A Field Study of PRT in Shanghai

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ABSTRACT

The survey objective is to clarify the feasibility of Personal Rapid Transit (PRT), a rail bound transit system, in Shanghai. It includes a technical description of the system, a survey of conditions in Shanghai and statistical analysis of traffic data for Shanghai.

Personal Rapid Transit, or PRT, is the name for a group of pod car systems. The cover page image shows a PRT made by Vectus Ltd., an Uppsala based company. PRT systems are considerably cheaper to build than metro or light rail and the fact that the pods do not stop at intermediate stations makes PRT faster providing higher levels of utilization than other transit systems reducing complete lifecycle costs per person transported.

Shanghai is a province of 19 million registered citizens of whom about 12 million make up the urban population. The main transit systems in Shanghai are the metro, the elevated light rail, buses and taxis. The passenger use trend for all these systems point towards increasing use and demand for affordable transportation in Shanghai is greater than the supply of such transportation at this point.

This survey concludes that PRT is a feasible option for Shanghai. PRT could be utilized further in the future when the demand for safe, fast, and comfortable transit is predicted to grow. The capacity of a PRT system can be estimated in the following manner;

- Safety distance: 3 seconds
- Speed of 50 km/h
- 4 out of 6 seats used

The capacity will amount to 4,800 passengers per hour and if every two pods were to interconnect the capacity would increase to maximum 9,600 passengers per hour. As a comparison, the Shanghai metro lines have a maximum capacity of 30,000 passengers per hour and the light rail half of that. Given the fact that the cost of building PRT is about one tenth of building metro and one forth of light rail it is a superior complement for the transit system in a new modern Shanghai.

Keywords: PRT, Pod Car, Rail Cab, Ultra, Shanghai Transit System
ACKNOWLEDGEMENT

A key driver in the continued development of this project has come from my curiosity and interest in exploring other countries and cultures. My studies here at Uppsala on the Masters program 'Global Energy Systems' has connected directly with my interest in investigating the prospects for a future, sustainable transit system.

I want to thank everybody who has helped me to complete this paper. Most of all I want to thank Professor Kjell Aleklett for making this project possible. I also want to direct special thanks to Professor Pan, Haixiao, Associate Professor Zou, Zhi-jun and Associate Professor Zhang, Jimin at Tongji University in Shanghai as well as Professor Ingamar Andreasson at the Centre for Traffic Research at the Royal Institute of Technology in Stockholm. The Nordic Centre at Fudan University was of great help in this project and therefore I want to thank the manager; Mr. Martin Bech and Assistant Manager; Mr. Paul Dai as well as the office assistant Ms. Mitty Leong from the Nordic Center at Fudan University in Shanghai.
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INTRODUCTION

Statement of Objectives

General Objectives
The general objective of this study is to verify if it is possible and feasible to build a full scale PRT system in Shanghai. This research was initiated as a way to verify whether the architectural transportation solution proposed by the 2007 Master Program (Beyond Oil - Shanghai) at the Royal University of Fine Arts in Stockholm was possible.

Specific Objectives
The specific objectives of this study include:

1. a description of the PRT concept focused on its logistical advantages and disadvantages;

2. a description of the conditions in Shanghai linked to the introduction of PRT. This includes an economic, cultural and logistical analysis of the Shanghai region and its transit systems;

3. a delineation of the problems serving as constraints to the implementation of a new non conventional transit system;

4. a statistical analysis showing quantitative estimates of the capacity of PRT in Shanghai and

5. conclusions concerning the realization of PRT in Shanghai as well as an answer to the Royal University of Fine Arts in Stockholm whether their proposals were feasible.

Methodology
The foundation of this paper relies on the data retrieved by the author during a field trip to Shanghai in April 2009. The two main sources of information were the regional administration in Shanghai and the expertise available at Tongji University. Some of the data was only available in Chinese and so Mr. Xiaochuan Cao from the College of Translation and Foreign Languages at Fudan helped by translating the data.

The only data that is not based on official figures is the estimated travel time for cars within Shanghai. This short survey was made on empirical grounds and does not hold a high level of reliability (see page 20). Even so it is of interesting to note actual traveling speed/times within central Shanghai.

Limitations of the Research
There are many limitations regarding this research considering that it is a 10 week project and not all aspects of the problem could be investigated in such a short period. I have not constructed any type of model, which could simulate a proposed PRT system in Shanghai. This is purely a statistical analysis of the problem.

One obvious bias is the culture difference and the language barriers. Even if the translation and interpretation has been done with great attention and precision from Mr. Xiaochuan Cao from the Fudan University I cannot exclude the fact that there may have been misunderstandings at some point.

Key Terms and Definitions
Pod car = A pod traveling on rail tracks
PRT = Personal Rapid Transit
PCU(E) = Passenger Car Unit(Equivalent)
BACKGROUND

PRT – The Concept

PRT stands for Personal Rapid Transit. These are pod car systems, completely automated transit systems, where a pod will take an individual, or group, from location A to location B without any of the intermediate stops that would be found on a regular rail transit system. PRT systems operate 24-7, providing high customer accessibility. One problem with today’s transit systems, whether they are public or private, is the intermediate stops, where an individual is forced to wait at a station that they specifically have no interest in. Since a pod car in a PRT system there are none of these breaks in the journey, a drastic decreased travel time will be attainable for the individual. Different reports on this issue have concluded that a PRT system is economically feasible for society. Some studies show that an isolated PRT system without the “network efficiency” effects can still be economically beneficial in some cases.

There are many different designs for pod cars and a few are described below, each with their own technical originality. Some of them have been, or are still, in use.

ULTra

ULTra, Urban Light Transport, was developed by Bristol University. The pod cars take 4 passengers every 3 seconds. This system is under construction at the Heathrow Airport in London. Each pod car has its own electrified motor and could be equipped for off track use.

Cabin taxi

This system was in use in Germany until 1979. The pod cars were designed to travel both on and underneath the track.

Morgantown

This system has been in use since 1975 in Morgantown in the US. The pod cars have enough space for 8 people and travel at a speed of 48 km/h. The system has a frequency of 0.067 pods/second or one pod car every 15 seconds. The track is made out of concrete and is operating at ground level.

Vectus

A commercial system of the Vectus design has not yet been built but Vectus Ltd has built a test track, which is operating in Uppsala in Sweden. The pods are designed to carry four passengers at the speed of 45-50 km/h. To comply with current safety standards the distance between each pod car will be 3 seconds.

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1 FOREX (World Wide Web: www.forex.se, 9-Apr-2009) Swedish Bank mostly dealing with currency exchange
2 Vectus Ltd (World Wide Web: www.vectus.se) A company that designs and constructs PRT

1 SEK = 0.83 RMB (Yuan) the Currency of China
Urban Railway = Includes Metro, Light Rail/Commuter Rail
Expressway = equivalent to the European motorway = equivalent of to the American interstate highway
High Speed Pod Car

There is a possibility of high speed intercity pod cars operating at speeds of up to 200 km/h between cities and at 50 km/h within cities. This system would demand tracks of much higher technical complexity and automated controls, especially since the pods would have to merge into pod trains while operating, to lessen air friction.\textsuperscript{7} Vectus Ltd. doesn’t think a high speed PRT is a transportation system for today but one of tomorrow. It would be hard to compete with intercity trains according to Vectus Ltd. The advantage of PRT lies within a city’s boundaries.\textsuperscript{8}

Capacity

Quantity

The capacity of a PRT system depends primarily on the frequency and the average number of people traveling in a pod car. Vectus Ltd. calculates with an average of 1.3 passengers per journey and pod car. The additional seats will be used to a greater extent during rush. Pricing models that subsidies additional passengers will be a part of the concept.\textsuperscript{9}

The frequency of the pod cars transiting the rail infrastructure differs between companies and designs. The range is often 2.5-5 seconds between each pod car on a specific section of rail. Vectus Ltd. has designed its system at 3 seconds/pod car. If the full capacity of 4 passengers per pod car is used, one track will have the capacity of 4800 passenger/h. A modern tram has an equivalent of 4000 passengers/h. If a more realistic number of 1.3 passengers/pod car the capacity will decrease to 1560 passengers/h.

In a report from SIKA, a pod car can be designed to take anywhere between 4-8 passengers. The report states that such a system will have the same capacity on one line as a commuter rail would have (11000-21000 passenger/h, both directions included). With a system where a pod car has 8 seats, the maximum capacity would increase to; 28,800 passengers/h.\textsuperscript{10}

It is not known if a PRT system would actually work in a city at the scale of Shanghai. There is an upper limit of the amount of pods to each track. The capacity could be increased further only if the pod cars were to be combined into trains. Therefore a PRT system in Shanghai would have to have an extensive net of tracks with a huge number of alternative routes between different locations. To have parallel tracks is not the solution since every cross road or major conjunction would become too complex. It would be virtually impossible to design since the tracks would have to be built at different elevation levels.\textsuperscript{11}

Time Savings

A PRT system would, according to figures from SIKA decrease travel time by 60% compared to the bus and by a third compared to trams. A distance of 10 km would take 28 min on the PRT, 44 min by tram, 57 min by commuter rail and 70 min by the bus.\textsuperscript{12} These estimates include walking and waiting time.

Cost/Benefit

A PRT system has proven to be socioeconomically beneficial according to calculations made by SIKA.\textsuperscript{13} SIKA has estimated that the life span of a PRT system to 40 years. The discount rate was set at 4% and the cost of capital

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\textsuperscript{7} SIKA (2006:2, page 24) Report from Transek and Logistikcentrum AB: GTS-Generellt Transportsystem

\textsuperscript{8} Ogéus, Maria (Interviewed by Anton Redfors 6-Mar-2009) Project Manager at Vectus AB

\textsuperscript{9} Ogéus, Maria (Interviewed by Anton Redfors 6-Mar-2009) Project Manager at Vectus AB

\textsuperscript{10} SIKA (2008:5, page 24) Report: Utvärdering av spårbilssystem

* It is not clarified how SIKA is expecting the PRT units to be saturated to such a high extent.

\textsuperscript{11} Professor Andreasson, Ingmar (Interviewed by Anton Redfors 2009-03-25) Professor at the Center for Transportation Research at the Royal Institute of Technology in Stockholm

\textsuperscript{12} SIKA (2006:2, page 60) Report from Transek and Logistikcentrum AB: GTS-Generellt Transportsystem
rate was set at 6.5%. The cost of building the track includes stations, and was set to 100 MSEK/km.\textsuperscript{14} SIKA has analyzed the construction of a full scale PRT system in Stockholm. The investment cost for such a system would be in the region of 16.55 billion SEK. If the cost of the track could be reduced to 70 MSEK/km it would cost 11.60 billion SEK. A comparison to a light rail system was made in the SIKA analysis and the investment cost for such a system was estimated to be 10.20 billion SEK.

The scale is very important for the PRT since a small system does not get the network effect that a larger system gets. If 25\% of the people reaches 25\% of its destinations 6.25\% of the population (25\%*25\%=6.25\%) would be able to use the PRT system. If built in a larger scale to the extent where 90\% of the people reach 90\% of their destinations 81\% of the population (90\%*90=81\%) would be able to use the PRT system.

**Technical Issues**

**Energy Efficiency**

A pod car system is not necessarily energy efficient and available figures vary a lot depending upon the source. The following schedule shows the energy efficiency ratio for different means of transportation. The figures are taken from Transek AB.\textsuperscript{15}

<table>
<thead>
<tr>
<th>Means of Transportation</th>
<th>Power [kW]/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferry</td>
<td>10.2</td>
</tr>
<tr>
<td>Car</td>
<td>9.4</td>
</tr>
<tr>
<td>Railway</td>
<td>6.5</td>
</tr>
<tr>
<td>Bus</td>
<td>4.5</td>
</tr>
<tr>
<td>Railcab (ULTra)</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*Table 1. Energy Consumption Comparison (Source: Transek AB, Consulting Firm)*

Professor Ingmar Andreasson at the Royal Institute of Technology estimated together with Vectus Ltd. that energy consumption is somewhere in the range of 7 kW/pod.\textsuperscript{16} PRT is often hailed as environmentally friendly but it really depends on how the electricity was generated. If the electrical power supply is dependent on coal-fired power plant then the rate of efficiency is roughly 30\%. That means that the estimates from Transek (above) are misleading. The actual power consumption would then be $\frac{1.8}{0.3} = 6$ kW coal/person. Either way the PRT consumes way less power per pod than a car does but the energy source is essential to understand the whole picture.

The pod car will consume electricity momentarily from the grid. The PRT can be designed to have the power supplied through the track or from an in pod power plant, either way, it is powered by electricity. Depending on how the electricity was produced, a PRT system does not rely on oil.

**Automation Control**

The automated control of a full scale PRT system (high speed tracks excluded) has been mentioned as problematic. The idea is to have a track where all pod cars are traveling at the same speed. At the station, the pod car will automatically change to a different lane where the speed will be reduced until the pod can unload. Pod cars will always be waiting for people at a station to minimize waiting time in a PRT system. The technical

\textsuperscript{13} SIKA (2008:6) Report: *Infrastructural planning for increased policy achievement within the transportation sector*

\textsuperscript{14} IST (2008:1) Report: *Sustainable Development: New transportation system podcasts, Study in Eskilstuna Kommun*

\textsuperscript{15} Transek AB, Consulting Firm Transek AB presented this information as if they were lobbying for a PRT System, which could be conflicting with the objectiveness of the information

\textsuperscript{16} Professor Andreasson, Ingmar (Interviewed by Anton Redfors 2009-03-25) Professor at the Center for Transportation Research at the Royal Institute of Technology in Stockholm
solution is ready as well as the automated control. According to Vectus Ltd. they already have a system in place, which they can build today.\(^\text{17}\)

The issue of capacity plays a role here. With increased speed the required safety margins between the pod cars increases, which leads to a reduction in capacity. To increase capacity, several pod cars could be combined into pod car trains. This would demand a very advanced level of automation control. According to Professor Ingmar Andreasson it has yet to be done.

Due to security regulations the pod cars could only be disconnected while traveling, which means that the connection of pod cars would take place at a station. Technically and logistically, it will be difficult to design such a system, yet not impossible.\(^\text{18}\)

### Speed

In the report from SIKA 2006:2, they describe a futuristic vision where pod cars could be linked into pod car trains and travel on high speed tracks between cities. This system is called a GTS, General Transportation System, and would be able to replace other means of transportation on all but the longest journeys. The high speed system is examined in this study and it is not currently economically feasible according to Ogéus, M. project manager at Vectus Ltd.

Light rail usually travels at a speed of around 80 km/h. The optimal speed depends upon the distance between two stations. The speed has to be attainable between the acceleration phase and the retardation phase.\(^\text{19}\) For PRT this problem poses no problems because there are no intermediate stops. The limitations are instead the safety distance between pod cars. With increased speed the safety distance must increase. The result is decreased capacity. The optimal speed is 40-50 km/h according to Vectus Ltd.

### Design

There are many different ways to design a PRT system. Figure 1 shows a variety of technical solutions. They all have their advantages and disadvantages.

### Sociological Acceptance

It is hard to know how a PRT system would affect traffic flow. If a road network is saturated, a PRT system would relieve the roads for a period, but only to see them fill up once more over time. The Southern Link (Södra Länken) in Stockholm is an example of that. It increased capacity but after a year it is once more saturated with vehicles.\(^\text{20}\)

\(^{17}\) Ogéus, Maria (Interviewed by Anton Redfors 6-Mar-2009) Project Manager at Vectus AB

\(^{18}\) Professor Andreasson, Ingmar (Interviewed by Anton Redfors 2009-03-25) Professor at the Centre for Transportation Research at the Royal Institute of Technology in Stockholm

\(^{19}\) Troche, Gerhard (Interviewed by Anton Redfors 20-Mar-2009) FOFU-Engineer at Traffic and Logistics at the Royal Institute of Technology in Stockholm

\(^{20}\) Professor Kottenhof, Karl (Interviewed by Anton Redfors 2009-03-24) Professor at the Center of Transportation Research at the Royal Institute of Technology

![Figure 1. Different Technical Solutions](source: SIKA, Statens Institut för Kommunikationsanalys (2008:5) Report: Utvärdering av spårhållsystem)
Studies show that 20% of people who drive would instead use the PRT if it existed. Certain policies could possibly increase that figure. Depending upon the saturation level of the road network it would result in a 0-20% decrease in trips made by cars. That is about the same level as the decrease resulting from the car tax that imposed in Stockholm. Since introduction, the tax has reduced the amounts of trips by cars by 18%.

**CONDITIONS IN SHANGHAI**

**Shanghai Region**

Shanghai is made up of 19 districts. In 2005, when the last survey was done 17.78 million people were registered as residents in Shanghai, of whom 11.49 million were urban residents. The most densely populated and central of them, which are also the ones suitable for the PRT system, are; Pudong (570 km² - 1,766,900 people); Xuhui (54.76 km² - 884,000 people); Changning (37.19 km² - 610,000 people); Putuo (54.99 km² - 843,600 people); Zhabei (29.2 km² - 810,000 people); Hongkou (23.45 km² - 860,000 people); Yangpu (55.53 km² – 1,240,000 people); Huangpu (12.47 km² – 575,000 people); Luwan (8.03 km² – 328,000 people); Jing’an (7.62 km² – 351,300 people).

The residential areas of Shanghai are evenly distributed throughout the city. Industrial areas, on the other hand, are located outside the city and consist of seven major industrial hubs, such as the Shanghai Auto City. 50% of the urban population use normal transportation (walking, biking or the use of electric bikes) to get to and from work. The average distance to work is 6 km.

**Means of Transportation**

**Metro and Light Rail**

Shanghai has eight metro lines and light rail services (elevated metro lines, Figure 2.) and there are three more under construction. Shanghai is planning for these to be ready for the 2010 WorldExpo. These 11 lines will result
in an increase from 230 km of metro lines in 2005 to a total of 640 km by 2010.\textsuperscript{25} By 2020 it is estimated that the length of urban railway will be 780 km consisting of 17 lines. The intention is to cover 40% of Shanghai’s passenger transit demand. Maximum capacity will be over 10 million passengers per day, compared to today’s maximum of 3 million passengers per day.\textsuperscript{26} During 2007 the metro made 814 million passenger trips. There were 1,117 carriages on the metro system and the number is increasing by 100-300 carriages every year.\textsuperscript{27} Opening another three metro lines will increase this number considerably in the near future. The capacity of Shanghai’s metro lines is; 30,000 people/hour per line one way.\textsuperscript{28} 

There are additional plans to extend the urban railway to 1000 km by 2030. It will then be one of the world’s largest metro systems but still topped by the 2000 km urban railway system of Tokyo.\textsuperscript{29} The speed of trains on the urban railway is a maximum of 80 km/h in the central parts of Shanghai but increases to 120 km/h within certain areas in the suburbs and outside Shanghai. The average speed over an entire line varies but according to Professor Zhang at Tongji University it is around 40 km/h.\textsuperscript{30}

The price for a single trip journey is 3-4 RMB (3.6-4.8 SEK) on the metro.\textsuperscript{31} This is considerably cheaper than the metro system in Paris (€1.50) or Stockholm (22.5 SEK per trip if you buy eight trips for 180 SEK).

The cost of building metro lines is almost the same as that in western countries according to Professor Pan Haixiao at Tongji University, at 70 million euro/km. The elevated light rail in Shanghai cost less, about 200-400 million RMB/km including the demolition of buildings.\textsuperscript{32}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Investment Figures for the Transportation Sector (Source: Shanghai Statistical Yearbook 2008)}
\end{figure}

\textsuperscript{26} Associate Professor Zhang, Jimin (Interview by Anton Anton Redfors, 14-April-2009) Associate Professor of Urban Railway and Mass Transit Institute at Tongji University in Shanghai
\textsuperscript{27} Shanghai Statistical Yearbook 2007 (World Wide Web: \url{http://www.stats.sh.gov.cn/2003sh/tjnj/nj08.htm?d1=2008tjnj/C1012.htm} Translated by Xiaochuan Cao from the Department of Translation and Interpretation at Fudan University
\textsuperscript{28} Professor Pan, Haixiao (Interviewed by Anton Redfors, 10-Apr-2009) Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai
\textsuperscript{29} Professor Pan, Haixiao (Interviewed by Anton Redfors, 10-Apr-2009) Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai
\textsuperscript{30} Associate Professor Jimin Zhang (Interviewed by Anton Anton Redfors, 14-April-2009) Professor of Urban Railway and Mass Transit Institute at Tongji University in Shanghai
\textsuperscript{31} Redfors, Anton (Field Trip to Shanghai Apr-2009)
The local government and policy makers in Shanghai are looking into automatic metro lines as a way to increase capacity. There are also discussions concerning a new type of elevated light rail, which has rubber wheels instead of steel. This was first introduced in large scale in Paris, France.  

**Car**

Shanghai had 11,496 km of highways by the end of 2008. Of these, 637 km are expressways, 364 Class I highways (see Appendix 3 for classification specification), 2,775 Class II highways, 563 km national highways, 897 km provincial highways and 2,272 km of country roads. There are a number of in- and outbound expressways in Shanghai that are interconnected by an inner and outer expressway ring. Even so, the Shanghai expressways are still occasionally subjected to long que. The urban planners in the regional government are planning to extend the expressways by building more radians leading in and out of the city. It implies very high costs since the demolition of buildings has to be absorbed in the budget. By 2020 the plan is to have 1000 km of arterial expressways and 2000 km of arterial highways of other classes.

The consumption of vehicle fuel was 278,500 tons of petroleum in 2007. That figure has been rising sharply in past years up from 42,700 tons in 1990 to 204,700 tons in 2000.

**Bus**

Buses are a popular mass transit system and Shanghai has one of the most extensive bus systems in the world. The price for a single trip on a bus is 2-3 RMB (2.4-3.6 SEK). These ticket prices are subsidized by the government and do not reflect the real marginal cost. By the end of 2007 there were 16,672 busses operating on 22,375km of bus lines in Shanghai. Together, the 991 bus lines had 2.65 billion passengers in that same year. The bus system still serves considerably more people than the metro. The capacity of the bus transit system is 10,000-15,000 people/hour per bus line one-way.

The estimated investment cost of an existing bus line is 50 million RMB/km on average (60 million SEK). To build a new bus line implies building new roads, which would be much more expensive.

The local administration of Shanghai are building separate lanes for public transportation. The system of traffic lights will be synchronized so that bus lines will be able to increase their capacity. The system is called BRT, Bus Rapid Transit. By October of 2010 Shanghai will have 300 miles of these roads to separate public transportation from other forms of transport.

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32 **Associate Professor Jimin Zhang** (Interviewed by Anton Redfors, 14-April-2009) **Professor of Urban Railway and Mass Transit Institute at Tongji University in Shanghai**
33 **Professor Pan, Haixiao** (Interviewed by Anton Redfors, 10-Apr-2009) **Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai**
35 **Redfors, Anton** (Field Trip to Shanghai Apr-2009)
36 **Associate Professor Zou, Zhi-jun** (Interview by Anton Redfors, 10-Apr-2009) **Associate Professor at the School of Transportation Engineering at Tongji University in Shanghai**
37 **Standard of Highway Engineering (JTG B01-2003) Department of Highway of Ministry of Transport of the People’s Republic of China & Committee of Highway Engineering of China Association for Engineering Construction Standardization**
40 **Professor Pan, Haixiao** (Interviewed by Anton Redfors, 10-Apr-2009) **Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai**
41 **Yang, Xiaoping** (Interview by Anton Redfors, 9-Apr-2009) **Engineer at the Shanghai Highway Administration Office**
Shanghai has launched a pilot project where bus line 11 runs on electricity. The new technology does not need batteries but is based on capacitors, which are charged in between every trip.

**Railway**
The train services in Shanghai transported 43.13 million passengers in and out of Shanghai in 2005.41

**Ferry**
There are 96 road lanes crossing the river Yangtze, the main reason behind a reduction in the number of people traveling by river. The number of ferries has gone down from 111 in 1990 to 55 in 2007. In 1990 374 million people used the ferries and by 2007 that figure was down to 113 million.

**Non-motorized and Motorized Bikes**
Regional government policy has been to reduce the number of bikes on the roads. The car lanes have been expanded at the expense of bike lanes. However, in recent years there has been a policy shift. Normal transportation (walking, biking and the use of electric bikes) is once more promoted. In Shanghai, 50% of the people use normal transportation to go to work.44

Electric scooters are also becoming increasingly popular. They are cheaper since electricity costs only a fraction of gasoline.

**Culture**
There are clear cultural differences between Sweden and China. The way Chinese authorities conduct business is more direct than in Sweden. In Sweden, changing the appearance of a city or introducing a new transit system takes many years with a long drawn out legal process involving many appeals. The Chinese process lends itself to rapid and successful introduction of PRT when compared to Sweden.45

One way of introducing PRT in Stockholm soon would be to make the set up so that it would be viewed as a high end transit system. In Sweden that would be close to impossible because of how Swedes view public transportation. In China the system is different and since the levels of congestion within public transportation is severe, it might be politically possible to introduce it as a luxury transit system. It would then be introduced and expanded as a complement to other transit systems.46

The Chinese people are used to following policies set by government. Chinese society is well organized for being a developing country and Shanghai is the most modern city in modern China. The collective culture that has permeated Chinese society since the establishment of the People’s Republic of China might make it easier to introduce and operate a PRT system even though it will still require guards at each station to secure the safety of passengers.

Overall the PRT should have a higher chance of success in Shanghai, China than it would have in, for example, Stockholm, Sweden.

**Political Interest**
The political establishment and public administration in Shanghai does not have much knowledge about PRT. The main priority for local government is to build transportation systems that can handle very large volumes of

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44 Associate Professor Zou, Zhi-jun (Interview by Anton Redfors, 10-Apr-2009) Associate Professor at the School of Transportation Engineering at Tongji University in Shanghai.
45 Redfors, Anton (Field Trip to Shanghai Apr-2009)
46 Redfors, Anton (Field Trip to Shanghai Apr-2009)
passengers rather than building the fastest or most convenient one. Currently the focus is to extend the metro system to 11 lines by 2010 and build more elevated Express Highways since they have very large capacity. A realization of a PRT system would only be possible if it did not interfere with road construction, since they have highest priority. Professor Zhang at Tongji University believes that interest within regional government will remain low until urgent transit needs have been fulfilled. The professor still thinks the policy makers will not see PRT as suitable for Shanghai beyond 2030.

Looking at transportation investment figures for Shanghai, one can conclude that the construction of a pod car system would be a major cost. In 2007 Shanghai invested 84 billion RMB (101 billion SEK) on the transportation sector. The cost of building a full scale PRT system in Stockholm (1/10 of Shanghai’s urban population) was estimated to be 11.6–16.6 billion SEK by SIKA. The construction of a PRT in Shanghai would require a major portion of the local investment budget. On the other hand, China has shown itself able to pursue difficult and costly projects if the political will is there.

Shanghai will be the host for the WorldExpo 2010, which is going to be a major event for the city. A PRT system has been a part of the discussions of a transit system for the millions of visitors expected to see the exhibition. One company has proposed to build a PRT but has not so far received official approval. The planned routes would be limited but could work as a catalyst for policy makers to consider PRT more seriously as an alternative to conventional mass transit systems in the future.

**Maglev Train**

Shanghai has two major international airports attached to the city. The Pudong International Airport and the Hongqiao Airport. Shanghai seeks to develop Pudong Airport as a top level Asian-Pacific aviation hub for passengers and cargo. The goal is to reach 100 million passengers (currently 80 million) and there is little motivation to build a PRT as an additional connection to the city center and the business districts as the metro is considered to be enough at the moment. There are instead plans to connect the central parts of Shanghai with the other major airport, Hongqiao. It would mean doubling the existing maglev track.

The trip from the airport to the city of Shanghai costs 50 RMB (60 SEK). The cost of a trip is expensive by Chinese standards and hints at how cheap/costly a PRT system must be if passengers are to use it.

Shanghai has a very modern maglev train that connects Shanghai City, if not the central parts, with the Pudong International Airport. It is a major transport feed for business passengers to and from the airport and has a maximum speed of 430 km/h. By maglev train the transit takes seven minutes. Metro line 2 connects the maglev train and the city metro system.
TRANSIT DATA FOR SHANGHAI

Public Transportation

Buses

The bus system in Shanghai was expanded until 2002. Since then a slight decrease in the number of public buses has been witnessed. It is not a decrease in demand for transit that we see, only a diversion of transit flows from buses to taxis and the extended metro system. The extremely high levels of 1990 is explained by the fact that there was no metro system in place at that time and the road network was very limited.

The decrease in passenger volume for buses between 2006 and 2007 was 90 million passenger trips. At the same time the metro system increased its passenger volume by 160 million passenger trips.

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54 Buses: 2.74 billion passenger trips (2006), 2.65 billion passenger trips (2007). Metro: 0.66 billion passenger trips (2006), 0.81 billion passenger trips (2007). (Source: Shanghai Municipal Engineering Administration, Urban Transport Authority)
Urban Railway

The growth of the metro system correlates with the physical extension. A couple of new lines have opened over the last years. New lines have approached their maximum capacity rapidly, displaying high levels of saturation on the metro system.

Private Transportation

Taxi

Figure 6 shows the rapid growth in numbers of taxis during the 90s. The growth has leveled off since then but is still increasing. It is quite affordable to travel by taxi in Shanghai. A trip from People’s Park to Fudan University (Crowne Plaza Campus) is a trip of about 10-15 minutes and costs around 30-35 RMB.\(^{55}\)

It is possible that the supply of taxis has met demand. It is also reasonable to believe that the extended metro system is a substitute to taxis for many citizens. A third possible explanation for Figure 6 is the limitation on cars in Shanghai imposed by the local administration. The right to register a car in Shanghai is auctioned. For a long time cars were prioritized in Shanghai but policymakers are undertaking a major shift in favor of normal* transportation at the expense of cars.\(^{56}\)

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\(^{55}\) Redfors, Anton (Field Trip to Shanghai Apr-2009)

\(^{56}\) Professor Pan, Haixiao (Interviewed by Anton Redfors, 10 Apr-2009) Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai
The operating mileage for taxis has not leveled off at the same pace as the number of taxi cars. From year 2000 each taxi car has increased the number of miles travelled. By the end of 2007 there were 48,614 registered taxi cars in Shanghai. It shows that there is demand for more high end transit systems that are faster and where people do not travel collectively. PRT meets these demands as well as reduces traveling time.

![Operating Mileage for Taxis](image)

Figure 8 shows the result of a small empirical survey made by the author in Shanghai, on 20-April-2009. It compares the travel time for different car trips in central Shanghai. As a reference Google Maps has been used to calculate the theoretical speed and time. During smooth traffic flow the actual time taken is almost twice that derived from Google Maps and average speed is 28.9 km/h. During rush hour the estimated time is around three times that of Google Maps. The average speed is now 15.7 km/h. These estimates include the use of the expressways.

<table>
<thead>
<tr>
<th>Smooth Traffic [h]</th>
<th>Distance [km]</th>
<th>Estimated traveling time by Google [min]</th>
<th>Estimated traveling time by Taxi Drivers [min]</th>
<th>Average Time [h]</th>
<th>Average Speed [km/h]</th>
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</thead>
<tbody>
<tr>
<td>People’s Square → Fudan University</td>
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<td>14</td>
<td>23.88</td>
<td>0.40</td>
<td>29.15</td>
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<tr>
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<td>14</td>
<td>18.48</td>
<td>0.31</td>
<td>21.75</td>
</tr>
<tr>
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<td>11</td>
<td>27.6</td>
<td>0.46</td>
<td>30.65</td>
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<tr>
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<td>13.2</td>
<td>16</td>
<td>23.4</td>
<td>0.39</td>
<td>33.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rush Hour [h]</th>
<th>Distance [km]</th>
<th>Estimated traveling time by Google [min]</th>
<th>Estimated traveling time by Taxi Drivers [min]</th>
<th>Average Time [h]</th>
<th>Average Speed [km/h]</th>
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</thead>
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<td>45</td>
<td>0.75</td>
<td>8.93</td>
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<td>16</td>
<td>43.65</td>
<td>0.73</td>
<td>18.14</td>
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</table>

Table 2. Time and Speed Estimates (Source: 5 random taxi drivers were asked how long different trips in Shanghai city center would take)

The average speed makes the car a time consuming transit. The PRT out competes cars/taxis in this regard since the average speed would be two or three times that of a car. A ten km trip during smooth traffic flow with a car would take 21 min* and 12 min** using PRT. In rush hour the car would make the trip in 38 min***.

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57 Shanghai Metropolitan Transportation Authority, the Urban Management Office

*10 km/28.8 km/h = 0.346 h ≈ 21 min
**10 km/50 km/h = 0.20 h = 12 min
***10 km/15.7 km/h = 0.637 h ≈ 38 min
Cars

The number of cars on the roads in Shanghai increase steadily as can be seen in Figure 9. According to Professor Pan Haixiao at Tongji University the road network in Shanghai is saturated. New roads must be built in order to sustain the growth in number of cars.

![Private Automobiles](source)

Figure 9. Private Automobiles (Source: Shanghai Metropolitan Transportation Authority, the Urban Management Office)

In Figure 10 the flux of people between Central Shanghai, the Suburbs and the Outskirts is shown. 1, 2 and 3 stands for Central, Suburbs and Outskirts respectively. The largest movement of people and vehicles is between different suburbs. There is a similar magnitude of movement between the central parts and the suburbs but not quite as large. The flux of people in and out of Shanghai city centre was up 54% between 1995 and 2004, from 5.1 million to 7.2 million trips per day.

![Flux of People](source)

Figure 10. Flux of People In and Out of Shanghai (Source: Professor Pan, Haixiao (Interviewed by Anton Redfors, 10 Apr 2009) Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai)
The capacity of the expressways is about 10,000 minibuses per lane per day (24 hour) or equivalent (see Appendix 3). The width of a lane is ~3.5 m which renders a capacity of 2857 minibuses per day per meter (width). The track of a PRT has a width of less than a meter but the pod itself is two meters wide. If the speed is 50 km/h with 2 seconds safety distance the capacity will amount to 1800 pods/hour or 10,800 pods per 12 hour day per meter (width). The ratio of full to empty seats on the minibuses and the pods will determine the exact outcome but it shows that PRT has a high capacity relative to the amount of space it utilises. Figure 11 shows the capacity figures for 6 out of Shanghai’s 23 expressways. The figures are from 2003 but it is realistic to assume that the figures look similar today since the congestion levels historically have been very high, 91% on average since 2005.

### CONCLUSIONS ON PRT IN SHANGHAI

**Capacity**

The capacity of PRT depends upon the assumptions being made. A realistic assumption, according to Professor Ingmar Andreasson at the Royal Institute of Technology, is one pod car every 2 seconds, traveling at a speed of 50 km/h. 1,800 pods will then pass a certain point every hour. If 4 out of 6 seats are filled, the capacity is 7,200 passengers per hour and if every two pods were to merge it could be increased to maximum 14,400 passengers per hour. The Shanghai metro lines have a maximum capacity of 30,000 passengers per hour and the light rail; half that, which is close to the capacity of PRT. The capacity of an expressway in Shanghai is considerably lower, see Figure 13.

<table>
<thead>
<tr>
<th>Transit System</th>
<th>Capacity [passengers/h]</th>
<th>Cost [million Euro/km]*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro</td>
<td>30000</td>
<td>70</td>
</tr>
<tr>
<td>Light Rail [passengers/hour] (including the cost of carriages)</td>
<td>15000</td>
<td>30</td>
</tr>
<tr>
<td>Expressway** [vehicles/lane/hour daylight]</td>
<td>249</td>
<td></td>
</tr>
<tr>
<td>PRT (single pod every 2 seconds, 4/6 seats)**</td>
<td>7200</td>
<td>8</td>
</tr>
<tr>
<td>PRT (double pod every 2 seconds, 4/6 seats)**</td>
<td>14400</td>
<td>8</td>
</tr>
</tbody>
</table>

*Including the cost of demolition of buildings for light rail and highway
**60% cars, 37% minibuses, 3% large buses
***Does not include the cost of carriages

Table 4. Capacity Comparison (Source: Metro and Expressway: Professor Pan Haixiao, Light Rail: Associate Professor Jimin Zhang, PRT: SIKA (2008:5)

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58 Shanghai Highway Administration Office (World Wide Web: [http://www.highway.sh.cn/jb/shucm/node13/node1061/index.html](http://www.highway.sh.cn/jb/shucm/node13/node1061/index.html)) Translated by Mr. Xiaochuan Cao from the Department of Translation and Interpretation at Fudan University (See Appendix 13)
Figure 11 shows the pattern of movement within Shanghai province and the movement between suburbs is the largest. The situation is suitable for PRT since it is desirable to build major hubs with high passenger flows. To further divert passengers from cars to PRT effort has to be put into building high capacity car parks.

It is obvious that the primary need for Shanghai today is to build and extend high volume capacity transit systems such as the urban railway. There is really nothing that can compete with it. Even so, the expansion will not keep up with the demand for transportation, especially non-public transportation. PRT could become a transit system for those who otherwise would have chosen the car. Its characteristics make PRT a good substitute for passengers who demand fast and comfortable transit.

**Saving Time**

Most transit systems are time consuming. In this regard PRT is superior to all other mass transit systems. Research made in Stockholm, Sweden, by SIKA shows that it reduces travel time by 60% compared to buses and by one third compared to trams. A distance of 10 km would take 28 min with the PRT, 44 min by tram, 57 min by commuter rail and 70 min by bus. \(^{19}\) In central Shanghai time savings would amount to 43% during smooth traffic flow and 68% during rush hour with PRT compared to a car, see Table 1.

**Cost**

The cost of building PRT is considerably lower than for both metro and light rail. Due to the small and light nature of the track the cost is only about one tenth of building metro tunnels and one forth of building elevated light rail. Since the capacity for PRT is close to, or the same as for light rail (combining two pods into one unit), the ROI for PRT is desirable.

**Success of PRT in Shanghai**

The success of PRT in Shanghai depends on the following factors:

- policy making
- economy
- social acceptance
- user friendliness
- energy supply

The conclusion of this survey is that the most important factor is policy making. If the political establishment embraces PRT its success is likely. Past effective policy decisions have been implemented due to a high level of commitment by the wider society. Therefore I conclude that PRT will be successful in this regard.

The economic feasibility of PRT is the second most important factor. Since it has shown to be cheaper than comparable transit systems relative to its capacity it will be successful in this regard. But if PRT ends up becoming much more expensive than stated, the premises will change.

Heavily subsidized public transportation is not controversial in China, which will make it easier to introduce PRT even if it does not prove cost effective at first. It is possible that subsidies will make it more difficult to advertise it as a luxurious transit system for the middle class.

Social acceptance would be the most important factor in Sweden. In Shanghai on the other hand, the society has been and is still going through big changes of modernization. There is a greater acceptance in Shanghai towards new systems since most citizens enjoy the modernization of their city. The extension of the metro system is an example of that. PRT would probably be seen as another improvement rather than here in Sweden where many... 

\(^{19}\) SIKA (2006:2, page 60) Report from Transek and Logistikcentrum AB: *GTS-Generellt Transportsystem*

*ROI = Return On Investment*
people would see it as an intrusion. Even if there are people in Shanghai who would object they have limited power to stop the authorities.

It is important that people use the PRT system as soon as it has been introduced. The lack of reliability, safety and comfort could undermine PRT. Especially reaching high levels of reliability seems uncertain. Accidents make PRT fragile since it will have domino effects on large parts of the system.

The energy infrastructure is important but does not threaten the introduction of PRT in Shanghai. China is currently planning expansion of nuclear power and the Three Gorges Dam is soon to be opened. On the other hand, during peak periods the power infrastructure could pose a problem. Air conditioning in Shanghai consumes half of the total power consumed in the summer for example and the PRT would put an additional strain to the system.

The overall conclusion is that PRT will be successful in Shanghai. PRT could be successful today but has a higher possibility of success in years to come. More urban citizens and more economic activity will increase the demand for flexible, safe, fast and reliable transit and PRT meets those demands to a high extent.

**BEYOND OIL - SHANGHAI**

**Comments on Report; Resources.07 Beyond oil: Shanghai**

The project team from KKH has made accurate assumptions concerning a future transportation system in Shanghai. Below are some comments to a few of the paragraphs in chapter; “Layin’ the tracks”.

“In a future Luwan, cars still travel the streets, but use biogas and are greatly reduced in numbers. Railbound public transport is the main system for people, goods and waste – the RailCab.” (“Layin’ the tracks”, Paragraph 2)

It is realistic to believe that rail bound passenger transit will increase greatly. However, it is improbable that cars will be reduced significantly in numbers since the road network is saturated, meaning that for every car that is taken off the street there are as many waiting to fill that gap. Biogas will probably be used as fuel in cars but electric cars will probably make up the major proportion of cars in Shanghai beyond the oil era. There are many reasons speaking in favor of that, for example the low cost of fuel and zero emissions.

“Accessibility for cars and buses is regulated with different priorities given to vehicles and non-motorized movement on differing streets.” (“Layin’ the tracks”, Paragraph 3)

A PRT system (RailCab) would have to be very extensive before closing down streets for cars. The car is a symbol of freedom and wealth in China almost as much as in America. What speaks in favor of this vision is that today policymakers are starting to shift from promoting cars to promoting normal transportation, meaning; walking, biking and using electric bikes.

“Differently sized vehicles that can be linked to trains allow greater speeds.” (“Layin’ the tracks”, Paragraph 5)

According to Professor Ingmar Andreasson at the Royal Institute of Technology connecting more than two vehicles during operation is technically very difficult. It also does not comply with safety standards since there has to be a certain distance in between two pods during operation. This more advanced system of PRT, which is proposed by; Resources.07 Beyond oil: Shanghai does not exist today and experts are not sure whether it will exist tomorrow.
"RailCab vehicles can be fixed on the track, or be dual-mode, meaning they can use both street and track."

It is not stated clearly how the question of ownership over the pod cars are to be solved. Since it is put forth as public transportation it is reasonable to believe that private ownership will not be possible. Many of the synergies with PRT are lost if the pods are owned privately but problems emerge when a dual mode is proposed.

Summary

Resources.07 Beyond oil: Shanghai has made accurate assumptions concerning technical compatibility and feasibility of the transportation system. I have stated my objections above and they have some implications on the transportation section of the report. The architectural solutions are interesting and when it comes to transportation most of them could be built and would help to create a more sustainable Shanghai.

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12. Transek AB, Consulting Firm Transek AB presented this information as if they were lobbying for a PRT System, which could be conflicting with the objectiveness of the information
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Interviews

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15. Associate Professor Zou, Zhijun (Interviewed by Anton Redfors, 10 Apr-2009) Associate Professor at the School of Transportation Engineering at Tongji University in Shanghai
16. Bech, Martin (Interviewed by Anton Redfors, 1-Apr-2009) *Programme Manager of the Nordic Centre at Fudan University*


18. Professor Andreasson, Ingmar (Interviewed by Anton Redfors 2009-03-25) *Professor at the Center for Transportation Research at the Royal Institute of Technology in Stockholm*

19. Professor Kottenhof, Karl (Interviewed by Anton Redfors 2009-03-24) *Professor at the Center of Transportation Research at the Royal Institute of Technology*

20. Ogéus, Marianne (Interviewed by Anton Redfors 6-Mar-2009) *Project Manager at Vectus AB*

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**Other**

24. Redfors, Anton (Field Trip to Shanghai Apr-2009)


26. Shanghai Museum of Urban Planning (Visited by Anton Redfors, 3-Apr-2009) Address: 100 Renmin Avenue, People’s Square, Shanghai, Phone: +86 21 6318 4477

Appendix 1

Map of Shanghai Urban Railway System in 2009 (Source: Shanghai Municipal Tourism Administrative Commission)
APPENDIX 2

Planned Urban Railway System in Shanghai by 2020 (Source: Associate Professor Zhang, Jimin at Tongji University)


APPENDIX 3

According to this technical classification (based on highway capacity), China’s highways are categorized into five classes: Expressway, Class I, II, III, and IV.

<table>
<thead>
<tr>
<th>Class</th>
<th>Number of lanes</th>
<th>Average daily transportation capacity (unit: 1000 minibuses or equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expressway</td>
<td>4</td>
<td>25-55</td>
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<tr>
<td></td>
<td>6</td>
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</table>


Translator’s note: According to this administrative classification (based on administrative/geographical division of China), China’s highways are divided into five categories: national highways, provincial highways, county roads, township roads, and special purpose roads (a.k.a. “accommodation highways”).

APPENDIX 4
## APPENDIX 5

### Shanghai Investment Figures

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Power Construction</th>
<th>Transportation</th>
<th>Postal &amp; Telecom</th>
<th>Public Utilities</th>
<th>Municipal Construction</th>
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<td>177.89</td>
</tr>
<tr>
<td>2002</td>
<td>583.49</td>
<td>62.14</td>
<td>63.01</td>
<td>108.23</td>
<td>148.42</td>
<td>201.69</td>
</tr>
<tr>
<td>2003</td>
<td>604.62</td>
<td>66</td>
<td>273.77</td>
<td>76.58</td>
<td>36.91</td>
<td>151.36</td>
</tr>
<tr>
<td>2004</td>
<td>672.58</td>
<td>89.52</td>
<td>316.96</td>
<td>54.39</td>
<td>26.92</td>
<td>184.8</td>
</tr>
<tr>
<td>2005</td>
<td>885.74</td>
<td>124.22</td>
<td>385.58</td>
<td>58.32</td>
<td>41.33</td>
<td>276.28</td>
</tr>
<tr>
<td>2006</td>
<td>1 125.54</td>
<td>116.23</td>
<td>589.52</td>
<td>113.72</td>
<td>56.23</td>
<td>249.84</td>
</tr>
<tr>
<td>2007</td>
<td>1 466.33</td>
<td>163.3</td>
<td>840.46</td>
<td>101.57</td>
<td>60.9</td>
<td>300.11</td>
</tr>
</tbody>
</table>

*Note: This table does not include the investment in residential construction investment. Since 2003, investment in transportation facilities, including public investment in public transport in the city.*

APPENDIX 6

Shanghai Petroleum and Gas Situation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas production capacity [10,000 cubic meters/day]</td>
<td>488</td>
<td>984</td>
<td>1,013</td>
<td>1,013</td>
</tr>
<tr>
<td>Gas pipeline length [km]</td>
<td>2,700</td>
<td>6,606</td>
<td>8,778</td>
<td>8,097</td>
</tr>
<tr>
<td>Gas sales volume [100 million cubic meters]</td>
<td>12.15</td>
<td>18.4</td>
<td>19.22</td>
<td>18.5</td>
</tr>
<tr>
<td>Home consumption [100 million cubic meters]</td>
<td>4.27</td>
<td>20.47</td>
<td>26.7</td>
<td>28.75</td>
</tr>
<tr>
<td># Home gas users [10,000]</td>
<td>113.19</td>
<td>255.89</td>
<td>230.22</td>
<td>213.4</td>
</tr>
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</table>

Liquefied gas petroleum

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol sales volume [10,000 tons]</td>
<td>5.97</td>
<td>45.94</td>
<td>45.86</td>
<td>50.65</td>
</tr>
<tr>
<td># Home number petrol users</td>
<td>29.64</td>
<td>239.3</td>
<td>260.1</td>
<td>277.3</td>
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</table>

Natural gas

<table>
<thead>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas sales volume [100 million cubic meters]</td>
<td>2.16</td>
<td>22.58</td>
<td>26.6</td>
<td></td>
</tr>
<tr>
<td>Home consumption [100 million cubic meters]</td>
<td>0.45</td>
<td>3.7</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td># Families using natural gas [10,000]</td>
<td>38.1</td>
<td>216.93</td>
<td>257.9</td>
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</tbody>
</table>

Note: The data in this table provided by the Municipal Engineering Administration.


APPENDIX 7

Shanghai Transit Table I

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of bus lines [km]</td>
<td>18,593</td>
<td>23,260</td>
<td>21,776</td>
<td>22,375</td>
<td></td>
</tr>
<tr>
<td># Bus lines</td>
<td>390</td>
<td>978</td>
<td>944</td>
<td>991</td>
<td></td>
</tr>
<tr>
<td># Operating public transports [vehicles]</td>
<td>6,264</td>
<td>17,939</td>
<td>17,284</td>
<td>16,944</td>
<td></td>
</tr>
<tr>
<td># Busses</td>
<td>5,341</td>
<td>17,358</td>
<td>16,899</td>
<td>16,672</td>
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<tr>
<td>Passenger volume [100 million]</td>
<td>54,377</td>
<td>26,490</td>
<td>27,400</td>
<td>26,500</td>
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</tbody>
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<table>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td># Operating vehicles</td>
<td>11,298</td>
<td>42,943</td>
<td>48,022</td>
<td>48,614</td>
<td></td>
</tr>
<tr>
<td># Small passenger cars</td>
<td>8,095</td>
<td>40,806</td>
<td>45,959</td>
<td>46,758</td>
<td></td>
</tr>
<tr>
<td>Passenger trips [10,000]</td>
<td>2,129</td>
<td>37,599</td>
<td>58,920</td>
<td>57,764</td>
<td></td>
</tr>
<tr>
<td>Operating mileage [100 million km]</td>
<td>3.76</td>
<td>46.48</td>
<td>61.05</td>
<td>60.66</td>
<td></td>
</tr>
<tr>
<td># Business mileage [100 million km]</td>
<td>2.97</td>
<td>24.35</td>
<td>36.72</td>
<td>36.68</td>
<td></td>
</tr>
<tr>
<td>Operating income [100 million RMB]</td>
<td>5.76</td>
<td>76.68</td>
<td>124.97</td>
<td>127.52</td>
<td></td>
</tr>
<tr>
<td># Taxi companies</td>
<td>1,666</td>
<td>25,89</td>
<td>23,022</td>
<td>213.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td># Ferries</td>
<td>111</td>
<td>95</td>
<td>53</td>
<td>50</td>
<td></td>
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<tr>
<td>Passenger trips [100 million]</td>
<td>3.74</td>
<td>1.85</td>
<td>1.19</td>
<td>1.13</td>
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</tbody>
</table>

Note: The data in this table provided by the Metropolitan Transportation Authority, the Urban Management Office to provide shipping.

APPENDIX 8

Shanghai Transit Table II

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Mileage [km]</td>
<td>3050</td>
<td>6078</td>
<td>10392</td>
<td>15458</td>
</tr>
<tr>
<td>High Speed Highways [km]</td>
<td>36</td>
<td>98</td>
<td>581</td>
<td>635</td>
</tr>
<tr>
<td>Annual Tonnage of Each Ton-wagon [10,000 tons*km]</td>
<td>1.72</td>
<td>1.5</td>
<td>0.85</td>
<td>0.79</td>
</tr>
<tr>
<td>Oil consumption of Gasoline Trucks [litre/100 tons*km]</td>
<td>6.5</td>
<td>6.87</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Oil consumption of Diesel Trucks [litre/100 tons*km]</td>
<td>4</td>
<td>4.77</td>
<td>6.6</td>
<td>7.52</td>
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</tbody>
</table>

Shanghai Statistical Yearbook 2008, page 300

APPENDIX 9

Shanghai Rail Transit Data

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Mileage [km]</td>
<td>259</td>
<td>257</td>
<td>269</td>
<td>281</td>
</tr>
<tr>
<td>Mainline Railway Length Extended [km]</td>
<td>356</td>
<td>397</td>
<td>412</td>
<td>415</td>
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</tbody>
</table>

Shanghai Statistical Yearbook 2008, page 300

<table>
<thead>
<tr>
<th>Metro</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating vehicles [carriage]</td>
<td>695</td>
<td>829</td>
<td>1117</td>
</tr>
<tr>
<td># Rail transit lines</td>
<td>6</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Operating line length [km]</td>
<td>147.80</td>
<td>169.40</td>
<td>262.83</td>
</tr>
<tr>
<td>Mileage [10,000 km*train]</td>
<td>1205</td>
<td>1457</td>
<td>1697</td>
</tr>
<tr>
<td>Passenger trips [10,000]</td>
<td>59406</td>
<td>65569</td>
<td>81395</td>
</tr>
<tr>
<td>Total profit [10,000 RMB]</td>
<td>2300</td>
<td>1692</td>
<td>1601</td>
</tr>
<tr>
<td># People employed</td>
<td>7411</td>
<td>8458</td>
<td>12581</td>
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</table>

The elevated bridge and tunnel

<table>
<thead>
<tr>
<th>Viaduct length [km]</th>
<th>77</th>
<th>77</th>
<th>77</th>
</tr>
</thead>
<tbody>
<tr>
<td># Huangpu River Bridges</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td># River tunnels</td>
<td>6</td>
<td>6</td>
<td>6</td>
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</tbody>
</table>

Note: The data in this table was provided by the Municipal Engineering Administration, Urban Transport Authority.

APPENDIX 10

### Flux of People

<table>
<thead>
<tr>
<th>People</th>
<th>1995</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross River Trips, up 73%</td>
<td>1100000</td>
<td>1800000</td>
</tr>
<tr>
<td>Daily Entering+Leaving the City Center, up 54%</td>
<td>5100000</td>
<td>7200000</td>
</tr>
<tr>
<td># Daily average trips entering and leaving the center, up 175%</td>
<td>1200000</td>
<td>3100000</td>
</tr>
</tbody>
</table>

### Vehicles (PCU/day)

<table>
<thead>
<tr>
<th>Passenger Traffic</th>
<th>Central City</th>
<th>Suburbs</th>
<th>Outside of Shanghai Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central City</td>
<td>19219</td>
<td>163364</td>
<td>22714 205297</td>
</tr>
<tr>
<td>Suburbs</td>
<td>173436</td>
<td>342033</td>
<td>28694 544163</td>
</tr>
<tr>
<td>Outside of Shanghai</td>
<td>23146</td>
<td>30913</td>
<td>54059 54059</td>
</tr>
<tr>
<td>Total</td>
<td>215801</td>
<td>536310</td>
<td>51408 803519</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Freight Traffic</th>
<th>Central City</th>
<th>Suburbs</th>
<th>Outside of Shanghai Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central City</td>
<td>16018</td>
<td>88470</td>
<td>27412 131900</td>
</tr>
<tr>
<td>Suburbs</td>
<td>90755</td>
<td>249292</td>
<td>52883 392930</td>
</tr>
<tr>
<td>Outside of Shanghai</td>
<td>24209</td>
<td>52436</td>
<td>0 76645</td>
</tr>
<tr>
<td>Total</td>
<td>130982</td>
<td>390198</td>
<td>80295 601475</td>
</tr>
</tbody>
</table>

Source: Figures provided by Professor Pan, Haixiao (Interviewed by Anton Redfors, 10-Apr-2009) Professor of Urban Planning for Land Use and Transportation at Tongji University in Shanghai

APPENDIX 11

### Traveling Time [h]

<table>
<thead>
<tr>
<th>Smooth Traffic [h]</th>
<th>Taxi driver 1</th>
<th>Taxi driver 2</th>
<th>Taxi driver 3</th>
<th>Taxi driver 4</th>
<th>Taxi driver 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>People’s Square → Fudan University</td>
<td>0.33</td>
<td>0.58</td>
<td>0.5</td>
<td>0.33</td>
<td>0.25</td>
</tr>
<tr>
<td>People’s Square → Xujiahui Park</td>
<td>0.33</td>
<td>0.42</td>
<td>0.29</td>
<td>0.33</td>
<td>0.17</td>
</tr>
<tr>
<td>Shanghai South Railway Station → Pusan Road</td>
<td>0.5</td>
<td>0.5</td>
<td>0.29</td>
<td>0.33</td>
<td>0.42</td>
</tr>
<tr>
<td>Nanpu Bridge → Shanghai Circus World</td>
<td>0.5</td>
<td>0.5</td>
<td>0.29</td>
<td>0.33</td>
<td>0.33</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rush Hour [h]</th>
<th>Taxi driver 1</th>
<th>Taxi driver 2</th>
<th>Taxi driver 3</th>
<th>Taxi driver 4</th>
<th>Taxi driver 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>People’s Square → Fudan University</td>
<td>0.5</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td>People’s Square → Xujiahui Park</td>
<td>0.5</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td>Shanghai South Railway Station → Pusan Road</td>
<td>0.67</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>1</td>
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<tr>
<td>Nanpu Bridge → Shanghai Circus World</td>
<td>0.75</td>
<td>0.83</td>
<td>0.75</td>
<td>0.75</td>
<td>0.58</td>
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APPENDIX 12

### Taxi Service Annual Report 2004

<table>
<thead>
<tr>
<th># Taxi Companies [entities]</th>
<th>857</th>
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</thead>
<tbody>
<tr>
<td>Domestically Owned [entities]</td>
<td>252</td>
</tr>
<tr>
<td>Hong Kong, Macao and Taiwan Invested [entities]</td>
<td>8</td>
</tr>
<tr>
<td>Foreign Invested [entities]</td>
<td>1</td>
</tr>
<tr>
<td>Self-employed [entities]</td>
<td>596</td>
</tr>
<tr>
<td># Taxi Drivers [people]</td>
<td>101603</td>
</tr>
<tr>
<td>End-of-Term # of vehicles in operation [vehicles]</td>
<td>42219</td>
</tr>
<tr>
<td>Number of trips [10,000 trips]</td>
<td>54480</td>
</tr>
<tr>
<td>Total kilometrage [10,000 km]</td>
<td>212208200</td>
</tr>
</tbody>
</table>

## APPENDIX 12

### Shanghai's Outbound Highways

<table>
<thead>
<tr>
<th>Name of the highway</th>
<th>Class of the highway</th>
<th>Total number of lanes (sum of both directions)</th>
<th>Daily traffic volume (vehicles per day)</th>
<th>The number of minibuses in this volume</th>
<th>The number of large buses in this volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>沪太路</td>
<td>I</td>
<td>6</td>
<td>7066</td>
<td>3153</td>
<td>383</td>
</tr>
<tr>
<td>Hutai Road</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>澄浏公路</td>
<td>II</td>
<td>4</td>
<td>3780</td>
<td>1772</td>
<td>47</td>
</tr>
<tr>
<td>Chengliu Highway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>娄陆公路</td>
<td>III</td>
<td>2</td>
<td>5934</td>
<td>2654</td>
<td>131</td>
</tr>
<tr>
<td>Loulu Highway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>沪宜公路</td>
<td>II</td>
<td>4</td>
<td>6816</td>
<td>2615</td>
<td>393</td>
</tr>
<tr>
<td>Huyi Highway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A12公路</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A12 Expressway</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>钱蓬公路</td>
<td>III</td>
<td>2</td>
<td>4078</td>
<td>2054</td>
<td>84</td>
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<tr>
<td>Qianpeng Highway</td>
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<td></td>
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<td></td>
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<tr>
<td>上宁高速A11 Huning Expressway, a.k.a. A11 Expressway</td>
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<td></td>
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<td></td>
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<tr>
<td>漕安公路</td>
<td>II</td>
<td>4</td>
<td>13895</td>
<td>7045</td>
<td>542</td>
</tr>
<tr>
<td>Ca'o'an Highway</td>
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<td></td>
<td></td>
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<tr>
<td>昌吉路</td>
<td>III</td>
<td>2</td>
<td>7567</td>
<td>6021</td>
<td>75</td>
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<td>Changji Road</td>
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<td>白石公路</td>
<td>II</td>
<td>2</td>
<td>8060</td>
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<td>Baishi Highway</td>
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<td></td>
<td></td>
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<tr>
<td>北青公路</td>
<td>I</td>
<td>4</td>
<td>10712</td>
<td>5550</td>
<td>44</td>
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<tr>
<td>Beijing Highway</td>
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<td>商周公路</td>
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<td></td>
</tr>
<tr>
<td>Shangzhou Highway</td>
<td>III</td>
<td>2</td>
<td>1561</td>
<td>1029</td>
<td>58</td>
</tr>
<tr>
<td>沪青平公路</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huqingping Highway</td>
<td>I</td>
<td>4</td>
<td>6526</td>
<td>3809</td>
<td>200</td>
</tr>
<tr>
<td>A9公路</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>洲桥汽车公园</td>
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<td>Huhang Expressway, a.k.a. A8</td>
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<td>青平公路</td>
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<td>A4高速公路</td>
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<td>A4 Expressway</td>
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<td>昌青公路</td>
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<td>Linqing Highway</td>
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### APPENDIX 13

#### Shanghai Traffic Data

- **Average traffic (vehicles/day):**
  - Jan-05: 12232
  - Feb-05: 10561
  - Mar-05: 13873
  - Apr-05: 13102
  - May-05: 13094
  - Jun-05: 13016
  - Jul-05: 13466
  - Aug-05: 13572
  - Sep-05: 13240
  - Oct-05: 13170
  - Nov-05: 13308
  - Dec-05: 13584

- **Average traffic (PCU/day):**
  - Jan-05: 12232
  - Feb-05: 10561
  - Mar-05: 13873
  - Apr-05: 13102
  - May-05: 13094
  - Jun-05: 13016
  - Jul-05: 13466
  - Aug-05: 13572
  - Sep-05: 13240
  - Oct-05: 13170
  - Nov-05: 13308
  - Dec-05: 13584

- **Average traffic (PCU/12 hour day):**
  - Jan-05: 12232
  - Feb-05: 10561
  - Mar-05: 13873
  - Apr-05: 13102
  - May-05: 13094
  - Jun-05: 13016
  - Jul-05: 13466
  - Aug-05: 13572
  - Sep-05: 13240
  - Oct-05: 13170
  - Nov-05: 13308
  - Dec-05: 13584

- **Average traffic volume (vehicle*km/day):**
  - Jan-05: 37846148
  - Feb-05: 41543413
  - Mar-05: 40224971
  - Apr-05: 39584940
  - May-05: 39987922
  - Jun-05: 40477482
  - Jul-05: 41307788
  - Aug-05: 41377719
  - Sep-05: 44506862
  - Oct-05: 45391069
  - Nov-05: 4551928
  - Dec-05: 4562840

- **Congestion (%):**
  - Jan-05: 0.87
  - Feb-05: 0.94
  - Mar-05: 0.94
  - Apr-05: 0.93
  - May-05: 0.95
  - Jun-05: 0.97
  - Jul-05: 0.99
  - Aug-05: 1.02
  - Sep-05: 0.89
  - Oct-05: 0.83
  - Nov-05: 0.95
  - Dec-05: 1.19

- **Average speed of vehicles (km/h):**
  - Jan-05: 53.2
  - Feb-05: 52.2
  - Mar-05: 52.8
  - Apr-05: 52.7
  - May-05: 53.1
  - Jun-05: 53.5
  - Jul-05: 52.8
  - Aug-05: 52.3
  - Sep-05: 51.8
  - Oct-05: 51.4
  - Nov-05: 54.4
  - Dec-05: 57.6

- **Average speed of vehicles (day) (km/h):**
  - Jan-05: 49.8
  - Feb-05: 48.5
  - Mar-05: 48.6
  - Apr-05: 48.6
  - May-05: 48.1
  - Jun-05: 47.2
  - Jul-05: 47.3
  - Aug-05: 47.3
  - Sep-05: 46.4
  - Oct-05: 47.6
  - Nov-05: 35.5
  - Dec-05: 44.3

- **Demand Index:**
  - Jan-05: 973
  - Feb-05: 1068
  - Mar-05: 1095
  - Apr-05: 1035
  - May-05: 1034
  - Jun-05: 1028
  - Jul-05: 1054
  - Aug-05: 1045
  - Sep-05: 1128
  - Oct-05: 1017
  - Nov-05: 1001
  - Dec-05: 1024

- **Supply Index:**
  - Jan-05: 1102
  - Feb-05: 1102
  - Mar-05: 1102
  - Apr-05: 1102
  - May-05: 1102
  - Jun-05: 1104
  - Jul-05: 1106
  - Aug-05: 1107
  - Sep-05: 1107
  - Oct-05: 1106
  - Nov-05: 1107
  - Dec-05: 1100

- **Operation Index:**
  - Jan-05: 917
  - Feb-05: 835
  - Mar-05: 1004
  - Apr-05: 1028
  - May-05: 972
  - Jun-05: 986
  - Jul-05: 973
  - Aug-05: 998
  - Sep-05: 1017
  - Oct-05: 978
  - Nov-05: 1070
  - Dec-05: 963

- **Crowded road mileage rate [%]:**
  - Jan-05: 39.9
  - Feb-05: 34
  - Mar-05: 47.1
  - Apr-05: 48.8
  - May-05: 43.9
  - Jun-05: 44.9
  - Jul-05: 46.7
  - Aug-05: 48.3
  - Sep-05: 45.9
  - Oct-05: 52.3
  - Nov-05: 41.3
  - Dec-05: 37.8
  - Jan-06: 41.2
  - Feb-06: 35.3
  - Mar-06: 37.5
  - Apr-06: 41.6
  - May-06: 43.2
  - Jun-06: 43.1
  - Jul-06: 40
  - Aug-06: 38
  - Sep-06: 40.3
  - Oct-06: 42.1


### APPENDIX 14

#### Shanghai Traffic Data

- **Service status (points):**
  - Nov-04: 75
  - Dec-04: 76
  - Jan-05: 75
  - Feb-05: 75.9
  - Mar-05: 76.2
  - Apr-05: 76.8
  - May-05: 76.1

- **Smooth rate [%]:**
  - Nov-04: 73.5
  - Dec-04: 75
  - Jan-05: 73.7
  - Feb-05: 76
  - Mar-05: 77.6
  - Apr-05: 77.7

- **Average travel speed (km/h):**
  - Nov-04: 60.2
  - Dec-04: 62.2
  - Jan-05: 60.3
  - Feb-05: 61
  - Mar-05: 61.4

- **Saturation:**
  - Nov-04: 0.91
  - Dec-04: 0.91
  - Jan-05: 0.91
  - Feb-05: 0.9
  - Mar-05: 0.9
  - Apr-05: 0.9

- **Traffic accidents:**
  - Nov-04: 816
  - Dec-04: 879
  - Jan-05: 767
  - Feb-05: 693
  - Mar-05: 643


### APPENDIX 15

#### Bus Service Annual Report 2004

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>Maj</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Okt</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
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<tbody>
<tr>
<td>737</td>
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<td>718</td>
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<td>780</td>
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## Appendix 16

<table>
<thead>
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<th>Metro Service Annual Report 2005</th>
<th>10,000 train km</th>
<th>10,000 carriage km</th>
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<tr>
<td>Total Distance Covered</td>
<td>1142</td>
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<tr>
<td>Distance Covered with Revenue</td>
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<tr>
<td>Total distance covered carrying passengers</td>
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<td>Number of Train Trips</td>
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<tr>
<td>Number of Train Trips Carrying Passengers</td>
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<td>Passenger Volume [10,000 passenger trips]</td>
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<td>Revenue [10,000 RMB]</td>
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<td>Revenue from Public Transportation Card [10,000 RMB]</td>
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<td>On-time Rate [%]</td>
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<td># On-time Train Trips</td>
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<td>Electric Consumption [10,000 kWh]</td>
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<td>The Electricity Consumption for Traction [10,000 kWh]</td>
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<td># Accidents</td>
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<td># Casualty</td>
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## Appendix 17

<table>
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<th>Vehicle Ownership 2004</th>
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<th>Of this, the Number of Private Ones</th>
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<tbody>
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<td>Of this, the Number of Large Vehicles [vehicles]</td>
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<td>Of this, the Number of Large Vehicles [seats]</td>
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<tr>
<td>Of this, the Number of Medium Vehicles [vehicles]</td>
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<td>Of this, the Number of Medium Vehicles [seats]</td>
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## Appendix 18

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<th>Passenger/Freight Volume on Highways 2004</th>
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<th>10,000 ton</th>
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<td>Freight [10,000 ton]</td>
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