Feedback Loops and Policy Scenarios in The Chinese Private Vehicle Demand Model

Ted Chu, General Motors Corp., USA
Changming Xu, State Information Center of China
Weishuang Qu, Millennium Institute, USA
Ming Liu, State Information Center of China

Millennium Institute
2200 Wilson Blvd
Suite 650
Arlington, Virginia 22201-3357
USA
Tel: 703-841-0048
Fax: 703-841-0050
Email: wqu@threshold21.com

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Abstract

This paper develops a system dynamics model for China's fast growing private vehicle market. The basic structure of the model relating to income and vehicle affordability is presented. Both the baseline projection and the sensitivity cases for private vehicle sales over the next decade are discussed in light of feedback loops between the economy, the vehicle market, the energy sector, and the transportation infrastructure.

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I. Introduction

Since 1978, the Chinese economy has expanded rapidly after Deng Xiaoping launched economic reforms and opened foreign trade. China's GDP was more than quadrupled over the period of 1980 – 2000. For 2000 – 2020, China has ambitious plans to quadruple its GDP again. Now four years have passed since 2000, and the Chinese economy seems to be well on its way toward its goal for 2020, although the structural reforms are still incomplete and political and economic risks are significant. With rapid income growth and market opening following its WTO entry in 2001, China has become the world's biggest emerging vehicle market. The annual sales of motor vehicles in China have grown from 745 thousand units in 1991 to about 4.6 million units in 2003, an average annual growth rate of over 16 percent. Between 1999 and 2003, China accounts for more than 88% of global vehicle demand increases.

The rapidly expanding vehicle market is experiencing profound structural changes. The share of passenger cars in total industry has consistently risen from less than 20% in the 80s to nearly 50% in 2003, so has the share of private vehicles. According to research conducted by the State Information Center of China (SIC), car sales to private buyers was less than 5% of total sales during the 1980s and early 90s. The share was rising but was still below 20% in 1997. In 2002, however, the share exceeded 40%. Of the total vehicles in operation (vehicle *parc*), in 1997 only 14% was private passenger vehicles, but in 2002, its share reached 28%.

The growth of private vehicle ownership will continue to be the main engine of vehicle market growth over the next decade. Without exception, the vast majority of vehicles in developed countries are privately owned and operated. China's private vehicle market has long been suppressed by low levels of family income and by high vehicle prices as a result of the country's restrictive industrial policies, such as a strict production license system, high import tariff rates and local governments' discouragement of private vehicle ownership. With the WTO entry, the Chinese government has committed to sharply lower the import tariff rates from over 100% in early 90s to 25% in 2006 and to adopt other market-opening measures such as allowing foreign companies into the auto financing and insurance business. With domestic demand for most low-valued consumer durable goods becoming increasingly saturated, the government has also recognized the need for a new growth engine and identified the automotive industry as one of its pillar industries (National Statistical Bureau of China, 2002). The vehicle manufacturing industry itself, plus its upstream and downstream industries and services, such as parts manufacturing and automobile repair shops, contributes significantly to GDP growth and employment; in turn, GDP and employment growth generates more automobile demand, stimulating the expansion of the automobile industry.

However, there are other significant social and environmental implications for the growth of the vehicle market, including urban air pollution, higher dependence on oil imports, and growing traffic congestion. The Chinese government is taking measures and developing policies to deal with these issues. Whatever they are, these measures and policies are part of the private vehicle environment and represent feedback loops that will undoubtedly affect congestion, oil demand, emissions, and vehicle sales.

General Motors Corporation (GM), SIC, and the Millennium Institute (MI), jointly developed a China Vehicle Market Demand model to analyze the issues outlined above. The model is primarily based on the principle of system dynamics. It has the capacity to analyze China's private and total automobile demand potential and its economic and social impact over the next ten years.

The focus of this paper is to present the basic structure of model and show how it could be used to explore the dynamics of the private vehicle market, including possible consequences of external shocks. These shocks include emergence of urban congestion bottlenecks, international oil price shock, and government emission/fuel efficiency standards shock.

We first discuss the algorithms and assumptions of the model. Second, we present a baseline forecast for the market. This is followed by a discussion of how external shocks are handled in the model through feedback loops. We conclude the paper by offering some ideas for further research.

II. Basic algorithms and assumptions:

Five vehicle markets

There are two types of vehicles in the model: passenger and commercial vehicles. Passenger vehicles are split into three categories according to ownership: Private, institutional, and taxi; and commercial vehicles are split into two categories based on primary function: buses and trucks. These five markets are driven by different factors in the model but are interlinked through road congestion and other factors, such as consumer choice between public transportation (represented by the number of buses) and private vehicle ownership. Thus although the private vehicle demand is the focus of this paper, other vehicle types and forms of different ownership will also be briefly introduced in places where they are relevant. Unlike most other countries, the institutional vehicle parc in China is huge for legacy reasons. It is estimated that in 2002, institutional passenger vehicles accounted for over 30% of the entire passenger parc in China.

The model has far more details on the demand side of the market, assuming that there will be generally no shortage of supply in China's vehicle market. Although demands for passenger and commercial vehicles have surged in recent years, production capacities have grown even faster, with both major multinational auto makers as well as domestic private businesses investing in China aggressively.. All the algorithms for the five markets are based on the assumption that demand will be met by either domestic production or imports.

Algorithm for the private market

With a fast growing middle class and rapid pace of urbanization, the private vehicle market is the fastest growing market in China. It was estimated that in 1997, only 20% of total vehicles were sold to private owners. In 2003, this percentage grew to 49%. It is expected that China's private market will converge to the norm in Western countries within two decades.

Private demand depends on disposable personal income and the cost of owning a vehicle, including both purchasing cost and operating cost. At a high level, this relationship is described in the following feedback loop.

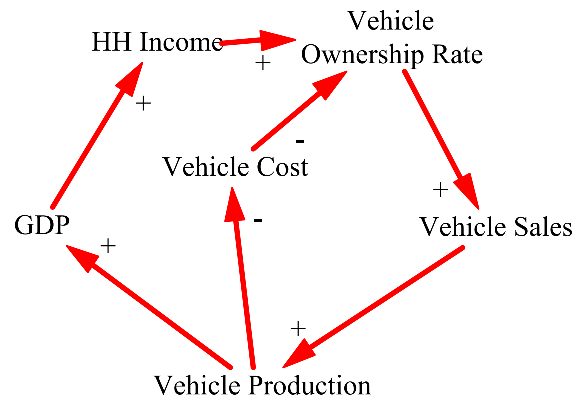

Figure 1: Income and sales feedback loop

Higher GDP drives higher household income (HH Income), which leads to more households that can afford to own vehicles (Vehicle Ownership Rate), given a certain level of vehicle cost. More vehicle owners will generate more vehicle sales (including both first time buyers and repeat buyers who trade in their old vehicles for new ones), which will drive up vehicle production and increase the need for other vehicle-related infrastructure and services. This in turn leads to higher GDP.

The number of households that has reached a certain level of income depends not only on aggregate GDP and national personal income, but also on how that income is distributed. Rising income disparity in China is becoming a social concern, but also implies that high-income households are taking a bigger share of national income. The model computes China's urban and rural income distributions based on GDP, public share of national income, and the Gini coefficient. The urban income distribution for the year 2001 generated by the model, as shown in the following figure, is very close to the urban income distribution data published by the National Statistical Bureau of China.

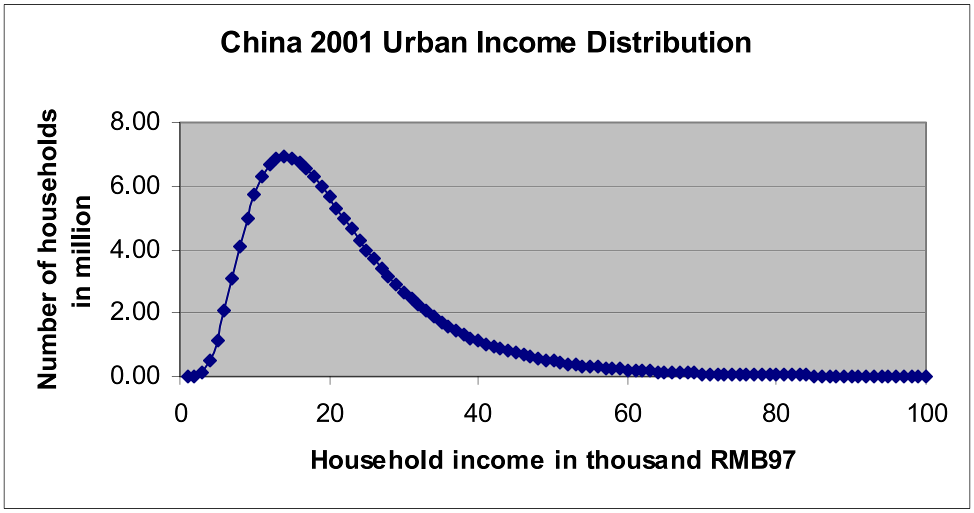

Figure 2: Urban Income Distribution for 2001 (8.28RMB = 1 US dollar)

Consumer surveys in China conducted by the SIC have shown that the desire of a household to own new vehicle is closely related to its income. Figure 3 presents such a relationship, called DOR (Desired Ownership Rate) Curve, which is based on two recent SIC surveys and some demographic data. Please notice that the vertical values could exceed one, meaning that at very high income levels, the average number of vehicles a household owns exceeds one.

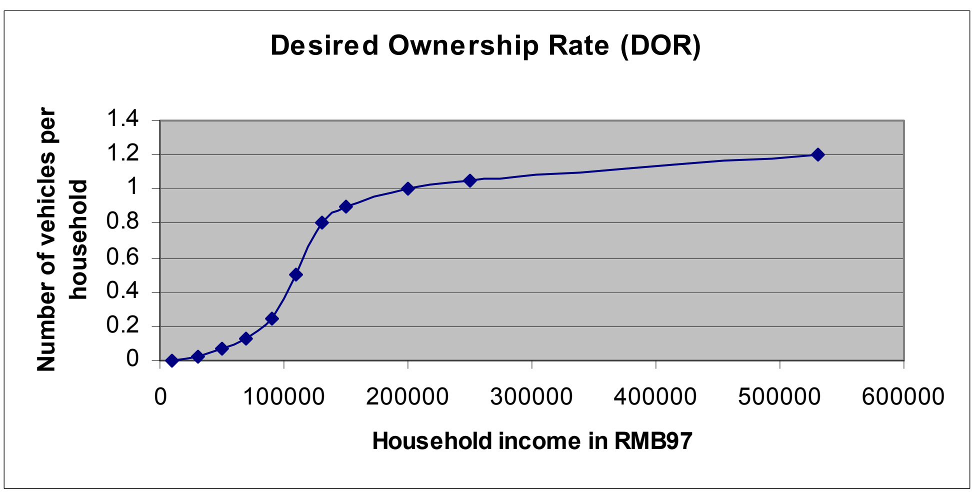

Figure 3: DOR Curve for China

The figure shows that at the annual income level of 30,000 RMB97, only 2% of households own a vehicle purchased new. At 50,000 RMB97 level, this percentage rises to 5%. At the income level of 110,000 RMB97, the level is 50%, and at the income level of 200,000 RMB97, the ownership level will reach 100%. Actually, this 100% represents the average for the group as there will be some households that do not want vehicles and some that want multiple vehicles. At the income level of 500,000 RMB97, the DOR increases to 1.2.

The DOR Curve is not static. When the cost of the vehicle increases, due to either higher prices or higher taxes, the curve could shift to the right. When the cost declines, it shifts to the left. The curve can also shift up or down. For instance, road congestion may reduce the desire of households to own a vehicle, resulting in a downward shift of the curve.

From Figures 2 and 3, we can compute the number of households that are, or will soon become, owners in a specific year. The difference between the desired ownership levels represents new vehicle buyers of vehicles. The sum of new and repeat buyers will be the total sales for the year, if supply is available.

Algorithms for the other four non-private markets

The dynamics of the other four vehicle markets, taxi car, institutional car, bus, and truck, is similar in that they all use a "desired parc" to estimate sales. The equation for calculating sales for time t is:

$$Sales_t = \text{Desired } Parc_t - Parc_{t-1} + Scrappage_t$$

in which the scrappage rate is estimated for each market based on historical data.

The desired parc for taxi is determined by three factors: the size of urban population, average urban income level, and vehicle prices. Higher income leads to higher demand for taxi service, but only to a point. As average income reaches about $5000 per household, demand for taxi begins to saturate as private vehicles become more popular.

The desired parc of institutional vehicles is broken down into three categories: 1) government agency desired parc, 2) public enterprise desired parc, and 3) non-public enterprise (including private, foreign, and joint venture enterprises) desired parc. Judging from a recent SIC survey of decision makers of institutional vehicle purchases, demand for the first category is projected to increase slowly, the second category would stay flat or even contract a little, while the third category could expand faster. Each category is further affected by vehicle prices.

As the vast majority of China's buses are being operated within urban areas, the desired parc of buses is determined by three factors: urban population, urban income, and vehicle prices. Like taxi, private vehicle ownership and other forms of mass transit also have an impact on demand for buses.

The desired parc of trucks depends on economic structure (share of industrial sector and regional economic integration), GDP growth and truck prices. Demand for large trucks also depends on the fast expanding highway system across the country.

Major assumptions of the model

The major assumptions of our baseline forecast include GDP growth, share of household income in national income, vehicle prices, Gini coefficient, vehicle taxes and other government regulations, and fuel prices and infrastructure building (roads and parking space).

1. GDP growth: Historical GDP data is from China's Statistical Yearbook, and the baseline GDP growth forecast is from GM and SIC estimates. GDP growth rates during 2004 to 2013 can be interactively changed when running the model to generate different vehicle demand scenarios.

	98-02 Average	2003	2004	2005	2006	2013
GDP Growth Rate	0.078	0.091	0.084	0.08	0.078	0.072

Table 1: Baseline GDP growth rates for the future

2. Disposable income: This is assumed to be a fraction of GDP, and is estimated from the "World Development Indicators" as the sum of private consumption and private investment. For China during the 1990s, this percentage is about 63%. It is assumed to be around 63% for 2004 - 13 in the model.

3. Population of China was 1.24 billion in 1997, 1.29 billion in 2002, and will grow to 1.36 billion in 2013. Population is further divided into urban and rural. The percent of urban population was 31.9% in 1997. It rose to 37.7% in 2001, and is expected to grow to 48% in 2013.

4. Average household sizes were 4.2 for rural and 3.1 for urban in 2002, and will continue to decline slightly over the next decade.

5. Gini coefficient for rural China was 28% in 2003, and will rise slowly to 30% in 2013. Urban Gini coefficient was 30% in 2003 and is expected to rise to 35% in 2013.

6. The income distribution for China is assumed to be log-normal, and is computed from the mean household income and the Gini coefficient. This distribution is found to fit historical data very well.

7. Vehicle price: since 2000, passenger vehicle prices (on a comparable basis) have dropped considerably in the domestic market, averaging about 10% per year. The model uses a vehicle price index to represent the average annual price changes. We assume 10% drop in vehicle prices in 2004 but the pace of price decline is expected to slow down in the coming years: 7.2% for 2005, 3.4% for 2006, and then stay flat.

8. Fuel price: The model baseline assumes that the real fuel price (adjusted for inflation) will stay constant over the forecast period. The expected moderation in global oil prices is likely to be offset by higher energy taxes in China.

III. Baseline results

The simulation of the model starts from 1997 (when private buyers became substantial and data was available), and extents ten years into the future year of 2013.

With the simulation of 1997 to 2003, the model parameters are calibrated against historical data In the baseline simulation for the forecast period of 2004-2013, sales mainly responds to higher income and lower vehicle prices without serious constraints from congestion, higher fuel prices, or more stringent standards on emissions and fuel efficiency.

Sales of all vehicles and private vehicles, and private share of all vehicle sales, are given in the Table 2. Table 3 shows vehicle parc numbers and shares.

	1997	2003	2008	2013
All vehicle sales	1,607,210	4,601,420	7,606,840	12,379,200
Private vehicle sales	291,168	2,268,810	4,626,270	8,690,250
Private share	18.12%	49.31%	60.82%	70.20%

Tables 2: Baseline sales

	1997	2003	2008	2013
All vehicle parc	11,815,900	22,152,300	45,808,300	83,480,300
Private vehicle parc	1,637,220	6,880,300	23,633,600	53,327,100
Private parc share	13.86%	31.06%	51.59%	63.88%

Tables 3: Baseline parcs

The reason that we have not imposed infrastructural constraints on demand is that the local governments all across China seem to have spent a great effort in upgrading and expanding urban roads, although reliable data to measure these efforts is hard to find. The official China Statistical Yearbook, seems to underestimate the length of total urban roads. So in the following text we use a road length index to measure the growth of urban road length, which is measured in road length times the number of lanes in each direction.

Most Chinese urban areas are densely populated, and expanding the length and the width of roads is difficult. In the baseline, urban road growth is shown in the following table. The level of new road construction is endogenously modeled. When congestion worsens, the government will increase its effort in building new urban roads or expanding existing ones. That is why the following table shows an increasing annual growth.

	1997	2003	2008	2013
Road length index	1.0000	1.2498	1.6855	2.4281
Average annual growth		3.79%	6.16%	7.57%

Tables 4: Baseline urban road growth

In spite of this urban road construction effort by the government, and the resulting fast growth of urban road length, the congestion (measured by cars and buses per kilometer per lane) in urban areas is going to get worse. From 2003 to 2013, this index will be more than doubled from 1.84 to 4.58. People who are familiar with the current traffic conditions in Beijing and Shanghai may have difficulty imagining such an increase in vehicle road density. But it is worth keeping in mind that other developed countries went through similar periods of growing pain.

	1997	2003	2008	2013
Vehicle road density index	1	1.84403	3.32777	4.58017

Tables 5: Baseline urban road congestion

Demand for fuel will grow with vehicle parc. Based on annual distances driven by different types of vehicles, and their fuel efficiency, we can calculate vehicle fuel demand in the future. To simplify, we assumed that per vehicle annual fuel demand will stay more or less constant, as fuel efficiency improvements offset longer driving distance.

The next table shows that in 2013, the annual vehicle fuel demand will be 339 million tons, which is almost 7 million barrels per day. By comparison, domestic oil production in 2003 was 170 million tons. China passed Japan in 2003 as the world's second largest consumer of oil. With domestic oil production not expected to rise significantly, China's dependence on imported oil is likely to rise significantly.

	1997	2003	2008	2013
Vehicle fuel demand	97,100,300	148,511,000	230,067,000	338,857,000
Average Annual Growth		7.34%	9.15%	8.05%

Tables 6: Baseline fuel demand in tons

Annual carbon dioxide emission from vehicles, measured in metric tons, will grow significantly as well as the following table shows.

	1997	2003	2008	2013
Vehicle CO2 emission	302,629,000	462,860,000	717,043,000	1,056,100,000

Tables 7: Baseline CO_2 emissions

IV. Additional feedback loops

Congestion feedback loop

As the baseline result shows, even as China is working hard to build more roads in urban areas, the urban congestion is going to get much worse and slow down traffic considerably. In many parts of Beijing riding a bicycle to work is faster than driving today. The effect of congestion on fuel demand is ambiguous. On one side, stop-and-go driving reduces fuel efficiency, and increases fuel demand for each mile driven. On the other side, it reduces the desire to drive, and reduces fuel demand. It is assumed in the model that these two sides balance out and the net fuel demand per vehicle is unchanged.

In matters related to vehicle buying, the impact of congestion and infrastructural issues is also significant. Rapid increase in vehicle sales has increased vehicle operating cost significantly, especially parking fees. If Beijing, which currently has the highest rate of private vehicle ownership in China, is any indication, parking space could become a big challenge in most of the urban areas. Only a few years ago when private vehicles were still quite rare, private owners in Beijing could often get a free parking place close to their apartments, and parking in downtown was either free or for a reasonable fee of 2 RMB/hour. But now many owners have to pay 100-300 RMB/month for a parking space at home. Parking fee in downtown Beijing was raised to 5 RMB/hour in 2003 and is likely to increase further.. In Beijing offices, a monthly parking fee of 300 RMB is becoming the norm. This means that the annual parking cost, including home, office, and downtown trips, could reach $1,000/Year. Congestion and rising operating costs are forcing some potential buyers to have a second thought on buying the vehicle. Depending on the severity of congestion, some may postpone their purchases, some may even abandon their buying plan. As a result, the DOR will be shifted to the right and downward.

The feedback loops of congestion are given in Figure 4.

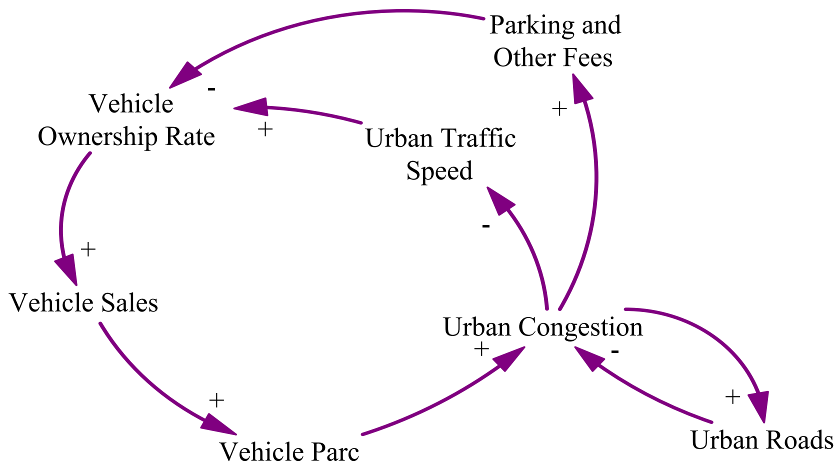

Figure 4: Congestion feedback loops

The above linkages are quantified in the model as below:

Parking fee and congestion: The vehicle road density index, which has the value of 1 for 1997, rose to 1.84 in 2003. Parking fees are beginning to become a major cost to owners in big cities, but not yet in smaller cities. It is assumed that nationally, when vehicle road density index increases, average parking fee will also increase, as shown in the next figure. When road density index increases to 5, national average annual parking fee will increase to 5,000 RMB (measured in 1997 value).

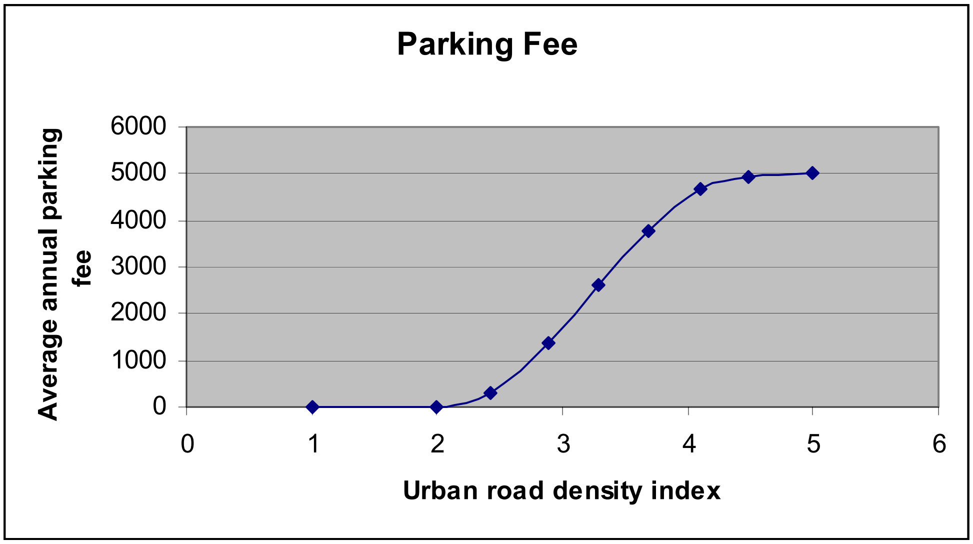

Figure 5: Relationship between congestion and parking fees

DOR and congestion: It is assumed when congestion (measured by urban road density) worsens, the DOR curve will be shifted lower, meaning at every income level, a smaller percentage or households will want to own vehicles. The relationship between urban road density and this percentage is shown in the next figure.

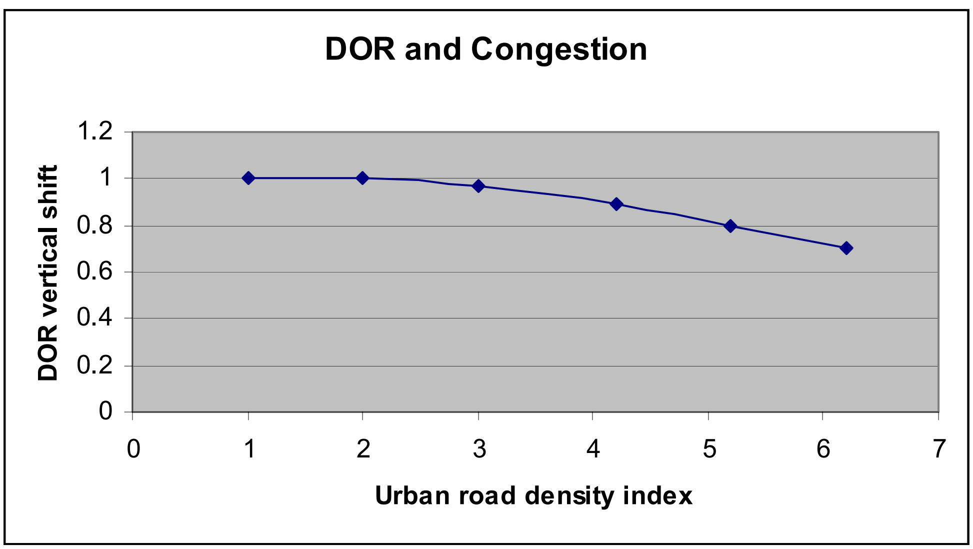

Figure 6: Relationship between congestion and DOR shift

It is assumed in the model that buses and institutional vehicles will also be affected by urban congestion, while trucks and taxi will not. It is believed that trucks use more inter-province highways which are not that congested, and while driving in urban areas, they can often avoid rush hours. Taxis seem to be affected by urban congestion in two ways: Higher congestion slows the taxi speed, so it could reduce taxi demand, but congestion also generates more people who prefer public transportation and taxi. We are not sure which of the effects is stronger, so we assumed that these two effects balance out.

Fuel price feedback loop

As the demand of fuel grows at such a rapid pace while domestic fuel production stays flat, the pressure for price rise is obvious. First, it becomes more and more expensive to produce oil from domestic fields to meet demand. Second, China's oil import growth will increase global demand, putting pressure on international oil prices. China accounted for 35% of incremental global demand in 2003. Third, a variety of other factors, such as the need to develop a strategic oil reserve and environmental protection, will either raise oil prices directly or indirectly through oil tax increase.

Before 1992 China was a net oil exporter, but became a net importer after that. Since 1992 there has been no major international oil crises like what happened in 1973 – 74 or in 1978 – 81, thus private vehicle owners in China have not experienced what their US and Japanese counterparts have, and their behavior under such a situation is unknown. However, it is believed that, in a similar situation, they would also cut back on driving.

In the model, higher fuel prices increase the annual vehicle operating cost, which will shift the DOR curve to the right, reducing the number of owners and desired owners, and thus reducing vehicle sales. It will also reduce the average annual distance driven. And with it, fuel demand and emissions will go down. The feedback loop is shown below.

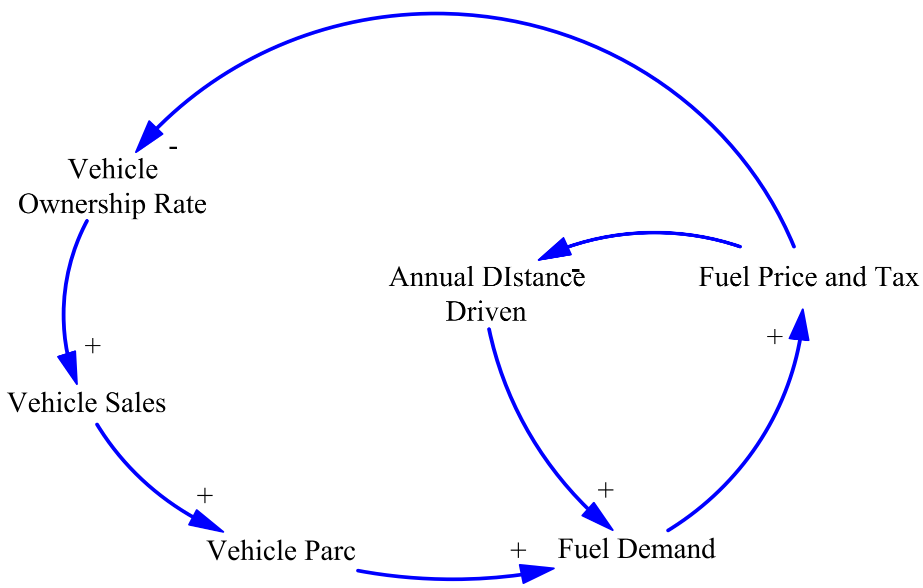

Figure 7: Fuel price feedback loop

It is assumed in the sensitive case that oil price will gradually rise from its current level (comparable to oil prices in USA today) to three times as high in real value (comparable to oil prices in Europe today) during 2004 to 2013. Higher fuel price will reduce annual distance driven with an elasticity of –0.1. This elasticity is applied to all the five markets of private, bus, institutional, taxi, and truck. As a result fuel demand and emissions will be lower.

Emission and vehicle efficiency feedback loop

In many big cities of China, pollution caused by vehicle emission is getting worse, and the Chinese government has already issued its plan to enforce the Euro III emission standard. Recent trend has shown that the government may even further raise the emission and fuel efficiency standards.

The higher emission and fuel efficiency standards will undoubtedly raise the manufacturing cost and final prices, which will shift the DOR curve to the right, reducing sales. It will also slowly reduce fuel demand and emissions, as the older vehicles in the parc are gradually scrapped. The feedback loop is shown in the next figure.

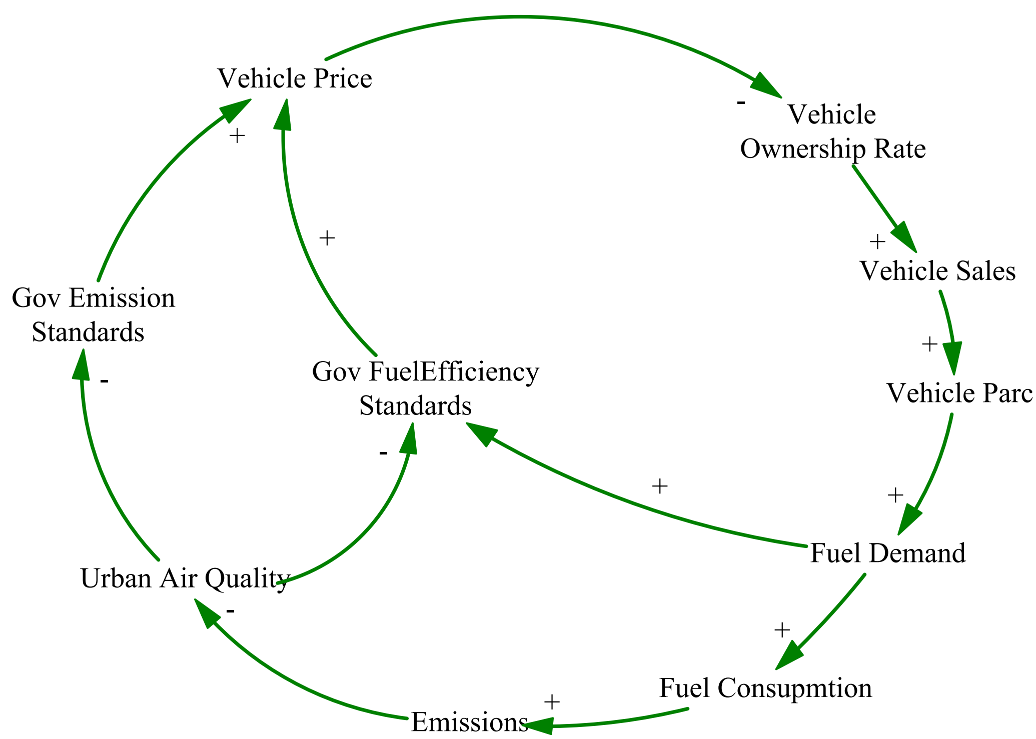

Figure 8: Emission and fuel efficiency feedback loop

In the sensitive case it is assumed that the higher emission and fuel efficiency standards will bring a 20% price rise to the popular, low cost vehicles by 2008. The price rise to more expensive vehicles will be less than 20%.

The higher fuel efficiency standards will undoubtedly reduce fuel demand, but there is a substantial delay, as this standard is only applied to new vehicles. The reduction on fuel demand will be more obvious after several years when new vehicles account for a bigger share (such as over 20%) and older, gas-wasting vehicles are scrapped.

Putting all these feedback loops together, the diagram is shown below.

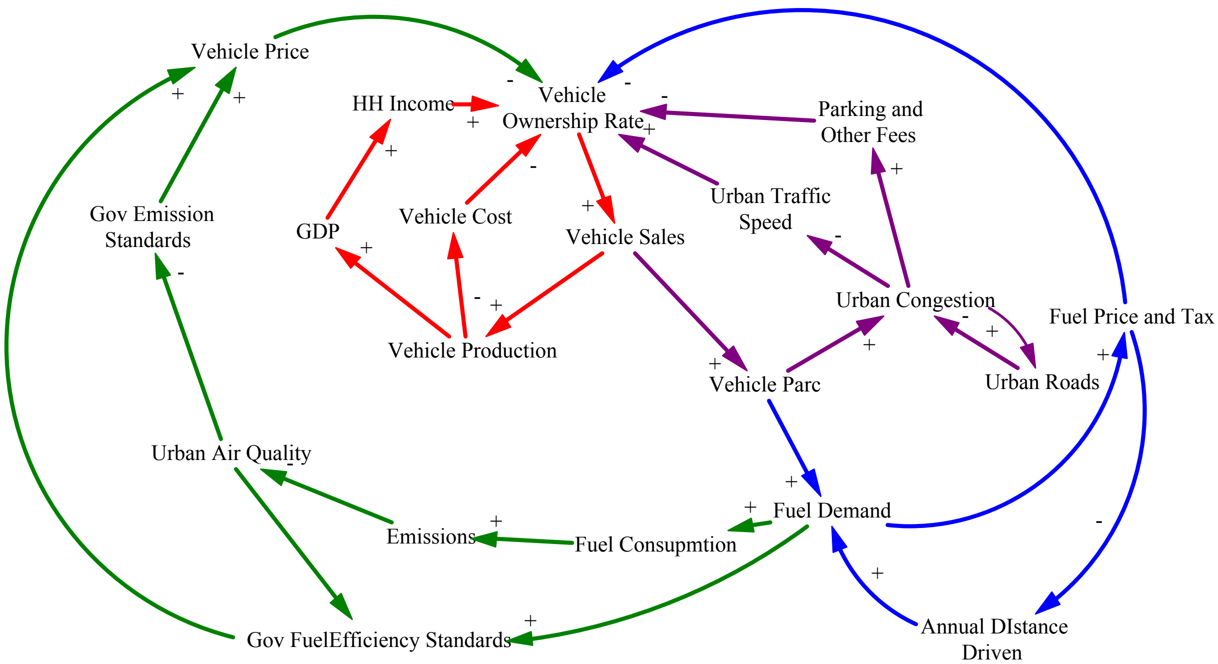

Figure 9: Combined feedback loops

V. Results of alternative scenarios

We have made three alternative scenarios. Scenario 1 includes the congestion effects only. Scenario 2 includes both the congestion and the fuel price effects. Scenario 3 includes all the effects resulting from the three feedback loops of congestion, fuel price, and emission/fuel efficiency standard changes.

In the tables and figures below, the baseline results are also included for quick comparison.

Vehicle sales

Private vehicle sales for these three scenarios and the baseline are given in Figure 10 and Table 8. From Table 8, private sales for scenario 3 will be 44% lower than the baseline. All vehicle sales are presented in Table 9.

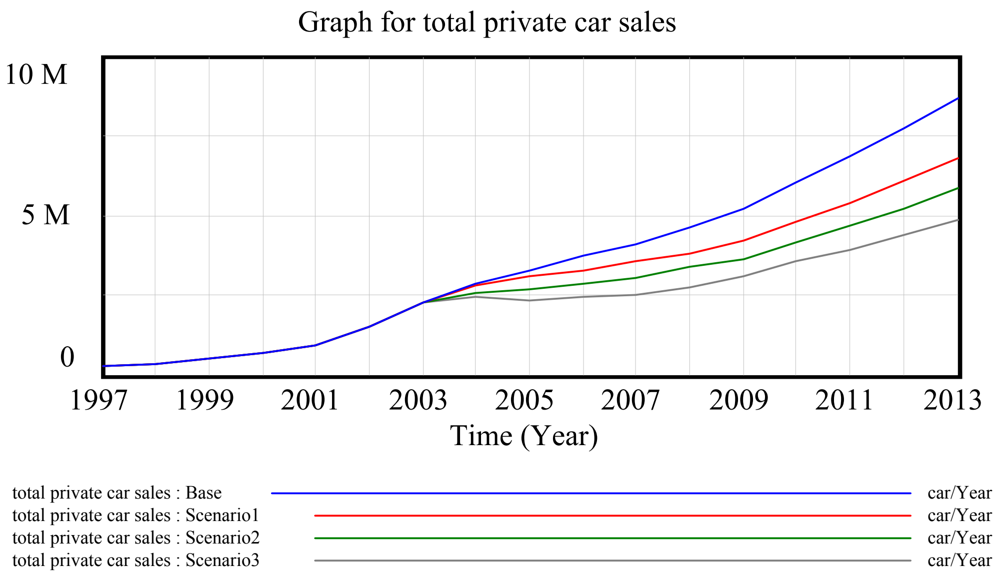

Figure 10: Private vehicle sales of 3 scenarios and the baseline

	1997	2003	2008	2013
Base	291,168	2,268,810	4,626,270	8,690,250
Scenario1	291,168	2,268,810	3,770,720	6,782,030
Scenario2	291,168	2,268,810	3,355,820	5,830,680
Scenario3	291,168	2,268,810	2,724,820	4,845,310

Table 8: Private vehicle sales of 3 scenarios and the baseline

	1997	2003	2008	2013
Base	1,607,210	4,601,420	7,606,840	12,379,200
Scenario1	1,607,210	4,601,420	6,713,670	10,415,500
Scenario2	1,607,210	4,601,420	6,307,020	9,474,400
Scenario3	1,607,210	4,601,420	5,682,990	8,499,100

Table 9: All vehicle sales of 3 scenarios and the baseline

Vehicle parc

Private vehicle parc for these three scenarios and the baseline are given in Figure 11 and Table 10. From Table 10, private parc for scenario 3 will be 34% lower than the baseline in 2013. All vehicle parc will be 22% lower than the baseline in 2013, as computed from Table 11.

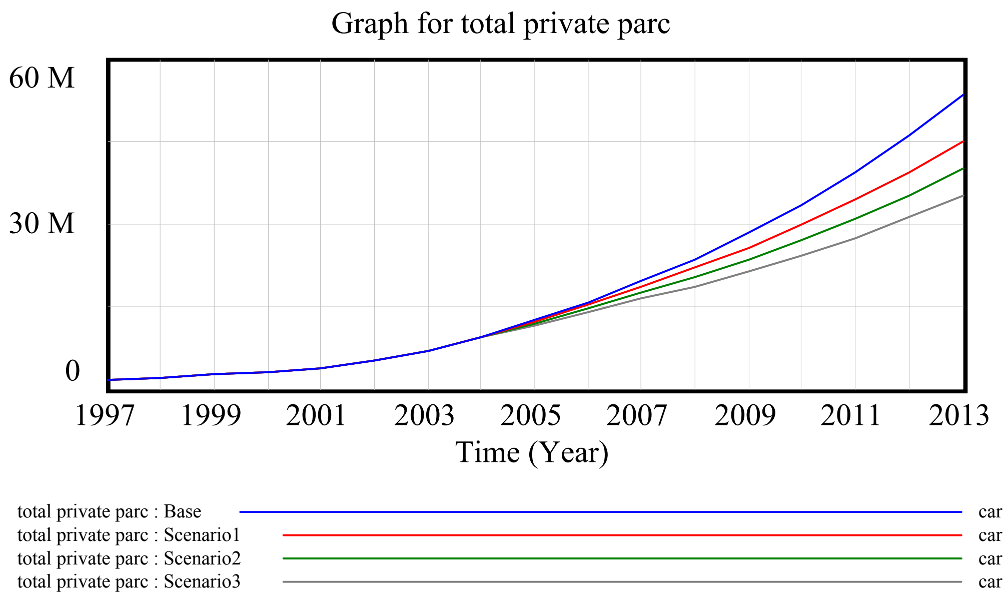

Figure 11: Private vehicle parc of 3 scenarios and the baseline

	1997	2003	2008	2013
Base	1,637,220	6,880,300	23,633,600	53,327,100
Scenario1	1,637,220	6,880,300	22,013,300	45,009,400
Scenario2	1,637,220	6,880,300	20,345,700	40,059,800
Scenario3	1,637,220	6,880,300	18,634,200	35,008,600

Table 10: Private vehicle parc of 3 scenarios and the baseline

	1997	2003	2008	2013
Base	11,815,900	22,152,300	45,808,300	83,480,300
Scenario1	11,815,900	22,152,300	44,076,900	74,879,900
Scenario2	11,815,900	22,152,300	42,425,200	69,976,500
Scenario3	11,815,900	22,152,300	40,728,400	64,974,100

Table 11: All vehicle parc of 3 scenarios and the baseline

Urban congestion

Urban congestion measured by urban road density index for the three scenarios and the baseline is presented in Figure 12.

	1997	2003	2008	2013
Base	1.0000	1.8440	3.3278	4.5802
Scenario1	1.0000	1.8440	3.1571	4.0200
Scenario2	1.0000	1.8440	2.9966	3.7108
Scenario3	1.0000	1.8440	2.83017	3.38347

Table 12: Urban congestion of the 3 scenarios and the baseline

Fuel demand

Fuel demand measured in tons will be significantly lower for scenarios 2 and 3 than the baseline. This will reduce the pressure on oil imports for China.

	1997	2003	2008	2013
Base	97,100,300	148,511,000	230,067,000	338,857,000
Scenario1	97,100,300	148,511,000	227,691,000	328,176,000
Scenario2	97,100,300	148,511,000	203,396,000	258,529,000
Scenario3	97,100,300	148,511,000	201,815,000	254,444,000

Table 13: Vehicle fuel demand of the 3 scenarios and the baseline

CO_2 emissions

CO_2 emissions for the three scenarios and the baseline are shown in the next table.

	1997	2003	2008	2013
Base	302,629,000	462,860,000	717,043,000	1,056,100,000
Scenario1	302,629,000	462,860,000	709,638,000	1,022,820,000
Scenario2	302,629,000	462,860,000	633,917,000	805,749,000
Scenario3	302,629,000	462,860,000	628,990,000	793,016,000

Table 14: CO_2 emissions of the 3 scenarios and the baseline

VI. Conclusions

We recognize that there are some limitations to both the model presented here and the analysis in this report. The vehicle market in China is huge and diverse, both geographically and structurally, not easily represented in a nationally aggregated model. Although we have spent many years working on vehicle demand modeling, there are still much to be learned. The forecast provided in this report should be viewed as:

- Issues for debate and further research/modeling
- Key indicators that represent trends and challenges almost sure to emerge, although their magnitudes and timing should be further studied.

The challenges of urban traffic congestion and urban air pollution have already begun in many large cities of China, and China is becoming more dependent on foreign oil. The fast expanding private vehicle ownership can bring other challenges not discussed in this paper, such as loss of farmland and loss of lives to traffic accidents. While the Chinese government wants to continue to grow its economy and raise standards of living, it also wants to protect its environment and have a secure future in terms of energy and food supply. These goals are sometimes conflicting, and there is no magic solution. With a model like this, we can explore the consequences of different policy alternatives easily and compare the results quantitatively. This will help the communication among all stakeholders, and build consensus among them.

The stakeholders may include the government, Chinese consumers and producers of motor vehicles, the public at large, and foreign investors.

There are several areas where we can extend the model and make it more robust and useful. First, the effects of congestion, fuel price, and emission and fuel efficiency standards on non-private vehicle markets (bus, truck, taxi, and institutional) are modeled crudely, but these markets will continue to play a significant role. Second, as China's market continues to grow, the interactions between the new and used vehicle markets will become more important, so the used market (for private, taxi, and institutional vehicles) should be added to the model. Finally, the interactions of private vehicle demand with the demand for public transportation and with the taxi and institutional vehicle demand need to be further studied and incorporated into the model.

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