

HAS SHANGHAI'S TRANSPORTATION DEMAND PASSED ITS PEAK GROWTH?

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ABSTRACT

Based on four comprehensive transportation surveys in Shanghai, this study examines the latest trends in Shanghai's travel demand, investigates their social, economic and spatial drivers, and compares the paces of travel demand growth in three periods: I, 1980s to early 90s; II, early 90s to mid 2000s; and III, mid 2000s to now. The demand growth is relative slow in Period I, and then speeds up in Period II, before returns to a slower pace in Period III. As for trip purpose, Shanghai's travel is much more diversified with increasing share of non-commuting trips (from 28% in 1995 to 46% in 2009). Spatially travel demand is dispersed from the central district to peripheral districts because of urban expansion and decentralization, and from Puxi (west of Huangpu River) to Pudong (east of Huangpu River) as a result of the significant economic development of Pudong New Area. Both spatial diffusion and purpose diversification favor the convenience and flexibility of private motor vehicles. Driven by rapid motorization, vehicle travel is growing at a much faster pace than person travel. Overall in terms of percentage growth, travel demand in Shanghai has passed its peak growth since 2004 for both person trips and vehicle trips. In terms of absolute number, person trip growth has peaked but vehicle trip growth has not. In response to the growing demand, especially rapid motorization, the local government has made tremendous investments in road infrastructure and public transit, and attempted to manage demand through vehicle ownership control.

Keywords: urban transportation, Shanghai, travel demand, motorization

1. INTRODUCTION

Built along the Huangpu River in the lower Yangtze delta, Shanghai is one of the largest cities in the world with a total population of over 23 million and a land area of 6,340.5 km² (Shanghai Municipal Bureau of Statistics, n.d.). Shanghai has experienced drastic social and economical changes in recent history, all of which could contribute to changes in Shanghai's transportation demand.

The market reform and the Open Door policy in 1978 marked China re-entered the global stage. Shanghai was bypassed by the first wave of economic take-off in 1980s, which was embraced by cities in South China (Z. Li, 2004). Nevertheless, Shanghai saw a decisive development opportunity in the beginning of 1990s when the central government announced its intention to develop the Pudong New Area, located along the east side of the Huangpu River, across from the historic city center of Shanghai in Puxi (Wu, 1999). Based on the model of China's Special Economic Zones (SEZs), Pudong has grown rapidly since the 1990s to become China's new financial and commercial hub. Its GDP was about 6 billion Yuan in 1990, and exploded to around 400 billion in 2009, increasing from one twelfth of Shanghai's total economy to a quarter. Driven by the development of Pudong, Shanghai entered a new era. Since early 1990s, Shanghai managed a double digit growth rate (until the latest recession in late 2000s). Shanghai is poised to regain its pre-1949 position as the leading industrial, financial and trading center in China and the East Asian region. Meanwhile, rapid urbanization leads to dramatic spatial expansion. Overcrowding in the central area forced more and more people move out to the suburban area. And the emergence of labor market and the disappearance of enterprise-based housing provision further contributed to the separation of residence location and employment location. Also, due to rapid economic growth in Shanghai, workers' average annual income has also experienced drastic increase, from 5,619 Yuan (adjusted to the 2010 value) in 1980 to 46,757 Yuan in 2010. With higher income, more Shanghai residents can afford the luxury of the private automobile. Automobile ownership has increased dramatically from 24 per 1000 persons in 1996 to 74 per 1000 persons in 2010. Along with the rapid urbanization and economic development in Shanghai over the past three decades, travel demand in Shanghai has been growing significantly. The growth in travel demand consists of more and longer trips, greater shares of motorized modes, and a higher proportion of trips relying on personal vehicles (Q. Shen, 1997). Bicycle used to be a dominant mode for travel, but plans and policies encourage a switch to public transport (Zacharias, 2002). Transit ridership began to slowly recover since 1996 after a decline in late 1980s and early 1990s (Lu & Gu, 2009). The increase in transit ridership paled compared to the increase in vehicle ownership. The number of registered private automobiles jumped from 200,000 in 1991 to 1.4 million in 2002 (M. Zhang, 2007). Shen (4) analyzed its increase of transportation demand from 1985 to 1994, and found the seven most important factors responsible for the explosive growth of transportation demand, including population growth, economic and income growth, urban expansion, land use reconfiguration, the emergence of labor market, disappearance of enterprise-based housing provision, and government decisions to nurture auto industry.

In response to rapidly growing travel demand, China has invested huge amounts of money in new transportation infrastructure. Between 1991 and 1996, about 10 billion US dollars was invested in infrastructure projects, such as two bridges (Nanpu and Yangpu bridges) and a

tunnel across the Huangpu River, an inner ring road, and elevated north-south throughway, and a new subway (Yatsko, 1997). Since mid 1990s, the metro system has been expanded significantly. In 2011, twelve metro lines (including the Shanghai Maglev Train), 278 stations and over 434 kilometres of tracks were in operation, most of which were built within the past decade, making Shanghai metro network the longest in the world (Shanghai Metro, 2010).

Despite the efforts to accommodate the rapidly growing demand, Shanghai, like many Chinese cities is suffering from severe and worsening transport problems: congestion, air pollution, noise, traffic injuries and fatalities, parking shortages, energy use, and a lack of mobility for the poor (Pucher, Peng, Mittal, & Zhu, 2007). These problems could be particularly serious for Shanghai because of its huge size, high density, and its position as China's economic center. How to manage the growth in transportation is a big concern for Shanghai as well as many other major cities in China and the rest of the world, which requires an investigation of changes in travel behaviors and the underlying driving forces, and an examination of transportation policies and strategies.

The growth of travel demand often follows a sigmoidal curve (logistic, "S" shaped). It is an intuitively representative curve for a process that begins slowly, matures into break-neck growth and must slow down at some point because of saturation. One interesting question is "whether Shanghai's transportation demand has passed its peak growth period". In order to answer this question, this study examines the latest trends in Shanghai's travel behavior, investigates their social, economic and spatial drivers, and compares the paces of travel demand growth across time.

Mainly based on review of Shanghai's economic performance, three time periods are used to characterize Shanghai's transportation development: 1980s – early 1990s, early 1990s – mid 2000s, and mid 2000s – present. These three periods are then analyzed using four waves of comprehensive travel survey data.

It is worth notice that the growth pace could be characterized using different measures. One measure is the growth in terms of the absolute number of demand, which is called annual absolute growth in this paper. What the sigmoidal curve implies is the existence of a peak of annual absolute growth. Although this study is inspired by the sigmoidal assumption, the measurement of the growth pace does not necessarily have to be limited to using the absolute number. Another widely measure of growth pace, annual growth rate (annual percentage growth relative to previous year), could be equally useful. Thus these two measures are used to quantify the pace of travel demand growth. The results of this paper can provide insights onto the current and future trends of transportation demand growth, which will be helpful for demand forecasting and transportation planning in Shanghai as well as other large developing cities.

2. DATA

The research is largely based on review and analysis of various literatures including transportation survey reports, statistical yearbooks, official planning documents, and academic papers.

The core task of this paper is to investigate the pace of transportation demand growth over time through examining trends of travel behavior. This has to be done based on travel survey

data. So far, four comprehensive transportation surveys have been conducted in Shanghai, respectively in 1986, 1995, 2004 and 2009. Most of the transportation data used in this paper come from the reports of the last three surveys (Shanghai City Comprehensive Transportation Planning Institute, 1997) (Shanghai City Comprehensive Transportation Planning Institute, 2005a) (Shanghai Urban Construction and Communications Commission, Shanghai City Comprehensive Transportation Planning Institute, & Office of the fourth Comprehensive Transportation Survey of Shanghai, 2010). The reports contain detailed survey results regarding not only the demand side but also the supply side, and some comparisons with previous surveys. On basis of the four survey years, this paper periodizes Shanghai's transportation development into three periods, namely, 1986-1995, 1995-2004, and 2004-2009, which could be used to roughly represent 1980s - early 1990s, early 1990s - mid 2000s, and mid 2000s - present. This is mainly attributed to the limitation of survey data. It is improbable that the three periods used in this paper can perfectly represent the periodization of Shanghai's transportation development. Therefore, the periodization used in this paper should be treated as an approximation. Aside from the four comprehensive transportation surveys, there are other relatively small-scale and specialized travel surveys. The results from these surveys are cited via other papers. For example, the modal split data for 1981, 1986 and 1991 are cited from Shen (1997).

Another important part of this research is to find out social, economic and spatial drivers of travel demand. Shanghai's annual social and economic data used in this research mainly come from Shanghai Statistics Yearbooks from 1978 to 2011 (Shanghai Municipal Bureau of Statistics, various years). For reasons that are unknown to the authors, only the vehicle ownership data for 1996 and later is accessible (online).

Shanghai's transportation planning policies and strategies are also evaluated in this study. This is done by comparing various official transportation planning documents with the actual demand growth and its possible causal factors.

3. CHANGING PACE OF TRAVEL DEMAND GROWTH

As expected, individual travel demand has been constantly growing in Shanghai, featuring increasing trip rate and average trip length. The trip rate of Shanghai's residents increases throughout years, reaching 2.23 a day in 2009. The pace of the increase seems to pick up between 1995 and 2004 but slow down afterwards. Residents living inside the central city travel more frequently than residents living outside (2.37 trips/day versus 2.06 trips/day in 2009), probably because people residing inside the central city usually have higher income and enjoy much more amenities because of high land use density. Average trip distance increases from 4.3 kilometers in 1986 to 6.5 kilometers in 2009. This probably results from urban expansion and separation of employment and housing.

Based on population, trip rate and trip length, the overall travel demand can be estimated. Increase of the gross population and trip rate made the amount of total person trips traveled rose from 22.1 million person-times per day to 42.1 million person-times per day, an increase of 91 percent from 1986 to 2009 (see Table 1). At the same time, the urban expansion and the separation of the workplaces and residences caused the average trip distance to be longer, resulting in the total person kilometers traveled increased from 94.8 million person-kilometers

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per day to 273.7 million person-kilometers per day, an increase of 189%. As expected, the travel demand in Shanghai has grown significantly in past 3 decades.

The increasing travel demand is fundamentally driven by Shanghai's rapid economic growth. First of all, the economic development, especially the development of the tertiary industry, brings about an urgent need for a greater labor force, which resulted in a great increase of the migrant population, a major driver of Shanghai's swelling population. Also, the development of the economy brings more social activities, which provide residents with more activity (and travel) options. With higher income, people can afford to travel more to do more activities, and to travel greater distance to access a wider range of goods and services.

Table 1 - Growth of Travel Demand

Year	Population ($\cdot 10^6$)	Trip Rate (times/day)	Person Trips Traveled ($\cdot 10^6 \cdot$ trips/d)	Average Trip Distance (km)	Person Kilometers Traveled ($\cdot 10^6$ km/d)
1986	12.32	1.79	22.1	4.3	94.8
1995	14.15	1.87	26.5	4.5	119.1
2004	17.10	2.21	37.8	6.2	234.3
2009	18.88	2.23	42.1	6.5	273.7

Source: The fourth comprehensive travel survey of Shanghai, 2009; calculations by author

Another major factor affecting the person travel demand increase is land use. On one hand, urban spatial expansion gives rise to longer trip distance. As Shanghai has grown in population, they have also spread outward to the suburbs at lower densities than previously. Many low- and middle-income households in China have been moving to peripheral suburban areas because of the lack of affordable housing in the central cities and the government's explicit programs to redevelop inner-city areas. Employment has also decentralized. In the process of urban expansion, most factories were relocated to the suburbs. Based on a current-day and retrospective survey of recent movers to three suburban neighbourhoods in Shanghai, job accessibility levels were found to decline dramatically following the move to suburban neighbourhoods (Cervero & Day, 2008). Furthermore, local governments in China have been promoting new industrial and technology parks on the fringe of urban areas, thus pushing urban development further into rural areas. The decentralization of Chinese cities has clear impacts on urban transport. The expansion of cities increases the length of trips for most urban residents. This in turn makes walking and cycling less feasible than before, thus encouraging a shift from non-motorized to motorized modes. On the other hand, land use can also affect trip rate. Using population density and trip rate data for 18 districts of Shanghai in 2009, the correlation can be found between population density and trip rate. The results show that districts with higher population density are usually associated with higher trip rate.

This paper is more interested in the growth pace of these indicators. The annual growth rates of population, economy and land use parameters, and the transportation characteristics are compared for the three periods between the four comprehensive surveys. The results are shown in Table 2. It is to be noted that GDP data has already been adjusted with Consumer Price Index. As expected, positive correlations are found among all these indicators. Both the growth of economic variables and travel demand indicators sped up after early 1990s. The principle drivers of growth also change over time. Between 1995 and 2004 the growth was driven by higher trip rate (annual growth rate of 1.9%) and longer trip distance (annual growth rate of 3.6%); but after 2004, the annual trip rate growth dropped to 0.2% and annual

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trip distance growth dropped to 0.9%. At the individual level, similarly, the growth rate of travel demand slowed down after 2004 while the increase in income level continues to pick up speed. Growth in urbanized area also reached the fastest pace in late 1990s and early 2000s, but the how the pace has changed after 2004 is unknown. The “acceleration” of travel demand in around 1995 is probably attributed to Shanghai’s economic take-off in early 1990s and rapid urbanization, but the reason for the “deceleration” in around 2004 are more subtle. One contributor could be the latest economic recession happened in 2008-2010. But it is not the primary cause because the average economic growth rate between 2004 and 2009 is still high. If assuming that the growth of travel demand over time a sigmoidal (logistic, “S” shaped) curve, this implies the growth pace of travel demand has already begun to slow down.

Table 2 - Annual Growth Rate of Population, Economy and Travel Demand

Periods	Population	GDP	GDP Per Capita	Urbanized Area*	Trip Rate	Average Trip Length	Person Trips Traveled	Person Kilometers Traveled
1986-1995	1.6%	4.5%	3.0%	6.5%	0.5%	0.5%	2.0%	2.6%
1995-2004	2.1%	11.6%	9.1%	8.5%	1.9%	3.6%	4.1%	7.8%
2004-2009	2.0%	10.9%	8.8%	NA	0.2%	0.9%	2.2%	3.1%

Source: The fourth comprehensive travel survey of Shanghai, 2009; Shanghai Statistical Yearbooks, 1978-2010; Xu et al. 2007, calculations by author

* For annual growth of urbanized area, growth rates during 1984-1993 and 1993-2002 are used to estimate the growth rates in 1986-1995 and 1995-2004. The growth rate after 2004 is unavailable.

4. DIVERSIFICATION OF TRAVEL DEMAND

It is widely recognized that travel demand is derived from the demand to perform activities in different locations. Thus travel purpose is a key feature of travel demand, which has influence on other travel decisions (e.g. mode choice). In Shanghai, it seems that people have growing demand for participation of activities other than work or school. This is evidenced by the rising proportion of non-commuting travel (neither to nor from one’s usual workplace or school), from 32% in 1995, to 49% in 2004, and to 51% in 2009. One explanation could be people are more likely to “choose to travel” rather than just “being required to travel” (e.g. commuting). It is further found that the rise of non-commuting travel demand mainly come from shopping travel. This is primarily driven by rocketing income and consumption power. Since commuting travel is relative fixed in terms of choice of destination, travel path, travel duration and time of day, it may be concluded that Shanghai residents’ travel demand is more and more diverse. Non-commuting travel is usually more elastic than commuting travel. Rising income and new technologies release the constraint of travel cost both in terms of money and time. Therefore, non-commuting travel demand is growing in a faster pace than commuting travel demand.

The increasing share of non-commuting travel demand could bring about two consequences. Firstly, such change could favor the flexibility and convenience of private transportation modes like car. Thus more and more people in Shanghai choose to own a car. Motorization is further discussed in Section 6. Secondly, because non-commuting travel does not have a strict constraint on time of travel, more people are likely to make trips during off-peak hours to avoid peak-hour congestion. An examination of the temporal distribution of trips indicates

that the peaking effect of travel demand seems to become weaker. Travel demand seems to be more evenly distributed across time of day, but that peak-hour traffic is still highly congested since the absolute number of demand is, although in a slower pace, increasing.

5. DIFFUSION OF TRAVEL DEMAND

In terms of spatial distribution of travel demand, survey data is analyzed by region. Based on the Inner Ring Road and the Outer Ring Road, Shanghai can be divided into 3 regions: central district (area within the Inner Ring), periphery district (area between the Inner Ring and the Outer Ring), and suburb (area outside the Outer Ring). The central city is used to refer the area within the Outer Ring, which is a combination of the central district and periphery district. Overall, travel demand still concentrates in central city. 61% of trips performed in central city. However, if looking at the change of spatial distribution of travel demand, it is found that total travel demand in central district is decreasing while most increase happens in periphery district and suburb. We can also look at the travel demand distribution between Puxi (west of Huangpu River) and Pudong (east of Huangpu River). The results show that the increase in travel demand is much more significant in Pudong than in Puxi. Within central district, travel demand has grown drastically in Pudong but actually decreased in Puxi. The shift of travel demand from the high-density (in terms of density of travel demand) central district to low-density periphery and suburban area, and from high-density Puxi to low-density Pudong, indicates the diffusion of travel demand. Such changes in spatial distribution of demand are primarily caused by land use changes.

To accommodate the huge demand for dynamic economic activities and the fast increasing in inflow population, the expansion of the city is inevitable. Urban sprawl around the central district or central city has been the main pattern for Shanghai's spatial expansion (Y. Li, Ye, Chen, Abdel-Aty, & Cen, 2010). The urban built-up areas experienced remarkable expansion, increasing from 1505 km² in the 2003 to 2288 km² in 2008. 35% of the increase happened in near suburban area. One key feature of Shanghai urban expansion is the development of Pudong, which reshaped the balance in the two sides of Huangpu River. A large number of residences and jobs were moved to Pudong. Meanwhile, a series of transportation infrastructure projects connecting Puxi and were carried out, such as Nanpu Bridge (1991), Yangpu Bridge (1993), and Xupu Bridge (1997). In return, the traffic volume across Huangpu River increased dramatically from 127 thousand pcu/day in 1995 to 864 thousand pcu/day in 2009.

An internal spatial restructuring of the city took place simultaneously with the outward expansion of its urbanized area. Land use in the urban core was reconfigured, with significant amounts of residential and industrial land converting to commercial land after 1988 (Xu, Liao, Shen, Zhang, & Mei, 2007). These changes were realized through urban renewal and real estate development. Consequently, residents have moved from the high-density central district (Puxi) to relatively low-density-periphery district and suburban area (Pudong), making the trip demand diffuse in the same direction. Meanwhile, low housing price in periphery and suburban area (Pudong) is also attractive for new immigrants. Thus the increase of population happens outside Inner Ring (in Pudong). While population moves out of the central district (Puxi), number of jobs is still clustering (see Table 3). This contributes to the separation of

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housing and employment, resulting in the increase of long-distance trips between the central district and outside (and between Puxi and Pudong).

Table 3 - Change Rate of Distribution of Population, Job and Number of Trips

Region	Area	Population			Number of Jobs			Number of Trips			
		2004	2009	Change	2004	2009	Change	2004	2009	Change	
Central District	Puxi	79	3.68	3.15	-14%	2.41	2.43	1%	9.09	7.66	-16%
	Pudong	31	0.41	0.54	32%	0.49	0.52	6%	1.05	1.36	30%
	Sum	110	4.08	3.69	-10%	2.90	2.95	2%	1.014	9.02	-11%
Periphery District	Puxi	294	4.12	4.49	9%	2.33	2.38	2%	9.34	10.38	11%
	Pudong	239	1.58	1.94	23%	0.79	0.94	19%	3.59	4.57	27%
	Sum	533	5.69	6.43	13%	3.11	3.32	7%	12.93	14.95	16%
Central City	642	9.77	10.12	4%	6.02	6.27	4%	23.07	23.97	4%	
Suburb	5698.5	7.35	8.76	19%	3.61	4.24	17%	14.83	18.06	22%	
Whole City	6340.5	17.12	18.88	10%	9.63	10.51	9%	37.90	42.03	11%	

Note: The unit for population is 10^6 persons, the unit for job is 10^6 jobs, and the unit for trip is 10^6 trips/d. A trip in a region is defined as a trip performed by a resident in the region

Source: The fourth comprehensive travel survey of Shanghai, 2009; calculations by author

Like diversification of travel demand, demand diffusion can also lead to people shifting to private motor vehicles. When the urban space was limited, walking and cycling were more appropriate modes of trip. Due the urban expansion, the percentage of walking and cycling decreases greatly because the distance makes those modes impractical. Apart from expansion, travel demand also becomes more dispersed. As a result, it is more costly and difficult to design an efficient and effective transit system to serve the increasingly disperse demand. On the contrary the advantages of using private motor vehicles, such as more comfort, door-to-door service, etc., bring about more trips by private motor vehicles.

6. RAPID MOTORIZATION

Because of rapid economic growth and land use transformation, trip distance is increasing, and travel demand is more diverse and diffused. All of these trends are favorable to the adoption of private motor vehicles, leading to rapid motorization. On one hand, people want to own cars. On the other hand, people can afford to own cars. Rising personal wealth, and technological improvement and commercialization of private motor vehicles makes owning a car a viable option. Rapid motorization contributes to the worsening traffic congestion. In Shanghai, the average motor vehicle travel speed on roads in the central area ranges from 9 to 18 km/h (Shanghai City Comprehensive Transportation Planning Institute, 2005b). Although congestion causes reducing mobility for auto users, it has an even larger influence on surface transit users than for auto users. And for the numerous individuals newly acquiring cars in the developing world, mobility is rising (Gakenheimer, 1999). Therefore, more people are attracted to use motor vehicles, in turn adding to traffic congestion.

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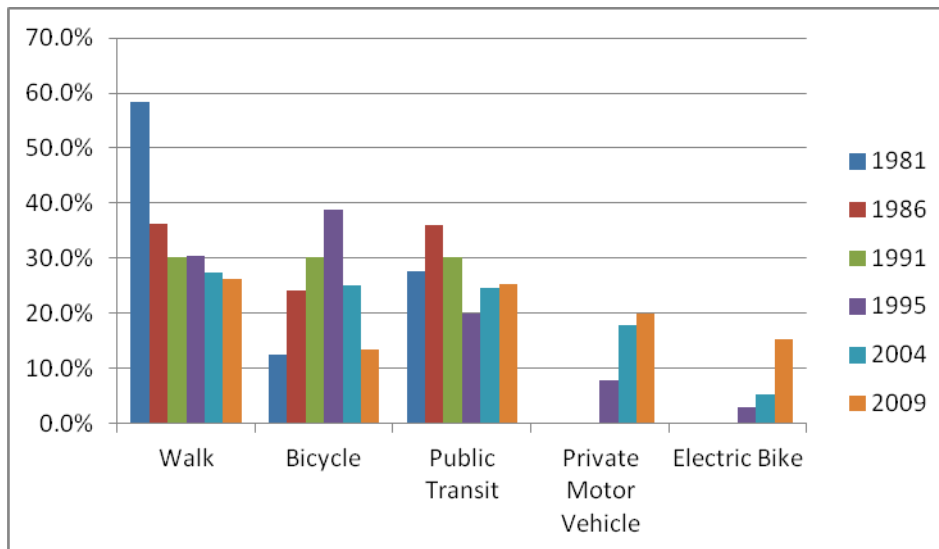


Figure 1 - Mode share comparison across years in Shanghai

Source: The fourth comprehensive travel survey of Shanghai, 2009; Shen, 1997
Note: mode share for private motor vehicle and electric bike is not available before 1995

Motorization can lead to two results. One result is a clear shift from non-motorized modes to private motorized modes. The mode share change in the past three decades is investigated. The modal split data before 1995 is cited from Shen (1997) who indicated Shanghai City Comprehensive Transport Planning Institute to be the original source. The results show that walking has been declining throughout the period between 1981 and 2009; biking peaked in 1995 with a mode share of 38.7% and declined dramatically to 13.5% in 2009; public transit reached its nadir in 1995 and then recovered to 25.2% mode share in 2009; and private motor vehicle and electric bike increased all the way since 1995 (see Figure 1). Overall, people are shifting from non-motorized modes to motorized modes. Within motorized modes, the mode share for private motorized modes is growing much faster than that for public transportation. Road transportation is the key component of the urban transportation system, and is usually where congestion happens. In road transportation, various modes coexist and share similar resources. What directly influences the traffic condition is not how many people on road but how many vehicles (or pedestrian). In Shanghai, while total turnover volume (person kilometers traveled) in road system only increased by 10%, total road traffic volume (PCU kilometers traveled) increased at a faster pace, reaching 133 million pcu-kilometers per day, an increase of 45% from 2004 (see Table 4). This means only 10% out of total 45% increase in traffic volume can be explained by more and longer trips, while the other 35% is mainly caused by rapid motorization, evidenced by significantly rising share of automobiles in both traffic volume and turnover volume. It may be concluded that the major reason for the growing demand in road system is not that people travel more, but people use motorized vehicles more.

Table 4 - Change of the Passenger Traffic Demand Decomposed by Mode in Central City

	Bus	Taxi	Social Motor Vehicle*	Motorcycle	NMV	Total
Traffic Volume						

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10 ⁶ PCU Kilometers	200	6.2	14.81	30.75	8.52	4.67	64.95
	4						
	200	5.8	18.1	60.5	6.8	4.85	96.05
Share	9						
	200	6.7%	16.1%	33.4%	9.3%	5.1%	100.0%
	4						
Change	200	4.3%	13.6%	45.3%	5.1%	3.6%	100.0%
	9						
		-6%	22%	97%	-20%	4%	48%
Turnover Volume							
10 ⁶ Person Kilometers	200	49.92	18.23	75.5	21.4	52.92	217.97
	4						
	200	49.79	19.85	102.35	18.31	48.55	238.85
Share	9						
	200	22.9%	8.4%	34.6%	9.8%	24.3%	100.0%
	4						
Change	200	20.8%	8.3%	42.9%	7.7%	20.3%	100.0%
	9						
		0%	9%	36%	-14%	-8%	10%

Note: The unit for traffic volume is 10⁶ pcu-kilometers per day, and the unit for turnover volume is 10⁶ person-kilometers per day
Source: The fourth comprehensive travel survey of Shanghai, 2009; calculations by author
* Social motor vehicle refers to the motor vehicle other than bus, taxi and motorcycle

The other result of motorization is decreasing vehicle occupancy. While turnover volume for social motor vehicles (motor vehicles other than buses, taxis and motorcycles) only increased by 36%, traffic volume rose by 97%. Dividing turnover volume of social vehicles by traffic volume reveals that the average number of people onboard decreased from 2.5 to 1.7, suggesting more single occupancy vehicles on roads. Therefore, it suggests that people in Shanghai tend to be not only more likely to use motor vehicles, but also less likely to share them with others. Besides, average number of people on board has decreased for taxis and non-motorized vehicles, and increased for bus and motorcycle.

Increasing mode share and decreasing occupancy for private motor vehicles can lead to unequal distribution of road resources. As for road transit, it was responsible for more than 20 percent of turnover volume but only took up about 5% of traffic volume. Similar finding also applied to non-motorized vehicles (NMV). Such distribution of road resources is not efficient, and the situation is worsening as the motorization level in Shanghai continues to go up.

To understand the impacts of traffic on road infrastructure, PCU kilometers traveled may be a better indicator than person kilometers traveled. Again, annual growth rate and annual absolute growth are calculated separately for PCU kilometers traveled (representing vehicle travel demand) and person kilometers traveled (representing person travel demand). It is found that the annual growth rate for vehicle travel demand declined after 2004, which is the same with person travel demand, but the decline for vehicle is relatively less pronounced (see Table 5). The annual absolute growth for vehicle travel demand is in an upward trend, which is the opposite of person travel demand. This suggests vehicle travel demand is growing in a different and possibly more complex pattern compared to person travel demand. In terms of annual growth rate, vehicle travel demand, although growing in a faster rate than person travel, is found to have begun to slow down the pace; but in terms of annual absolute growth, it is still in fast growing and has not reached its peak. This may suggest that transportation demand in Shanghai has been evolving from increasing travel frequency and distance (quantity) to greater travel speed and comfort (quality).

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Table 5 - Change of Motor Vehicle Traffic Volume and Person Travel Demand

Periods	Annual Growth Rate		Annual Absolute Growth	
	Person Kilometers	PCU Kilometers	Person Kilometers	PCU Kilometers
	Traveled ($\cdot 10^6$ km/d)	Traveled ($\cdot 10^6$ km/d)	Traveled ($\cdot 10^6$ km/d)	Traveled ($\cdot 10^6$ km/d)
1986-1995	2.6%	NA	2.69	NA
1995-2004	7.8%	11.0%	12.83	5.92
2004-2009	3.2%	8.1%	7.82	8.26

Source: The fourth comprehensive travel survey of Shanghai, 2009; calculation by author

7. PLANNING AND POLICY ACTIONS

In order to meet the rising travel demand and to mitigate the pace of motorization, the Shanghai local government has developed various measures. Looking back at the history of Shanghai's urban transportation planning ((Xue & Gu, 2011), (Chen & Zhao, 2011), (Wikipedia, 2012), (Shanghai City Comprehensive Transportation Planning Institute, 2000), (Shanghai Municipal Government, 2002), and (W. Shen & Wang, 2006)), three major streams of actions have been taken: building more roads, improve public transportation, and control automobile demand.

7.1 Road Infrastructure

Realizing demand growth and rapid motorization, heavy investments have been made to improve transportation infrastructure and service. A comparison on the balance between road capacity and traffic volume is performed for different region, and the results are shown in Table 6. For the whole city, the road network capacity increased by 90% from 2004 to 2009, compared to an increase of 47% in traffic volume. It seems like the growth in supply has outpaced the growth in demand, but this is not the case for central district. Most of the increase in road capacity is concentrated on suburban area and only very limited improvement is in central district. Although the growth in traffic volume in central district is slower compared to other regions, it is still faster than growth in capacity. As a result, road traffic condition in central district may continue to get worse. This is verified by the change in traffic speed in major trunk roads in central district. Average traffic speed is 15.6 km/h for am peak and 14.8 km/h for pm peak, decreasing by 9% and 3% respectively compared to 2004.

Table 6 - Change of Road Traffic Supply and Demand Decomposed by Region

Region		Capacity (10^6 pcu-km/h)			Volume (10^6 pcu-km/d)			Growth Ratio (Volume/Capacity)
		2004	2009	Change	2004	2009	Change	
Central District	Puxi	1.54	1.64	6%	15.87	18.26	15%	231%
	Pudong	3.6	5.9	64%	3.04	4.90	61%	95%

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	Sum	1.89	2.23	18%	18.91	23.16	22%	122%
Periphery District	Puxi	2.65	3.73	41%	19.73	26.67	35%	86%
	Pudong	1.76	2.68	52%	9.49	14.60	54%	103%
	Sum	4.41	6.41	45%	29.22	41.27	41%	90%
	Central City	6.30	8.64	37%	48.13	64.43	34%	92%
	Suburb	8.95	20.31	127%	39.25	64.26	64%	50%
	Whole City	15.25	28.95	90%	87.38	128.69	47%	52%

Source: The fourth comprehensive travel survey of Shanghai, 2009; calculations by author

Overall, the capacity growth has outpaced demand growth. However, uneven distribution of supply and demand is still a major problem transportation planners are facing. In the future road supply provision should be combined with demand management approaches to solve the uneven distribution. Congestion charging could be set in central area to divert some traffic to other districts. At the same time, in many cases the uneven distribution of demand and supply is not caused by irrational driver decisions, but by poor driver decisions due to lack of information. Thus information provision should also be emphasized on. For example, if a driver is shown that the expressway is congested, he or she may choose a minor road to travel instead.

7.2 Public Transportation

Shanghai has an extensive public transportation system, largely based on metros, buses and taxis. Overall, the total ridership for public transportation has increased a lot, especially since 2000. But the change is different for different component of transit system. Here, only metro and bus are discussed.

Shanghai's metro system incorporates both subway and light railway lines and extends to every core urban district as well as neighboring suburban districts. As of 2010, there are twelve metro lines (including Shanghai Maglev Train), 273 stations and over 420 km of tracks in operation (Shanghai Metro, 2010). Despite of an increase of 176% in metro ridership from 2004 to 2009, the increase in operation mileage is even larger at 260%, (see Table 7). Shanghai's metro network is still under mass construction. According to plan, the total operation length will reach 970 km in 2020 (Y. Zhang, 2007), more than 10 times of the length in 2004. Shanghai's metro system still has plenty of potential in terms of ridership growth.

Shanghai also has the world's most extensive network of urban bus routes, with nearly one thousand bus lines, operated by 43 bus companies (Zhong, 2009). Once having the highest bus ridership in the world, Shanghai's bus ridership is in a decreasing trend, from 84% of total transit ridership in 1995 to 53% in 2009, primarily because of the expansion of metro system. The municipal government has decided to develop metro system as the backbone of the transit system, and adjust bus network to be complementary to metro service (Shanghai City Comprehensive Transportation Planning Institute, 2000). While operation length of bus network increased, number of vehicle trips decreased (see Table 7). This means the overall frequency of bus service has decreased but the service range has improved, indicating that the bus service is shifting to suburban area to serve longer distance travel demand. As a result, the

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bus ridership decreased by 18% in central district, decreased by 4% in periphery district and increased by 54% in suburb.

Table 7 - Change of Supply and Demand in Metro and Bus System

Parameters	Metro			Bus		
	2004	2009	Change	2004	2009	Change
Operation length (km)	92.5	364	294%	3,378	5,903	75%
# of vehicle trips	1,241	2,755	122%	183,482	153,133	-17%
Operation mileage (10 ³ km)	139	500	260%	NA	NA	NA
Ridership (10 ⁶ rides/day)	1.31	3.61	176%	7.75	7.41	-4%
Mode share	3.0%	7.9%	163%	17.9%	15.7%	-12%
Average ride length (km)	9.6	8.8	-8%	6.2	6.6	6%

Source: The fourth comprehensive travel survey of Shanghai, 2009; calculation by author

Overall, it is found that the mode share is growing very slowly compared to the growth in the mode share of private motor vehicles (see Figure 1). This indicates that increasing supply itself may not be a very efficient way. Other measures like marketing and passenger-centered service could also be potentially helpful in attracting ridership. In the future, promoting transit and controlling car use could be further combined. For example, a certain incentive program may be created to offer discounted fare to those who switch from car to transit.

7.3 Demand Management

Although increasing supply could alleviate traffic congestion and improve mobility, it is limited by space and financial resources. Moreover, new supply may induce new demand. Thus supply provision alone cannot completely solve the transportation problem. Demand, especially motorization, needs to be controlled. To control the pace of motorization, Shanghai has issued various transportation policies and strategies across years. As early as 1992 when motorization level in Shanghai was still very low, in the first comprehensive transportation planning of Shanghai, it was clearly stated that the growth of automobiles needed to be controlled in central area through regulating and pricing (Xue & Gu, 2011). Two years later, the license plate auction policy was implemented. The policy was first adopted by Singapore before referenced by Shanghai. In this policy, monthly private auction is used to limit the number of vehicle licenses issued. It has been proven to be effective in damping the growth of motor ownership in Shanghai (Chen & Zhao, 2011). At the same time, public transportation infrastructure and service have been much improved since early 1990s, making transit a viable alternative for private motor vehicle in most cases.

Despite of these efforts to control motorization, the automobile ownership growth is still accelerating. Auto ownership control does not necessarily lead to auto use control to the same extent. For those who managed to get car licenses via auctions, they are likely to use car to take more and longer trips. For example, on average a car runs 39 kilometers per day, 30% more than that of London and 110% more than that of Tokyo (Shanghai Urban Construction and Communications Commission et al., 2010). Two reasons may help explain this. Firstly, one's willingness-to-pay (for the license plate auction) is usually positively related to one's demand for car travel. Secondly, once one got the license, the money paid for the auction

becomes sunk cost. And thus those licensed car users tend to use car more to make the most of it. Therefore, the policy's effects on vehicle ownership control could not be fully translated to effects on traffic volume on road. Further measures on restricting vehicle use may be adopted, for example, congestion charging in the most congested central Puxi area.

8. CONCLUSION

This paper provides insights on the latest trends of travel demand in Shanghai, their causal factors, and the corresponding transportation strategies developed by the municipal government. With a particular focus on the change of demand growth pace over the years, the results of the paper may help to understand how Shanghai's transportation demand has evolved.

Travel demand has been constantly increasing characterized by more and longer trips, but the growing pattern has changed over time. The growth pace (both in terms of growth rate and growth speed) was relative low from 1980s to early 90s, reached its peak from early 1990s to mid 2000s, and then has slowed down since then.

Because of rapid growing personal income, more and more people perform activities that are not related to work/school. Therefore, increase in non-commuting trips is much more significant than the increase in commuting trips. Higher share of non-commuting trips indicates that travel demand in Shanghai has become more diverse. It may favor the convenience and flexibility of private motor vehicles and results in the faster growth in off-peak-hour travel compared to peak-hour travel. With decentralization in the central area of the city and relocation of employment and housing, urban areas in Shanghai has expanded significantly. In result, spatially travel demand is dispersed in two directions: 1) from central districts to peripheral districts because of urban expansion and decentralization; and 2) from Puxi to Pudong as a result of the significant economic development of Pudong New Area. Most of demand growth is likely to be generated in areas with low land use density and transit accessibility, which may further increase travel distance and stimulate the use of private automobile.

Motorization (rather than the natural growth of travel demand) is found to be the major causal factor of the drastic increase in road traffic volume. Two results of motorization are found. The first one is a modal shift from non-motorized modes to motorized modes. The other is the decreasing occupancy of private motor vehicle, meaning people tend to use motor vehicles on their own rather than share them with others. Consequently, vehicle travel demand is growing in much faster speed compared to person travel demand. It is found that in terms of annual growth rate, vehicle travel demand, although growing in a faster rate than person travel, is found to have begun to slow down the pace; but in terms of annual absolute growth, it is still in fast growing and has not reached its peak. This may suggest that transportation demand in Shanghai has been evolving from increasing travel frequency and distance (quantity) to greater travel speed and comfort (quality).

To cope up with the growing demand, the local government has carried out 3 measures, namely, road construction, transit provision and demand management. For road infrastructure, it is found that the traffic volume growth has been much faster than the turnover volume growth. Analysis also shows that although growth rate of road capacity is higher than that of

traffic volume in whole city, demand growth has outpaced supply increase in central district, indicating worsening traffic congestion in the area. For public transportation, while metro ridership increases significantly over the years, the pace of growth still does not meet the growth pace at the supply side. At the same time, slight decrease is found in bus ridership, probably due to the change of role major carrier of passengers to extension of metro system, indicated by the adjustment in the supply side. Since its implementation in 1994, Shanghai's car license plate auction policy has shown certain effects on controlling motorization, but the success cannot be fully translated into traffic volume control.

Shanghai is not the only city facing the dilemma between the ever growing demand for mobility on the one hand and the supply limited by environmental and financial constraints on the other. Planning implications drawn on this study may provide insights to other cities, especially those located in China's coastal regions and those in other developing countries that share with Shanghai some of its major urban transportation planning issues.

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