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A Comparison of Traffic Operations among Beijing and Several International Megacities

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Abstract

High-Efficient traffic system is very important for economy and society of cities. Previous studies on the traffic comparison mostly took a city as a whole, but ignored the differences among areas inside the city. But in fact, the traffic congestion in different areas with a city is mostly different. Taking typical megacities like Beijing, London, New York, and Tokyo as objects, this paper makes cross-comparison in the traffic operation and performance based on intelligent algorithm. Transportation infrastructure and travel demand data are discussed and unbalanced transport system is found in Beijing because of the conflict between too much traffic demand and defect road networks. From the aspects of traffic load, operational efficiency and safety, indexes including traffic v/c ratio, average vehicle speed and accident rate are selected to assess the performance of road traffic. It is concluded that road networks of Beijing have the worst performance compared with other three megacities and the primary reasons are the inappropriate distribution of utilization rate among the freeways, arterials, and local streets, and the high traffic concentration in urban area. So, several measures are recommended to improve the operation efficiency of traffic in Beijing especially for the green intelligent traffic system.

Keywords: Traffic operation; Operational efficiency; Intelligent traffic system (ITS); Traffic load; traffic safety; Intelligent algorithm.

1. Introduction

Just as other international megacities, Beijing has obtained the economy development, but at the same time has to be confronted with rigorous challenge of traffic problems. The motor traffic has been increasing sharply in last two decades[1]. The amount of motor and the operational Length of the subway is 1,500 thousand and 41km by the end of 1990, but by the end of 2009 it had increased to 4,000 thousand and 228 km in Beijing Though the traffic networks have kept improving, the traffic conditions still have a trend to deteriorate. According to the statistic data surveyed by Beijing Traffic Authority, there were 27 roads with serious traffic jams in 1993 and it turned to 99 with a sharp increment in 1999, after traffic management in 2009,

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there were still jammed roads[2]. Owing to the increasing traffic jams, the average speed of vehicle has still decreased in recently years in Beijing.

Previous studies on the traffic comparison mostly took a city as a whole, but ignored the differences among areas inside the city[3,5]. But in fact, the jams of traffic in different areas with a city are mostly different. For example, Beijing covers an area of 16,800 square kilometers including 6 districts in urban area and 8 wards and 2 counties in near and far suburb. The traffic operation in suburb is good, especially outside the Fifth Ring Road, where the average speed reached 70 km/h in 2009. In contrast, the roads with server traffic jams are mainly located within the Third Ring Road. According to the statistic data surveyed by Beijing Traffic Authority, the average speed in area between the Second and Third Rings was 45 km/h in 1994 and it dropped to 20 km/h in 1996. Even worse, it was inferior to 12km/h in peak period in 2003, and in some roads. The traffic became a little better in 2006, during the AM peak period while the speed was 36.2 km/h in highway and 23.1km/h in main roads[15]. Therefore, the consideration of selected area is essential when comparing the traffic conditions among several cities because the traffic performances can be absolutely different in different areas.

2. Selection of Study Cities

Only based on the cities with similar backgrounds could the comparative analysis be meaningful. London, New York and Tokyo are selected as the comparison objects to Beijing for several reasons. First of all, these cities all have a large population of over 5million, which we called super cities, and the traffic problems are similar. Secondly, their transport systems have all types of travel modes such as auto, bus, subway, bicycle, walk etc., and the traffic compositions are relatively stable. Lastly, they all have mature and successful transport systems after over hundreds of years development and get a lot of experiences and lessons which worth being learned[6,11-13].

In different areas of a city, the traffic conditions are totally diverse because of the differences on population density and level of economy. It is a kind of ridiculous to compare Beijing which covers 16,800 km^2 with New York which covers 776 km^2. So we firstly make a brief introduction of all selected cities and confirm the area of each city in the comparison.

(i) Beijing is the capital of China. The urban 6-districts, which include Dongcheng, Xicheng, Chaoyang, Haidian, Fengtai, Shijingshan districts, is chosen to be the compared area. The total square of 6-districts is 1368 km^2, the resident population is 9,800 thousand in 2005.

(ii) London is the capital of England and the Greater London area covers 1,579 km^2, including central London 27 km^2, inner London 294 km^2, and outer London 1,259 km^2.The resident population of Outer London is 4,500 thousand in 2005.

(iii) New York locates at the eastern coast with an area of 776 square kilometers, the resident population is 8,210 thousand at the end of 2005. It consists of 5 Counties (Manhattan, Queens, Brooklyn, Bronx, Staten Island), and Manhattan is the center of the city with an area of 60 square kilometers, and its population is 1,590 thousand at the end of 2005.

(iv) Tokyo is the capital of Japan and consists of 23-wards, Tama area, and Island area. The area of the 23-wards is 631 square kilometers, and its population is 8,460 thousand. The total area of Tokyo is 2,187 square kilometers, and its population reached 12,560 thousand at the end of 2005.

The selected area can be found in Table 1.

Table 1. Socio-economic index of the four cities

Cities	Beijing (2005)	London (2005)	New Work (2005)	Tokyo (2005)
Comparable Area	Urban (6-disricts)	Great London	Urban (5-districts)	Urban (23-yards)
Square(km^2)	1368	1580	785	631
Population (ten thousands person)	980	750	821	846
Population Density (person/km^2)	716	471	1046	1341
GDP(billion $)	86.73	284.7	415.9	802.8
Per Capita GDP($)	8616	37960	53715	63917
Per Capita Annual Income($)	2730	28350	36916	37317

Note: The sources of the data are from the reference [19-22].

Table 1 shows the social-economic statistics like area, population, GDP (General Domestic Products), income etc. The population densities in Beijing and London are relatively lower than that of other 2 cities because of the large number of residential area in suburbs. The low population density in urban area makes residents have a good living environment but puts great commute traffic pressure on roads.

According to the statistic surveyed by Word Bank in 2005, Tokyo is No.1 with a GDP of 802.8 billion$ and

New York and London are No.2 and No.3 respectively. Beijing is No.21 with the GDP of 84.44 billion$ which is only 1/5 of Tokyo's. The index 'per capita income' among these cities has the same trend but the gaps between Beijing and other cities are much larger. All these data reveals that the economy of Beijing is far behind the level of other three international megacities. To some extent, the level of economy decides the transport investment, so Beijing is facing big challenge to develop transport system, and effective measures are necessary to implement.

3. Traffic Infrastructure Comparison

When it comes to traffic infrastructure, Beijing currently has been equipped with developed urban traffic networks, which is on the top among Chinese cities, but still has large gap with other developed cities.

3.1. *Size of traffic Network*

Traffic density and traffic are a ratio are always used as two indicators to estimate the size of traffic network[2]. The first one is the quotient of traffic length and city area, and the second one is the proportion of traffic construction land in total land area. As showed in Table 2, Beijing are far behind other cities, only has 1/6 road density of Tokyo and 1/4 road area ratio of New York.
The proportions of all types of roads in network indicate the composition of the road network. In recent decades, Beijing has paid great concentration on the expressway and arterial road construction, but neglected the improvement of low-grade road network. As showed in Table 2, the length of freeway in Beijing has exceeded other cities, but the proportion of low-grade road in the network is much smaller.

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3.3. *Average Width of Road*

The gap of road area ratio between Beijing and other cities is far smaller than that of road density. Beijing has made great progress on building expressway and arterial roads, so the average lane width is wider than that of other cities. In fact, it is 2.2 times of Tokyo.

3.4. *Demand and Supply Balance*

The traffic supply of Beijing has improved a lot. By June 2008, 5 railway lines had been built with the total length reaching 148 km, and the road length is increasing year-by-year. But the railway network is still has low density compared with the corresponding in London, New York and Tokyo, and large proportion of travels still happen on the road networks.
The traffic demand in Beijing is as great as in other cities, and the total number of resident trips even has exceeded Tokyo (as showed in Table 2). Though motor vehicle owned in Beijing is the smallest among these cities, the motor traffic still has great pressure on the traffic network.
As analyzed above, the traffic networks in Beijing have quite low capacity because of its size and structure. However, the traffic demand is great. It is concluded that the balance of demand and supply can only be gotten on a very busy traffic situation.

Table 2. Traffic infrastructure of four cities

Cities	Beijing (2005)	London (2004)	New Work (2005)	Tokyo (2005)
Length of road network(km)	4073	14676	13352	11845
Road network density(km/km^2)	2.98	9.29	17.01	18.74
Road area ratio (km/km^2)	5.58%	16.4%	23.0%	15.9%
Length of expressway (km)	232	60	-	191
Proportion of local streets	71.7%	87.9%	-	94.5%
Average width of road(m)	18.7	17.6	13.5	8.5
Length of railway networks(km)	142	410	416	292
The total travels in full day(ten thousands person/day, including walk trips)	2604	2710	-	2100
Vehicles ownership(vel/100 person)	20.5	26.9	22.5	24.8

Notes: The sources of the data are from the reference[18,19-22].GDP data is the whole city's GDP. The data of the proportion of private car in London is the data of Greater London.

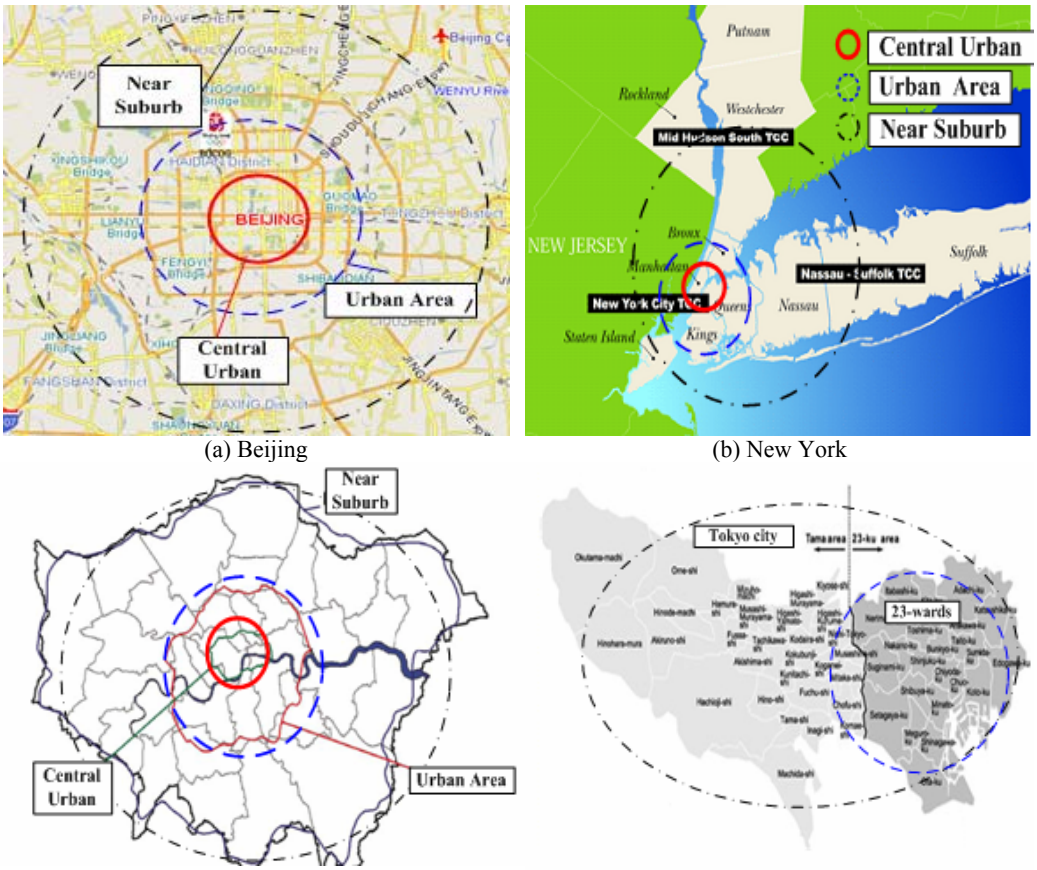
In conclusion, the traffic infrastructure in Beijing has the following features compared with the infrastructure in London, New York and Tokyo.

- The size of traffic networks is smallest among four cities from the aspects of both road density and road area ratio
- The structure of road networks is improper, for the proportion of low-class road is too low
- The average width of roads is larger than others, because Beijing has taken a great effort to build the freeway and arterials
- The Traffic Pressure on traffic Networks is Great, For The Large Number of Metro travels and low Capacity of the traffic Network

4. Operational Comparison

To estimate the performance of traffic operation, one can begin with the traffic load, efficiency and safety. By considering the availability of the data, the v/c ratio, vehicle average speed and accident rate are selected as the measures to compare traffic operation among different cities.

The distribution of vehicle flow has a close relationship with the location. The city center has a tremendous attraction to traffic flow, so most of the traffic jams always happens here and the volume of vehicle flow is the highest. With respect to different traffic features in different areas, the Beijing is divided into three areas including central urban area (within the second ring), urban area (between Second Ring and Fourth Ring Roads), near suburb (outside of Fourth Ring Road). New York is also divided into central urban area (Manhattan), urban area (Brooklyn, Bronx, Queens and Staten Island), nearby suburb (Nassau, etc.). London is divided into central urban area (Central London), urban area (Inner London), and near suburb (Outer London). Tokyo is divided into metropolitan area and 23-wards.



(a) Beijing (b) New York

(c) London (d) Tokyo

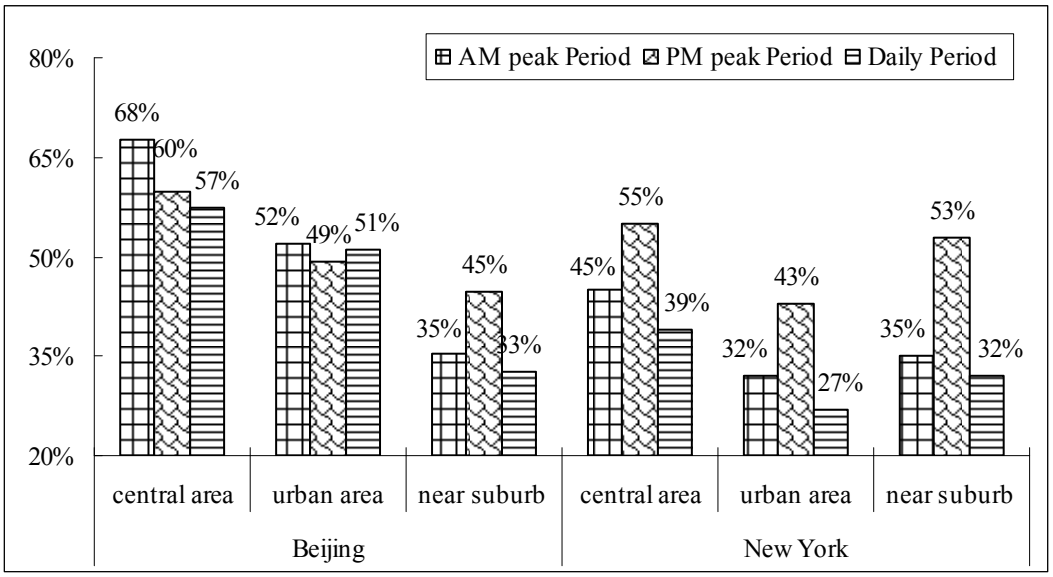
Fig. 1. Areas division in study cities

4.1. Traffic Load

The road v/c ratio reflects the load of road network, and indicates the relationship between traffic supply and demand. It is defined by following formula.

v/c ratio = traffic volume /road carrying capacity

Road v/c ratio is influenced by road location. The closer to the city center, the higher the v/c ratio is. In Beijing, the ratio gap between central urban area and suburb is about 20%. As showed in Fig.2, in central urban of Beijing, the average v/c ratio is 57% daily and 68% in peak period. In area between the Second and Fourth Ring Roads, the v/c ratio is 51% daily and 52% in peak period, and outside fourth ring, it is about 33% daily and 40% in peak period. On the contrary, the average ratio is just around 30% and the distinctions among different areas are not so obvious in New York. The road load of Beijing is much heavier than that of New York, especially in the city central area.



Note: The sources of the data are from the reference[4, 20, 23].

Fig. 2. V/C ratio comparison of different area in Beijing and New York

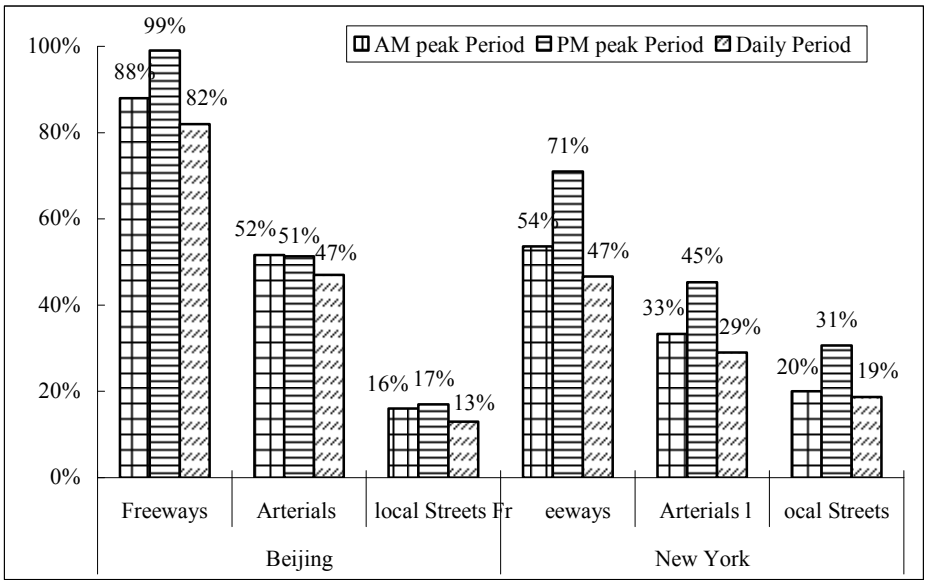
Another factor that influences the road v/c ratio is the road grade. The v/c ratio of freeway is the highest among all type of roads for the reasons that there are good pavements, high-speed design, free of signal interference. As illustrated in Fig.3, the following conclusions about the Beijing's road load could be drawn.

- The average load is in a very high level. The average v/c ratios of freeway and arterial in Beijing are 35% and 18%, which are higher than the corresponding ones in New York respectively. Though the v/c ratio of local streets is about 5% lower, the whole road load in Beijing is higher than in New York.
- The road v/c ratio of freeway almost reaches 100% in peak period but the one of local street is just about 15%.The gap between them is about 70% in daily period, about twice the gap in New York. That means the freeways in Beijing are overload, and when in peak period the v/c ratio reaches 100%, the traffic flow will be unstable and a little disturbance will cause traffic jam.

After analysis above, we know that the freeways in Beijing have already overload, and the load of arterial roads also reaches the top due to the influence of signal-lights, but the utilization rate of local street is far from being satisfied. The reasons are as follows.

- Compared with other cities, the capillary road network which is composed by low-grade roads in Beijing has a lower density. The whole length of capillary road network is 2920km, much lower than 12900km in London and 11193km in Tokyo.

- Too many discontinuous and bottleneck sections exist in the capillary road networks, so the whole capacity drop a lot.
- There are no isolation belts or barriers between motor and non-motor lanes in low-grade roads. Some sections have curb parking on non-motor lane. So the vehicles suffer severely negative influences from the bicyclist.

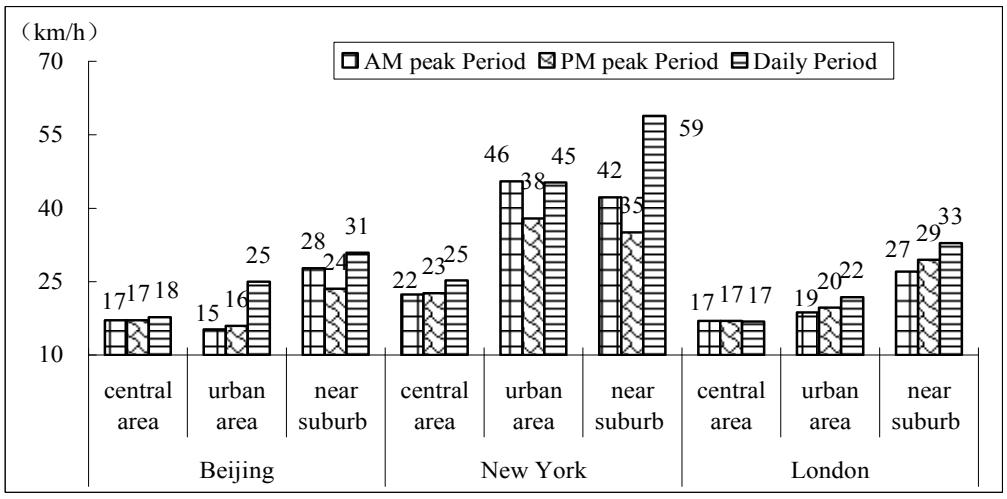


Note: The sources of the data are from the reference [4, 14, 15, 23].

Fig. 3. V/C ratio comparison of different grade road in Beijing and New York

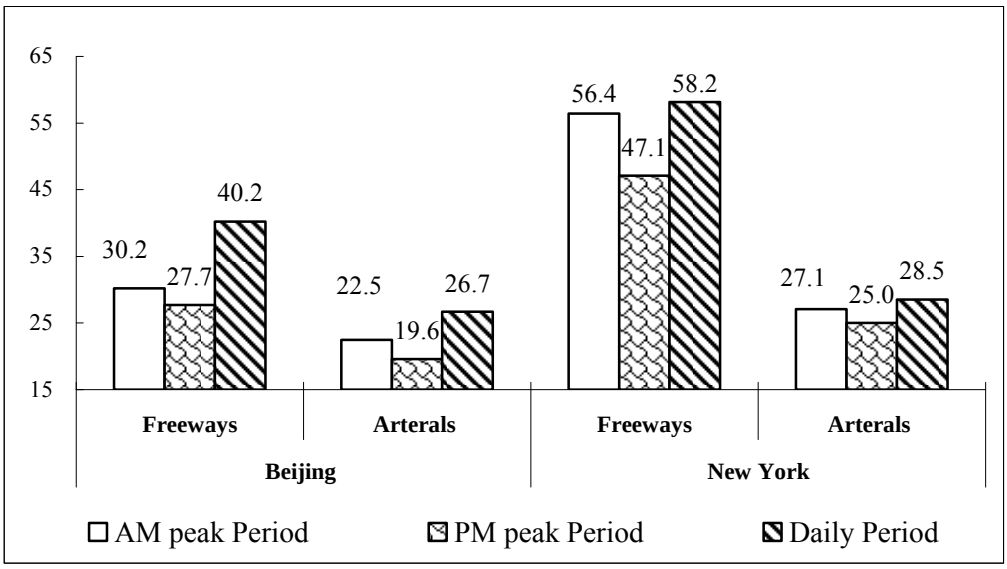
4.2. Operation Efficiency

The average vehicle speed reflects the service level and operation efficiency of road. Based on surveyed data by the author's research group and floating car data from Beijing Transportation Research Center[7], the average speeds in different areas and grade of roads are obtained. As showed in Fig.4 and 5, the vehicle speed in Beijing has the following features.



Note: The sources of the data are from the reference [4, 8, 9, 10, 23].

Fig. 4. Vehicle speed comparison in different grade road of Beijing, New York and London



Note: The sources of the data are from the reference.[4, 8, 9, 10, 23]

Fig. 5. Vehicle speed comparison in different grade road of Beijing, New York and London

The main reasons leading to this situation are almost same ones analyzed in last section.

- The average speed is lower than other cities. From the aspect of region, in Beijing the averages speed in central area are 17.7km/h which makes the service level F (referenced from "Highway Capacity Handbook", 2000), and 22.5km/h in suburb which is less than 1/2 of the corresponding speed in New York. From the aspect of road grade, the average speed of arterial road is 22.5km/h which is 5km/h lower than in New York, and the speed of freeway is 40.8km/h while it is 58.2km/h in New York.
- There is not so obvious switch of speed between peak period and non-peak period, especially in central urban area.
- The speed gap between central and urban areas is very small, while the gap is about 20km/h in New York.

4.3. Traffic Safety

The traffic accidents not only bring about great economic loss, but also may lead to death[24-26]. The traffic security is an important index when estimate traffic condition of a city, and also an essential index to the development of economy and stability of the society. The following historical data of Beijing, Tokyo, New York and London show the rate of traffic accidents per hundred thousand people per year, death toll of traffic accident per hundred thousand persons per year and the number of casualties per hundred thousand persons per year. The rate of traffic accidents per hundred thousand people per year is the number of traffic accident per year in one hundred thousand persons in a city and death toll of traffic accident (the number of casualties) per hundred thousand persons per year is the number of death persons (the number of injured persons) in one hundred thousand persons in a city.

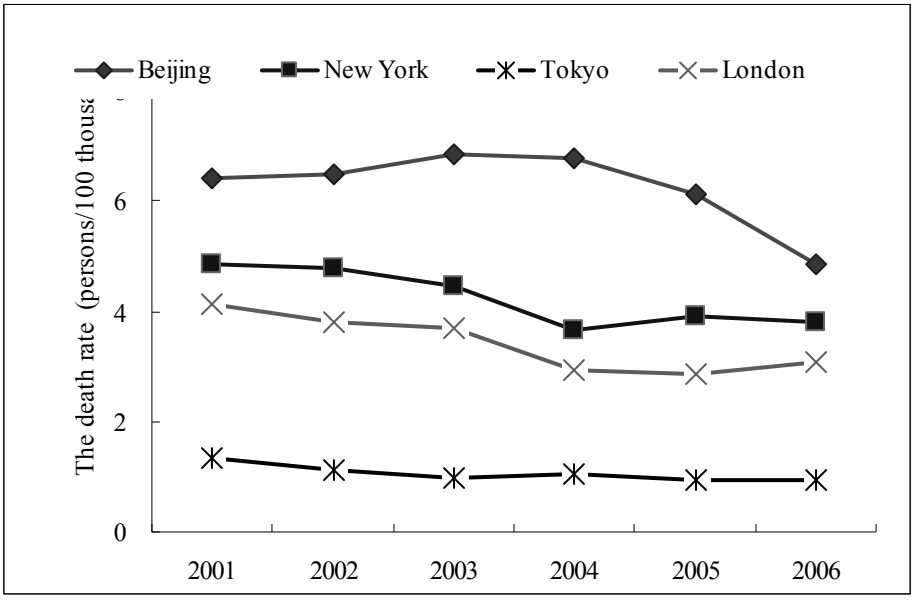
The death rate is crucial to reflect the extent of harm and injury caused by traffic accidents. As showed in Fig 6, the death tolls of these cities are all between one and seven. Among them, the death toll of Tokyo is lowest(less than 2), and these of New York and London are between 2 and 4. Beijing has the highest death toll which is as 6 times as Tokyo. The reason is that there are a lot of pedestrian-vehicle and bicyclist-vehicle accidents in Beijing which cause much higher death rate than the vehicle-vehicle accident. Additionally, it is showed in Fig 9 that the death rates in London, New York and Tokyo had a trend to decline year by year while the death rate in Beijing increased from year 2001 to year 2003 and then declined from 2003 to 2006. The

Road Traffic Safety Law has taken effect since 2003, so the death rate declined gradually from then on.

The rate of traffic accidents and the number of casualties by accidents each year reflect the frequency of accidents and the efficiency of emergency relief. From the Fig.6 and 7, we can get two conclusions. First of all, Compared to Tokyo, the rate of accidents and the numbers of casualities in 100 thousands persons are smaller in Beijing, but the death rate is higher than Tokyo. This is due to most of accidents data are reported by parties in Tokyo, however, in Beijing the data are recorded by the police arriving at the spot and some lightly accidents are solved without police absence, which means accidents are not fully recorded. And if the accident has some person died and it must be recorded. Therefore, the death rate in Beijing is higher than that of Tokyo. Secondly, the rate of accidents and the numbers of casualities in 100 thousands persons in Beijing declined in recent years, esp. in 2006 respectively decreased with 51% and 41% compared to 2003. The Road Traffic Safety Law of Tokyo was modified in 2004 in view of the numbers of causalities in 100 thousands persons of Tokyo are largest that year, including no using mobile phone when driving. Then, it desirable made the rate of traffic accidents declined year by year.

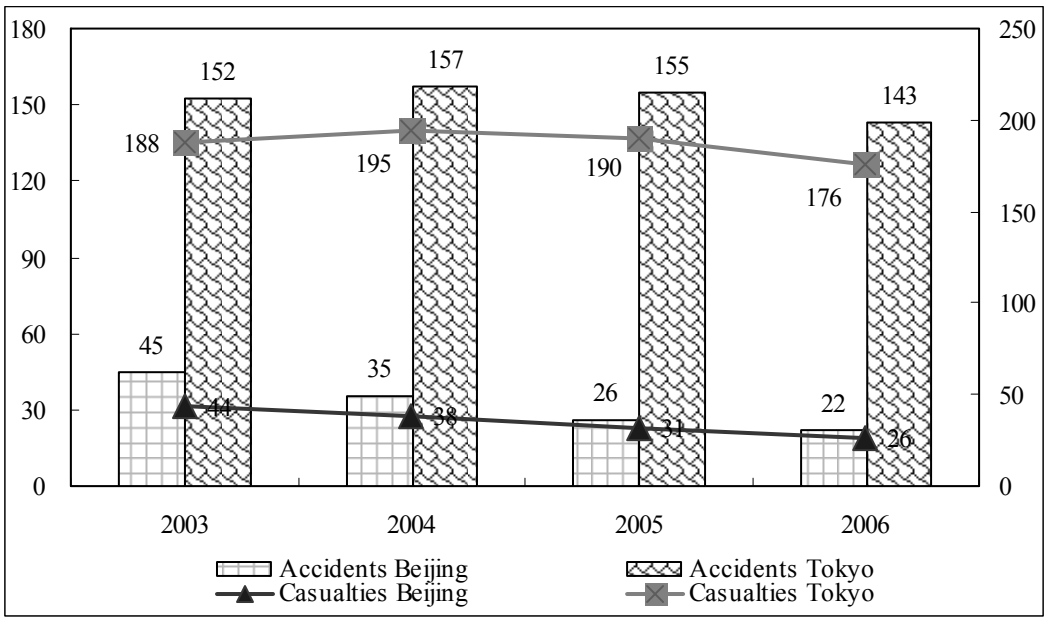
The conclusions about the traffic safety in Beijing compared between Beijing and other international metropolis are as follows.

- The rate of traffic accidents and death in Beijing and other cities descend year by year, which indicates that these cities have tried to improve the traffic safety and achieve success gradually.
- Compared with other international metropolis, the death rate in the urban 8-wards of Beijing is the highest, which is 6 times of Tokyo. The traffic safety in Beijing is not optimistic, and the advanced traffic management should be brought in.
- In comparison, the rate of traffic accidents and the numbers of causalities in 100 thousands persons are relatively smaller than that of Tokyo, but the death rate is larger than that of Tokyo. That is due to the accidents in Beijing must be recorded at the spot and some minor accidents are missed record while they are recorded by report in Tokyo. In addition, Beijing's medical emergency is inferior to Tokyo, and sometimes making some injuries died without timely medical care.



Note: The sources of the data are from the reference[4, 7, 8, 9, 10, 23]. New York's Data are from "Traffic Safety Improvements in New York City" and New York State Data Center June, 2007. London's data are from"Transport for London" Tokyo's Data are from internet, and the addresses are http://www.pref.ky-oto.jp/fukei/koke_k/tokei/kotujiko.pdf and http://www/metro.tokyo.jp/CH-INESE/PROFILE//overviwe03.

Fig. 6. Comparison of traffic death rate



Notes: "Accidents" denotes that the rate of traffic accidents (times/100 thousand persons). "Casualties" denotes that the number of casualties (persons/100 thousands persons). The sources of the data are from the reference[4, 7, 8, 9, 10, 23]. New York's Data are from "Traffic Safety Improvements in New York City" and New York State Data Center, June, 2007.
Tokyo's Data are from internet, and the addresses are http://www.pref.kyoto.jp/fukei/kotu/koki_k/tokei/kotujiko.pdf and http://www.metro.tokyo.jp/CHINESE/PROFILE/overview03.htm.
Fig. 7. Comparison of safety-related indicators

5. Conclusions

Compared with London, New York and Tokyo, the traffic operation in Beijing has the following features.

- The level of economic development of Beijing is far behind other international cities. So the burdens on construction investments of transport infrastructure is heavier and the road transport efficiency improvement should been given more emphasis.
- The area of Beijing is large, and traffic conditions are varied in different areas, but most commercial activities and heavy traffic areas locate in urban 8-wards. According to population density and function, comparison study objects are chosen, which include Beijing urban 6-wards, Greater London, New York 4-counties and Tokyo 23-wards.
- Though the length of expressways and the average width of road networks in Beijing are advantageous, the length and area of roads are still lagging behind other cities, and the road structure is irrational.
- Average vehicle speed in Beijing is lower than that of other cities and the traffic pressure on road networks is obviously higher.
- The utilization rate of expressways in Beijing almost reaches the up-limit 100% while the v/c rate of low-grade roads is just less than 20%. It could be attributed to the insufficient density, poor connectivity and severer horizontal influence of capillary road network.
- From the aspect of road traffic safety, the death rate of Beijing is also the largest one, with average 6-7 death per 100 thousands persons. There are a large number of residents riding bicycle or motor and pedestrians without enough sense of traffic safety, which lead to the accidents are always between passer(s)-by and vehicle(s), and the high death rate.

In general, the key to improve traffic operation in Beijing is equilibrating the traffic flow over the traffic network. Firstly, to induce the metro traffic in central urban area, the traveler can be encouraged to use public transport. TDM measures like developing transit system, charging on congestion are strongly recommended. Secondly, to increase the utilization rate of low-class road, the capillary road networks should be improved, and when enough traffic moves to capillary road, the pressure on freeway and arterials can be released. Measures like building more low-class road to increase

road density, widening necklace road section and canceling inner-road parking to enhance the capacity are recommend. Lastly, road safety is also an important indicator to assess the traffic operation. Measures like making complete and effective traffic laws, taking traffic safety education to deduce the road accidents are recommended.

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