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Overview

Since the 1990s, China has experienced tremendous growth in its transportation sector. By the end of 2010, China's road infrastructure had emerged as the second-largest transportation system in the world after the United States. Passenger vehicle sales are dramatically increasing from a little more than half a million in 2000, to 3.7 million in 2005, to 13.8 million in 2010.[1] This represents a twenty-fold increase from 2000 to 2010. The unprecedented motorization development in China led to a significant increase in oil demand, which requires China to import progressively more petroleum from other countries, with its share of petroleum imports exceeding 50% of total petroleum demand since 2009.[2] In response to growing oil import dependency, the Chinese government is adopting a broad range of policies, including promotion of fuel-efficient vehicles, fuel conservation, increasing investments in oil resources around the world, and many others.

In recent years, oil demand forecasting has been gaining prominence as a tool utilized by the Chinese government in preparation of Five-Year Plans and long range planning. Several government agencies in China are tasked with providing oil demand forecasts to aid in formulating long-term policies. The Energy Research Institute (ERI) of the National Development and Reform Commission (NDRC) carries out energy supply and demand forecasting. The Chinese Academy for Social Sciences (CASS) is a think tank affiliated with the State Council, who conducts economic research on oil in China. China's largest national oil company—China National Petroleum Corporation (CNPC)—forecasts oil supply and demand via the CNPC Research Institute of Economics and Technology. Although these forecasts are not directly from the government, they are quite influential in China.

Since the transportation sector now accounts for the largest share of petroleum demand and is projected to remain the driving force of oil consumption growth in the long term (having recently surpassed industrial petroleum demand), transportation demand modeling has been given increased attention in China in recent years. The regulatory provisions of the Law of the People's Republic of China on Urban and Rural Planning require all cities to regularly submit city-level master transportation plans, which has prompted many Chinese cities to develop their respective transportation models. Regularly updated comprehensive transportation plans are now a norm in many Chinese cities, with most of these plans based on travel demand models with a land-use component. In addition, many think tanks and research institutions are working on developing national travel demand models.

The most prominent travel demand modeling efforts in China are conducted by several public and semi-public entities including the China Academy of Urban Planning and Design (CAUPD), Transportation Planning Institutes, and Transportation Research Centers in major cities. These entities are the main authorities on travel demand forecasting and are recognized for their strong modeling capabilities. These capabilities stem in part from the entities' access to statistical datasets, which are obtained through relationships with the government. Access to statistical datasets owned or collected by the government is the most significant barrier for other entities' transportation modeling efforts. The

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[1] Economist Intelligence Unit (www.eui.com), annual data series "Passenger Vehicle Registrations," and China Association of Automobile Manufacturers (www.caam.org.cn/english/).

[2] CERA, "China oil data center," annual data series 2002-2013; PFC Energy, "Oil Balance Summary," annual data series, 2008-2014. Proprietory data sets.

primary reasons for government restrictions on data access include concerns over the political implications of data and lack of regulatory requirements for public access, as well as data reliability and accuracy.

Chinese travel demand models are based in large part on western travel demand methodologies, which have a long history (80+ years) and a large volume of accumulated literature, modeling methods, and research. The most commonly used models in China are based on urban planning methodologies and include the 4-step and activity-based models, which utilize software packages such as TransCAD, PTV Group suites, EMME, Citilab's suites, and others. The key variables in these models include mode choice, vehicle ownership, land use, commute distance, geographic files for road/transit networks, employment by zone, chosen travel path, residential and work locations, and socio-economic variables (income, gender, age, etc.). These models are designed to simulate existing travel conditions and forecast future year travel for the entire transportation system of a given city for the transit, auto, and walk/bike modes. Data inputs in these models include household travel surveys, Master Land Use Plans of base and future years, public rider surveys, socio-economic and road traffic surveys, employment surveys, transportation network information, and others.

Travel demand forecasting in China is done primarily for urban and long-range planning to project crude oil and products demand by the transportation sector. Each of these forecasting methods and corresponding models has its own set of drivers, inputs, and variables. Very little information is available on methodology used for long-range planning particularly with respect to Five-Year Plans. Urban planning models are local in nature and cannot be uniformly applied to every city or area to generate a national oil demand forecast based on aggregating cities' models. There are no known national transportation models as of now, however, several entities are known to be working on their development. Thus, there is both much and little information available about Chinese transportation energy demand: a rich, but difficult-to-access base of urban-level data and forecasting, coupled with scant national-level information. This is a challenging situation when considering the importance of Chinese transportation energy demand for the global outlook.

The key drivers of travel demand considered in the travel demand and transportation models are varied depending on the purpose of the forecast. Urban planning models utilize various surveys, while other forecasting models focus on estimates of long-term vehicle stock, ownership, and saturation levels to generate oil demand view. Yet other models consider travel behavior to be most indicative of the future direction of travel demand and include various behavioral survey data. It would be useful to review the existing transportation methodologies, with a particular focus on methodologies most frequently used by the Chinese forecasters to examine the determinants of travel demand. This could then be related to the need for an internationally consistent methodology for application to China as well as other regions.

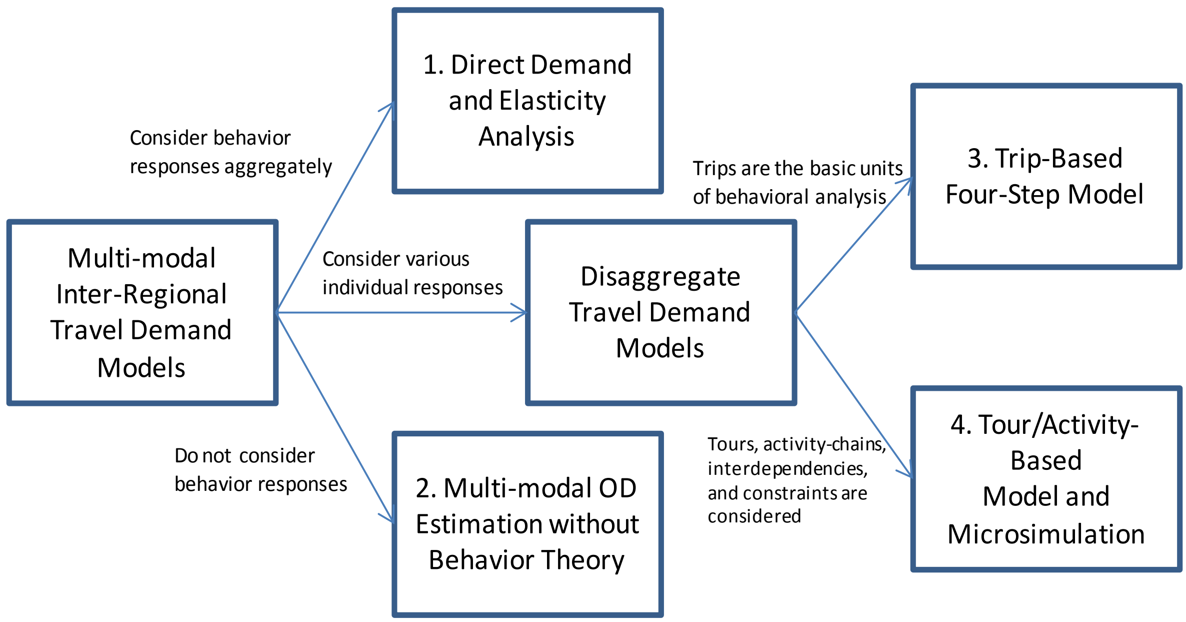
Travel demand forecast methodologies

Travel demand forecast methodologies trace their beginnings to the 1950s, when the first models were introduced. These models play a central role in urban and regional transportation modeling. In the last few decades, methods for travel demand forecasting have been expanded and advanced, with two primary modeling approaches gaining most prominence: activity-based and trip-based.

The countries of the European Union utilize advanced large-scale travel models. As the need for analyzing travel between member countries and worldwide becomes increasingly important, several pan-European travel demand models have also been developed, including the MYSTIC project, the STREAM model, and the most recent TRANS-TOOLS project. In addition, aggregate direct demand studies have been conducted to estimate multimodal travel demand patterns in countries outside of the European Union. Integrated national models have also been applied in analyzing travel demand in many European countries.

One recently completed international study has reviewed approximately 60 multimodal inter-regional travel demand models across the world and categorized them into four distinct groups (Figure 1).[3] All of these methodologies are capable of estimating multimodal origin-destination matrices (OD), and have produced operational models. The key difference between these methodologies lies in consideration of the travel behavior in response to changing policies.

Figure 1: Categorization of multimodal inter-regional travel demand analysis methods



Source: Lei Zhang and Chenfeng Xiong, "Multi-Modal Inter-Regional Travel Demand Estimation: A Review of National-Level Passenger Travel Analysis Methodologies and Their Implications on the Development of National and Statewide Travel Demand Models in the U.S.," TRB 2011.

EIA and IEA transportation methodologies

The transportation models developed by national and multinational government entities such as EIA and IEA focus on specific aspects of transportation demand relevant to policy-making and scenario analysis. EIA's NEMS Transportation module is designed to evaluate various policy options with respect to fuel economy standards and alternative fuel use by determining the relationship between technology cost, fuel availability and demand for travel; consequently, it looks at the drivers relevant to this requirement.

[3] Lei Zhang and Chenfeng Xiong, "Multi-Modal Inter-Regional Travel Demand Estimation: A Review of National-Level Passenger Travel Analysis Methodologies and Their Implications on the Development of National and Statewide Travel Demand Models in the U.S.," Transportation Research Board 2011.

IEA's Mobility Model (MoMo) transportation model evaluates policy options for reducing fossil fuel emissions and oil dependency and is based on the well-known "ASIF" methodology, which calculates emissions per unit fuel use. EIA's WEPS+ ITran methodology is based on relationships between service demand and service intensity to estimate transportation demand in various regions and countries and can also quantify impacts of government policies or vehicle stock.

Four-step trip-based methodology

Of all national travel demand models, the four-step trip-based approach is the most commonly used methodology due to its relatively simple structure and availability of well-developed commercial software packages. The four-step urban transportation planning process was first developed in the 1950s to forecast automobile travel and is now applied in urban areas throughout the world. To predict how travel patterns will change as a result of future changes in land use patterns and the transportation system, this framework integrates models of various aspects of travel behavior (e.g., trip-making or mode choice) with spatial information on land use patterns and the transportation network.

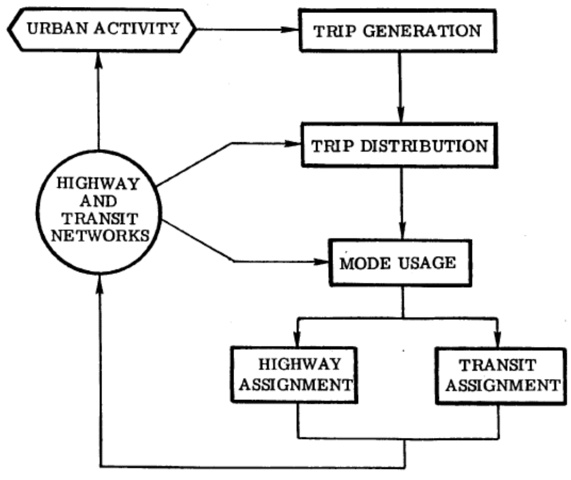
Under the four-step trip-based modeling framework, travel demand is typically described as a sequential process of four modeling steps: trip generation, trip distribution, mode split, and traffic assignment. Each of these steps represents an aggregation of the demand-supply interactive results of individual travel choices of a certain type. Demand for transportation is created by the separation of urban activities. The supply of transportation is represented by the service characteristics of highway and transit networks.

The most comprehensive trip-based models for national travel analysis include:

- Pre-processing (e.g. socio-economic, demographic, and vehicle ownership forecasts)
- Trip generation – converts the demographic/land use data into number of trips. The number of potential trips is determined on the basis of demographic information.
- Trip distribution – converts trip generation data into trip tables containing the number of trips from point of origin to point of destination. The number of trips is determined on the basis of geographic location.
- Mode choice – allocates the person-trips from trip distribution to available modes based on factors such as travel time, availability of public transit, and accessibility.
- Trip assignment - calculates the total vehicle trips as estimated travel demand on each link identified in the major roadway network. Trip assignment also forecasts future vehicle trips on road network in the area.
- Post-processing (e.g. policy impact analysis, and emission estimation modules)

Figure 2 summarizes graphically the four-step trip-based methodology:

Figure 2: Traditional 4-step trip-based methodology



Source: U.S. Department of Transportation

Activity-based methodology

Trip-based methodology has remained fairly static from the 1960s through the 2000s. In the early 2000s, a new structure, so-called "activity-based" methodology, began to be implemented in practice. The key feature of this methodology is the simulation of individual household and person choices as well as the consideration of whole travel tours (round trips beginning and ending at either home or workplace) rather than trips; and an explicit modeling of activity duration. Trip-based models describe travel as a collection of disconnected trips moving through space. Because trips are separated from trip makers, it is impossible to sum travel quantities (e.g., VMT) by geographies of residence or workplace (e.g., residents of city A generate, on average, X vehicle-miles per day) from the output of trip-based models. Structurally, a trip-based model cannot estimate the average vehicle-miles traveled by a resident of city X. The activity-based framework facilitates this type of analysis. The core output of an activity-based model is a list of trips, fully identified as being part of a specific tour, occurring at a specific time of day, undertaken by a specific individual (or group of individuals) via a specific travel mode.

Activity-based models are used widely to inform climate action plans on regional, national and multi-national levels. Such models aid in governments' efforts to develop a diverse array of policies to mitigate emissions and establish targets for regulatory policies. Assessing urban travel behavior is one of the most challenging issues in travel demand forecasting and much effort is focused on building activity-based models that aid in analyzing behavioral patterns of individuals and households in both developed and developing countries, in order to quantify the impact of government policies promoting reduction in travel-related greenhouse gas (GHG) emissions. Activity-based models on city and regional levels are often aggregated into state/provincial level models to help policy makers identify the types of changes that are necessary to achieve climate stabilization goals, including necessary improvements in vehicle technologies and other factors.

Multinomial logit methodology

Multinomial logit models use maximum utilization theory in disaggregate models to examine user choice between four patterns of car use: no use, mixed use, one trip and multiple trips. These models typically use utility functions.

Recent findings from the application of this model type on car use patterns in China were presented in "Transportation Models and Their Mobile Source GHG Modules in Chinese Cities: Findings Based on Structured Interviews and On-line Surveys."[4] The analysis was conducted in large- and medium-size Chinese cities and found the following patterns of personal car use:

1. "One trip" patterns accounted for more than 55% of all car use patterns
2. The eligible car users take the "mixed use" pattern only as part of required trips
3. Individual socio-demographic characteristics and trip activity attributes (travel pattern, locational attribute, distance of longest trip, etc.) appear to provide a robust explanation for characteristics of car use in China.

Nested-logit methodology

Generally, the nested-logit mode-choice methodology includes three parameters: nesting coefficients, mode-specific constants, and level-of-service coefficients. A common practice in developing a mode-choice model is to borrow coefficients from some representative cities and adjust the modal bias coefficients to replicate the transit ridership data. This methodology requires various survey data as inputs.

There are many variations on these core travel demand methodologies involving interrelated variables such as city scale, urban form, level of economic development, trip distance, travel time, etc. relevant to specific modeling purpose. The modeling purpose determines the selection of travel demand drivers that are expected to best capture and predict transportation demand on a local, national, or global level.

Travel demand forecasting in developed vs. developing countries

In developed countries the four-step trip-based approach is the most dominant methodology. The activity-based models tend to be more costly and more difficult to develop since they require many additional survey-based inputs and are less transparent; however, they have been gaining popularity due to a well-represented behavioral component. The next section of this report presents a comparison of German and Spanish travel demand estimation as a case study.

In theUnited States, travel demand modeling is well developed on both national and state levels. U.S. travel models are based on over 100 rigorous empirical studies utilizing 30+ years of historical data series. Commonly used methodologies include Structural Equation Modeling (SEM), aggregate travel studies, disaggregated travel studies, regional simulation studies, and several others. These methodologies rely heavily on large sets of survey data conducted to measure urban development patterns and individual or household travel behavior and patterns. Forecasts of VMT as part of travel demand methodology involve analysis of variables such as population density, transit revenue miles, transit passenger miles, density, diversity, urban design, destination accessibility, distance to transit, etc.

[4] Jiangping Zhou, PhD, and Wan, Chen and Wang presented at TRB 2012 (paper submitted Nov 2011)

Most travel demand studies rely on historical data series obtained from various surveys. Typical data sources for travel demand forecasting models in developed countries include cross-sectional household and personal travel surveys; user interception surveys on roadsides, transit terminals, airports, and borders; special-purpose stated preference (SP) and SP-RP (Revealed Preference) surveys; tourism data; dedicated long-distance travel surveys; traffic counts, and other supply-side network and cost data.

While such surveys are widely available in the United States and other developed countries, they are very hard to find for developing countries, and in most cases, these survey-based data series are available in native countries' languages and not available in English. Issues with data availability are further complicated by rapidly changing development patterns, which are hard to capture even for countries making significant efforts to conduct surveys and collect necessary data frequently and on a regular basis. Most studies on this topic for China are done by local analysts who apply closely related methodologies and use national surveys as data inputs.

Travel demand forecasting in China

In China, transportation demand modeling has been given increased attention due to unprecedented motorization growth in the last decade and resultant growing oil import dependency, which is considered a national security issue, as well as regulatory requirements of the Urban and Rural Planning Law of China, which requires all cities to submit their city-level master or transportation plans regularly. The 11th Five-Year Plan (2006-2010) set specific compulsory targets to decrease energy intensity, while energy conservation, efficiency improvements, and replacement of fossil fuels with renewable energy are the three pillars of the Chinese long-term energy strategy and planning. The 12th Five-Year Plan (2011-2015) sets a goal to increase the share of renewable energy in the overall energy mix and targets development of seven new strategic industries including renewable energy, new energy vehicles, environmental protection technologies, new materials, high-end manufacturing, energy savings, and new energy. Additionally, the Medium and Long Term Development Plan for Renewable Energy set the goal of achieving a 15% share of non-fossil fuels in total Chinese energy supply by 2020. [5]

In accordance with the Urban and Rural Planning Law of China, transportation modeling and planning in large cities such as Class One cities and provincial capitals has been assigned to government entities called Transportation Research Center (TRC) or Transportation Planning Institute (TPI). These entities are responsible for the development, maintenance, and calibration of local transportation demand models. Large cities in China tend to have well-staffed TRC or TRI offices, with transportation modelers, who independently develop and maintain transportation demand models.

In smaller cities, however, there are generally no TRC or TRI offices, and local transportation modeling is done through for-profit public or semi-public entities such as the China Academy of Urban Planning and Design (CAUPD) or provincial-level Institutes of Urban Planning and Design (IUPD). CAUPD develops and maintains transportation models for many cities across China, while IUPDs develop models only for cities within their respective provinces.

[5] National Development and Reform Commission. Medium and Long Term Development Plan for Renewable Energy in China, Report # 14, Beijing, NDRC, 2007.

Legally, private modeling firms with a Class I Qualification Plan-Making Permit issued by the Ministry of Housing and Urban-Rural Development (MoHURD) are allowed to develop transportation models for all cities in mainland China, however, such firms cannot compete with CAUPD or various IUPDs due to data access problems and general lack of suitable survey data for modeling inputs. As a result, private firms play a secondary role in transportation modeling in China.

China conducts regular transportation surveys in order to support transportation modeling. Usually surveys are conducted every five years or on an "as needed" basis in specific cities. In Beijing, for example, city-wide household travel surveys have been conducted once every five years since 1986. Regular household travel surveys provide local modelers with sufficient data to establish and calibrate city-level transportation models. However, most survey data are not shared internally across government agencies. For example, TRC and TPI offices are generally responsible for household travel surveys, and since these agencies sponsor the surveys, they consider the data "proprietary" and thus rarely share it with any other entities or individuals, particularly those outside of the government. There are no regulations or laws in China that require entities to share survey data or make these data series public.

In addition to official urban planning travel demand forecasting, other forecasting and analytical efforts in China can be classified into four broad categories: (1) forecasting of the vehicle population and vehicle penetration rates; (2) analysis of shifts between different modes of travel; (3) analysis of impacts of alternative fuels and energy demand; and (4) forecasting of CO_2 emissions from the transportation industry.[6] These methodologies and their variations are utilized by various research institutions, government and quasi-government agencies in China, including; the CNPC Research Institute of Economics and Technology; Chinese Academy of Sciences; Transportation Research Centers in Beijing and other Class One cities and provincial capitals; China Academy of Urban Planning and Design (CAUPD); Ministry of Housing and Urban-Rural Development (MoHURD), which is in charge of urban and transportation planning on behalf of the State Council of China; municipal and provincial Institutes of Urban Planning and Design; and others.

Similar methods are used across Chinese entities to project motorization, which also includes estimates of vehicle penetration rates. These methods estimate relationships between petroleum product usage, vehicle ownership, projected economic growth, fuel technologies, and government policies. While variables considered in this methodology are very similar between forecasts, uncertainty about long-term government policies along with wide ranging assumptions for vehicle penetration rates and vehicle fuel mix lead to significantly different projections of long term oil and petroleum products demand, with differences in forecasts ranging from 1 MM bbl/d to 4 MM bbl/d, creating uncertainty in both the availability and requirements for the incremental long-term oil supply (Table 1).

[6] Wen Liu et al. "The integration of transportation with the energy system in China." Department of Development and Planning, Aalborg University, Denmark.

Table 1. Long-term forecasts of Chinese crude oil and petroleum products demand

	Million bbl/d			Million Tons		
Consumption/Demand	**Oil**	**Gasoline**	**Diesel**	**Oil**	**Gasoline**	**Diesel**
CNPC Research Institute						
1980	1.8	0.2	0.3	88	10	17
2000	4.5	0.8	1.4	224	35	68
2008	7.8	1.5	2.8	387	63	139
Annual Growth Rate 1980-2008				5.5%	6.8%	7.9%
2015 Planned Scenario	10.1	2.3	4.0	505	98	194
2015 BAU Scenario	10.6	2.3	4.1	527	100	200
2015 High Scenario	10.8	2.4	4.2	539	102	203
2020 Planned Scenario	11.7	2.8	4.4	583	119	217
2020 BAU Scenario	12.7	3.1	4.7	632	132	229
2020 High Scenario	13.3	3.3	4.8	662	139	236
Chinese Academy of Sciences						
2015 Basic Scenario		1.9	4.6		80.9	227
2015 Optimistic Scenario		2.2	5.6		95.9	272
2015 Pessimistic Scenario		1.5	3.7		65.9	182
Transportation Research Center (TRC), Beijing						
2015 First Scenario (9% GDP CAGR)	14.1	2.3	2.2	700	97.3	106
2015 Second Scenario (7% GDP CAGR)	12.3	2.0	1.9	610	84.9	92
2020 First Scenario (9% GDP CAGR)	15.9	2.8	2.3	790	119.1	114
2020 Second Scenario (7% GDP CAGR)	13.3	2.3	1.9	660	99.1	95

Sources: Wang, H. "Characteristics and Trends of China's Oil Demand," CNPC Research Institute of Economics and Technology, Beijing, China; "Demand Forecast of Petroleum Product Consumption in the Chinese Transportation Industry," Chinese Academy of Sciences; Wang J., "Unprecedented Motorization Development and Emerging Critical Issues in China in the Next Decade," Transportation Research Center, Beijing University of Technology.

Factors contributing to this wide range of forecasted energy demands are lack of historical statistical data from government agencies, lack of transparency in data collection procedures, and significant issues with data sharing not only between national and local Chinese government agencies, but also with the public at large both in China and internationally. Furthermore, growth and change in China are so rapid, official data may become outdated soon after they are produced. Current studies on availability of survey data for Chinese transportation models indicate that the regional transportation surveys are carried out along the same lines as in Western metropolitan areas and typically document household and individual socio-economic and demographic characteristics, vehicle stock, and trips made by mode, purpose, and destination. However, these datasets are not usually available to users outside of the sponsoring agency. In addition, because the data are typically collected every 5-7 years (as has been the case in Shanghai and Beijing), rapid change in urban structure and socio-economic conditions can result in the regional data sets not being sufficiently timely or detailed for the needs of planning and policy analyses. It may also be the case that the awareness of governmental policies and priorities may introduce systematic bias into forecasts, in that success of certain policies may be tacitly or explicitly assumed. It is difficult to determine the relative importance of policy assumptions compared to other determinants of transportation energy consumption without detailed comparative studies using these same models, which is a different analytic agenda than that currently being carried out in Chinese cities.

Many agencies in Chinese cities also conduct special studies on traffic safety, vehicle ownership, household composition by location, transit ridership, etc. However, these datasets are not necessarily available to other agencies or to researchers, or may not be sufficiently comprehensive or detailed to support planning efforts. For example, datasets often do not include information on the "floating population" (urban dwellers who do not have registration in the metro area where they reside). Thus, for a combination of access, cost, and completeness reasons, agencies and researchers often seek to gather their own survey data in Chinese metro areas.

Motorization vs. travel behavior

In addition to limited availability of relevant transportation survey datasets, modelers and researchers of travel demand in China are faced with rapidly changing trends that even recent surveys may not be able to capture adequately. China is experiencing rapid urbanization, a trend which is likely to continue for decades. A projected 350 million or more Chinese will move to cities in the next 15 years, and the urbanization rate is projected to increase from 46% in 2010 to 60%, with an estimated 221 Chinese cities housing more than one million people, by 2025 (McKinsey & Company, 2009). Urbanization and the urban form will largely affect travel demand, and government policies will play a crucial role in how travel needs are met through control over urban development patterns and the accessibility of public mass transit.

The current Chinese urbanization experience indicates that most cities are suffering from severe congestion, insufficient road infrastructure, and significant pollution. By the end of 2010, Chinese total roadway mileage reached 2.5 million miles and became the second largest in the world after the United States in terms of highways' mileage. [7] Even though this growth has occurred, existing highways and roadways seem to lag behind the rapidly rising motorization levels. Forecasts of the expansion of transportation infrastructure, given projected urbanization and motorization trends, are critical for Chinese policy makers and are typically carried out using urban planning models on a city level.

The key uncertainties in the long-term transportation demand forecasts for China are the assumptions of vehicle ownership rates, saturation levels, and economic growth. Over the last decade, the Chinese passenger vehicle stock has increased dramatically, from 3.8 million vehicles in 2000 to 55.8 million vehicles in 2010[8] growing at Compound Annual Growth Rate (CAGR) of 31%. However, while the growth rate in vehicle ownership has been high over the last decade, a recent study by Junlei Wang of the Beijing Transportation Research Center[9] indicates that Chinese motorization is likely shifting from the

[7] CIA, "The World Factbook."

[8] Economist Intelligence Unit, "Passenger car registrations," annual data series (NPCR), 1990-2014. Vehicle stock is calculated as a cumulative sum of passenger car registrations for years 1990-2010.

[9] Wang, Junlei et al. "Unprecedented Motorization Development and Emerging Critical Issues in China in the Next Decade," TRB 2012.

stage of very rapid growth to a slower growth as measured by the Gompertz function,[10] and China is entering Stage III on the motorization curve.

Estimates of vehicle saturation levels[11] in China vary widely across forecasts, and represent a key uncertainty in the long-term projections of transportation demand. Dargay and Gately (1999) assumed a saturation level of 850 for all vehicles per 1,000 people and 620 cars per 1,000 people for the 26 countries (including China) that they studied. However, Kobos et al. (2003) believed that it was impossible for China to support such a high level of vehicle ownership. Instead, they used a saturation level of 292 passenger vehicles per 1,000 people. Button et al. (1993) established a range of 300-450 cars per 1,000 people for low-income countries such as China. A forecast by the Beijing TRC estimates vehicle saturation levels at 333 vehicles/1,000 people as an average saturation rate for developing countries, with specific forecasts for Chinese vehicle saturation rates at 242 vehicles/1,000 people at 9% GDP CAGR (2010-2020) and 201 vehicles/1,000 people at 7% GDP CAGR by 2020.

Variability in assumptions concerning economic growth, vehicle ownership and saturation levels, fuel economy, and government policies lead to significant differences in forecasts of long-term fuel demand in China. Further complicating the issue is the driving behavior pattern, which is typically investigated and measured in disaggregate models requiring survey data, the availability of which is limited due to reasons discussed above. Studies conducted by Western researchers found that behavioral patterns of private vehicle owners in China are different from those of the developed countries in that vehicles in China are perceived as a status symbol, rather than as routine means of transport, leading to lower vehicle utilization rates and lower vehicle-miles traveled than would be estimated based on generic assumptions of vehicle stock and travel behavior. Lack of available survey data and rapidly changing behavioral trends make it difficult for forecasters outside of China to build more robust and accurate forecasts of Chinese travel demand.

Motorization pathways[12] in China will have major implications for urban development, land use, energy use, and climate change. Some of the recent studies by Chinese researchers indicate very diverse motorization pathways for Chinese cities. A recent case study for Shanghai has found that there are potentially 331 distinct pathways per 1,000 inhabitants in a motorization pattern with three or more pathway stages.[13] The paper concluded that only about one-half of survey respondents came to their current motorization stage through a hypothesized motorization direction. The survey further found that no common path exists toward private vehicle ownership in Shanghai, and that at least for Shanghai, residents make transition towards private vehicle ownership as much as they transition away from it. Another survey analyzed an impact of the urban form on motorization pattern in 36 Chinese

[10] The Gompertz model estimates vehicle ownership penetration rates and predicts vehicle ownership per 1,000 people on the basis of economic growth (GDP). The Gompertz model indicates that the relationship between per capita income and the level of motorization is not linear, but rather an S-shaped curve, which is typically split into four main stages of motorization: in stage I, vehicle ownership increases slowly as per capita income increases, in stage II vehicle ownership increases at the highest rate with the increasing income, in stage III the rate of increase slows down with the increasing income, and in stage IV vehicle ownership rate stabilizes and no longer increases with the increasing income. This approach is closely related to the 'stage theory' model of international development, as pioneered by Solow and used extensively by the World Bank and others.

[11] Number of vehicles per 1,000 people.

[12] A move from non-motorized to motorized mode of transport.

[13] Meng-Cheng Ni et al, "Motorization Pathway in China: Case Study of Shanghai," ITS UC-Davis, Oct. 2008.

megacities and utilized household surveys for aggregate and disaggregate analyses. The survey concluded that urban affluence, urban scale, and road infrastructure supply factors have significant impact on the city level of private car ownership across cities and that urban form has direct impact on the motorization pattern in Chinese megacities (Jieling Li et al, 2011).

Chinese government policies will play a crucial role in shaping travel demand in the next few decades. As dependence on oil imports continues to grow and concerns over pollution and GHG effects become more and more prominent, Chinese government policies will likely continue to focus on promoting use of more fuel-efficient vehicles and fuel conservation. Recent heavy investments in transit infrastructures from the national stimulus package have made transit-oriented development look promising in future China. If travel demand can be reduced through intervention in the urban built environment, there is a large-scale potential in China to mitigate strong growth in transport demand in the latter stage of urbanization. Forecasts of travel demand will play an important role in this process.