On Modal Choice and Transportation Facilities Development in Cities

Dissertation Submitted to Hachinohe Institute of Technology for Degree of Doctor in Engineering

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Abstract

With the social and economic development, urban functions are gradually improving, living standards are gradually increasing, and residents' trip modes are also been greatly changed. Residents' trip has started to shift from non-motorized trip to motorized trip and the proportion of private motorized trip is getting higher and higher, but this has led to a lot of traffic problems, such as environmental pollution, traffic congestion and low trip efficiency, especially in the developing cities, as the speed of traffic infrastructure construction increases, it does not solve the traffic problem very well, instead, the more traffic infrastructure the more traffic problems occur. In Tokyo, there are the similar traffic problems since the 1850s, with serious air pollution and traffic congestion. However, Tokyo has successfully solved these problems with many years of construction and development. Now, Tokyo has a well-developed public transport network, especially the railway transport network, extends in all directions. The structure of residents' trip modes has been greatly improved and optimized. In this dissertation, summarizing and combing the successful experience of Tokyo transportation development and optimizing the structure of residents' trip modes, comparing with Tokyo, combing the problems of urban traffic and the structure of residents' trip modes with that of Tokyo, it can provide reference for the traffic planning, improvement of the developing cities and the adjustment of residents' trip modes, etc.

The dissertation is bases on "The 5th Tokyo Metropolitan Area Person Trip Survey"[1], Cluster Analysis was used to cluster 23 wards of Tokyo into three clusters and Principal Component Analysis was used to analyze and compare the principal component of modal choices data in 23 wards of Tokyo, Beijing and Shanghai.

1. Analyzed the research background, proposed the research purpose, the research contents and research flow.

2. The literature is reviewed and summarized, including the development of traffic pattern structure and modal choices influencing factors (individual and group factors), development and application of Cluster Analysis and Principal Component Analysis.

Puts forward own conclusion, the research mainly concentrates on the influence of macroscopic factor and microcosmic factor on residents' trip, and then found the research of comparative analysis among international cities is lesser. The main gap of urban traffic development can be sorted out by comparison and analysis (Cluster analysis and Principal component analysis), and the experience and reference of urban transportation are provided.

3.The development history of Tokyo, Beijing and Shanghai, especially the rail transit, the main traffic policy history and road network structure are sorted out, and found that the development of Tokyo rail transit and urban development, population distribution has a close relationship, urban spatial expansion and population distribution are with the expansion of rail transit and distribution, and Beijing and Shanghai appeared different situations, the development of rail transit after the urban development is a certain extent, there are many difficulties and problems need to face.

4. Based on the distribution of population and population density in the three Circles of Tokyo special wards during the day and night, analyzed the law of population flow, the generation and regularity of commuting flow and school-based flow and the orientation trend in each Circle, summarized the development experience of efficient transport in Tokyo by the analysis of the trip distribution in Tokyo 23 wards, it is found that urban sub-centers have good traffic attraction and population redistribution functions, the traffic distribution can be effectively carried out through the construction of urban sub-centers, so as to relieve traffic pressure in urban centers and balance urban traffic pressure.

5. By comparing the composition of urban road network, road network density and urban road network area ratio, analyzed the construction and development of traffic infrastructure in comparative cities and focuses on the formation of rail transit network and the layout of urban traffic routes, found the differences and gaps among comparative cities in urban transport development, proposed advice and measures for the developing cities in development of future traffic development.

Statistics and analysis of the residents' trip purpose and modal choices in 23 wards in Tokyo show that the residents' main trip modals choice tend to rail transit and walking, but the proportion of non-public transport (private cars, etc.) is relatively high in comparative cities and with the increase year by year.

Collating and analyzing air pollution caused by air pollutants from various modes of trip and laws and policies governing air pollution in Tokyo can provide a good direction and successful experience for structural adjustment and air pollution control of residents in developing city.

The air pollution caused by traffic pollutant emission, laws and measures to govern air pollution in Tokyo are summarized and analyzed, proposed experience and measures of air pollution control caused by traffic in Tokyo, that can provide a good development direction and successful experience for the urban residents to adjust their traffic patterns, prevent air pollution and then improve the air quality.

6. Principal component analysis was used to analyze the principal components based on the data of residents' trip mode share in 23 wards of Tokyo, Beijing and Shanghai and 2 principal components were obtained by the data standardization, eigenvalues, eigenvectors and principal components. Principal component 1 is public transportation and walking, Principal component 2 is motor vehicles and other trip modes and scatter plot matrix, the distribution of the main component score and other means, the 23 wards of Tokyo, Beijing and Shanghai residents' trip modes structure were compared, analyzed and concluded that residents trip in Tokyo are mainly rely on public transport, and that Beijing and Shanghai are gradually formed the trend that residents' trip mode transform from public transportation to motor vehicle. The relationship of various trip modes in Tokyo can provides references to the other cities in the future.

Finally, the advice and suggestions are put forward for the transportation planning, construction and development of developing cities.

Keywords: Modal Choice, Trip Distribution, Traffic Assignment, Trip Generation Attraction, Cluster Analysis, Principal Component Analysis

Chapter 1 Introduction

1.1 Research background and purpose

After 1950s, with the world economy recovery, industrialization and city urbanization, city expanding development, developed countries have improved the development level by improving the development of traffic and the traffic conditions, the spatial integration of city transportation and other measures, and the traffic is the foundation and skeleton of city, for economy, society, industry, urbanization and other aspects, traffic has played an important role.

At that time, the industry, commerce, etc. in Japan were mainly concentrated in Tokyo. Due to job opportunities and other reasons, the population influx into the special wards in Tokyo rapidly, caused a sharp increase of population and brought a series of problems, including traffic congestion, environmental degradation and the other. In order to prevent urban sprawl and environmental deterioration, the government of Japan started to plan and adjust the metropolitan area development plan, after planning and adjustment five times, with years of construction and development, it has become a successful case of the world metropolitan area.

During the process, the development of Tokyo urban transport network is very representative case, especially, the public transport network in the special wards of Tokyo (23 wards) has successfully solved the huge pressure brought by the large number of population on transportation. With the special wards of Tokyo as the center, various modes of traffic converge here and connect with the rail traffic as a network by Yamanote line of JR (Japan Railways) and Oedo Line of Tokyo metro, formed a convenient traffic network with circular and radial interlacing. Tokyo successfully solve the traffic congestion, motor vehicle increasing and the other issues, formed a developed transportation network system, three-dimensional traffic system, traffic network system in the intelligent and developed public transport, reflecting the strong development of transportation technology and capacity, has a mature development experience.

In spite of the good achievements made in the economic, social, urban and transportation development in developing countries, but there are also lagging behind in development, slow and unreasonable phenomena. With the development of China in recent years, the level of urbanization has been continuously increasing. However, many problems have emerged in the process of urbanization. As a large number of people are pouring into the cities, the population density has increased obviously, traffic congestion has appeared and the problems of environmental pollution caused by traffic gradually revealed. In addition, due to the unreasonable private trip modes, the trip efficiency is low and the preference for private motor vehicle trip has exerts tremendous pressure on the urban traffic network and great challenge to environmental protection.

The similar situation has appeared in transport construction in developing countries. It is in the transportation infrastructure construction or the traffic related laws and regulations, there are imperfect problems, and lack of construction experience, resulting in repetitive construction, imperfect traffic network, unreasonable structure of residents' trip modes, etc., all of above has brought great losses to the development of society, economy, transportation and environmental protection. Therefore, based on the successful experience of traffic construction and management in Tokyo, it has a good reference and practical significance for the construction of the modernized transportation network system, the efficient transportation and the reduction of the pressure to the economic and social development.

1.2 The main research contents

In the past more than 10 years, the urban traffic problems have been properly solved by optimizing the urban transportation structure and reasonable traffic distribution and other policies and measures, which has provided the guarantee and vitality of the urban traffic development. This dissertation compares the population, urban road, vehicle volume, rail transit, metro and structure of trip modes in Tokyo, Beijing and Shanghai so as to provide some reference and enlightenment for the future urban traffic development in developing countries. The main contents of this dissertation are composed of the following parts:

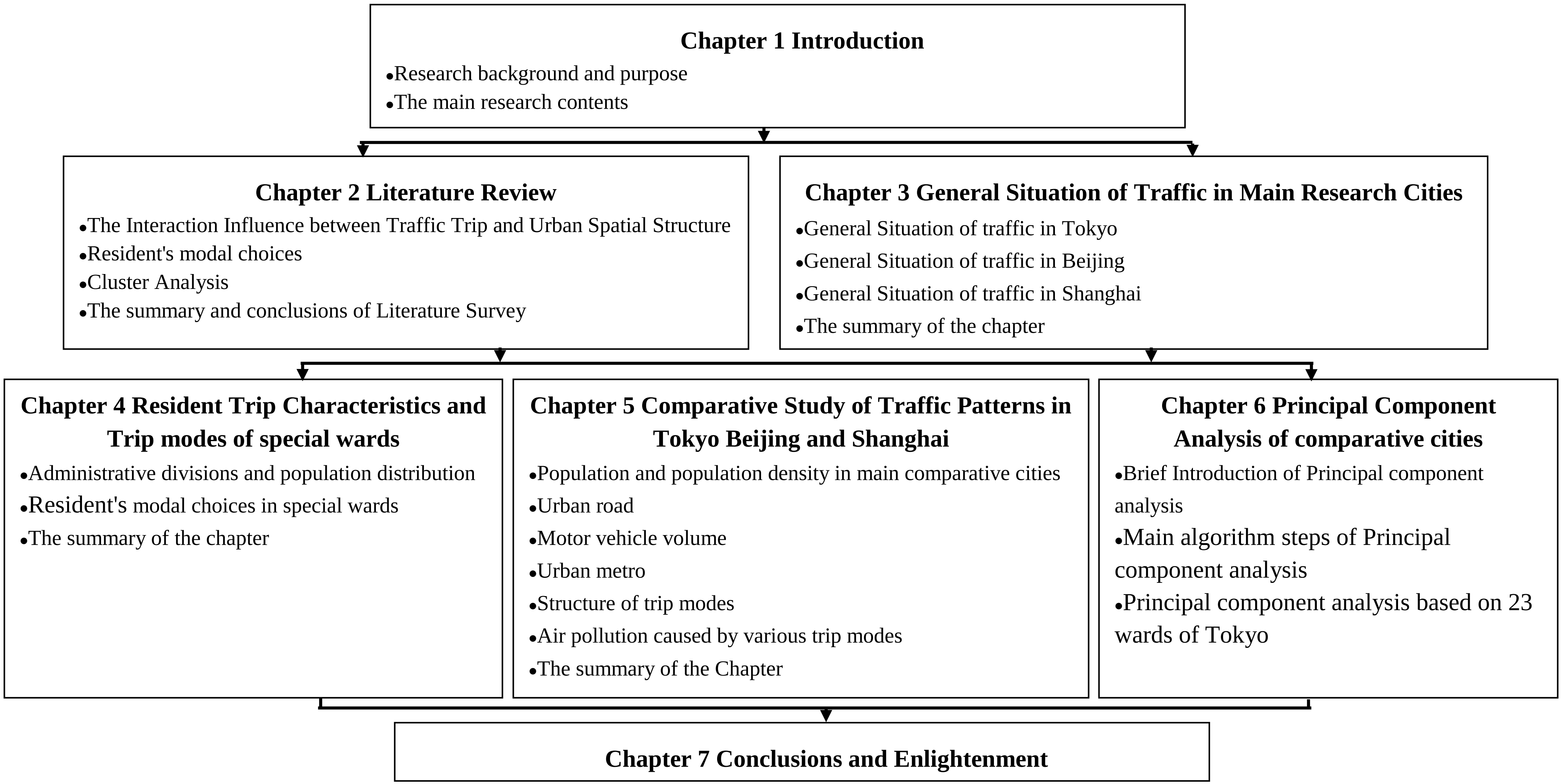
1.Base on the historical evolution of urban traffic development in main contrastive cities (Tokyo, Beijing and Shanghai), including: policies, urban structure and traffic development, etc. summed up the time series of urban traffic development, policy sets and measures in Tokyo and provide framework recommendations for the urban traffic development in other cities.

2. Base on "The 5th Tokyo Metropolitan Area Person Trip Survey"[1] and takes special wards of Tokyo as the research object. The population during the daytime and nighttime, D-value, distribution of population and residents' trip purposes, traffic volume and trip scale in each ward and trip modes proportion are collected, organized and analyzed, the basic characteristics and main rules of residents' trip in special wards of Tokyo are obtained.

3. Take 23 wards of Tokyo, Beijing and Shanghai as the research objects, based on the data of "The 5th Tokyo Metropolitan Area Person Trip Survey"[1], compare and analyze with that of Beijing and Shanghai, it concludes demographic data, population density, urban road network density and length, motor vehicle volume and per capita volume, urban rail traffic and residents' modal choices structure in the last 15 years, comb the experiences of Tokyo in urban traffic development. Based on the analysis of Tokyo traffic pattern and compared with that of Beijing and Shanghai, propose some advice and enlightenment on traffic development of Beijing and Shanghai.

5. Based on the above comparative analysis, explore the contrast among the Tokyo traffic mode and the urban traffic development in developing countries such as Beijing and Shanghai, and puts forward corresponding suggestions.

1.3 Research flow



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Chapter 2 Literature Review

2.1 The interaction influence between trip and urban spatial structure

The spatial structure of the city has an interactive relationship with the traffic trip, specifically the structure of the urban land use[2], including the size, shape, density, functional layout and the interaction between land use and transportation network. Different urban spatial structures may cause different social, ecological and environmental characteristics and different impacts on traffic trip.

The degree of mixed land-use is a typical factor of the spatial structure and has a significant impact on the mode of traffic. R. Cervero[3] pointed out that the mixed land-use is conducive to motor vehicle traffic and balancing traffic flow. Frank et al.[4] presented that the higher the degree of mixed land-use, the less probability for people to use the motor vehicle alone.

Based on theoretical and empirical studies of engineering, economics and social sciences, Wegener[5] analyzed and explained the capacity of land-use and traffic to interact with each other, and the relationship between land-use and transport patterns is governed by the numerous activities include living, work and shopping, land-use, traffic flow, traffic infrastructure to change the land-use patterns, the land-use and traffic trip have an impact each other.

Using the San Francisco Bay Area data, R. Cervero and M. Duncan, et al.[6]established a relationship between job-housing balance and vehicle mileage found that the job-housing balance can reduce traffic trip within 4 miles in the residential area and every 10% of the same jobs increase can reduce the amount of commuting trip by 3.29%.

Increasing the density of the city space structure, increasing the balance of the work-life, increasing the accessibility of residents and destinations, connecting the main destinations of day-to-day activities and increasing employment opportunities in public transport centers can effectively reduce trip distances and reduce the use of cars. At the same time, it will also increase the proportion of public transport trips[7, 8] and adopt comprehensive control measures, including: increasing the cost of using private car, increasing the attractiveness of public transport, and strengthening land planning[9].

Banister[10] pointed out that land development and management can affect transportation in many ways, including increasing density, mixed land-use, building energy efficiency, regional planning, space and road planning, public transport oriented development mode, around the transportation node development mode and improve services, etc.

The interaction between the development of urban space and traffic trip is mainly conducted by quantitative methods. More and more researches tend to include some columns of socioeconomic variables in quantitative research, such as family characteristics and private attributes in order to understand well the impact of urban space on traffic.

2.2 Residents' modal choices

2.2.1 The development of trip mode structure

The development of traffic trip mode began in the middle of the 20th century, according to J.M.[11], the urban traffic trip structure is mainly divided into four modes, the first is the development mode of the car-led development, full development of the car, dispersion from the city center to the regional. The second is the leading mode of rail transit, the construction of well-developed rail transit network in the city center, the use of cars in the city limits and the construction of radial roads to encourage the use of cars in the suburbs.

The third is the balanced development of public transport and private cars, public transport can use radial public transport system to build a perfect "radial + circular" road network in the city, private cars and buses can enter the city center by the road network.

Fourthly, it is a bus-based development mode. The urban road network is dominated by public transport services. Each road is provided with a bus-only road and the population density in the downtown area is controlled.

The fourth is the bus-based development mode, the urban road network is dominated by public transport service and the road is equipped with a bus-only road and controls the population density in the downtown area.

K Sasaki[12] compared and analyzed the stability of a single traffic trip structure and that of a composite traffic trip structure, considering that the composite traffic trip structure is more stable than a single traffic trip structure, and that the mode of traffic trip structure and urban space exist interactions. Newman. P et al. [13] found that there is a close relationship among urban passenger traffic trip structure, urban residential density and the proportion of urban population with high population density is high too.

Elkin T, et al.[14]propose that slow-transit and public transport-oriented urban transport trips are more sustainable and that car ownership can be controlled by large-scale centralization of public transport infrastructure.

H.P. Glathe[15], analyzed the development trend of traffic trip structure in typical European countries and pointed out that the development of traffic trip structure is influenced by the automobile industry, living habits and urban layout. The famous family living conditions affect the traffic trip structure most significant impact.

Messenger T. et al.[16]proposed the level of public transport services, the number of private motor vehicles, the spatial distribution of workplaces, places of residence in the city center work together on the structure of urban traffic trips, it is affecting the changes on the structure of urban traffic trip.

T. Messenger and R. Ewing[17] study on the relationship among residential density, urban land-use and private vehicle, bus trips and concluded that residential density has a more significant impact on the proportion of commuter cars and buses traveling.

Joachim S. et al.[18]found that the traffic trip structure is affected by the living conditions, living habits and urban layout of residents and considers that the family life conditions of residents have the most significant impact on the traffic trip structure.

Francisco A. et al.[19] proposed that the traffic structure, trip expenses and public transport service in Costa Rica. It was found that trip expenses and public transport services have a greater impact on the trip structure.

The study of traffic trip modes focuses on the comparative analysis of single mode and hybrid mode, the level of public service, number of vehicle volume, residential density, spatial layout of working place, family residence, urban land-use, family life conditions, etc. and the impact of trip modes of transport structure.

2.2.2 Individual characteristics on traffic modal choices

Since the 1970s, scholars have gradually applied environmental psychology, sociology and mathematics to the study of influencing factors of residents' trip modal choices. The focus of the study is to discuss the influence of different individual psychological variables on the trip modal choices, using simple quantitative or qualitative analysis method[20].

Black[21] considered instrumental attitude to be a low-bound behavior, while environmental-friendly trip is highly constrained for individuals, while the choice belongs to low-bound behavior environmental protection is a highly restrictive choice, while emotional attitudes affect the choice based on private excitement and happiness. Wall[22] considered that emotional attitudes have a significant impact on the choice, the role of environmental protection may not be significant.

In the 1990s, the sociological study took the family as the main body of consumer behavior, and put forward that the trip individuals would constantly compare the similarities and differences among themselves and the trip behavior, and maintain or change their way of trip by constant comparison and imitation, and sociological research consider that the choice was a social behavior, therefore, social norms and other factors such as trip behavior will affect the choice of residents' modal choices, this research method is mostly qualitative[23].

From about 2000, based on "cost-benefit" and "rational agent", the scholars started to study the influence of economy, policy, working day, holidays and other factors on the choice, and gradually became to be research hot spot, the methods of research are mainly based on quantitative research and combined with qualitative research[23]. R. Antimova, J. Nawijn and P. Peeters[24]proposed that when residents are aware of the importance and responsibility of environmental protection, they can effectively choose environmentally, friendly modes of trip. A study by Morris et al.[25] found the most positive and pleasurable feeling of cycling among residents, followed by cars, followed by rail and walking.

Individual characteristics include individual attitudes, behavioral imitation, "cost-benefit", rational-agent assumptions, economy and policy, working days and holidays, all of the above have some impact on the choice of private trip modes.

2.2.3 Group characteristics on traffic modal choices

From the perspective of population characteristics, the individual awareness of their own are formed by interaction with others, it has certain influence to choose this behavior mode of trip.

G. M. Breakwell[26] argues that because of different occupations, identities and status, residents tend to be similar to groups and make themselves distinguished.

T. F. Golob and D. A. Hensher[27] and S. Hounsham[28] argue that scholars may misunderstand the meaning of cars to residents and it may be a self-image for residents rather than just a vehicle, that resident would not reduce the use of cars because of traffic jams.

A. Ellaway, S. Macintyre, R. Hiscock and A. Kearns[29]based on the surveys found that residents using cars had a more pronounced feeling than residents using public transport, driving cars meant better status and higher status.

The separate space, privacy and comfort of a car, it can't be replaced by public transport. Therefore, the improvement of the service level and accessibility of public transport, the improvement of basic road construction, the protection of trip safety and the residents' choice of low-carbon public transport will be beneficial to the public. M. Van Vugt, P. A. Van Lange and R. M. Meertens[30]proposed that if the trip time by public transport can be reduced to an ideal level, the proportion of residents choosing public transport will increase significantly. Yang et al.[31] argue that residents have a high dependence on cars when trip within 5 km. When it is between 10 km and 20 km, the public transport alternative will be significantly improved.

M. Hunecke, A. Blöbaum, E. Matthies and R. Höger[32]proposed that reducing the price of public transportation will reduce the resident's dependence on trip of car. Base on the Government participation in the regulation of cars, such as tax collection, higher operating costs, trip restrictions on license plate numbers and parking restrictions, the green transportation to residents and the reduction of dependence on cars will result in a shift towards public transport effect.

H. Xiao and X. Wang[33] claimed that the trip choice behavior of the travelers under the government participation base on evolutionary game theory, and obtained the government incentive effect on the bus and the control effect on the private car. The evolution of behavior plays a crucial role.

The choice of group characteristics and individual modes of trip have an interactive effect. There are many influencing factors in the process of imitation and continuous development, such as private occupation, identity, status, recognition of tools of transport, traffic trip time, traveling cost and other aspects of private trip modes, all of those will have a certain impact on the choice of trip.

2.3 Cluster Analysis

Clustering is a process of grouping data items based on a measure of similarity, that is to divide a group of objects into several clusters according to the similarities among them and to make the similarity of data objects in the same cluster as large as possible while meeting the similarity of data objects in different clusters as small as possible[34, 35], Intuitively, patterns within a valid cluster are more similar to each other than they are to a pattern belonging to a different cluster and it is a set of objects that are similar to each other, and in many actual references, one category of data can be treated as a whole. As an important research area of data mining and statistical analysis, clustering has gradually formed a systematic method system[36].

A. K. Jain, M. N. Murty and P. J. Flynn[34]reviews the clustering algorithms and other cluster analysis related research topics, clustering has a wide range of attractiveness and practicality.

P. Hansen and B. Jaumard[37]discussed A survey is given from viewpoint of mathematical programming. Steps of a clustering study, types of clustering and criteria are discussed. Then algorithms for hierarchical, partitioning, sequential, and additive clustering are studied.

E. Kolatch[38] and Q. He[39]studied the application of clustering algorithms in spatial database management systems and information retrieval.

At present, clustering algorithms are mainly divided into Hierarchical Clustering Algorithms, Partition Clustering Algorithms, Density-based and Grid based Clustering Algorithms and other Clustering Algorithms, the following is brief Classification of classical clustering algorithms [40-43].

Table 1 Classification of classical clustering algorithms

Classification	Algorithms	Comments
Hierarchical clustering algorithms	CLIQUE, ENCLUS, MAFIA, etc.	Clustering Algorithms
	PROCLUS,ORCLUS, etc.	Decomposition method
	BIRCH,CURE, WARD, etc.	Hybrid algorithm
Partition clustering algorithms	K-means, K-medoids, etc.	-
Density-based clustering algorithms	OPTICS, DBSCAN,CLIQUE, etc.	-
Grid-based clustering algorithms	WAVE CLUSTER, STING, etc.	-
Fuzzy clustering algorithms	FCM, PCM, PFCM, etc.	-

2.4 Principal component analysis

Principal Component Analysis (PCA) is a statistical method to convert a set of possible variables into a set of linearly independent variables by orthogonal transformation, and this group of variables is called the principal component.

The concept of principal component analysis was first introduced in 1901 by Karl[44] in Physiology.

In 1933, mathematician H. Hotelling[45] popularized it to random vectors in the study of psychology.

In 1947, K. Karhunen[46] independently displayed the theory in the form of probability theory.

2.5 The summary and conclusions of the chapter

Based on the above literature review, it can be seen that the research on the selection of transportation modes and the development of transport facilities mainly considers the urban form, the choice of residential areas, residents' living habits, individual factors and group factors, space, and based on the establishment and improvement of the mode to improve the microcosmic study of transportation and traffic trip, etc., there are few comparative studies among international cities, especially comparative analysis among developed and developing cities, and there is also less contrast at the micro level, such as: trip cost of residents, trip times, trip distance, trip modes, trip modes structure and other aspects of the comparative study.

Therefore, by comparing and analyzing the process of urbanization, population distribution, population flow, motor vehicle volume, urban spatial distribution, the development of urban transport, the structure of residents' traffic and other aspects of the comparative study, and cluster analysis of comparative analysis of international cities, successful experiences of cities with developed traffic, and transportation development for developing cities.

Chapter 3 General Situation Based on Traffic in Research Cities

3.1 General situation of traffic in Tokyo

3.1.1 Brief policies history of traffic development

In 1991，the Light railway subsidy law provided government subsidies to new private railway companies for 5 years after establishment and the size of subsidies depended on profits, but was limited to a ceiling of 5% of construction costs. The 5-year limit was raised to 10 years after the law was amended in 1914.

In 1941, the Rapid Transit Authority was established. The mission at that time was to construct a metro line around Tokyo. In the more than 60 years from 1941 to 2004, formed a certain metro network and operated 169 km of metro lines. The completion of the metro line 13 (8.9 km) marks the maturity of the Tokyo Metro network.

In 1951, the "Road Transport Law" was issued, and the urban public transport project invested by the government was specified.

In 1977, the "Third National Comprehensive Development Plan" was formulated. It was proposed that transportation facilities should be fully coordinated with the development of the city. The priority should be given to the mass transit system and the comprehensive arrangement of expressways and other modes of transport. Its influence area is composed of a multi-center structure system.

In 1986, the "Railway Business Law" was issued to allow the construction and maintenance of facilities such as lines and stations to be operated separately from vehicles such as vehicles to encourage competition and improve service quality.

In April 2004, the Tokyo Metro Co., Ltd. was established. The government believes that the mission entrusted to the Rapid Transit Authority is basically completed and decided to privatize the Rapid Transit Authority as Tokyo Metro Co., Ltd.

In April 2004, in order to facilitate passengers, the two metro systems in Tokyo have adopted a unified numbering system, particularly convenient for passengers from abroad. According to the line function direction, each line stipulates one letter, namely "the line mark", and arranges the serial number to each station. Many of these lines are connected to the JR and private railways, which operate not only in Tokyo, but also in suburban cities.

In March 2007, a new traffic card called "PASMO" was started to use in Tokyo. This kind of traffic card can be used on most buses, metro and suburban railway in Tokyo, the card greatly facilitates the passengers.

3.1.2 City and population based on rail network

According to the development of Tokyo rail transit network construction, the urban space has also changed and the population was also attracted, the following describes the development characteristics of Tokyo rail transit and urban space development.

1.1880s

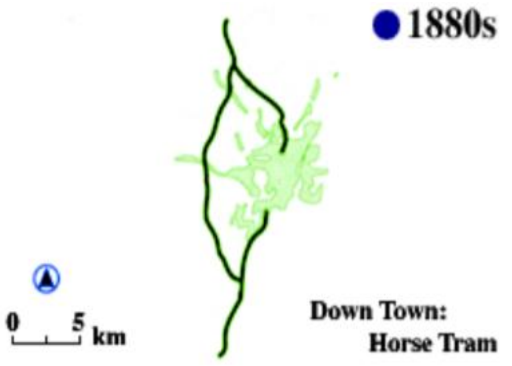
At this stage, urbanization area in Tokyo is concentrated in the Yamanote line area. In 1882, the carriage railway was opened in Tokyo. The density of rail transit road network was very low, and the radius of the area where people daily activities were greatly restricted. But the mass transit of rail transit relative to the original mode of transportation (walking, horse riding etc.) still attracts large numbers of people in the surrounding area, resulting in a relatively small area of the entire city. At the time the activities in the city were still basically on foot. The centralized distribution of population in Tokyo at the initial stage of railway development is shown in Figure 1 (a)

2.1880s-1920s

In 1903, there was a tram in which urban space in Tokyo spread to the suburbs. In 1904, Iidamachi-Nakano began operations. In 1919, rail transit links Ueno, Shinjuku, Shinagawa, Tokyo and Nakano, connecting with the central line at Tokyo station. The city has seen tremendous growth. In the meantime, the construction of private railroads began in the suburbs of Tokyo, and the city continued to expand outward. It is shown in Figure 1 (b).

3.1920s-today

In this stage is the basic formation of urban spatial structure period, the area around the Yamanote line has basically completed the urbanization, rail transit network is basically completed, and the branch network has also been greatly developed. It is



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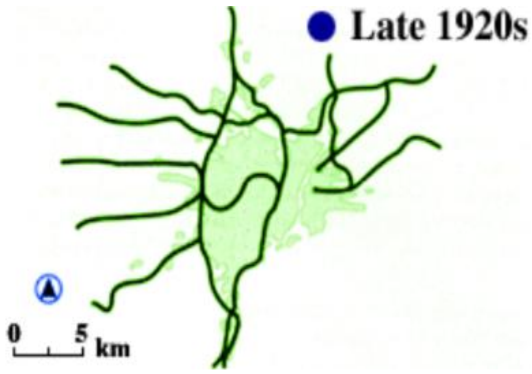

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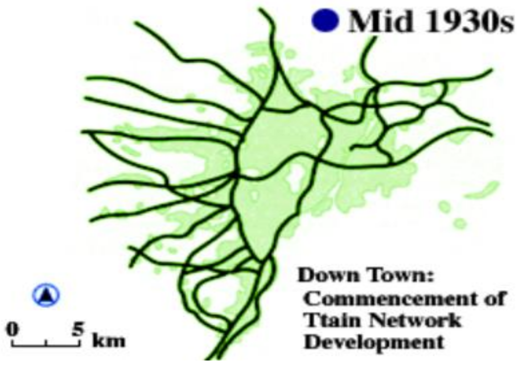

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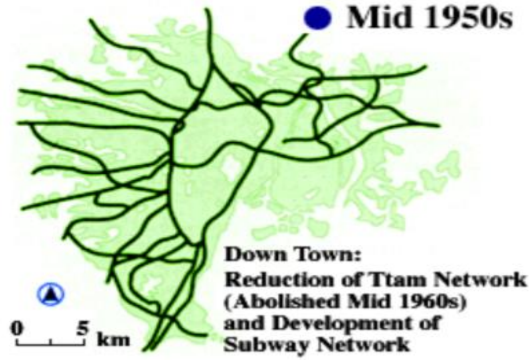

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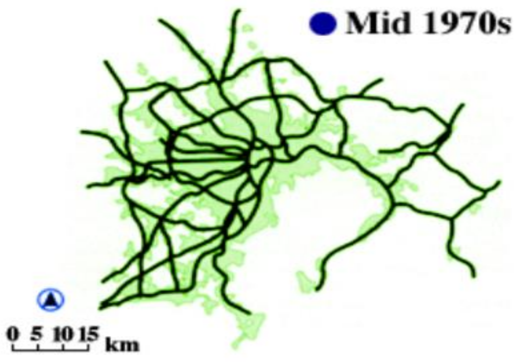

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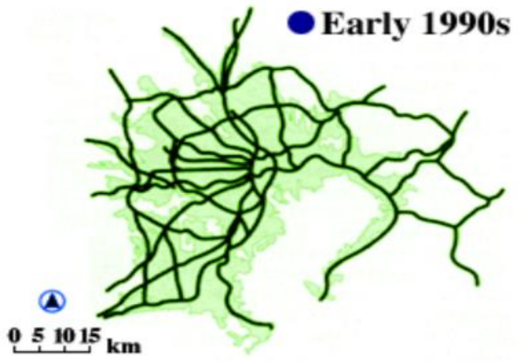


(f)

Figure 1 Growth of railway and population in Tokyo

Sources: Japan Railway & Transport Review

shown in Figure 1 (c, d, e, and f) and Figure 2 is the urban rail network in Tokyo[47].

3.1.3 General situation of traffic in 23 wards of Tokyo

The special wards are 23 municipalities that together make up the core and the most populous part of Tokyo, The special wards' structure was established under the Japanese Local Autonomy Law and is unique to Tokyo, The population in 23 wards of

Tokyo is about 9.727 million, the population density is 14796 pop./km^2 (2015)[48],area is about 626.70 km^2. Table 2 is shown the list of special wards and the part of basic data.

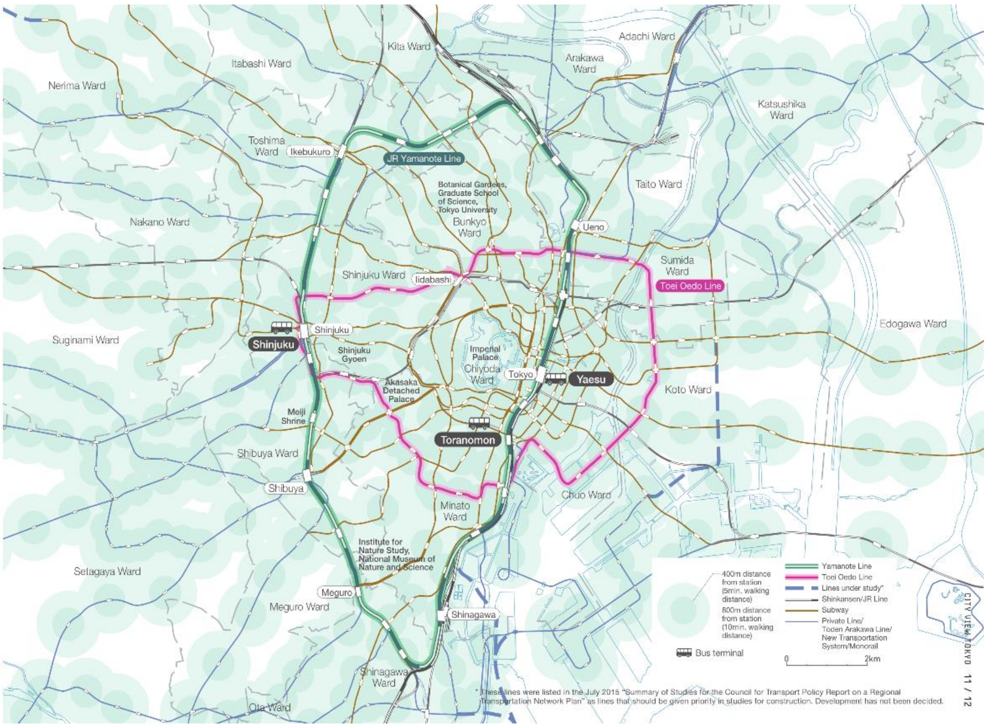


Figure 2 Urban rail network in Tokyo (2016)
Source: City View of Tokyo (2016)

Table 2 List of special wards and the part of basic data (2015)

No.	Name	Area (km^2)	Length of road (km)	Area of road (km^2)	Road network Density (km/km^2)	Urban road area ratio (%)
1	Chiyoda	11.66	175.63	2.79	15.06	23.89
2	Chuo	10.21	194.81	2.99	19.08	29.30
3	Minato	20.37	304.80	4.39	14.96	21.54
4	Shinjuku	18.22	355.75	3.39	19.52	18.59
5	Bunkyo	11.29	207.44	1.95	18.37	17.30
6	Taito	10.11	258.41	2.62	25.56	25.94
7	Sumida	13.77	295.66	2.95	21.47	21.39
8	Koto	40.16	393.28	5.69	9.79	14.16
9	Shinagawa	22.84	388.42	3.85	17.01	16.84
10	Meguro	14.67	358.97	2.30	24.47	15.71
11	Ota	60.66	852.50	7.55	14.05	12.44
12	Setagaya	58.05	1185.97	8.23	20.43	14.18
13	Shibuya	15.11	272.58	2.78	18.04	18.40
14	Nakano	15.59	367.83	2.15	23.59	13.80
15	Suginami	34.06	688.93	4.62	20.23	13.56
16	Toshima	13.01	308.26	2.37	23.69	18.21
17	Kita	20.61	372.24	2.97	18.06	14.43

Table 2 List of special wards and the part of basic data (2015) (continue)

No.	**Name**	**Area (km^2)**	**Length of road (km)**	**Area of road (km^2)**	**Road network density (km/km^2)**	**Urban road area ratio (%)**
18	Arakawa	10.16	215.08	1.66	21.16	16.36
19	Itabashi	32.22	740.26	5.84	22.97	18.13
20	Nerima	48.08	1132.00	7.40	23.54	15.40
21	Adachi	53.25	1049.10	9.75	19.70	18.31
22	Katsushika	34.80	703.78	5.38	20.23	15.45
23	Edogawa	49.90	1075.97	9.24	21.56	18.52

3.2 General situation of traffic in Beijing

3.2.1 Development of rail transit in Beijing

1. Before 1970

Before 1970, the urban transport infrastructure level in Beijing is relatively low, residents trips mainly rely on walking, bicycles, buses and trolley, etc. During this period, residents mainly trip ward on non-motor vehicles, for example walking and bicycle.

2. 70s-80s

With the reform and the opening-up in China, traffic in Beijing began to develop. This period was dominated by bus-based development. Data from traffic trip survey in 1986 showed that residents with the highest proportion of trip is bicycle and the second is the public transport, the third is walking, in this period, the trip proportion of car and rail are lower, but the rapid development of public transport, from 1977 to 1985, operating vehicles increased from 2455 to 4398 vehicles, nearly 2 times, and operating line from 115 to 189, operating mileage increased from 1371.1 km to 2272.2 km, rail transit was also gradually to develop, in October 1969 Beijing metro line 1 began to operate, and Line 2 began to operate in September 1984.

In 1984, the Beijing government promulgated the measures named "Interim Measures of the administration of taxi in Beijing" to encourage taxi to entry the transportation field and then the taxi passenger volume increase quickly 29.63 million by 1984 to 648.95 million by 1996.

3. After 90s

Since 1996, the motor vehicles volume in Beijing has grown rapidly. The motor vehicle volume was 3.39 times in 2006 that of 1996 and the proportion of motor vehicles increased rapidly from 5.24% in 1986 to 31.60% in 2006. At the same time, it came to cause problems such as road congestion and environmental pollution with the increase of motor vehicles trip, and has put pressure on the construction of urban transport infrastructure and road traffic.

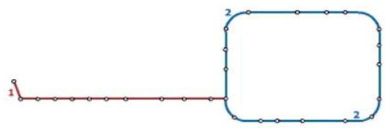
In 2004, the Beijing government promulgated the "Beijing Transportation Development Program" to speed up rail network construction. In 2006, it implemented the public traffic card and reduced the fare in 2007 to attract passenger flow. By 2008, the proportion of public transportation trips exceeded that of car again.

Till now, Beijing rail transit system consists of grid-like lines that cross the horizontal lines and vertical lines and connected by loop lines No.2 and 10 to form a rail transit network. As of December 2015, there were 18 rails transit network operating lines, 554 kilometers of operating lines, 911 million passengers per day, 334 operating stations and 53 transfer stations, covering 11 districts of Beijing.

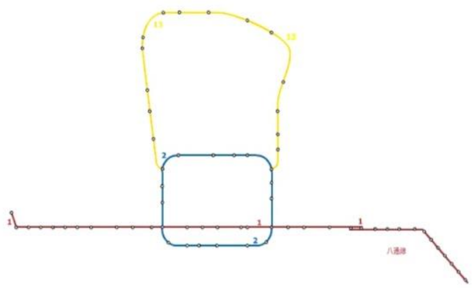
3.2.2 Main process of rail transit network construction in Beijing

The construction of rail transit in Beijing began in October 1969, and the rail transit network has been formed by 2017, and in the process of continuous development and construction. Figure 3 is rail transit construction and development process in Beijing.

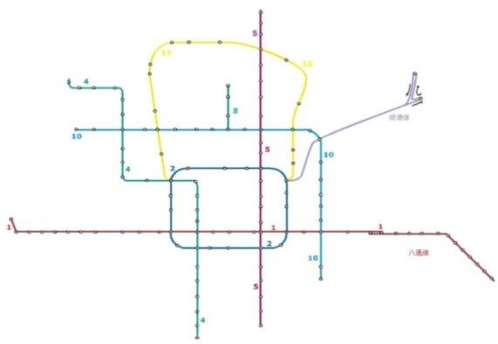
1973



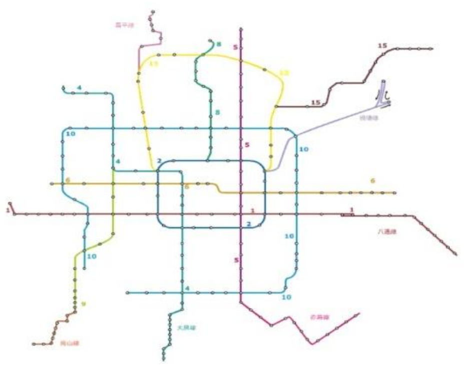
1987



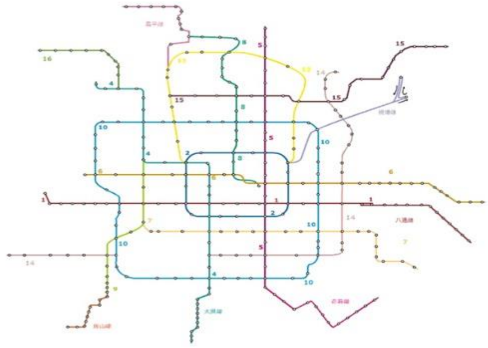
2003



2009



2012



2016

2017

Figure 3 Rail transit construction and development process in Beijing

Source: https://www.bjsubway.com/

3.3 General situation of traffic in Shanghai

3.3.1 Development of rail transit in Shanghai

In 1913, the first tram opened in Shanghai.

In 1914, the first trolley bus line opened.

In 1922, the first bus route opened.

In 1908, taxi came out in 1926, and there was 51 companies by 1926, became an emerging industry and the Taxi Federation of Shanghai was established in 1928. At this time, public transport extended from the public concession to the entire Shanghai area.

The construction of rail transit in Shanghai started in the 1850s. In August 1956, the Shanghai government submitted "Shanghai Metro Preliminary Planning (Draft)" and started the experimental construction of rail transit construction from 1959 to 1960. After years of demonstration and testing, Shanghai started construction of metro line 1 in 1993 and has gradually formed mainly in the north-south direction of the main vertical lines. The lines are connected to each other, and the entire rail transit network is circularly connected by No. 4 to form a rail transit network. As of December 2015, 14 lines of railways with a total length of 617 km, 366 stations and 54 transfer stations, with loop lines links (Table 3).

At the end of 2002, the world first maglev train line was tested in Shanghai.

Table 3 List of Shanghai metro line and the part of basic data

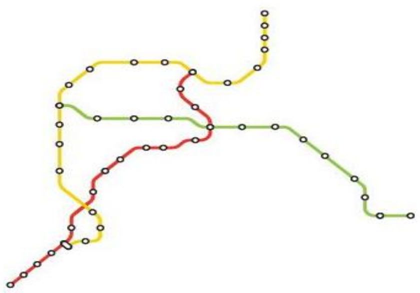
Line	**Departure station**	**Terminal**	**Opened**	**Newest extension**	**Length (km)**	**Stations**
1	Fujin Road (Baoshan)	Xinzhuang (Minhang)	1993	2007	36.4	28
2	East Xujing (Qingpu)	Pudong International Airport (Pudong)	1999	2010	63.8	30
3	North Jiangyang Road (Baoshan)	Shanghai South Railway Station (Xuhui)	2000	2006	40.3	29
4	Yishan Road (Xuhui)	Yishan Road (Xuhui)	2005	2007	33.7	26
5	Xinzhuang (Minhang)	Minhang Development Zone (Minhang)	2003	-	17.2	11
6	Gangcheng Road (Pudong)	Oriental Sports Center (Pudong)	2007	2011	32.3	28
7	Meilan Lake (Baoshan)	Huamu Road (Pudong)	2009	2014	44.2	33
8	Shiguang Road (Yangpu)	Shendu Highway (Minhang)	2007	2012	37.4	30
9	Songjiang South Railway Station (Songjiang)	Middle Yanggao Road (Pudong)	2007	2012	52.1	26
10	Xinjiangwancheng (Yangpu)	Hongqiao Railway Station (Minhang)	2010	2010	35.4	31
10	Xinjiangwancheng (Yangpu)	Hangzhong Road(Minhang)	2010	2010	35.4	31
11	North Jiading (Jiading)	Disney Resort (Pudong)	2009	2016	82.4	38
11	Huaqiao (Kunshan, iangsu)	Disney Resort (Pudong)	2009	2016	82.4	38
12	Qixin Road (Minhang)	Jinhai Road (Pudong)	2013	2015	40.4	32
13	Shibo Avenue (Pudong)	Jinyun Road (Jiading)	2012	2015	22.0	19
14	Longyang Road (Pudong)	Dishui Lake (Pudong)	2013	2014	59	13

3.3.2 Main process rail transit network construction in Shanghai

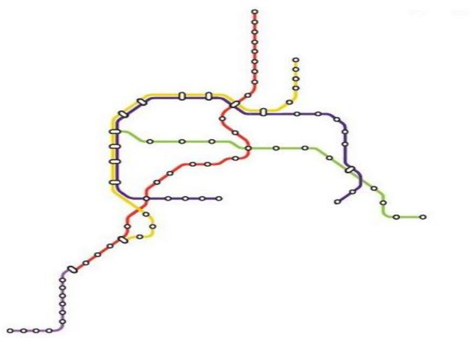
Rail transit construction of Shanghai began in 1993, the rail transit network has gradually become mature, and in the continuous development and construction now, Figure3 is rail transit construction and development process in Shanghai.

1998

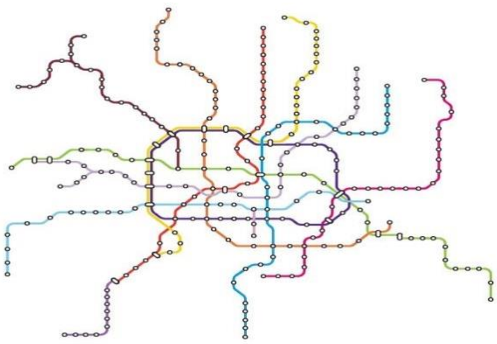
1999



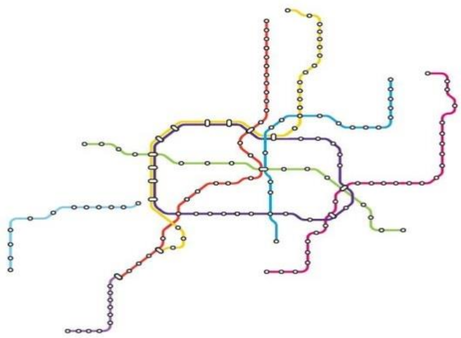
2000



2005



2007



2010

2017

Figure 4 Rail transit construction and development process in Shanghai

Source: http://www.shmetro.com/

3.4 The summary of the chapter

Since 1880, Tokyo rail transit has developed into an efficient, high density and high coverage traffic network with many characteristics and advantages compared with Beijing and Shanghai:

- City development of Tokyo is developing with the development of rail transit and population distribution, that is, the first thing to Tokyo is traffic development and then the urban spatial development and population distribution.
- The rail way line in Tokyo connects by loop lines, and with several year construction and development, the railway network became a high-density network, it is convenient for residents to trip.
- In 23 wards of Tokyo, urban road and rail transport formed a well-developed ground transportation network.

With the years of railway construction in Beijing and Shanghai, some achievements have been made in rail transit construction, but there are some questions as following:

- The construction of rail transit network is begun after the development of the city, but this situation brought some difficulties to the rail network planning, construction and the cost of construction.
- Compared with Tokyo, the rail transport coverage in Beijing and Shanghai are still lower, although there are loops connecting various lines, but the traffic network is still relatively inefficient.

Chapter 4 Resident Trip Characteristics and Trip modes of Special Wards

4.1 The basic introduction of Cluster Analysis and algorithm

4.1.1 Introduction of Cluster Analysis

Cluster Analysis is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters). It is a main task of exploratory data mining, and a common technique for statistical data analysis, used in many fields, and used for traffic research. Cluster analysis can classify the analysis objects scientifically and effectively and achieve the purpose of scientific research by different classification methods and algorithms. Cluster analysis is a useful classification method and tool. There are several categories, the main as follows:

- Hierarchical clustering
- Partition clustering
- Density-based clustering
- Grid-based clustering
- Fuzzy clustering

The classification of the different application scope is different, in order to divide 23 wards of Tokyo into several categories of a similar nature, so the first method been selected, i.e., Hierarchical clustering.

4.1.2 Introduction of Ward method

There are many kinds of algorithms for Cluster Analysis, which have been systematically summarized and analyzed in the literature review (see 2.3). In this dissertation the Ward algorithm will be taken.

Brief introduction of Ward algorithm:

- Introduction of Ward algorithm

Ward algorithm is one of the algorithms, it emphasis on the inner differences of similar things. The equivalent of variance or standard deviation should be small, so Ward minimum variance criterion minimizes the total within-cluster variance. To implement it, at each step find the pair of clusters to leads to minimum increase in the total within-cluster variance after merging. The increase is a weighted squared distance between cluster centers.

- Definition of Euclidean distance

In mathematics, the Euclidean distance or Euclidean metric is the "ordinary" straight-line between two points in Euclidean space. With this distance, Euclidean space becomes a metric space. The associated norm is called the Euclidean norm. The Euclidean distance between p and q is the length of the line segment connecting them ($\overline{pq}$).

In this case, the above formula is used to calculate the distance between different wards, $\overline{pq}$ .represents the distance, in which $\boldsymbol{p}$ and $\boldsymbol{q}$ represents the different ward respectively.

In Cartesian coordinates, if p = (p1, p2 ... p_n) and q = (q1, q2 ... q_n) are two points in Euclidean n-space, then the distance (d) from p to q or from "q" to "p" is given by the Pythagorean formula:

$$d(p, q)=d(q, p)=\sqrt{(q_1-p_1)^2+(q_2-p_2)^2+\ldots+(q_n-p_n)^2}$$

$$=\sqrt{\sum_{i=1}^{n}(q_i-p_i)^2}$$

The Euclidean distance between "q" and "p" is just the Euclidean length of this distance (or displacement) vector:

$$\|(q-p)\| = \sqrt{(q-p)(q-p)}.$$

4.1.3 Data description of 23 wards of Tokyo based on Ward algorithm

1. Data description

According to the data of "The 5th Tokyo Metropolitan Area Person Trip Survey"[1], the cluster analysis (SPSS) is based on the proportion of private trip choices of 23 wards of Tokyo, as shown in the following table.

Table 4 Cluster analysis variables in 23 wards of Tokyo (%)

Name	Railway& Metro	Bus	Motor Vehicle	Motorcycle	Bicycle	Walking	The other	Unknown
Chiyoda	76.00	0.74	6.24	0.37	1.79	14.38	0.11	0.36
Chuo	65.73	1.54	7.99	0.65	4.07	18.71	0.14	1.19
Minato	68.16	1.92	8.91	0.69	2.97	16.13	0.13	1.09
Shinjuku	62.43	2.40	6.25	0.98	5.13	21.23	0.11	1.48
Bunkyo	55.55	3.07	7.43	1.10	9.69	21.59	0.18	1.40
Meguro	42.70	4.23	10.32	1.71	12.95	26.47	0.08	1.52
Shinagawa	50.46	2.36	8.54	1.40	11.08	24.37	0.11	1.68
Taito	48.54	2.86	9.12	1.17	13.73	22.66	0.30	1.63
Sumida	37.19	3.46	10.38	1.91	20.95	23.22	0.12	2.78
Koto	40.66	4.71	12.98	1.53	15.23	22.63	0.14	2.11
Shibuya	61.28	3.67	7.01	1.01	5.11	20.48	0.15	1.29
Ota	50.24	3.26	9.06	1.36	11.45	22.79	0.14	1.70
Setagaya	37.52	3.89	12.35	1.76	17.04	25.18	0.11	2.15
Suginami	37.55	3.61	9.26	1.64	20.89	25.15	0.13	1.78
Nakano	40.41	3.82	7.27	1.87	17.41	26.77	0.16	2.29
Nerima	29.11	2.56	13.33	1.92	24.56	25.79	0.09	2.64
Itabashi	32.22	2.53	12.39	1.90	21.17	26.75	0.08	2.97
Toshima	54.63	3.16	5.90	1.23	11.11	21.71	0.17	2.09
Kita	36.05	4.35	8.99	1.59	18.33	27.22	0.15	3.33
Arakawa	33.61	3.74	9.90	1.54	22.22	26.13	0.11	2.75
Adachi	24.03	2.75	17.44	2.26	26.85	22.66	0.18	3.83
Katsushika	24.67	2.52	14.09	1.90	28.65	24.88	0.12	3.18
Edogawa	24.79	3.78	16.21	1.82	24.85	26.14	0.07	2.34

The following table (Table 5) is a descriptive statistics table after the SPSS 20.0 software described the table 4.

As can be seen from Table 5, the largest standard deviation is railway and metro, which is 14.886, indicating that rail transit is the most influential factor in residents' trip choice, followed by bicycles with a standard deviation of 7.998 and the third is standard deviation is 3.392.

Table 5 Descriptive statistics

	N	Minimum (%)	Maximum (%)	Mean (%)	Std. Deviation (%)
Railway and Metro	23	24.03	76.00	44.935	14.886
Bus	23	0.74	4.71	3.084	0.947
Motor vehicle	23	5.90	17.44	10.060	3.167
Motorcycle	23	0.37	2.26	1.448	0.482
Bicycle	23	1.79	28.65	15.096	7.998
Walking	23	14.38	27.22	23.175	3.392
The other	23	0.07	0.30	0.134	0.048
Unknown	23	0.36	3.83	2.068	0.829
Valid N (list wise)	23				

2. Cluster analysis

Using the Ward method in the system clustering method, the metric-interval (N) adopts the Euclidean distance to obtain the similarity matrix (Euclidean distance table) as shown in Table 6.

Table 6 Euclidean distance

Case	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
1	.000	2.200	2.042	3.403	4.442	6.712	4.853	6.191	6.931	6.872	4.208	5.079	6.946	6.525	7.060	7.488	7.464	4.866	7.805	7.226	8.955	8.008	8.230
2	2.200	.000	.966	1.604	2.490	4.894	2.934	4.402	5.030	4.945	2.492	3.064	5.003	4.622	5.065	5.638	5.596	2.928	5.736	5.258	7.079	6.148	6.406
3	2.042	.966	.000	2.025	2.814	5.068	3.385	4.772	5.217	4.944	2.533	3.319	5.170	4.910	5.430	5.929	5.921	3.263	6.047	5.560	7.234	6.423	6.548
4	3.403	1.604	2.025	.000	1.825	3.651	1.851	4.318	4.033	4.081	1.588	2.046	3.984	3.555	3.863	4.865	4.700	1.903	4.587	4.177	6.631	5.499	5.605
5	4.442	2.490	2.814	1.825	.000	3.402	2.157	2.657	3.507	3.147	1.251	1.309	3.455	2.834	2.977	4.525	4.585	1.067	3.841	3.653	5.806	4.979	5.161
6	6.712	4.894	5.068	3.651	3.402	.000	2.380	5.117	2.399	2.173	3.370	2.238	1.390	1.693	2.302	3.014	2.900	3.282	2.771	2.180	5.195	3.876	2.898
7	4.853	2.934	3.385	1.851	2.157	2.380	.000	4.200	2.655	3.174	2.505	1.342	2.510	2.140	2.646	3.155	2.995	2.055	3.431	2.748	5.282	3.921	4.016
8	6.191	4.402	4.772	4.318	2.657	5.117	4.200	.000	4.594	4.172	3.717	3.354	4.699	4.086	3.822	5.364	5.643	3.071	4.543	4.731	5.534	5.414	6.043
9	6.931	5.030	5.217	4.033	3.507	2.399	2.655	4.594	.000	2.144	3.943	2.392	1.373	1.513	1.916	1.757	1.831	3.007	1.970	1.239	3.308	2.114	2.503
10	6.872	4.945	4.944	4.081	3.147	2.173	3.174	4.172	2.144	.000	3.292	2.213	1.520	2.041	2.533	3.178	3.368	3.094	2.450	2.265	4.114	3.519	2.863
11	4.208	2.492	2.533	1.588	1.251	3.370	2.505	3.717	3.943	3.292	.000	1.742	3.732	3.334	3.541	5.091	5.048	1.620	4.239	4.078	6.518	5.646	5.499
12	5.079	3.064	3.319	2.046	1.309	2.238	1.342	3.354	2.392	2.213	1.742	.000	2.204	1.793	2.194	3.397	3.411	1.326	2.963	2.566	4.988	3.974	3.965
13	6.946	5.003	5.170	3.984	3.455	1.390	2.510	4.699	1.373	1.520	3.732	2.204	.000	1.320	2.072	1.950	2.025	3.257	2.161	1.391	3.834	2.635	1.938
14	6.525	4.622	4.910	3.555	2.834	1.693	2.140	4.086	1.513	2.041	3.334	1.793	1.320	.000	1.422	2.309	2.479	2.610	2.193	1.340	4.309	2.920	2.782
15	7.060	5.065	5.430	3.863	2.977	2.302	2.646	3.822	1.916	2.533	3.541	2.194	2.072	1.422	.000	3.005	2.981	2.505	1.660	1.798	4.467	3.443	3.647
16	7.488	5.638	5.929	4.865	4.525	3.014	3.155	5.364	1.757	3.178	5.091	3.397	1.950	2.309	3.005	.000	.844	4.242	2.971	1.911	2.957	1.083	1.707
17	7.464	5.596	5.921	4.700	4.585	2.900	2.995	5.643	1.831	3.368	5.048	3.411	2.025	2.479	2.981	.844	.000	4.188	2.810	1.858	3.397	1.621	2.065

Table 6 Euclidean distance (continue)

Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
18	4.866	2.928	3.263	1.903	1.067	3.282	2.055	3.071	3.007	3.094	1.620	1.326	3.257	2.610	2.505	4.242	4.188	.000	3.246	3.181	5.539	4.647	5.019
19	7.805	5.736	6.047	4.587	3.841	2.771	3.431	4.543	1.970	2.450	4.239	2.963	2.161	2.193	1.660	2.971	2.810	3.246	.000	1.398	4.053	3.137	3.300
20	7.226	5.258	5.560	4.177	3.653	2.180	2.748	4.731	1.239	2.265	4.078	2.566	1.391	1.340	1.798	1.911	1.858	3.181	1.398	.000	3.841	2.322	2.365
21	8.955	7.079	7.234	6.631	5.806	5.195	5.282	5.534	3.308	4.114	6.518	4.988	3.834	4.309	4.467	2.957	3.397	5.539	4.053	3.841	.000	2.145	3.413
22	8.008	6.148	6.423	5.499	4.979	3.876	3.921	5.414	2.114	3.519	5.646	3.974	2.635	2.920	3.443	1.083	1.621	4.647	3.137	2.322	2.145	.000	2.120
23	8.230	6.406	6.548	5.605	5.161	2.898	4.016	6.043	2.503	2.863	5.499	3.965	1.938	2.782	3.647	1.707	2.065	5.019	3.300	2.365	3.413	2.120	.000

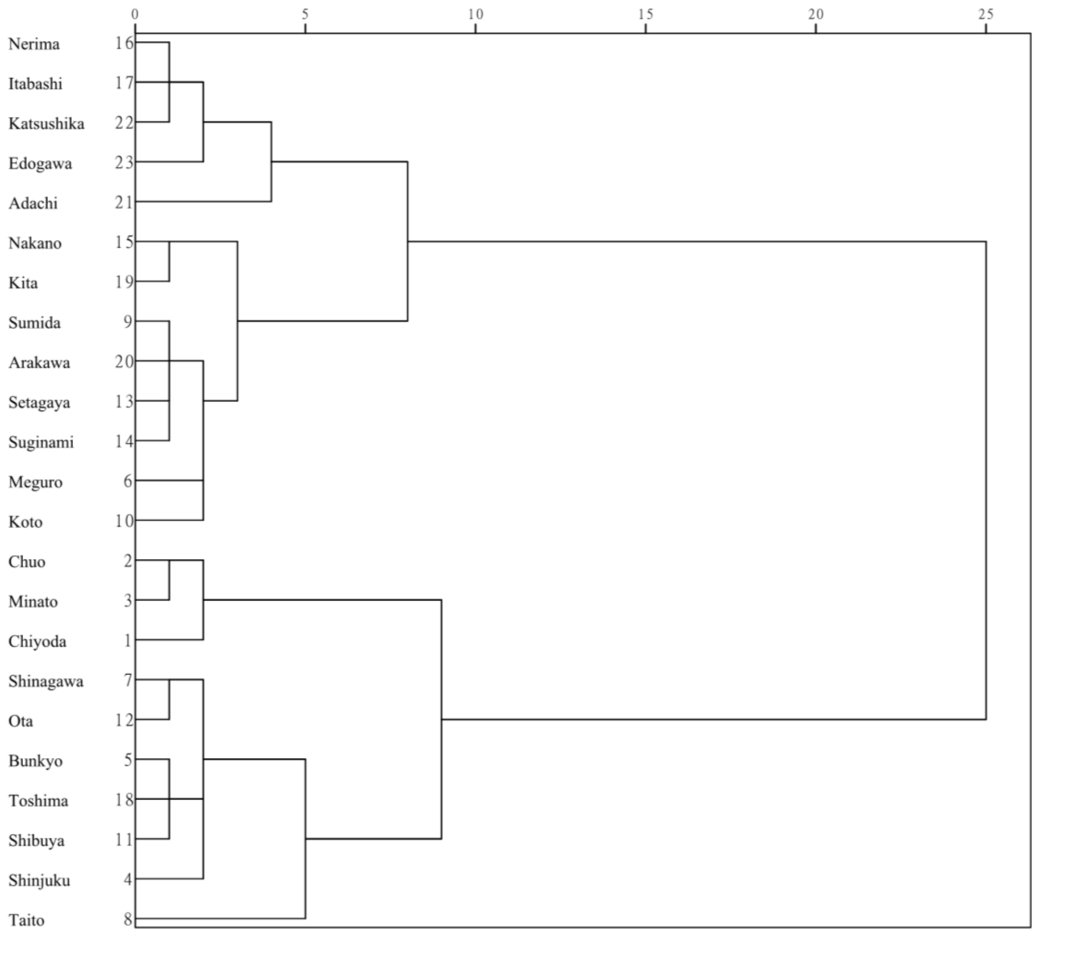


Figure 5 Dendrogram based on Cluster Analysis

The Figure 5 is dendrogram based on Cluster Analysis, it generated by the Ward method. According to the Figure 5, 23 wards of Tokyo can be divided into three Circles.

According to Figure 5, it can be seen that there are two main categories, I and II. In II, there are the traditional "core 3 wards" and the surrounding areas. In this case, according to the results of Cluster analysis, the actual traffic conditions and the methods used by researchers [41, 42], I is divided into two clusters, While II is a separate category.

That is:

Cluster 1: 1, 2 and 3.

That is, Chiyoda, Chuo and Minato.

Cluster 2: 4, 5, 7, 8, 11, 12 and 18.

That is, Shinjuku, Bunkyo, Shinagawa, Taito, Shibuya, Toshima.

Cluster 3:16, 17, 22, 23, 21, 15, 19, 9, 20, 13, 14, 6 and 10.

That is, Nerima, Itabashi, Katsushika, Edogawa, Adachi, Nakano, Kita, Sumida, Arakawa, Setagaya, Suginami, Meguro and Koto.

In this dissertation, the "Cluster" is called as Circle and base on the above, 23 wards of Tokyo divided into 3 Circles as following.

4.1.4 Administrative divisions

The 23 wards of Tokyo is also called "special wards" and it expanded around the Chiyoda and formed a " multi-center" structure with Shinjuku and Ikebukuro as the urban sub-centers[49], while Chiyoda, Chuo and Minato is generally known as "core 3 wards"[50, 51], the "core 3 wards" has concentrated a large number of political, economic and cultural facilities, but compare with the other wards the residential area is limited in this area, and the surrounding wards could provide residential area, the same situation also appears in the peripheral wards of the urban sub-centers.

According to 4.1.3 analysis results, Tokyo 23 is divided into three Circles as following:

Circle 1: Chiyoda, Chuo and Minato.

Circle 2: Shinjuku, Bunkyo, Shinagawa, Taito, Shibuya, Toshima.

Circle 3: Nerima, Itabashi, Katsushika, Edogawa, Adachi, Nakano, Kita, Sumida, Arakawa, Setagaya, Suginami, Meguro and Koto.

The division as shown in Figure 6, Circle 1 is the "core 3 wards", Circle 2 (middle area in special wards) is the area around Circle 1, including 7 wards in special wards, Circle 3 (marginal area in special wards) is the area around Circle 3, including 13 wards.

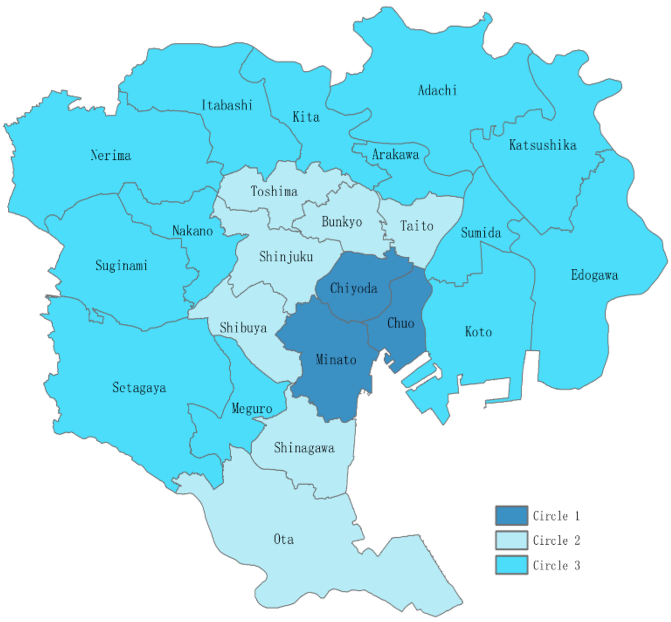
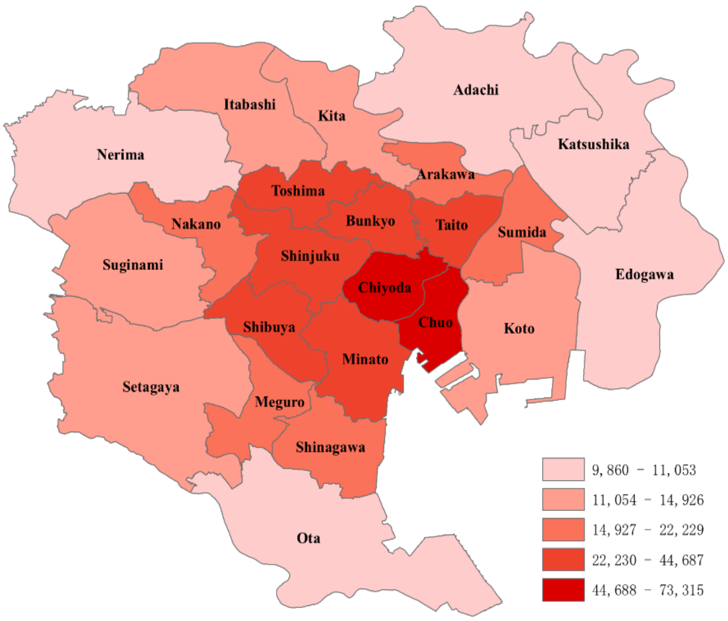


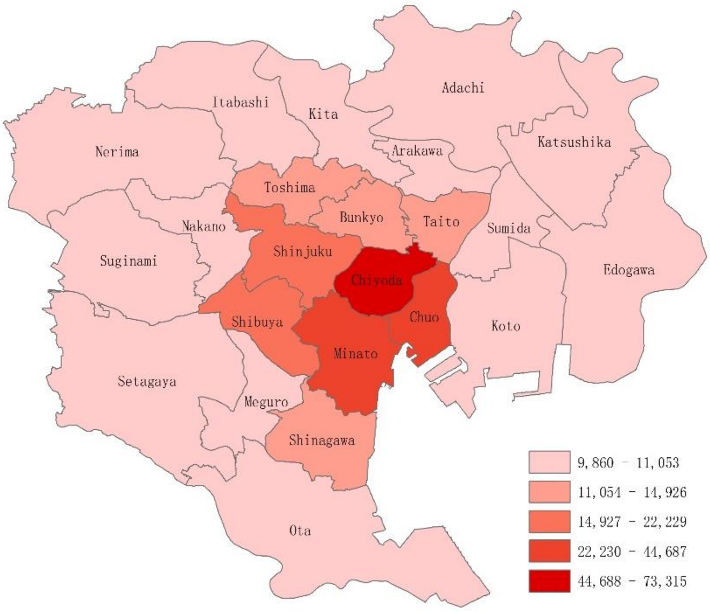
Figure 6 Circle of Tokyo special wards

4.1.5 Population distribution by wards and Circle

Figure 7 is distribution of population density by Circle in daytime and nighttime and Figure 8 is D-value and population in daytime and nighttime in special wards, Table 6 is basic statistical data of daytime and night population in 23 wards of Tokyo.



(1) Distribution of population density in 23 wards of Tokyo (daytime) (Unit: person)



(2) Distribution of population density in 23 wards of Tokyo (nighttime)

Figure 7 Distribution of population density by Circle in daytime and nighttime

As can be seen from Figure 7, the population density in the 23 districts of Tokyo is high in the central wards and low in the surrounding wards, both during the day and night.

In the daytime, density of the population of wards that from high population density to the low are as following:

The first are Chiyoda and Chuo.

The second are Taito, Bunkyo, Toshima, Shinjuku, Shibuya and Minato.

The third are Sumida, Arakawa, Nakano, Meguro and Shinagawa.

The fourth are Koto, Kita, Itabashi, Suginami and Setagaya.

The fifth are Edogawa, Katsushika, Adachi, Nerima and Ota.

In the daytime, density of the population of wards that from high population density to the low are as following:

The first is Chiyoda

The second are Minato and Chuo.

The third are Shinjuku and Shibuya.

The forth are Taito, Bunkyo, Toshima and Shinagawa.

The fifth are Koto, Edogawa, Sumida, Katsushika, Adachi, Arakawa, Kita, Itabashi, Nerima, Suginami, Nakano, Setagaya, Meguro and Ota.

The distribution of population density is not balanced during the day and night, and concentrate to the center during the day and spread to the surrounding wards during the night (the D-value and population is shown in Figure 8).

As can be seen from the Figure 8, D-value of population between daytime and nighttime in Circle 1 is the largest, the population in daytime is 6.16 times of that of nighttime, of which, 17.39 times in Chiyoda. A lot of workplaces (such as government agencies, businesses and commercial facilities, etc.) are gathered in the Circle 1, which attracts lots of people during the daytime while flowed back to the surrounding wards (surrounding wards is contained within 23 wards. If not specifically described below, the meaning is the same.) and flowed to Circle 1 at nighttime, the passenger flow is similar to the pendulum which flows into the central city in the morning and flows back to The passenger flow brings greater pressure on the urban transport system, forming a time-based and spatial flow of commuter and school-based passengers.

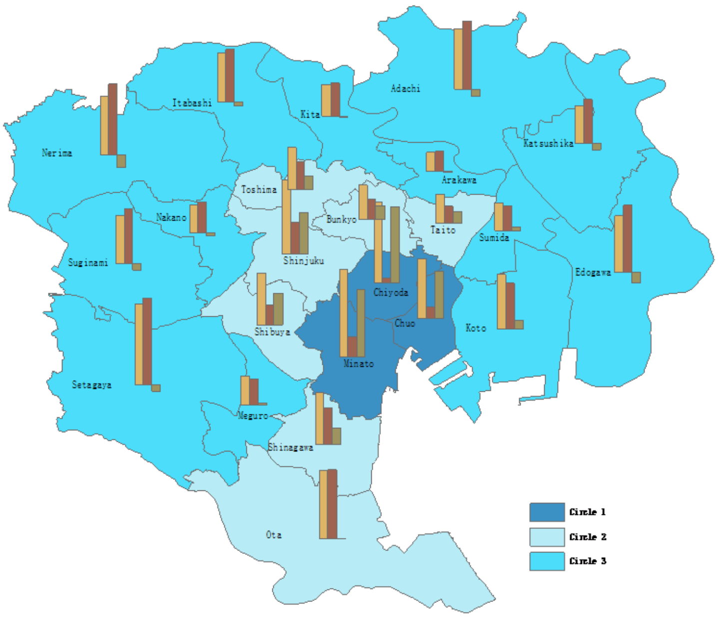


Figure 8 D-value and population in daytime and nighttime (2010)

The population of daytime in Circle 2 is 1.57 times than that of nighttime, with population of Shibuya and Shinjuku are 2.55 times and 2.30 times respectively, indicating that Circle 2 attracts a large population from the surrounding wards during the daytime and Shibuya and Shinjuku as the urban sub-centers of city attracts a large population too and has formed large traffic flow. The population of daytime in Circle 3 is 0.92 times than that of nighttime (1.49 times in Toshima), it indicate that the population flow into Circle 1 and Circle 2 in daytime, and flow back to the Circle 3 at nighttime. Table 7 is the population and D-value between daytime and nighttime in special wards by Circle and Table 8 is the basic statistical data of daytime and night population in 23 wards of Tokyo (2010).

Table 7 Population and D-value between daytime and nighttime by Circle

Circle	**Population ('000) (Daytime)**	**Population ('000) (Nighttime)**	**Population (Daytime)/ Population (Nighttime) (%)**
Circle 1	2,311	375	616.35
Circle 2	3,559	2,255	157.83
Circle 3	5,840	6,315	92.48

Resource: Tokyo Statistical Yearbook (2010).

Table 8 Statistic of daytime and night population in 23 wards of Tokyo (2010)

No.	Name	Population (daytime) (A) ('000)	Population (nighttime) (B) ('000)	D-value (A)-(B) ('000)	Population density (daytime) ('000)	Population density (nighttime) ('000)
1	Chiyoda	853	42	812	73	2
2	Chuo	648	98	550	63	660
3	Minato	909	186	723	45	489
4	Shinjuku	770	304	466	42	254
5	Bunkyo	336	190	147	30	177
6	Taito	304	164	140	30	186
7	Sumida	263	231	31	19	114
8	Koto	491	421	70	12	117
9	Shinagawa	505	345	160	22	146
10	Meguro	271	249	23	18	109
11	Ota	657	664	-7	11	99
12	Setagaya	736	820	-84	13	90
13	Shibuya	543	199	344	36	272
14	Nakano	286	310	-25	18	92
15	Suginami	439	523	-83	13	84
16	Toshima	378	233	145	29	162
17	Toshima	307	330	-23	15	93

Table 8 Basic statistical data of daytime and night population in 23 wards of Tokyo (2010) (continue)

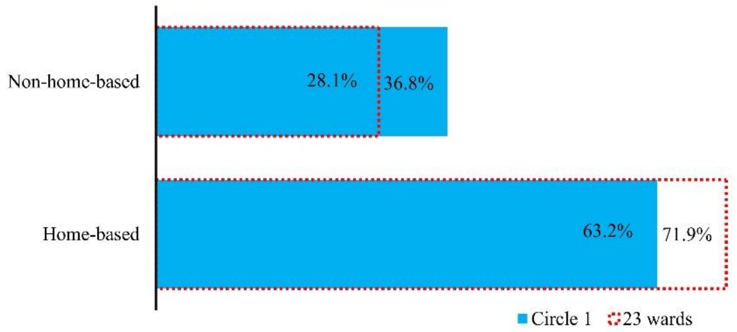
No.	Name	Population (daytime) (A) ('000)	Population (nighttime) (B) ('000)	D-value (A)-(B) ('000)	Population density (daytime) ('000)	Population density (nighttime) ('000)
18	Arakawa	184	191	-7	18	96
19	Itabashi	4,575	508	-51	14	90
20	Nerima	531	644	-113	11	82
21	Adachi	539	623	-83	10	87
22	Katsushika	343	425	-82	10	81
23	Edogawa	535	654	-119	11	82

4.2 Residents' modal choices in special wards

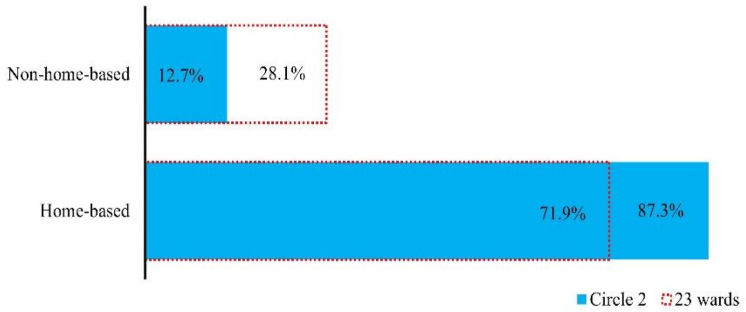
4.2.1 Characteristics of residents' trip purpose

In the special wards, the main trip purpose of residents are "Home-Work"，"Home-School", "Go-home", "Home-Business", "Home-Private Affairs"， "Private", "Work and Business" and "The other" etc., in this dissertation, various trip starting from home be merged and referred to as: Home-based, the other as Non-home-based. Figure 9 is the comparative figure of distribution of resident s' trip purpose in each Circle and special wards (based on data of the traffic departure in the Circle[1]),

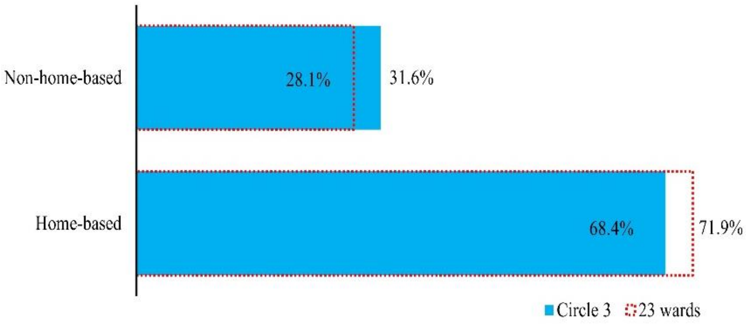
As can be seen from Figure 9, Home-based trip is the most important trip destination among the three Circles. The highest proportion of the Circle 2 of Home-based is up to 87.30%, indicated that the proportion of residential area in Circle 2 is higher than that of Circle 1 and Circle 3, and it is also higher than the average of 23 wards of Tokyo, the residential area of the three Circles is arranged descending order: Circle 2, Circle 3 and Circle 1.



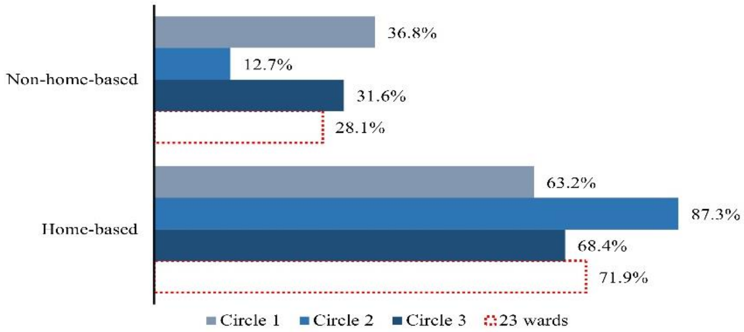
(1) The distribution of trip destination in Circle 1



(2) The distribution of trip destination in Circle 2



(3) The distribution of trip destination in Circle 3



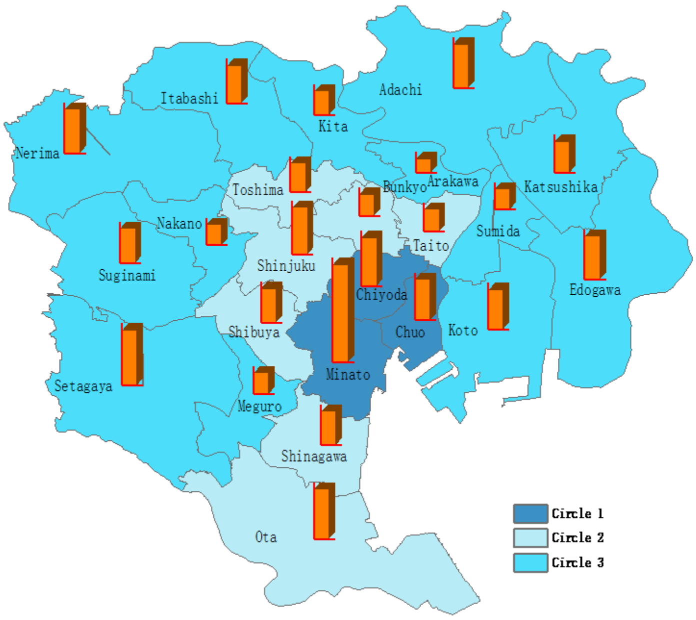
(4) The distribution of trip destination in special wards

Figure 9 Distribution of resident trip destination in special wards

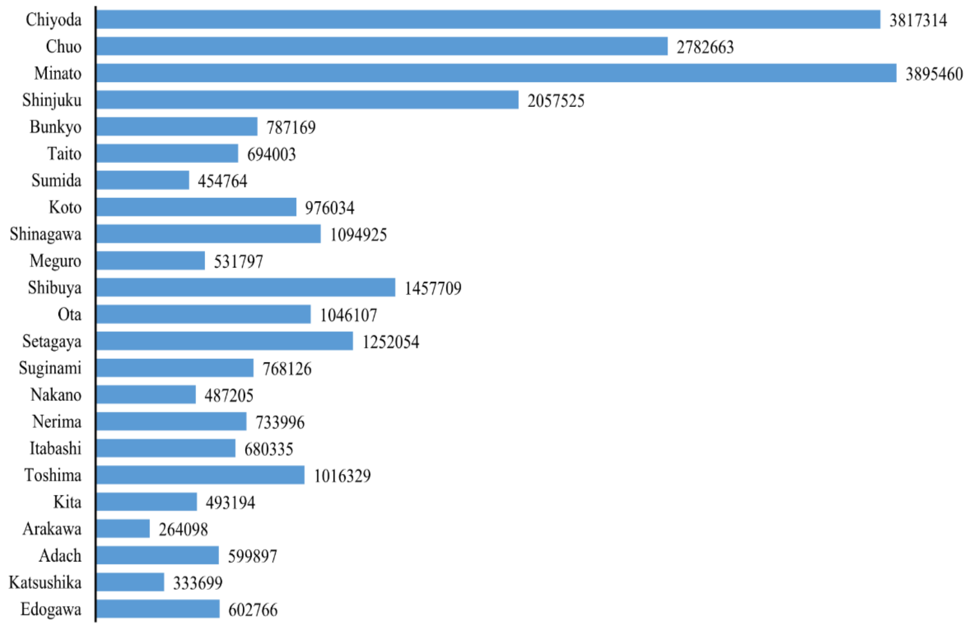
The proportion of Non-home-based is less than that of Home-based, and the highest proportion of 36.76% in the Circle 1. It is noteworthy that in Non-home-based, the proportion of the trip between the Circle 1 and the Circle 3 which is higher than that in the Circle 2 and 23 wards of Tokyo, indicate that there are lots of opportunities, such as job, private trip and business, etc. while Circle 2 occupies a greater proportion of residential area.

4.2.2 Traffic trip volume

In special wards, the resident traffic trip volume is different that due to the geographical location, traffic network infrastructure and the other factors such as population spatial distribution of regional trip quantity, etc., according to the data of "The 5th Tokyo Metropolitan Area Person Trip Survey"[1], special wards traffic statistics data is shown in Figure 10.



(a)Traffic volume distribution in special wards



(b)Traffic volume comparison in 23 wards of Tokyo

Figure 10 Traffic flow value in special wards

In the special wards, the Circle 1 has large traffic trip volume, accounting for 39.21% of the total volume, the Circle 2 which surrounding the Circle 1 is 30.02% and the Circle 3 is 30.86%, the trip volume showed a trend of high traffic volume in central city and low in the surrounding. As can be seen from Figure 10, the traffic volume of Circle 1, the urban sub-centers "Shinjuku" and "Shibuya", "Setagaya" of Circle 3 are higher than that of special wards, the other wards are lower than special wards, indicating that the Circle 1 has a greater traffic concentration, attracting a large number of traffic trips, and the urban sub-centers, due to the sharing of functions of the central city, it plays a role of diversion. Traffic volume of Setagaya in Circle 3 is more prominent in the surrounding wards, this ward has a strong regional attraction, attracts some traffic trip volume.

Circle 1: Chiyoda, Chuo and Minato.

Circle 2: Shinjuku, Bunkyo, Shinagawa, Taito, Shibuya, Toshima.

Circle 3: Nerima, Itabashi, Katsushika, Edogawa, Adachi, Nakano, Kita, Sumida, Arakawa, Setagaya, Suginami, Meguro and Koto.

4.2.3 Trip scale of residents in each ward

The following is statistical table of traffic trip proportion in special wards, which based on the each ward as departure ward and arrival ward, the Table 9 is based on the data of "The 5th Tokyo Metropolitan Area Person Trip Survey"[1], as shown in Table 9.

Table 9 Statistical table of traffic trip proportion in special wards

Departure wards	Arrival wards (%)																						
	Chiyod	Chuo	Minato	Shinaga	Bunky	Shinjuk	Shibuy	Taito	Ota	Toshim	Megur	Sumida	Koto	Araka	Nakano	Suginam	Setaga	Nerima	Itabash	Kita	Adachi	Katsushi	Edogawa
Chiyoda	**27.17**	7.09	7.49	2.48	3.29	5.77	3.50	2.69	3.44	2.75	1.70	1.73	3.76	1.10	2.04	3.37	4.64	2.86	2.96	1.82	2.92	2.08	3.36
Chuo	7.62	**32.53**	6.65	1.96	1.57	2.77	6.41	1.25	2.47	1.70	1.20	0.97	2.13	0.57	5.42	5.49	5.10	4.50	4.16	0.55	0.27	3.97	0.75
Minato	9.69	5.82	**29.68**	4.61	2.03	4.03	5.24	2.53	4.10	2.08	1.92	1.69	3.37	1.95	1.31	2.05	4.21	1.88	1.75	1.99	2.32	3.55	2.19
Shinagawa	3.90	2.54	8.50	**51.55**	0.79	2.21	3.12	0.83	10.43	0.97	3.88	0.58	1.70	0.37	0.67	0.97	2.59	0.73	0.81	0.54	0.74	0.57	1.01
Bunkyo	7.80	3.06	3.75	1.25	**38.92**	5.65	2.07	4.23	1.21	7.27	0.95	1.20	2.10	1.48	1.00	1.66	1.88	2.56	3.46	2.85	2.54	1.46	1.65
Shinjuku	5.19	2.69	3.99	1.56	2.44	**42.73**	5.63	1.10	1.42	3.76	1.11	0.86	1.88	0.50	4.77	4.82	4.48	3.96	2.15	1.38	1.26	0.79	1.53
Shibuya	4.12	2.64	7.66	3.04	1.19	7.84	**37.11**	1.07	2.57	1.96	4.72	0.81	1.45	0.56	2.45	4.04	9.21	2.24	1.41	1.06	1.11	0.70	1.03
Taito	5.66	4.11	3.25	1.16	3.67	2.59	1.67	**47.38**	1.17	1.74	0.56	4.21	2.36	4.34	0.57	0.82	1.07	1.01	1.28	1.81	4.56	2.92	2.08
Ota	2.68	2.00	5.07	6.91	0.52	1.32	1.67	0.53	**70.07**	0.58	2.06	0.29	1.03	0.19	0.31	0.32	2.36	0.35	0.33	0.31	0.31	0.33	0.44
Toshima	3.98	1.98	2.69	0.99	4.98	5.71	2.32	1.10	0.98	**45.72**	0.55	0.47	1.23	0.80	1.47	1.21	1.24	7.07	8.04	4.44	1.53	0.74	0.77
Meguro	4.19	2.56	6.03	6.00	1.05	2.66	7.59	0.67	5.22	0.87	**45.69**	0.44	0.84	0.23	0.56	1.08	11.41	0.72	0.62	0.39	0.51	0.24	0.43
Sumida	4.10	3.82	2.90	0.94	1.31	1.83	1.18	4.26	0.78	0.51	0.41	**55.07**	8.31	0.85	0.40	0.55	0.79	0.44	0.61	0.50	2.62	3.60	4.22
Koto	4.97	6.41	4.30	1.45	1.19	2.17	1.35	1.36	1.36	1.03	0.45	4.40	**56.06**	0.51	0.58	0.79	1.07	0.88	0.84	0.55	1.46	1.27	5.55
Arakawa	3.94	2.63	2.94	0.94	2.62	1.88	1.31	6.53	0.68	1.85	0.43	1.16	1.44	**56.27**	0.21	0.36	0.52	0.60	0.88	4.19	6.55	1.23	0.86
Nakano	5.05	2.19	3.98	1.10	1.19	10.29	4.06	0.53	0.69	1.84	0.63	0.42	1.10	0.17	**50.07**	7.76	1.48	4.87	1.12	0.47	0.26	0.22	0.50
Suginami	4.66	2.23	3.85	1.02	1.06	5.94	3.68	0.54	0.43	1.07	0.75	0.34	0.98	0.18	4.70	**59.63**	3.85	3.26	0.65	0.35	0.29	0.20	0.33
Setagaya	4.58	2.21	4.92	1.67	0.79	3.65	5.21	0.43	2.14	0.69	4.32	0.30	0.77	0.18	0.57	2.47	**63.27**	0.54	0.40	0.23	0.27	0.13	0.28
Nerima	3.32	1.75	2.91	0.62	1.41	4.02	1.78	0.46	0.41	4.00	0.39	0.20	0.84	0.16	2.31	2.41	0.69	**67.35**	3.99	0.48	0.26	0.06	0.17
Itabashi	3.91	1.97	2.60	0.73	2.07	2.66	1.37	0.80	0.48	5.83	0.40	0.36	0.97	0.37	0.66	0.63	0.57	4.59	**64.41**	3.40	0.64	0.31	0.26
Kita	3.81	2.23	2.89	0.79	2.82	2.62	1.52	1.76	0.66	5.09	0.35	0.47	0.96	2.57	0.39	0.53	0.55	0.96	5.40	**59.86**	2.82	0.65	0.32
Adachi	3.07	2.21	1.96	0.54	1.32	1.23	0.85	2.11	0.37	0.94	0.26	1.23	1.31	2.05	0.15	0.20	0.36	0.25	0.55	1.50	**73.15**	3.68	0.69
Katsushika	3.29	2.59	2.45	0.58	1.03	1.19	0.65	1.96	0.46	0.70	0.17	2.26	1.70	2.26	0.11	0.20	0.30	0.11	0.34	0.49	5.21	**67.22**	4.71
Edogawa	3.69	3.42	2.67	0.85	0.85	1.65	0.77	0.99	0.57	0.48	0.21	1.96	4.94	0.26	0.23	0.28	0.34	0.19	0.28	0.22	0.68	3.22	**71.29**

Note: [25%, 100%] [10%, 25%) [5%, 10%) [2.5%, 5%) [0, 2.5%)

With the Circle 1 as a departure ward, the highest trip proportion is inner trip in departure ward, that are Chiyoda, Chuo and Minato, the proportion are 27.17%, 32.53% and 29.68% respectively. As far as way from the Circle 1, the trip proportion gradually decreased. The traffic trip proportion in Circle 2 is higher than that of other wards, but lower than the proportion inner trip in ward. With the increase of the distance from Circle 1 to Circle 3 the trip proportion decrease gradually, but Nakano, Suginami and Setagaya in Circle 3 have stronger regional radiation ability, it attracts more trip of residents.

With the Circle 2 as a departure ward, the highest trip proportion is also inner trip in the departure ward, and it is higher than that of Circle 1 (especially the Koto by 56.06%), followed by the proportion of trip to Circle 1, which shows that the Circle 1 has a great attraction. The Circle 2 is adjacent to the Circle 1, so a large amount of trip volume is generated, while the same adjacent Circle 3 does not show this phenomenon, indicating that the traffic volume impact of Circle 1 is greater than that of Circle 3.

The highest proportion departure from Circle 3 is also inner trip in the departure ward, and it is the highest proportion in three Circles, for example, the highest proportion reached 73.15% in Adachi. The proportion of urban sub-centers from Circle 3 to Circle 1 and Circle 2 is higher than other Circles.

In summary, the proportion of inner trip in departure ward increased gradually from Circle 1 to Circle 3 and higher than the other wards in the same Circle, the short-distance inner trip is obvious in each Circle. Urban sub-centers "Shinjuku" and "Shibuya" shared the function of the city, so it has a certain attraction and aggregation effect on residents' trip. It seems that Circle 1 has a tendency to work, Circle 2 has one to the balance of work and life, and the Circle 3 has one to life.

4.2.4 Residents' trip modes

Due to the different purpose of trip, the trip modal choices is also different, the following figures are residents' modal choices in each Circle (Figure 11).

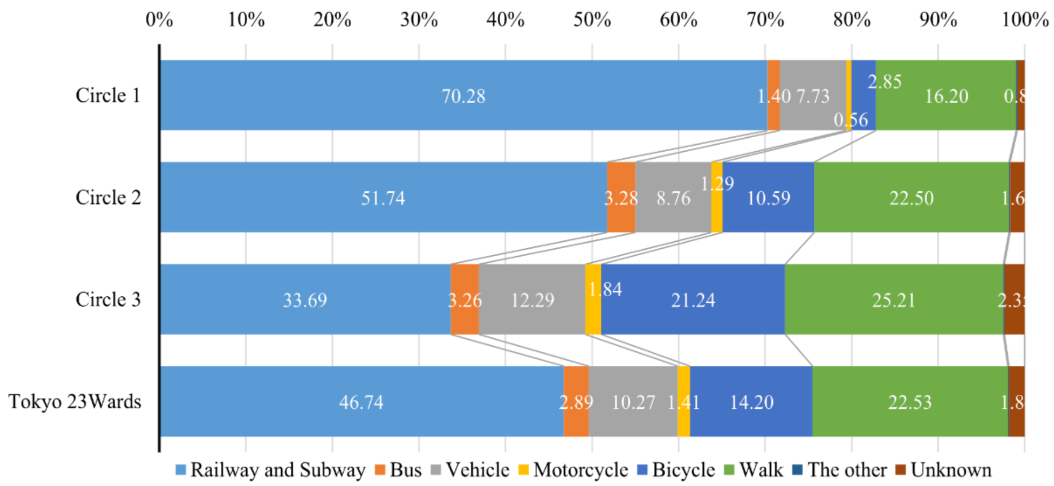


Figure 11 Residents' modal choices in each Circle

A large number of job opportunities are concentrated and the residential area is relatively inadequately in Circle 1, residents who living in Cirle2 and Circle 3 need to reach Circle 1 by various modes of trip and return back from Circle 1. As can be seen from Figure 6, in the Circle 1, the railway and metro is the main trip mode (accounting for 70.3%) and it is significantly higher than special wards and other Circles. Proportion of motor vehicle trip is much smaller than public trips, accounting for 7.7%. In Circle, the railway and metro conditions is mature and convenient, it meet the demand of distance for residents' trip.

In Circle, the railway and metro conditions is mature and convenient, it meet the demand of distance for residents' trip. In Circle2, although the trip proportion of rail and metro is 18.54% lower than that of Circle 1, it is still the highest (accounting for 51.74%) of Circle 2, while the proportion of bicycle and walking both increased by 7.74% and 6.3%respectively than that of Circle 1, and in Circle 3 the proportion of motor vehicle, bicycle and walking are the highest ways among the three Circles, accounting for 12.29%, 21.24% and 25.21% respectively, while the proportion of rail and metro in Circle 3 decrease rapidly, accounting for 33.69%, it is the lowest proportion of the three Circles, indicating that the proportion of short-distance trips increased due to the lager residential area in the Circle 3, but rail and metro transit is the main choice for residents to trip, while motor vehicle, bicycle and walking are complementary.

In summary, in the trip modes of special wards, the rail and metro trip is the main trip modes and the proportion is gradually decreasing from Circle 1 to Circle 3. With the more farther away from Circle 1, the more resident’ trip mode trend is inner trip in the wards, so the chances of short-distance trip increase, it promote a gradual increase in the proportion of motor vehicle, bicycle and walking with the more farther away from Circle 1, the more proportion increase.

4.3 The summary of the chapter

The 23 districts of Tokyo are divided into three Circles, namely, the core three Circles by the ward method of Cluster Analysis, that are "core 3 wards", "middle Circle" and "marginal Circle". The population, population density and traffic flows of different Circles, etc. those are sorted and analyzed. The main conclusions are as following:

- The urban central area has a strong population aggregation and traffic volume attraction, the urban sub-centers shared part of the urban function, which can alleviate the population and traffic pressure of the urban central wards, and can effectively play the certain role of population redistribution.

- In the purpose of resident trip, the inflow of population in the Circle 1 is mainly for work, and the outflow is mainly for go-home. The urban sub-centers in Circle 2 provide certain employment opportunities, so it has a certain attraction of traffic trip and makes the Jobs-housing relatively balanced. In Circle 3, the mainly purpose of trip is home-based trip. So the optimization of urban spatial structure can effectively relieve population and traffic pressure and guide the redistribution of population and traffic trips.

- In residents' modal choices of special wards, during the resident trip proportion from Circle 1 to Circle 3, the inner trip in the ward is the highest, followed by the urban central wards, and finally is the urban sub-centers. The closer to the edge area, the higher the proportion of inner trip in the Circle, the closer to the central wards and the urban sub-centers, the higher the proportion of cross-wards trip. Reasonable regional planning and supporting transport system of special wards is better to solve the traffic problems existing in metropolis.

- In each Circle of residents' modal choices, the rail and metro is the main trip modes, non-motor vehicle trip is a secondary, while the proportion of motor vehicle trip is declining year by year, and gradually formed a public transport-based and non-motorized as a subsidiary of the trip pattern, effectively solve the traffic congestion, environmental pollution and other issues.

Chapter 5 Comparative Study of Traffic Patterns in Tokyo, Beijing and Shanghai

5.1 Population and population density in comparative cities

Since 1985, Land Ministry of Japan and Bureau of Urban Development Tokyo Metropolitan has planned a regional transformation and proposed to change urban construction. In 1986, the " Basic Plan of the Metropolitan Area " proposed to nurture the urban development modes from one-pole to multi-pole and to "distributed network structure"[52]. Nowadays, a "multi-center" urban structure has been formed, the sub-centers are Shinjuku, Ikebukuro, Shibuya, Ueno-Asakusa and Osaki, etc.[49].

Beijing is the center of China politics and culture, it concludes 16 administrative districts (Dongcheng-district, Xicheng-district and Haidian-district, etc.), with a total area of 16410.54 km^2, the resident population of Beijing is 2170.5 million in 2015, the density is 1323 pop./km^2. The central city of Beijing are Dongcheng-district and Xicheng-district, with the area of 92.39 km^2,with population of 2.203 million and population density of 23,845 pop./km^2[53]

Shanghai is the center of China economy, it concludes 16 administrative districts (Huangpu-district, Hongkou-district and Jingan-district, etc.) with a total area of 6340.5 km^2, the resident population of Shanghai is 2.415 million in 2015, the population density is 3908 pop./km^2[54].The central city of Shanghai refers to the urban area within the inner ring road of Shanghai, it concludes Huangpu-district, Hongkou-district and Jingan-district[55], with a total area of 51.5 km^2, the resident population is about 1.705 million in 2015[54].

The following are the contrastive figures, Figure 12 is population density of contrastive cities and Figure 13 is population density of central city in contrastive cities.

As Figure 12 shows, in the last 15 years, the population density of Tokyo was significantly higher than that of Beijing and Shanghai. For example, in 2015, Population density in Tokyo is 11.33 times and 3.93 times than that of Beijing and Shanghai respectively, and Tokyo has a high population density in relatively small land area; In

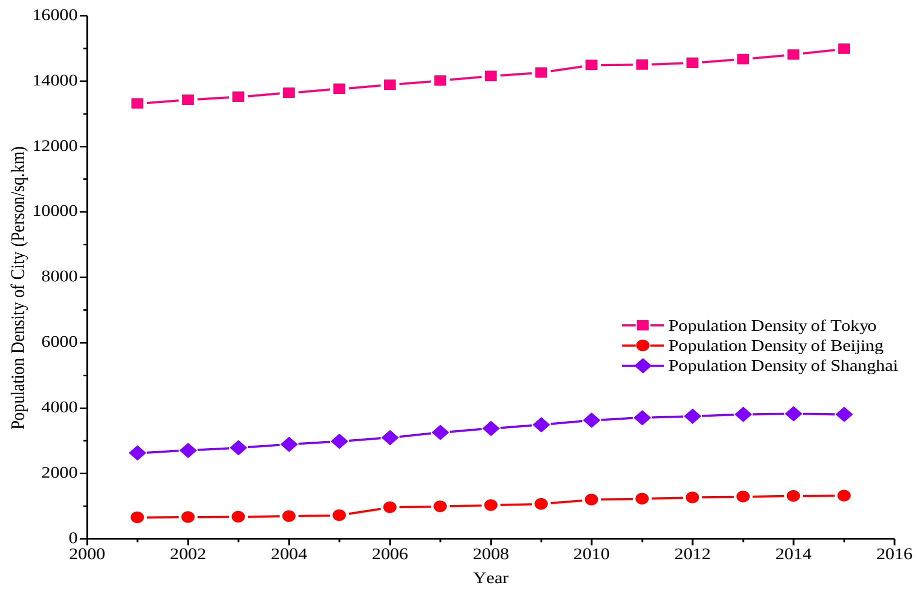


Figure 12 Population density of contrastive cities

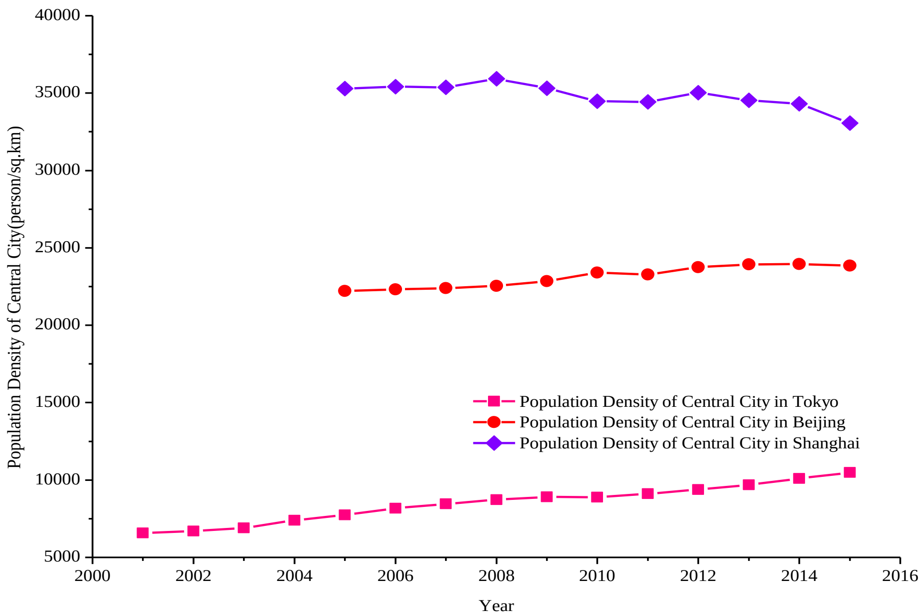


Figure 13 Population density of central city in contrastive cities

Figure 13, although the population density in Tokyo central city increased by 28.41%, it is higher than that in Beijing and Shanghai (Beijing and Shanghai is 6.89% and -6.61%, respectively), however, population density in Tokyo central city is lower the that in Beijing and Shanghai, which is 43.98% and 31.71% of that of Beijing and Shanghai. It shows that the population density of central city in Tokyo is lower than that of surrounding wards, and the sub-centers such as Shinjuku, Ikebukuro and Shibuya have played a role in redistribution of population. There is different situation in Beijing and Shanghai, the population distribution is unbalance, population density of central cities, there are both higher than the surrounding districts.

In Beijing, the urban function expanding districts (such as Chaoyang-district, Fengtai-district and Haidian-district, etc.) has played a certain role in attracting the population distribution, it came to appear that the population density of central city in Beijing has been decreasing year by year, and the population has begun to migrate to the urban function expanding districts and the other surrounding districts.

In Shanghai, the population density in central city is the highest in contrastive cities, but the growth rate has shown a negative growth, which is -6.61% (2006-2015), and the population begun to migrate to the surrounding districts, Table 10 is statistical table of population density increase.

Table 10 Statistical table of population density increase

Contents (%)	**Tokyo**	**Beijing**	**Shanghai**
Urban population density increase	12.55 (2001-2015)	60.54 (2001-2015)	44.77 (2001-2015)
Population density increase in central city	28.41 (2006-2015)	6.89 (2006-2015)	-6.61 (2006-2015)

Based on the Table 10, the urban population density increase of Tokyo is far smaller than that of Beijing and Shanghai, accounted for only 22.8% and 28.9%, while the central city population growth is bigger, but combining Figure 12 with Figure 13, as can be seen that the population density of Tokyo central city is far less than that of the Beijing and Shanghai, and the population density in the surrounding wards of Tokyo is much larger than that of the central city, it is still a low population density in the central city and the surrounding wards is higher than central city of Tokyo.

Beijing and Shanghai have obvious geographical advantages to attract a large number of population, in the last 15 years, the urban population growth is obvious, high and both close to about half. The trend is beginning to slow in central city of Beijing, while it is different situation in Shanghai, the population and population density in central city of Shanghai appeared a negative growth. The surrounding districts of Beijing and Shanghai central city due to share a part of the function of central city, it attracts the population to migrate and has played an important role in population redistribution, population began to expand form central city to the surrounding districts, but the pattern is still the high population density in central city and the low in the surrounding districts.

5.2 Urban road

Urban road length of Tokyo is longer than that of Beijing and Shanghai. For example, urban road length of Tokyo is 1.12 times and 1.35 times respectively than that of Beijing and Shanghai in 2015. But the density of the urban road network is much larger than that of Beijing and Shanghai obviously, which are 8.4 times and 3.9 times respectively. Figure 14 is urban road length of comparative cities, Figure 15 is the urban road network density of comparative cities.

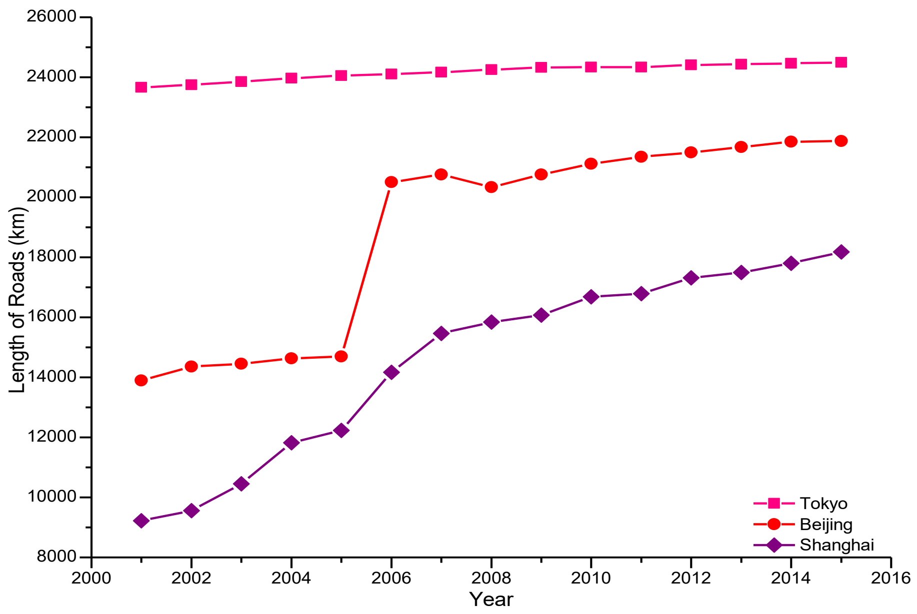


Figure 14 Urban road length (2001-2015)

In term of Figure 14, in the past 15 years, urban road length of Tokyo increased by 3.55% and tended to saturation, but it is greater than that of Beijing and Shanghai, for example, in 2015, the length of urban road in Tokyo is 11.99% and 34.72%, longer than that in Beijing and Shanghai respectively. However, it increased by 57.48% and 97.12% in Beijing and Shanghai respectively over the past 15 years. Especially, with the 29th annual Summer Olympic Games has been held in Beijing in 2008, the length of the urban road increased by 41.22% from 2005 to 2007, and in the same period, road

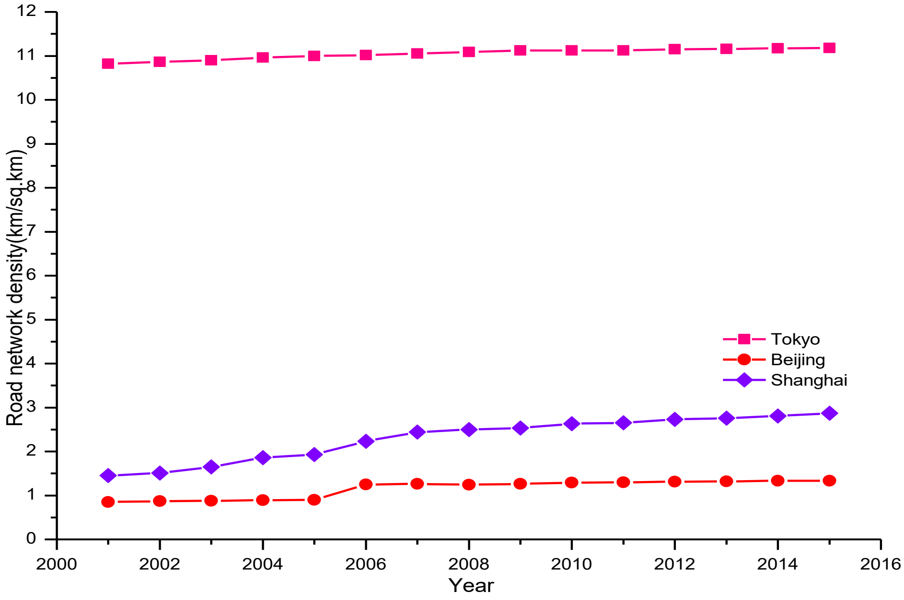


Figure 15 Urban road network density (2001-2015)

Sources: Tokyo Statistical Yearbook, Beijing Statistical Yearbook and Shanghai Statistical Yearbook

construction in Shanghai has been developed rapidly, the length of urban road increased by 26.43%.

In term of Figure 15, urban road network density of Tokyo is much higher than that of Beijing and Shanghai, which is 8.41 times and 4.11 times respectively. After long-term planning and continuous construction, urban roads of Tokyo is very well-developed, and the average width of roads in Japan is about 6 m, of which the average width of lanes is 4.2 m[56], the average width of roads in Beijing and Shanghai is about 15.27m (2013) and about 15.6m (2013) respectively, it is 2.55 times and 2.6 times that of Tokyo. Under the same road area ratio in Tokyo, it can get more road extension and can accommodate more road traffic volume, conductive to the improvement of road capacity, can provide more choices for residents' trip and reduce the probability of traffic congestion effectively. After years of construction and development in Beijing and Shanghai, although the framework of urban road network has been formed, the road mileage increased rapidly, however, from the perspective of road network density, it is far less than that of Tokyo, it gives a certain amount of pressure for residents to trip, and there is a great space for construction, development and improvement in the future.

5.3 Motor vehicle volume

In the 1980s, automobile production in Japan broke by 11 million and became the third automobile industry development center after the United States and Europe, with increasing of motor vehicle volume year by year, by 2001, the volume of motor vehicle in Tokyo (23 wards) has exceeded 2.29 million. However, with the development of urban public transport, the volume of motor vehicle has dropped to 1.96 million[57].The situation is different in Beijing and Shanghai, the following Figure 16 is motor vehicle volume in contrastive cities and Figure 17 is per capita motor vehicle volume in contrastive cities.

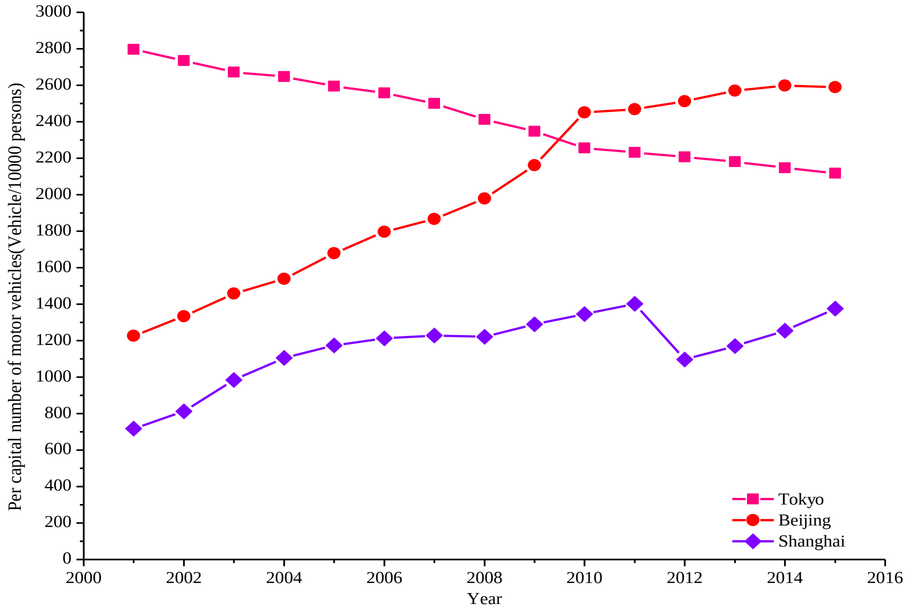


Figure 16 Motor vehicle volume

As can be seen from Figure 16, since 2001, the volume of motor vehicle in Tokyo has declined year by year, by 14.52% in 2015, the per capita motor vehicle volume has also declined, with a decrease of 32.02% from 2001 to 2015.There are three main reasons for the decline: the one is to limit the volume of motor vehicles by legislation (e.g.:1962, "Law Regarding the securing of storage spaces for automobiles ", etc.), the law requires that the purchaser need to have a non-roadside parking space before buying car. The second is to reduce the parking requirements of buildings and even allow the small building not to be fitted with the parking spaces. The third is the high cost of car use, the government levy taxes on the use of motor vehicle, including Consumption tax, Automobile tax, Acquisition tax and other taxes, in addition, parking fee is very high, for example, in 2015, the general car parking fee is about 240,000 yen monthly, self-service car costs 600-1500 yen/hour, the parking rate of self-service parking is 600 to 1500 yen / hour, and the high penalties for parking violations, etc. These policies strictly limit the volume, usage of car and encourage car users to switch to the public transport system.

At the same time, the volume of motor vehicle in Beijing and Shanghai has increased significantly, by 230.92% in Beijing and by 111.18% in Shanghai respectively. In order to control rapid increase of motor vehicle volume, Beijing began to implement vehicle license-plate lottery system in December 2010 and traffic restrictions based on the last digit of license-plate numbers, etc. After 2010, the increase of motor vehicle volume began to decrease in Beijing (Figure 16), the measures has played a certain role.

In Shanghai, the motor vehicle volume has increased by 174.67% from 2001 to 2011, and private motor vehicle volume increased by 95.21% (since 2012,the data on the volume of motor vehicle do not include mandatory scrap). Since 1994, the "License-plate Auction" system has been implemented to control the rapid increase of motor vehicle volume. As can be seen from Figure 17, the measure has played effectively role, and the increase of motor vehicle volume is less than that of Beijing.

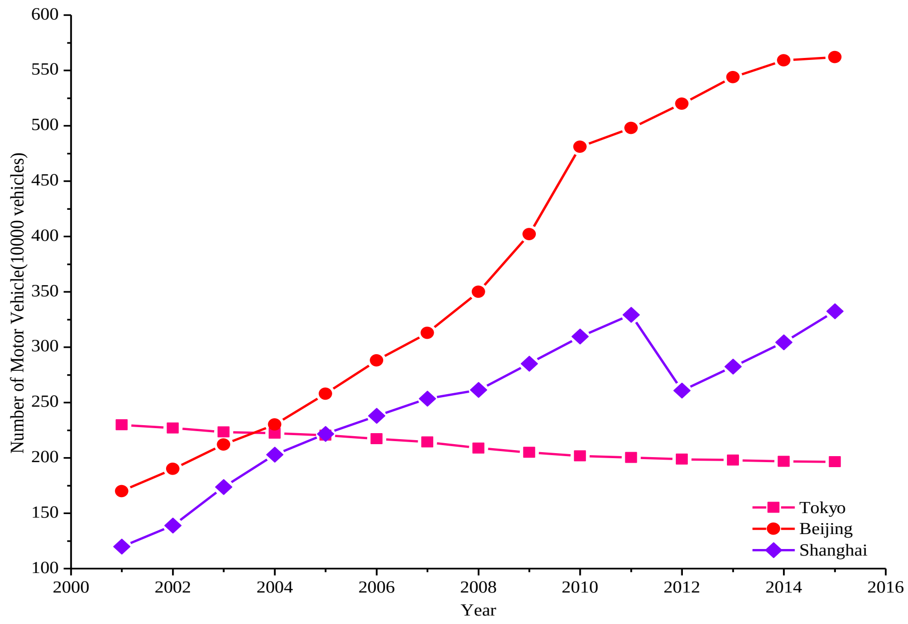


Figure 17 Per capita motor vehicle volume

Data Sources: Tokyo Statistical Yearbook, Beijing Statistical Yearbook and Shanghai Statistical Yearbook

Among the comparative cities, the motor vehicle volume in Tokyo declined year by year, and the per capita volume decreased by 30.02% over the past more than 10 years, it shows that the measures taken by Tokyo has played a positive role in controlling the volume of motor vehicles, residents' trip has reduced their reliance on motor vehicles and has turned to other trip modes.

In recent years, the volume of motor vehicles in Shanghai has begun to show a slowing growth trend, and tends to be stable, while that of Beijing has gradually slowed down the growth rate, but still maintained a growth trend, in the future, motor vehicles volume control still need to do a lot of work to alleviate the congestion and environmental problems caused by motor vehicles.

5.4 Urban metro

There are many appellations about the metro, such as Metro, Subway, Underground, the Tube, the L, the T, MRT, etc. In this dissertation choose metro, and of course the other appellations are available.

Tokyo is a typical international metropolis dominated by rail transit with very convenient traffic. Tokyo metro began in 1927, it is the first city with metro in Asia, the earliest opening is the Ueno-Asakusa line, traffic mileage is about 2.2km, since the development, there are variety of rail transport types, including ordinary railways (JR railways, private railways), metros, monorails, targeted population transport GMTs and trams, etc., the structure is formed by combination of loop line and radial line, of which are the Oedo line (Metropolitan Metro) and the Yamanote line (Japan Railway) and the main radial lines are metros, private railways and JR. The 23 wards of Tokyo Metropolitan railway length of 997.8 km, density of 0.95 km/km^2, the total length of the metro system line is 304.1 km (Tokyo Metro 195.1km, Metropolitan Metro109 km; Excluding the line connect with private line), 285 stations (Tokyo Metro 179 stations, Metropolitan Metro 106 stations, of which with the repeated calculation of the stations of the multi-line shared). Currently, 13 lines are operating (9 lines of the Tokyo Metro and 4 lines of the Metropolitan Metro), the average daily traffic volume in 2014 was 9.35 million passengers (about 6.44 million in the Tokyo Metro and about 2.28 million in the Metropolitan Metro)[58, 59].

Figure 18 Tokyo urban rail and metro network

Sources: http://www.jreast.co.jp

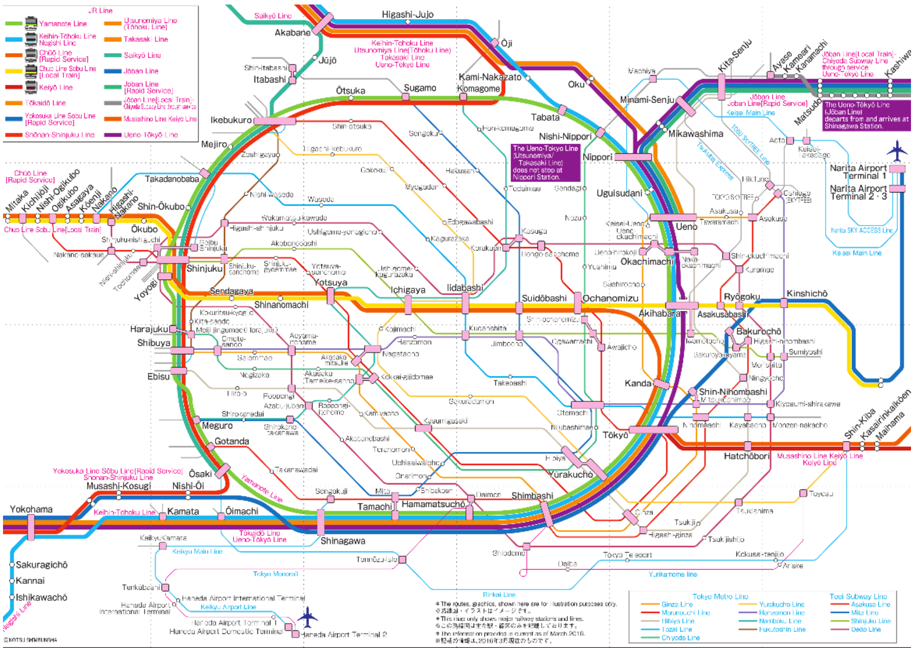


Figure 19 Yamanote line

Sources: http://www.jreast.co.jp

Table 11 Basic information of urban metro loop comparative cities

	Contents	Type	length (km)	Number of stations	Number of transfer stations	Average station distance (km)
23 wards	Yamanote-Line	loop	34.5	29	24	1.19
Beijing	Line No.2	loop	23.1	18	10	1.28
	Line No.10	loop	57.1	45	24	1.27
Shanghai	Line No.4	loop	33.7	26	18	1.30

Data Sources: The 5th Tokyo Metropolitan Area Person Trip Survey, Annual report of Beijing traffic development and Annual report of Shanghai General Traffic.

The Yamanote line (Figure 19) is a closed loop in 23 wards of Tokyo, connecting Tokyo central city and the various radial railroad routes, metro lines and private railway lines, of which 7 JR lines, 13 metros lines and 13 private railway lines form a rail network of loop and radial routes.

Beijing rail transit system consists of grid-like lines that cross the horizontal lines and vertical lines (Figure 20) and connected by loop lines No.2 and 10 (Table 11) to form a rail transit network. It is began in 1965, as of December 2015, there were 18 rails transit network operating lines, 554 kilometers of operating lines, 911 million passengers per day, 334 operating stations and 53 transfer stations[60], covering 11 districts of Beijing.

The rail transit system in Shanghai has been built since 1986 and has formed mainly in the north-south direction of the main vertical lines. The lines are connected to each other, and the entire rail transit network is circularly connected by No. 4 (Table 11) to form a rail transit network (as shown in Figure 21). As of December 2015, 14 lines of railways with a total length of 617 km, 366 train stations and 54 transfer stations, with loop lines links. The annual passenger traffic volume was 3.068 billion.

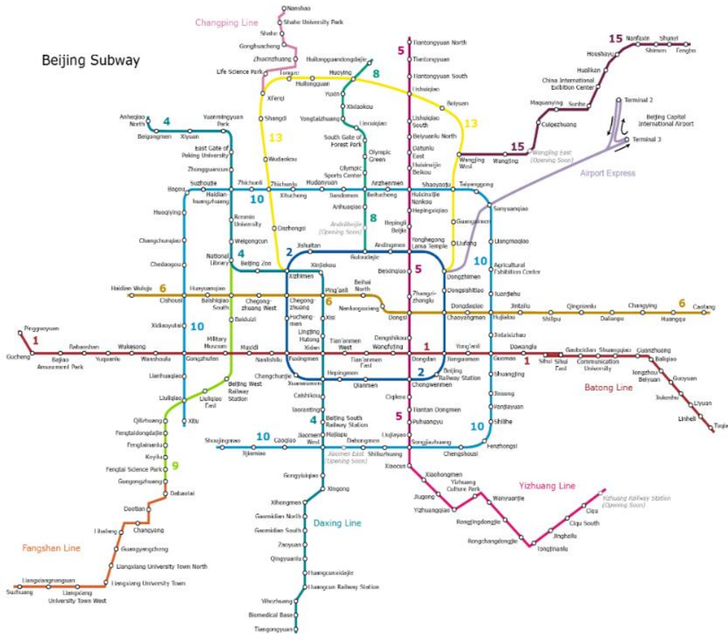


Figure 20 Beijing metro map

Sources: https://www.bjsubway.com/

Figure 21 Shanghai metro map

Sources: http://shmetro.com/

As can be seen from Table 12, Tokyo has the highest metro line network density of 0.49km/km^2, while that of Beijing and Shanghai are 0.034 km/km^2 and 0.097 km/km^2 respectively much lower than that of Tokyo, the per capita metro line network density is 0.033 m/person, and it is longer than that of Beijing and Shanghai by 0.033 m / person and 0.026 m/person respectively, although the length of metro lines in Beijing and Shanghai are longer than that in Tokyo, but the urban metro network density and the per capita density in Tokyo have been developed fast with higher coverage rate, the residents have much choices in their trip than that of Beijing and Shanghai, and it is convenient and accessibility, the average time of residents that walk from home to metro stations is 9.7 minutes, accounting for 67.8% and 8.8 minutes from stations to destination, accounting for 92%[61] (2015), the proportion of railway transit in urban traffic modes share is as high as 48%[47], and while in Beijing and Shanghai, the rail transit network density is relative low, residents' trip time is longer than that of Tokyo, for example, the average trip time is about 60 minutes in Beijing[60], and about 62 minutes in Shanghai[62] and the proportion of trips is only 19.4% and 8.3% respectively, the proportion of motor vehicles and buses are both high in Beijing and Shanghai, which brings great pressure to the traffic trip.

Table 12 Basic information of urban metro in comparative cities (part) (2015)

Contents	**Line network Density (km/km^2)**	**Per capita network density (m/person)**	**Average daily passenger volume (10000 passengers)**	**Traffic sharing rate (%)**
Tokyo (23 wards)	0.490	0.033	935.00(2014)	48.0
Beijing	0.034	0.026	911	19.4
Shanghai	0.097	0.026	840.50	8.3

Sources: The 5th Tokyo Metropolitan Area Person trip Survey, Annual report of Beijing traffic development and Annual report of Shanghai General Traffic.

5.5 Structure of trip modes

5.5.1 Structure of trip modes and analysis of Tokyo 23 wards

Structure of trip modes refers to the proportion of traffic volume undertaken by different trip modes in urban traffic system[63]. Traffic infrastructure, resident's trip psychology and living standards affect the residents' trip modes structure from different aspects. The following Figure 22 is the residents' trip modes in ward of special wards based on "The 5th Tokyo Metropolitan Area Person Trip Survey"[1].

The 23 wards of Tokyo in Figure 22 is arranged according to the order of diffusion around the geographical center of the special area (data base on "the Tokyo

Metropolitan Area Person Trip Survey"[1]) According to the classification method of 4.1.1, it is arranged from the center of the special wards to the marginal special wards. The trip modes in 23 wards of Tokyo, in addition to Adachi, Katsushika and Edogawa, the trip percentage in the other 19 wards, the highest is the railway, 76% of Chiyoda to 29.11% of Nerima, the proportion of railway is more than that of the others. It can be seen that railway transport is the most important trip modes in 23 wards of Tokyo and proportion of railway transport in Shinjuku, Shibuya and Toshima is much obvious than that of other wards, of which Shinjuku is the sub-cities, Shibuya and Toshima, on the other hand, are more attractive to traffic trips and have obvious traffic attraction. They are potential traffic and traffic hubs and urban sub-centers.

However, walking is the second-largest trip mode, as can be seen from Figure 22, the proportion of walking in the 23 wards of Tokyo changes slightly, the overall trend remains stable, distributed in the range of 14.38 % to 26.77 %, both in the urban center, urban sub-center and in the urban marginal wards, remain basically stable.

The proportion of bicycle trips gradually decreases from the marginal special wards to the center, which has the opposite trend with that of the rail trip, the closer to the center of the city, the lower proportion of bicycle trips. It illustrate that the closer to the city center, the higher proportion of rail trip, the closer to the marginal wards, the more dependent on other traffic modes.

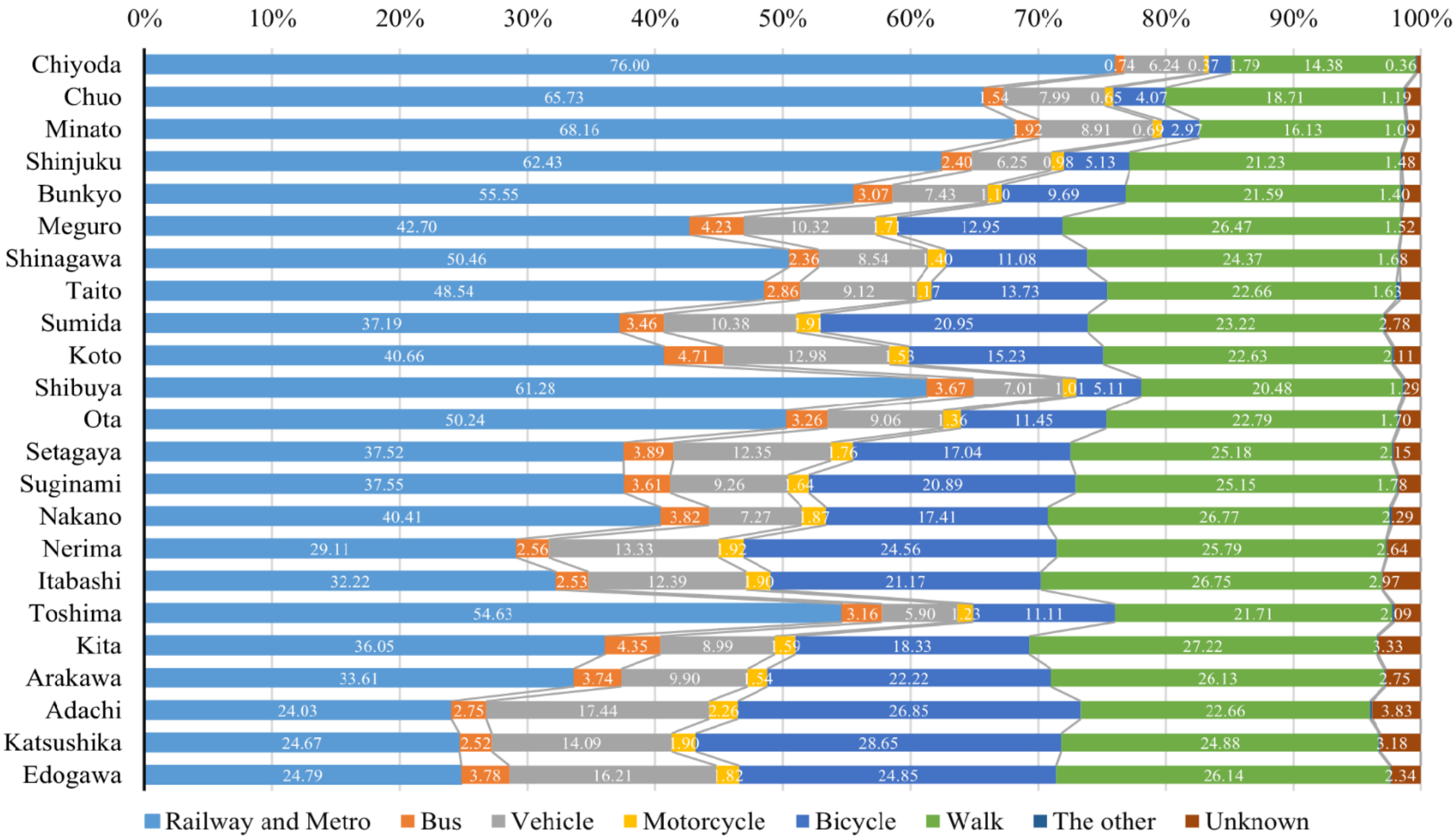


Figure 22 Residents' trip modes share in ward of special wards

5.5.2 Structure and analysis of traffic trips in comparative cities

The analysis in previous section based on "The 5th Tokyo Metropolitan Area Person Trip Survey"[1] and Tokyo Statistical Yearbook[64], the railway trip is the main way of resident 23 wards of Tokyo. In this section, statistics and analysis are made on the trip patterns of Tokyo 23 wards, Beijing and Shanghai in the past 30 years. Figure 23 shows the structure of the trip modes share in Tokyo. Figure 24 and Figure 25 show the trip modes share in Beijing and Shanghai structure chart.

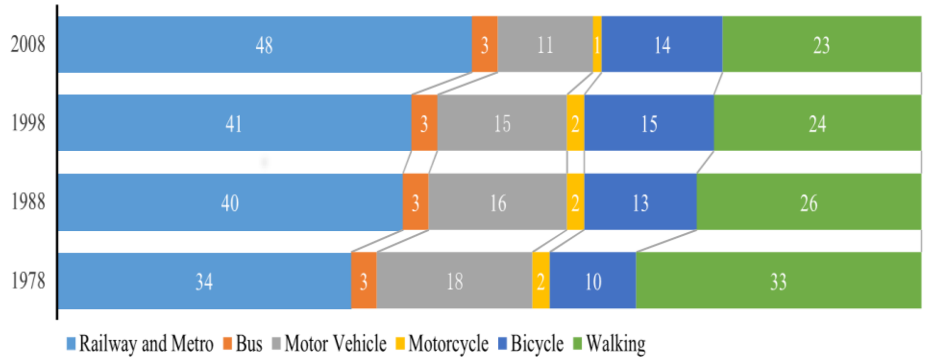


Figure 23 Structure of trip modes share in 23wards

As can be seen from the Figure 23, from 1978 to 2008, the trip modes in 23 wards of Tokyo, the largest proportion is rail transit that increased by 14% from 34% to 48%, although the proportion of walking decreased from 33% to 23%, but the proportion is still ranked second, the other followed by bicycles, motorcycles and motor vehicles, etc., of which the proportion of motor vehicle decreased by 7% from 18% to 11% year by year, meanwhile the proportion of bicycle increase by 4%. Till 2008, the rail transit still occupies the most important position. As can be seen from the Figure24, the main trip modes of resident in Tokyo is rail transit and the proportion was increasing from 1978 to 2008, so residents' trip is convenient and quick, it is benefit from the well-developed rail transit network, restrictive policies on motor vehicle, short trip time and low cost etc., and it can effectively alleviate and solve the problems of traffic congestion, environmental populations, etc.

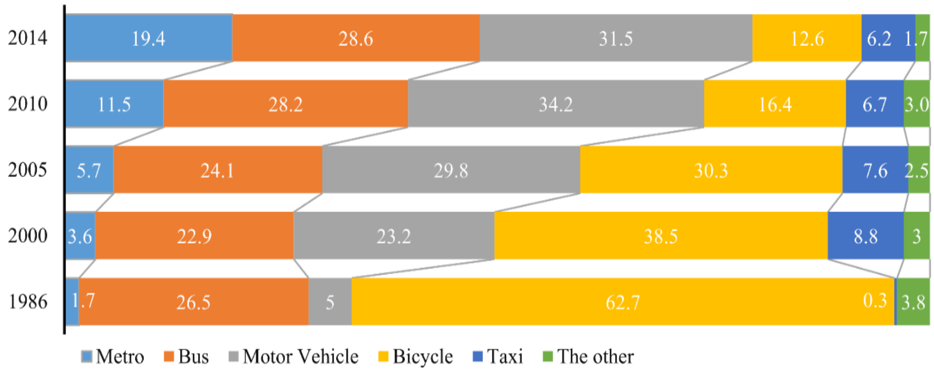


Figure 24 Structure of trip modes share in Beijing

As can be seen from Figure 24 (data base on the Beijing Statistical Yearbook[65] and Beijing Traffic Development Report[60], the data does not include the amount of walking.), the bicycle is the main way of trip and the bus is the auxiliary way in the residents' trip modes in Beijing from 1986, and till 2014, the proportion has changed, the motor vehicle trip proportion is the highest, and the bus is the second, the rail trip proportion increased by 17.7% from 1.7% to 19.4%, and bus trip proportion remained largely unchanged, increasing by 2.1%. In the past over 10 years, Beijing commitment to the policies of the public traffic has played a certain role in making public traffic scale increased year by year, but the proportion of motor vehicle increased quickly by 26.5% from 5% in 1986 to 31.5% in 2014. In the traditional way of trip, bus trip proportion basically remained unchanged, the bicycle trip proportion decreased significantly by 50.1%. With the increase of motor vehicle proportion, traffic congestion, environmental pollution and other issues began to appear.

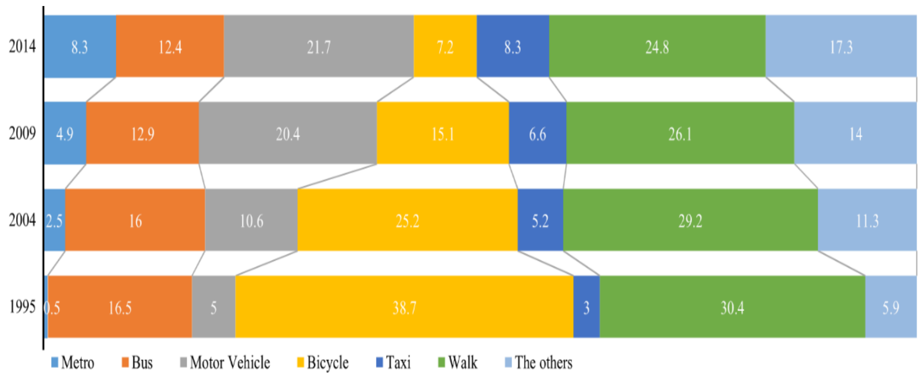


Figure 25 Structure of trip modes share in Shanghai

In Shanghai, the traffic trip modes structure was dominated by bicycle, walking and bus (38.7%, 30.4% and 16.5% respectively，Figure 25, data base on the Shanghai

Statistical Yearbook[66] and The fifth comprehensive traffic survey in Shanghai[67]) in 1995. After years of development, the trip modes has changed greatly, by 2014, the trip modes mainly include walking, motor vehicle and other modes (24.8%, 21.7% and 17.3% respectively, other ways include ferry trips), the fastest growing in all of trip modes was rail transit (form 0.5% to 8.3%), the second was motor vehicle (from 5% to 21.7%) and the third is taxi (from 3% to 9.3%), while the proportion of bus trip and bicycle are declining year by year, of which the proportion of bus trip declined from 16.5% to 12.4%, and the that of bicycle dropped rapidly from 38.7% to 7.2%. The proportion of motor vehicle trip (including taxi) in Shanghai is increasing year by year, although the motor vehicle volume has been strictly controlled by the policies, such as the number plate auction, etc., but the proportion of motor vehicle trip is still increasing gradually.

The rail trip proportion of Tokyo is the highest in comparative cities, accounting for 48% (2008), the second is Beijing for 19.4% (2014) and the third is Shanghai for 8.3% (2014).Tokyo has a well-developed rail network and feeder system, there are series of motor vehicle restrictions policies and other public transport system support policies, the time and the cost of motor vehicles trip are high, while rail trip is rapid and low-cost, so it make proportion of rail trip is higher and higher. Although Beijing and Shanghai have a lot of investment in construction of public transport in recent years, there is still a certain gap in trip time, accessibility and convenience. As a result, the proportion of resident motor vehicles trip is still relatively large, resulting in a certain amount of traffic and the environment problem.

5.6 Air pollution caused by various trip modes

5.6.1 Air pollution caused by traffic

With the development of economy and the increasing level of urbanization, the demand for energy is also increasing, including electricity, fuel, natural gas and so on, however, it cause consequent greenhouse gas emissions and urban air pollution, and the world largest greenhouse gas emissions industry is the electricity industry, then the transportation[68, 69]. With transport emissions of greenhouse gases, it also emit the air pollutants, so the motor vehicle emissions have gradually become the main source of air pollution in cities [70-72].

According to the national air emissions inventory report released in 2010, 18 % of PM10, 24 % of PM2.5, 54 % of co, 32 % of NO_x and 26 % of benzene in the UK atmosphere are derived from transport emissions[73].

Motor vehicle exhaust emissions caused many problems, such as: urban air pollution, environmental degradation, adverse effects on the health of residents and so on, especially the healthy, air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs[74]. With the increasing level of urbanization, the increasing number of motor vehicles, etc. makes lots of problem of environmental pollution caused by motor vehicles more, and now the researcher in the world come to pay more attention in this filed.

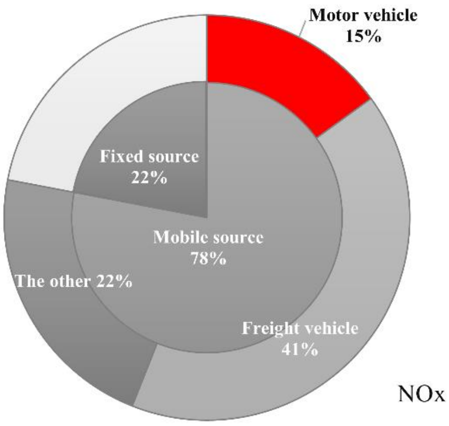
5.6.2 Impact of various trip modes on air quality

Different trip modes have different impacts on the environment. Among them, the emissions of engine affect the air quality greatly. Due to different types of engines, different fossil fuels, different emissions standards， different speed, different driving distance and other factors, exhaust emissions contained greenhouse gases and air pollutants are also different. However, the different manufacturing standards and exhaust emission standards in different countries or regions makes it difficult to calculate the specific proportion of air pollutants contained in the exhaust gas discharged by a uniform standard.

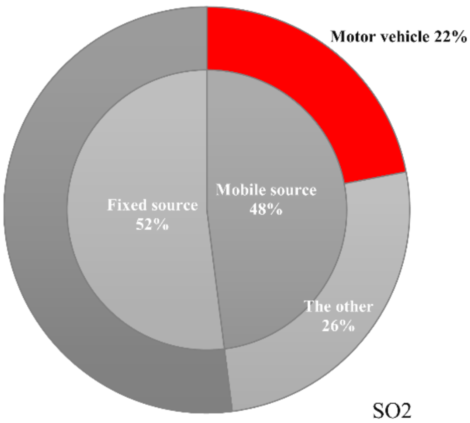
W. Majewski and M. Khair obtained the highest proportion of nitrogen compounds in diesel engine exhaust emissions by research, accounting for over 67% and CO_2 accounting for 12%[75]， Of the total CO_2 emissions in Tokyo, emissions from automobiles in the transportation sector account for about 25%[76], one of the research objects in this paper is Tokyo, so according to the Japanese Ministry of Land and Transportation website data, the initial development of a variety of transport 1-kilometer CO_2 emissions (as shown in Figure 26).

Figure 26 is Tokyo major air pollutants and proportion based on the motor vehicle, air pollution in Tokyo mainly comes from fixed sources (including: factories, construction, and family, etc.) and mobile sources (including: passenger motor vehicles, freight vehicles, ships and aircraft, etc.), the data base on website of Bureau of Environment Tokyo Metropolitan Government[76], in this case, due to base on the residents' trip choice, so Figure 26 is based on the passenger motor vehicle emissions of air pollutants in Tokyo.

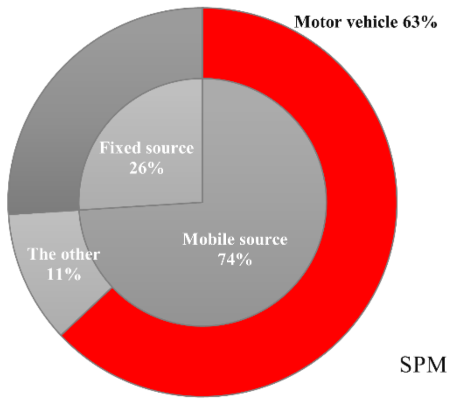
As can be seen in the Figure 26 the exhaust emission of motor vehicle in Tokyo has a relatively large impact on air quality, among them, the emission of SPM is 63%, and the emission of NO_x and SO_2 is 22% and 15%. It can be seen that the exhaust emission of motor vehicles plays an important role in air pollutants. Therefore, it is a necessary research to control air pollution by adjusting the residents' trip choices.



(a) NO_x



(b) SO_2



(c) SPM

Figure 26 Main pollutants and proportion of motor vehicle emission (Part)

Source: Bureau of Environment (Tokyo Metropolitan Government)

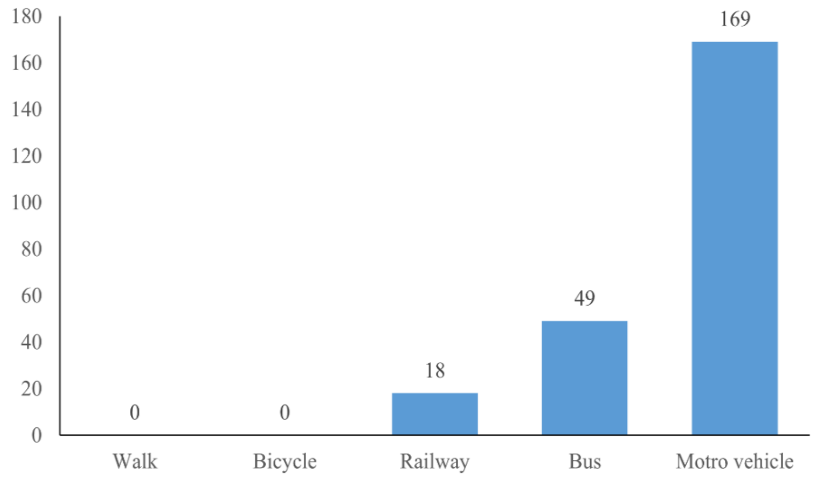


Figure 27 CO_2 emissions from various modes of trip in 1 km

The transportation modes listed in Figure 27 include walking, cycling, railway, bus and car. As shown in the figure, CO_2 emissions from walking and bicycles are zero and are the most environmentally friendly trip modes. Rail transit, bus and private car, rail traffic CO_2 emissions are 18g/km, accounting for bus trip 36.73% (49g/km), the private car trip 10.65% (169g/km), and CO_2 emission of railway is the lowest way in the motor vehicles trip. So the impact from small to large in turn is: walking, bicycles, rail transit, bus and private car. In rail transit, bus and private car trip, the amount of CO_2 emissions from orbital trip is 18g / km, accounting for 36.73% (49g/km) of bus trip and 10.65% (169g/km) of private car trip, Motor vehicle emissions in the lowest

CO_2 emissions. Therefore, the impact from small to large are: walking, cycling, rail transit, bus and private cars.

The structure of the residents' trip mode plays an important role in the urban air quality, under the same traffic total quantity, the proper adjustment of the trip modes structure is favorable to the improvement of air quality, which can effectively reduce the air pollution and the emissions of greenhouse gases and other pollutants. The table 13 is the proportion of main trip modes in 23 wards of Tokyo, Beijing and Shanghai (part).

Table 13 Proportion of trip modes in 23 wards, Beijing and Shanghai (part)

Cities	**Trip modes and Proportion**					
	Railway	**Walking**	**Bicycle**	**Motor vehicle**	**Bus**	**Comments**
23 wards	48	23	14	11	3	Date for 2008
Beijing	11.5	-	16.4	34.2	28.2	Date for 2014
Shanghai	4.9	26.1	15.1	20.4	12.9	Date for 2014

As can be seen from Table 13 and Figure 26, according to the proportion of their trip modes, the residents' trip modes in Tokyo are mainly in rail transit, walking, bicycle and motor vehicle, and the proportion of public transport trips is larger. Based on the impact on the air pollution by the various trip modes, the impact of trip modes in Tokyo is less on air quality than Beijing and Shanghai. The proportion of private motor vehicle is the largest trip mode, and then bus, bicycle and rail transit, and the proportion of air pollution is larger than that of Tokyo. The highest trip mode in Shanghai is walking, the second is private motor vehicle, followed by bicycle and bus (the other trip modes in Shanghai include ferries), the structure of trip modes is reasonable than that of Beijing, but the air pollution is greater than in Tokyo.

Different trip modes will release different air pollutants and impact on air quality, which may also adversely affect health. The main pollutants are: NO_x, PM, SO_2 and greenhouse gas (CO_2), the impact on living environment briefly as following:

Nitrogen oxides (NO_x) These pollutants cause lung irritation and weaken the body's defenses against respiratory infections such as pneumonia and influenza. In addition, they assist in the formation of ground level ozone and particulate matter.

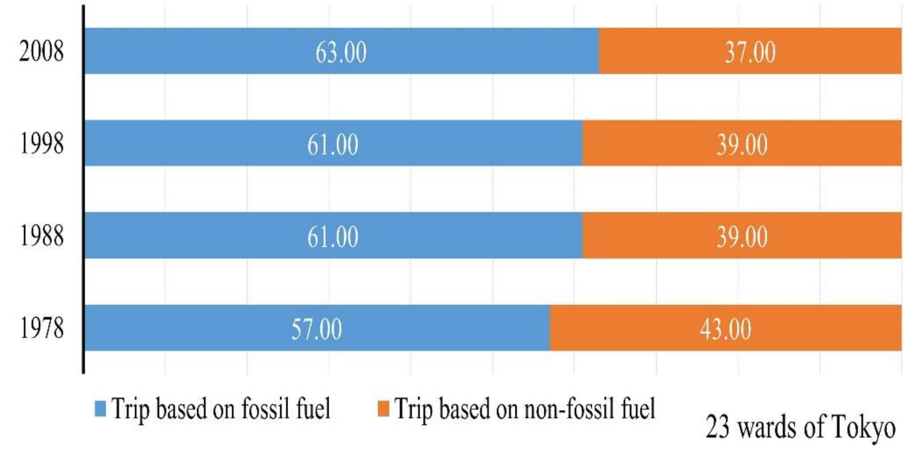
Particulate matter (PM) This is the Fine particles-less than one-tenth the diameter of a human hair-pose the most serious threat to human health, as they can penetrate deep into lungs.

Sulfur dioxide (SO_2) Motor vehicles create this pollutant by burning sulfur-containing fuels. Sulfur dioxide can react in the atmosphere to form fine particles and poses the largest health risk to young children and asthmatics.

Hazardous air pollutants (toxics) Those chemical compounds have been linked to birth defects, cancer, and other serious illnesses.

Greenhouse gases Motor vehicles also emit pollutants, such as carbon dioxide, that contribute to global climate change.

In the case of residents' trip modes, different way of trip has different effect on the air quality. In this case, according to the proportion of the major pollutants emitted by motor vehicle exhaust in Figure 26, the trip based on the fossil fuels and non-fossil fuels in 23 wards of Tokyo, Beijing and Shanghai, as shown in Figure 28 (a), Figure 29 (a) and Figure 30 (a), Figure 28 (b) and Figure 29 (b) and Figure 30 (b) are detailed contents of the trip proportion based on fossil fuel in Figure 28 (a), Figure 29 (a) and Figure 30 (a) respectively, the proportion is same. It can be seen from Figure 28 (a) that



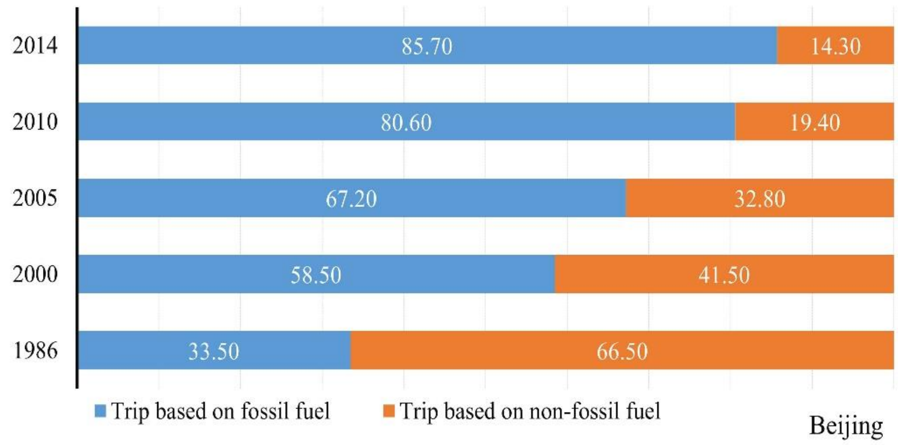
(a) Statistic of trip proportion based on fossil and non-fossil fuel in 23 wards of Tokyo

(b) Statistic of trip proportion based on public and non-public transit in 23 wards of Tokyo

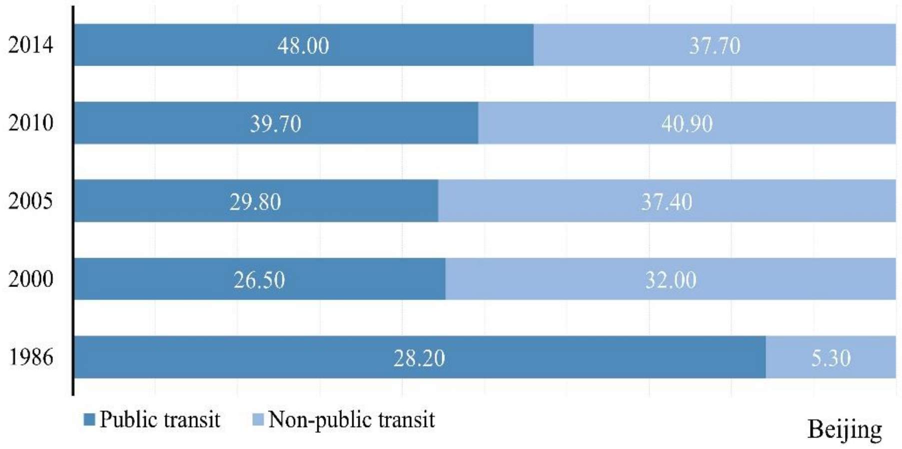
Figure 28 Statistic of trip proportion based on fossil or non-fossil fuel in 23 wards

the proportion of trip that based on the fossil fuel is increasing year by year in Tokyo, from 57% in 1978 to 63% in 2008, although it is growing year by year, but the growth rate is decreasing become slower. In the same period, the proportion of trip that based on non-fossil fuel is decreasing from 43% in 1978 to 37% in 2008. But in the Figure 28 the proportion of public transit is increasing year by year (in this case, public transit conclude rail way, metro and bus), from 37% in 1978 to 51% in 2008, it illustrate that residents' modal choices is transferring to public transit year by year, due to the public transit capacity is far larger than the non-public transit, so air pollution caused by public transit is relatively smaller, it is an effective method to control air pollution.

Figure 29 is statistic of trip proportion based on fossil or non-fossil fuel in Beijing[60, 65], the proportion of trip based on fossil fuel is increasing rapidly, from 33.5% in 1986 to 85.7% in 2014, but the public transit is growing at a slower rate.

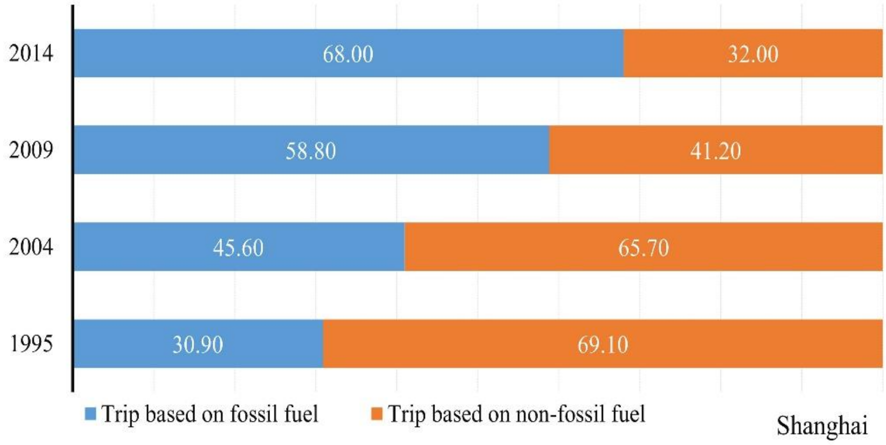


(a) Statistic of trip proportion based on fossil and non-fossil fuel in Beijing

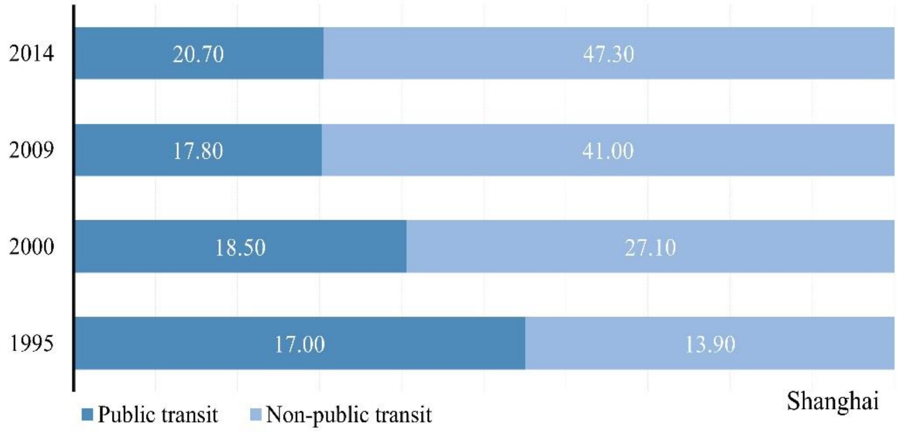


(b) Statistic of trip proportion based on public and non-public transit in Beijing

Figure 29 Statistic of trip proportion based on fossil or non-fossil fuel in Beijing



(a) Statistic of trip proportion based on fossil and non-fossil fuel in Shanghai



(b) Statistic of trip proportion based on public and non-public transit in Shanghai

Figure 30 Statistic of trip proportion based on fossil or non-fossil fuel in Shanghai

Base on the Figure 30 (based on the data of the fifth comprehensive traffic survey in Shanghai[67] and Shanghai statistical yearbook[66]), it is the similar situation with

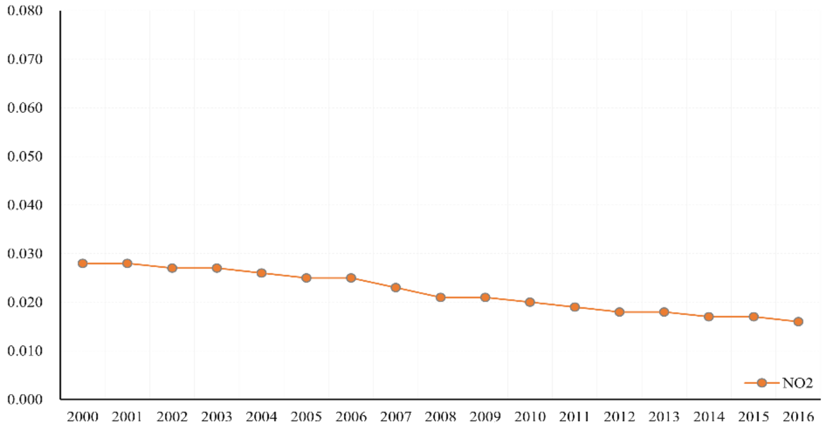
Beijing, the trip based on fossil fuel is also increasing, from 30.9% in 1995 to 68% in 2014, but proportion of public transit in Figure 30 (b) is began to stabilize. The trip based on non-fossil fuel is decreasing year by year, 33.5% in 1986 to 85.7% in 2014. The status in Shanghai is similar to that of Beijing, but the rate is slower than that of Beijing.

In term of Figure 26 to Figure 30, transportation has a great influence on air pollution. Proportion of trip that based on fossil fuel is increasing year by year and it has a great influence on air pollution.

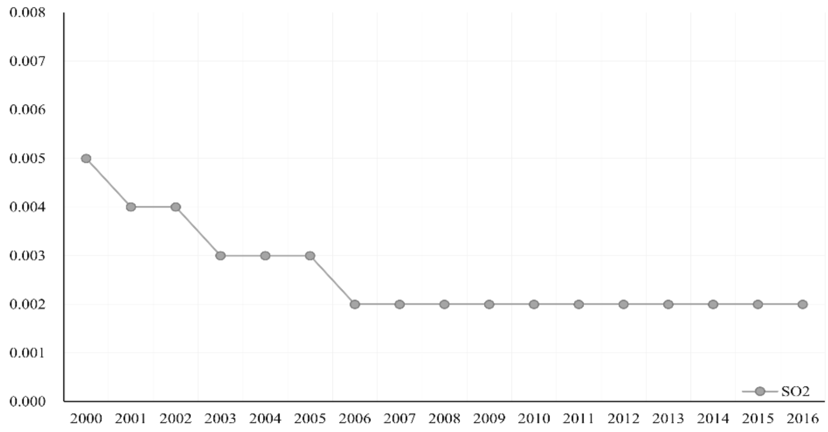
At the same time, although the proportion of air pollutants are decreasing totally, but the value of air pollutants is much larger than that of Tokyo, so attention should be paid to the air pollution control and guide the residents' trip transfer to the modes that based on the non-fossil fuel by laws, policies and other measures, etc. It will attract residents' trip modes of low pollution and reduce the impact of transportation on air pollution.

5.6.3 Comparative analysis of main air pollutants

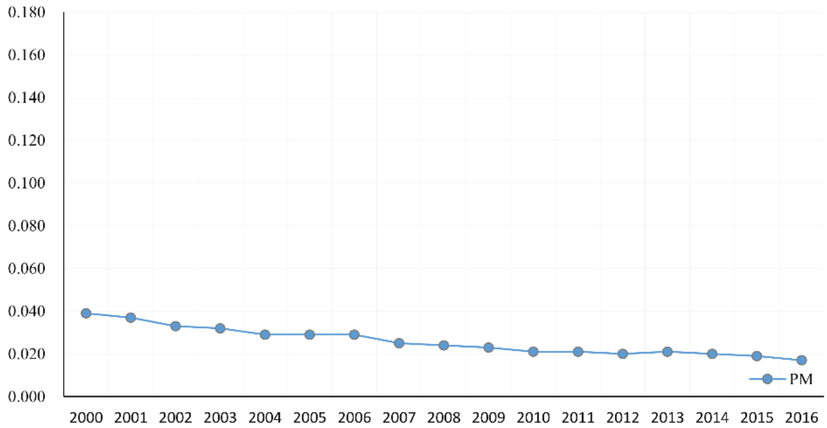
In Tokyo, the government has done a lot of work to control air pollution and improve air quality. According to the data released by the Tokyo Environment Bureau website, we drew the statistical figures of main kinds of air pollutants in special wards of Tokyo (as shown in Figure 31 based on data of Tokyo environment white paper[77]).



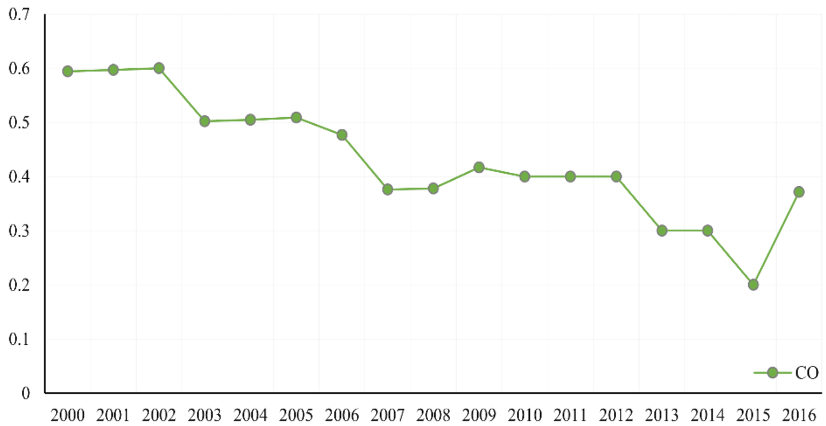
(a) NO_2



(b) SO_2



(d) PM

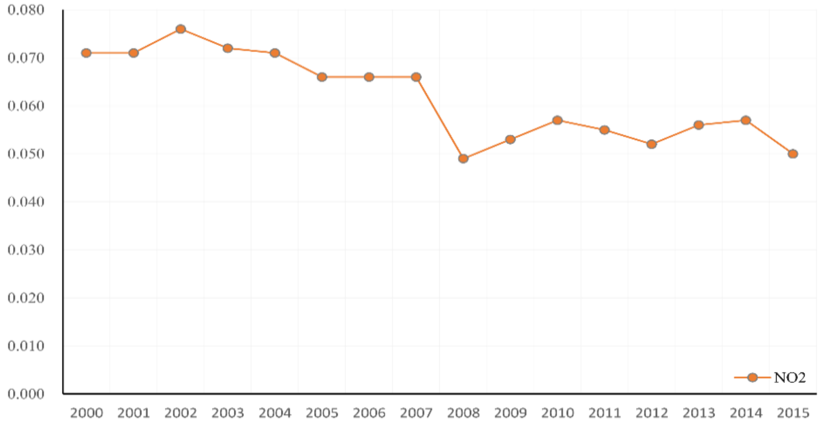


(d) CO

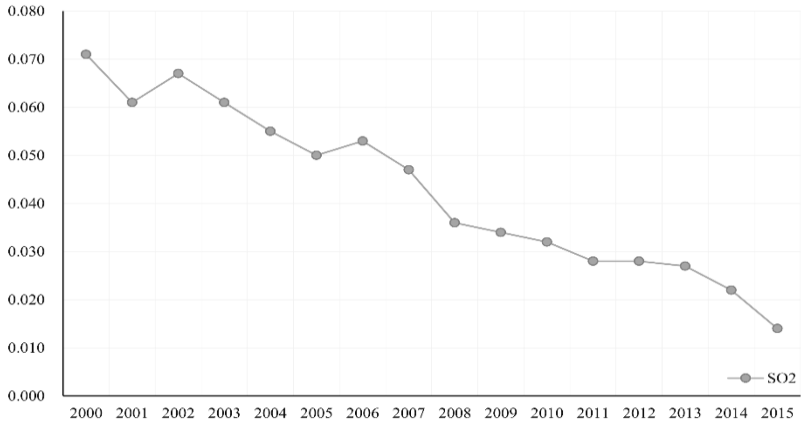
Figure 31 Statistics of air pollution components of 23 wards (Part)

Sources: https://www.kankyo.metro.tokyo.jp/

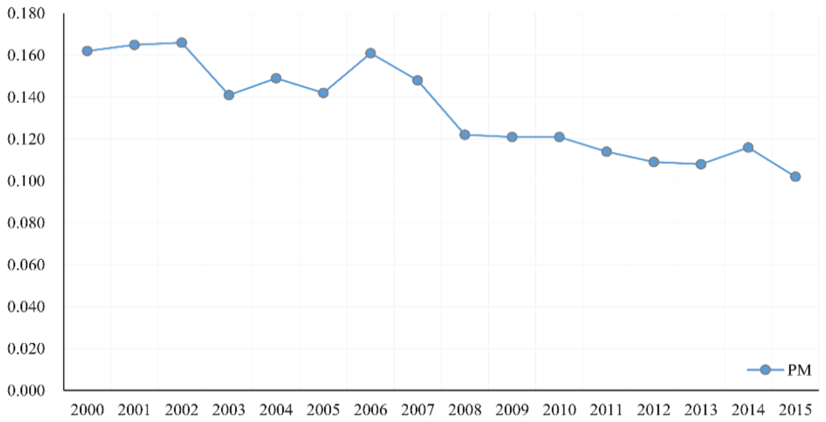
From Figure 32 (based on data of Beijing Environmental Status Bulletin[78]), we can see that the overall trend of NO_2, SPM and CO in air pollution emissions is decreasing year by year, while SO_2 basically remains unchanged, but PM2.5 has increased suddenly since 2010, and has remained at a level since 2011. With years of efforts, the air pollutants indicators in Beijing show a downward trend and it indicate that Beijing environmental protection policies have begun to play a positive role.



(a) NO_2

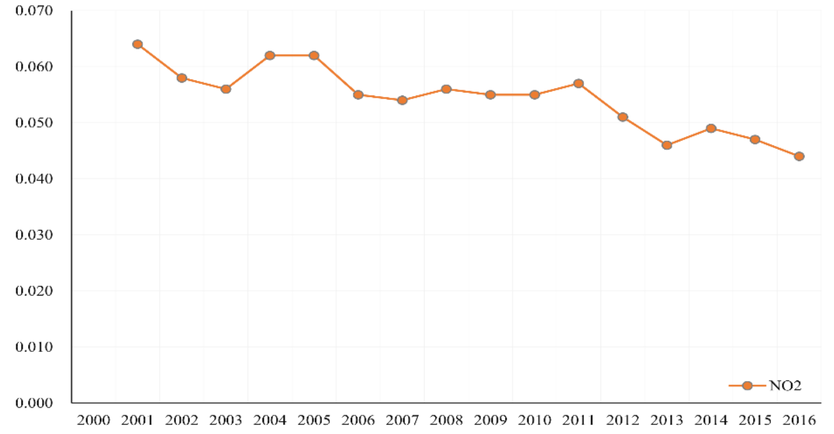


(b) SO_2

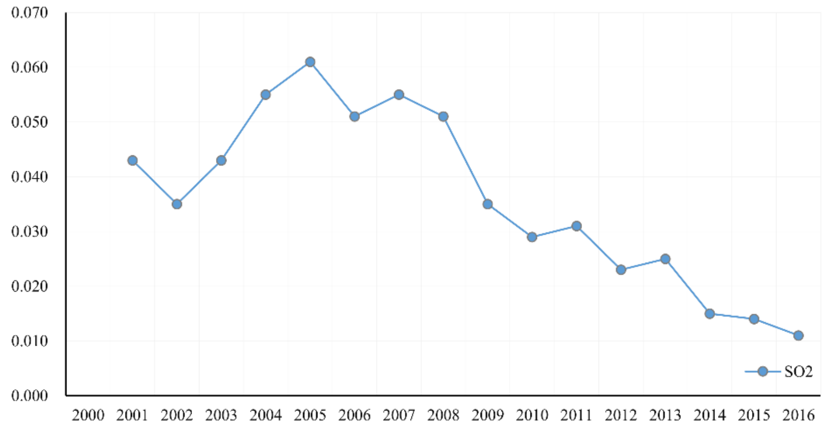


(c) PM

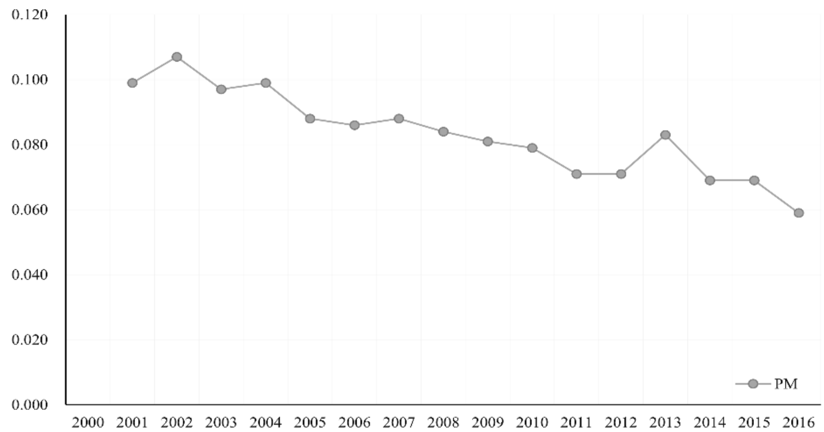
Figure 32 Statistics of air pollution components in Beijing (Part)



(a) NO_2



(b) SO_2

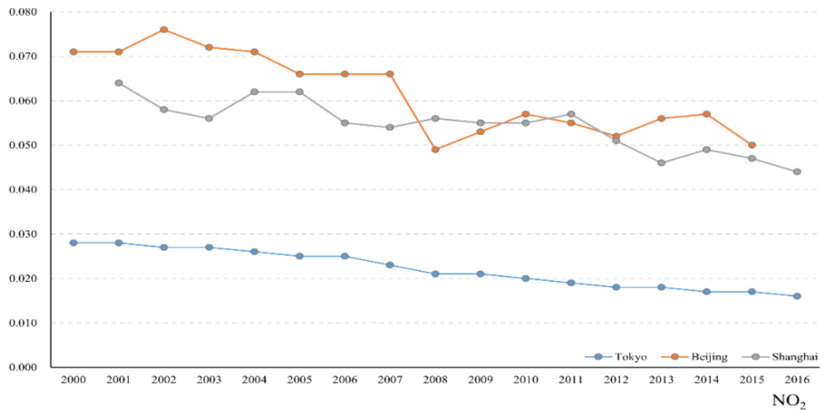


(c) PM

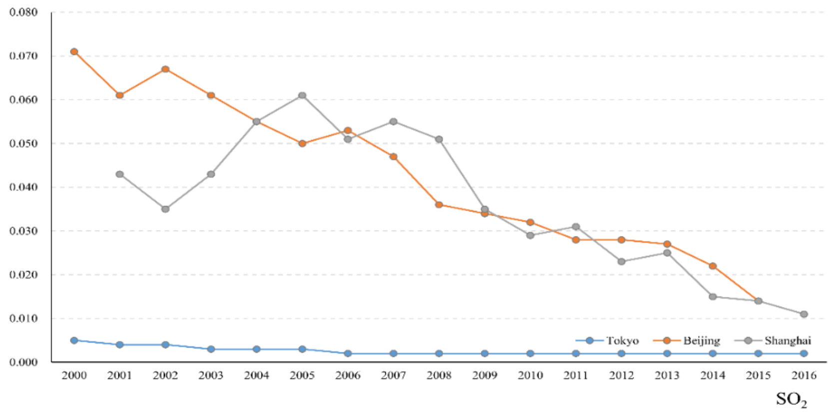
Figure 33 Statistics of air pollution components in Shanghai (Part)

The Figure 33 is statistics of air pollution components in Shanghai (based on data of Shanghai Environmental Protection Bureau[79])， we can see that the air pollutants also showed a downward trend in Shanghai and deterioration of environmental quality is gradually controlled, the downward trend of pollutant emissions is obvious.

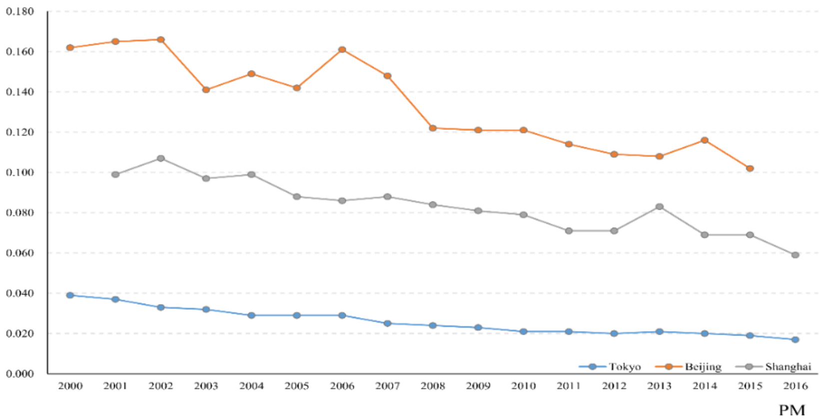
Figure 34 is statistical of main pollutants in comparative cities, Figure 34 (a), (b) and (c) showed that NO_2, SO_2 and PM in Tokyo are relatively low than that of Beijing and Shanghai. The air pollutants of Tokyo are still in the relatively low level and stable state. Although the air pollutants emissions in Beijing and Shanghai reduced year by year, but it's higher than that of Tokyo. Air pollutant emissions are mainly caused by traffic emission[75], it can effectively control the emission of air pollutants in this case that is to adjust and control the modal choices, guide the residents to the public transportation or other type of transport without the fossil fuels, low pollution can effectively control the emissions of air pollutants.



(a) Statistics of NO_2 in comparative cities



(b) Statistics of SO_2 in comparative cities



(c) Statistics of CO in comparative cities

Figure 34 Statistics of major pollutants in comparative cities (Part)

5.6.4 The main methods of air pollution control caused by traffic in Tokyo

After the 1950s, with the rapid development of economy and industry, the increasing degree of motorization in the cities has brought tremendous environmental impact, resulting in the worsening of the environment, the increasing popularity of motor vehicles and the continuous increase of motor vehicles volume, resulting in more air pollution serious, economic, society and health losses and the same situation in Tokyo.

- Legal measures

The earliest vehicle emission control system was set by the Ministry of transport in 1966, which is the first national standard to limit the use of gasoline fuel vehicle emissions CO. The regulation CO is less than 3% to 2.5%, in 1971, CO (small car) is less than 1.5%, and light vehicle CO is less than 3%.

In 1986, restricted the use of diesel fuel for car exhaust emissions and enacted regulations to inspection the use of vehicles on a regular schedule. Since the 90's, divided its vehicles into petrol and diesel vehicles in accordance with regulations restricting emissions, and has begun to control emissions from diesel vehicles.

In 1992, the "Law on Special Measures on Total Nitrides to Reduce Motor Vehicle Emissions in Specific Areas" ("Vehicle NO_x Act") was enacted to prohibit the use of trucks, buses, etc. that do not meet the special emission standards in specific areas motor vehicles, Tokyo and Osaka and the surrounding areas are designated as specific areas, and the total amount of NO_x emissions included in the special plan.

In 2006, Japan began implementing the "Law on Regulation of Exceptional Specified Motor Vehicle Exhaust," commonly known as the "OFF-ROAD Law," which was the first Japanese law to regulate the exhaust emission of off-road vehicles. The law was strict and required NO_x reduction of 25 ~ 43%, PM reduction of 15 ~ 50%.

In May 2007, the Japanese government revised the "Vehicle NO_x • PM Method" to further intensify efforts to curb NO_x and PM emissions. The law stipulates that measures should be taken to prevent pollution in this particular region and to limit vehicle traffic from the beginning of 2009 in the areas where individual traffic is more serious and the areas where countermeasures need to be taken. In September 2009, Japan air quality standards increased the PM2.5 target to the same standard as the United States (daily average of 35 g/m^3 and annual average of 15 g/m^3).

Major laws and regulations affecting air pollution control trend in Tokyo as following table.

Table 14 Major laws and regulations affecting air pollution control trend

Year	Laws or regulations
1967	Basic law for environmental pollution control
1968	Air pollution control law
1971	Creation of environment agency
1973	EQSs for CO, SO_2, NO_2, OX, and SPM
1992	Automobile NO_x law
2001	Automobile NO_x/PM law
2003	Diesel vehicle regulation (Tokyo, Chiba, Saitama, and Kanagawa Prefectures)
2006	VOCs regulation
2007	NO_x/PM Law was amended
2009	EQS for PM2.5

- Renewable energy plan
- Sustainable environmental transportation

To achieve the target declared in the Tokyo Metropolitan Environmental Master Plan to "reduce greenhouse gas emissions in Tokyo as a whole by 25% from the 2000 level by 2020, it is necessary to significantly reduce CO_2 emissions in the transportation sector by promoting the introduction of low-environment-load automobiles and by practicing the use of highly efficient automobiles[76].

- Smart energy strategy

Expansion of use of low carbon, distributed energy resources, including: cogeneration, renewable energy, solar panel, storage battery, thermal storage etc.

The air pollution caused by automobile exhaust emission has been control effectively by a series of measures and air quality has been significantly improved.

5.7 The summary of the chapter

This chapter compares and analyzed the population, population density, urban road, motor vehicle ownership, urban rail transit, residents' trip modes and air pollution caused by traffic in Tokyo, Beijing and Shanghai. The main conclusions are as following:

- Population and population density of Tokyo have tended to be relatively stable with low population density in central city and high in surrounding wards and population aggregation of sub-centers in special wards is obvious. Population distribution in Beijing is similar to that of Shanghai, that is, high population density in the central city and low population density in marginal area, the D-value of population among areas has formed a huge population movement, which puts great pressure on urban traffic.

- Urban road length and urban road network density in Tokyo is much larger than that of Beijing and Shanghai, the high road network density can provide more traffic options for residents, convenience and accessibility.

- The development trend of motor vehicle volume in Tokyo is decreasing year by year, residents' trip has begun to shift from motor vehicle to public transit by a series of policies and measures, such as: raise the cost of car use, reduce the parking requirements of buildings, etc. but the situation in Beijing and Shanghai is totally different, motor vehicle volume is increasing year by year.

- The rail transit and feeder system in Tokyo are well-developed that can effectively solve problems and effectively control the motor vehicle trip by means of policy restrictions and other measures. Residents mainly rely on public transit, of which rail transit, bicycle and walking are obviously, the proportion of motor vehicle trip is decreasing year by year. The traffic pattern and development experiences in Tokyo could provide useful references for the traffic development in Beijing and Shanghai.

- Structure of trip modes in 23 wards of Tokyo is mainly based on the public transit, while the railway and metro is the most important way for residents' trip, the second is walking, but structure of trip modes in Beijing and Shanghai mainly based on the motor vehicle, bus and motor vehicle, walking.

- Tokyo established a legal system by a series laws and measures to govern the air pollution caused by motor vehicles and effectively guided residents from motor vehicles to public transport and the air quality was significantly improved.

Chapter 6 Principal Component Analysis of Comparative Cities

6.1 Brief introduction of Principal Component Analysis

Principal Component Analysis (PCA) is based on the concept of dimensionality reduction, converting multiple indicators into a few comprehensive indicators (i.e., principal components), where each principal component can reflect most of the information of the original variables, and the information contained is not repeated. Principal Component Analysis is to try to combine many of the original correlation to form a new set of independent comprehensive indicators to replace the original indicators. This method can simplify the problem and get more scientific and effective data information while introducing many variables. In the case of practical problems, in order to analyze the problems comprehensively and systematically, we must consider many factors. These factors are commonly referred to as indicators, also known as variables in multivariate statistical analysis, is a multivariate analysis method.

The general practice of Principal Component Analysis is to express the variance of F1 (the first linear combination selected, i.e. the first comprehensive index), i.e. the larger F1 the more information F1 contains. Therefore, F1 selected in all linear combinations should be the largest variance, so F1 is called the first principal component. If the first principal component is not enough to represent the original index of information, and then consider choosing F2 is the second linear combination, in order to effectively reflect the original information, F1 existing information does not need to appear in F2, expressed in mathematical language is the requirement of Cov (F1, F2) = 0, then called F2 as the second main component by analogy, we can construct third, fourth...nth principal component.

The main advantages of Principal Component Analysis are:

- The Principal Component Analysis method can eliminate the mutual influence among multiple evaluation indexes, as the Principal Component Analysis in the original variables formed after the changes on the basis of the independent principal components each other.

- The Principal Component Analysis can effectively reduce the workload of index selection because the main component analysis represents the information contained in variance f1 and does not contain the original information when considering the second main component under the premise of first principal component failure.
- Principal Component Analysis of each principal component arrange according to the size of the variance, the analysis of the problems, can base on the concrete research situation, choose only variance larger principal components to replace the original variable, so that we can reduce the computational effort.

6.2 Main algorithm steps of Principal Component Analysis

6.2.1 Standardization of raw data

There are n research samples, p indices, to get the data matrix:

$$X=(X_{ij})_{nxp}$$

i=1,2,…,n (n represents n original samples);

j=1,2,…,p (p represents p indicators);

x_{ij} : Value of item J of sample I.

6.2.2 Correlation coefficient matrix

$$\mathrm{R} = (r_{jk})_{p\times p}$$

j=1,2…p

k=1,2…p

r_{jk} is correlation coefficient between index j and K.

$$\mathrm{R}_{\mathrm{jk}} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i=1}}^{1}[(x_{ij}-\overline{x_j})^2/S_j][(X_{ik}-\overline{X_k})^2/S_k]$$

Where

$$r_{jk} = \frac{1}{n-1}\sum_{i=1}^{n} Z_{ij} Z_{jk}$$

Where

$$r_{ij} = 1, r_{jk} = j_{kj}$$

i=1,2…n.

j=1,2…n.

k=1,2…n.

6.2.3 Eigenvalues and eigenvectors of correlation matrix

From the eigenvalue equation, we can get p eigenvalues λ_g (g = 1, 2 ... n), λ is the variance of the principal components and is arranged in descending order. The eigenvector L_g can be obtained from the eigenvalues.

The principal component can be obtained by eigenvalue and eigenvector:

$$F_g = l_{g1}Z_1 + l_{g2}Z_2 + ... + l_{gp}Z_p$$

g=1,2…p.

F is called the principal component, F1 is the first principal component, F2 is the second principal component, F_3…, and so on.

4. Determine the number of the main components

In general, the number of principal components is equal to the number of original indicators, that is, the original indicators have several, the main component of a few, the main component analysis is to choose as little as possible principal components, but also as far as possible is the least information loss.

5. Principal component evaluation

Calculate the linear weighted values of principal components.

$$F_g = l_{g1}Z_1 + l_{g2}Z_2 + ... + l_{gp}Z_p$$

g=1,2…k.

The final evaluation value is obtained by weighted sum of K principal components.

That is:

The weighted number is the variance contribution of each principal component $\lambda_g \sum_{g=1}^{p} \lambda_g$, the final evaluation value $F = \sum_{g=1}^{k} (\lambda_g \sum_{g=1}^{p} \lambda_g) F_g$.

6.3 Principal Component Analysis based on the 23 wards of Tokyo

In section 4.1.1-4.1.3, based on the trip modes share of residents in 23 wards of Tokyo, we conducted a cluster analysis of 23 wards and divided into three Circles. In this section, I will use the same indicator data (Table 4) for Principal Component Analysis.

6.3.1 Raw data standardization

In the analysis, in order to avoid the difference of data dimension to the impact of the analysis, so before the main component analysis of the original data to standardize operations, this dissertation uses Z-score (Zero-mean normalization). The standardization refers to the elimination of the original data variables discrete differences in the process, the elimination of differences can make each variable in the main component composition of the role tends to be equal. This example of the original data is normalized to the data shown in table 14.

Table 15 is the normalized data table for Table 4.

Table 15 Standardization data of 23 wards

	Railway& Metro	Bus	Motor vehicle	Motorcycle	Bicycle	Walking	The other	Unknown
Chiyoda	2.087	-2.474	-1.206	-2.240	-1.664	-2.593	-0.504	-2.064
Chuo	1.397	-1.629	-0.653	-1.658	-1.379	-1.316	0.128	-1.061
Minato	1.560	-1.228	-0.363	-1.575	-1.516	-2.077	-0.082	-1.182
Shinjuku	1.175	-0.722	-1.203	-0.973	-1.246	-0.574	-0.504	-0.711
Bunkyo	0.713	-0.015	-0.830	-0.723	-0.676	-0.467	0.971	-0.808
Meguro	-0.150	1.210	0.082	0.544	-0.268	0.971	-1.136	-0.663
Shinagawa	0.371	-0.764	-0.480	-0.100	-0.502	0.352	-0.504	-0.469
Taito	0.242	-0.236	-0.297	-0.578	-0.171	-0.152	3.500	-0.530
Sumida	-0.520	0.397	0.101	0.959	0.732	0.013	-0.293	0.859
Koto	-0.287	1.716	0.922	0.170	0.017	-0.161	0.128	0.050
Shibuya	1.098	0.619	-0.963	-0.910	-1.249	-0.795	0.339	-0.940
Ota	0.356	0.186	-0.316	-0.183	-0.456	-0.114	0.128	-0.445
Setagaya	-0.498	0.851	0.723	0.648	0.243	0.591	-0.504	0.098
Suginami	-0.496	0.555	-0.252	0.398	0.724	0.582	-0.082	-0.349
Nakano	-0.304	0.777	-0.881	0.876	0.289	1.060	0.550	0.267
Nerima	-1.063	-0.553	1.033	0.980	1.183	0.771	-0.925	0.690
Itabashi	-0.854	-0.585	0.736	0.938	0.759	1.054	-1.136	1.089
Toshima	0.651	0.080	-1.313	-0.453	-0.498	-0.432	0.760	0.026
Kita	-0.597	1.336	-0.338	0.294	0.404	1.192	0.339	1.523
Arakawa	-0.761	0.692	-0.050	0.191	0.891	0.871	-0.504	0.823
Adachi	-1.404	-0.352	2.331	1.686	1.469	-0.152	0.971	2.127
Katsushika	-1.362	-0.595	1.273	0.938	1.695	0.502	-0.293	1.342
Edogawa	-1.353	0.735	1.942	0.772	1.219	0.874	-1.346	0.328

6.3.2 Calculation of correlation coefficient matrix

After data normalization, the discrete difference is eliminated to some extent, and the variance of single index is stripped after data normalization, and the correlation coefficient matrix is the correlation matrix after the normalization of the original data (Table 16).

Table 16 Correlation matrix

	Railway & Metro	Bus	Motor vehicle	Motorcycle	Bicycle	Walking	The other	Unknown
Railway& Metro	1.000	-0.523	-0.804	-0.951	-0.980	-0.834	0.185	-.877
Bus	-0.523	1.000	0.224	0.550	0.405	0.675	0.007	0.393
Motor Vehicle	-0.804	0.224	1.000	0.727	0.780	0.430	-0.239	0.672
Motorcycle	-0.951	0.550	0.727	1.000	0.915	0.834	-0.192	0.856
Bicycle	-0.980	0.405	0.780	0.915	1.000	0.759	-0.153	0.875
Walking	-0.834	0.675	0.430	0.834	0.759	1.000	-0.204	0.684
The other	0.185	0.007	-0.239	-0.192	-0.153	-0.204	1.000	-0.059
Unknown	-0.877	0.393	0.672	0.856	0.875	0.684	-0.059	1.000

As can be seen from Table 15, indicators with significant correlations are:

1. Bus, walking, motorcycle are significantly related

2. Motor vehicle, motorcycle, bicycle are significantly related

3. Motorcycle is significantly related to bicycle, walking, motor vehicle and bus

3. Bicycle is significantly related to motorcycles, motor vehicles and walking

4. Walking is significantly related to motorcycles, bicycles and buses

6.3.3 Eigenvalues

In the Principal Component Analysis, the eigenvalue can be regarded as an indicator of the degree of influence of the principal component. If the eigenvalue is greater than 1, it can be used as the principal component, and if the eigenvalue is less than 1, it is discarded. Therefore, the principle of determining the number of principal components is the first m principal components with eigenvalues greater than one.

Principal Component Analysis of variance decomposition principal component extraction analysis table in 23 wards of Tokyo is shown in Table 17.

In the table, the component 1 and component 2, that eigenvalues are greater than 1, extract 2 principal components.

Eigenvalues as following:

$$\lambda_1 = 5.361,\ \lambda_2 = 1.073$$

Table 17 Total variance explained

Component	Initial Eigenvalues			Extraction sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.361	67.006	67.006	5.361	67.006	67.006
2	1.073	13.407	80.413	1.073	13.407	80.413
3	0.889	11.112	91.525			
4	0.357	4.461	95.986			
5	0.179	2.235	98.222			
6	0.073	0.912	99.133			
7	0.069	0.867	100.000			
8	1.398E-7	1.747E-6	100.000			

Extraction Method: Principal Component Analysis.

The Figure 35 is the scree plot of 23 wards. The x axis represents the number of possible factors. In the process of decreasing the whole curve, based on the Table 16 the first two factors account for 80.413% of information, which means that the two factors represent most of the information of the original data, and we can see from the Figure 33, there is a clear bent in the curve, and the number of the x axis corresponding to the point should be retained.

So,

$$\lambda_1 = 5.361$$

$$\lambda_2 = 1.073$$

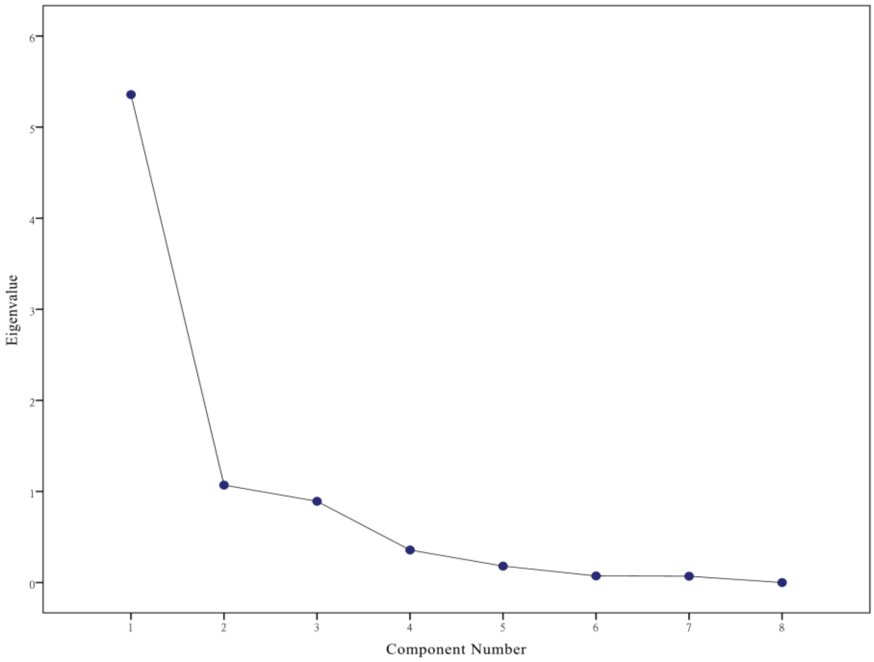


Figure 35 Scree plot of 23 wards

6.3.4 Component matrix

Table 17 is the two principal component Load matrix identified in section 6.3.2, which can be seen on motorcycles, bicycles, walking, unknown and buses in the first main component of the load value is large, indicating that the first principal component can basically reflect the information of these indicators. Bus, the other and walking in the second main component of higher load, it indicate that the second main component can also basically reflect the bus, other and walking indicators information. So the 2 main component indexes can basically reflect the information of all indexes, so the two indexes can be used instead of other indexes.

Table 18 Component matrix

Contents	Component 1	Component 2
Railway& Metro	-.992	0.026
Bus	0.583	0.547
Motor vehicle	0.779	-0.347
Motorcycle	0.969	0.014
Bicycle	0.956	-0.070
Walking	0.858	0.204
The other	-0.212	0.778
Unknown	0.892	0.024

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

However, the coefficients in Table 18 are not the eigenvectors of the principal components, that is, they are not the coefficients of the principal components. If you want to get the principal component coefficient also need to be based on the Table 18 matrix data divided by the main component of the corresponding eigenvalue square root, you can get the main component of the corresponding index coefficient.

Eigenvector calculation:

1. First principal component eigenvector

The first principal component load vector is (-0.992, 0.583, 0.779, 0.969, 0.956, 0.858, -0.212, 0.892)

The first principal component eigenvalue:

$\lambda_1 = 5.361$

The first principal component eigenvector (the first principal component load vector divided by the square root of the first principal component eigenvalue):

The first principal component eigenvector is:

(-0.428, 0.252, 0.336, 0.419, 0.413, 0.371, -0.092, 0.385)

2. The second principal component eigenvector

The second principal component eigenvalue is:

(0.026, 0.547, -0.347, 0.014, -0.070, 0.204, 0.778, 0.024)

The second principal component eigenvalue:

$\lambda_2 = 1.073$

The second principal component eigenvector is:

(0.251, 0.528, -0.335, 0.014, -0.068, 0.197, 0.751, 0.023)

6.3.5 Principal component expression calculation

Based on the above analysis, the Principal Component Analysis in 23 wards of Tokyo has two main components (Figure 36), and the eigenvectors are obtained by calculation. The principal component expression is the product of the standardized data and eigenvectors:

The first principal component expression:

F1=-0.428Railway&Metro+0.252Bus+0.336 Motor vehicle

+0.419Motorcycle+0.413Bicycle+0.371Walking-0.092The other+0.385Unknown

The second principal component expression:

F2=0.251Railway&Metro+0.528Bus-0.335Motor vehicle+0.014Motorcycle

-0.068 Bicycle+0.197Walking+0.751The other+0.023 Unknown

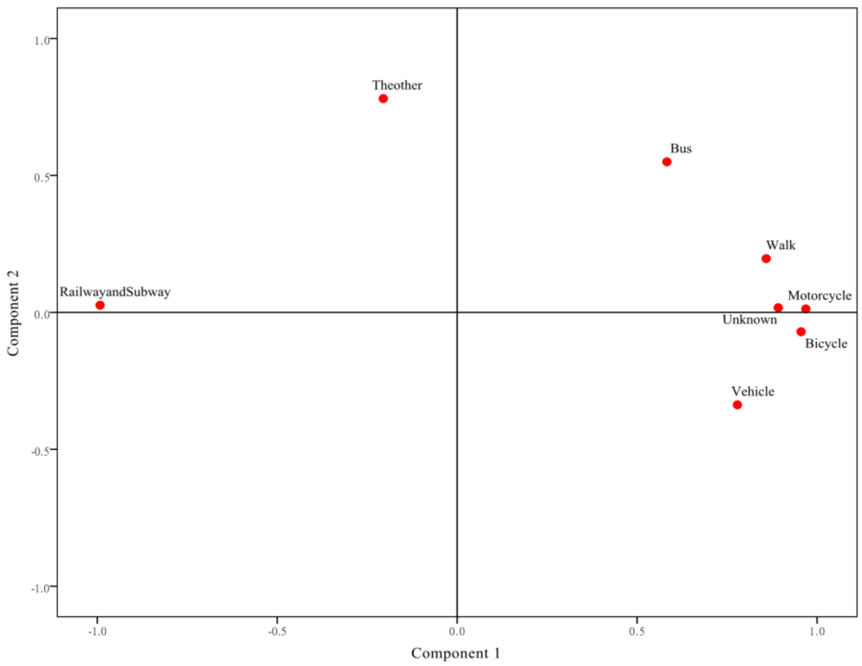


Figure 36 Component plot of 23 wards

6.3.6 Scatter plot matrix of various trip modes

After standardizing the raw data, a scatter plot matrix of various trip modes in 23 wards of Tokyo can be drawn. Figure 37 is a scatter plot matrix of various trip modes in 23 wards of Tokyo, the proportion of other trip modes is decreasing with the proportion of railways and metro increases.

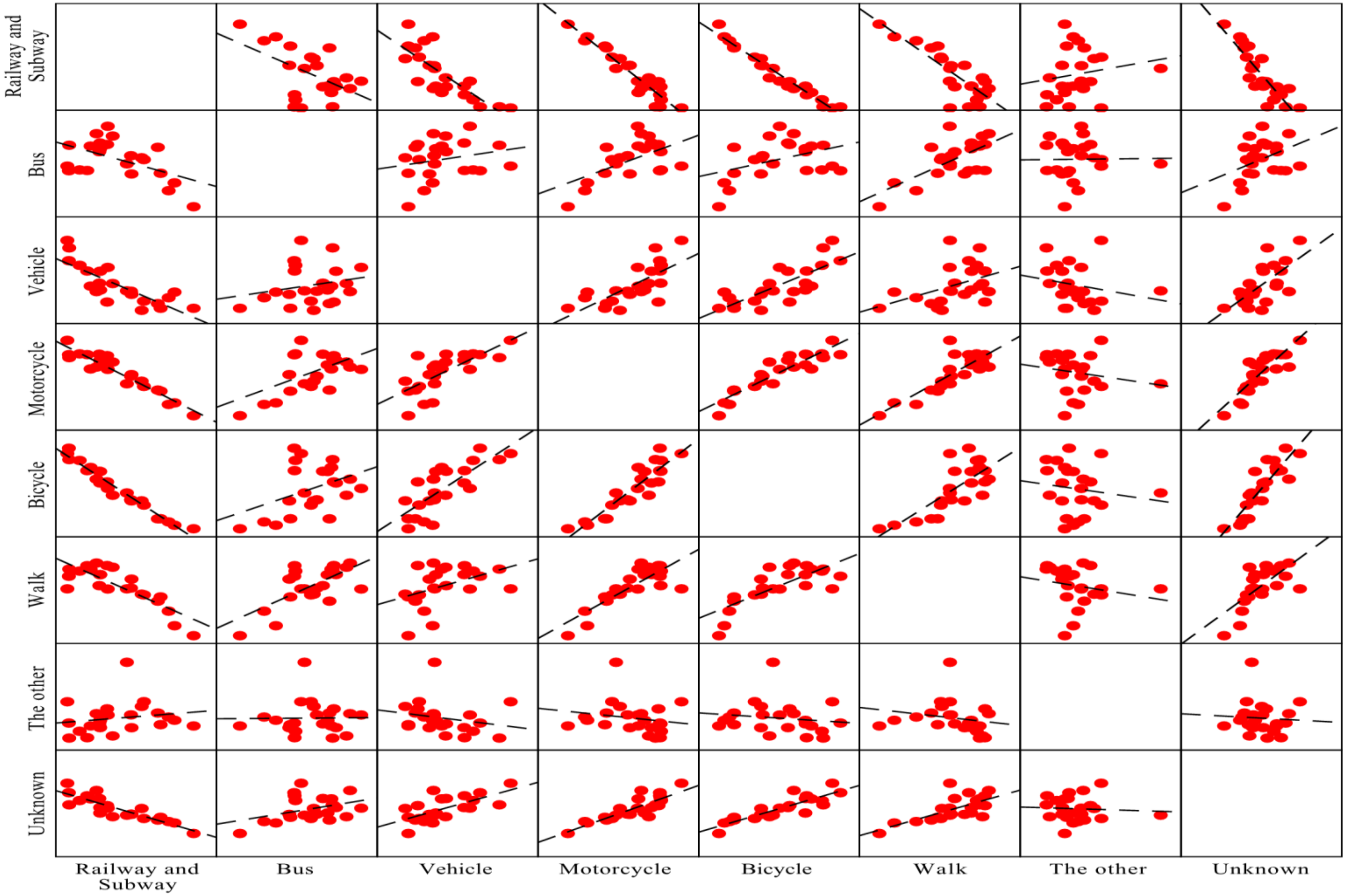


Figure 37 Scatter plot matrix of various trip modes in 23 wards of Tokyo

6.3.7 Weighted processing of principal components

In 6.3.4, the two principal components F1 and F2 are obtained by calculation. In practice, the two principal components need to be considered simultaneously. Therefore, it is necessary to consider the weights of two principal components, the weight calculation is related with the eigenvalues of the principal components, and weights are expressed by weight coefficients as following:

$$P_{F_1} = \frac{\lambda_1}{\lambda_1 + \lambda_2}$$

Where,

P_{F_1} is weighting coefficient of principal component 1.

λ_1 is the eigenvalue of F1, in this case, λ_1=5.361

λ_2 is the eigenvalue of F2, in this case, λ_2=1.073

$$P_{F_2} = \frac{\lambda_2}{\lambda_1 + \lambda_2}$$

P_{F_2} is the weighting coefficient of principal component 2.

λ_1 is the eigenvalue of F1, in this case, λ_1=5.361

λ_2 is the eigenvalue of F2, in this case, λ_2=1.073

So,

$P_{F_1} = 0.8332$

$P_{F_2} = 0.1668$

F_{Total}=0.8332F1+0.1668F2

6.4 Principal Component Analysis based on the comparative cities

6.4.1 Raw data standardization and correlation coefficient matrix

1. Raw data standardization

Table 19 is the parameters base on the cluster analysis of 23 wards of Tokyo, Beijing and Shanghai, Table 21 is the raw data standardization table base on the Table 20. The steps are similar to the 6.3, so the detailed calculation procedure is omitted, and only a brief introduction of the calculation is made as following.

The data in Table20 is the proportion of residents' modal choices in comparative cities, it is should be noted that classification in Table 20 is different with that of in Figure 24. "walking" has been added into the Table 20, so the other classification data also changed accordingly, the data resources of Table 20 and Figure 24 are both base on "Annual report of Beijing traffic development"[60] and Beijing traffic comprehensive survey report[80].

Table 19 Cluster analysis variables in 23 wards, Beijing and Shanghai (%)

	Year	Railway& Metro	Bus	Motor vehicle	Bicycle	Walking	The other
23 wards of Tokyo	1978	34	3	20	10	33	0
23 wards of Tokyo	1988	40	3	18	13	26	0
23 wards of Tokyo	1998	41	3	17	15	24	0
23 wards of Tokyo	2008	48	3	12	14	23	0
Beijing	2000	0.94	11.76	7.22	39.6	31.93	8.55
Beijing	2005	2.62	20.39	16.32	26.9	31.73	2.04
Beijing	2010	4.98	23.34	22.31	16.07	30.2	3.1
Shanghai	1995	0.5	16.5	8	38.7	30.4	5.9
Shanghai	2004	2.5	16	15.8	25.2	29.2	11.3
Shanghai	2009	4.9	12.9	27	15.1	26.1	14
Shanghai	2014	8.3	12.4	30	7.2	24.8	17.3

Table 20 can be obtained after standardized processing of Table 19 as following.

Table 20 Standardization data of 23 wards of Tokyo, Beijing and Shanghai

	Year	Railway& Metro	Bus	Motor vehicle	Bicycle	Walking	The other
Tokyo	1978	0.884	-1.125	0.337	-0.911	1.355	-0.902
Tokyo	1988	1.197	-1.125	0.056	-0.640	-0.627	-0.902
Tokyo	1998	1.249	-1.125	-0.085	-0.459	-1.193	-0.902
Tokyo	2008	1.615	-1.125	-0.787	-0.549	-1.476	-0.902
Beijing	2000	-0.842	0.050	-1.459	1.767	1.0520	0.462
Beijing	2005	-0.754	1.207	-0.180	0.618	0.995	-0.576
Beijing	2010	-0.631	1.602	0.661	-0.362	0.562	-0.407
Shanghai	1995	-0.865	0.685	-1.349	1.685	0.619	0.039
Shanghai	2004	-.76054	0.618	-0.254	0.464	0.279	0.901
Shanghai	2009	-.63524	0.202	1.320	-0.450	-0.599	1.331
Shanghai	2014	-.45773	0.135	1.741	-1.164	-0.967	1.858

6.4.2 Eigenvalues and component matrix

1. Eigenvalues

After standardized processing and base on the Table 20, the total variance explained can be obtain, as Table 21.

In the table, the component 1 and component 2 that eigenvalues are greater than 1, extract 2 principal components.

Eigenvalues as following:

$$\lambda_1 = 2.945$$

$$\lambda_2 = 1.954$$

Table 21 Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.945	49.080	49.080	2	49.080	49.080
2	1.954	32.569	81.649	1	32.569	81.649
3	0.721	12.014	93.662			
4	0.349	5.815	99.477			
5	0.031	0.523	100.000			
6	1.841E-17	3.069E-16	100.000			

Extraction Method: Principal Component Analysis.

The Figure 38 is the scree plot of comparative cities as following.

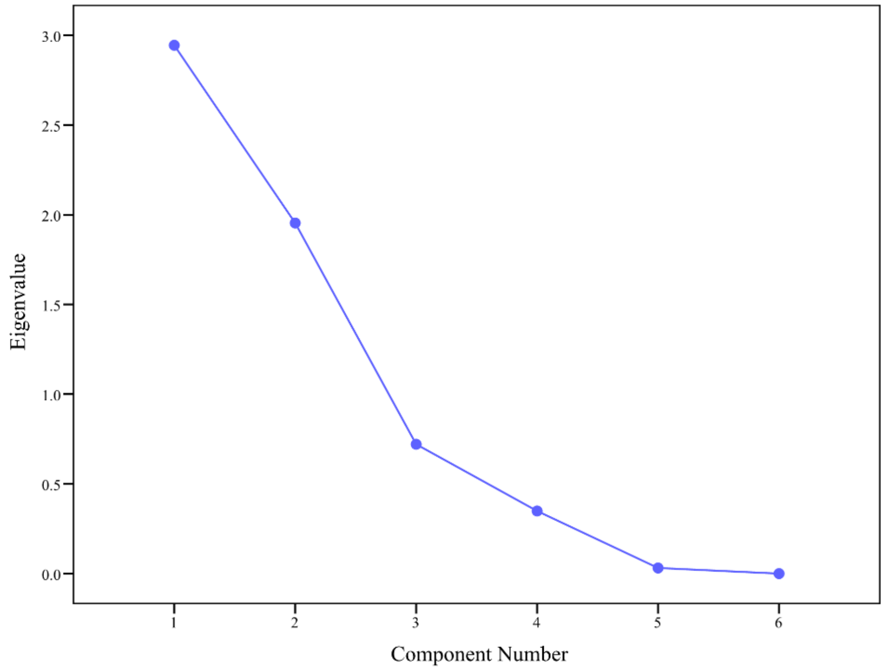


Figure 38 Scree plot of 23 wards, Beijing and Shanghai

It can be seen from Figure 38, there are is a bent in component 3, and the value of component 3 is less than 1 (the eigenvalues are generally less than 1), so in this case, there are two principal components.

2. Component matrix

According to the eigenvalue judgment, there are two principal components. As can be seen from Table 22, principal component 1 is railway and metro, bus, bicycle and walking, principal component 2 is motor vehicle and others, in this case, we call principal component 1 as public and walking, principal component 2 as motor vehicle and others.

Table 22 Component matrix

Contents	Component 1	Component 2
Railway& Metro	-0.938	-0.341
Bus	0.838	0.299
Motor vehicle	-0.286	0.900
Bicycle	0.786	-0.520
Walking	0.702	-0.310
The other	0.413	0.756

Extraction Method: Principal Component Analysis.
a. 2 components extracted.

Eigenvector calculation:

1. First principal component eigenvector

The first principal component load vector is:

(-0.938, 0.838, -0.286, 0.786, 0.702, 0.413)

The first principal component eigenvalue:

$\lambda_1 = 2.945$

The first principal component eigenvector (the first principal component load vector divided by the square root of the first principal component eigenvalue):

The first principal component eigenvector is:

(0.547, 0.488, -0.167, 0.458, 0.409, 0.241)

2. The second principal component eigenvector

The second principal component eigenvalue is:

(-0.341, 0.299, 0.900, -0.520, -0.310, 0.756)

The second principal component eigenvalue:

$\lambda_2 = 1.954$

The second principal component eigenvector is:

(-0.244, 0.214, 0.644, -0.372, -0.222, 0.541)

6.4.3 Principal component expression calculation

Based on the above analysis, the Principal Component Analysis in comparative cities has two main components (Figure 39), and the eigenvectors are obtained by calculation. The principal component expression is the product of the standardized data and eigenvectors:

The first principal component expression:

F1=0.547Railway&Metro+0.488Bus-0.167Motor vehicle+0.458Bicycle+0.409Walking +0.241The other

F2=-0.244Railway&Metro+0.214Bus+0.644Motor vehicle-0.372Bicycle-0.222Walking+0.541The other

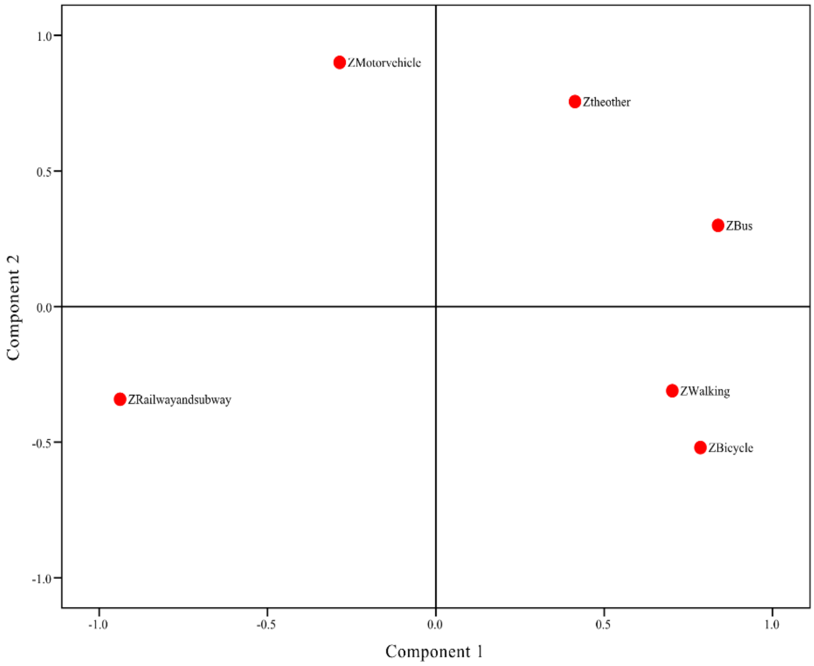


Figure 39 Component plot of 23 wards, Beijing and Shanghai

6.4.4 Distribution of principal component score

In order to compare and analysis the comparative cities in terms of residents' trip modes share, in this case, SPSS was used to calculate the scores of the two principal components of different years in different cities (i.e. public transport and walking scores, motor vehicles and other scores), Figure 40 is principal component score figure, as following.

As can be seen from Figure 40, in Tokyo, although the proportion of public transport and walking is slowing down year by year, but it is also the main trip way of residents and the proportion of motor vehicles is well under control.

There is a similar trend of the development of trip mode in Beijing and Shanghai, from the beginning of the 20th century to nowadays, the proportion of public transport and walking is decreasing year by year, while the proportion of vehicles is increasing quickly, that brings lots of traffic problems, environmental problems, etc. and need to pay more attention in the future.

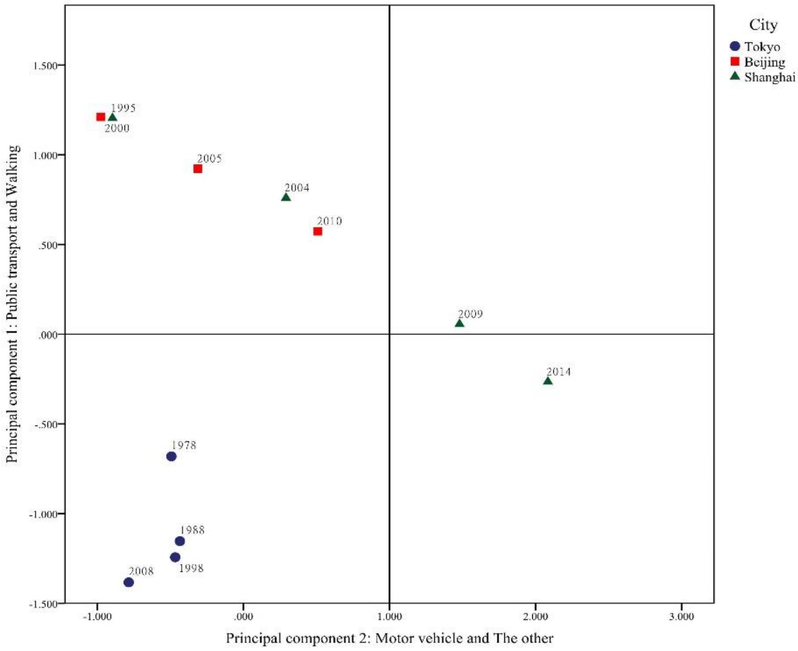


Figure 40 Distribution of principal component score

According to Figure 40, it can be seen as following:

At the end of last century and the beginning of this century, the public transportation and walking are the main way of residents in Beijing and Shanghai, and the proportion is higher than that of Tokyo. But with the development of economic and social, more and more motor vehicles began to be a way of residents' trip modes and the proportion of motor vehicle in Beijing and Shanghai increased rapidly, gradually become to be a residents' daily way of trip. The trip mode in Beijing and Shanghai gradually transform from public transportation and walking to motorized vehicles.

In Tokyo, since 1978, the public transport and walking, motor vehicles maintain a good balance, and the public transport and walking is increase steady year by year, while the proportion of motor vehicles is also decreasing steady, the main residents' trip is based on public transport and walking.

Figure 40 and Figure 42 are the scatter plot matrix of various trip modes in 23 wards of Tokyo, Beijing and Shanghai. According to Figure 41 and 42, the public transit and motor vehicles are negatively related and the statistics relationship among various trip modes in the past years can be used as references in the future.

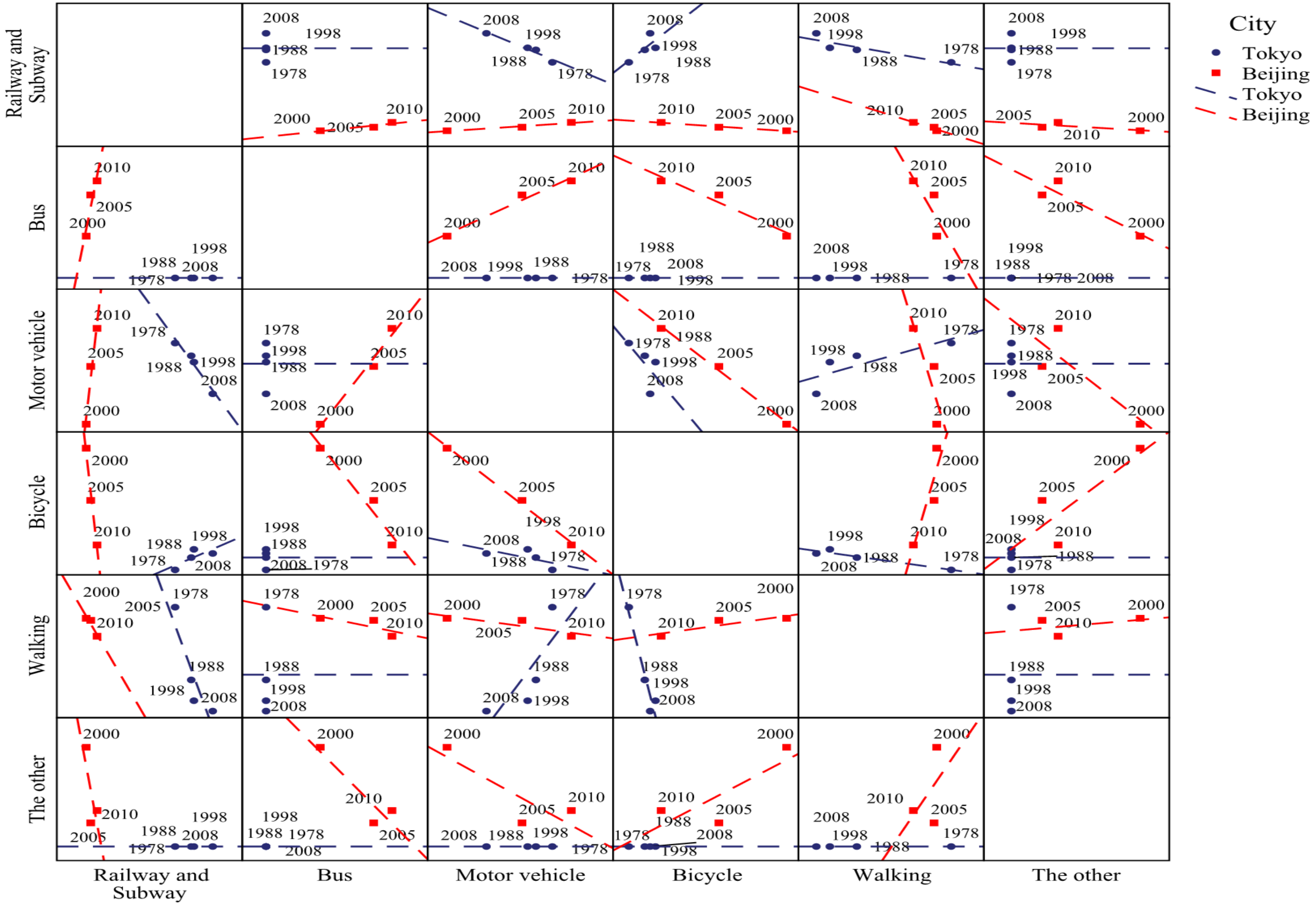


Figure 411 Scatter plot matrix of trip modes in 23 wards of Tokyo and Beijing

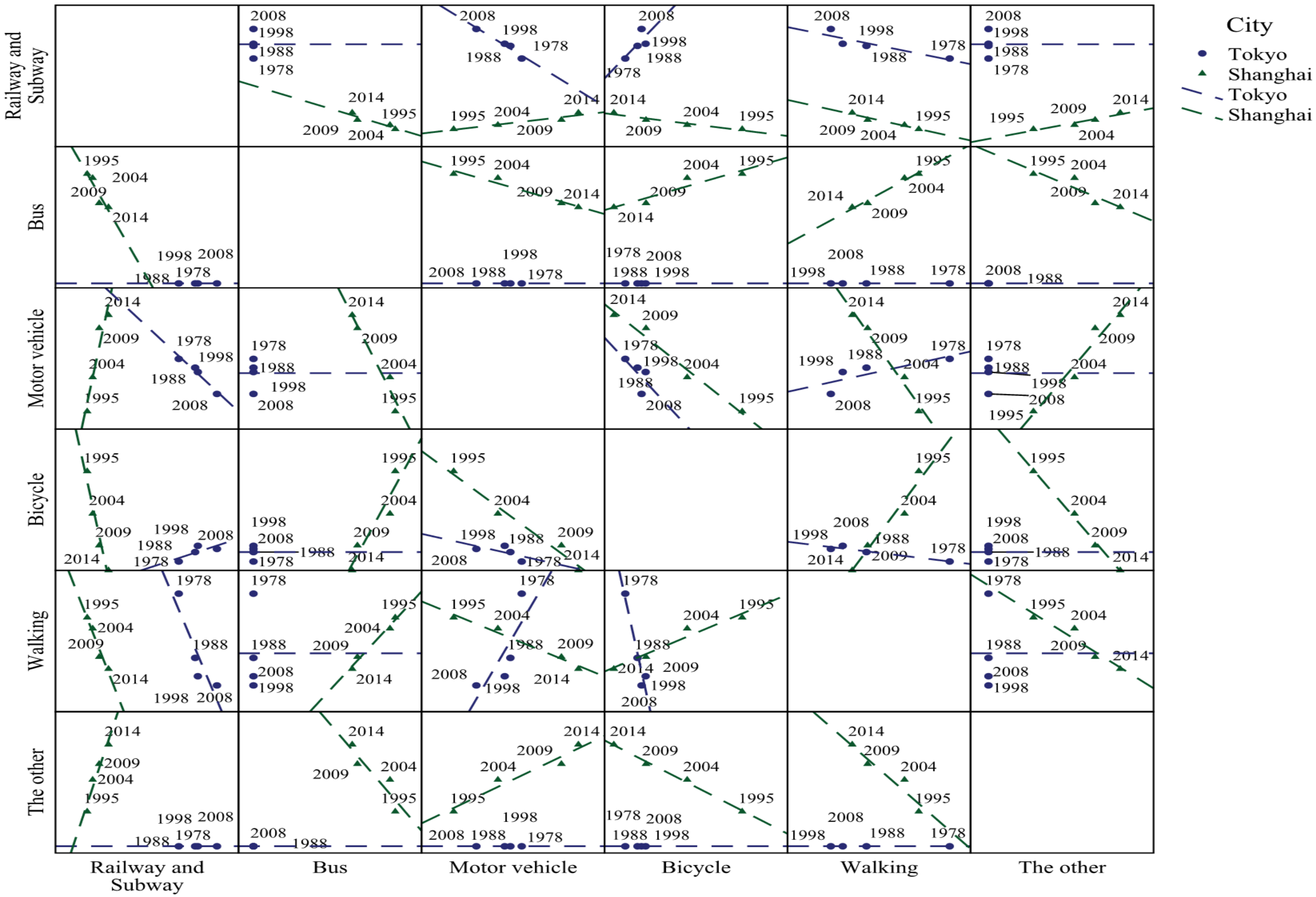


Figure 42 Scatter plot matrix of trip modes in 23 wards of Tokyo and Shanghai

Chapter 7 Conclusions and Enlightenment to Cities

7.1 Conclusions

On the basis of "The 5th Tokyo Metropolitan Area Person Trip Survey"[1], this dissertation divides the 23 wards of Tokyo into three Circles by the Ward method of Cluster Analysis, and combed and analyzed the basic traffic data of three Circles, and finds out the main influencing factors of the Circle layer division by the principal component analysis method, the dissertation finds out the gap between Tokyo and the other contrastive city in traffic development by contrasting with the city, puts forward the suggestion of traffic development and draws the following main conclusions by research:

- Urban development and population distribution along with the development of rail transit development in 23 wards of Tokyo, the development of rail transit in the former and the urban development, population distribution in the post, this mode of development can effectively solve the urban and population development of traffic pressure and problems, which for developing cities to rationalize urban development. The relationship between population distribution and traffic development provides an important reference.

- Rail transit pattern in 23 wards of Tokyo is the "loop line + Ray line", the planning and construction of rail transit are based on this pattern. Ray line can be directly from the central city to the surrounding urban areas and cities, and the loop line is to solve the various ray lines between the exchange and contact problem, thus formed a convenient transit network, this kind of development model can provide some inspiration for the development of urban rail transit construction to some cities.

- Population distribution pattern in 23 wards of Tokyo is low population density in central city and high population density in the wards around the central city, so the mobility of people brings challenges to the transit, but Tokyo through the construction of rail network, convenient public transport conditions, low cost of public transport and other measures to guide residents to large volume of public transport transfer, and set up the city sub-centers of city to share part of the city function, alleviate the urban center population and traffic pressure, play a role of population redistribution. Appropriate policies and the establishment of sub-centers of city have played an active role in the development of traffic and the redistribution of population.

- The modal choices for residents of each Circle in 23 wards of Tokyo, the railway transit is the main way, non-motor trip comes second, the proportion of motor vehicle trip is decreasing year by year, and the Tokyo government has made efforts to promote the residents from the original mode of transport to public transport or non-motorized trip, the main efforts include: improve the cost of purchase, use and maintenance of motor vehicle, improve motor vehicle emission standards, improve parking costs, eliminate the building parking space constraints, improve the accessibility of rail traffic. It can be seen that the government guidance can effectively change the traffic structure and the residents' modal choices.

- Tokyo has also experienced air pollution, but Tokyo established a legal system by a series laws and measures to govern the air pollution caused by motor vehicles and effectively guided residents from motor vehicles to public transport and the air quality was significantly improved. And the adjustment of residents' trip mode has a great influence on the air quality, which can be adjusted by the following ways:

  ●Reduce the proportion of residents' trip that based on fossil fuel

  ●Increase the proportion of low-pollution ways (such as: rail and metro, bus and the other way of public transport)

●Increase the proportion of trip based on non-fossil fuels.

- Base on comparative analysis with Beijing and Shanghai, it is found that the traffic construction in Beijing and Shanghai is developing rapidly, but there are still many problems, such as: the traffic problem caused by the rapid increase of motor vehicle volume, the residents' trip modal choices depends mainly on motor vehicle instead of public transport, and the development of urban and traffic is not coordinated, The speed of traffic development is not in harmony with the increase of population, the air pollution caused by traffic, etc. By contrasting with Tokyo, the gap between the traffic and the Tokyo experience has been revealed.

- This dissertation attempts to compare and analyze the research on the traffic structure, development modes, traffic basic data, environmental problems caused by traffic and residents' modal choices in Tokyo and comparative cities, and the successful experience and effective measures of Tokyo traffic development is benefit to the comparative cities and other cities. It can provide effective reference for other cities to deal with urban development and traffic development.

7.2 Enlightenment to cities

Base on the study and analysis of development and distribution of traffic network, cluster analysis of 23 wards of Tokyo, population distribution and flow, characteristics of resident's trip, structure of residents' trip modes and modal choices, air pollution control, principal component analysis, etc. There are some enlightenment to Beijing, Shanghai and other cities as following:

- The development of rail transit is coordinated with that of population and urban. That is, the first thing to Tokyo is traffic development and then the urban spatial development and population distribution. Rail way and metro in Tokyo connected by loop line and formed a pattern of "loop Line + Ray line". So in the future development of cities, such as Beijing and Shanghai, it can be learn from the successful experience of Tokyo and should pay attention to the relationship among railway, metro, population distribution and development of urban spatial.

- The urban sub-centers can shared a part of the urban function, such as economy, society and transportation hub, etc. which can alleviate the population and traffic pressure of the urban central, and can effectively play the certain role of population redistribution. The optimization of urban spatial structure can effectively relieve population and traffic pressure and guide the redistribution of population and traffic trips. So in Beijing and Shanghai, in the process of urban development, it is possible to transfer some functions of city and traffic by the construction of sub-centers in cities to reduce the pressure of urban centers.

- Base on the implementation of laws and measures, a set of development system and pattern formed, and it provided effectively guarantee of urban development, traffic development, distribution of population and air pollution control. According to the situation in cities such as Beijing and Shanghai, the support system could be build base on the establishment of laws and measures to promote and improve the development of urban, population and traffic, etc.

- Different modes of residents' trip have different impacts on transportation, air pollution, environmental protection, traffic pressure and so on. Tokyo has guided residents' trip to public transport with low pollution, mass transit. Tokyo has accumulated a great deal of successful experience in traffic construction by adjustment of laws and policies.

- With the rapid development of Beijing, Shanghai and other cities, the proportion of motor vehicle is increasing in the residents' trip modes of Tokyo, it has brought the huge pressure. So it can be learn from successful experience of Tokyo by laws, policies and other measures to guide the residents' trip to public traffic, reduce the traffic pressure on urban centers and improve urban air quality and efficiency, convenience, accessibility of traffic.

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