban area.

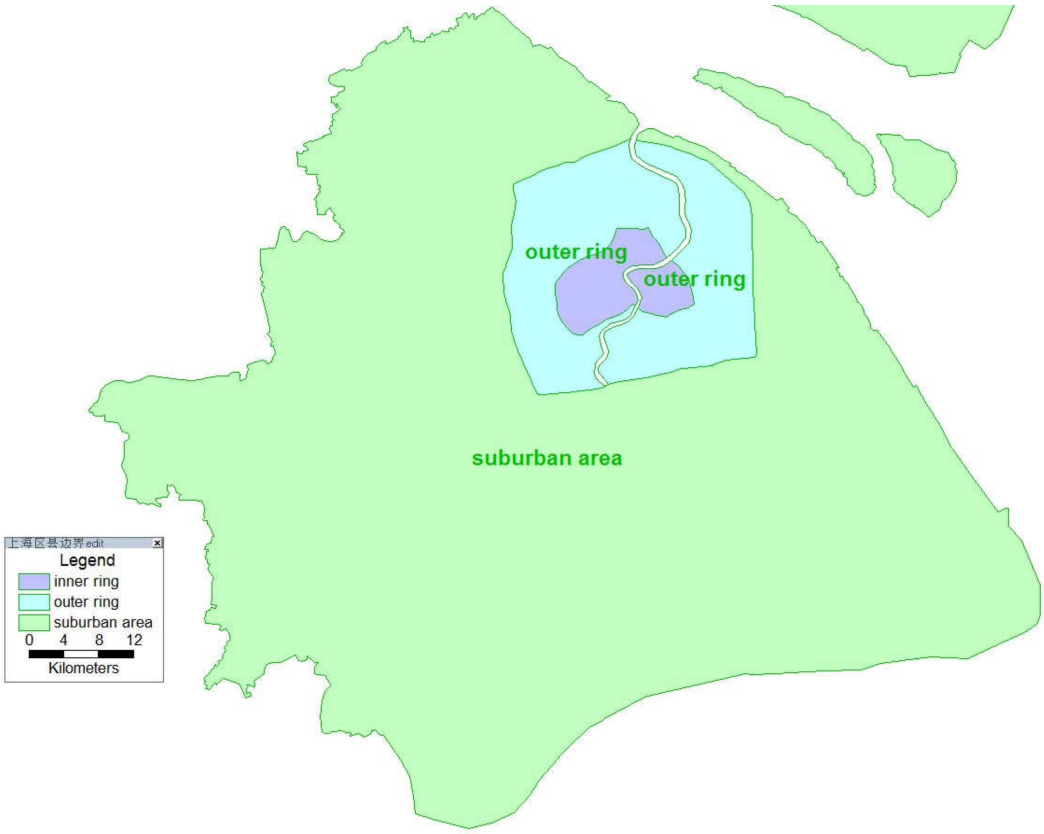



Fig4.1 Objective area of Shanghai

(Source: Report of Shanghai Transportation Survey in 2009)

### 4.2.1 Data

The data of population is from Shanghai statistical yearbooks, the data of railway energy efficiency is from report of Shentong Group[75], who is the operator of Shanghai's metro system, and the data of car fuel efficiency is from other local researcher's report and papers[76]. The data of Shanghai mode share, trip rate and travel distance in this study is from Shanghai Investigation report of comprehensive transportation in Shanghai in the year of 1995, 2004 and 2009[77].

### 4.2.2 Methodology

The total $CO_2$ emissions can be obtained by equation 4-1.

$$C^{t}=POP\times TN_{i}\times MS_{i}\times DT_{i}\times LF_{i}\times EF_{i} \tag{4-1}$$

$POP$: population of the year t, unit: person

$TN_i$: trip generation rate, unit: trip/person

$DT_i$: average travel distance of i mode, unit: km/passenger

$MS_i$: mode share, unit: %

$LF_i$: load factor, how many people use on car/bus/transport equipment,

unit: vehicle-km/passenger

$EF_i$: emission factor, unit:$CO_2$ / vehicle-km

Each individual factor that affects $CO_2$ emission from the base year to the year t can be calculated as equation 4-3 as shown:

$$\Delta C_{tot}=\Delta C_{POP}+\Delta C_{TN}+\Delta C_{MS}+\Delta C_{DT}+\Delta C_{LF}+\Delta C_{FE} \tag{4-2}$$

Each variable in this equation can be calculated as follows by using the LMDI method as follows:

$$\Delta C_{POP}=\sum_{i}\Delta C_{POP,i}$$
$$=\begin{cases}\Delta C_{POP,i}=0, \quad \text{if} \quad C_i^t\times C_i^0=0\\ \Delta C_{POP,i}=\sum_{i}L\left(C_i^t,C_i^0\right)\ln\left(\dfrac{POP_i^t}{POP_i^0}\right), \text{if} \quad C_i^t\times C_i^0\neq 0\end{cases}$$

$$\Delta C_{TN}=\sum_{i}\Delta C_{TN,i}$$
$$=\begin{cases}\Delta C_{N,i}=0, \quad \text{if} \quad C_i^t\times C_i^0=0\\ \Delta C_{TN,i}=\sum_{i}L\left(C_i^t,C_i^0\right)\ln\left(\dfrac{TN_i^t}{TN_i^0}\right), \text{if} \quad C_i^t\times C_i^0\neq 0\end{cases}$$

$$\Delta C_{MS} = \sum_i \Delta C_{MS,i}$$

$$= \begin{cases} \Delta C_{MS,i} = 0, \quad \text{if} \quad C_i^t \times C_i^0 = 0 \\ \Delta C_{MS,i} = \sum_i L\left(C_i^t, C_i^0\right) \ln\left(\frac{MS_i^t}{MS_i^0}\right), \text{if} \quad C_i^t \times C_i^0 \neq 0 \end{cases}$$

$$\Delta C_{DT} = \sum_i \Delta C_{DT,i}$$

$$= \begin{cases} \Delta C_{DT,i} = 0, \quad \text{if} \quad C_i^t \times C_i^0 = 0 \\ \Delta C_{DT,i} = \sum_i L\left(C_i^t, C_i^0\right) \ln\left(\frac{DT_i^t}{DT_i^0}\right), \text{if} \quad C_i^t \times C_i^0 \neq 0 \end{cases}$$

$$\Delta C_{LF} = \sum_i \Delta C_{LF,i}$$

$$= \begin{cases} \Delta C_{LF,i} = 0, \quad \text{if} \quad C_i^t \times C_i^0 = 0 \\ \Delta C_{LF,i} = \sum_i L\left(C_i^t, C_i^0\right) \ln\left(\frac{LF_i^t}{LF_i^0}\right), \text{if} \quad C_i^t \times C_i^0 \neq 0 \end{cases}$$

$$\Delta C_{EF} = \sum_i \Delta C_{EF,i}$$

$$= \begin{cases} \Delta C_{EF,i} = 0, \quad \text{if} \quad C_i^t \times C_i^0 = 0 \\ \Delta C_{EF,i} = \sum_i L\left(C_i^t, C_i^0\right) \ln\left(\frac{EF_i^t}{EF_i^0}\right), \text{if} \quad C_i^t \times C_i^0 \neq 0 \end{cases}$$

$$\text{where, } L(a,b) = (a-b)/(\text{In}a - \text{In}b) \qquad (4\text{-}3)$$

Each component in equation (4-3) stands for different factors that affect $CO_2$ emission. $\Delta C_{POP}$ is utilized to state how much population affects $CO_2$ emission of the urban transport sector, $\Delta C_{TN}$ is used to describe how much average trip generation rate affects $CO_2$ emission of the urban passenger transport sector, $\Delta C_{DT}$ is used to describe how much average travel distance affect $CO_2$ emission of the urban passenger transport sector, $\Delta C_{MS}$ is used to describe how much load factor affect $CO_2$ emission of the urban passenger transport sector, $\Delta C_{EF}$ is use to describe how emission efficiency affect $CO_2$ emission of the urban passenger transport sector.

### 4.2.3 Result

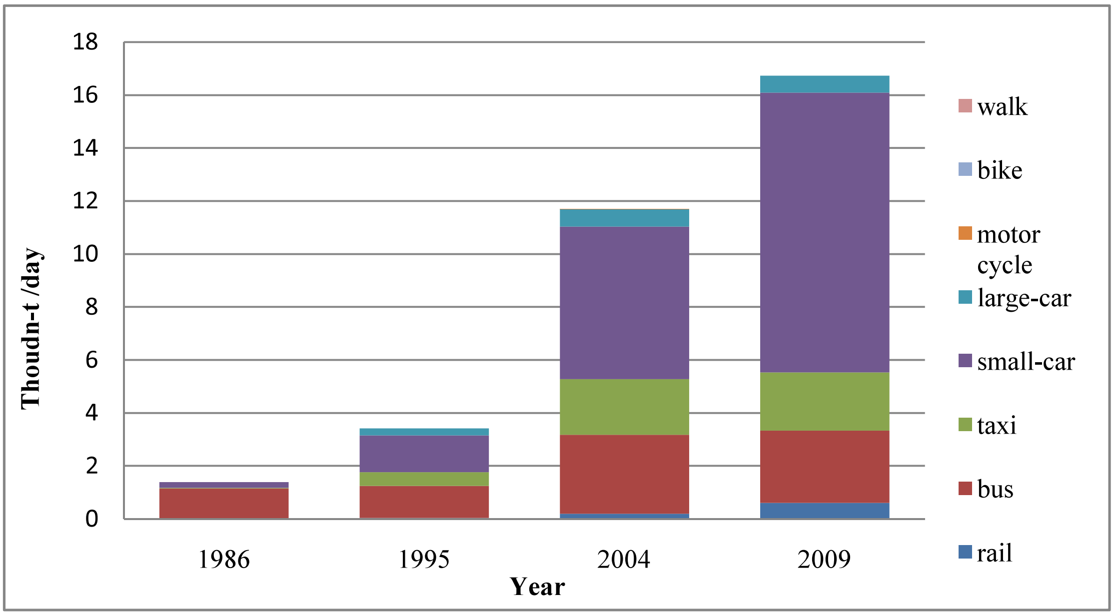



Fig 4.2 $CO_2$ emission of passenger transport sector in Shanghai

From Fig 4.2, we can see that, the total $CO_2$ emission is increased from 1.4 thousand-t in 1986, 3.4 thousand-t in 1995 to 11.7 thousand-t in 2004 and then to 16.7 thousand-t in 2009, the increase ratio is 12% yearly. At the same time, the GDP of Shanghai is \$561 in 1986 and \$2525 in 1995 and \$6284 in 2004 and \$9724 in 2009. The increase ratio is 13%, the total transport sector $CO_2$ emission increase ratio is similar with the economic development.

In the year of 1995, we find that the main contributor of $CO_2$ emission is the small vehicle and bus, in the year of 2004, the share of small vehicle and bus increase, in the year of 2009, the share of small vehicle increase a lot but the share of bus decrease, that's because the number of vehicle increase a lot and hence the use of small vehicle is more frequent.

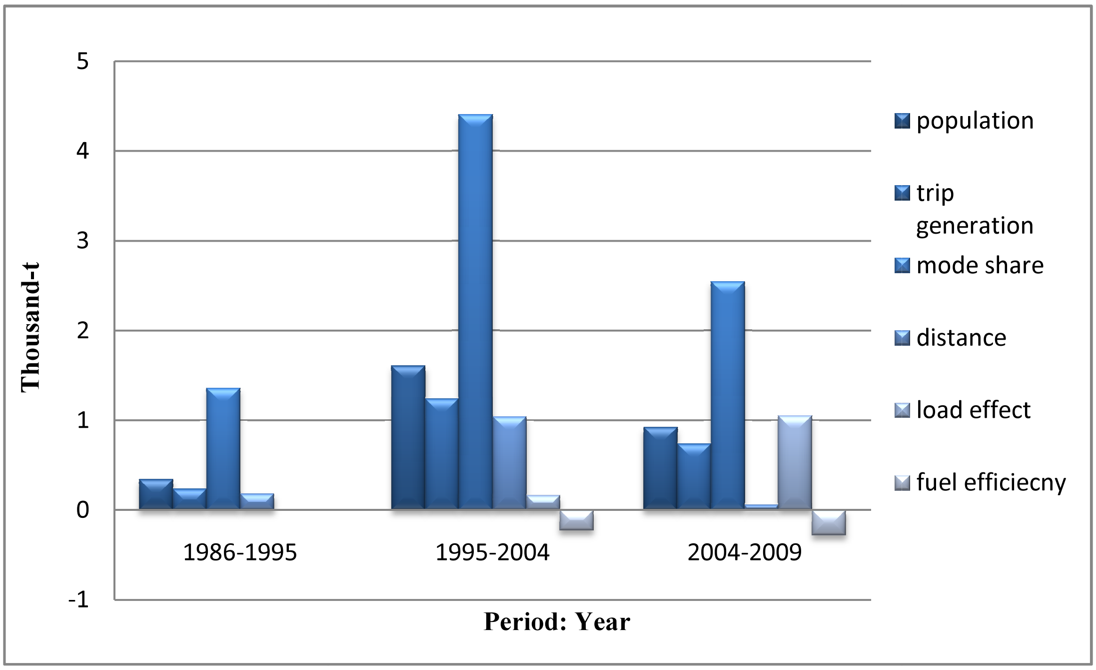



Fig4.3 Decomposition result of Shanghai

We can see from the result, all the influence factor have positive impact on $CO_2$ emission. The biggest contributor is the mode share, the second is the population increase, the third is average trip times and then travel distance. The mode share is the biggest contributor, we can see from Fig 4.3, in the year of 1986, there is nearly no private vehicle, the motorization is not yet start, at that time, people's income is very low and they cannot afford personal traffic, most of the people choose walk and bicycle, this trend kept till 1995. We can see from the mode share as shown in Fig 4.6, we can see that the share of eco-friendly mode such as bike, walk and bus were decreasing constantly. While the share of small car and taxi was increasing dramatically. The share of zero emission modes (walk and bicycle) was 73% in 1986, 72% in 1995, 55% in 2004 and 51% in 2009. Because of the longer travel distance, hence more and more people choose the motorized travel mode. In the year of 1986, the biggest share is bike and walk, the third largest share is bus. From 1995 to 2009, the share of small car and large car was increasing quickly, the share of walk and bicycle was decreasing constantly because of bad environment for bicycle and walk, people trends to use car more and more, there is another phenomena, the share of rail increased constantly, that's because the supply of rail is more and more. It reached 420km till the end of the year of 2009, the share of the rail also increased from 0.8% in 1995 to 7.5% in 2009.

**(1) Cause of travel demand---population, trip rate and travel distance**

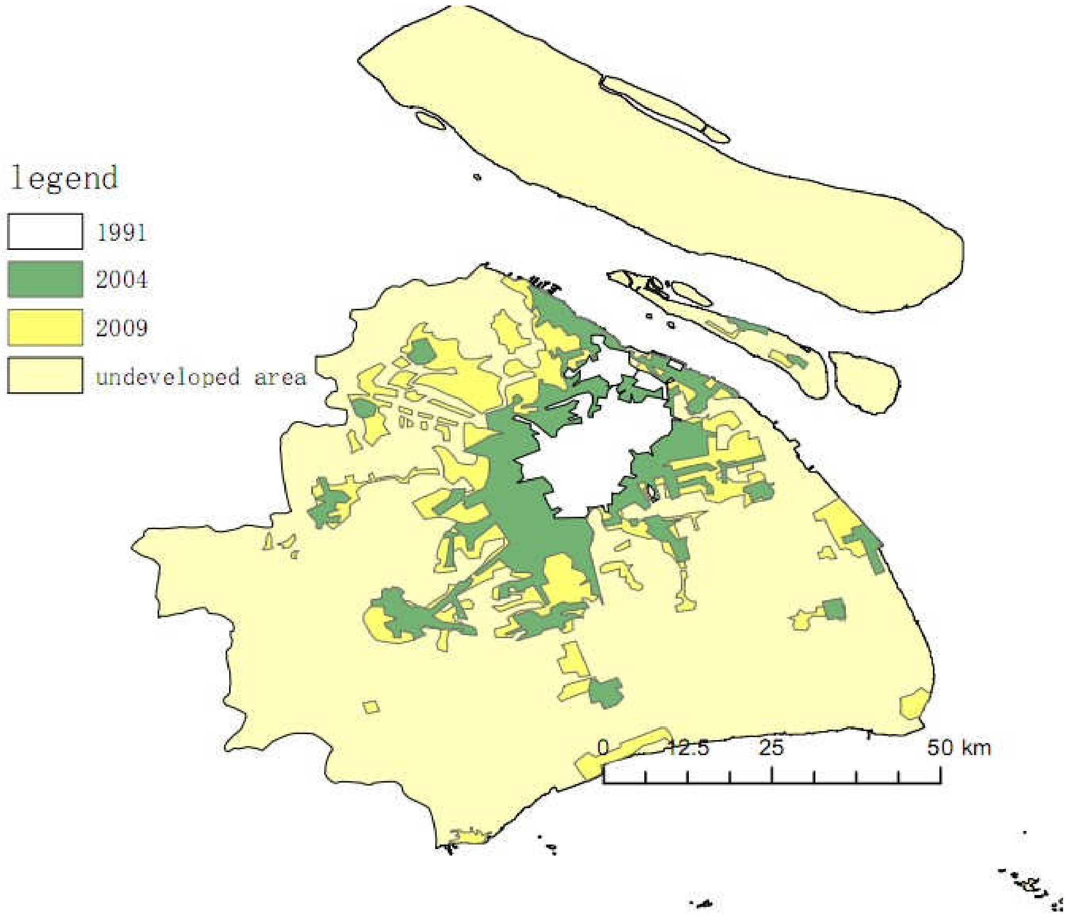



Fig 4.4 Build-up area in Shanghai (1991,2004,2009) [73]

(Source: authors' drawing based on the picture in the Report of Shanghai Transportation Survey in 2004,2009)

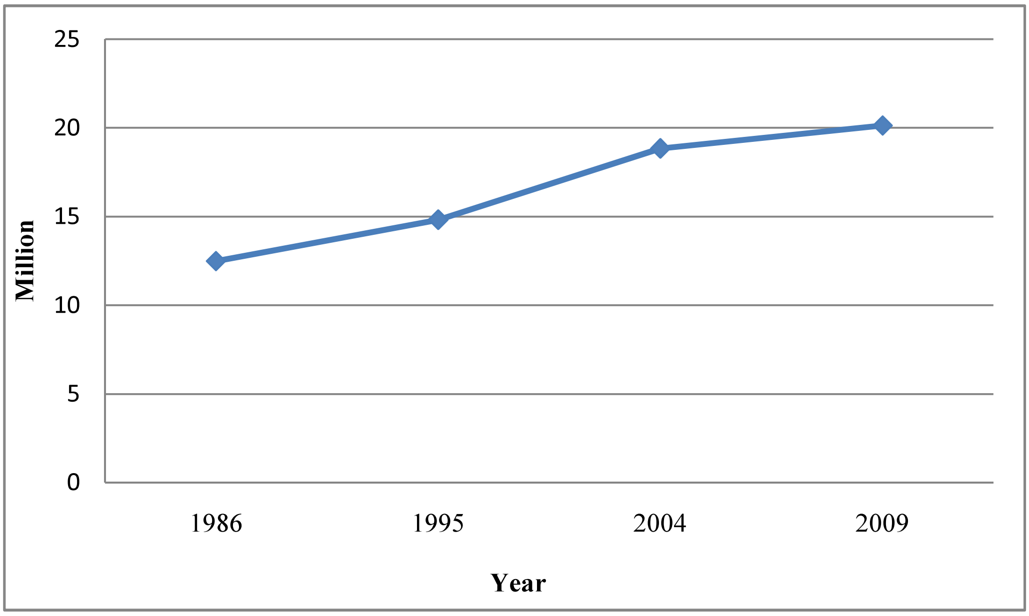



Fig 4.5 Population in Shanghai

(Source: Report of Shanghai Transportation Survey in 2009)

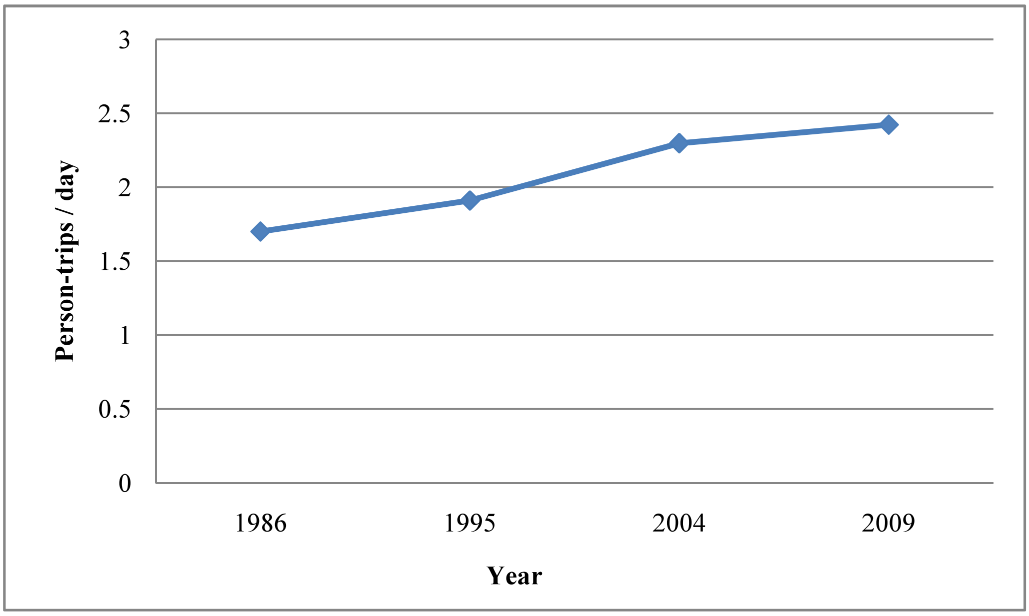



Fig 4.6 Trip generation rate in Shanghai

(Source: Report of Shanghai Transportation Survey in 2009, 2004, 1995)

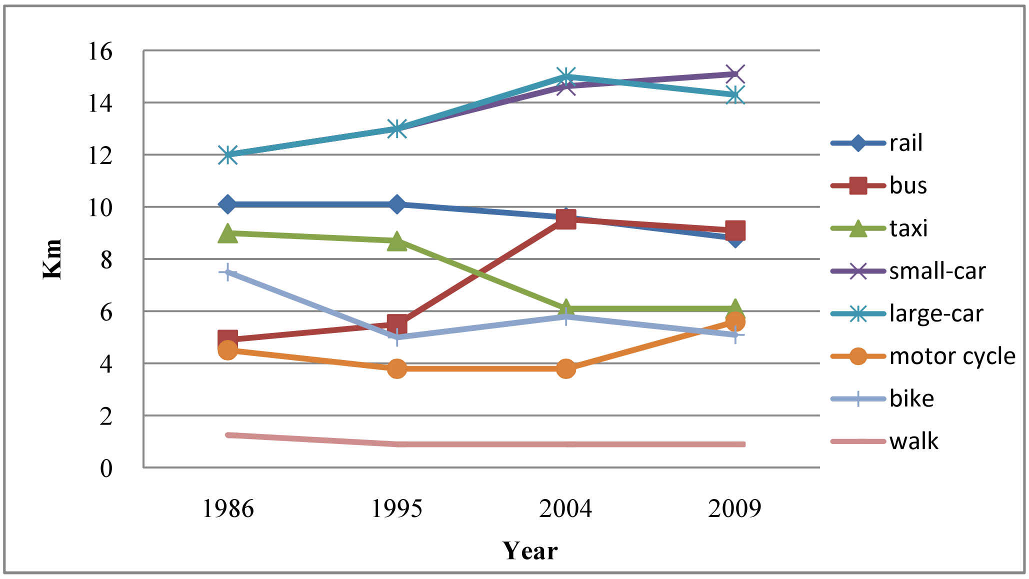



Fig 4.7 Travel distance by mode in Shanghai

(Source: Report of Shanghai Transportation Survey in 2009, 2004, 1995)

As shown in Fig4.4, built-up area in Shanghai increase quickly, the built-up area increased from 203 $km^2$ in 1986 to 2303 $km^2$ in 2009, the annual increase rate is 11%. The population and the average travel times in shanghai increased constantly, as shown in Fig 4.5 and Fig 4.6, the population increased from 1249 in 1986 to 2013 in 2009, the average trip times is increased from 1.7 to 2.42. The increase of population is uncontrollable because the economic development attracts more people move in Shanghai for chances.

The average trip generation also increase from 1.7 in 1986 to 2.4 in 2009, the objective of travel is firstly mainly for commuting and then the share for entrainment increase. The population of central area decrease from 1986 to 2004 is from 4.85million to 4.05 million, the share of total population decrease from 37.4% to 23.%. The averag travel distance increased from 4.3km in 1986 to 6.9 in 2009, the average travel time was increased from 25min in 1986 to 33.2min in 2004. The detail travel distance by mode can be shown in Fig 4.7,we can see that the average distance of rail increase because of the rail decreased, even the rail expand in the suburban area, the travel distance does not changed a lot.

**(2) Cause of travel mode share change**

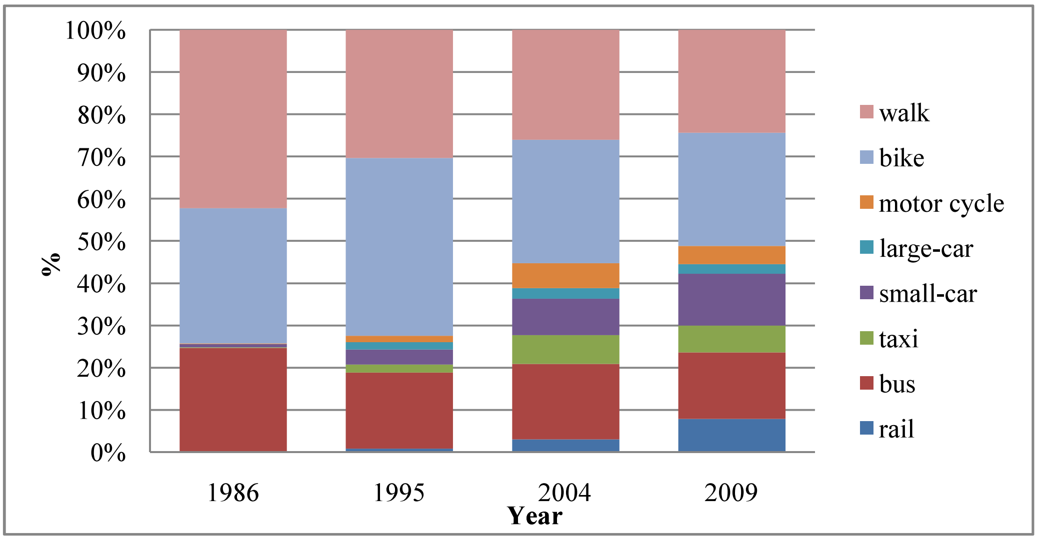



Fig 4.8 Mode share change in Shanghai

(Source: Report of Shanghai Transportation Survey in 2009, 2004, 1995)

Table 4.1 Service level of bus

| | 1986 | 1995 | 2004 | 2009 |
|---|---|---|---|---|
| Bus on operation | 5505 | 11637 | 18186 | 16513 |
| Passenger seat on operation | 73.6 | 92.2 | 121.1 | 118.4 |
| Bus ownership per 10000 person | 4.5 | 5.7 | 9.67 | 8.2 |

Source: PT investigation in Shanghai [82]

Table 4.2 service level of bus

| | Trip length (km/per time) | Travel time | Car speed(km/h) |
|---|---|---|---|
| 1986 | 8.7 | 48 | 10.9 |
| 1995 | 6.6 | 62 | 6.4 |
| 2004 | 8.4 | 58 | 8.7 |
| 2009 | 8.8 | 60 | 8.8 |

Source: PT investigation in Shanghai [82]

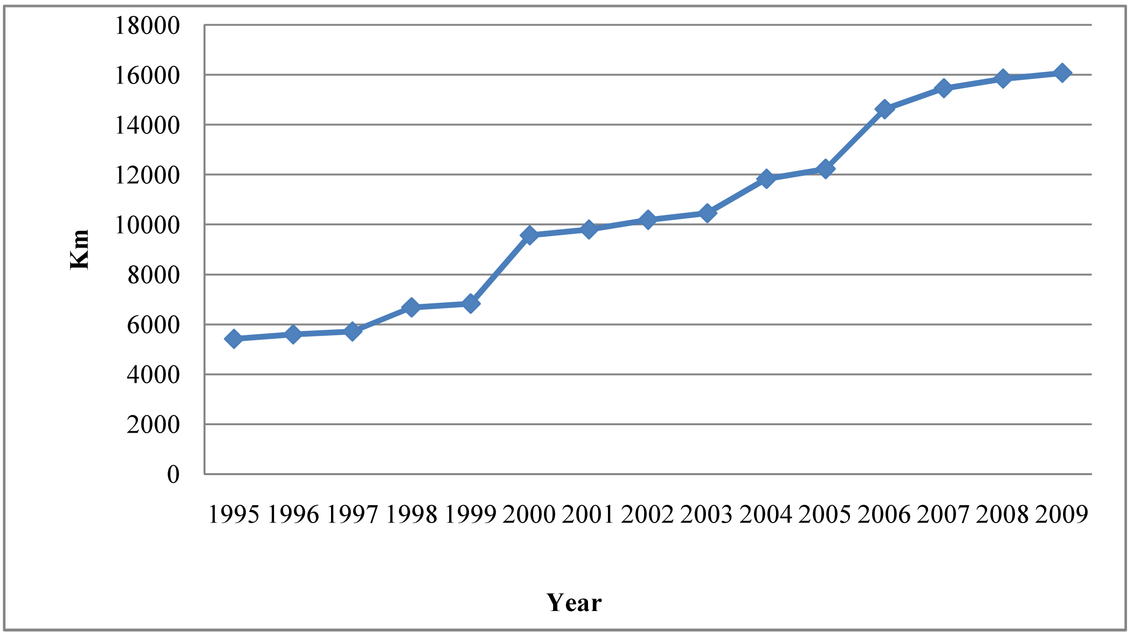



Fig 4.9 Road length in Shanghai

(Source: Report of Shanghai Transportation Survey in 2009[82])

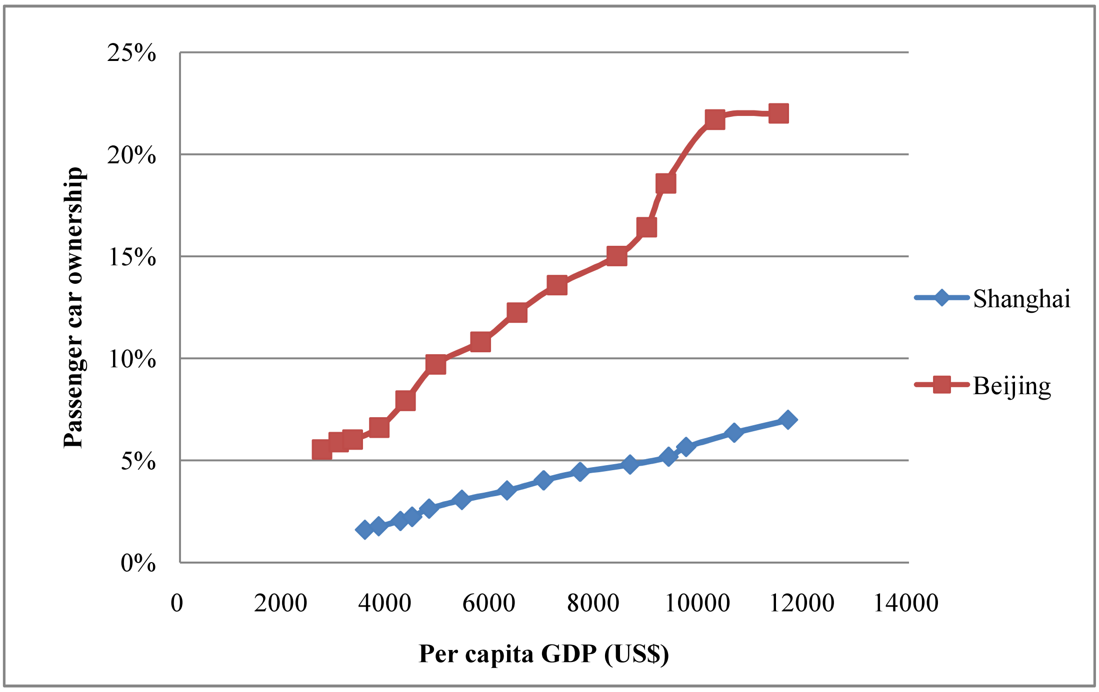



Fig 4.10 Car ownership in Shanghai and Beijing

(Source: Shanghai statistical yearbook, Beijing statistical yearbook[78])

From the table we can see that, the bus of every people is increasing constantly, but the share of bus is decreasing or keeping constant, that's because the other competitor is increasing and the service level of the other mode was increasing. The travel distance of bus first decreased and then increased, the service level of bus was increasing from 1995, that's because of the investment in bus and policy for bus first and so on. Shanghai use car plate auction policy from 1986, the road infrastructure investment of Beijing is higher than that of shanghai but the traffic situation is worse than Shanghai.

**(3) Cause of travel fuel efficiency and occupancy rate change**

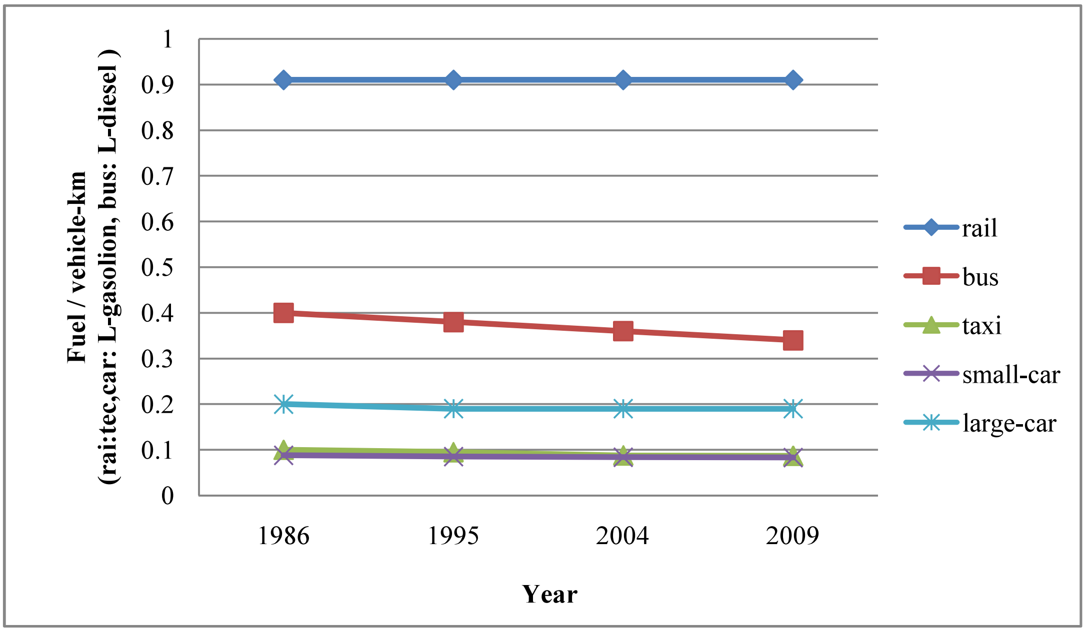



Fig 4.11 Fuel efficiency change in Shanghai

(Source: data of rail is from Yearbook of Shentong[78], data of taxi, bus, small car, large car is from local research's data[79])

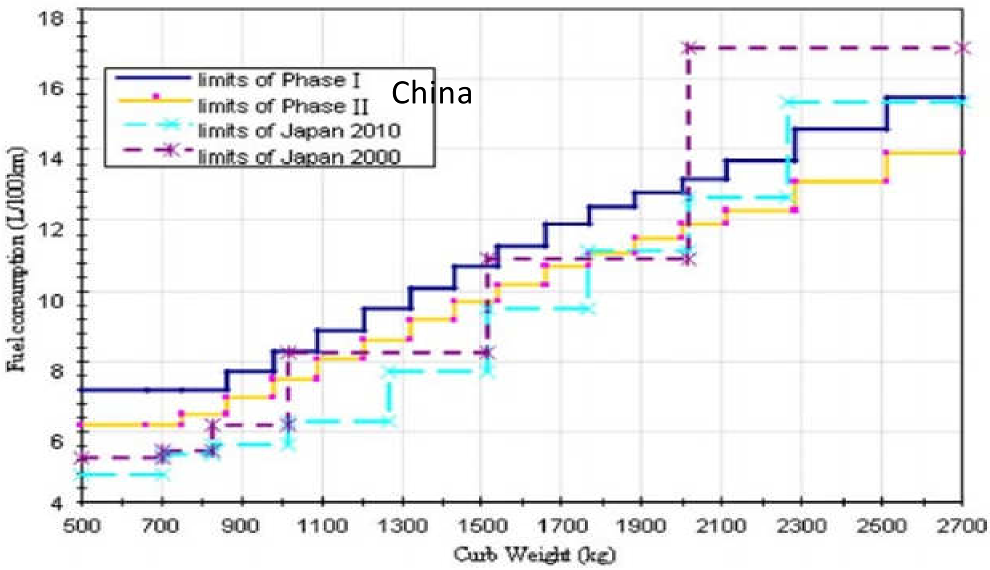



Fig 4.12 Limits of Fuel Consumption for Passenger Cars

(Source: National Code, Limits of Fuel Consumption for Passenger Cars)

The Fuel efficiency has became better that's becau of the engine technoloyg has improved slightly, and the oil price increase has also stimulate the auto company to develop high efficient engine. And China also publish Limits of Fuel Consumption for Passenger Cars (GB19578-2004)[80] in 2004, this code also contribute to the improvement of fuel efficiecny. In terms of occupancy rate, the occupancy rate of private car decrease from 2 in 1986 to 1.7 in 2009, and the occupancy rate of taxi decreas from 1.8 to 1.6, that's mainly becaue of the income growth and more diverse aim of travel.

**(4) Analysis of the investment and financial system in Shanghai transport system**

Because of the government always has the certain budget of the investment, so how use the limit budget for the biggest user benefit will be important, the sustainable transport system should not only focus on the infrastructure, but it also should have a sustainable financial system to support the transport development.

Hereafter is the investment structure of Shanghai transport system recently.

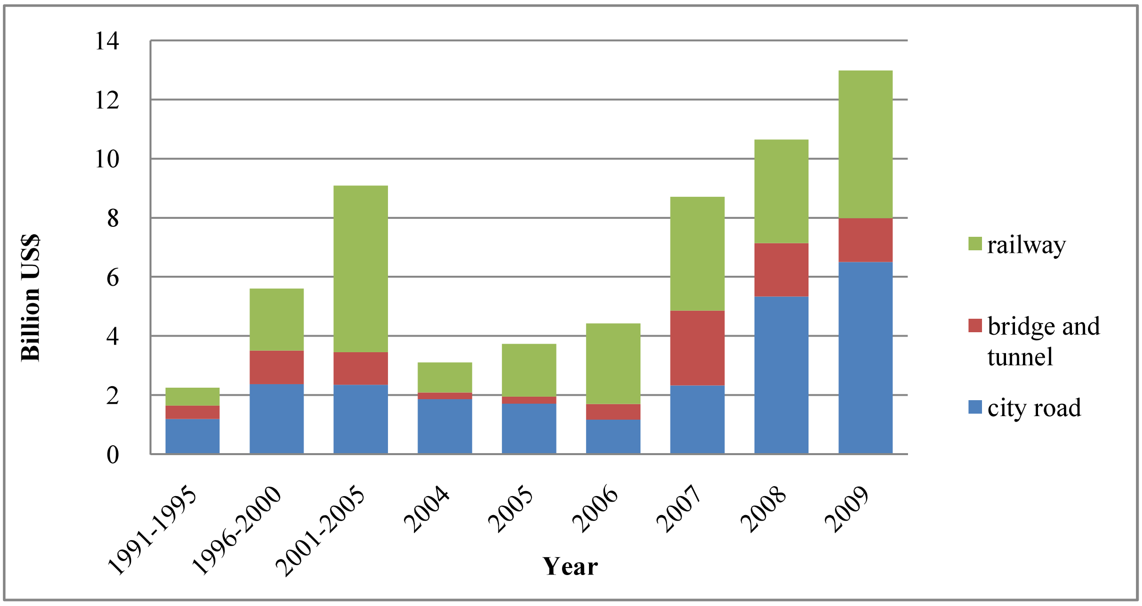



Fig 4.13 Infrastructure investment in Shanghai

(Source: Report of Shanghai Transportation Survey in 2009)

As we can see from the Fig 4.13, the investment was increasing quickly year by year, the investment of rail occupy big share of the investment. From 2005 to 2009, the investment in the railway system was 17.8 billion US$. Till 2009, the total railway length achieved 355 km, and has 255 railway stations. And in the year of 2009, the total railway transport volume was 3.61 million times per day, the average travel distance of railway was 17.8km, the turnover of railway was 42.2 million person-km/day. While in 2004, the total railway system length was 92.5km, and there are 68 stations. The railway transport volume was 0.95 million, the average travel distance by rail was 12.1 km, the turnover of railway was 11.8 million person-km/day. From 2005 to 2009 the investment in the road system was 132 billion. in 2004, the traffic volume increase in road was increased from 4.28 million in private car and 197 in taxi and 607 in bus, the traffic turnover of bus was 49.9 million person-km, taxi was 1593 and 7550 was private car. The detail data was shown in the following Tables.

Table 4.3 Transport supply

| | Travel generation(million) in 2004 | Turnover(million passenger-km) in 2004 | Travel generation(million) in 2009 | Turnover( million passenger-km) in 2009 | Investment from 2004 to 2009(billion) |
|---|---|---|---|---|---|
| rail | 0.95 | 11.79 | 3.86 | 68.7 | 125.2 |
| Bus | 6.07 | 49.22 | 7.67 | 69.7 | |
| Taxi | 1.97 | 15.93 | 3.11 | 18.9 | |
| Private car | 4.28 | 75.50 | 7.1 | 10.0 | 132.3 |

Source: PT investigation in Shanghai [82]

So, based on Table 4.3, the (△Turnover/ △investment ) $_{rail}$ = 4.54, (△Turnover/ △investment ) $_{(private\ car+taxi)}$ = 2.1

From the investment achievement we can see that, even the investment in the railway was very high, but it can absorb more traffic volume. The marginal effect of the railway was much higher than that of road. The average travel speed of the road actually decreased.

What's more, the investment in the road make the road occupies more and more space, which is not accounted as the cost. And the construction of the railway we can capture the value of the land price increase more easily, based on Liu's research (2011) of value capture,

## 4.3 $CO_2$ emission and decomposition of Tokyo urban transport

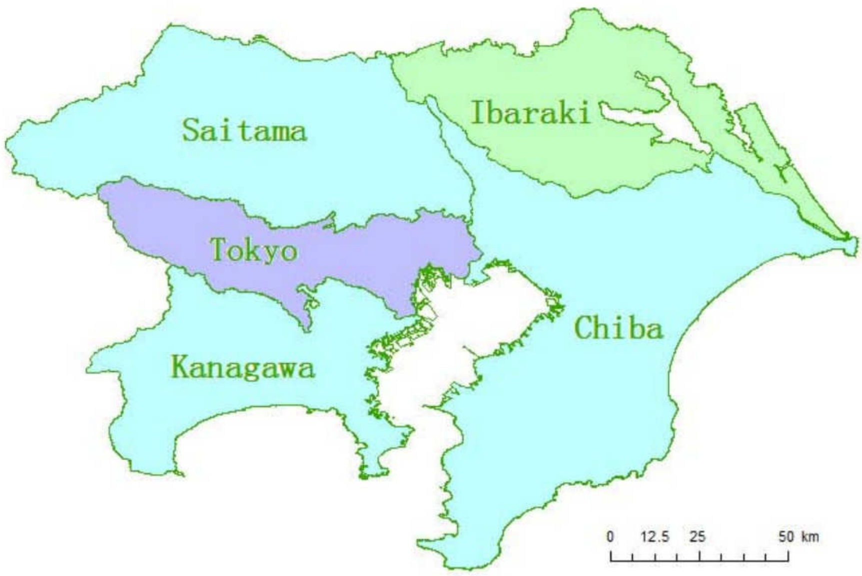



Fig 4.14 Introduction of Tokyo metropolitan area

(Source: Report of 5th Tokyo metropolitan area PT investigation[81])

Tokyo metropolitan area, the biggest city in Japan, has experienced quick development since the Second World War. It now has a population of 36 million and area of 17000 $km^2$.

### 4.3.1 Data

The data of car energy efficiency is from Japan automobile statistical yearbooks[82,83], the data of railway efficiency is from Japan railway statistical yearbooks[84,85]. The data of Tokyo mode share, trip rate is from Tokyo Personal trip investigation held in 1968,1978,1988,1998 and 2008[86]. The travel distance is partly from the statistical yearbooks and partly from the Personal trip investigation of Tokyo in each corresponding year. The methodology is the same as that of Shanghai as described in section 4.2.2

### 4.3.2 $CO_2$ emission and decomposition result

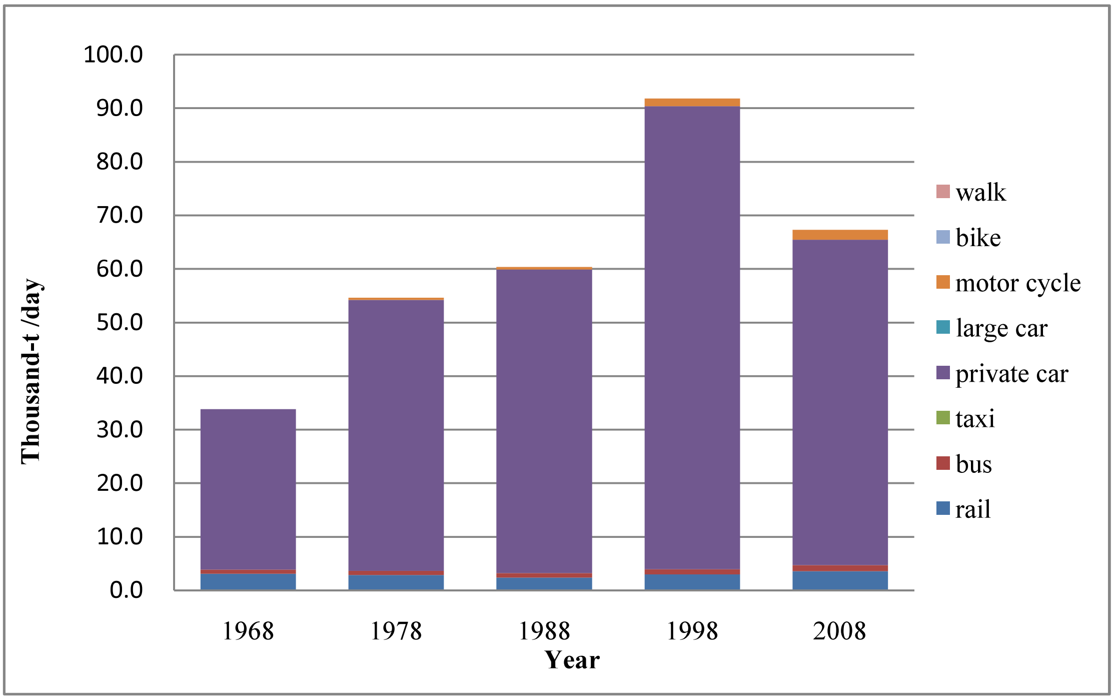



Fig 4.15 $CO_2$ emission in Tokyo urban passenger transport sector

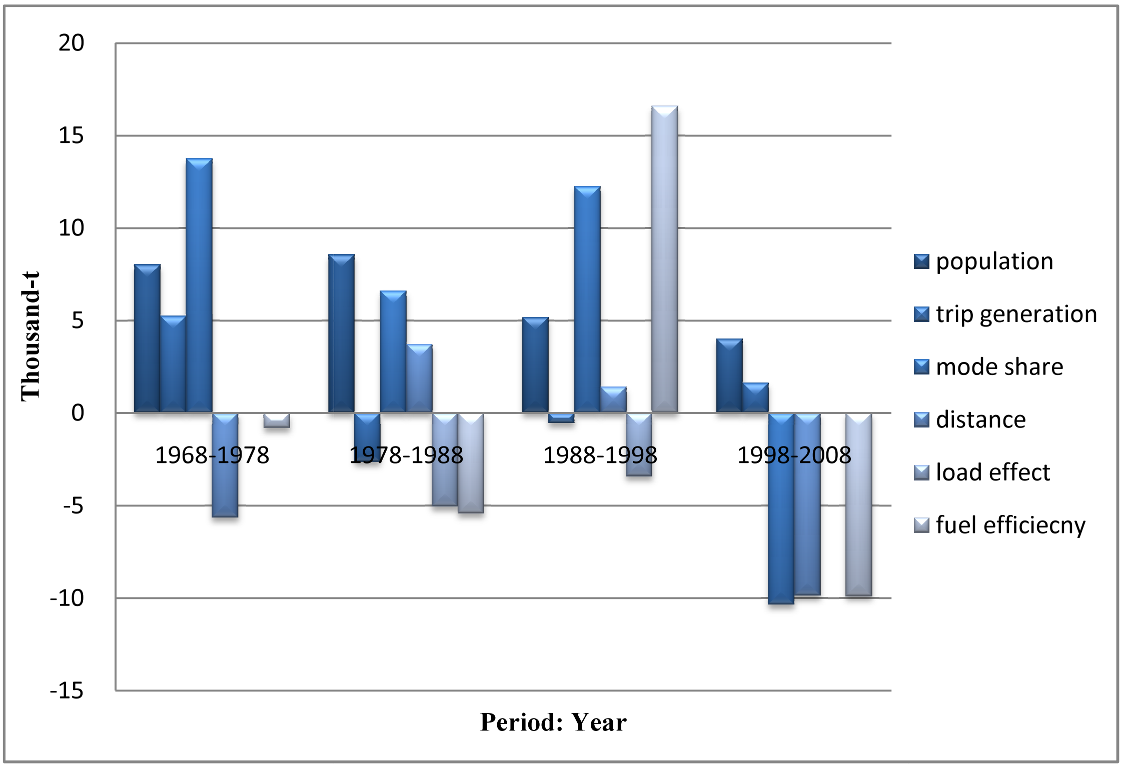



Fig 4.16 Decomposition result of Tokyo

From the Fig 4.15, we can see that the $CO_2$ emission increased from 1968 to 1998 and then decreased from 1998 to 2008. The main contributor is the private car mode, the second biggest contributor is the rail, and the third contributor is the bus. We can see that, in each year, the car contributed more than 90% of the total $CO_2$ emission, and the absolute value of the car oriented $CO_2$ emission kept a steadily increase trend.

The contribution of each factor affect $CO_2$ emission in Tokyo is shown in Fig 4.16, we see that the population effect constantly kept a positive effect to $CO_2$ emission. The effect of trip rate is positive from 1968 to 1978, and then negative in the period of 1978-1988 and 1988-1998, and then became positive from 1998 to 2008. Mode shift effect shows positive in the previous 3 periods and shows negative effect in the last period. The load effect always shows the negative effect because of the improvement of occupancy rate. What interesting is that, the fuel efficiency shows small negative effect from 1968-1978, and stronger negative effect from 1978 to 1998 and suddenly positive effect from 1988-2008 and then sudden negative effect from 1998-2008, that's mainly because of the energy technology improvement and people's preference changes on car. The distance effect shows negative effect from 1968-1978, and shows positive effect form 1978-1988 and 1988-1998, and then again shows negative effect from 1998-2008.

Hereafter we introduce that cause of each factor.

**(1) Cause of travel demand---population, trip rate and travel distance**

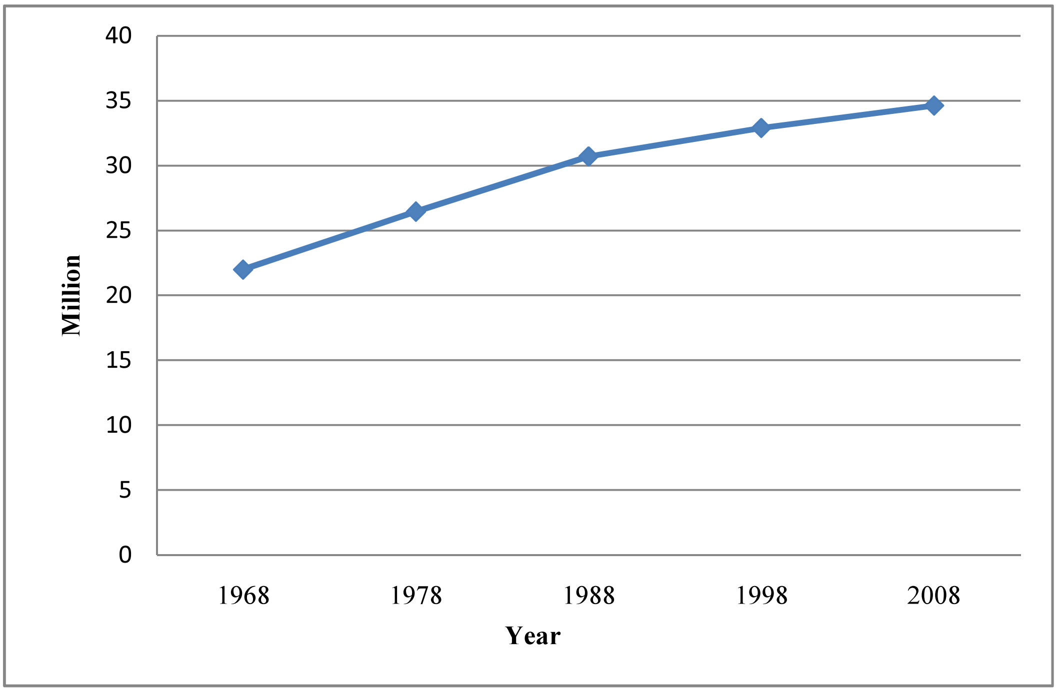
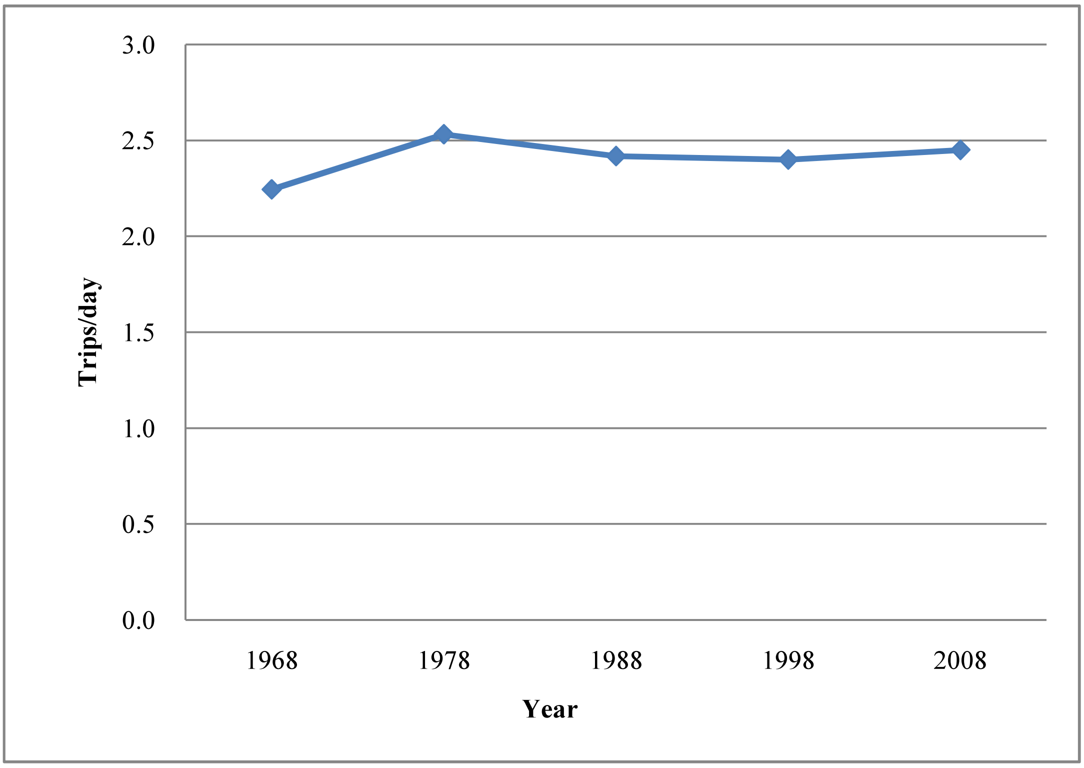



Fig 4.17 Population in Tokyo metropolitan area

(Source: PT investigation of Tokyo in 1968, 1978, 1988, 1998, 2008)




()

Fig 4.18 Trip rate in Tokyo metropolitan area

(Source: PT investigation of Tokyo in 1968, 1978, 1988, 1998, 2008)

The population increase constantly in Tokyo because more and more work opportunity occurs in Tokyo, so the population increased in a very high speed, the population increase rate of these 4 periods was respectively 1.8%, 1.5%, 0.6% and 0.4%, hence the population effect contributes 7.9 thousand-t, 8.5 thousand-t, 5.1 thousand-t and 4 thousand-t in each period. The trip rat of Tokyo was increased from 2.24 to 2.45 from 1968 to 1978, and then decreased a little to 2.41 and then kept a constant value, accordingly, the contribution of tripe rate was 5.2 thousand-t, -2.65 thousand-t, -0.5 thousand-t and 1.6 thousand-t in each period. It seems that the contribution of trip rate is now stable, while the population increase in Tokyo is still going on by the economic attractiveness.

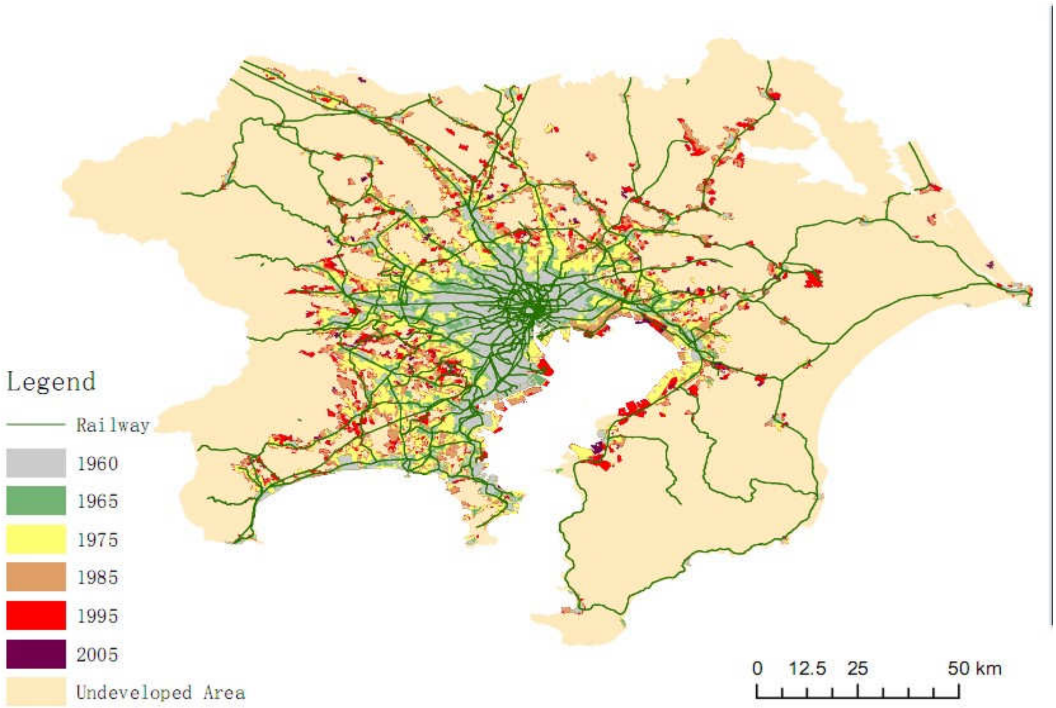



Fig 4.19 DID area change in Tokyo metropolitan area

(Source: website of Japan National Land information Division, National and Regional Bureau[87])

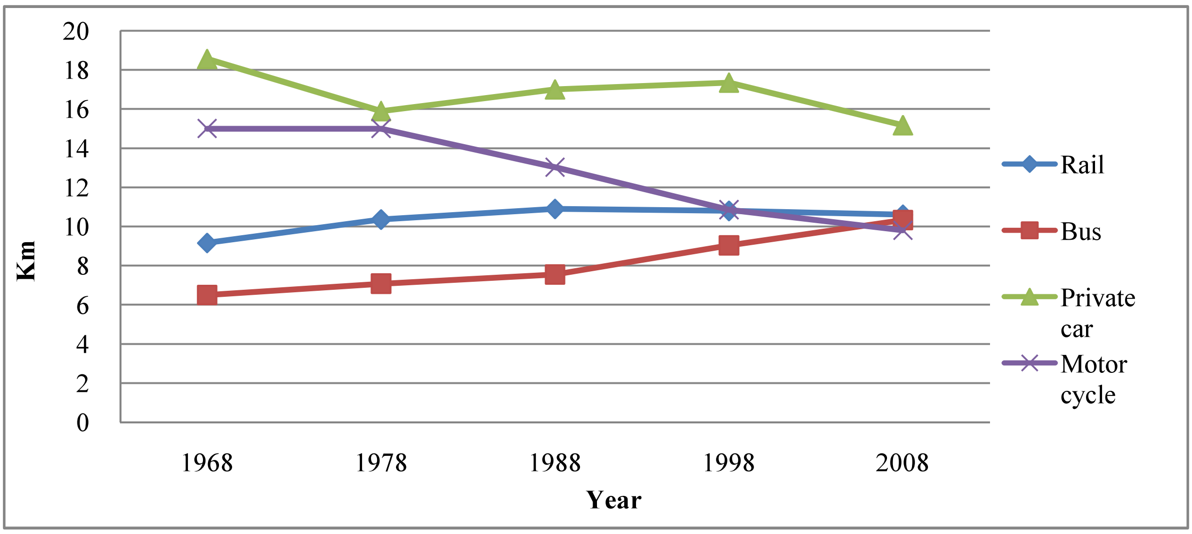



Fig 4.20 Travel distance by mode in Tokyo metropolitan area

(Source: Rail travel distance is from Annual Report of Rail Transportation Statistics[89], bus, private car and motor cycle's travel distance is from the Motor Vehicle Transport Statistical Yearbook)

Because the car mode is the dominate mode, hence the car's travel distance have the biggest influence to the factor. From 1968 to 1978, we can see from the Fig 4.18, we can see that the urban area expanded from 1965 to 2005, but the expansion kept a very good TOD manner, DID area was developing around the railway lines. And the convenience of the railway system was very high. So, even with the development of urban area and the trend of suburbanization, the travel distance of bus did not increased, actually it decreased a little bit in 2 period respective because of the oil crisis between 1968 and1978 and the railway system improvement between 1998 and 2008.In another hand, the main job opportunities was in the inner part of Tokyo, more than 90% people use railway to commute for longer distance, hence the rail travel distance increased constantly.

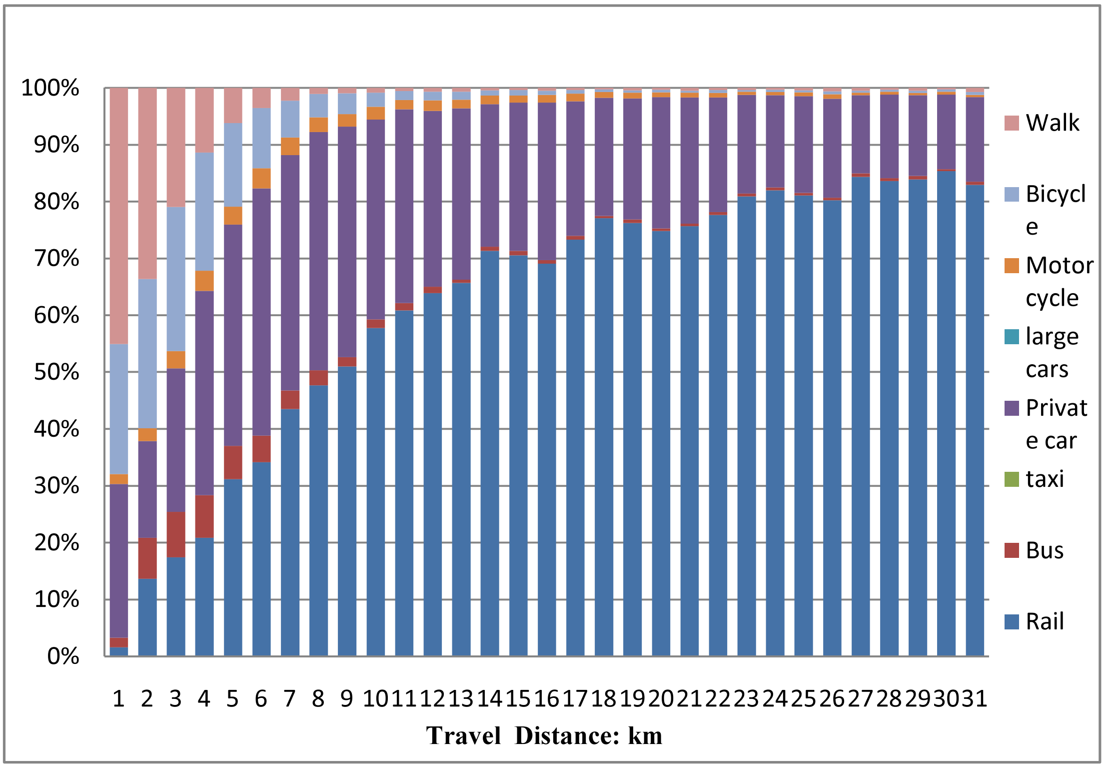



Fig 4.21 Travel distance by mode in Tokyo metropolitan area in 2008

(Source: author's calculation based on the data of PT investigation of Tokyo)

As shown in Fig 4.21 we can see that the longer travel distance, he bigger share of rail, that's mainly because of the convenience of the railway, and accordingly high usage fee for car (oil price, parking fee).

**(2) Cause of travel mode share---mode share**

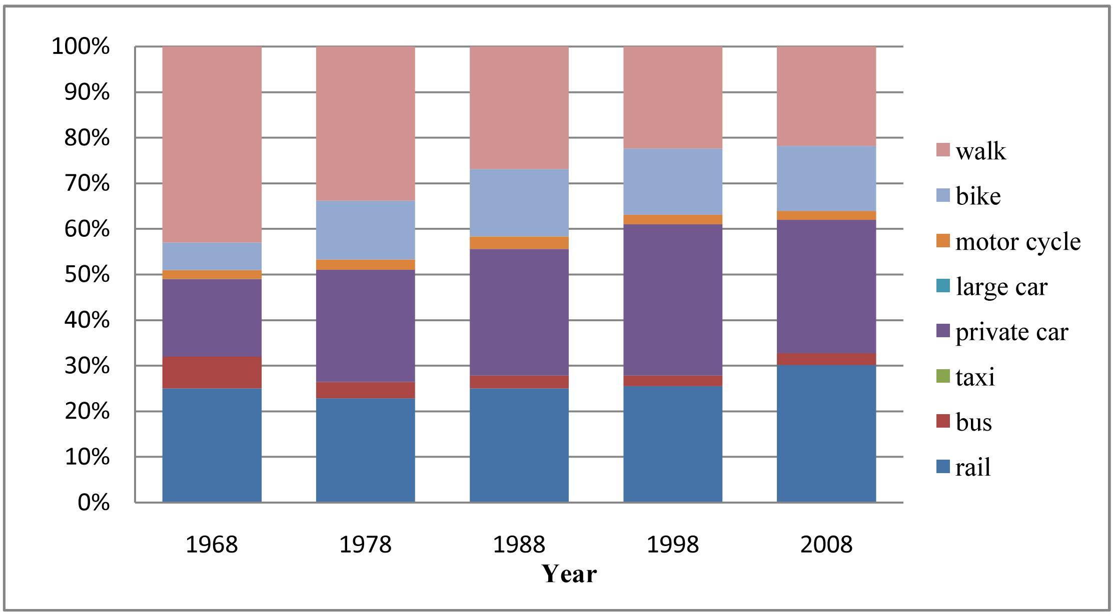



Fig 4.22 Mode share in Tokyo metropolitan area

(Source: PT investigation of Tokyo in 1968, 1978, 1988, 1998, 2008)

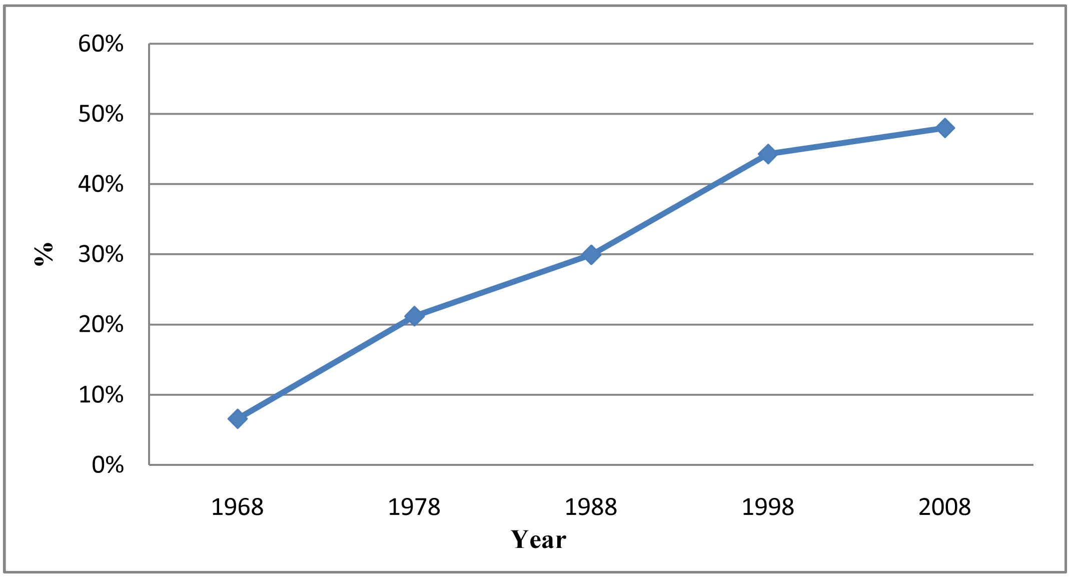



Fig 4.23 Per capita car ownership in Tokyo metropolitan area

(Source: Statistical Yearbook of Japan)

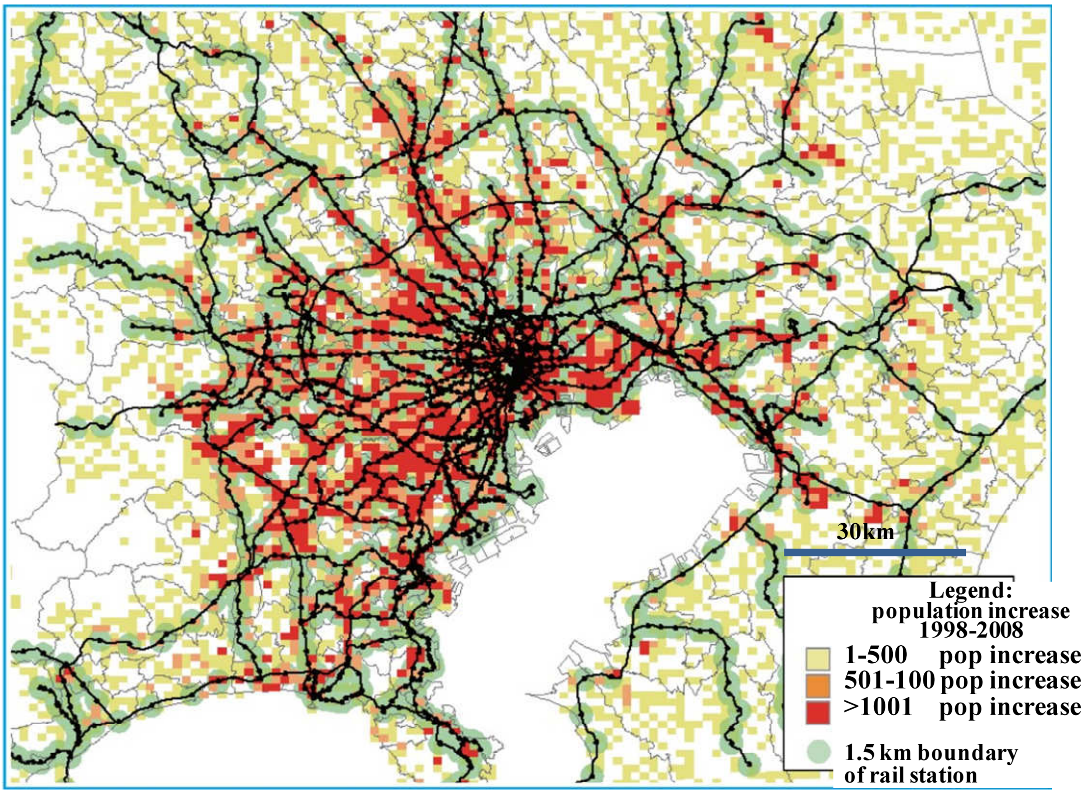



Fig 4.24 Population change between 1998 and 2008

(Source: Report of 5th Tokyo metropolitan area PT investigation)

As shown in Fig 4.21, the mode share in Tokyo is made up of walk, bike, motor cycle, car, bus and rail. We can see that the mode share of walk was decreasing very quickly, the share of bike increased constantly in these periods. The mode share of rail kept a constant value from 1968 to 1998, and increased from 1998 to 2008. The mode share of car increased from 1968 to 1998, but decrease quiet a lot from 1998 to 2008. The increase from 1968 to 1998 was because of the quick increased of car ownership as shown in Fig 4.22, the decrease of mode share of the car is because of the policy of promoting public transport in Tokyo, and the population concentrated in the surrounding areas of railway station, from 1998 to 2008, the population increase in these area was 1.88 million, while the population only increased 0.08 million in the other places. Because of the increase of the convenient access to railway station, more and more people trend to use railway, also, the increasing oil price also promote people to use the railway more frequently.

We can also see from Fig 4.24, because DID area expanded in the shape of TOD, so the long distance travel was mainly use the rail mode but not car mode.

**(3) Cause of travel fuel efficiency---fuel efficiency and occupancy rate**

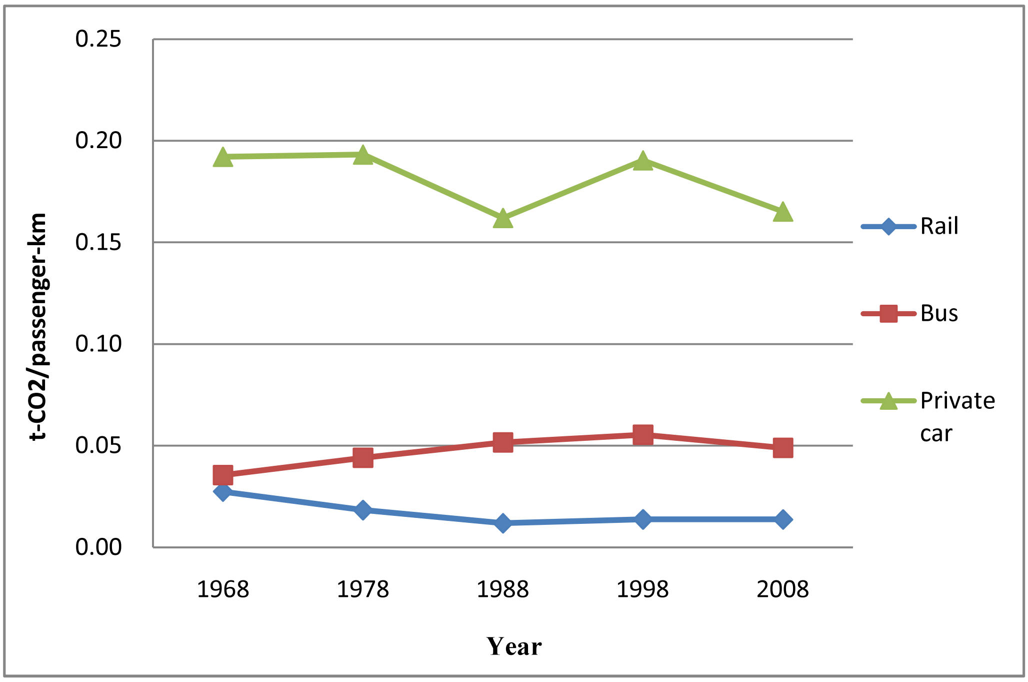



Fig 4.25 Vehicle fuel efficiency by mode in Tokyo metropolitan area

(Source: Rail fuel efficiency data is from Annual Report of Rail Transportation Statistics[86], bus, private car's fuel efficiency data is from the Japan Motor Vehicle Transport Statistical Yearbook)

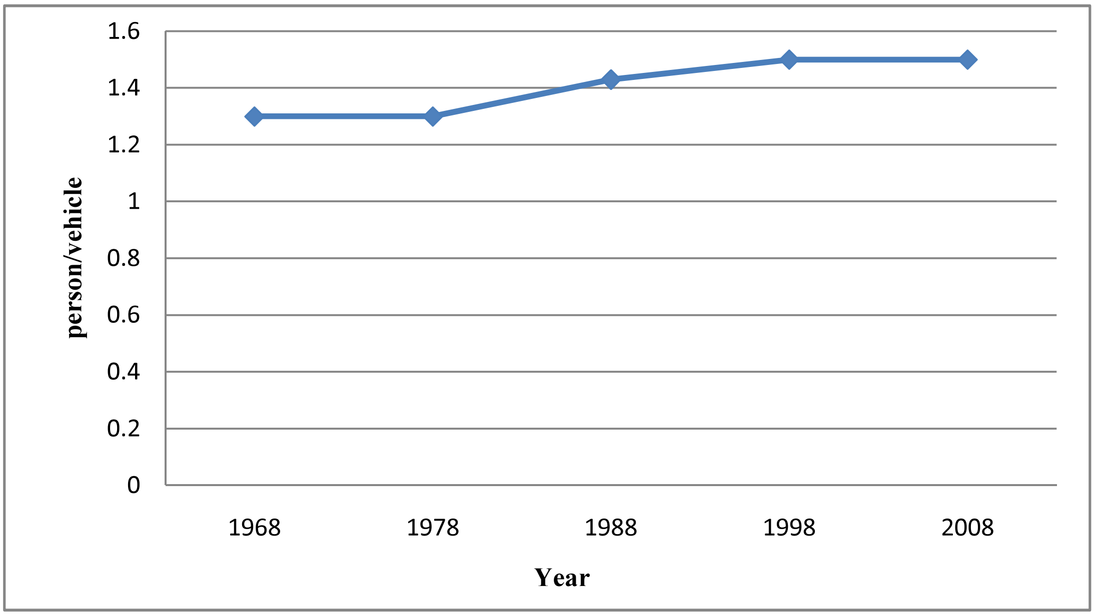



Fig 4.26 Private car occupancy rate in Tokyo metropolitan area

(Source: Japan Motor Vehicle Transport Statistical Yearbook)

We can see form the result from the decomposition result, the factor of fuel efficiency

1. 1968-1978: no big change in fuel efficiency.
2. 1978-1988: start of economic cars, because of the oil crisis, people became prefer to buy economic cars to save travel cost
3. 1988-1998: start of economic booms, 30's-40's people cannot afford housing, the money rush to car market , at the same time, special tax on luxuries cars are cancelled, these two effect make people prefer SUV and other big car in 1989, the number of big car increase increased dramatically, the emission efficiency became worse. And from 1990-2000, there is nearly no improvement in engine technology.
4. 1998-2008: introduce of low emission cars, government provide subsidy for low emission car and low purchase tax for low emission cars, it stimulated the quick spread of low emission make the fuel efficiency changed quickly.

The technology of rail is continually improved, hence, the fuel efficiency of rail was improved year by year. While, the fuel efficiency of bus was increased, that's mainly because of the lower occupancy rate of the bus, because the high efficiency of the railway, the bus system was less and less used.

**(4) Analysis of the investment and financial system in Tokyo transport system**

Because the railway company and the land is owned by private person, hence the company and person would like to chase the highest profit from the railway system.

In Tokyo, the railway development is strongly connected with the commercial land use, the population flow stimulates the prosperous of commercial areas, and the commercial areas bring more passenger system. The integrated system made very big profit and stimulates the good development of the railway station and the surrounding real estate market.

## 4.4 Mechanism in urban transport emission changes

### 4.4.1 Description of the causality map

Based on the analysis of Section 4.2 and 4.3, Based on the analysis of the above, we can get causality map of Shanghai and Tokyo, the causality map is vertically divided into 3 parts:(1) AVIOD: In this part, we described relation between factors with the traffic demand, it mainly caused by the suburbanization and job-housing unbalancing. The factors are marked as A1, A2…, the related policies are marked as AP1, AP2…; (2) SHIFT: In this part, we mainly described the competition in different modes, it described how different policy affect the mode share. The factors are marked as S1, S2…, the related policies are marked as SP1, SP2…; (3) IMPROVE: In this part, we mainly described how each policy affect improvement of the transport system, such as the occupancy rate and the engine technology improvement. The factors are marked as I1, I2…, the related policies are marked as IP1, IP2…;

And the phenomenon in the causality diagram can be horizontally divided into 5 stages: (1) Background: Economic development and population growth; (2) Direct Cause: the deeper level of cause; (3) Land use and Transport phenomenon: the phenomenon in the land use and transport phenomenon; (4) Direct Impact on $CO_2$ emission: Increase of travels, trip rate, travel distance, mode shift, fuel efficiency and occupancy rate. (5) Social problem: global warming.

From the analysis of section 4.2 and 4.3, we get the causality map of Shanghai (1986-2009) and Tokyo (1968-1988, 1988-2008) in Fig 4.36, 4.37 and 4.38. As shown in Fig 4.34, it's the economy quick development era of Shanghai. The land development cause unbalance of job-housing, and the quick urbanization and the weak public development lead to the bad pattern of land use and car dependence increase, these factors cause the final increase of travel distance increase and trip rate increase. In these periods, even with very strong car ownership control policy (plate auction), with the economic growth, the car ownership increase a lot, and the improvement of road network also stimulate people to use cars more. At the same time, the urban rail way length increase a lot, this lead to the increase of the user of railway, while the universal design of railway is not so good, this reduce the attractiveness of the rail mode. The share of bus service level became worse by competing with the rail mode and car mode. The walk and bicycle mode decrease a lot because the bad travel environment and strict policy for these modes, and the increase of travel distance is another reason. The gasoline price increase and emission standard together with the engine technology cause the increase of low emission cars, this make the car fuel efficiency improve. With the economic growth, the diversity of travel demand occurs, these lead to the occupancy rate decrease. All of these factors make the $CO_2$ emission increase from 1986 to 2009, and then consequently cause the global warming and social cost increase.

As shown in Fig 4.35, it's the economy quick development era (1968-1988) of Tokyo. The quick population increase leads the increase of travels. The land development cause unbalance of job-housing, even there is quick and the quick urbanization, but the well designed public transport system and TOD development mode make Tokyo a good pattern of land use and not very strong dependence on cars. Consequently, the unnecessary travel demand does not increase a lot, the travel distance increase mainly in the mode of rail, hence the total effect to the $CO_2$ emission is small. With economy growth, the car ownership increase very quick in that period, hence the car use increases quickly. The railway system in Tokyo is well designed and the value capture makes the operator can continually improve the service of railway mode. But the bus service was weak because the competition of the rail service. Because of the long travel distance, the share of walk and bike decrease. And the subsidy and the gasoline price increase and the engine technology improve increase the amount of low emission cars. Finally, the car efficiency improved a lot. With the economic growth, the diversity of travel demand occurs, these lead to the occupancy rate decrease. All of these factors make the $CO_2$ emission increase from 1968 to 1988, and then consequently cause the global warming and social cost increase.

As shown in Fig 4.36, it's the economy stable era (1988-2008) of Tokyo. The land demand is very small, and the good service of public transport and TOD development mode make the trip rate and travel distance nearly do not change. The population move to the place near the railway station, hence more and more people use the rail mode. Consequently, the modes shift to be eco-friendly way. The subsidy and gasoline increase lead to the people's preference to low emission cars, and the continual engine technology improve make the fuel efficiency improve. While the economic development became stable, the diverse of travel aims do not change a lot, hence, the occupancy rate does not change a lot. Finally, the $CO_2$ emission does not increase a lot, the global warming and social cost keep stable.

### 4.4.2 Key findings in the causality map

Here we introduce the key finding and key factor or policies in the causality map. As the analysis shown in the section 4.2 and 4.3, the main contributor of $CO_2$ emission is in the private car sector. So, to understand the factors that affect private car sector and to known the relationship between these factors is very necessary for the analysis of total $CO_2$ emission. The relation and the performance can be seen in Fig 4.27 as follows:

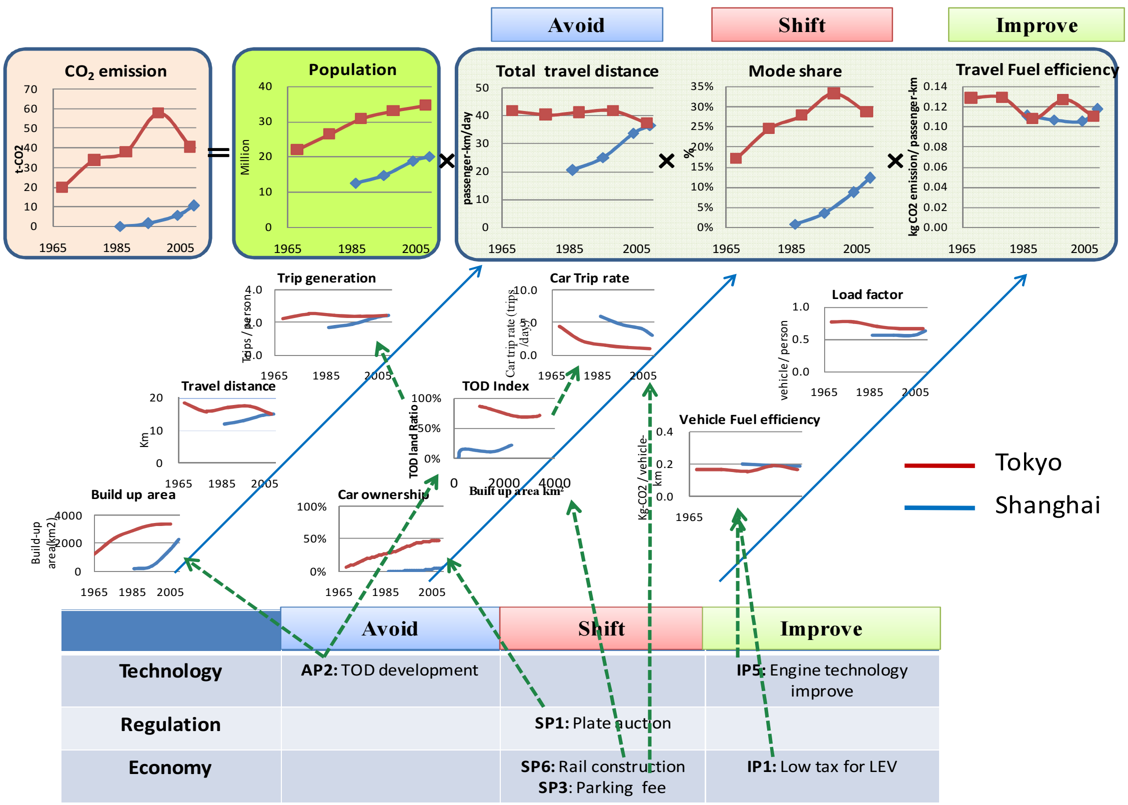



Fig 4.27 Dynamic Tracking of Transport Related Emission Mechanism

From Fig 4.27, we can see that, in the upper part is the $CO_2$ measuring equation, the population is individual factor. Total travel distance, mode share and travel fuel efficiency respectively stand for the travel demand, mode shift and travel fuel efficiency, and it's respectively relate to the policy of Avoid, shift and improve.

The bellows small figures are the performance of the deeper factors. Total travel distance is affected by trip generation rate, travel distance, and the travel distance is affected by built up area, trip generation is affected by TOD index(explanation can be seen in the detailed explanation). Car mode share is affected by car trip rate and car ownership, and car trip rate is affected by TOD index. Travel fuel efficiency is affected by load factor and vehicle fuel efficiency.

In the lowest part, it's the key transport policy, the TOD policy affect the TOD index and built up area, plate auction affect car ownership, rail construction affect TOD index, parking fee affect car trip rate. Energy technology improves and low tax for LEV contributes to the vehicle fuel efficiency improvement.

After examining the main factor's relationship in the private car mode, the detailed individual importance policies and factors as conclude as follows:

**(1) TOD index and Tip generation rate (A6, AP2)**

The 1km boundary around railway is consider as the TOD land, the share of the TOD land in the total built-up area is consider as the TOD index.

$$TOD\_index = \frac{TOD\_Land}{Built\_up\_area} \tag{4-4}$$

Based on the calculation of Shanghai and Tokyo, we find that the TOD index in Tokyo and Shanghai is as follows:

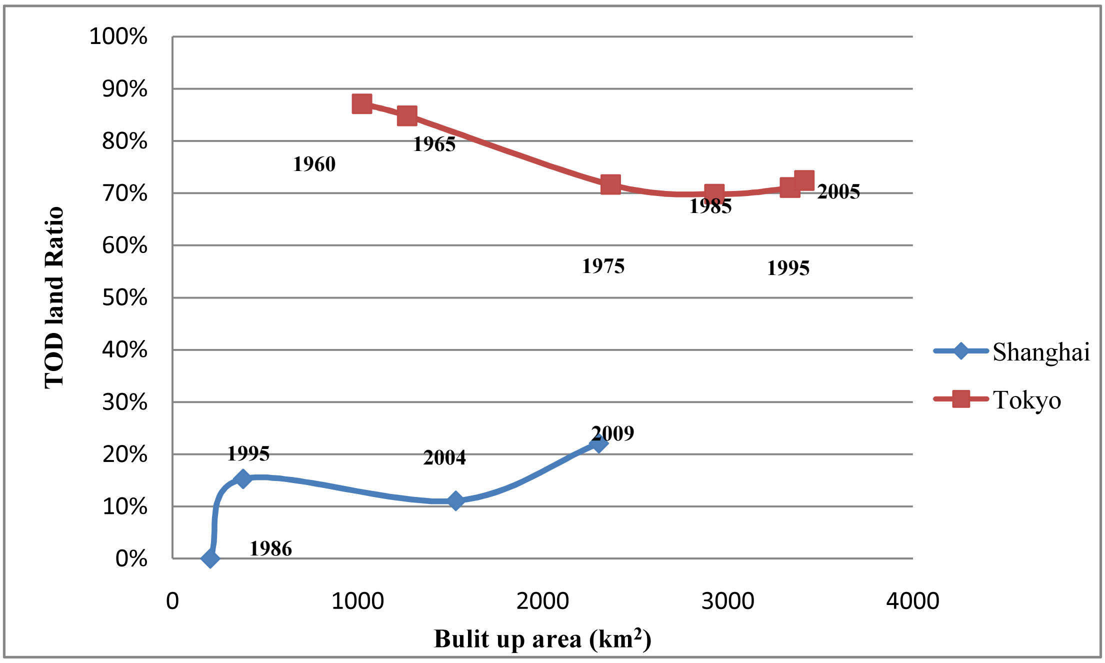



Fig 4.28 TOD index of Shanghai and Tokyo

(Source: PT investigation of Tokyo, PT investigation of Shanghai)

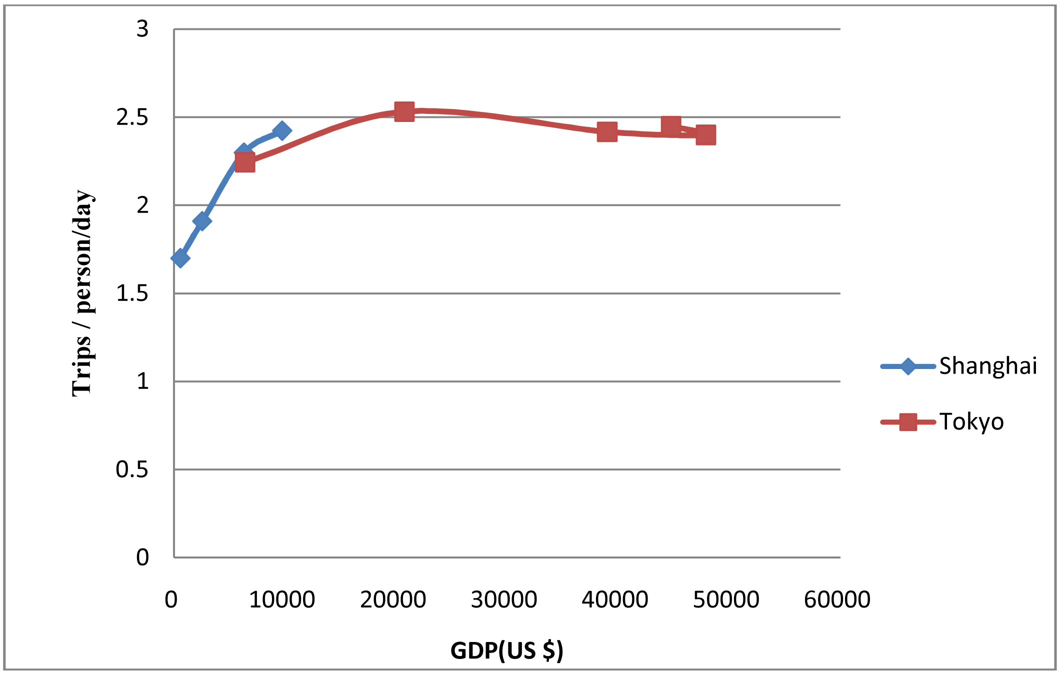



Fig 4.29 GDP V.S Trip generation rate

(Source: PT investigation of Tokyo, PT investigation of Shanghai)

From Fig 4.28, we can find that the TOD index in Tokyo is much higher than that of Shanghai, that's because in Tokyo the railway construction is very early, the travelers have strong habits to use the railway system, the TOD development also stimulate related mixed land use and then reduce the unnecessary traffic demand.

From Fig 4.29, in Tokyo, we can see that the trip rate of in 1968 is 2.24, at that time per capita GDP is 7000 US$, the trip rate of Tokyo in 2008 is 2.45, at that time per capita GDP is 44,000 US$, the trip generation rate's increase rate is only 9%. Actually, from 1968 to 1998, it's the quick suburbanization period of Tokyo, the low trip generation rate increase rate in Tokyo is because of its well designed railway system and its mixed land use. While in Shanghai, the trip rate is 1.7 in 1986, at that time per capita GDP of Tokyo is 560 US$, the trip rate in 2009 is 10000 US$, the trip generation rate is 2.42, the trip generation rate's increase rate is 42%. And we can see that, the tendency is also increase, if it keeps this tendency, it will surpass Tokyo.

**(2) Suburbanization, Land use pattern and travel distance (A2)**

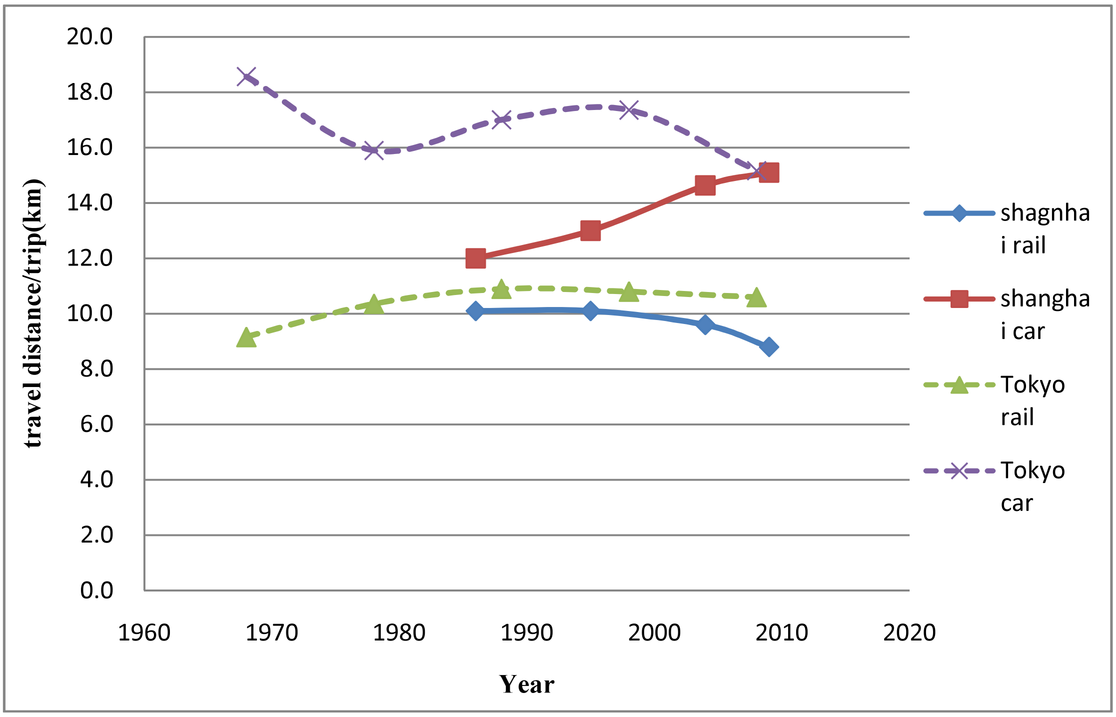



Fig 4.30 Travel distance in Shanghai and Tokyo

(Source: PT investigation in Shanghai, PT investigation in Tokyo)

As shown in Fig 4.30, the car travel distance of Tokyo firstly decrease from 1968 to 1978, that's mainly because of the oil crisis in 1973 that stimulate use car less. And then the car travel distance increase from 1978 to 1998, that's mainly because of the suburbanization, but not a lot, that's mainly because of the well designed land use pattern (TOD, as shown in Fig 4.19). The travel distance of Tokyo decreased from 1998 to 2008, that's because of the improvement of the railway system and from 1998 to 2008, the population more and more accumulate to the railway stations, namely the city is more and more compact, hence the travel distance decreased. The rail travel distance increase a little bit because of the tendency of the suburbanization. While in Shanghai, the car travel distance increased because of the suburbanization. The rail travel distance is mainly because of the network has been shown, because of the shorter distance travel demand can be met.

**(2) Car ownership and related policy (S1)**

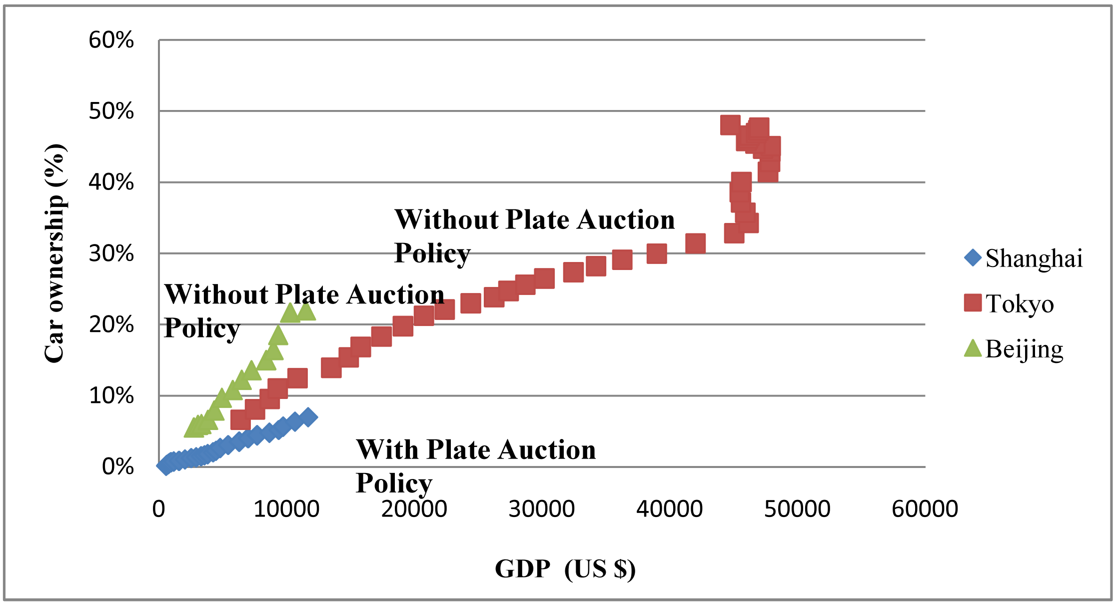



Fig 4.31 Car ownership in different policy (Source: Shanghai statistical yearbook, Beijing statistical yearbook, Tokyo statistical yearbook)

We can see that, the current total car ownership in Tokyo is much higher than that of Shanghai and Beijing, that's mainly because of its high GDP and income level. We can see that, in the same per capita GDP level, the car ownership of Beijing is much higher than Tokyo and Shanghai, Beijing's car ownership is 22% in the per capita GDP level of 10000 US$, Tokyo's car ownership is 12% in the per capita GDP level of 10000 US$, while Shanghai's car ownership is only 6% in the per capita GDP level of 10000 US$. In Beijing, there public transport supply (rail and bus) is much weaker than that of Tokyo, so, in the same GDP level, the car ownership is higher. In Shanghai, the public transport system is much weaker than that of Tokyo, but the car ownership is much lower than that of Tokyo, the biggest reason is the plate auction policy that carried out since 1994, that's a successful policy that can well control the car ownership.

**(3) Car use and related policy (S5)**

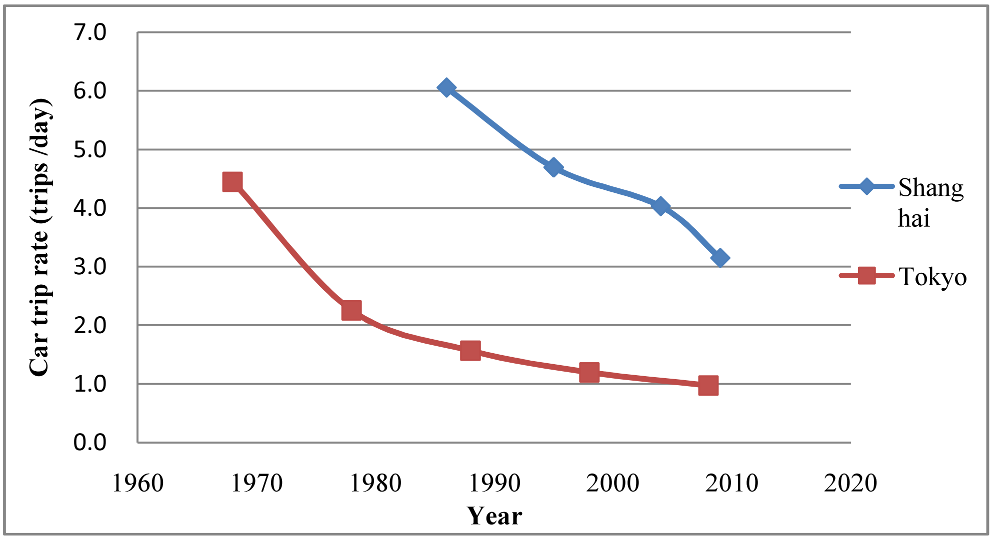



Fig 4.32 Car trip rate in Shanghai and Tokyo

(Source: Calculation based on PT investigation in Shanghai)

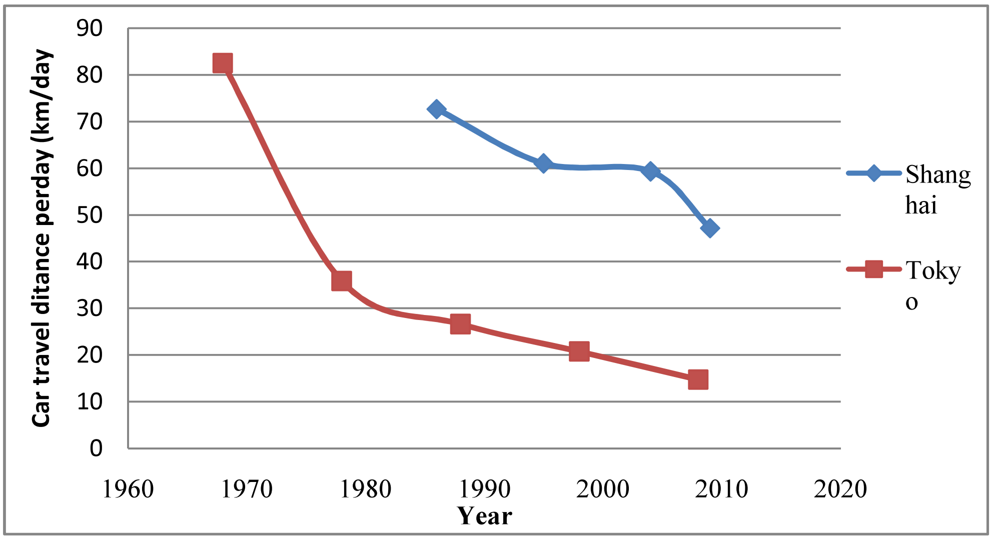



Fig 4.33 Car trip rate in Shanghai and Tokyo

(Source: Calculation based on PT investigation in Shanghai)

From Fig4.32 and 4.33, we can see that, even the car ownership of Shanghai is much lower than that of Tokyo and the total car use and car travel distance is much lower than that of Tokyo, but the usage of per car is much higher than that of Tokyo. In Shanghai, the car trip rate of Shanghai is 6 in 1986 and generally decreased to 3 in 2009. While in Tokyo, the car trip rate is 1 in 2008, the car use rate in Shanghai is 3 time of Tokyo. In terms of per car travel distance, Shanghai is also much higher than that of Tokyo, in 2008, the car travel distance of Shanghai is 48km/day, but in Tokyo the car travel distance is 15 km/day.

The difference in Shanghai and Tokyo is mainly because of the strict car parking policy in Tokyo and other high usage fees. While in Shanghai, the parking fees actually have not yet increased as quick as CPI index, and the plate auction fee is also stimulate people to use car more frequently once they buy the cars. Another reason is the government’s attitude to the road policy, in Tokyo, in Tokyo ,the road length keep a stable value, that discourage people to use car, while in Shanghai, the road increased 3 time from 1995 to 2009.The uncontrolled urban sprawl of Shanghai also stimulate people use car more frequently.

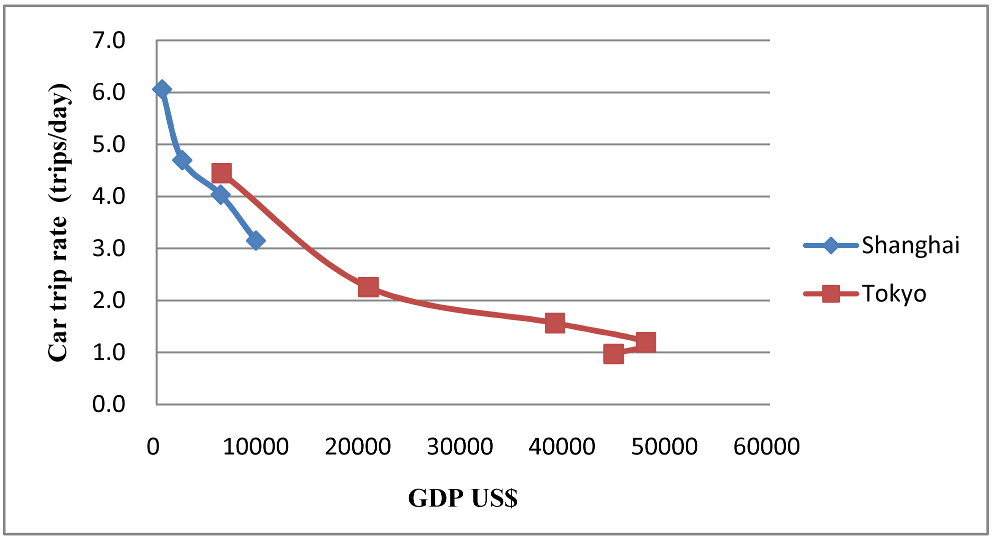



Fig 4.34 Car trip rate v.s GDP rate in Shanghai and Tokyo

(Source: Calculation based on PT investigation in Shanghai)

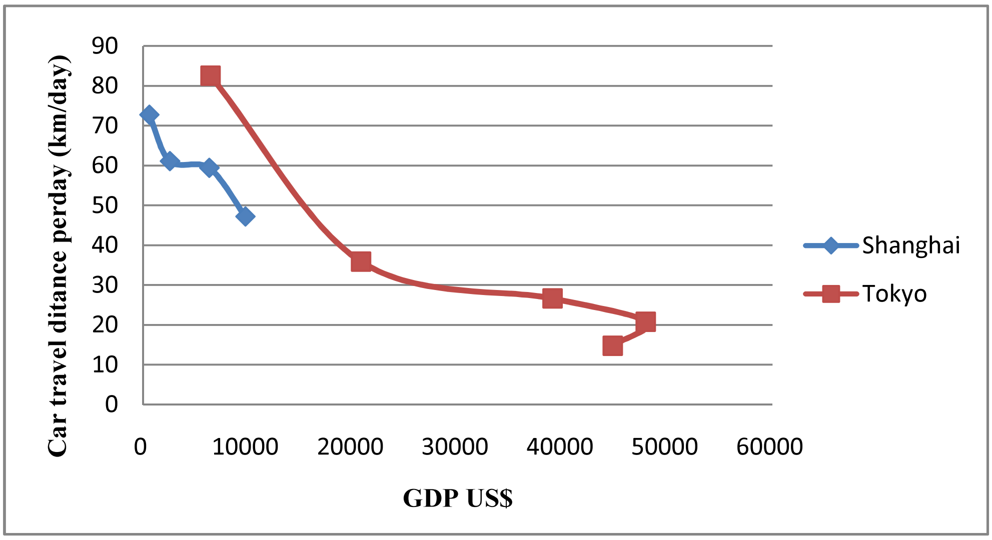



Fig 4.35 Car travel distance v.s GDP in Shanghai and Tokyo

(Source: Calculation based on PT investigation in Shanghai)

From Fig 4.34 and 4.35, we can also see that, even the curve of Shanghai and Tokyo in Fig 4.32 and Fig 4.33 are so different, but in the Fig 4.34 and Fig 4.35, the curve of Shanghai and Tokyo are similar, the trip rate and total car travel distance are decreasing with the GDP increase, Tokyo's car trip rate and car total travel distance was even higher than that of Shanghai , but Tokyo successfully decrease the car trip rate and total car travel distance with economic development, while Shanghai's case will be decided the future policies on land use and car ownership and usage related policies.

**(4) Railway service (S3), Value capture (SP7), urban rail construction (SP6)**

As Show in Fig 4.28, the railway influence area in DID area of Tokyo keep a very high value, hence it can provide a very good service for everybody. What's more, there is also very good financial policy value capture, that can help the government or railway owner to capture the land value increase around the railway, this policy get great success in Japan, and encourage the development of new railways. While in

Shanghai, there is no this policy, the government suffer the big financial burden of the railway system.

**(5) Increase of low emission cars (I5) - Car fuel efficiency**

Tokyo has experience a very big fuel efficiency change between 1998 to 2008, the low tax for low emission cars encourage more people to buy these cars, and the we can see from the Fig4.16, one the biggest contributor to the transport sector CO2 emission reduction in the period of 1998 to 2008 is the fuel efficiency change. Because the technology transformation is now quicker and quicker, the fuel efficiency change could have big influence on the $CO_2$ mitigation in Shanghai.

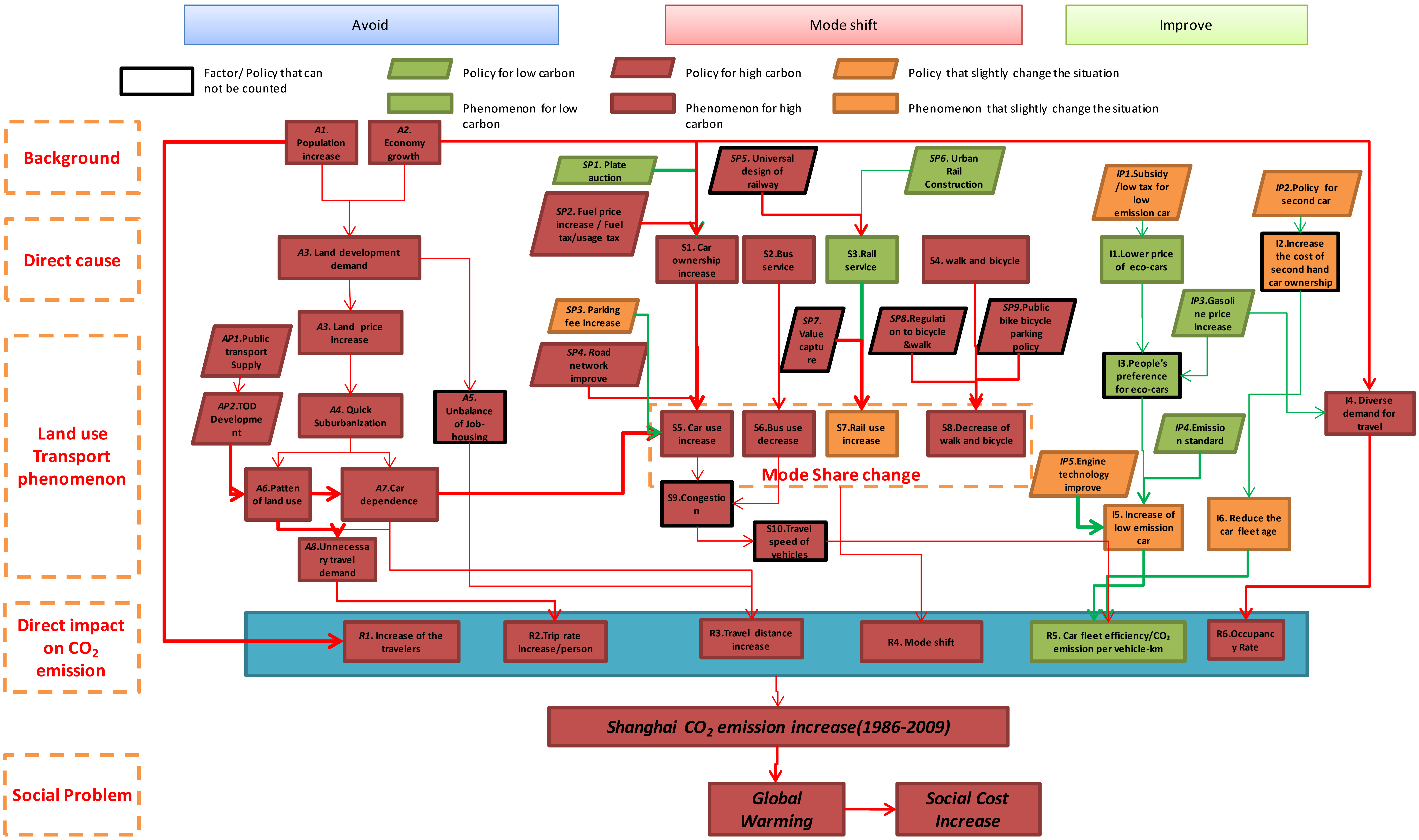



Fig 4.36 Causality diagram of Shanghai (1986-2009)

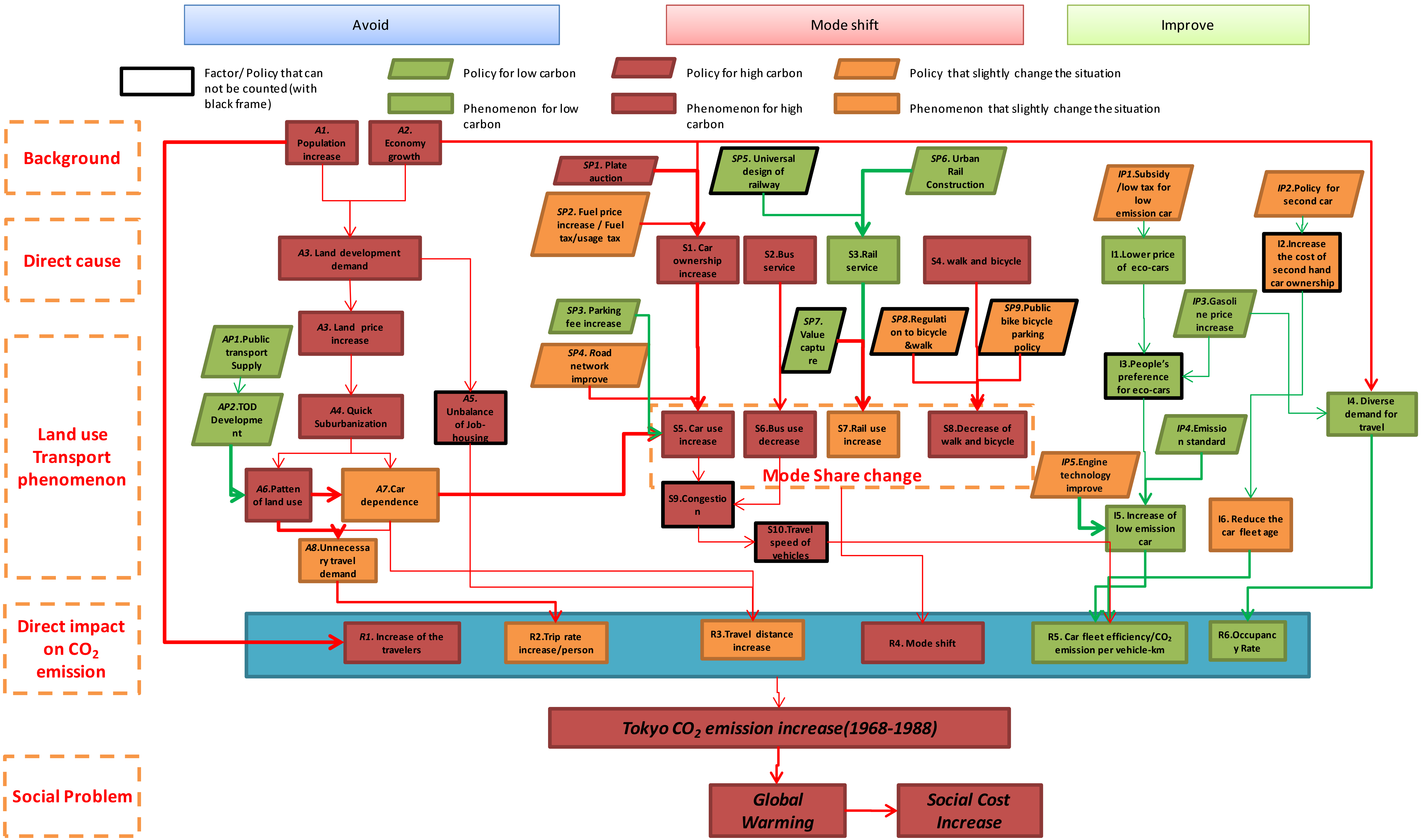



Fig 4.37 Causality diagram of Tokyo metropolitan areas (1968-1988)

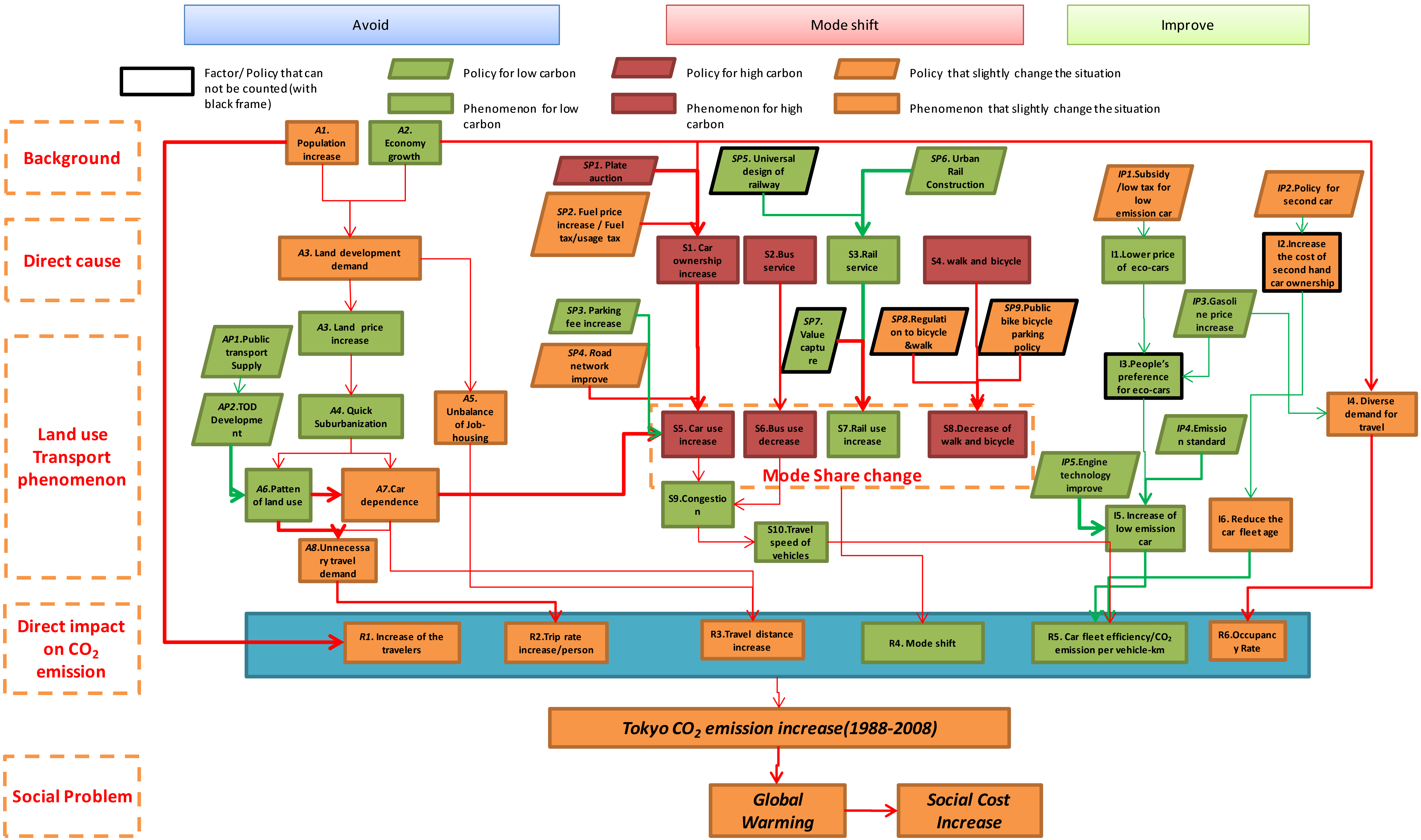



Fig 4.38 Causality diagram of Tokyo metropolitan areas (1988-2008)

## 4.5 Conclusion

This chapter takes Shanghai and Tokyo as case study city, firstly decompose the influence factors that affect urban transport $CO_2$ emission in different, and then based on the analysis, we draw the causality diagram in Tokyo and Shanghai in different periods, the main findings in this chapter is as follows:

(1) In the total research period, population, trip generation rate, mode shift, travel distance, load effect show strong effect on the $CO_2$ emission increase. From 1986 to 1995, mode shift effect shows the strongest positive effect, contribute to 73% of the total change. From 1995 to 2004, mode shift also shows the strongest positive effect, it contribute 56% of the total change, trip generation rate and population contribute 15% and 19% to the total change respectively. From 2004 to 2009, mode shift also shows the strongest positive effect, it contribute 52% of the total change, trip generation rate and population contribute 14% and 18% to the total change respectively. While the fuel efficiency constantly contribute negative to the $CO_2$ emission, the contribution in the period of 1986 to 1995, 1995 to 2004, 2004 to 2009 are respectively -0.1%, -3% and -6%.

(2) In Tokyo, the contribution of each factor changed in different periods. From 1968 to 1978, population, trip rate and mode shift contribute positive to the $CO_2$ emission increase, travel distance contribute negative to the $CO_2$ emission. From 1978 to 1988, the population, mode shift, travel distance contribute positive effect,

while the trip generation rate, load effect and the fuel efficiency contribute negatively. From 1988 to 1998, population, mode shift, travel distance and fuel efficiency contribute positively, only the load effect shows negatively effect. From 1998 to 2008, only population and trip rate effect shows positive effect, mode shift, travel distance and fuel efficiency shows the strong negative effects. Totally, population constantly shows positive effect, mode shift and fuel efficiency is very sensitive factor to the $CO_2$ emission change.

(3) Based on the key policy capture, we find that the car ownership policy, car use policy and TOD development policy are the key policies that affect $CO_2$ emission. Measures should be taken to control car ownership, car use and to enhance the TOD development.

(4) The advantage of Shanghai transport sector is that, Shanghai has successfully control the car ownership, it has very strong policy power and financial ability to construct the subway quickly. The disadvantage of Shanghai is its quiet high usage of car and its weak connection between land use system and transport system, what's more, the generally deteriorating walk and bicycle system is another problem.

(5) The advantage of Tokyo transport sector is that, the land use system and transport system is well combined, the TOD develop in Tokyo is very successful. Tokyo has very well built and designed rail system, people also have very good habit to use public transport system. Even the car ownership is very high, the usage rate of car is very low. The disadvantage of Tokyo is its high car ownership and the high emission car boom in 1990s.

(6) The detailed relation between policies and the background and the phenomenon can be seen in the causality diagram of Shanghai and Tokyo as shown in Fig 4.36, Fig 4.37 and Fig 4.38.

# Chapter 5 Policy for mitigating passenger transport $CO_2$ in Shanghai

Based on the analysis of chapter 3 and chapter 4, we get the conclusion of Tokyo and Shanghai's city development and transport development. Tokyo is a mature city that has experienced development, and now the developing speed is coming down, while Shanghai is a city with quick development speed, hence some scenarios are set to measure the future possibility of Shanghai's transport system development, and then provide policy suggestions to Shanghai's transport system development.

## 5.1 Introduction

### 5.1.1Experience from Tokyo

From the analysis we can see that, the public transport service level is very important for the shift of the mode share and improvement of the energy efficiency. The major mode share in Tokyo is rail mainly because of the good transport system and joint development policy of the railway station and the city development.

We can conclude the experience of Tokyo as follows:

1. Well constructed railway system, high mode share in coming in Tokyo center area.(nearly 90%)
2. Strong control on car use (high parking fee, narrow road)

3. Population will increase quickly within 20 years.

4. With capacity restriction in the city center, the increased population will more and more be allocated to the suburban areas.

5. Huge investment in the transport system will be needed.

6. The average trip rate will increase, and the diversity of travel purpose will occurs.

7. People will have strong willingness to buy car.

8. With policy of the government, low emission car/E-car will be more and more popular.

9. Stronger policy for controlling car use and parking will be stimulated.

10. Government will encourage people more and more use public transport system, especially railway system.

### 5.1.2 Prospect of Shanghai

Shanghai is a developing city, the GDP will increase very quickly, and the population will also increase very quickly. Based on the Urban planning and yearbook of Shanghai, we can get the prospect of Shanghai as follows:

**(1)Population**

If the population also increased as the speed of today, the population increase rate was 3% per year, if we keep this speed, in the year of 2020, the total population of Shanghai will achieve 27.86 million, which is 1.83 times of 2009. And the inner ring cannot hold so much population; hence, people can only go to the suburban areas.

**(2) Future development**

As shown in Fig 3.9, Central town is surrounded by outer ring road, it's the political, economic and culture center of Shanghai. The central city is planned to adopt the "multi-centric and opening" layout structure, the CBD area consists of XiaoLujizaui and Bund in Puxi, The planned area is about 3 $km^2$, CBD is the integration of finance, trade, information shopping, culture, recreation, tourism and business, with moderate amount of residential buildings. The main public activity centers are referred to civic and sub civic centers, the civic center is centered with People's Square, there are four sub-civic centers: Xujiahui, Huamu, Jiangwan-Wujiaochang and Zhenru. We can see that, the future development in Shanghai will be mainly in the suburban areas.

**(3)Economic development**

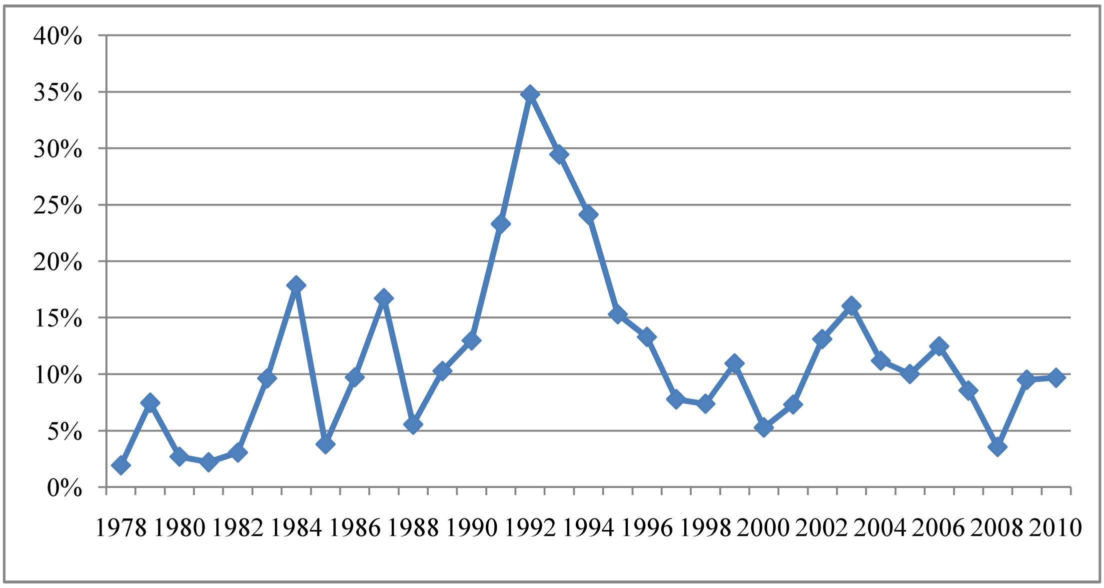



Fig 5.1 per capita GDP increase rate

(Source: Shanghai Statistical Yearbook)

Based on the data of Shanghai Statistical Yearbook[88], The economy developed very quickly from 1978 to 2009, the annual per capita GDP increase rate was as follow charts. We can see that, the GDP increased very quick, within recent 10 years, the GDP increase rate was always more than 10% expect 2008, so we can assuming the per capita GDP can grow at least 7% per year till 2020. So, we conclude that, in Shanghai, per capita GDP will be 2.1 time than the year of 2010, namely 223 thousand per year.

## 5.2 Description of the model

### 5.2.1 General description of the model

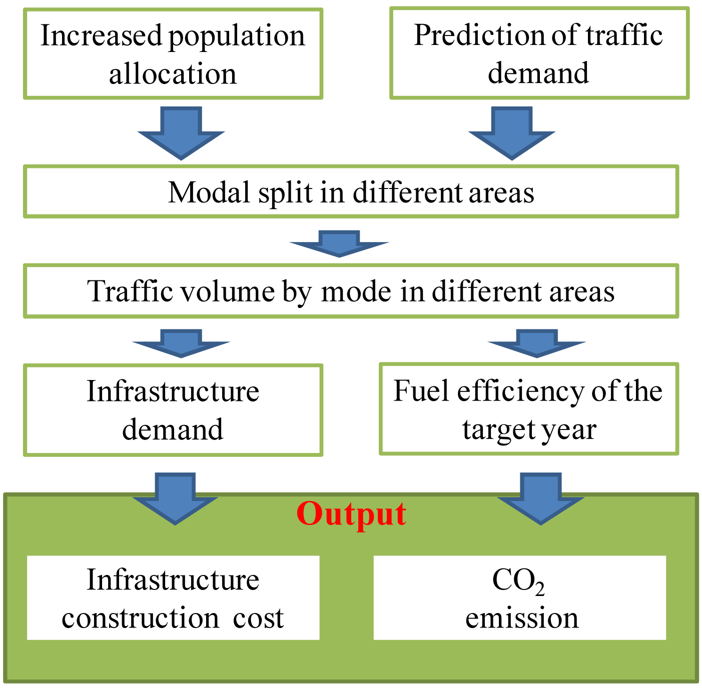



Fig 5.2 Description of the model

Just as Fig 5.2 shows, in the model we first set the population allocation ,and then we can get the future traffic demand, and then we can get the mode split in different areas, and then we can get the traffic volume, combined with the fuel efficiency we can get the final output of the model.

In the analysis of Chater4, we find that, there are many key factors that affect the $CO_2$ emission increase in Tokyo. So, we pick out these factors, to analysis the influence of these factors in the future of Shanghai. We set different policies as shown in the Fig5.3 as follows:

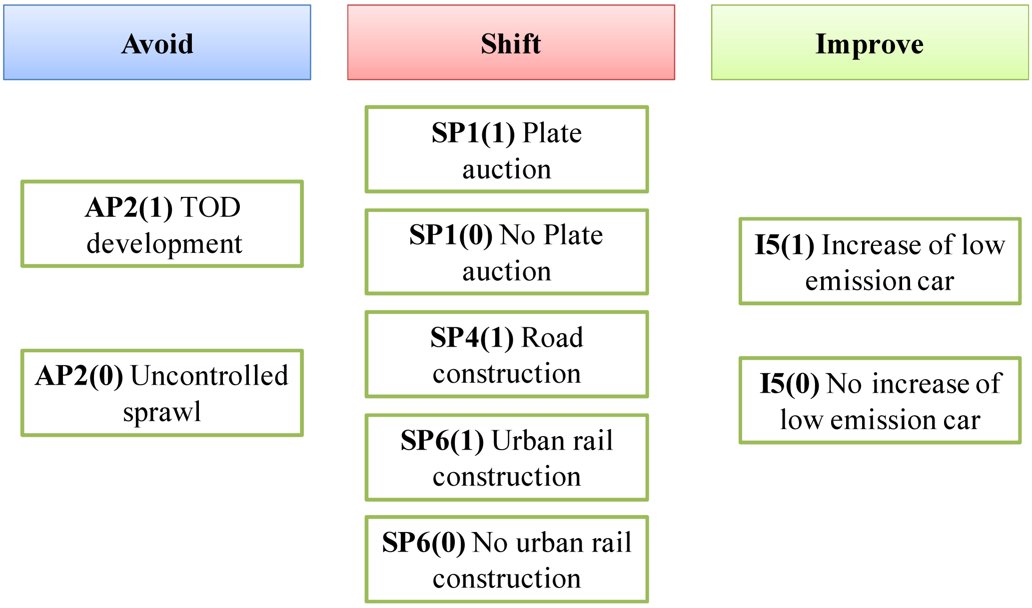



Fig 5.3 Individual policies and their combination

The policy can be divided into 3 stages, AVOID, SHIFT and IMPROVE as shown in the following tables. The Avoid means to cut unnecessary traffic demand, the Shift means to shift to more eco-friendly mode, IMPROVE means to improve each transport mode efficiency and then use less energy to reduce the final $CO_2$ emission. In the avoid stage, there are 2 option. One is uncontrolled sprawl, in this option, the new increased population is distributing averagely in Shanghai; the other is TOD, in this option, the new increased population is assumed around the railway stations. In the shift stage, there are 3 options, railway construction with feeder transport improvement, railway construction without feeder transport improvement, only road construction and car usage control. In the rail construction option, the railway length is assumed to increase 350km till 2020. In the car use un-control option, the car ownership will be double compared with the car control option. In the improve stage, there are 2 options, the fuel efficiency improvement is calculated based on the scenario of IEA in 2010. As a whole, the scenario is designed as follows:

Table 5.1 Identified scenarios for Shanghai in 2020 in this study

| | **AP2(0)** Uncontrolled Sprawl | **AP2(1)** TOD development | **SP6(1)** Urban rail construction | | **SP4(1)** Only road construction | **R5(1)** Fuel efficiency change | **R5(0)** No fuel efficiency change |
|---|---|---|---|---|---|---|---|
| | | | **SP1(1)** Plate auction | **SP1(0)** No Plate auction | **SP1(0)** No Plate auction | | |
| Scenario 1 | ● | | ● | | | ● | |
| Scenario 2-BAU | ● | | | ● | | ● | |
| Scenario 3 | ● | | | | ● | ● | |
| Scenario 4 | | ● | ● | | | ● | |
| Scenario 5 | | ● | | ● | | ● | |
| Scenario 6 | ● | | ● | | | | ● |
| Scenario 7 | ● | | | ● | | | ● |
| Scenario 8 | ● | | | | ● | | ● |
| Scenario 9 | | ● | ● | | | | ● |
| Scenario 10 | | ● | | ● | | | ● |

### 5.2.2 Setting of different scenarios

### (1) Population allocation

Shanghai can be divided into 5 areas, namely: (1) Central district in Puxi (2) Central district in Pudong (3) Periphery district in Puxi (4) Periphery district in PuDong (5) Suburban area. These are shown in the following Fig 5.4.

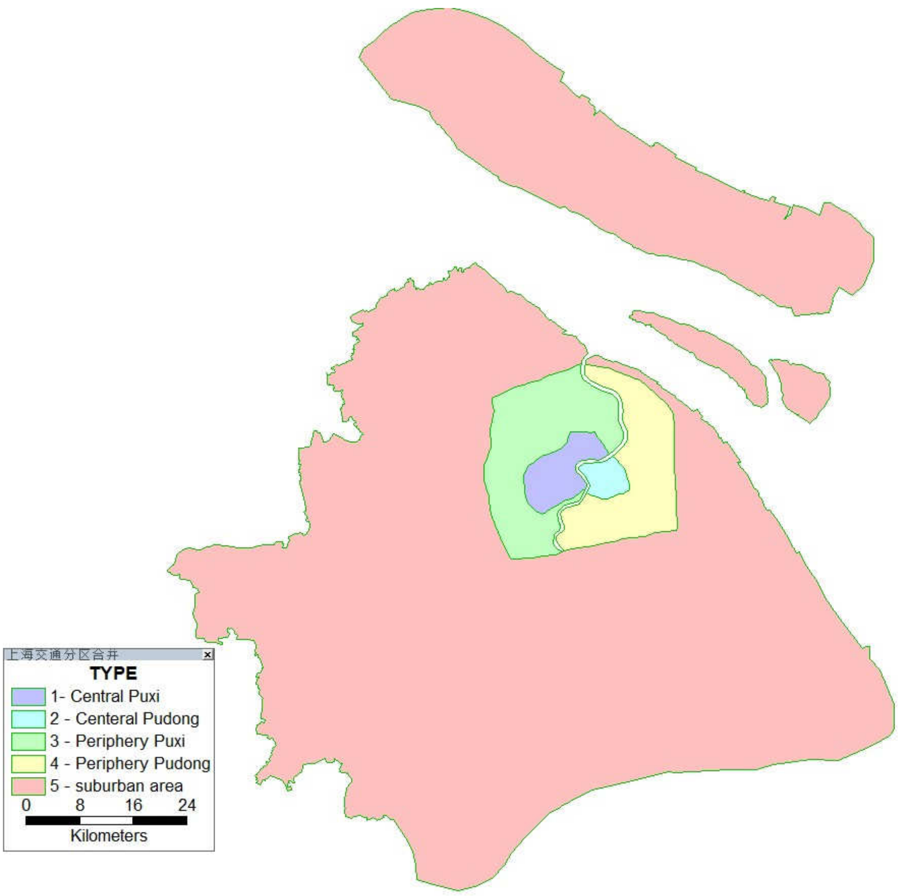



Fig 5.4 Map of Shanghai (1- Central Puxi, 2- Central Pudong, 3- Periphery Puxi, 4- Periphery Pudong, 5- Suburban)

(Source: PT investigation of Shanghai)

**Assumption 1:** population will increase from 2009 to 2020 the annual increase rate was 3%per year. Hence, in the year of 202, the total population in Shanghai will be 27.8 million, approximately 0.7 million population increase per year.

**Assumption 2:** The intrinsic population does not relocate, the new population located by the Setting of the scenario, the historical population increase in Shanghai is shown as shown in Table 5.2:

Table 5.2 Population increase from 2004 to 2009

| | 1. Central Puxi district | 2. Central Pudong district | 3. Periphery Puxi district | 4. Periphery PuDong district | 5.Suburban area |
|---|---|---|---|---|---|
| Population 2004 | 3.68 | 0.41 | 4.12 | 1.58 | 7.35 |
| Population 2009 | 3.15 | 0.54 | 4.49 | 1.94 | 8.76 |
| Change | -0.53 | 0.13 | 0.37 | 0.36 | 1.41 |
| Change (%) | -14% | 32% | 9% | 23% | 19% |

Source: PT investigation in Shanghai[73]

We can see from table 5.2 that he increase from 2004 to 2009 is mainly in the suburban area. In the inner part of Shanghai, in the central district, the population density was actually decreasing.

Based on the assumption the total population increase will be 7.73 million, assuming the same ratio of the share of the increased population from 2009 to 2020 with that of 2004 to 2009, we can get the population allocation as follows:

Table 5.3 Population increase from 2009 to 2020

| | 1. Central Puxi district | 2. Central Pudong district | 3. Periphery Puxi district | 4. Periphery PuDong district | 5.Suburban area |
|---|---|---|---|---|---|
| Population increase from 2009 to 2020 | 0 | 0.44 | 1.26 | 1.23 | 4.80 |
| Population in 2009 | 3.36 | 0.58 | 4.79 | 2.07 | 9.34 |
| Population in 2020 | 3.36 | 1.02 | 6.05 | 3.29 | 14.14 |

**(2) Trip generation rate**

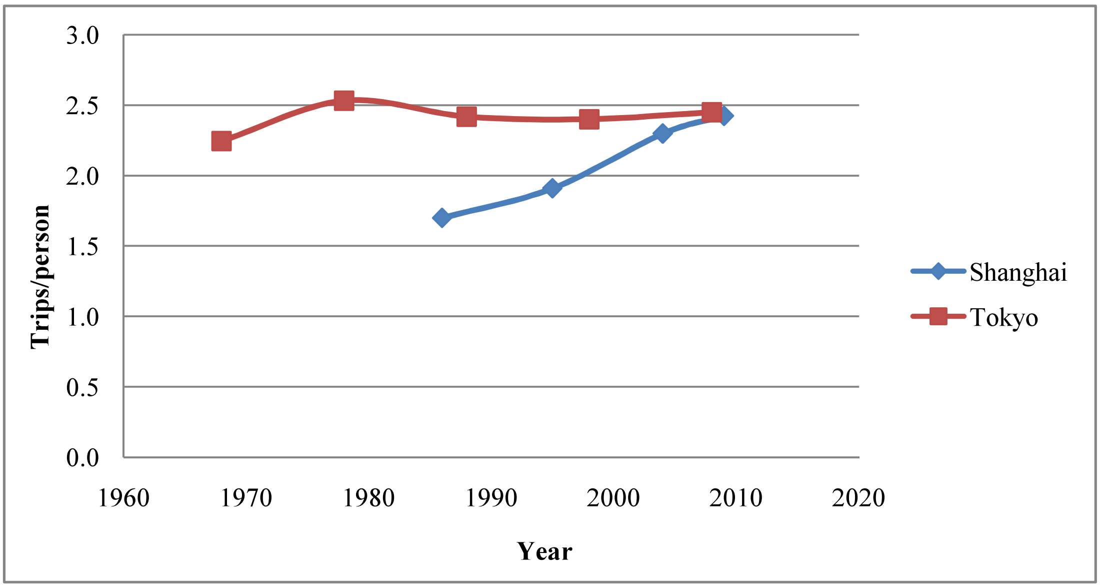



Fig 5.5 Historical trip generation rate of Tokyo and Shanghai

(Source: PT investigation in Shanghai, PT investigation in Tokyo)

Base on the experience of Tokyo and the other developed cities, the average trip rate will became stable number of 2.45 to 2.6. The value of Tokyo was 2.45 in 2008. Because the trip rate will became some certain value and be stable, just as shown in fig 5.5, in the case of Tokyo, in the year of 1978, the trip generation rate has achieved the peak. So we can set the trip generation rate in 2020 will be 2.6.

### (3) Mode share

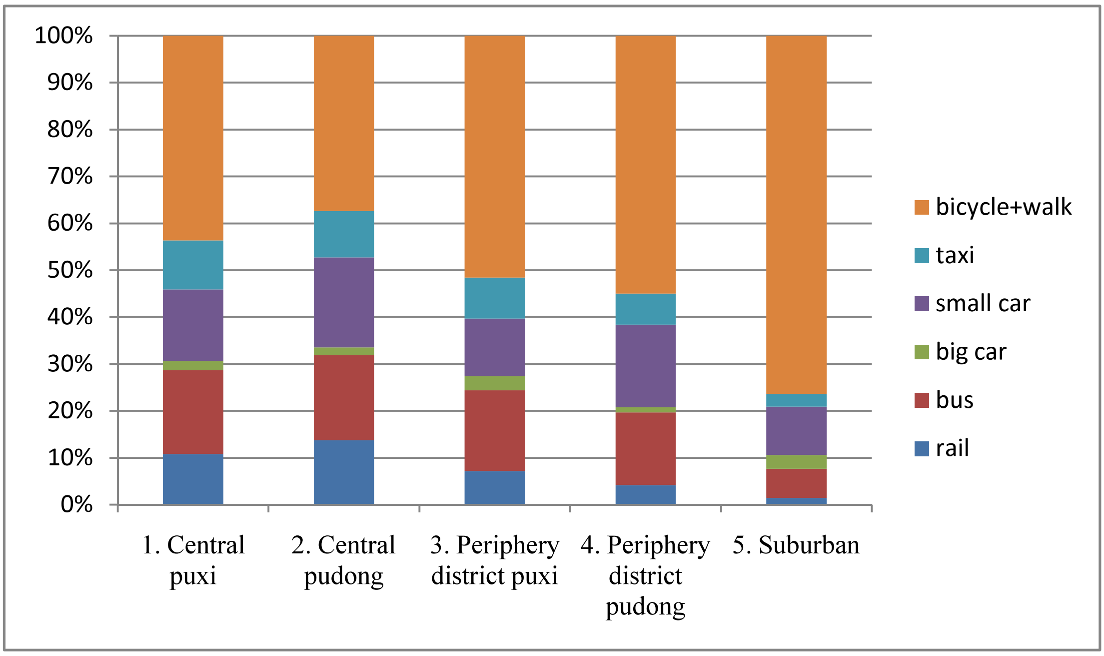



Fig 5.6 Current mode share in different areas

(Source: PT investigation in Shanghai)

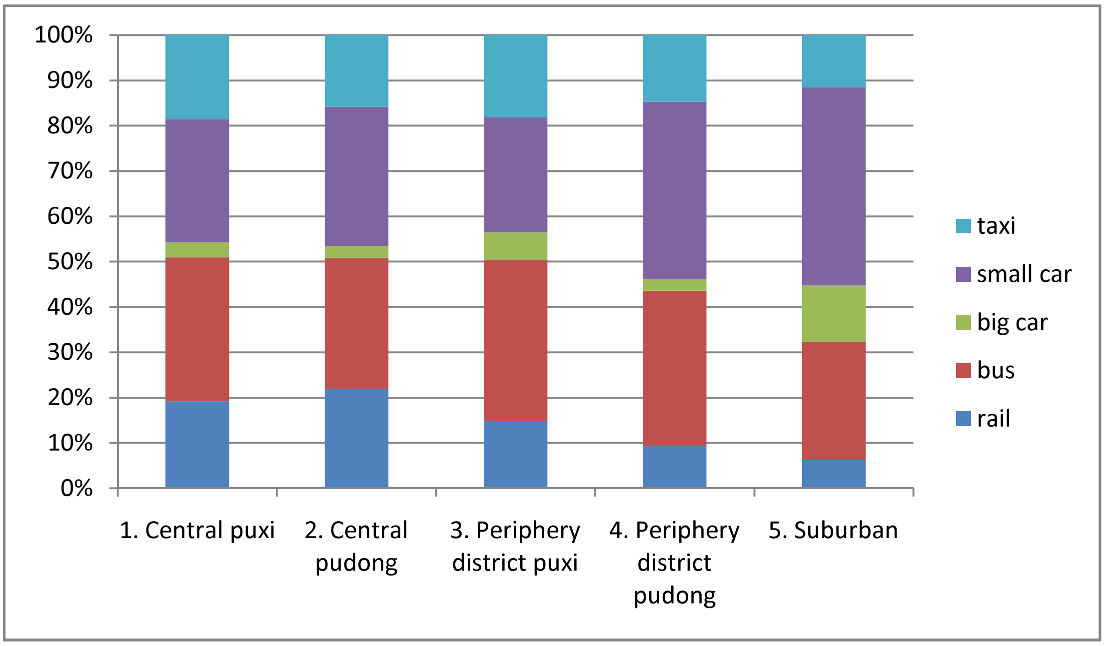



Fig 5.7 Current mode share in different areas (without bike and walk)

(Source: PT investigation in Shanghai)

Mode shift in different area of Shanghai, we can see that there are more bicycle and walk in suburban area, that's mainly because of in the far suburban area, the main transport is within the suburban area, there are less long travel distance travel, while in the mode choice in motorized travel, the private is the dominate mode. With the progress of suburbanization, if there is less supply in the public transport mode, the car use in these areas will be big problem.

In the scenarios, if the population is uncontrolled sprawl, the mode share of small car has linear relationship with the car ownership, the rail mode share has the lineal relationship with the rail density.

Based on a case study of a suburban area railway[89], we get the mode share in the influence boundary of the railway station of line 7. The mode share as shown in the following tables, the definition of the influence boundary was the 0-1.5 km, the outer boundary was defined as 1.5-3km:

Table 5.4 Mode share of different station when commuting to city center

| Name of the station | Within boundary | | Without boundary | | Distance to city center |
|---|---|---|---|---|---|
| | Rail | private | Rail | private | |
| Meilanhu | 93.09 | 6.91 | 52.4 | 47.6 | 25.78 |
| Luonanxincun | 91.45 | 8.55 | 48.96 | 51.04 | 24.78 |
| Panguanglu | 82.96 | 17.04 | 34.15 | 65.85 | 21.98 |
| Liuhang | 74.18 | 25.82 | 25.94 | 74.06 | 22.02 |
| Gucungognyuan | 67.88 | 32.12 | 22.22 | 77.78 | 21.77 |

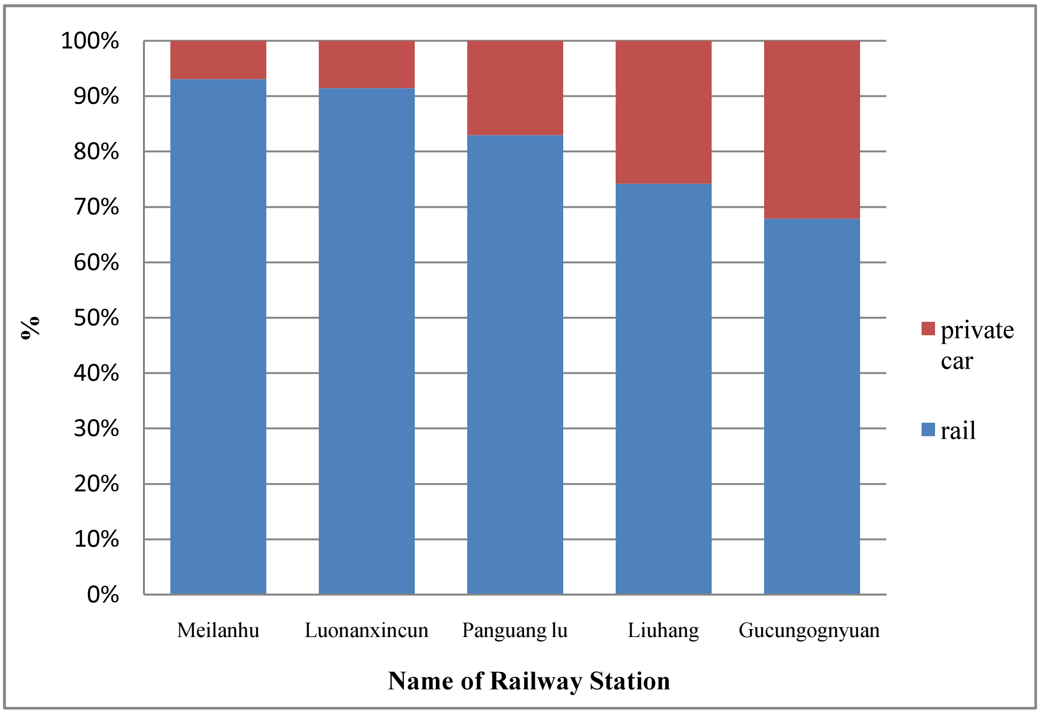



Fig 5.8 Mode share of inner boundary when commuting to city center

(Source: Liu's doctor thesis[97])

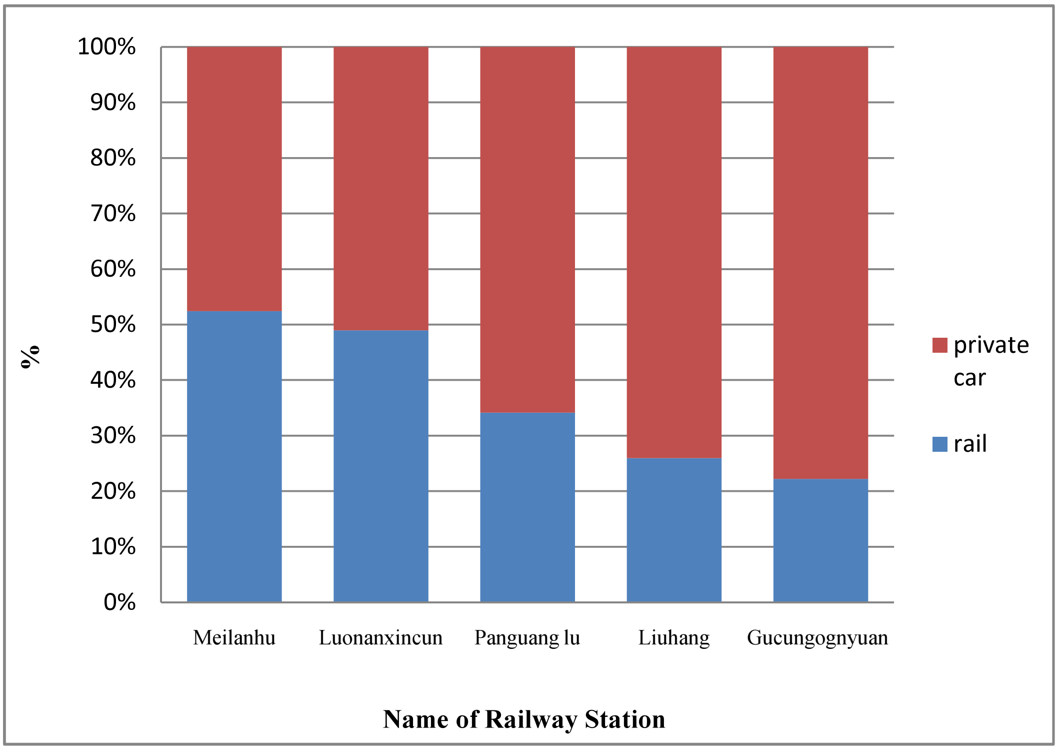



Fig 5.9 Mode share of outer boundary when commuting to city center

(Source: Liu's doctor thesis)

By assuming all the TOD development follows the way of Line 7, we can assume that: if the population is developed in the TOD mode, we can set the mode share of the rail in suburban area will be 70% in the option of with feeder transport improvement, and the share would be 55% in the option of without feeder transport improvement. And the future away from city center, the bigger the mode share of rail mode.

**(4) Average travel distance**

Table 5.5 OD matrix in Shanghai

| | 1.Central Puxi district | 2.Central Pudong district | 3.Periphery Puxi district | 4.Periphery PuDong district | 5.Suburban | total |
|---|---|---|---|---|---|---|
| 1.Central Puxi district | 712 | 37 | 219 | 30 | 65 | 1063 |
| 2.Central Pudong district | 37 | 85 | 14 | 35 | 11 | 182 |
| 3.Periphery Puxi district | 219 | 14 | 737 | 19 | 82 | 1071 |
| 4.Periphery PuDong district | 30 | 35 | 19 | 336 | 33 | 453 |
| 5.Suburban | 65 | 11 | 82 | 33 | 1580 | 1771 |
| total | 1063 | 182 | 1071 | 453 | 1771 | 4540 |

Source: PT investigation in Shanghai[83]

To know the average travel distance, we can first see the OD in Shanghai in 2009, We can see from Fig 5.6 and Fig 5.7, the transport in near suburban area and far suburban area, the most traffic demand is within itself (it occupy respectively 75% and 86%), the connection and the demand with center area of Shanghai is very low. But, with the suburbanization and land price increase, more and more people will be force to go to suburban areas, the travel demand will change greatly. From more detailed OD investigation in Shanghai, the average travel distance of suburban are shown as follows:

Table 5.6 Mode share of different station when commuting to city center

| Mode | rail | bus | taxi | small-car | large-car | motor | bike and e-bike | walk |
|---|---|---|---|---|---|---|---|---|
| Distance (km) | 8.8 | 9.1 | 6.1 | 15.1 | 14.3 | 5.6 | 5.1 | 0.9 |

Source: by calculation of author

Table 5.7 Mode share of different station when commuting to city center

| | 1. Center Puxi district | 2.Center Pudong district | 3.Puxi Periphery | 4.Pudong Periphery | 5.Suburban |
|---|---|---|---|---|---|
| Distance(km) | 6.1 | 8.2 | 7.4 | 10.4 | 30 |

Source: by calculation of author

We can see that, in the center, the average travel distance is the least in Center Puxi, that's because it's the most developed area, in the Pudong district the population density is much lower and the diversity of land use is not as that of Puxi. And in the periphery area, the travel distance is a little higher than that of center area. In the suburban area, the cross traffic zone travel volume is very little because mainly the people are not willing to live in the suburban area for its inconvenience of connection. Hence the travel mode is mainly the walk and bicycle.

In the scenario, we assume the travel distance in central area and periphery area will not change. In the option of uncontrolled sprawl, in suburban areas, the travel distance in car and taxi mode is the distance of the population mean pointer centre to the city center. In the option of TOD, in suburban areas, the travel distance of car and taxi mode will not change, the travel distance of is calculated by averaging each station's distance to the city center.

**(5) Technology improvement**

As Chinese government has paid special attention on the fuel efficiency improvement on the vehicle engine improvement, the energy improvement can be assumed as the following graph as suggested by IEA[90].

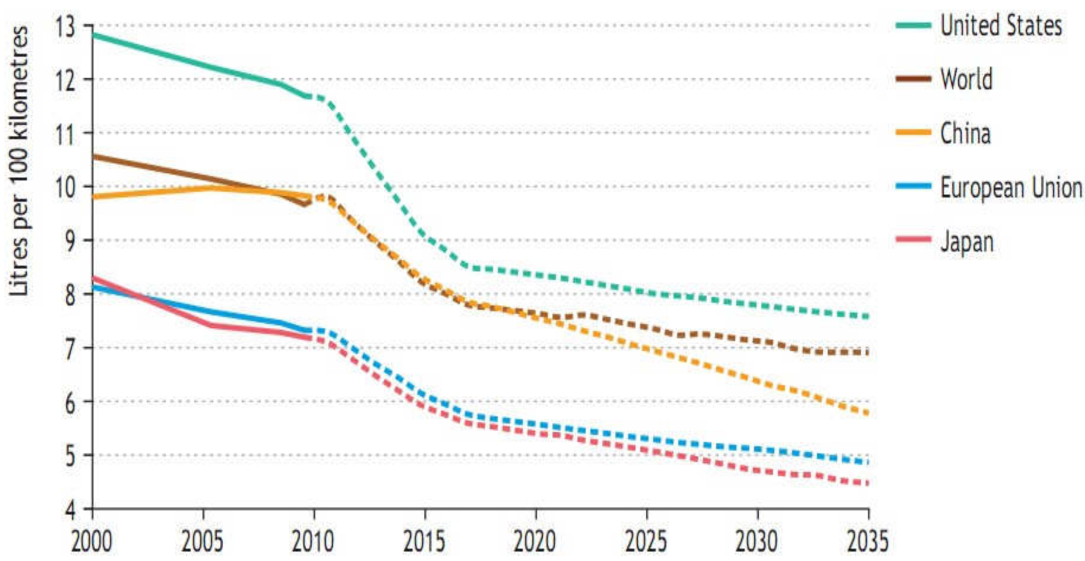



Fig 5.10 Fuel efficiency of new passenger cars

(Source: $CO_2$ emission from Fuel efficiency Combustion-Highlights, IEA, 2011)

We can see from the Fig 5.10 that, the fuel efficiency will improve 26% in the year of 2020 by comparing the year of 2009. Hence, in the scenario, the fuel efficiency will improve 26% in the year of 2020.

**(6) Land cost and financial cost of infrastructure**

In the research of the line 7 of Shanghai, the value increase by railway construction was show as follow individually. The land value increase in suburban area was more than 1000 Yuan/m$^2$, take the ratio of residential area of 50% of the total area, and take the floor area ratio, the total value increase of the influence area will be 5.6 billion RMB. Even the government can only capture 20% of the total value increase of the land, it will be 1.4 billion RMB. While the construction fee of the rail was 0.37 billion RMB each km, so only 20% of the value capture method can afford the construction of 3.8km, actually , the railway construction in the suburban area will be a little cheap than the average cost.

The transfer ability of railway was 30-60 thousand person/h. While, a normal design road's capacity was 850 PCU/lane. If the car occupancy rate was 1.6, it means that there should be 66 lanes for the same capacity for the same capacity of 45 thousands person/h. It means that we should build 16.5 two-way four lane road for the same amount of traffic volume. The cost of two-way four lane road was 16.5 million/km, so the same mount ability will be 80milllion. Normally the lane width of roads is 3.75 m, hence the average road width should be at least 20m. Hence, the land occupied by the road should be 330000 m$^2$.

Based on the land price in Shanghai, in the suburban area the land price was at least 1000/m$^2$, these land's value will be 3.3 billion. Hence, we can get the table as follows:

Table 5.8 Construction cost and land consumption

| | Rail(per km) | | | Road(per km) | | |
|---|---|---|---|---|---|---|
| | Construction cost(RMB) | Value capture(RMB) | Cost of land(RMB) | Construction cost(RMB) | Potential of value capture(RMB) | Cost of land(RMB) |
| 20% value capture, land price 1000 $m^2$ | 0.37 | 1.4 | 0.02 | 0.08 | 0 | 3.3 |
| 20% value capture, land price 1000 $m^2$ | 0.37 | 0.7 | 0.02 | 0.08 | 0 | 3.3 |
| No value capture, land price 1000 $m^2$ | 0.37 | 0 | 0.02 | 0.08 | 0 | 3.3 |

We can see clear from the table, the biggest share of the cost was not in the construction, but in terms of the cost of the land. And the value capture can give very big amount of profit for the construction of the railway. Even with a amount of 10% of value capture, it can also afford the construction of the railway. Assume there will be 200 newly build railway station built in suburban area, each station can hold 24 thousand people, the average floor area is 35$m^2$. The value added by the construction of rail is 1000 RMB/$m^2$, (based on Liu's calculation)[91], hence the value capture can be 0.84 billion by each station.

## 5.3 Results of scenarios analysis

Base on the method described, the detail result is shown as follow tables:

Table 5.9 The Result of different scenario

| Scenarios | $CO_2$ (Thousand-t-$CO_2$/day) | Rail construction cost(billion US$) | Road construction length(km) | Road construction cost(billion US$) | Land occupied by road($m^2$) | Value of the land that occupied by road | If value capture, the value captured(billion US$) | Total without value capture(billion US$) | Total with value capture(billion US$) |
|---|---|---|---|---|---|---|---|---|---|
| S1 | 35.5 | 18.5 | 4986.8 | 10.7 | 9.97E+07 | 14.2 | | 43.4 | 43.4 |
| S2 | 48.5 | 18.5 | 6520.6 | 14.0 | 1.30E+08 | 18.6 | | 51.1 | 51.1 |
| S3-BAU | 60.7 | 0.0 | 10095.8 | 21.6 | 2.02E+08 | 28.8 | | 50.5 | 50.5 |
| S4 | 28.4 | 18.5 | 1808.1 | 3.9 | 3.62E+07 | 5.2 | -24 | 27.5 | 3.5 |
| S5 | 38.6 | 18.5 | 2411.2 | 5.2 | 4.82E+07 | 6.9 | -24 | 30.6 | 6.6 |
| S6 | 26.8 | 18.5 | 4986.8 | 10.7 | 9.97E+07 | 14.2 | | 43.4 | 43.4 |
| S7 | 36.4 | 18.5 | 6520.6 | 14.0 | 1.30E+08 | 18.6 | | 51.1 | 51.1 |
| S8 | 41.0 | 0.0 | 10095.8 | 21.6 | 2.02E+08 | 28.8 | | 50.5 | 50.5 |
| S9 | 19.6 | 18.5 | 1808.1 | 3.9 | 3.62E+07 | 5.2 | -24 | 27.5 | 3.5 |
| S10 | 26.0 | 18.5 | 2411.2 | 5.2 | 4.82E+07 | 6.9 | -24 | 30.6 | 6.6 |

Based on the calculation, the output of the model can be seen as follows:

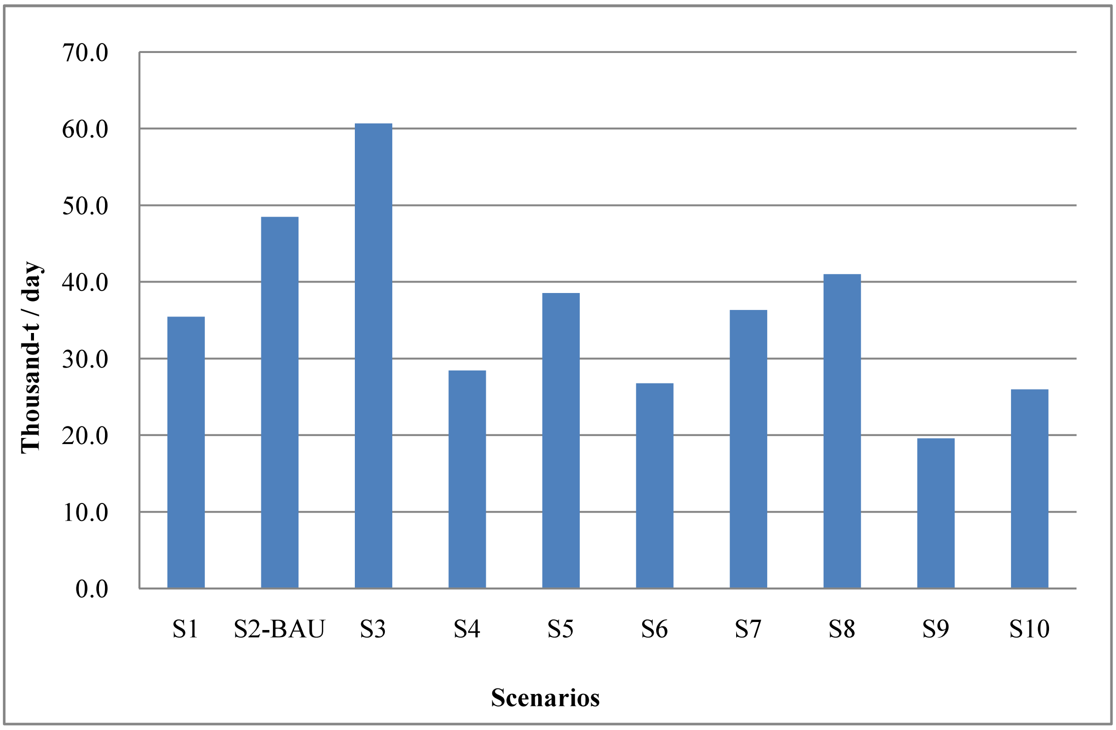



Fig 5.11 $CO_2$ emission in different scenarios

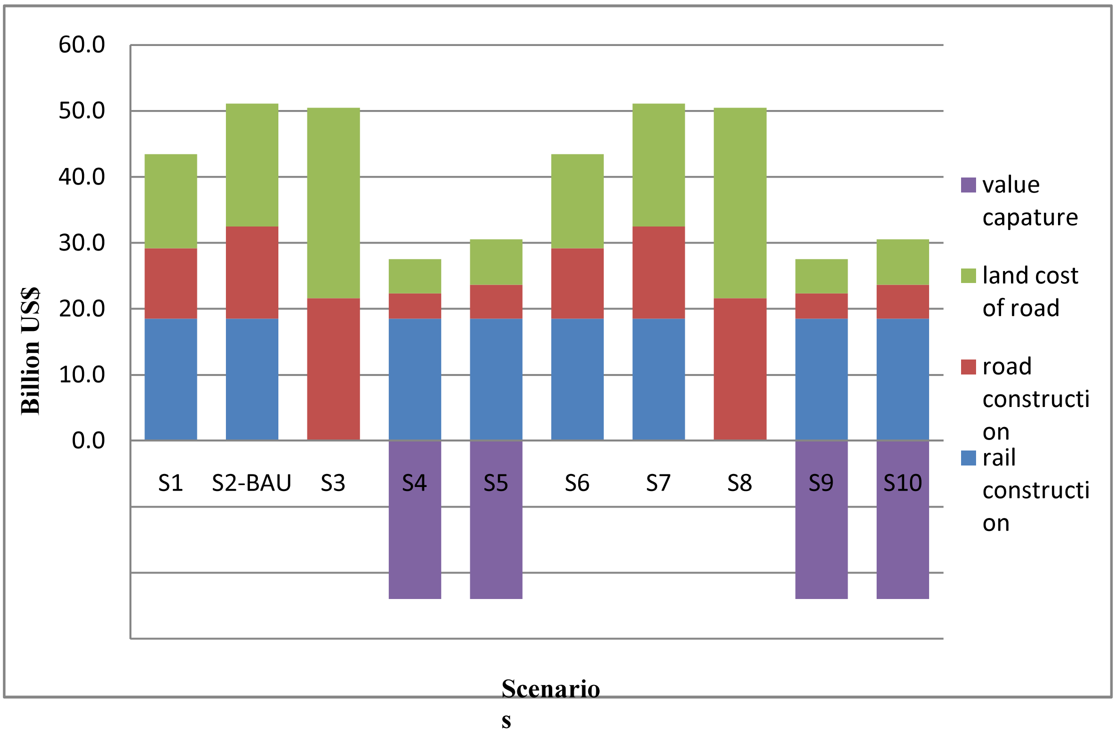



Fig 5.12 Construction cost in different scenarios

From the different scenario, from Scenario 1 to Scenario 5 are the scenarios without fuel efficiency improvement, Scenario 6 to Scenario 10 are the scenarios with fuel efficiency improvement. We can see that the scenarios with fuel efficiency improvement have less $CO_2$ emission than the scenario without fuel efficiency improvement. And car usage control shows very strong effect on the $CO_2$ emission and consequently less demand on road and then less construction fee and less consumption on the land.

Compare with Scenario 3 and Scenario 4, we can find that, if we do not consider the land cost or value capture, the construction of Scenario 3 is lower than that of Scenario 4. That's because of the high construction fee of railway and the relative low construction cost of road. If we could consider the land cost, the construction fee of road is very high, and furthermore, if we consider the value capture in Scenario 4, the construction will only be 3.5 billion US$, and the total cost of Scenario 3 will be 50.5 billion US$.

Value capture is a very strong tool to reduce the financial burden. In the scenarios, the value capture (24 billion US$) can be bigger than the railway construction cost (18.4 billion US$). Without this tool, in Scenario 4 and Scenario 9, the financial burden will be 26.7 billion US$, but with the value capture tool, the financial burden will only be 2.7 billion US$.

The best Scenario 4, only emit 58% $CO_2$ as that of BAU scenario, and the construction cost of Scenario 4 is only 7% as that of BAU scenario. The environmental efficiency and economic efficiency both improved greatly.

From the scenarios, we can see that, the best scenario for the low carbon transport and least financial burden is Scenario 4, namely the TOD development with railway construction and control on the car ownership, and also with the fuel efficiency improve. If it can be combined with the use of the value capture, the financial burden will also be very low, namely 2.7 billion US$.

## 5.4 Conclusion and discussion

Using the AVODI, SHIFT and IMPROVE matrix policy framework to evaluating $CO_2$ emission in Shanghai, this chapter calculated $CO_2$ emission and the infrastructure financial cost under different scenarios. The policy on avoiding unnecessary travel demand, shifting to eco-friendly mode and improving fuel efficiency are considered in different combination.

From the result, we can see that: (1) Car ownership control will be the most important point to mitigate the $CO_2$ emission; (2) TOD development is very necessary for controlling the travel distance and control the mode shift to the eco-friendly mode; (3) TOD development is also necessary for the land use saving from the construction of the road. (4) Value capture is a very important financial tool to alleviate the financial burden of the government. (5) Only one individual policy will not be efficient enough to control the $CO_2$ emission and alleviate the financial burden, an integrated framework is the best method to reduce the $CO_2$ emission and alleviate the financial burden and reduce the land resource waste at the same time.

# Chapter 6 Conclusion and Future works

Based on the analysis in the previous chapters, this chapter concludes the contribution of this research, and looking forward the future research

## 6.1 Findings of the dissertation

The main objective of this research is to find the factors that affect urban transport $CO_2$ emission and find the inter-factor mechanisms between factors. And base on that, by applying the policy generation system, n, design a policy package to achieve the target of low carbon and high efficient transport.

This research firstly compared the urban development and transport system development of Shanghai and Tokyo in terms of population growth, economic development, land use development and travel pattern change, and find that the change in Tokyo is now stable while the development in Shanghai is very quick, and the experience of Tokyo can be borrowed by Shanghai to develop the city in a better way. After that, decomposition analysis on inner city passenger transport system $CO_2$ emission. Shanghai and Tokyo are taken as the case cites, the factor that influences the passenger transport system are founded, and the contribution of each factor are calculated. The deeper reason that cause the change of these factors are found in a systematically way, based on the systematically analysis, a causality map of passenger transport system $CO_2$ emission was drawn in Shanghai and Tokyo, key factors that affect the $CO_2$ emission in Shang and Tokyo also has been found in the causality map. Based on finding of the key factors in Shanghai and Tokyo, we build a integrated policy framework to model the behavior of urban passenger transport in Shanghai. 18 scenarios are set to capture future possible change in different policies. The major findings of this research are summarized as follows:

1. From chapter 3, we find that Shanghai is now in the stage of high speed of suburbanization, the population in Shanghai will constantly increase and traffic demand and transport infrastructure will also increase very quickly in the next 10 years.
2. Based on the decomposition analysis in Shanghai's passenger transport system in chapter 4.2, in the total research period, population, trip generation rate, mode shift, travel distance, load effect show strong effect on the $CO_2$ emission increase. From 1986 to 1995, mode shift effect shows the strongest positive effect, contribute to 73% of the total change. From 1995 to 2004, mode shift also shows the strongest positive effect, it contribute 56% of the total change, trip generation rate and population contribute 15% and 19% to the total change respectively. From 2004 to 2009, mode shift also shows the strongest positive effect, it contribute 52% of the total change, trip generation rate and population contribute 14% and 18% to the total change respectively. While the fuel efficiency constantly contribute negative to the $CO_2$ emission, the contribution in the period of 1986 to 1995, 1995 to 2004, 2004 to 2009 are respectively -0.1%, -3% and -6%.
3. Based on the decomposition analysis in Tokyo in chapter 4.3, the contribution of each factor changed in different periods. From 1968 to 1978, population, trip rate and mode shift contribute positive to the $CO_2$ emission increase, travel distance

contribute negative to the $CO_2$ emission. From 1978 to 1988, the population, mode shift, travel distance contribute positive effect, while the trip generation rate, load effect and the fuel efficiency contribute negatively. From 1988 to 1998, population, mode shift, travel distance and fuel efficiency contribute positively, only the load effect shows negatively effect. From 1998 to 2008, only population and trip rate effect shows positive effect, mode shift, travel distance and fuel efficiency shows the strong negative effects. Totally, population constantly shows positive effect, mode shift and fuel efficiency is very sensitive factor to the $CO_2$ emission change.

4. From chapter 4.4, we get the causality map of Shanghai, we find that: urban sprawl is the main reason for the travel distance increase of Shanghai, the car ownership increase is main reason of the mode shift to cars, and the low service level of public transport and lack of strong control on car use is another reason for the mode shift to the car. And the weak connection between the residential people to the railway is another reason for the low rail mode, and the lake of financial tool such as value capture is another reason for the sustainable construction and operation for the urban rail transport. The decreasing occupancy rate contribute negative to the fuel efficiency improve, the emission standard, preferential low tax on small size engine cars contribute to the fuel efficiency improvement.
5. From chapter 4.4, we also get the causality map of Tokyo, we find that: TOD development contribute a lot on the control of travel distance and mode shift to railway. Strict car parking policy on car and high usage fee of car, together with

the high service level of rail make the car use manner in a very eco-friendly way, name shorter travel distance and less use ratio. And the recent policy on redevelop the railway station make the population increased 1 million around railway stations, which also contribute to the mode shift to railway. The fuel efficiency change contributes a lot to improvement, the main reason is the improvement of the engine technology and tax policy changed to presence of the low emission cars.

6. From Chapter4 ,we find that, the advantage of Shanghai transport sector is that, Shanghai has successfully control the car ownership, it has very strong policy power and financial ability to construct the subway quickly. The disadvantage of Shanghai is its quiet high usage of car and its weak connection between land use system and transport system, what's more, the generally deteriorating walk and bicycle system is another problem. The advantage of Tokyo transport sector is that, the land use system and transport system is well combined, the TOD develop in Tokyo is very successful. Tokyo has very well built and designed rail system, people also have very good habit to use public transport system. Even the car ownership is very high, the usage rate of car is very low. The disadvantage of Tokyo is its high car ownership and the high emission car boom in 1990s.
7. From chapter 5, in the simulation of Shanghai, different scenarios show different $CO_2$ emission and different financial burden, from 1.17 times to 3.63 time of the $CO_2$ emission of 2009. We find that the scenario combined TOD development, car use control and feeder transport improvement of railway station has the best

performance in $CO_2$ emission mitigation, if the fuel efficiency improvement can follow the scenario of IEA, the total transport system $CO_2$ emission will even be less than the amount of 2009. If we take a financial tool of value capture, the total financial burden will be 3.5 billion US$. While the scenario only with the road construction has the worst performance, the total $CO_2$ emission would be 2.48 times even with the fuel efficiency improvement, and the financial burden would be 50.4 billion US$, which is 18.5 times of the best situation. The best scenario only emits 58% $CO_2$ emission and use 7% of the construction cost compared with BAU scenario.

## 6.2 Future works

Future research could be expected in both deeper investigation of the elaborate preference investigation of the local people and the land use- transport integrated modeling, and the proper policy of value capture policy should be researched in more detailed manner.

Firstly, because of the limitation of the investigation data, the preference of the people cannot be captured, the preference data will be helpful for the people's travel behavior analysis, such as housing location choice and the detailed mode choice, and the inter-relationship of the infrastructure construction and the housing location choice. With the development data collecting methods such as taking advantage of smart phone information and GPS data of vehicles, this information could be obtained, and the preference measurement would be helpful for the better design of the urban planning and policy design for better social welfare.

Second, the relocation of people should be considered in the model, especially the relocation to the railway station that has already happened in Tokyo has shown the attractiveness of the railway station. And the case study of the joint-development of railway station and the diversity use of railway station should be carried to get the key factor that attracts population.

Thirdly, the policy of value capture should be studied more detailed, firstly the measure of the value added by railway construction and the proper policy that can be accepted by the government and the residential people should be investigated.

## Reference


[1] IEA, $CO_2$ emission from Fuel combustion- Highlights [R]. 2012

[2] IEA, $CO_2$ emission from Fuel Combustion 2012[R],2012c

[3] Dargay, J., Gately, D., Sommer, M., 2007. Vehicle ownership and income growth, worldwide: 1960–2030. Energy J. 28, pp.143-170.

[4] Haddock, R., Jullens, J., 2009. The best years of the auto industry are still to come. Strategy Business 55, pp. 2-12.

[5] Qi Ye. Annual review of Low-carbon Development in China:2010, Science publisher(in Chinese)

[6] David Banister. The sustainable mobility paradigm, Transport Policy, Volume 15, Issue 2, 2008, pp.73-80

[7] Yoshitsugu Hayashi, John R. Roy ets.(1996). Land use, Transport and the Environment, Kluwer.

[8] AngBW, ZhangFQ. A survey of index decomposition analysis in energy and environmental analysis. Energy，2000，25:1149-1176.

[9] SunJW. Accounting for energy use in China,1980-1994.Energy,1998，23:835-849.

[10] AngBW, Pandiyan G. Decomposition of energy-induced $CO_2$: emissions in manufacturing. Energy Economies:1997 19:363-374.

[11] AngBW, ZhangFQ. Inter-regional comparisons of energy-related $CO_2$: emissions using the decomposition technique. Energy, 1999, 24:297-305.

[12] Lee Schipper, Lynn Scholl, Lynn Price. Energy use and carbon emissions from freight in 10 industrialized countries: An analysis of trends from 1973 to 1992. Transportation Research Part D: Transport and Environment, Volume 2, Issue 1, March 1997, Pages 57-76

[13] Fatumata Kamakaté , Lee Schipper. Trends in truck freight energy use and carbon emissions in selected OECD countries from 1973 to 2005. Energy Policy, Volume 37, Issue 10, October 2009, Pages 3743-3751

[14] W.W. Wang, M. Zhang, M. Zhou. Using LMDI method to analyze transport sector $CO_2$ emissions in China. Energy, Volume 36, Issue 10, October 2011, Pages 5909-5915

[15] Jiyong Eom, Lee Schipper, Lou Thompson. We keep on truckin': Trends in freight energy use and carbon emissions in 11 IEA countries. Energy Policy, Volume 45, June 2012, Pages 327-341

[16] Hongqi Li, Yue Lu, Jun Zhang, Tianyi Wang. Trends in road freight transportation carbon dioxide emissions and policies in China. Energy Policy Volume 57, June 2013, Pages 99-106

[17] Govinda R. Timilsin, Ashish Shresth. Transport sector $CO_2$ emissions growth in Asia: Underlying factors and policy options. Energy Policy Volume 37, Issue 11, November 2009, Pages 4523-4539

[18] María Mendiluce, Lee Schipper. Trends in passenger transport and freight energy use in Spain. Energy Policy, Volume 39, Issue 10, October 2011, Pages 6466-6475

[19] Tae-Hyeong Kwon. The determinants of the changes in car fuel efficiency in Great Britain (1978-2000). Energy Policy, Volume 34, Issue 15, October 2006, Pages 2405-2412.

[20] Lynn Scholl, Lee Schipper, Nancy Kiang. $CO_2$ emissions from passenger transport: A comparison of international trends from 1973 to 1992. Energy Policy, Volume 24, Issue 1, January 1996, Pages 17-30.

[21] Jiyong Eom, Lee Schipper. Trends in passenger transport energy use in South Korea. Energy Policy, Volume 38, Issue 7, July 2010, Pages 3598-3607.

[22] V. Andreoni, S. Galmarini. Decoupling economic growth from carbon dioxide emissions: A decomposition analysis of Italian energy consumption. Energy, Volume 44, Issue 1, August 2012, Pages 682-691.

[23] I.J. Lu, Sue J. Lin, Charles Lewis. Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany, Japan and South Korea. Energy Policy, Volume 35, Issue 6, June 2007, Pages 3226-3235.

[24] Katerina Papagiannaki, Danae Diakoulaki. Decomposition analysis of $CO_2$ emissions from passenger cars: The cases of Greece and Denmark. Energy Policy, Volume 37, Issue 8, August 2009, Pages 3259-3267.

[25] Becky P.Y. Loo, Linna Li. Carbon dioxide emissions from passenger transport in China since 1949: Implications for developing sustainable transport. Energy Policy, Volume 50, November 2012, Pages 464-476

[26] Ming Zhang, Huanan Li, Min Zhou, Hailin Mu. Decomposition analysis of energy consumption in Chinese transportation sector. Applied Energy, Volume 88, Issue 6, June 2011, Pages 2279-2285

[27] A.D. May, M Roberts. The design of integrated transport strategies. Transport Policy, Volume 2, Issue 2, April 1995, Pages 97-105.

[28] Anthony D. May, Charlotte Kelly, Simon Shepherd, Ann Jopson. An option generation tool for potential urban transport policy packages. Transport Policy, Volume 20, March 2012, Pages 162-173.

[29] David A. Hensher, Truong P. Truong, Corinne Mulley, Richard Ellison. Assessing the wider economy impacts of transport infrastructure investment with an illustrative application to the North-West Rail Link project in Sydney, Australia. Journal of Transport Geography, Volume 24, September 2012, Pages 292-305.

[30] Xiaoyan Zhang, Neil Paulley , Mark Hudson , Glyn Rhys-Tyler. A method for the

design of optimal transport strategies. Transport Policy, Volume 13, Issue 4, July 2006, Pages 329-338

[31] WCTRS and ITPS: Hideo Nakamura, Yoshitsugu Hayashi and Anthony, May (2004).Urban Transport and the Environment. An International Perspective. Elsevier Ltd.

[32] Kazuki Nakamura, Yoshitsugu Hayashi. Strategies and instruments for low-carbon urban transport: An international review on trends and effects. Transport Policy, Available online 18 August 2012

[33] Louis de Grangea, Rodrigo Troncoso, Felipe Gonzáleza. An empirical evaluation of the impact of three urban transportation policies on transit use. Transport Policy, Volume 22, July 2012, Pages 11-19

[34] Rui Mua, Martin de Jonga. Establishing the conditions for effective transit-oriented development in China: the case of Dalian. Journal of Transport Geography, Volume 24, September 2012, Pages 234-249

[35] Tao Fenga, Junyi Zhangb, Akimasa Fujiwarab, Harry J.P. Timmermansa. An integrated model system and policy evaluation tool for maximizing mobility under environmental capacity constraints: A case study in Dalian City, China. Transportation Research Part D: Transport and Environment, Volume 15, Issue 5, July 2010, Pages 263-274

[36] Robin Hickman, Sharad Saxena, David Banister, Olu Ashiru. Examining transport futures with scenario analysis and MCA. Transportation Research Part A: Policy and Practice, Volume 46, Issue 3, March 2012, Pages 560-575

[37] Christopher Yang, David McCollum, Ryan McCarthy, Wayne Leighty. Meeting an 80% reduction in greenhouse gas emissions from transportation by 2050: A case study in California. Transportation Research Part D: Transport and Environment, Volume 14,

Issue 3, May 2009, Pages 147-156

[38] Philippe Barla, Luis F. Miranda-Moreno, Martin Lee-Gosselin. Urban travel $CO_2$ emissions and land use: A case study for Quebec City. Transportation Research Part D: Transport and Environment, Volume 16, Issue 6, August 2011, Pages 423-428.

[39] Peter W. G. Newman, Jeffrey R. Kenworthy. Gasoline Consumption and Cities: A Comparison of U.S. Cities with a Global Survey. Journal of the American Planning Association, Volume 55, Issue 1, 1989

[40] Robert Cervero, Kara Kockelman. Travel demand and the 3Ds: Density, diversity, and design. Transportation Research Part D: Transport and Environment, Volume 2, Issue 3, September 1997, Pages 199-219

[41] Reena Tiwari, Robert Cervero, Lee Schipper. Driving $CO_2$ reduction by Integrating Transport and Urban Design strategies. Cities, Volume 28, Issue 5, October 2011, Pages 394-405

[42] Chao Liu, Qing Shen. An empirical analysis of the influence of urban form on household travel and energy consumption. Computers, Environment and Urban Systems, Volume 35, Issue 5, September 2011, Pages 347-357

[43] Atsushi Akisawa, Yoichi Kaya. Two model analyses of the urban structure of minimal transportation energy consumption. Applied Energy, Volume 61, Issue 1, 1 September 1998, Pages 25-39

[44] James Cooper, Tim Ryley, Austin Smyth, Edward Granzow. Energy use and transport correlation linking personal and travel related energy uses to the urban structure. Environmental Science & Policy, volume 4, Issue 6, December 2001, Pages 307-318

[45] James Keirstead, Nilay Shah. Calculating minimum energy urban layouts with mathematical programming and Monte Carlo analysis techniques. Computers,

Environment and Urban Systems, volume 35, Issue 5, September 2011, Pages 368-377

[46] Leonardo J. Basso, Cristián Angelo Guevara, Antonio Gschwender, Marcelo Fuster. Congestion pricing, transit subsidies and dedicated bus lanes: Efficient and practical solutions to congestion. Transport Policy, Volume 18, Issue 5, September 2011, Pages 676-684

[47] Zheng Li , David A. Hensher. Congestion charging and car use: A review of stated preference and opinion studies and market monitoring evidence. Transport Policy, Volume 20, March 2012, Pages 47-61

[48] Miao Fu, J. Andrew Kelly. Carbon related taxation policies for road transport: Efficacy of ownership and usage taxes, and the role of public transport and motorist cost perception on policy outcomes. Transport Policy, Volume 22, July 2012, Pages 57-69

[49] Tina Gehlert, Christiane Kramer, Otto Anker Nielsen, Bernhard Schlag. Socioeconomic differences in public acceptability and car use adaptation towards urban road pricing, Transport Policy, Volume 18, Issue 5, September 2011, Pages 685-694

[50] Kian Ahmadi Azari, Sulistyo Arintono, Hussain Hamid, Riza Atiq O.K. Rahmat. Modeling demand under parking and cordon pricing policy. Transport Policy, Volume 25, January 2013, Pages 1-9

[51] Bharat P. Bhatta, Odd I. Larsen. Errors in variables in multinomial choice modeling: A simulation study applied to a multinomial logit model of travel mode choice. Transport Policy, Volume 18, Issue 2, March 2011, Pages 326-335.

[52] Graham Currie, Alexa Delbosc. Understanding bus rapid transit route ridership drivers: An empirical study of Australian BRT systems. Transport Policy, Volume 18,

Issue 5, September 2011, Pages 755-764

[53] Ari Rabl, Audrey de Nazelle. Benefits of shift from car to active transport. Transport Policy, Volume 19, Issue 1, January 2012, Pages 121-131

[54] Yunlong Zhang, Jinpeng Lv, Qi Ying. Traffic assignment considering air quality. Transportation Research Part D: Transport and Environment, Volume 15, Issue 8, December 2010, Pages 497-502

[55] Serge Pahaut, Catharina Sikow. History of thought and prospects for road pricing. Transport Policy, Volume 13, Issue 2, March 2006, Pages 173-176

[56] Brian Caulfield, Elaine Brick, Orla Thérèse McCarthy. Determining bicycle infrastructure preferences – A case study of Dublin. Transportation Research Part D: Transport and Environment, Volume 17, Issue 5, July 2012, Pages 413-417

[57] Ryoichi Sakano, Julian Benjamin. A structural model of mode-activity choice: The case of commuter rail in a medium-size metropolitan area. Transport Policy, Volume 18, Issue 2, March 2011, Pages 434-445

[58] Maya Abou-Zeid, Moshe Ben-Akiva. Travel mode switching: Comparison of findings from two public transportation experiments. Transport Policy, Volume 24, November 2012, Pages 48-59

[59] Alexander Y. Bigazzi, Miguel A. Figliozzi. Congestion and emissions mitigation: A comparison of capacity, demand, and vehicle based strategies. Transportation Research Part D: Transport and Environment, Volume 17, Issue 7, October 2012, Pages 538-547

[60] Hans Michiels,Inge Mayeres, Luc Int Panis, Leo De Nocker, Felix Deutsch, Wouter Lefebvre. PM2.5 and NOx from traffic: Human health impacts, external costs and policy implications from the Belgian perspective. Transportation Research Part D: Transport and Environment, Volume 17, Issue 8, December 2012, Pages 569-577

[61] Brian Caulfield, Séona Farrell, Brian McMahon. Examining individual's preferences for hybrid electric and alternatively fuelled vehicles. Transport Policy, Volume 17, Issue 6, November 2010, Pages 381-387

[62] Michael Sivak, Brandon Schoettle. Eco-driving: Strategic, tactical, and operational decisions of the driver that influence vehicle fuel economy. Transport Policy, Volume 22, July 2012, Pages 96-99

[63] Timon H. Stasko, H. Oliver Gao. Reducing transit fleet emissions through vehicle retrofits, replacements, and usage changes over multiple time periods. Transportation Research Part D: Transport and Environment,Volume 15, Issue 5, July 2010, Pages 254-262

[64] Ulrike Huwer. Public transport and car-sharing benefits and effects of combined services. Transport Policy, Volume 11, Issue 1, January 2004, Pages 77-87

[65] Rui Wang. Shaping carpool policies under rapid motorization: the case of Chinese cities. Transport Policy, Volume 18, Issue 4, August 2011, Pages 631-635

[66] Brian Caulfield. Estimating the environmental benefits of ride-sharing: A case study of Dublin. Transportation Research Part D: Transport and Environment，Volume 14, Issue 7, October 2009, Pages 527-531

[67] Jörg Firnkorn. Triangulation of two methods measuring the impacts of a free-floating car sharing system in Germany. Transportation Research Part A: Policy and Practice, Volume 46, Issue 10, December 2012, Pages 1654-1672

[68] Susan A. Shaheen, Mark A. Mallery, Karla J. Kingsley. Personal vehicle sharing services in North America. Research in Transportation Business & Management, Volume 3, August 2012, Pages 71-81

[69] Gonçalo Correiaa, José Manuel Viegas. Transportation Research Part A: Policy and PracticeVolume 45, Issue 2, February 2011, Pages 81-90

[70] Shanghai Statistical Yearbook, China Statistical Press, 1978-2012.

[71] Urban statistical yearbook of China, China Statistical Press, 1985-2002

[72] Statistical Yearbook of Japan 1955-2011

[73] The Comprehensive Plan of Shanghai, 1999-2020, Government of Shanghai.

[74] Ming Zhang, , Hailin Mu, Yadong Ning. Accounting for energy-related CO2 emission in China, 1991–2006. Energy Policy, Volume 37, Issue 3, March 2009, Pages 767-773.

[75] Annual Report of Shentong Group,2009.

[76] Juan Zou, An Analysis on the Preference of Shanghai Customers on the Private Cars and Its Influence on the Unit Energy Consumption, Master thesis of Shanghai Jiaotong university.

[77] Shanghai City Comprehensive Transportation Planning Institute. Report of Shanghai Transportation Survey in 1995, 2004 and 2009.

[78] Beijing Statistical Yearbook, China Statistical Press, 1978-2011

[79] Energy Consumption, Emissions and their Comparison among Different Transport Modes, Integrated Transport Research Center of China Beijing Jiaotong University December, 2009.

[80] Limits of Fuel Consumption for Passenger Cars (GB19578-2004)

[81] Report of 5th Tokyo metropolitan area PT investigation, available on line: http://www.tokyo-pt.jp/person/

[82] Statistical Survey Department of Minister's Secretariat, Annual Report of Land Transportation Statistics, 1968, 1978. (in Japanese)

[83] Department of Transportation management of Transport Policy Bureau, Department of Transportation , Japan Automobile Statistical Yearbooks, 1968, 1978, 1988, 1998, 2008.(in Japanese)

[84] Supervision Bureau of Railway Department, Private Railway Statistical Yearbook, 1968, 1978. (in Japanese)

[85] Department of Transportation management of Transport Policy Bureau, Annual Report of Rail Transportation Statistics, 1988, 1998, 2008.(in Japanese)

[86] Tokyo Metropolitan Area Transportation Planning Council, PT Survey Data of Tokyo, 1968,1978,1988,1998,2008. From: http://www.tokyo-pt.jp/index.html

[87] Japan National Land information Division, National and Regional Bureau. From: http://nlftp.mlit.go.jp/ksj/

[88] Shanghai Statistical Yearbook, China Statistical Press, 1978-2011

[89] WeiWei Liu. Chapter 5 of Doctoral dissertation. Research on the Value Capture for Mass Rail Transit Development

[90] IEA. $CO_2$ emission from Fuel efficiency Combustion-Highlights[R]. 2011b

[91] WeiWei Liu. Chapter 4 of Doctoral dissertation. Research on the Value Capture for Mass Rail Transit Development

# Acknowledgement

First of all I want to express my great thanks to my supervisor, professor Hayashi. He provide me lots of opportunities on research, he give a broad scope and encourage me to challenge new things. He does not only teach me knowledge on study, but handover some the wisdom in life, which must benefit me in my future life.

I would like also thank Prof. Kato's instruction and kindly help in my emergent time, he helped me to improve the level of the thesis, and his concentration on works always moves me and stimulates me to work harder.

I will also thanks Prof.Xue jinjun in graduate school of economy, his instruction in academic field and life will valuable wealth in all my life. I also would like to express my sincerely thanks to Prof. Tanikawa's instruction on my thesis.

In the progress of writing my thesis, Dou yi help me a lot in data collecting and inputting jobs, which help me a lot. Other of my friends, your encouraged me and help me a lot in various affairs, I will never forget the time that spend with you. I would also like to thanks the members in our lab, for your kindness and help.

As I am about to finish my Ph.D study, I cannot forget my former supervisor in master cause, Prof. ZHU hehua in Tongji University, he taught me the basic knowledge of research and give me consistent help.

Finally I would like to thanks to my parents, without your support, I cannot freely stay in Japan for such a long time and exactly I have leaved my home for 12 years science I went to college in 2001.