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Automobility in India: A Study of Car Acquisition and Ownership Trends in the City of Surat

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Automobility in India: A Study of Car Acquisition & Ownership Trends in the City of Surat

by

Ipsita Banerjee

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Committee in charge:

Professor Adib K. Kanafani, Chair
Professor Joan L. Walker
Professor Elizabeth A. Deakin

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Abstract

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Aided by economic development, India is undergoing rapid motorization. Growth of car ownership and use is attributed to rising per capita income and introduction of many car models are promoting the growth of ownership and use of cars. This growth portends a sea change in a country that relies mostly on non-motorized and public modes of transportation. It also signifies the transformation to a car based lifestyle in a country where motorized two-wheelers are the dominant personal motorized vehicle.

Such a transformation calls for various policy pertaining to auto-ownership that aim to i) reduce fuel emissions, ii) enable environmental protection, and iii) support infrastructure development. This research aims to support such policy development by providing information on the substitutions among various categories of motorized vehicles owned by households. To this end, a primary survey was conducted in Surat, a prosperous, industrial city in western India in 2009. The survey involved home interviews of 196 motorized vehicle owning households.

The research explains the effects of increased per capita income and of the decreasing sizes of households on the composition of motorized vehicle fleet. The analysis involves econometric modeling supplemented with qualitative observations based on interviews and interactions with the residents. The research focuses on the possible shift from motorized two-wheelers to cars, and the substitutions among different sizes of cars. It reveals that household income is the key determinant of the number and the sizes of cars that households own, and that household size is a much less significant factor; smaller vehicles are preferred even by larger households. Some of the possible reasons for this preference are the relative expense of larger vehicles, lax enforcement of regulations allowing many more passengers than mandated by the seating capacity, and the need for maneuverability for driving in congestion and for parking.

An integrated choice and latent variable model is used to study the effect of different attitudes on the type of vehicles purchased, such as new versus pre-owned motorized two-wheelers or different sizes of cars. The results reveal that underlying perceptions and cultural beliefs regarding the different modes of transportation,

attitudes on saving or spending money and similar subjective factors are not significant in explaining the type choice behavior of the households surveyed. Instead, the measurable vehicle attributes, such as price and cost of fuel, and those of household characteristics, such as household size, are what explains purchase behavior of these households.

The contribution of this research is in analyzing the choice of car size categories in a developing country. In a single framework, it studies the substitutions among i) motorized two-wheelers and different sizes of cars, and ii) between new and used vehicles.

To my father.

Contents

List of Figures

List of Tables

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Chapter 1

Introduction

Aided by its economic growth, India moves towards a car-based culture. While most Indians still use non-motorized modes and those in the larger cities use public transport, with the growth of the economy, personal motorized vehicle ownership and its use is growing rapidly. With the liberalization of markets in the nineties, leading to the introduction of foreign competition and collaboration, consumerism began, spurred by the wide variety of goods in the market (Nagaraj, 2008). This boosted the growth of motorized vehicle ownership in India. Now, with the availability of easy financing with low-interests, and the growing purchasing power of the burgeoning middle-class, Indians are increasingly buying personal motorized vehicles, namely motorized two-wheelers and cars.

Studies show that growth in income leads to growth in car ownership. As the economy of lower-income countries like India, with relatively uniform distribution of income grows, the growth in car ownership happens very rapidly (Kutzback, 2010). Congestion and its associated malaises, such as increased fuel consumption, emissions, and decreasing road safety, are unavoidable by-products of this growth. Yet the benefits of motorized vehicles are many; motorized two-wheelers offer speed and flexibility of both time and route, increasing mobility and access to jobs and goods; cars, in addition to those benefits, offer greater safety to the passengers and increased convenience. As per the last census of the country taken in 2001, a mere 2.5 percent of the population owned cars and 11.7 percent owned motorized two-wheelers. Consequently, owning a motorized vehicle, especially a car, is associated with high societal status, and is the aspiration of the 'have-nots' in the country.

Policies being implemented have been dichotomous. On one hand, some manifest interest in encouraging use of transit and non-motorized modes. On the other hand, others support the growth of the booming automotive industry that provides employment to many and is a major support for the economic development of the country. Except for a negligible share of exports, most of the cars and motorized two-wheelers manufactured in India are sold within the country. Policies that support the sales of

the personal motorized vehicles indirectly add to the growth in its ownership and subsequent use. This in turn increases congestion on the roads, affecting travel time by road-based public transport more adversely than travel times by cars, and therefore causing public transport to lose ridership to cars.

Infrastructure building in the country also follows a similar two-pronged approach. While bus rapid transit is being introduced in many cities with varying levels of success, highways, roads and flyovers are also being built to accommodate the growing numbers of cars.

At the confluence of such growth and infrastructure building activities, it is important to study the factors that affect the future composition of the vehicle fleet. As India moves away from public and non-motorized modes towards personal motorized modes, there is also a shift from owning motorized two-wheelers to cars. This phenomenon is in line with observations in other developing countries with rising per capita income. Furthermore, Indian consumers who could afford a personal motorized vehicle, have so far bought new vehicles and held them for a long time (Roychowdhury, 2007). This trend has also changed with the increase in consumerism and increasing preference for owning the latest models. The share of used cars in the car sales figures has increased from half to two-third or more. Finally, Indian consumers have preferred small cars, those forming the majority of what the market offered for a long time. Now, with the introduction of many new models in various sizes, it remains to be seen whether the Indian consumer would continue to prefer the small cars. Knowledge of the composition of the vehicles on the road would assist both infrastructure building and framing policies for reducing fuel use and emissions, and improving traffic safety. Knowledge of the factors that influence this composition could be useful to policy makers for designing means to direct development towards more environment-friendly options.

Along with increasing income, the household structure of the Indian population is also changing with traditional joint families giving way to nuclear families. The goal of this research is to study whether these changes would change the preference of personal motorized vehicle types. The research question that we aim to answer in this dissertation is: *what is the effect of changing income and household size on the vehicle ownership and purchase characteristics of the Indian citizen?* To do that, we study the motorized vehicle fleet and recent motorized vehicle purchase of urban residents in Surat, a rapidly motorizing city in India. We obtain the data through a survey of vehicle-owning households.

The outline of this dissertation is as follows: Chapter 1 describes the motivation, followed by the research question and the methodology. Chapter 2 describes previous studies that the dissertation draws from, and finds the gap in the existing study that this work aims to fill. Chapter 3 describes the survey process. Chapters 4 and 5 describe the analyses of the vehicle type choice and observations on the travel characteristics of the survey respondents. Finally, Chapter 6 concludes the study with

a summary of main findings, their implications, and a description of the contributions made by this dissertation. Appendix A outlines some of the salient policies relating to vehicle ownership and use in India. Appendix B appends secondary data on the socio-demographics, vehicle ownership, and use characteristics of Surat. Appendix C contains the survey questionnaire. Finally, Appendix D outlines the details of the exploratory factor analysis process.

1.1 Background of Motorization in India

As a British colony, India witnessed the use of the personal motorcar from the early part of the twentieth century. Indigenous motorization had a modest beginning in 1957, ten years after independence from British rule, with Hindustan Motors designing the Ambassador based on the Morris Oxford Series II and Series III designs. The only other car in the market was the Premier Padmini, a Fiat 1100 assembled in India. Under strict government control of industrial production, these cars monopolized the Indian market for many years to come.

The Ambassador reached its peak sales in the seventies at 30,000 units per annum. Until the 1980s, industrial production was still licensed and the car industry was comprised of two models selling 40,000 cars a year. In February 1981 another indigenous automobile manufacturing company Maruti Udyog Limited was founded, and they built the then 'people's car', the hatchback Maruti 800. Entering into a joint venture with Suzuki they became Maruti Suzuki in October 1982. With the cars instantaneous popularity, the company captured a majority of the market share in a very short while.

Liberalization of the economy took place in the early 1990s. Maruti continued to be the market leader in the late 1990s and introduced new models to compete with foreign brands and other joint ventures. Tata Motors, a third Indian auto-manufacturing company, shifted its focus from building trucks to building SUVs and sedans. Car sales started on an increasing trend, along with that of the sales of motorized two-wheelers, and continued until 2002 (BBC, 2007) as shown in Figure 1.1. The rapid pace of growth of the economy since 2002 became a source of additional stimulus to the growth of motorized vehicle sales. Currently, India is the eleventh largest passenger car market globally and the fourth largest commercial vehicle market in the world. It is thus a good venue for a study of vehicle ownership and its use.

In the year 2005 through 2006, Maruti was the market leader controlling over half of the market share. Hyundai Motors India Limited followed next with 19 percent and Tata Motors with 16.6 percent of the market share. HondaSiel cars India Limited and Ford India Private Limited held a major share of the remaining market. In the SUV market, Mahindra & Mahindra Limited controlled 45 percent with the other major players being Toyota Kirloskar Motor Private Limited, Tata Motors, and

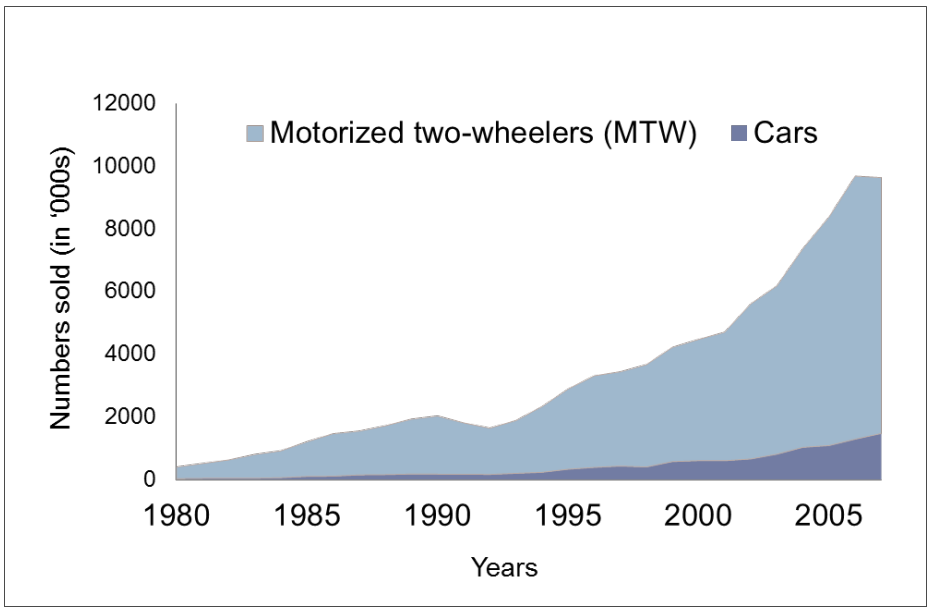

Figure 1.1. Sales of cars and motorized two-wheelers 1980-2007, (SIAM, 2009).

General Motors India Private Limited (SIAM, 2009). Concurrently, Audi, BMW, Chevrolet, Fiat, Mercedes, Mitsubishi, Skoda, Suzuki, Volkswagen, and Volvo have set up manufacturing facilities in India. Manufacturers now import cars and spares to meet the demands of this growing market.

India is the second largest two-wheeler market in the world. The sales of two wheelers have exceeded that of cars by multiples since the seventies. Until the mid-eighties however, there were very few competitors in that market. Scooters and motorcycles were each manufactured by only three companies. With opening of the market to foreign manufacturers and collaborators, many new models have been introduced. At present, the Indian market carries a wide range of two-wheelers that include scooters, motorcycles, mopeds, electric bikes, and motorcycles with higher volume engines. (Automobileindia.com, 2009) It is postulated that a large segment of the target consumers of the affordable Mini cars will constitute consumers who, in its absence, would have bought two wheelers. This large consumer base shifting to cars could cause drastic changes in the market and in mode shares. While the first affordable Mini car, the much publicized Nano by Tata Motors, did not contribute significantly to the growth in car ownership, other small cars, priced both at and below the prices of cars in the market at present, are either being launched or would be launched in the near future. Overall, the market share of cars is expected to increase.

1.2 India in the Global Context

Unlike the United States, growing demand of motorized vehicles in India is concentrated in the urban areas. As per census 2001, 28 percent of the billion-plus population of India lives in the urban areas of which more than 27 percent lives in the million plus cities. The million-plus cities are expected to witness the fastest growth rates. Like most other developing economies, urbanization in India is taking place rapidly.

Table 1.1, presented below, compares the income, population, vehicles, and their growth rates for India along with that of China and the United States.

Table 1.1. Comparative statistics of India and other countries

		India	**China**	**United States**
Population	Total (billions, 2003)	1.14	1.33	0.3
	Growth rate (percent, 2000-2005)	1.5	0.7	1
Per Capita Income	Total (thousands, 1995 $ PPP, 2002)	2.3	4.3	31.9
	Growth rate (percent, 1960-2002)	2.3	6.5	2.1
Vehicles/1000 people	Total (2002)	17	16	812
	Growth rate (percent, 1960-2005)	6.8	9.8	1.6
Vehicles	Total (millions, 2002)	17.4	20.5	233.9
	Growth rate (percent, 1960-2002)	9.1	12	2.8

Growth rate: Annual Average Growth Rate
Source: UNFPA, State of the World Population 2003, (Dargay *et al.*, 2007)

Table 1.1 shows that India's rate of population growth is the highest among the three countries compared. China exceeds India in the growth of per capita income, vehicles per thousand persons, and total number of vehicles. But India's rate of growth is still very high compared to that of more developed economies like the United States. In the ten years interval since 1995, the GDP of India has doubled and its annual sales of two wheelers and cars have tripled. From 1970 to 2000, motorized mobility or passenger-kilometers has risen by 888 percent, compared with an 88 percent population growth (Singh, 2006). Consequently, its fuel consumption and emissions are also rising rapidly.

Studies link the rise in car ownership of a country to the increase in its per capita income (Button *et al.*, 1993), (Dargay *et al.*, 2007), (Gakenheimer, 1999). Figure 1.2 shows the motorization and economic growth in developing countries from 2002-2007 (Kutzback, 2010). Among low-income countries, countries with less equal income distribution like Nicaragua and Bolivia tend to have higher car ownership than the more equal societies of India. The order reverses for middle income countries where the more equal societies have higher car ownership than the less equal ones. This is because, when income rises in countries with more equal income distribution, car purchases occur more quickly across a large share of the population, causing a rapid increase in car ownership and use (Kutzback, 2010). The vehicle ownership of

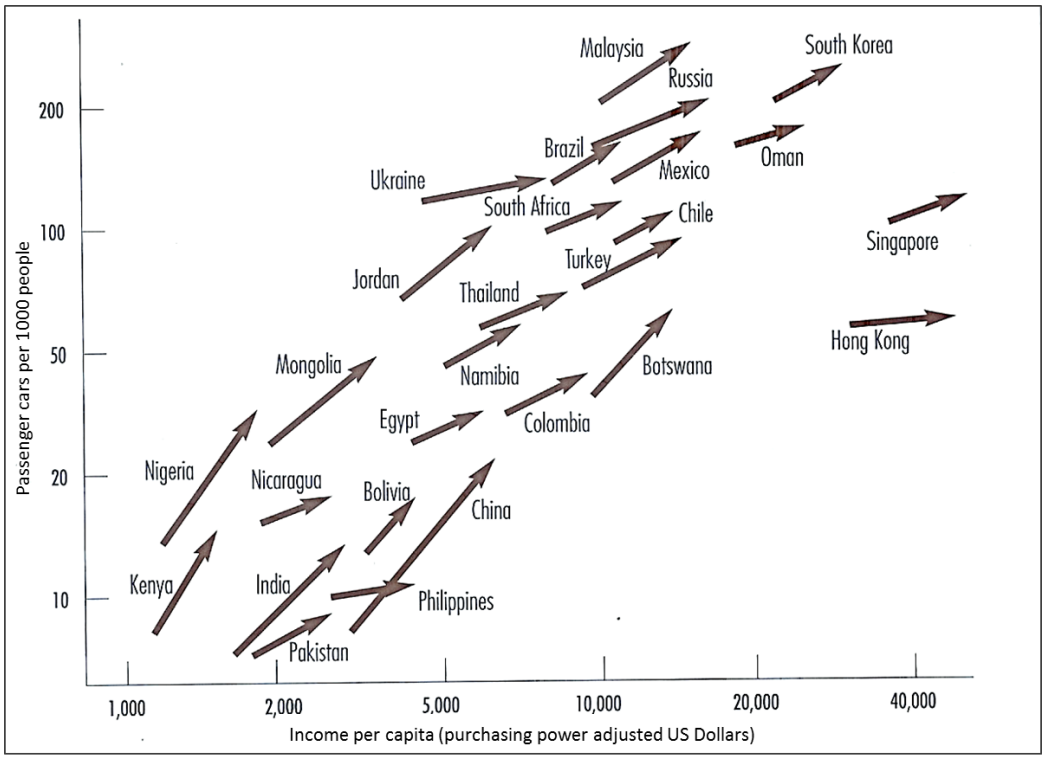

Figure 1.2. Motorization and economic growth in developing countries: 2002-2007, logarithmic scale, (Kutzback, 2010).

India was at 17 vehicles per thousand persons as compared 812 vehicles per thousand persons in the United States in 2002 (Dargay *et al.*, 2007). Even in urban India, with higher concentrations of motorized vehicles, only 5.6 percent of the Indian households in India owned cars, and 24.7 percent owned motorized two wheelers as per the Census 2001. Making up rapidly in terms of growth in car ownership, the country's volume of sales in light vehicles is now projected to grow at 14.5 percent in the next five years, one of the fastest of all the developing economies. India is also developing as a car producer being the eleventh in the world in the production of cars.

The used car market of India is growing faster than the new car market. As of 2007, the sales of used cars to new cars was estimated to be 1:1, which is less than the global ratio of 2:1. This is primarily because Indians held their cars longer (Roychowdhury, 2007). Now with rapid introduction of new models and many Indians preferring to own the latest models, the market for used cars is growing. Vehicle dealers and media sources estimate the present ratio of used to new cars as 2.5:1.

Figure 1.3 compares mode shares in Indian cities with those of other world cities. All developing economies record higher percent of public transport and non-motorized trips, as compared to the developed economies that record higher percent of private motorized vehicle use. Among the Indian cities, public transport contributes more to

mode shares in bigger cities, and non-motorized modes contribute more to the mode shares in the smaller ones. A large majority of trips by private motorized modes in Indian cities are by motorized two wheelers.

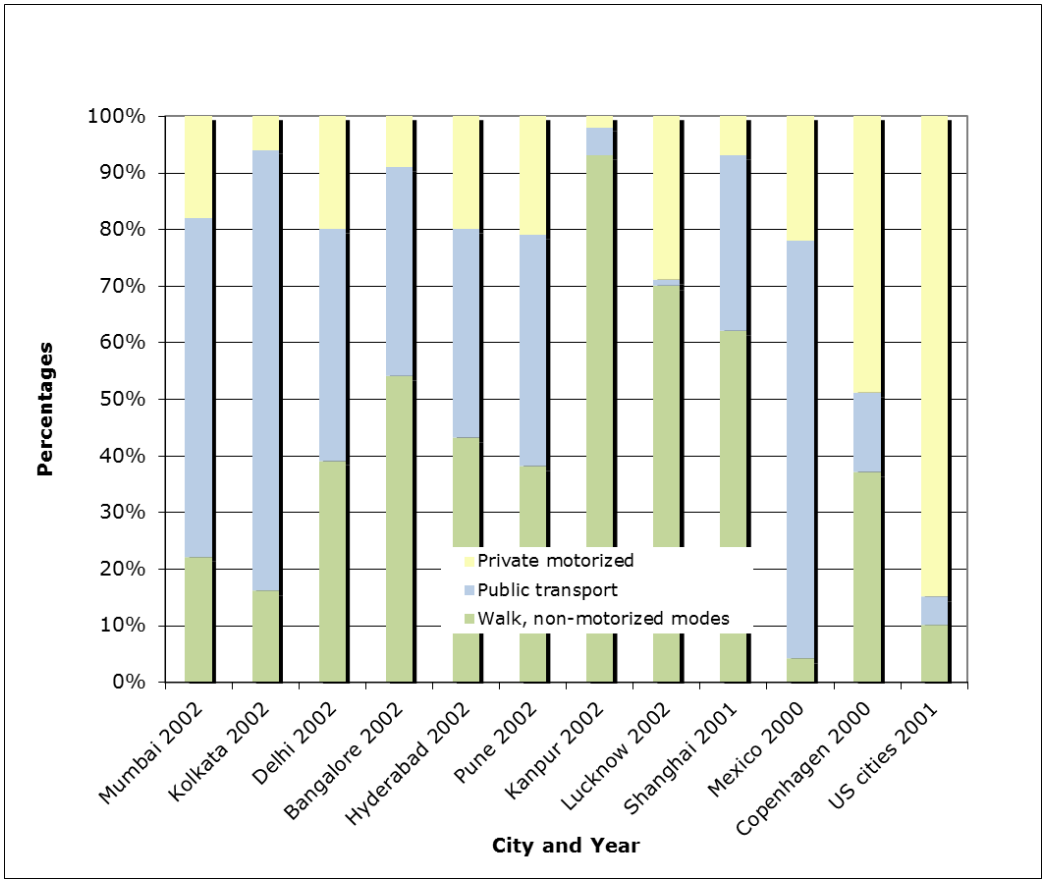

Figure 1.3. Trip shares of selected Indian and international cities; Indian cities in descending order of population; Mumbai (16.3M) and Lucknow (2.26M). Sources: Pendakur (2002) for Mumbai, Delhi, Bangalore, Kanpur; and World Bank (2002) for Kolkata, Hyderabad, Pune, Lucknow; Ni (2008) for other cities.

1.3 Changing mode shares in India

Mode share and proportion of passenger kilometers traveled by cars in India is marginal. Of the total annual passenger kilometers traveled in 2001, India recorded 21 percent of passenger kilometers in private motorized modes with 9 percent trips by cars and 12 percent by motorized two wheelers. In comparison, United States recorded 90 percent share of private motorized vehicles with 54 percent in passenger cars and 36 percent in light trucks.

With the rise in car ownership, the mode share of cars is also increasing. Figures 1.4 and 1.5 compare percent trips by various modes in cities of different sizes in India. Comparing between 1998 and 2007, it is evident that the percent car trips have increased in all city types at the cost of public transport and non-motorized trips. This shift has been more marked in smaller cities.

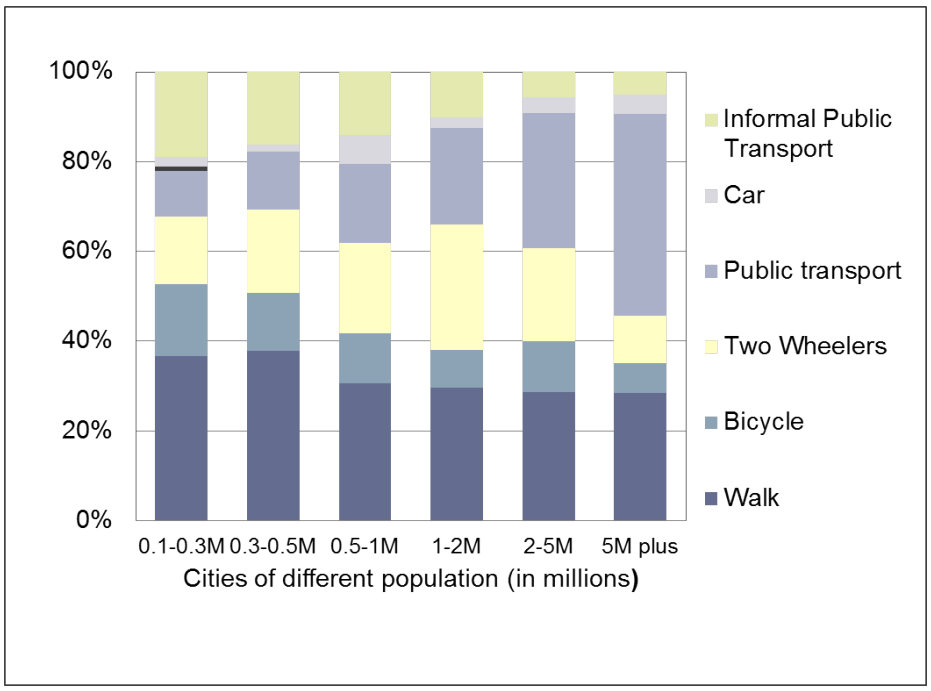

Figure 1.4. Percent trips by various modes in cities of different sizes (1998). Note: Intermediate public transport (IPT) includes both motorized and non-motorized modes. Source: (Associates, 1998)

The anticipated rapid growth of car ownership and use (Padam & Singh, n.d.), (Sibal & Sachdeva, 2001) could amount to major changes in the modal shares. Without policy interventions, there is likely to be a shift i) from non-motorized to motorized means of transport, ii) from public to private modes, and iii) from motorized two-wheelers to cars. The ownership of used cars is also likely to rise. Since the modal composition affect the road capacity, emissions, and even safety, it is important to study the motivation for use of different types of personal motorized vehicles, including different sizes of cars.

1.4 Different Car Size Categories

Currently, there are eight different categories of cars in India. Of these, six categories are segregated on the basis of length. The remaining two categories are segregated on the basis of weight and seating capacity. These are the Utility Vehicle (UV),

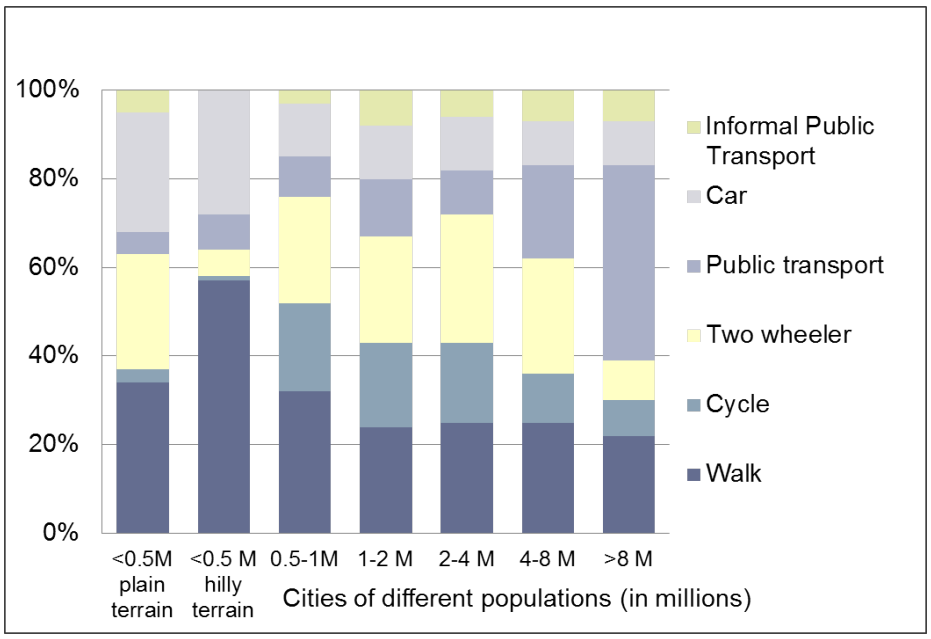

Figure 1.5. Percent trips by various modes in cities of different sizes (2007) Source: (Associates, 2008)

equivalent of the *Sports Utility Vehicle (SUV)*, and the Multi-Purpose Vehicle (MPV), equivalent of the *Minivan*. Table 1.2 lists the number of models in each car segment, their respective five-year compound annual growth rate, the number of seats, and the price of the category averaged over the constituent models in the category for September 2009, concurrent with the study.

The constituent variants of a car model are considered together as one when accounting for the number of models. For example, the 3-series, 5-series, and 7-series in BMW, and the C-class, E-class, and S-class in Mercedes are each broadly considered as one model. The numbers of models in this nascent market vary vastly across the different size categories. Manufacturers assess the consumer demand for a particular size category and launch models in the category. As such, the size categories with more models are more popular. Until 2007, the *Mini* car segment comprising only one model, the Maruti 800, had shown a decline in growth with the five-year compound annual growth rate (CAGR) being -11 percent. The introduction of the *Nano* by Tata Motors in this size category, as the least expensive car in the world, led to speculations on the projected consumer preference of the car over other pre-owned cars available for the same price. The sales of this car was not enough to change the market share of *Mini* cars, but other affordable, small cars poised to be launched in the market may bring about some changes. The next size category, *Compact* cars, is ubiquitous comprising half of the car market.

All categories other than the *Mini* car have positive five year CAGR with the *Executive* category recording as high as 112 percent (Center for Science and Environ-

ment, 2008). The large growth in the higher priced *Executive* or *Luxury* car sectors is due to their very low initial sales. The *Executive*, *Premium*, and *Luxury* class of cars record low sales, owning to their prohibitively high prices. These are also evident from Figure 1.6, that plots the sales in the different car size segments from 2001 to 2007.

The prices of different models in the same car size category vary widely, leading to an overlap in the prices of the models across the categories. For example, the price of the BMW 3-series or the Mercedes Benz C-class in the Executive size category is equal to the average price of the Premium size category. Typically, the average price of a particular size category increases with size. The two exceptions to this rule are the *Minivan* and the *SUV*. The average price of the *Minivan* is lower than that of the *Compact* car category although the size is larger as evident from the number of seats. The average price of the *SUV* is higher than than of the *Midsize* and lower than that of the *Executive* category, although its size and seating capacity are larger than both categories. The price of each size category is presented in 2008 dollars at purchase power parity. The price in dollars at purchase power parity indicates the relative expense of buying cars in India.

Appendix A shows the basis for classification of the different categories, called 'segments' in India, along with the names of the constituent models in September 2009, concurrent with the field data collection for this research (Nations, 2011).

Table 1.2. Car size segments in India

'Segment'	**Number of Models**	**Five year Compound Annual Growth Rate (CAGR) percent**	**Seats**	**Average Price (in 2008 $ PPP**
A1 Mini	2	-11	4	11900
A2 Compact	18	22	4	25200
A3 Mid-size	15	19	4	36000
A4 Executive	11	112	5	82900
A5 Premium	11	6	5	184900
A6 Luxury	4	33	5	499820
B Utility Vehicle/Sports Utility Vehicle	48	16	7-13	57200
C Multi-Purpose Vehicle/Minivan	3	6	5-8	19850

1.5 Transport Characteristics

India has its unique transport characteristics that influence the nature of trips made and vehicles purchased by households. Most developments are dense with mixed land use; neighborhood grocery and provision stores, and vendors selling fresh produce on carts, are still prevalent over consolidated departmental stores. As a result, grocery trips are everyday walk trips. Roads are congested; there are no marked lanes and

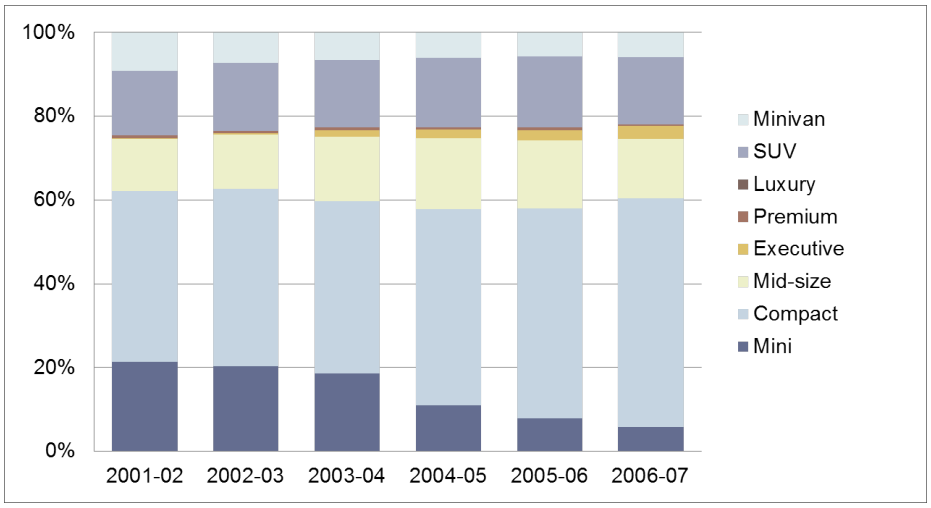

Figure 1.6. Trends in sales of cars of different sizes, 2001-2007

lane driving is not common; the traffic consists of a mix of different motorized and non-motorized modes. Additionally, marked slots for parking are also not present at most locations. All of these factors make it easier to maneuver smaller vehicles.

Safety norms are often flouted due to relatively lax enforcement of regulations. Vehicles are frequently overloaded; small businessmen carrying goods on bicycles or motorized two-wheelers, or householders carrying a family with young children on motorized two-wheelers are common sights; riders of motorized two wheelers or bicycles often do not wear helmets and drivers commonly use their cellular phones while driving.

Private transport in general and cars in particular are expensive to own and use. A trip made by public transport is substantially less expensive than the fuel cost of the same trip made using personal car or motorized two-wheeler. However, since labor is inexpensive, many car-owning households employ drivers.

Household sizes are large with a prevalence of traditional joint families, the members of which frequently make discretionary trips together. Informal social trips are frequent between neighbors, friends, and relatives, especially in smaller cities and older neighborhoods.

1.6 Salient Transportation Policies in India

In the last couple of years, several new transportation policies have been implemented in India. Some of these support sustainable, transit oriented development and discourage private motorized vehicle use. Yet others support the booming automobile industry of the country.

The Jawaharlal Nehru National Urban Renewal Mission (JnNURM) was launched in 2005 to improve urban infrastructure and service delivery mechanisms. It was aimed to improve community participation and accountability of urban local bodies or parastatal agencies towards citizens. Beginning from the year 2005-06 the window of this mission is open until 2011. It aims to invest a total of INR 120,536 crore (28 billion USD) in urban infrastructure in 63 cities across the country. The program has two parts: one focuses on services for the urban poor and the other on infrastructure development. The latter is administered by the Ministry of Urban Development (MoUD) and includes among others, projects in road network and urban transport.

The same ministry also launched the National Urban Transport Policy (NUTP) in mid-2006. This policy was created to improve access to the growing number of urban residents to work, education and recreation. It was further aimed to enable people centric developments instead of developments that are centered on improving conditions for private motor vehicles. It recommends integrated land use and transport planning, equitable allocation of road space, priority to public and to non-motorized transport, coordinated planning, and association with the private sector, and discourages use of personal motor vehicles. After the launch of the NUTP, a decision was made for all urban projects that receive financial assistance from JnNURM to confirm to NUTP. This policy motivates cities to implement bus rapid transit (BRT) along with other sustainable transport solutions.

Taxes and excise are structured to discourage ownership of 'big cars'. Vehicles longer than 4 meters and engines above 1200 cc for gasoline based engines and above 1500 cc for diesel based engines are classified as big cars. At present, the excise duty on big cars is 22 percent whereas that on small cars is 10 percent. There is also a tax worth INR 15,000 on big cars.

While developing policies that encourage public and non-motorized modes of transport, the government has also developed policies to boost the growth of the automobile industry. The Automotive Mission Plan 2006-16 aims at doubling the contribution of the automotive sector in GDP by taking the turnover to 145 billion USD in 2016 with special emphasis on export of small cars, vans, two wheelers and auto components. The plan outlines policies to boost the industry that include fiscal incentives, education and training, enhancement of transport, communications and export infrastructure (Government of India, 2006).

In end-2008, the government reduced excise duty on cars and two wheelers by 4 percent to aid the struggling industry in the middle of recession. The Reserve Bank of India lowered policy rates and other banks followed. At the time of the launch of the affordable small car, the Tata Nano in 2009, the State Bank of India had lowered interest rates on car loans to 10 percent. The income eligibility of car loans for this car has also been relaxed from INR 1,00,000 to INR 75,000.

The National Highway Authority of India (NHAI) has been instrumental in developing, maintaining, and managing a national network of intra and interstate high-

ways. Since its opening in 1995, it has undertaken major road initiatives such as the Golden Quadrilateral, North-South and East-West Connectors and Port Connectivity projects. While this does not affect urban trips, it may be expected to increase the number of road tripsl.

1.7 Research Questions and Methodology

This dissertation aims to answer the question: *what is the effect of changing income and size of household on vehicle ownership and purchase characteristics of the Indian citizen?* Given the landmark changes expected in motorized vehicle ownership in India, and the unique characteristics of the Indian culture, urban environment, and transportation, studying vehicle ownership and use in India justifies itself in many ways. The knowledge of the factors affecting vehicle ownership and purchase decisions will help framing policies that are best for the community and the environment. Correct prediction of future vehicle composition will assist policy decisions relating to infrastructure, energy, emissions, and road safety.

This research is based on observations and interviews, as well as findings from data analysis and models. The methodology and the survey questionnaire are based on the findings of earlier studies of similar nature that we will discuss in Chapter 2. A study of this nature has not been undertaken in India or other developing economies before, possibly because it was not as relevant even some years ago, and primarily because of the challenges of obtaining the data required. The data and observations are obtained from a survey conducted in late 2009 in the city of Surat, a fast-motorizing, second tier city with population over four million. The survey involves home interviews of 196 vehicle owning households. Through broad statistical analysis, we identified many of the important factors that affect the nature of vehicle ownership and purchase. We then used models to assess the extent to which each factor affected the various decisions. Data limitations due to the small sample size were overcome by analysis on aggregate level.

The contribution of this research is in analyzing preference among car categories in a developing nation. We study the substitutions across motorized two-wheelers and different car categories, as well as between new and used vehicles in a single framework. Chapter 2 discusses the existing literature on this topic and better explains the relevance of the present research.

Chapter 2

Literature

In this chapter, studies on vehicle choice and mode choice are reviewed. While vehicle choice is the focus of the research, the few studies based in developing economies mostly address vehicle choice along with vehicle use or mode choice. There are many studies based in India that shed light on the effect of owning cars and motorized two-wheelers on mode choice. Only one Indian study directly addresses vehicle choice.

These are the three sections in which the literature is categorized:

1. Vehicle type choice
2. Vehicle type choice along with vehicle use or mode choice
3. Mode choice studies conducted in India

2.1 Vehicle Type Choice

This discussion focuses on the type choice of a single vehicle. Most studies on the type choice of a single vehicle are based on new vehicle purchase, while some are based on the choice of the most expensive or most frequently used vehicle in the household fleet. Some of the studies focus on the details of makes, models, and vintages, while others focus on the choices of vehicle classes.

The multinomial logit (MNL) model is most commonly used in studies on vehicle type choice. Among the explanatory variables, the vehicle attributes of purchase price, operating cost, number of seats, luggage space, vehicle weight, and age are typically found to be explanatory (Berkovec & Rust, 1985), (Mannering & Mahmassani, 1985), (Mannering & Winston, 1985), (Manski & Sherman, 1980), (Martin, 2009). The two household attributes that are found to influence vehicle type choice in many of these studies are income and the number of household members (Bunch, 2008). In

many studies, one or more vehicle attributes are interacted with socio-demographic attributes to explore the change in preferences with change in socio-demographics. The interaction of income with vehicle price is a typical example. Some studies capture the effect of the household size on vehicle choice (Kitamura *et al.*, 2000), (Lave & Train, 1977). Lave and Train find that increasing household size decreases the probability of a household owning a sports or a specialty vehicle. Kitamura et. al. find that it has a positive effect on the choice of vans and wagons. Kitamura et.al. also explore the effect of transit accessibility and find that four door sedans, vans, and station wagons tend to be favored in areas with public transit access, while SUV and trucks are favored in the metropolitan fringe. In studying the choice of makes and models, Mannering and Winston find the effect of brand loyalty to be substantial (Mannering & Winston, 1985). Manski and Sherman find the effect of transaction search cost to be an important explanatory variable in household vehicle holdings (Manski & Sherman, 1980). The increase in the share of used vehicles of all vehicle sales in India leads to the hypothesis that there has been a change in transaction cost, and is a potential subject of interest in a study of vehicle purchase, holding, and scrappage. Choo and Mokhtarian explore attitude and lifestyle preferences in the form of attributes like subjective and objective mobility, travel liking, attitudes, personality, lifestyle and demographics. They find that owners of cars of different size categories vary in many of attitude and lifestyle preference factors (Choo & Mokhtarian, 2004).

Specification issues are a concern for the MNL models due to the independence of irrelevant alternative (IIA) property of these models (Train, 2003). Mannering and Mahmassani, while not specifically addressing IIA, find that vehicle attributes are valued differently for foreign vehicles than they are for domestic vehicles (Mannering & Mahmassani, 1985). Nested multinomial models and mixed logit models have been used in choice model literature to deal with IIA violations. Additionally, nested multinomial models have also been used to model the joint probability of two decisions. For example, Berkovec studies the choice of the number of vehicles owned at the upper level, and of the type choice among 131 vehicle classes and vintages at the lower level (Berkovec, 1985).

2.2 Vehicle Type and Mode Choice

Some studies of vehicle choice, specifically those in developing economies, cover both the choice of modes and vehicles. Besides addressing vehicle choice, some studies research the number of miles traveled on each vehicle in the household fleet. Some of them estimate the two choices separately while others estimate them in a single model framework.

The three studies based in developing economies estimate the two choices using separate models. Ni, in his study on motorization pathways, vehicle purchase, and use

behavior in Shanghai, estimates MNL models for the most expensive vehicle owned, and the most frequently used mode for weekday and weekend travel. He conducts a factor analysis on Likert scale questions exploring attitudes and preferences, and uses the output to analyze choice of the most expensive vehicle owned. He finds gender, income, and the perceived effect of status to have significant effects on vehicle purchase and use behavior (Ni, 2008). Joewono, Susilo and Mohamad calibrate an ordered probit model to study the number of vehicles per household. They further calibrate multinomial logit models for choice of vehicle type and vehicle brand and a regression model for car use in Kuala Lumpur region and its surroundings. They find that lower salaried households prefer motorcycles and that households in general prefer the national vehicle brand (Joewono & Susilo, 2008).

Srinivasan et.al. find in their study of Chennai city conducted between 2004 and 2005, that income, presence of female workers, and of school age children lead to increased probability of a household owning a car. Their study of longitudinal data of the current year, and that of five years before, capture some of the key transitions in the Indian society, for example, decreasing family sizes and increasing participation of women in the workforce. Their key findings are that peer pressure and credit card holdings influence car ownership positively; households with grocery stores or markets nearby are less likely to acquire cars than other households; and the propensity to buy motorized two-wheelers or cars is the largest among households that did not own motorized two-wheelers or cars respectively five years earlier. Given that many households possessed motorized two-wheelers and more than seventy percent of the households did not possess a car, the authors conclude that car ownership may grow faster than motorized two-wheeler ownership in the future (Srinivasan *et al.*, 2007b).

The studies discussed in the remaining part of this section are those in which estimation of vehicle type choice and mode choice are combined. These are based on the premise that vehicle ownership and mode choice decisions are made endogenously and that treating one of these as exogenous in the decision process of the other lead to inconsistent estimation of model parameters (Train, 1980).

Lerman and Ben-Akiva, and Ben-Akiva et.al. (Ben-Akiva *et al.*, 1976), (Lerman & Ben-Akiva, 1976), model the joint probability of owning a certain number of vehicles and taking a certain mode to work. Lerman and Ben-Akiva formulate a variable for the remaining income in which considerations of the total income, the number of household members, and the number of vehicles owned gives a value for the disposable income. However, the value estimated for the variable is approximate since vehicle makes and models are not considered separately. The authors find that introducing new transit service to areas can have a measurable decreasing effect on auto ownership, but the effects on auto ownership of improvement in existing transit is marginal.

Train estimates a model of automobile ownership, and a work-trip mode choice model conditional on automobile ownership level. The models are estimated separately but are connected through an aggregate work trip utility term estimated as

a part of the auto ownership model (Train, 1980). Dissanayake and Morikawa, in their study of Bangkok Metropolitan area use a nested logit model in which the upper level represents vehicle ownership types and the lower level represents work trip mode choices for two worker households. Because the sharing of a vehicle is very common in developing countries, the authors consider trip chaining by two household workers as one of the mode choice options.They find that the presence of schoolchildren in households increases the probability of owning cars (Dissanayake & Morikawa, 2002), Dissanayake & Morikawa (2003).

Although the combined estimation framework is adopted to eliminate the endogeneity between vehicle choice and mode choice, none of the studies conduct any tests to demonstrate the existence of such endogeneity. It may be argued that other variables like location of residence or work, or the decision of whether or not to work is also endogenous to vehicle ownership and mode choice. Additionally, combined estimation models have their limitations too. Many of the studies do not attempt to separate variables that affect only vehicle ownership or mode choice but not both. While Train's model allows use of a separate set of variables to explain vehicle ownership and mode choice, in Ben-Akiva's model, the same set of variables explains both. Ni, in his estimation using separate models find that purchasing a car is positively associated with household income; however, weekday car use is positively associated with personal income (Ni, 2008). It is also challenging to capture the effect of a household vehicle ownership decision on the mode choice of all household members.

Based on our review, the longitudinal study conducted by Srinivasan et.al. is the only one study on vehicle choice in India. For further information on the transportation characteristics of India we reviewed some mode choice studies that discuss the influence of the type of vehicles owned. We summarize these studies in the next section.

2.3 Mode Choice Studies Conducted in India

Most of the studies in this section discuss the differing effects of the ownership of cars and motorized two-wheelers on mode choice. Sarna, in his study based on a survey conducted in 1969-70 in Delhi, finds that households with more motor vehicles record a higher percent use of private motor vehicles as compared to the use of transit or bicycles (Sarna & Sarin, 1985). Parida et.al. infer that a very small percent of those who owned a car or owned both a car and a two-wheeler used public transport in Delhi, which implies that people owning cars are almost captive to their own modes. However, a fair share of those who owned a two-wheeler alone used public transport (Parida *et al.*, 1993).

Different studies explore the concept of captivity due to ownership or lack thereof of private vehicles. Srinivasan et.al. stratify the sample of survey respondents in

Chennai based on the extent of captivity, namely availability of private vehicle as a modal option for the commuter (Srinivasan *et al.*, 2007a). Chari and Khanna define workers using a government or company vehicle for the work journey as captive and do not include them in modeling mode choice (Chari & Khanna, n.d.).

Saleh and Sikdar find from a survey of Guwahati conducted in 1991-92, that most modes have their characteristic lead distance within which they are used the most. Trip data suggests that transit is the choice for large household size, low-income groups and long distance travel for households without vehicles. Self-driven vehicle is more appropriate to small household size, high-income groups and medium travel distance (Saleh & Sikdar, 1996).

On the basis of a survey conducted in Ahmedabad in 1972-73, Chari and Khanna find that car owners have the highest value of time, followed respectively by two wheeler owners, bicycle owners and those who do not own any vehicle. They also find that people who walk or ride bicycles have the greatest propensity to shift towards bus use (Chari & Khanna, n.d.).

Arasan, Rengaraju, and Krishna Rao, observe in their study of Tiruchirapalli in the mid-1990s that the demand for travel by bus with respect to travel time is highly elastic for both owners of motorcycles and that of cars. This indicates that a reduction in travel time by bus may result in a substantial shift of travelers to the bus from personal transportation modes. The authors further observe that in India, motorized vehicle ownership is an index of the economic status of the households (Arasan *et al.*, 1998).

By means of a stated preference study conducted in Hyderabad in 2004, Gorham et.al. explore the possibility of personal vehicle users shifting to buses. They find that all else being equal, as levels of vehicle ownership rise, households become more sensitive to time and reliability and less sensitive to cost. They also find for all groups that reliability is a more important criterion than time and that buses suffer from an image problem. Even after controlling for time, cost and reliability, vehicle owners prefer their own vehicles and non-vehicle owners prefer to walk (Gorham *et al.*, 2004).

Based on the analysis of a survey conducted in Chennai in 2005-06, Srinivasan et.al. observe significant differences in two-wheeler and four wheeler use propensities due to income, vehicle ownership, length of commutes and costs. The authors find that the sensitivity to travel time and cost vary across different user groups based on captivity status and work distance. Subjective ratings of comfort, reliability, and flexibility affect the choice of public transportation modes. The authors further find that of the different road users, motorized two-wheeler and bus users are likely to be affected by an increase in fuel price, vehicle ownership, and by transit improvement measures (Srinivasan *et al.*, 2007a).

Rajagopalan and Srinivasan study mode choice and modal expenditure in a discrete-continuous framework based on the Chennai Household Travel Survey data

(2004-05). They find that the four-wheeler owners show stronger preference for personal vehicle and informal public transport (IPT) usage while two-wheeler owners exhibit positive preference for public transport and IPT. Increased congestion on roads increases a household's modal expenditure on trains and decreases that on private vehicles. Poor pedestrian safety levels reduce the household's marginal utilities for public transport and increases usage tendencies for personal vehicles and IPT. Finally, state dependence or inertia in mode switching is evident among all mode users but households that previously chose bus have a tendency to spend on personal vehicles instead (Rajagopalan & Srinivasan, 2008).

2.4 Discussion

In addition to identifying factors for input into the survey design, the literature reviewed provides a datum with which to compare the findings of the present study. Studies based on developed economies infer that changes in size of the household, accessibility to transit, and different attitudes and perceptions, are some of the variables that cause households to own and purchase different size categories of cars. From the studies on developing economies we find that higher income households own cars and lower income households own motorized two-wheelers. Most studies concur that increased ownership of motorized vehicles, especially cars, is associated with reduced use of public transport. In the present research, we will update these findings based on the analysis of the survey data obtained from Surat, a rapidly motorizing city of population over four million.

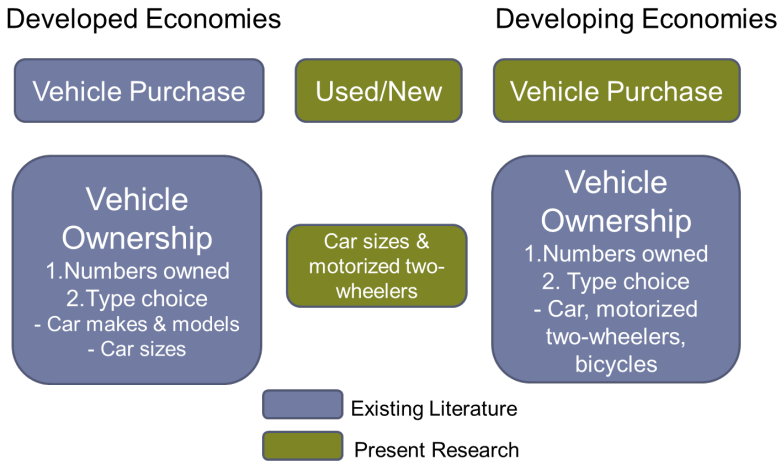

Figure 2.1. Research contributions

Review of the literature on vehicle choice, and vehicle and mode choice, reveals that while studies on vehicle choice in developed economies focus on the choice among

makes and models, or size categories of cars, that in the developing economies researches the choices across the broad categories of car, motorized two-wheeler, and bicycle etc. There is no study that researches the substitutions across car size categories as well as motorized two-wheelers, a research necessary in the present context as cars take away from the shares of motorized two-wheelers. Additionally, none of the studies reviewed, research substitutions across new and used vehicles. In this work, we study the substitutions across i) different size categories of cars and motorized two-wheelers, in addition to that between ii) new and used motorized vehicles. This integrated framework is important to observe the substitutions by affordable mini cars being introduced in the market, in the share of motorized two-wheelers and of used vehicles Another important contribution of this research is in studying vehicle purchase in developing economies. Figure 2.1 represents the research contributions of this study.

Chapter 3

Survey

The data for the research was obtained through a survey conducted in the city of Surat in western India. The city well represents the issues of growth in personal motorized vehicle ownership, having witnessed its sharp rise due to a rapid growth in per capita income. Home-interviews were conducted from July through October 2009 and the respondents interviewed on their recent vehicle purchase, existing vehicle fleet, demographic composition of household, and the previous day's travel diary. The respondents also expressed their opinion on a set of Likert scale questions relating to their attitudes and perceptions on status, peer influence, image and convenience of public and non-motorized modes, and on cost and utility consciousness. This chapter includes a discussion of the following:

- City characteristics as obtained from previous studies on the city
- City characteristics as obtained from observations and interviews
- Details of the survey

3.1 The City

Surat is situated in the west coast of India at the mouth of the river Tapi. Located in the state of Gujarat, it is 270 km to the north of Mumbai. It the 9th most populated city in India (Parimal, 2001). With its annual population having grown at around six percent since 1960, the city is projected to double its population by 2021 (Pai, n.d.). The city has extended its boundaries several times since then, of which the most recent extension took place in 2006. Table 3.1 shows the area and population in the 2001 city limits, and that in the extended 2006 city limits, based on the previous census. The table also cites the 2009 population estimates.

Table 3.1. Surat: summary of characteristics

Area and Population	**Value**
Population	2.43 million
Municipal Area (2001)	112.28 square kilometer
Municipal Area (2006)	326.52 square kilometer
Population of extended municipal area	2.88 million
Population 2009 (estimated)	5.06 million

The city is characterized by a large number of small and medium unorganized industries. A major manufacturing center, the economic base of Surat comprises textile manufacturing, diamond cutting and polishing, intricate 'zari' (gold and silver thread) works, chemical, petrochemical, and natural gas industries. Special economic zones, in which industries are exempt from duties, tariffs and many of the taxes, are being set up in and near the city to further boost its industrial development. The diamond factories of Surat constitute 42 percent of the world's total rough diamond cutting and polishing, while the textile factories constitute 40 percent of the nation's total synthetic fabric production (CEPT and Urban Initiatives, Surat, 2004).

The municipal area is divided into seven administrative zones. The traditional old city with narrow alleyways, one-way streets, and old houses constitutes the central zone of the city. Most of the government offices are housed here in historical buildings. The other six zones surround the central zone. Of these, the more affluent residents live in the southwest zone and some in the west zone across the river. The east zone houses the laborers with the lower literacy and income, of which many are diamond cutters and textile workers. The south zone is mostly industrial. Eight bridges across the river connect the main development on the south and the east of the river to that on the west and the north. Figure 3.1 shows the zonal map of Surat.

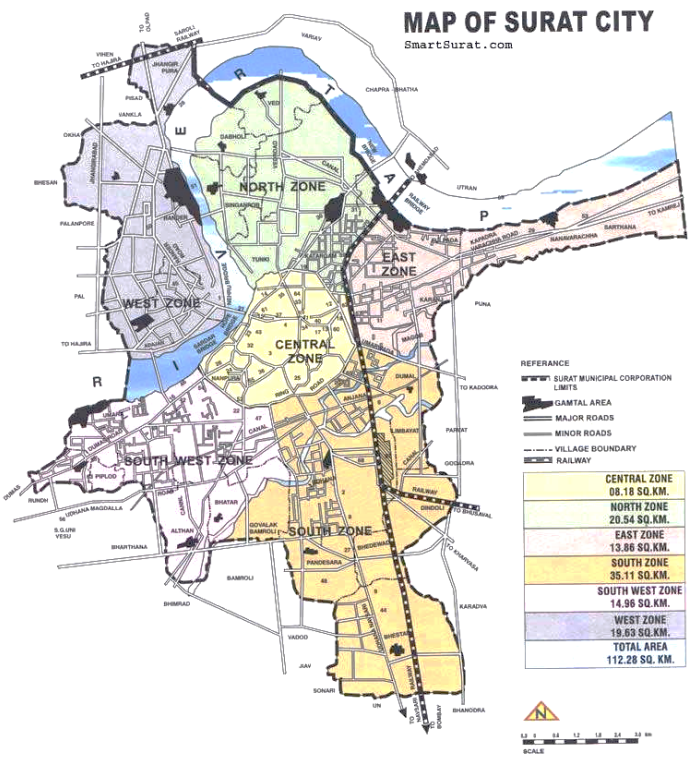

Figure 3.1. Zonal map of Surat

The following sections describe the demographic and travel characteristics of Surat.

3.2 Population Charcteristics

Surat has experienced very high migration. Since 1971, the population of Surat has experienced high growth rates primarily because its wealth has attracted a large migrant population. Its decadal growth rate in 2001 was the highest in the country. 56 percent of its population in 2001 consisted of migrants, of which 47 percent were from other states. As mostly male workers have migrated, the ratio of women to men has fallen steadily as shown in Figure 3.2. In 2001, there were only 774 women for every 1000 men (Parimal, 2001).

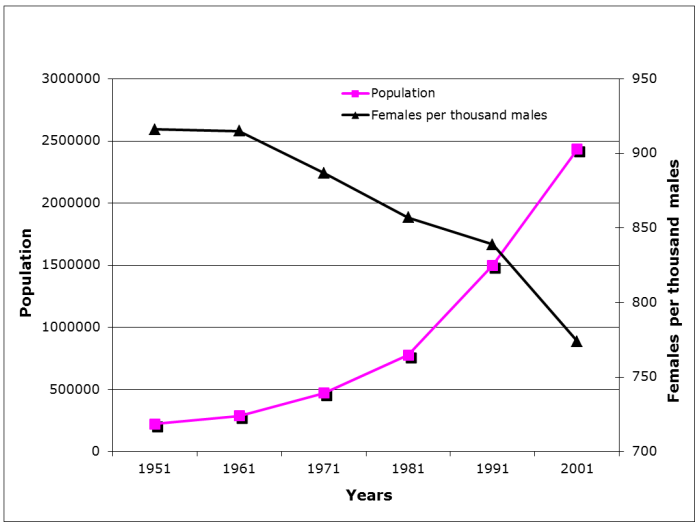

Figure 3.2. Trend in population and gender ratio in Surat

In India, the participation rate of women in the workforce rose from 14 percent to 26 percent over the past 30 years. Comparatively, the participation rate of women in the workforce in Surat was only 8 percent in 2001. Since a recent study of travel behavior in India has found households with female workers more likely to buy a car (Srinivasan *et al.*, 2007b), changes in ratio of females to males and in the female work force participation rates are potentially important factors affecting trip making and vehicle buying characteristics. Some key demographic characteristics of Surat are compiled in Table 3.2 (Parimal, 2001).

Table 3.2. Demographic data

Year	Population	Decadal growth rate	Gender ratio	Female WFPR	Male WFPR
2001	2,433,785	62 percent	774: 1000	8 percent	61 percent

The census on urban households in the state of Gujarat, in which the city of Surat is located, lists the number of households of different sizes. Households with 6 to 8 members consist nearly a quarter of all households. Together with the 4 to 6 person households, they comprise nearly seventy percent. 73 percent of the households own their residence while only 23 percent rent, the remaining having other dwelling options such as employer provided housing. The number of vehicles in the city has grown from 0.29 million in 1991 to 1.5 million in 2009 due to the rapid addition of motorized two-wheelers and car. Of all vehicles registered, the share of motorized two-wheelers has changed from 78.6 percent in 1994 to 79.1 percent in 2009, while that of cars has grown from 7 percent to nearly 10 percent. In 2009, there were 335 personal motorized vehicles per thousand persons but only 35 cars and jeeps (Regional Transport Office,

Surat, 2009), (**?**). Table 3.3 compares the ownership of different personal vehicles in the city of Surat, urban India, and India total (urban & rural) (Parimal, 2001). Since vehicles are concentrated in urban areas, a higher percent of residents of Surat as well as urban India owned vehicles at the time of the last census. While the car ownership of Surat approximated that of urban India, a much higher percent of Surat residents owned motorized two-wheelers compared to urban Indians overall, and a much lower percent owned bicycles.

Table 3.3. Distribution of vehicle ownership in India (urban & rural), India (urban), and Surat (urban), Census 2001

Vehicles	**India (urban & rural) 2001**		**India (urban) 2001**	**Surat (urban) 2001**	
	Households	**percent**	**percent**	**Households**	**percent**
Bicycle	83,838,450	43.7	46	182,396	37.2
Motorized two-wheeler	22,484,686	11.7	24.7	156,013	31.8
Car	4,801,899	2.5	5.6	26,889	5.5
Total	191,963,463	100	100	489,969	100

3.3 Travel Activity

Three wheelers known as 'auto-rickshaws' provide informal public transport in the city. A typical three-wheeler is shown in Figure 3.3. They are widely available and serve all neighborhoods. These vehicles are lightweight, but with inadequate vibration dampers, sound proofers, and shock absorbers. They offer three different types of services. 'Private' or 'special' auto-rickshaws have flexible routes and are less expensive to hire than taxicabs. Drivers usually serve passengers from the fixed neighborhood where their 'stand' or 'stop' is located. Usually 'private' three-wheelers also offer hired service in return for a monthly wage. The most common instance of this is children's transportation during school and after-school hours. The third three-wheeler service moves on fixed routes. Called 'shuttle' or 'shared auto-rickshaws' they stop along the way to pick up or drop off passengers, and usually proceed on their route only when their vehicle is full. They are inexpensive and are mostly used by lower-income workers or young students.

Since 2007, Surat has city bus services that are operated by private contractors on a route contract basis. The Surat Municipal Corporation allocates routes and services. However, buses are rarely used within the city. They are believed to be inefficient and unreliable.

Information on the travel activity of Surat is based on data obtained from four transportation studies of the city conducted by three different consultants (Rayle, n.d.), (Associates, 2008), (Rayle & Pai, 2010). Central Road Research Institute

Figure 3.3. Auto-rickshaw

conducted a study in 1988 and another in 2004. Consulting Engineering Services conducted a study in 2005. Finally, Wilbur Smith Associates conducted a study in 2008. These four studies are good references that form a datum for the present study. Details of travel behavior and mod share obtained from these studies are in Appendix B.

In 1986, the municipal area of Surat was expanded to 55.56 square kilometers from the initial 111.16 square kilometers. The 1988 study by the Central Road Research Institute captured the trip lengths of the residents during and shortly after the acquisition of additional area. However, it is the 2004 study that captured the impact of this acquisition, a possible reason being that, by then the newly acquired area developed and integrated with the main city. Trip lengths by all modes increased. The length of the private car and bus trips more than doubled. However, the mode share of buses fell to less than half its original share in this interval while that of cars doubled. As such, more people were driving longer distances by cars than riding buses for long distances.

The average vehicle occupancy of cars at 1.25 passengers is only slightly above that of motorized two-wheelers at 1.11 passengers. This indicates that there is a large number of drive alone car trips similar to the more motorized western countries. Informal public transport in the form of three-wheeled auto rickshaws have higher occupancy levels of 2.65 for the privately hired auto-rickshaws and 3.42 for the shared or 'shuttle' auto-rickshaws.

As with most Indian cities, Surat has inadequate enforcement of traffic laws, signage and road marking. Parking is mostly on street, informal, and high density,

Figure 3.4. Unmarked parking

with double, triple, or more tiers of parking being prevalent, as shown in Figure 3.4. It is easier to find a gap for parking motorized two-wheelers and small cars as parking locations do not have demarcated slots for vehicles. For an Indian city of its size, Surat has many flyovers and a bus rapid transit system is being introduced. The residents of Surat take pride in their city being one of the cleanest in India. The municipal corporation has been very efficient especially in cleaning up the city after an epidemic of plague in 1994. It has successfully maintained the standards, despite the city being affected by floods every couple of years.

3.4 Observations on Trip Characteristics

Traditions, culture, as well as the built environment of a city lead to the unique trip-making characteristics of its residents. During the home interviews we observe the following trends among the households in Surat.

3.4.1 Work Trip Patterns

A majority of those surveyed are owners of businesses of various sizes, from large diamond businesses to neighborhood level small laundry and clothes ironing services. For them, a typical work day starts before 10 am and ends beyond 6 pm, with a lunch trip home between 1 pm and 3 pm. Since the work is shared in a family business,

household members, usually brothers, split the time among themselves. Businessmen sometimes work through the weekend.

Salaried workers, especially those employed in the government, have shorter work hours. Their work sometimes includes commuting to the various office locations everyday. Work related trips are common overall. Commuting between office locations and various clients is a part of the job of some government or privately employed workers; Business owners in the textile market make multiple work related walk trips within the extended market area. The east zone in Surat houses diamond polishers, who are daily wage earners paid by the number of diamonds they polish. They work the longest hours and are the poorest of the laborers. Their workdays often start at 6 am and end as late as 11 pm. They and other low-income salaried workers frequently work over weekends.

While in many Indian cities workers typically use employer-provided vehicles, there are very few instances employer provided vehicle use in our sample of mostly private business owners. Some salaried workers working in the distant industrial zone of Hazira, use their company-provided buses to commute.

3.4.2 Education Trips

A child's school day starts with the onward trip at 6:30 am and the return trip at noon or 1 pm. Younger school children usually travel in groups of six or more by means of a hired three-wheeler or a minivan service that is paid on a monthly basis. Some students also travel by school buses and others are transported to and from school by parents on their motorized two-wheelers. Older schoolchildren ride their bicycles to school. Most children attend after-school preparatory classes in the early evening, which is again served by the three-wheelers or vans.

College going students drive motorized two-wheelers, share rides with classmates, or take the 'shuttle' auto-rickshaw or the bus.

3.4.3 Maintenance Trips

Local grocery and convenience shopping trips are typically everyday walk trips. Occasional motorized vehicle trips are made to the departmental stores which offer a greater choice of brands, for buying items in bulk. The high-density mixed land use fosters more walk trips and less trips by cars or informal public transport. However, since even the specialty stores may be accessed by a short trip on the motorized vehicle, even the specialty shopping trips are made relatively frequently, possibly more so because of lower participation of women in the work force, which allow more time for household chores. Comparing with a city in which the commercial land-use is zoned separately from the residential land-use, and that which has more female work-

ers, would help assess whether it is the mixed land use or the lower participation of women in the work force that affect the frequency and mode choice of maintenance trips.

3.4.4 Discretionary Trips

The religious trip is the most common discretionary trip. Many Hindu residents of Surat stop by the neighborhood temple early in the morning or on their way to work and Muslims frequent the mosque. Religious trips with family and friends are common outings and sometimes such outings involve long distance trips. Social trips form the other major discretionary trip category, with frequent, informal interactions between neighbors, relatives and friends. Others discretionary trips are those to the movie theaters, the beach, the malls or the traditional markets. Car-owners use their cars for this purpose. Trips for physical fitness or outdoor sports purposes are negligible. Intercity trips are usually rail-based.

Among children's trips, apart from after-school preparatory classes, there are few examples of regular organized discretionary activities that need transportation. Informal play in the neighborhood is the most common activity.

3.4.5 Travel Patterns of the Senior Male Member of the Household

In business-owning households, the male head of the household sometimes retires when his sons begin to work in the business. The retirees typically do not use motorized vehicles with most of their trips being short, walk trips. Their travel consists of trips to the neighborhood park, social trips, or everyday grocery shopping. If the senior male continues to work, his work trips follow the typical work trip pattern with shorter work hours in the case of a family business.

3.4.6 Women's Travel

Most women in our survey sample are homemakers. Their travel consists of daily walk trips to the local grocery, vendor or convenience store, dropping off kids to school or to after school classes on their motorized two-wheelers, and occasional specialty shopping trips. Younger women or those from lower income households ride their motorized two-wheelers or sometimes hire a three-wheeler, whereas those from higher income households either ride their chauffeur-driven cars or drive themselves. Women mostly drive smaller vehicles and cars, with maneuverability being the primary consideration. Lower participation of women in the workforce lead to fewer trips for childcare, for

carry-outs and eating outside, and fewer trip chains for workers to pick up grocery on their return trip.

3.5 Survey, Sample Size and Secondary Data

While home interview surveys are logistically harder to conduct, (Cherry, 2007), it was the chosen means of surveying for the present research. This is because this study aims to capture characteristics of households that have recently bought new motorized vehicles. Since motorized vehicle ownership especially car ownership is low, addresses of households that had recently purchased a motorized vehicle were obtained from government and private sources. 3000 addresses compiled from different sources were sorted by the seven different municipal zones and by the type of vehicle bought, for example, new motorized two-wheeler or used compact car. We aimed to get representative surveys of all vehicle types from each zone, and to capture a sample size proportional to the total number of households in the zone. As we intended to capture the effect of vehicle acquisition on the household trips, we surveyed a set of households that have obtained their vehicle shortly before the survey, assuming no major change in household socio-demographic structure, work or residence location could have occurred in the interim period to distort the effect. Since the scope of our survey was limited to household vehicle use, we typically eliminated vehicles that were registered to a business. Small business owners often used their vehicles both for business and household purposes. We included their instances in our survey.

Since the survey started in August, we chose households that had bought new vehicles since April 2009. The mini car Nano by Tata Motors was launched in the market at this time. However, our data collected so shortly after its launch holds only a negligible sample of households that acquired this car.

For the study of vehicle ownership, we interviewed other vehicle-owning household that had not purchased new vehicles in the study period. We surveyed 128 households that had acquired new or used vehicles since April 2009, and 68 households that had not.

Besides the face-to face interview that we conducted,the following methods of survey were considered: a) drop off and mail back or pick up survey, b) telephone interview survey, and c) internet based survey. Literature on earlier survey studies revealed that the response rate depends on the method of disbursement of the survey questionnaire. Ni used internet-based surveys in Shanghai, China, successfully (Ni, 2008). Muralidhar et.al. found telephone interview, drop off and mail back to be unsuccessful in Thane, India (Muralidhar *et al.*, 2006). Based on the suggestions of the local surveyors and past experience, face to face interview was used as the primary method of survey. Most Surat residents were hospitable to the surveyors. However, the surveys were more succcessful if the respondent was approached at his

home, and less so if the survey team tried to arrange for an appointment beforehand. In instances when it was especially difficult to interview the head of the household during regular hours, survey questionnaires were dropped off to be picked up later. Telephone interviews were mostly used as a follow-up for survey validation or further clarification.

We interviewed the vehicle buyer and his household members in their homes or, if necessary, in their workplaces. An interview took 25 minutes on average.

3.6 The Questionnaire

While the focus was on the study for the present reserach on vehicle ownership and purchase, the survey questionnaire also included questions on trip patterns for use in future reserach. Questions were asked on the following broad subjects:

New vehicle purchased : Details of the new vehicle purchased, such as make and model, fuel type, and new or pre-owned, were noted.

Existing vehicle fleet : Make, model, and year of purchase of all vehicles owned were noted along with availability of parking at home.

Socio-economic details : The age, gender, and occupation of all members of the household were recorded.

Previous day's travel diary : Details of the previous day's travel, i.e. purpose, mode, destination, and time of travel were noted for all the members of the household.

Likert Scale questions : The respondents were asked to express their opinion on various statements relating to different attitudes and perceptions of the respondents on a five point scale: definitely agree, somewhat agree, neither agree nor disagree, somewhat disagree, definitely disagree. Some of these statements were inspired by statements from a similar survey conducted in Shanghai (Ni, 2008). The respondent wrote his own responses to this section and then marked the income category that he belonged to. The respondents were given the options of responding to this section in one of three languages, English, Hindi, and Gujarati.

The type of dwelling unit, for example: apartment or single family house, and the ownership type, for example: owned or rented, were noted to validate the responses on stated income. Due to lack of data on transit accessibility, respondents were asked how long it took to walk to the nearest auto-rickshaw or bus stop. Before embarking

on the actual survey, the survey questionnaire was pre-tested on various respondents both within and outside the study city and modified to adhere to cultural norms and minimize survey duration. Appendix C shows the final survey questionnaire.

3.7 Details of Survey: Time and Duration

The interviews were conducted from August through October 2009. Households who had obtained new vehicles between April and September 2009 were surveyed. Vehicle purchase in Surat is marked by seasonal variations. Traditionally, the monsoon months, or Shravan, are a period of high sales in Surat. This is followed by a fortnight of Shraadh, which has traditionally been a period of low sales. Shraadh leads to Navratri marking the beginning of the festive season and the highest volumes of sales and registrations of vehicles. Most Surat residents adhere to these norms in their purchase behavior. Since our study period spanned both the high and low sales period, such seasonal variations did not affect the survey process.

3.8 Lessons Learnt

The survey faced its share of challenges. These are outlined along with some suggestions for overcoming them, with the intent that future researchers would take these factors into account when planning their survey.

As mentioned, since motorized vehicle ownership is low in India, a random survey would have produced a negligible sample of new vehicle buyers. As such, addresses of such buyers needed to be obtained in advance. The addresses being proprietary information, multiple endorsements and authorizations were needed to obtain those.

While electronic records of purchase and registrations could be obtained for buyers of new vehicles, those of used vehicles were non-electronic. Hand written registration entries in bound volumes were manually sifted through, to arrive at the 200 records of vehicles that had undergone a transfer of titles to a second owner after April 2009. This process was time-consuming and tedious.

Locating the addresses of the vehicle buyers on ground was an involved process, since Surat, like many older Indian cities, follows an arbitrary system of numbering plots. Addresses are located by the proximity to a neighborhood landmark, which is sometimes difficult to locate. Occasionally, the addresses listed are of businesses or residences under construction or uninhabited. The additional time for locating such addresses needed to be built into the survey process. We also needed to build in the time spent in locating those addresses in which the households either did not respond, or gave incomplete responses to the interview.

We were especially interested in interviewing the male head of the household, as typically he was the most knowledgeable about the new vehicle purchased. We succeeded in interviewing them in the surveys we conducted before 9 am or after 6 pm, and those we conducted over the weekends. Weekends are fewer in Surat as only the second and the fourth Saturdays of the month are observed as holidays besides all Sundays. Additionally, some laborers and private business owners worked over the weekends. While there were many religious and cultural holidays observed at the time of the survey, they were not ideal for conducting surveys as the residents either traveled or socialized with family and friends during those times. We supplemented our early morning and late evening surveys with surveys conducted during lunchtime, as most workers came home for lunch. Outside of these times, we mostly intercepted the women and children in the household. To obtain the responses of the male head for these households, we either followed up with a second visit to the household at their suggested times, or interviewed them at their workplace after obtaining the address from other household members. Because of these reasons, each survey took longer to complete.

The respondents were sometimes concerned that the information they revealed to the survey group might reach the tax authorities. As such, they were cautious about any indication of their wealth. Many suppressed information on their household income levels and some about their recent vehicle purchase.

The biggest challenge faced was that the survey organizations, paid by the number of forms they filled, had little interest in the outcome of the survey and the quality of the data. The employees conducting the surveys obtained a minimal share of the payment, which further decreased their interest in accuracy and data quality. Rigorous supervision was required to ensure data quality, and as a result only a small sample could be obtained. To motivate the surveyors to follow procedure and obtain accurate information, future surveys could include an additional amount per form to be paid to the surveyor once the forms were checked and found to be satisfactory. In light of the issues outlined, it is useful for outside or foreign researchers to conduct surveys collaboratively with an ongoing survey conducted by a local group, so that the interest in data quality is shared. Alternatively, it is imperative to work with a local contact known personally to a member of the research group, whose advice can be trusted in matters relating to finance and labor rules. It is also advisable to adhere to formal legal contracts. In the case of informal contracts, a system of daily or weekly payments, in place of a lump-sum payment would minimize the loss to either group in the case of a disagreement.

3.9 Secondary Data

We obtained supplementary secondary data from various sources. The data obtained and their sources are listed in Table 3.4.

Table 3.4. Secondary data sources

	Data type	Data source
1	New vehicle prices by makes and models; showroom price, registration and taxes	Vehicle dealers
2	Used vehicle prices by makes, models, vintage and kilometers on vehicle	Authorized used vehicle dealers
3	Number of different vehicles registered	Regional Transport Office
4	Fuel costs	Fuel stations
5	Fuel consumption: values certified by Automotive Research Association of India	Society of Indian Automobile Manufacturers
6	Zonal distribution of households; zonal densities and schedule of parking rates	Surat Municipal Corporation
7	Details of vehicle loans	Housing Development Finance Corporation
8	Details of vehicle insurance	Axis Bank
9	Public transport: routes and fares	Regional Transport Office
10	Fares of informal public transport	Informal public transport operators

3.10 Survey Validation, Data Entry, Cleaning, and Imputation

We validated the household surveys by follow-up telephone calls in which we asked about the vehicles owned, number of members in the household, occupations, and principal work destinations. This method worked for validating the vehicle ownership, household socio-demographic and trip information. The Likert scale questions could not be validated as the responses would change based on the respondent, and could even change for the same respondent at different times.

The raw data from the survey forms was transcribed into Excel 2007. After converting the data to electronic format, each field was filtered for outliers. Next, 20 household entries were randomly selected and each field checked to ensure that all the information was consistent. For any field for which the information did not fit that for the rest of the household, the entries were re-checked and re-entered in the correct sequence. There were some fields for which the data entered was exceptionally sparse due to multiple no-responses. Depending on the type of analysis, we either did not use the fields that had more than 20 percent of missing data or in some cases cut down further on the sample size to use only those entries that had responses for the specific field. For example, of the 196 households, only 116 had stated their income. Where possible, we used car ownership as a proxy for income as we had complete information for that field. For the models in which income was a better explanatory variable, we used logistic regression to impute the missing income values, using home ownership, type and zone of residence, and the number of years the household has owned the newest and the oldest car in the fleet, as explanatory variables.

Chapter 4

Analysis of Vehicle Fleet Mix

Analysis of survey data sheds light on the numbers and types of vehicles owned by a household, and on the type of vehicle recently purchased by some households. The sample consists of 196 motorized vehicle-owning households. Of these households, 128 had purchased a motorized vehicle since April 2009 and the other 68 had not. Before discussing the analysis, it is useful to discuss the socio-economic characteristics of the survey sample. Comparing these characteristics with those of the population in Surat enables better understanding of the social stratum that the vehicle owning population studied belongs to.

The analysis begins with a study of the various factors that affect ownership of motorized two-wheelers and cars, and the factors that influence the transition from owning motorized two-wheelers to owning cars. We next explore the size of car owned. For households owning more than one car, we study the size of the largest car owned. The final analysis is a study of the purchases made by a subset of these households in some months before the survey, and the various factors that affect the purchase. All analyses involve statistical analysis of data including the estimation of choice models, and qualitative observations based on the interviews.

4.1 Socio-economics of the Survey Sample

The two dynamic factors that influence vehicle purchasing and ownership behavior are the size and the income of a household. Per capita income is rising rapidly with the improvement of the economy. Household sizes continue to be larger than those in more industrialized nations, but they are declining over time with more households opting for a nuclear family instead of the traditional joint family structure. The average household size is 5.19, and that obtained in 2001 for the urban population of India was 5.1 (Government of India, 2001a). 57 percent of the households in the sample are traditional joint families with more than one married couple or more than

two generations living in the same unit. Appendix B contains the details of the distribution of households of different sizes both in the survey sample, and in the state of Gujarat.

Summing over all members of the hosueholds surveyed, a gender ratio of 845 women per 1000 men is obtained. This is larger than that obtained for Surat from Census 2001. Section 3.2 suggests the large proportion of male immigrants in the population as the reason for there being only 774 women for every 1000 men in Surat. The difference in gender ratio between that obtained for the survey sample and in the Census 2001 could be due to a change in the demographic structure since 2001. A more likely reason is that the sample of motorized vehicle-owning households surveyed has a negligible number of immigrant male-only households. Figure 4.1 plots the gender and age distribution of the sample. The age pyramid representing motorized vehicle owning, higher income households in Surat is more 'constricting' compared to the present age pyramid of India, and highly similar to the age pyramid of more industrialized nations with low birth and mortality rates. The bulge of the pyramid lies in the age ranges of 17 and 31.

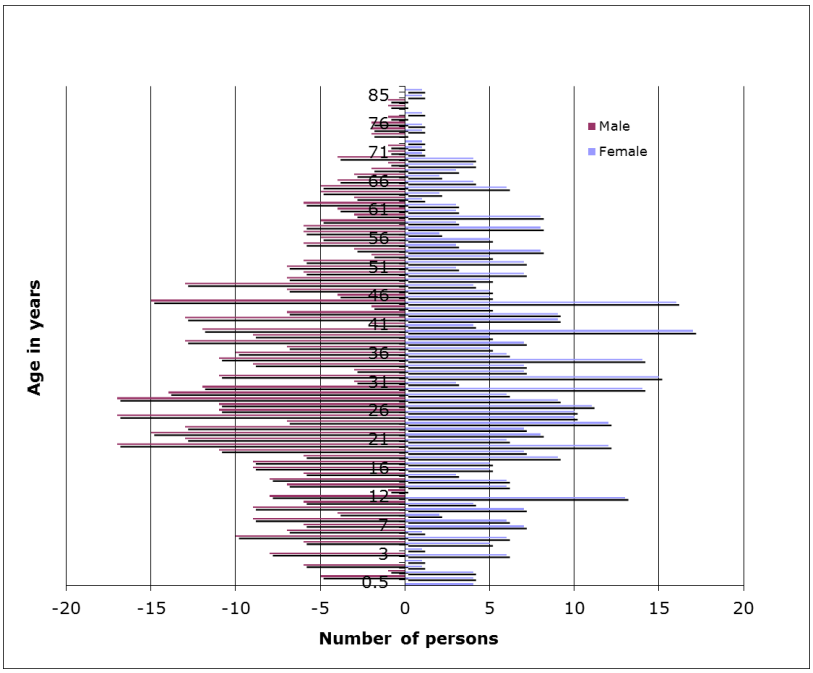

Figure 4.1. Age pyramid of the sample

35 percent of the household members in the survey sample are workers compared to 32 percent for the urban Indian population in 2001. 64 percent of the households surveyed own cars and 94 percent own motorized two-wheelers. As per Census 2001, 5.5 percent of the population of Surat owned cars and 32 percent owned motorized two-wheelers. Assuming that the purchasing power of Surat residents have increased since 2004, the households surveyed would belong to the top two quintiles of the pop-

ulation. Figure **??** compares the distribution of vehicle ownership in urban Gujarat as per Census 2001 with that of the households surveyed in Surat. The sample over-represents car owners and does not represent households that do not own motorized vehicles.

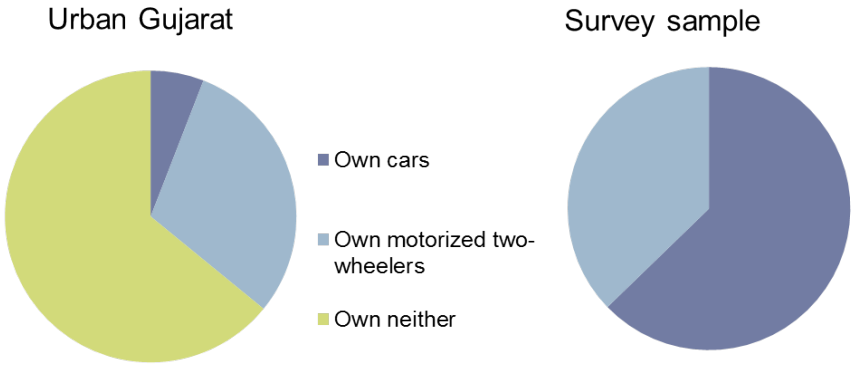

Figure 4.2. Households owning vehicles in i) Urban Gujarat (Census 2001) and ii) survey sample

Table 4.1 compares the income categories of the 59 percent of the sample that stated their income with that obtained for the city in 2004 (CEPT and Urban Initiatives, Surat, 2004). Assuming that the income distribution has remained constant between 2004 and 2009, 89 percent of the households surveyed belonged to the most affluent 7 percent of the Surat residents. However, since income is rising rapidly, the survey samplewould now represent a larger percent of the population. The income category 'less than 120,000' is an aggregate of more than four categories in the 2004 study. Thus the income quintiles for the 11 percent of the survey sample belonging to the 'less than 120,000' income category remains indeterminate.

Table 4.1. Income distribution of the sample compared with that of the population of Surat in 2004

Income Distribution of Sample		**Income Distribution of Surat, 2004**	
Annual Income Ranges ('000 INR)	**Percent**	**Annual Income Ranges ('000 INR)**	**Percent**
Less than 120	11	Less than 25	60
120-360	57	25-50	27
360-1500	14	50-75	5
1500-3000	12	75-100	1
3000-15000	5	100-150	1
15000-30000	1	150-200	3
-	-	More than 200	3

Income ranges may also be assessed from the home ownership, type of residence, and location in the city. While the percent of households owning their dwelling unit was 73 in the state of Gujarat (Government of India, 2001c), that in our motorized

vehicle-owning sample is much higher at 94. The remaining 6 percent of households in our sample mostly live in rented houses and occasionally in employer-provided housing. Motorized vehicle owners live in four types of residences: bungalows, row houses, apartments and 'gala types'. [1] 26 percent of the households surveyed live in bungalows, 23 percent in row houses, 33 percent in apartments, and 18 percent in 'gala type'. The wealthiest households live in bungalows with the exception of the households in the southwest zone, of which many wealthy households also live in apartment complexes. Many of these apartment dwellers are more affluent than residents of bungalows in some of the other zones. Apartments also house medium income households such as small business owners or salaried persons, especially in zones other than the southwest zone. The row house owners form the next category in terms of their wealth and the 'gala type' houses the least wealthy. Exceptions can be found especially in the central zone in which, households that have always lived in a 'gala type' of residence continue to live in their traditional home even after becoming affluent.

The first three residential types typically provide abundant parking space. Bungalow owners have drive yards or paved front yards to park their vehicles. Ground-level floors of apartments are dedicated to parking and the cost of the parking space is included in the maintenance fee. Vehicles are parked in the unmarked and unpaved street shoulder or on the semi-private access street in front of row houses. The only residential type with a relatively inconvenient parking situation is the 'gala type', in which bicycles and motorized two wheelers are sometimes kept inside the house in a hallway or under the staircase. These households mostly park their vehicles on the public road or its shoulder abutting their home.

Excel 2007 was used for the data analysis, along with SPSS 17, and MATLAB 7.7.0. BIOGEME 2.0 and Python BIOGEME 1.8 are used for estimating the choice models. Different subsets of the data is used for the different analyses. The analysis of number of vehicles owned and of transition from motorized two-wheeler to car ownership is done using the sample of 112 households that stated their income category. The analysis of the largest car owned by the household includes the 123 households that owned cars. Finally, the analysis of vehicle purchase is done on the 128 households that had purchased a vehicle in the last few months.

4.2 Vehicle Ownership

The sample consists of households that have and ones that have not made recent vehicle purchases. For the households that made a recent vehicle purchase, we count

[1] The 'gala type' of residence is old-style vernacular architecture similar to a smaller row house without the front and rear setbacks. The word may have its origin in the word 'galo' in Gujarati, the local language, which means 'a narrow bay' and roughly translates to a plot of land with a narrow frontage.

the recently purchased vehicle with the rest of the vehicles in the fleet. All households surveyed own either one or more motorized two-wheelers or cars or both, the number of cars ranging from zero to four and that of motorized two-wheelers ranging from zero to six. Figure 4.3 shows the number of households owning different numbers of cars and motorized two-wheelers before and after purchase. Post-purchase, while the maximum number of cars owned increases from three to four, that of motorized two-wheelers owned remains at six. Households with no cars constitute the largest share before purchase and those with one car, the largest share after purchase. Post-purchase, 71 percent of the car owning households own one car. Households owning two motorized two-wheelers continue to hold the largest share both before and after purchase.

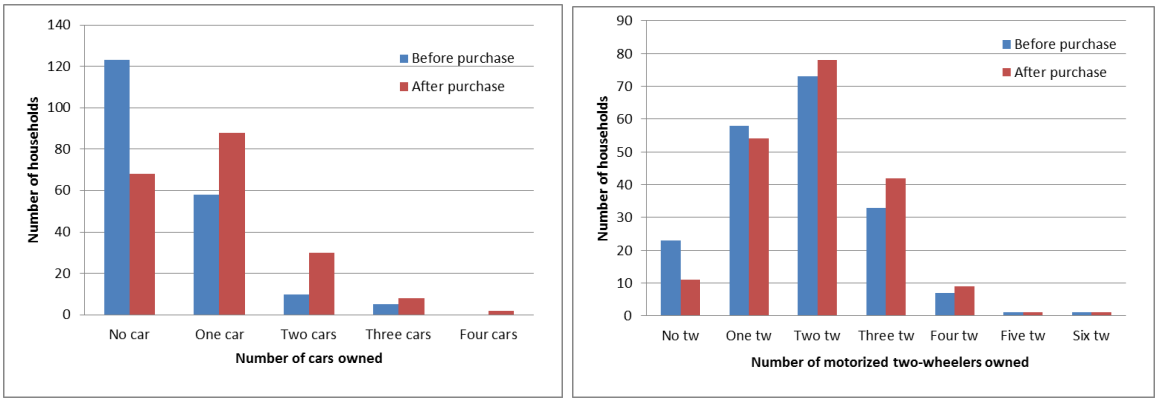

Figure 4.3. Car and motorized two-wheeler ownership before and after purchase

Figure 4.4 shows the various combinations of number of cars and motorized two-wheelers owned by the households surveyed. The number of motorized two-wheelers that households own increases with the number of cars owned, up to two cars. Beyond two cars, the number of motorized two-wheelers owned drops with the increase in the number of cars owned. The majority in the sample own zero or one car, and up to three motorized two-wheelers.

The correlation between the number of cars and motorized two-wheelers owned by households is low (correlation coefficient: -0.028). We next examine the number of cars and motorized two-wheelers owned by a household and the influence of the following factors:

- income
- size of the household
- zonal density
- typology of residence: 'gala type'

- accessibility to transit and informal transit

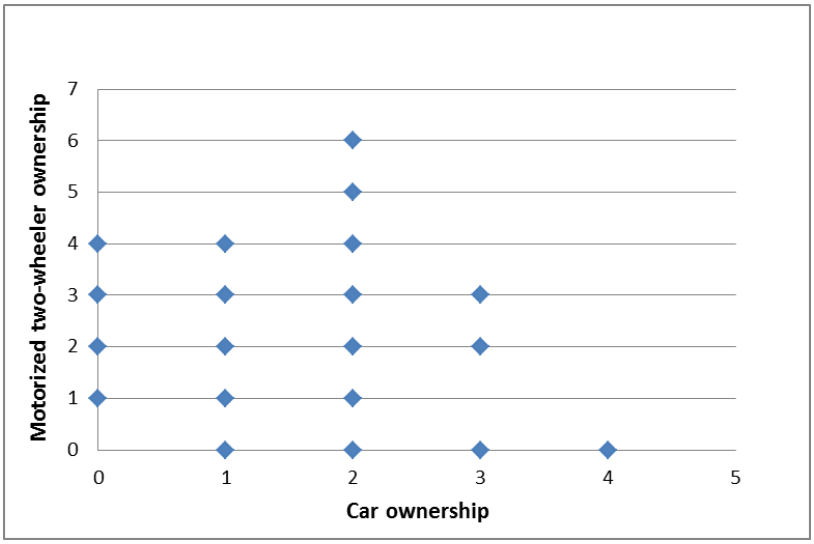

Figure 4.4. Combinations of car and motorized two-wheeler ownership

Income and size of household are the two dynamic socio-demographic factors in the Indian society with incomes increasing with the economic development of the country and household sizes reducing with more households choosing to live as a nuclear over a traditional, joint family (Government of India, 2001b). Household annual income is noted in six categories that range from 'below INR 120,000' to'15,000,000 - 30,000,000'. The sizes of households vary from one to twelve persons. Increase in household size would increase the need for mobility and the number of personal vehicles owned. Increase in income will raise the affordability of households to buy the additional vehicle. Broadly, the price of the least expensive, commonly owned compact car is the same as that of five motorized two-wheelers of average prices. Motorized two-wheelers being far less expensive compared to cars, an increase in income is not as important for a household to own an additional motorized two-wheeler, for the income category surveyed. Also, while only one car would suffice to hold three or more adults going to the same destination, two separate motorized two-wheelers would be needed to serve the same trips. The numbers of motorized two-wheelers owned are likely to be more sensitive to an increase in the size of the household. Figure 4.5 shows the average car and motorized two-wheeler ownership for households of different income and size.

The four plots suggest the following: that car ownership increases with increase in household income and motorized two-wheeler ownership increases with increase in household size. Additionally, household size affects car ownership to a much lesser extent than does income. In addition to the reason that cars have capacity to carry several extra persons over motorized two-wheelers and are as such less sensitive to increase in the household size, this is also explained by the fact that cars are much

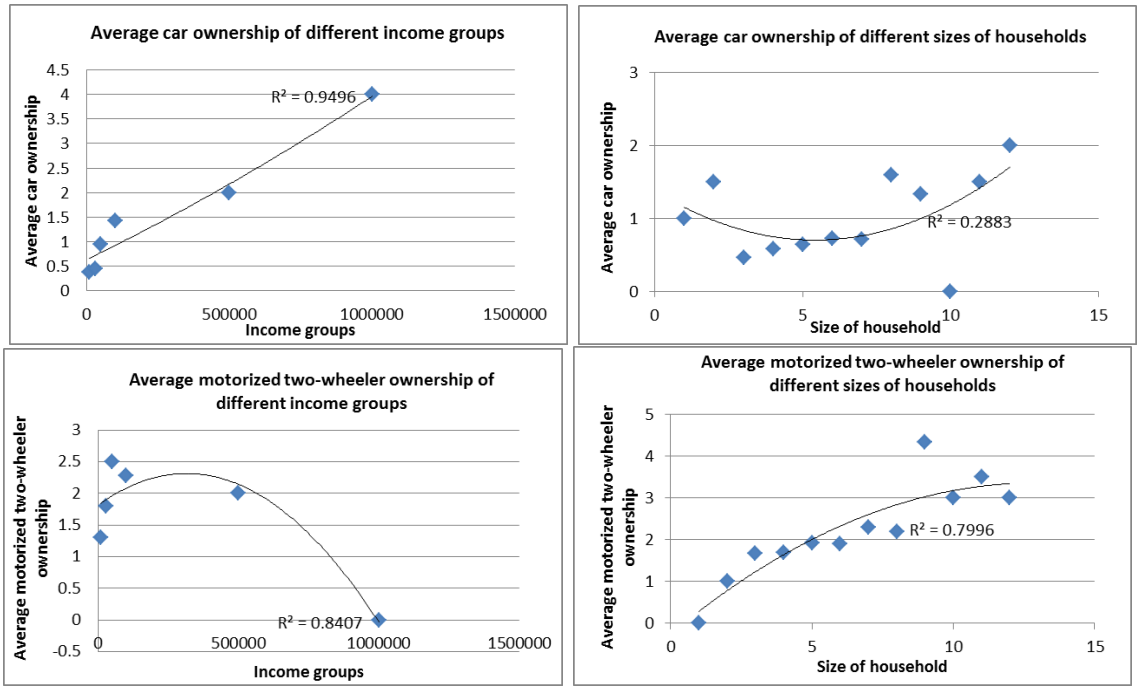

Figure 4.5. Effect of household size and income on car and motorized two-wheeler ownership

more expensive compared to motorized two-wheelers. As only the top 5.5 percentile of the households in the city can afford cars, and an even lower percentage can afford more than one car, motorized two-wheelers cater to most of the extra mobility needs for larger households.

The relation between income and motorized two-wheelers is more complex. Figure ?? also shows that the average motorized two-wheeler ownership increases with income up to a threshold beyond which it decreases. This is similar to the relationship observed in Figure 4.3, and motivates the hypothesis that motorized two-wheelers are the inferior goods which consumers buy less with increase in their income. The hypothesis is further supported by the correlation coefficient between motorized two-wheeler ownership and household size, which also varies across the different income categories increasing up to a monthly income INR 50,000 and decreasing beyond that.

We hypothesize that higher zonal densities have a negative effect on car ownership as cars will be more difficult to park and maneuver in denser areas. Zonal densities in Surat vary from less than 2,200 to more than 50,000 persons per square kilometer. The central zone being the oldest is the densest. The south-west zone has the lowest density followed by the west zone. The latter two are also the zones in which households with the highest incomes reside. The east zone with the poorest residents has the third highest density. Since different income groups prefer different zones, we included both the zonal density and household income in the model to parse out the

effect of one from the other on vehicle ownership. Initial model runs showed zonal densities to be insignificant in explaining vehicle ownership of a household.

Since residents of 'gala type' houses do not have private parking space and can only park their cars on the city streets, we hypothesized that residents of 'gala type' houses would be less likely to own cars or greater numbers of motorized two-wheelers. Initial models estimated also negated this hypothesis.

For information on neighborhood accessibility to transit, we noted the time it took for the survey respondents to walk to the auto-rickshaw stop and to the bus stop nearest their home. We found both of these factors to be insignificant in explaining vehicle ownership.

We estimated a multinomial logit model with the different combinations of car and motorized two-wheeler ownership as the dependent variables, and income and household size as the two independent variables. We used multinomial logit instead of a model that pertains to count data, since we found it to fit the data well. Additionally, Bhat and Pulugurta found that the multinomial logit explains the variations in count data on car ownership better than an ordered logit or ordered probit model (Bhat & Pulugurta, 1998) (De Jong *et al.*, 2004). We estimated the model using the open source software BIOGEME 2.0 (Bierlaire, 2003), (Bierlaire, 2008). The choice set follows:

1. zero car and one motorized two-wheeler
2. zero car and two motorized two-wheelers
3. zero car and three motorized two-wheelers
4. zero car and four motorized two-wheelers
5. one car and zero motorized two-wheeler
6. one car and one motorized two-wheeler
7. one car and two motorized two-wheelers
8. one car and three motorized two-wheelers
9. one car and four motorized two-wheelers
10. two cars and zero motorized two-wheeler
11. two cars and one motorized two-wheeler
12. two cars and two motorized two-wheelers
13. two cars and three motorized two-wheelers

14. two cars and four through six motorized two-wheelers
15. three cars and zero motorized two-wheeler
16. three cars and two motorized two-wheelers
17. three cars and three motorized two-wheelers
18. four cars and zero motorized two-wheeler

In this model, we test the hypothesis that the socio-demographic and built environment variables affect car ownership and motorized two-wheeler ownership differently. To that end, we estimate different sets of coefficients for each variable, income for example, for the different numbers of cars owned, and for the different numbers of motorized two-wheelers owned. Since these are more aggregate than alternative specific coefficients, we refer to them as cluster specific coefficients. There are eighteen elements in the choice set. For the purpose of estimating coefficients, alternatives with less than ten responses are combined together with adjacent alternatives. For example, we estimate one aggregated constant for the two and three car owning households. Additionally, we estimate a set of alternative specific constants for the different numbers of cars owned and the different numbers of motorized two-wheelers (mtw) owned. Coefficients for owning zero cars are fixed to zero as were those for owning one two-wheeler. A typical utility functions is as follows:

$V(0car, 3mtw) = \alpha_{0car} + \alpha_{2+mtw} + \beta_{0car} Income + \beta_{2+mtw} Income + ...$

$V(1car, 4mtw) = \alpha_{1car} + \alpha_{2+mtw} + \beta_{1car} Income + \beta_{2+mtw} Income + ...$

β_{0car}, β_{1car}, β_{2+mtw}, are the cluster specific coefficients.

Table 4.2 shows the model results. They suggests that while household size is not significant in explaining the shift from owning zero to one car, a larger household is more likely to own two or more cars. Similarly, household size does not explain whether a household owns zero, one, or two motorized two-wheelers. But a larger household is more likely to own three or more motorized two-wheelers. Income is not significant in explaining the number of motorized two-wheelers owned by a household. However, it significantly explains that a household is likely to shift to car ownership and to own more cars with increasing income. The other three variables, zonal density, dummy for living in 'gala' type of residence, and access to informal transit are not significant in explaining the numbers of cars or motorized two-wheelers owned.

We summarize two important insights from this analysis: i) that as income increases, households buy more cars; and ii) household size is not significant in explaining small increases in owning cars or motorized two-wheelers, but does explain owning two plus cars and three plus motorized two-wheelers. Despite small sample sizes, the model indicates that income is more significant than household size in explaining increase in car ownership. As increase in household size or population of a

Table 4.2. Logit model on number of vehicles owned

Name	**Parameter Value**	**t-statistic**
Const_{0Car}	0.000	Base
$Const_{1CAR}$	-2.060	-2.21
$Const_{1+CAR}$	-6.900	-4.47
$Const_{0MTW}$	-1.810	-1.01
$Const_{1MTW}$	0.000	Base
$Const_{2MTW}$	0.195	0.21
$Const_{2+MTW}$	-3.440	-3.23
$Beta_{0CAR}$ HHSIZE	0.000	Base
$Beta_{1CAR}$ HHSIZE	0.225	1.45
$Beta_{1+CAR}$ HHSIZE	0.536	2.41
$Beta_{0MTW}$ HHSIZE	-0.581	-1.45
$Beta_{1MTW}$ HHSIZE	0.000	Base
$Beta_{2MTW}$ HHSIZE	0.016	0.09
$Beta_{2+MTW}$ HHSIZE	0.621	3.18
$Beta_{0CAR}$ INCOME	0.00	Base
$Beta_{1CAR}$ INCOME	0.048	2.82
$Beta_{1+CAR}$ INCOME	0.058	3.34
$Beta_{0MTW}$ INCOME	0.017	1.84
$Beta_{1MTW}$ INCOME	0.000	Base
$Beta_{2MTW}$ INCOME	0.008	1.02
$Beta_{2+MTW}$ INCOME	0.002	0.26
Built environment variables	-0.616 - 0.751	not significant
Dependent variable	Probability of owning x cars and y two-wheelers	
Number of observations	112	
Initial log-likelihood	-323.722	
Final log-likelihood	-223.968	
Rho bar	0.215	

city is not influential in increasing the number of cars, increase in car ownership has hitherto never been an issue despite the explosive population growth in the country until the recent increase in per capita incomes. While the model does not capture that with increase in income beyond a threshold, households tend to own less motorized two-wheelers, as observed in the plots, we follow this up with some further statistical analysis plotted in Figure 4.6.

Figure 4.6 shows the average motorized two-wheeler ownership of households of different car ownership. Assuming that the plot represents the vehicle ownership of a household with growing affluence over time, since increase in car ownership is influenced by increase in income. There is no significant change in motorized two-wheeler ownership as car ownership increases from zero to two, with households owning close to two or more motorized two-wheelers. However, when ownership increases to 3 cars, there is a significant drop in motorized two-wheeler ownership bringing it close to one. Earlier we saw that motorized two-wheeler ownership of a household increases with increase in size of the household. The average size of a two car-owning household does not differ significantly from that of a three car-owning household. As such, the decrease in motorized two-wheeler ownership is not due to any significant decrease in household size.

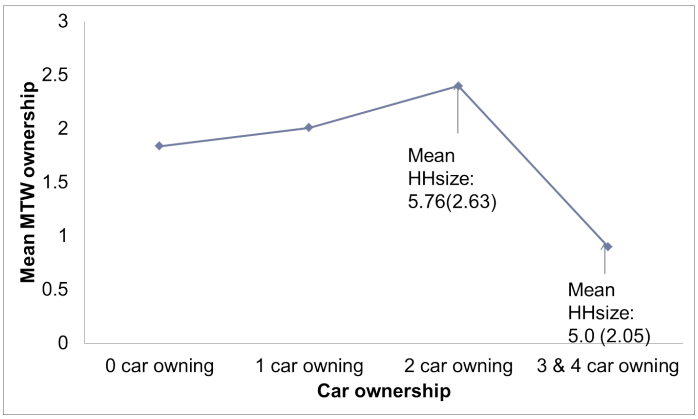

Figure 4.6. Progression in household car and motorized two-wheeler ownership

Only 5 percent of the households surveyed own three or four cars. 100 percent of the four car owners and 50 percent of the three car owners did not own any motorized two-wheelers compared to only 4 percent of the one or two car owners that did not own motorized two-wheelers. Overall this plot signifies that with rising income, households typically progress from owning motorized two-wheelers only, to owning a combination of motorized two-wheelers and cars, and subsequently to owning cars only. The substitutions in the type of motorized vehicle ownership mark important milestones, and knowing the various factors that influence these milestones would be useful for planners and policy makers. Section 4.3 discusses the analyses of the factors influencing the switches in the type of motorized vehicle ownership.

4.3 Substitutions in the Type of Motorized Vehicle Ownership

A number of factors influence households to add cars to their fleet of motorized two-wheelers, and subsequently to shift to a car-only vehicle fleet. To explain these changes in the composition of the vehicle fleet, we examine the same factors as in the previous model:

- income
- size of the household
- zonal density
- typology of residence: 'gala type'
- accessibility to transit and informal transit

Additionally, we examine if the household has any children younger than fourteen, to test the hypothesis that ceteris paribus, households with children will be more inclined to own cars for safety. We considered fourteen as the limiting age for children since, beyond that age, many children ride bicycles and take public transport to travel independently. Therefore, their travel is not an important consideration during purchase of a household vehicle.

Table 4.3 shows the average values of the different socio-economic and built environment characteristics for households owning different vehicle types. We compare the means to observe if there is a statistically significant difference across households owning different vehicle types. Households owning mixed fleets are found to have higher income, reside in zones with lower population density, and be less likely to live in 'gala' type of residences compared to those owning motorized two-wheelers only. But while households that own cars alone have a higher sample mean for income than those owning a mixed fleet, the difference in the sample means between the two groups is statistically significant only if both variances are assumed to be equal. We earlier saw that it is not the increase in the household size that causes a household to buy the first car. But households that own only cars in their fleet have significantly smaller households than those owning a mixed fleet. Note that the sample size (N) over which the mean income is computed is lower than that for the rest of the variables since a smaller percent of respondents stated their income.

Table 4.3. Differing characteristics of households owning different vehicle fleets

Factor	**MTW only mean/std dev**	**MTW & car mean/std dev**	**Car only mean/std dev**	**t-statistic* MTW & Mixed**	**t-statistic* Mixed & Car**
N	68	117	11		
Size of household	4.96/1.91	5.44/1.97	3.73/1.56	X	✓
Children dummy	0.38/0.49	0.52/0.50	0.27/0.47	X	X
Zonal density (persons/sq. km)	25260/20050	14800/18020	18000/21570	✓	X
'Gala' type dummy	0.43/0.49	0.2/0.41	0.09/0.30	✓	X
Walk time to three-wheeler stop (minutes)	6.78/4.72	7.59/5.54	5.64/3.29	X	X
N	50	56	6		
Income(monthly INR)	29400/13763	80900/120518	275000/401833	✓	✓(if equal variances)

*for difference in means
T-statistic significant ✓
T-statistic not significant X

As discussed, households select residential types and specific zones for residence based on income. As such, the previous univariate analysis comparing across the means of single variables does not explain the relative significance of these factors in

accounting for the changes in the fleet. To deal with this we estimate a multinomial logit model in which the choice set consists of three options:

1. owning motorized two-wheelers only
2. owning a mixed fleet
3. owning cars only

The model is estimated with alternative specific coefficients for the factors discussed along with presence of a child in the household. The coefficients and constants for the alternative 'owning motorized two-wheelers only' is fixed to zero. This and all subsequent models are estimated using a beta version of the Python BIOGEME. Table 4.4 shows the model results.

Table 4.4. Logit model on the type of motorized vehicle owned

Name	**Value**	**t-test**
$Const_{MTW}$	0.000	Base
$Const_{MIXED}$	-2.320	-2.55
$Const_{CAR}$	-2.160	-1.07
$Beta_{MTW}$ INCOME	0.000	Base
$Beta_{MIXED}$ INCOME	0.055	2.98
$Beta_{CAR}$ INCOME	0.063	3.26
$Beta_{MTW}$ HHSIZE	0.000	Base
$Beta_{MIXED}$ HHSIZE	0.141	0.91
$Beta_{CAR}$ HHSIZE	-0.548	-1.26
$Beta_{MTW}$ DENSITY	0.000	Base
$Beta_{MIXED}$ DENSITY	-0.109	-0.84
$Beta_{CAR}$ DENSITY	0.547	1.63
$Beta_{MTW}$ GALA	0.000	Base
$Beta_{MIXED}$ GALA	0.058	0.12
$Beta_{CAR}$ GALA	-1.230	-0.78
$Beta_{MTW}$ CHILD	0.000	Base
$Beta_{MIXED}$ CHILD	0.706	1.46
$Beta_{CAR}$ CHILD	-4.76	-0.70
$Beta_{MTW}$ WALKTIME3W	0.000	Base
$Beta_{MIXED}$ WALKTIME3W	0.028	0.62
$Beta_{CAR}$ WALKTIME3W	-0.093	-0.65
Dependent variable	Probability of owning MTW only, mixed fleet, and cars only	
Number of observations	116	
Initial log-likelihood	-127.439	
Final log-likelihood	-74.720	
Rho bar	0.304	

The model shows that income overrides every other factor considered in explaining the acquisition of a car, i.e. with increase in income, the probability of a household owning a mixed or a car-only fleet increases relative to that of owning motorized two-wheelers only. 50 percent of the three car owning households and 100 percent of the four car owning households are do not own motorized two-wheelers. This adds

strength to the hypothesis that with the increase in income and the number of cars owned, households discard the motorized two-wheelers and shift to a fleet composed entirely of cars.

The size of household is not a factor in explaining any of the substitutions. However, cars being much more expensive, cars alone are unlikely to meet the mobility needs of the larger households with more than six members, especially since Surat has inadequate public transport. To probe what the model did not capture, the composition of car-only households by their car-ownership and household sizes is shown in Table 4.5l.

Table 4.5. Car-ownership and household sizes of cars-only households

Car-ownership of households	**Number of households surveyed**	**Household size (mean/std dev)**	**Number of car-only households**	**Size of car-only households (meandev)**
0 car-owning	68	4.96/1.91	NA	NA
1 car-owning	88	5.11/1.64	4	3.5/1.73
2 car-owning	25	5.76/2.63	1	$3/\infty$
3 car-owning	8	5.5/1.93	4	4.5/1.73
4 car-owning	2	3/1.41	2	3/1.41

Table 4.5 indicates that all car-only households have a lower average household size as compared to the size of mixed fleet households owning the same number of cars. From the previous model on the number of cars and motorized two-wheelers owned, households were more likely to own two or more cars with increase in the size of the household. Table 4.5 shows that the 25 two car owning households and the 8 three car owning households are larger than the 88 one car owning household. However, the car-only households in each of these categories have smaller household sized than the mixed fleet households. We need to study the switch from a mixed fleet to a car-only fleet in greater details with a larger dataset to conclude on this phenomenon.

4.4 Size Category of Car Owned

So far we saw that the individual mobility of household members is catered to by a mix of cars and motorized two-wheelers, car ownership being strongly influenced by the household income. Having established that the increase in household size does not influence households to buy cars, we now analyze the preference for car size categories. As discussed in Section 1.4, typically the average price of a particular size category increases with size. Since households are typically large and make multi-person social and religious trips, they would prefer increased seating capacity and thus a larger car. Conversely, congestion and difficulty in parking would favor a smaller car.

Compact cars are the most popular with 65 percent of the 128 car-owning households owning one or more *Compact* cars. The category holds the highest share, 61 percent and 77 percent, among households owning cars from a single category, and those owning cars from more than one category respectively. The *Mid-size* category forms a low second in terms of popularity, with 22 percent of all car owning households owning a *Mid-size* car in their fleet. *SUV*s are the next most popular followed by *Minivans* and *Mini* cars. The more expensive *Executive* and *Premium* cars are always owned along with one or more cars from other categories and never as the only car. Only 6 percent of households owning a single car type own a *SUV*, and 11 percent own a *Minivan*. However, 35 percent of households that own more than one car type own a *SUV* whereas only 10 percent owns a *Minivan*, indicating that the more expensive *SUV* is more popular as a second car.

In the analysis of car sizes preferred by households, we categorize households on the basis of the largest car owned, which is for the most part the only car owned. Table 4.6 shows the categorization of the sample for the analysis of the largest car owned by a household. Note that the *Mid-size* car belongs to two different categories. The category labelled '*Mid-size*' consists primarily of households that own only *Mid-sizes* and motorized two-wheelers. The other category *Mid-size*, *Executive*, and *Premium*, consists of a majority of households that own *Midsize* cars along with cars from other categories, and a minority of households that own *Executive* and *Premium* cars along with cars from other categories including *Mid-size*. The households owning the composite car categories are expected to be weathier than those owning the *Mid-sizes* only.

We compare the means of socio-demographic and built environment factors across households owning different car sizes as classified in Table 4.6. The factors we consider are:

- size of the household
- presence of children
- zonal density
- typology of residence: 'gala type'
- accessibility to transit and informal transit

There is no significant difference to explain the choice across the various car size categories. However, on comparing income across households owning different car categories we find that households that own either a *Mid-size*, *Executive*, or *Premium* car have significantly higher income than households that own any other cars. Next, we calibrate a multinomial logit model to explain the choice of size category of car owned. The choice set consists of the folowing:

Table 4.6. Car size categories

Size category	**Different fleet compositions**	**Number of households**	Percent
Mini	Mini & MTW, Mini, Mini & Compact	10	8
Compact	Compact, Compact & MTW	59	46
Mid-size	Mid-size & MTW, Mini & Mid-size & MTW	13	10
Mid-size, Executive, Premium	All combinations of Mid-size, Executive, Premium except those included in category 'Mid-size'	16	13
SUV	SUV & MTW & Compact, SUV & MTW, Mid-size & SUV & MTW, Mini & SUV & MTW	17	13
Minivan	Minivan, Minivan & MTW, Compact & Minivan & MTW, Minicar & Minivan & MTW	13	10
Total	-	128	100

MTW Motorized two-wheelers
Only one household owned a *Mini* & *Compact*. Although *Compact* is the larger car, it was included with the *Mini* car to add to its sample size. The *Mid-size* category comprised *Mid-size* & MTW only except for one household that also held a *Mini* car. The remaining households that held a *Mid-size* along with other cars were included with households holding an *Executive* or *Premium* car, again in order to increase the sample size

1. Mini
2. Compact
3. Midsize
4. Mid-size, Executive, Premium
5. SUV
6. Premium

The constant for *Compact* and its alternative specific coefficients are set at zero. Recall that only 59 percent of the households surveyed stated their income category. In order to use the maximum number of data points possible without imputing values, we use car ownership instead of income as an explanatory variables in this model and find this variable to explain the variations in the data well. This could not be done in the earlier models in which we work with a more restricted sample as car ownership was the dependent variable in those models. Household size is the other explanatory variable used. In the initial runs of the model, we find that the built environment variables are not significant in explaining the size of the largest car owned. Finally, to acount for the fact that the alternatives in this model are aggregations of the different elemental make and model alternatives in a single vehicle size class, we include the

natural log of the number of makes and models in each size category (Ben-Akiva & Lerman, 1985), (Train, 1986).

Table 4.7. Logit model on the size category of a household's largest car

Name	**Value**	**t-test**
$Const_{MINI-COMPACT}$	0.000	Base
$Const_{MINIVAN}$	-0.156	-0.11
$Const_{SUV}$	-5.400	-4.79
$Const_{MID-EXEC-PREMI}$	-3.690	-4.13
$Beta_{MINI-COMPACT}$ CAROWN	0.000	Base
$Beta_{MINIVAN}$ CAROWN	-0.824	-0.78
$Beta_{SUV}$ CAROWN	1.470	3.20
$Beta_{MID-EXEC-PREMI}$ CAROWN	1.500	3.79
$Beta_{MINI-COMPACT}$ HHSIZE	0.000	Base
$Beta_{MINIVAN}$ HHSIZE	0.164	0.96
$Beta_{SUV}$ HHSIZE	0.192	1.34
$Beta_{MID-EXEC-PREMI}$ HHSIZE	-0.040	-0.30
LNCATSIZE	0.791	5.31
Number of observations	123	
Initial log-likelihood	-220.386	
Final log-likelihood	-172.934	
Rho bar	0.17	

The model results indicate that households are more likely to own an *SUV*, *Mid-size*, *Executive*, or *Premium*, relative to a *Mini* car, *Compact*, or a *Minivan* with increase in car ownership, or income. The results further indicate that household size does not affect the size of the car owned. This finding is corroborated by Figure 4.7 in which, regardless of the household size, the share of households owning *Mini* and *Compact* cars as their largest car remains constant. The higher cost of a larger car, of enforcement of rear seat belt laws allowing overcrowding of vehicles, and the need for increased manueverability in congestion and for parking, all favor smaller cars.

The built environment variables were not significant in explaining any of the choice processes discussed, probably because they were fairly uniform across the city. While there were differences in the zonal densities, they were due to the expansion of the city limits in 2006, due to which the outer zones included areas of undeveloped land. The developed land was mostly uniformly dense, with fairly uniform mixed land-use. As discussed before, the 'gala-type' of residence was not significant in explaining ownership or otherwise of any particular type of vehicle. Since street parking is abundant, the relative disutility of parking was not sufficient to explain vehicle choice in addition to the effects of income and household size. The same reasoning applies for the transit accessibility variable as the stops for the privately hired three-wheelers or buses are equally accessible to all neighborhoods. As such, this variable also did not explain any of the differences in choices. We expect these factors to be significant in a city with a more diverse set of built environment factors, or in a study conducted across various cities.

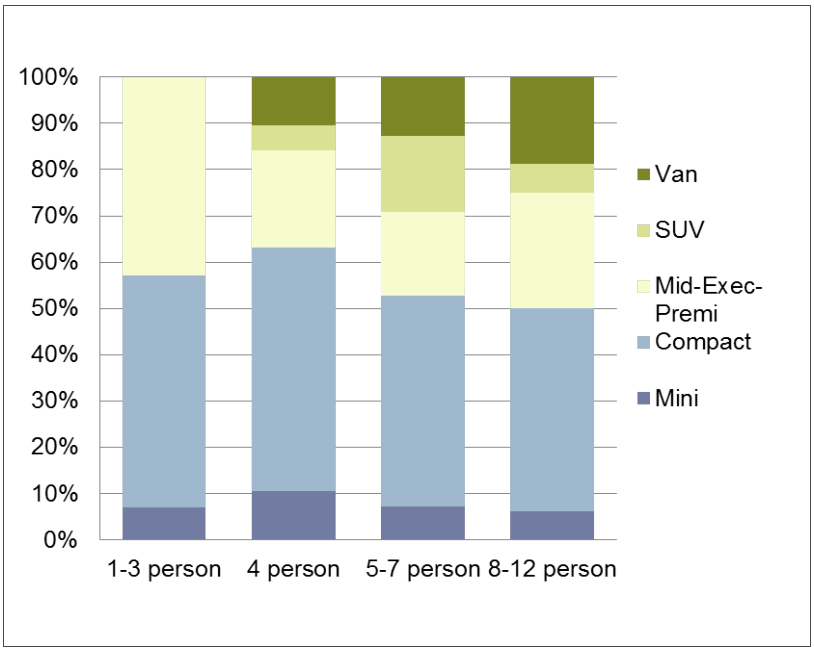

Figure 4.7. Household size and size of largest car owned

4.5 Vehicle Purchase

The study of vehicle purchase is an important contribution of this research. Since the *Mini* car *Nano* by Tata Motors had just been introduced in the market at the time of the study, the data represents the choices that the consumers made with an affordable *Mini* car available in the choice set.

In this analysis, we study the choice across new and used motorized two-wheelers and seven size categories of cars in a single model. Of all the motorized vehicle sales in the nation in September 2009, 83 percent were motorized two-wheelers and 17 percent were cars. In contrast, 68 percent of the respondents in our survey was car buyers and 32 percent were motorized two-wheeler buyers. The ratio of vehicle buyers surveyed who bought new vehicles to those who bought used vehicles was 4:1. There were no data on that ratio among the whole population of Surat as the vehicle dealers only had access to the official sales numbers of their respective makes, and the registration records for used cars were not consolidated as well as those for the new cars. A couple of months after completion of the survey, several sources including Surat automobile dealers estimated the ratio to be 1:2.5. The sample collected is thus a choice-based sample in both the ratio of cars and motorized two-wheelers and that of new and used vehicles. The distribution over various car size segments of the car buyer respondents, however, closely approximates the sales at the national level in those car size segments.

Figure 4.8 shows the different car size categories that were bought by the house-

holds surveyed and the placement of the newly-bought car in their existing fleet. *Compact* cars and *SUV*s range from being a first car to being the fourth car in the fleet. The small sample of *Mini* car buyers includes many buyers of third and fourth cars, similar to that in the more expensive *Mid-size* segment. The sample of *Mini* car buyers included four households that had obtained their *Nano*. Of them, two owned two motorized two-wheelers each, one owned a car as well as three motorized two-wheelers, and one owned two cars besides the newly bought *Nano*. Only one of the households had bought the car for use in everyday work trips, the rest having bought it for their family trips. Even from our small sample we can infer that, low price and image of a poor person's first car notwithstanding, affluent car buyers buy the *Nano* as their second or third cars. The sample obtained for buyers of cars of the *Executive* and *Premium* size categories are very small and there is no representative buyer of the *Luxury* size category of cars. This is indicative of the low affordability, and hence low volume of sales of vehicles in these classes. The few *Executive* and *Premium* car buyers sampled were all buying their second cars. In contrast, the *Minivan* buyers were all either buying their first motorized vehicle or their first car.

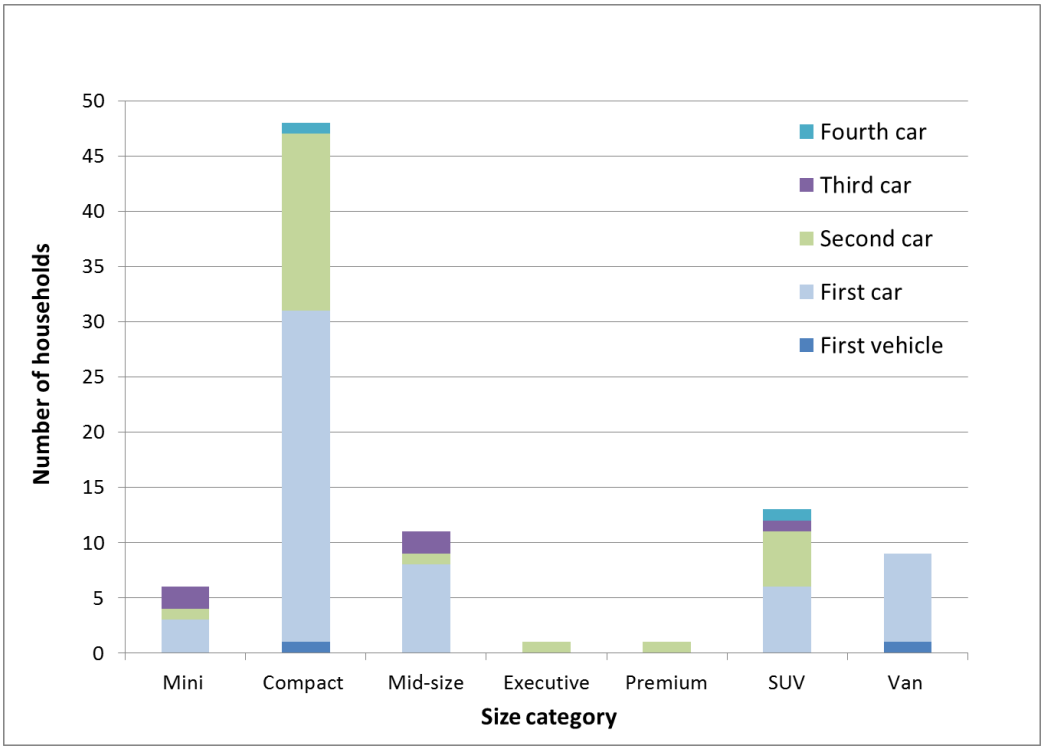

Figure 4.8. Car size categories purchased by car ownership

Observations and interviews revealed that the Surat consumer is sensitive to fuel cost. Besides gasoline, three major fuel types are used by the vehicles. The national government subsidizes diesel to aid low-income taxicab and three-wheeler operators. Some automobile manufacturers have capitalized on the resulting low price of diesel and manufactured popular diesel-powered cars and SUVs. Vehicles powered with

compact natural gas (CNG), and liquefied petroleum gas (LPG), are also available, and households sometimes buy gasoline-powered vehicles and have them fitted with a CNG kit. Electric bikes have also been introduced in the market. We interviewed some users of these bikes in our surveys.

Since our analysis is at the more aggregate level of size categories, we can assess if size categories with low average fuel costs are preferred. This is a function of both the fuel efficiency and the price of fuel used by most vehicles in that category. We will also assess in this analysis if size of household affects that of the recent vehicle purchase.

Besides these considerations of cost and utility, some underlying attitudes and perceptions influence the preferences of the consumers. The households in Surat speak of their preference for comfort, utility, and reliability in the goods they purchased, rather than the brand name and the associated status. There was also a tendency to understate purchasing power. This may explain the reason that there are fewer households owning luxury or premium cars in our sample as compared to what may be obtained in other equally prosperous Indian cities. To assess some of the dominant attitudes and perceptions of the Surat residents and their effect on the vehicle choice, a set of Likert scale questions was posed to the survey respondents. We usually suggested that the head or other responsible member of the household answer these, with the assumption that they made the vehicle choice decision for the household.

4.5.1 Likert Scale Questions for Attitude Analysis

A set of 26 statements were designed to test the respondents perceptions in the following categories: perception of status, perceptions about the personal vehicle and other modes, responses to monetary considerations, peer influence, and miscellaneous. The statements are in Section B of the survey questionnaire in Appendix C.

Perception of Status

These statements assess the extent to which the respondents agree that a personal vehicle or a car is a status symbol.

Perceptions about the Personal Vehicle and Other Modes

A set of statements pertains to whether the personal vehicle or car improves one's career opportunity and personal life. A second set deals with the issues of expenses in owning a personal vehicle, and the hassle of driving or parking in congestion. A third set of statements deal with whether walk, bike, private and shared three-wheeler services, and buses, are inconvenient. The fourth set of statements test the

respondent's level of comfort in being seen in any of the modes mentioned. Finally, one statement assesses whether inclement weather inspires ownership of cars.

Responses to Cost Considerations

Different cost-related statements assess the respondents priorities in buying a vehicle, for instance whether the operating cost of a vehicle is an important consideration in vehicle purchase. Some statements assess whether saving is considered a virtue.

Peer Influence

These statements assess whether the respondent liked to be the first among peers to do something new, and whether the respondent felt the need to buy an item that his peer possessed. A choice phenomenon that both dealers and consumers reported about vehicle purchase in Surat was the 'bandwagon effect'. Residents reported that consumers made their purchase choices based on the choices made by their peers, and did not do individual research for themselves. Since that effect is more applicable to makes and models, we do not attempt to capture that effect at the level of the size categories. Besides, incorporating such an effect in the model would also need corrections for endogeneity.

Miscellaneous

Some miscellaneous statements assessed the presence or absence of strong national feelings and tendency to buy the national brand. Others assessed willingness to draw attention to oneself, being a compulsive shopper, and the need for some time to oneself.

The survey respondents could select one of five responses for a set of 26 statements, the responses being definitely agree, somewhat agree, neither agree nor disagree, somewhat disagree, and definitely disagree.

4.5.2 Factor Analysis on the Likert Scale Responses

Each Likert scale response obtained from the survey is an indicator of underlying attitude or attitudes, that are a mix of one or more of the perceptions discussed. We conducted an exploratory factor analysis on these responses to extract the most significant factors that influence the different perceptions on private vehicle ownership and use in the city. The details of the exploratory factor analysis are in Appendix D. For the analysis, we used the statistical software SPSS. The method of factor analysis used was principal axis factoring with orthogonal varimax rotation applied

to the loadings obtained. We retained five factors that cumulatively explained 43.62 percent of the variance in the data. The Kaiser-Meyer-Olkin measure of sample adequacy was 0.7, which is rated as middling'. The statements with highest loadings for each factor are shown in Table 4.8.

Table 4.8. Statements with the highest loadings and names of the factors

Statements with high loadings	**Factor names**
The operating cost considerations are important in my vehicle purchase* Saving is a virtue* Driving in congestion is a hassle Finding parking is a hassle The personal vehicle is important for my career opportunities* The loan is important for my vehicle purchase* Cars are expensive	Monetary & Utility Considerations Final Eigenvalue: 3.345 Percent of variance: 12.865
It is inconvenient to be a bus rider It is inconvenient to be a pedestrian It is inconvenient to ride a bicycle	Inconvenience of non-motorized & public modes Final Eigenvalue: 2.149 Percent of variance: 8.265
A car is a status symbol A personal vehicle is a status symbol On hot or rainy days I wish I had my own car*	Perception of status Final Eigenvalue: 2.027 Percent of variance: 7.795
I consider buying a vehicle for infrequent need* I don't want to be seen riding a bus or an auto I don't want to be seen walking or cycling	Negative image of non-motorized & public modes Final Eigenvalue: 1.935 Percent of variance:7.442
When there is something new in the market I have to buy it I have to be the first among my peers to get something new When my peers have a certain type of vehicle, I have to own it	Peer influence Final Eigenvalue: 1.886 Percent of variance: 7.253

*(Ni, 2008)

The first factor is a composite of monetary and utility considerations. The statements on monetary considerations assess the consumer's perception on the importance of the operating cost and the loan in the vehicle choice decision, the fact that cars are expensive, and that saving money is a virtue. Those on utility assesses the consumer's perception on whether the personal vehicle is useful for the owner's career, and whether driving in congestion and finding parking are troublesome.

The perceptions of negative image and of inconvenience deal with two aspects of using non-motorized and public modes. The inconvenience factor pertains to issues like discomfort and delay in using non-motorized and public modes while the negative image factor pertains to their association with low societal status. Another statement that obtained high loading for the negative image factor is the one about buying a vehicle even for infrequent need. It expressed the extent of adversity of the respondents towards using all but private motorized modes.

The peer influence factor includes statements expressing both leader and follower behavior. Some want to be the first among peers to buy a new vehicle while others buy

a vehicle when the rest of the peers have it. Additionally, it includes the sentiment that anytime there is something new in the market, the respondent feels the need to buy it.

Finally, the perception of status factor includes statements that the car and the personal vehicle is a status symbol. It also includes the wish of non-car owners to own a car during times of inclement weather.

Monetary and utility considerations explain the biggest proportion of the variance in the data partly because the factor is a composite of several factors. The rest of the factors explain smaller and roughly equal parts of the variance. This reflects the socio-cultural make-up of the particular community surveyed. Table 4.9 shows the correlation among all of the factors.

Table 4.9. Correlation matrix of the latent factors

	Monetary utility	**Inconvenience**	**Status**	**Negative image**	**Peer influence**
Monetary utility	1				
Inconvenience	0.025	1			
Status	0.109	0.077	1		
Negative Image	-0.046	0.045	0.040	1	
Peer Influence	-0.002	0.039	0.044	0.085	1

The correlations among all of the factors are low as seen from the correlation matrix in Table 4.9. In other words, there are no pairs among the five latent attitudes that are commonly held together.

Next we examine different socio-economic variables in order to study if these affect a person's set of latent attitudes. The variables studied are:

- age, gender & occupation of the head of the household
- household income
- household car ownership
- household structure: nuclear or traditional, joint family

We do not find any of these variables to affect the latent attitudes at the 95 percent level of confidence. However, at lower levels of confidence we can make a set of observations on the effects of these variables on the attitudes. Compared to heads of households employed by the government, those who own a business are less likely to get high scores on the factor 'monetary and utility consciousness', and those who are privately employed are the least likely. With increasing age of the head of the household, the respondent is more likely to get high scores on the factor 'inconvenience of non-motorized and public modes'. With increasing household income, the

respondent is more likely to have obtained a high score on the 'perception of status' factor. Compared to heads of households who work for the government, respondents in households in which the head owns a business are less likely to obtain high scores on the 'negative image of non-motorized and private modes' factor, and those in households in which the head is employed in a private company are the least likely. None of these factors affect the peer influence variable even at a lower level of significance.

4.5.3 Integrated Choice and Latent Variable Model

In some earlier studies, factor analysis was first conducted on the indicators and then the fitted latent variables were used in the choice model (Ni, 2008). As these fitted latent variables would contain measurement errors, the choice probability should instead be integrated over the distribution of the latent variables as obtained from the factor analysis model to obtain consistent estimates. This combined estimation is done using integrated multi-equation models. Several alternative models consisting of the discrete choice model and the latent variable model's structural and measurement equations were estimated (Ben-Akiva *et al.*, 2002), (Bollen, 1989). Figure 4.9 shows the layout of the model structure used for estimating vehicle choice. The indicators in the figure are the responses to the Likert Scale questions and these are explained by some of the explanatory variables. Factor analysis conducted on these indicators output the latent variables. These, in turn, are included along with other explanatory variables in the utility function of the choice model, with the choice probability being integrated over the distribution of the choice model.

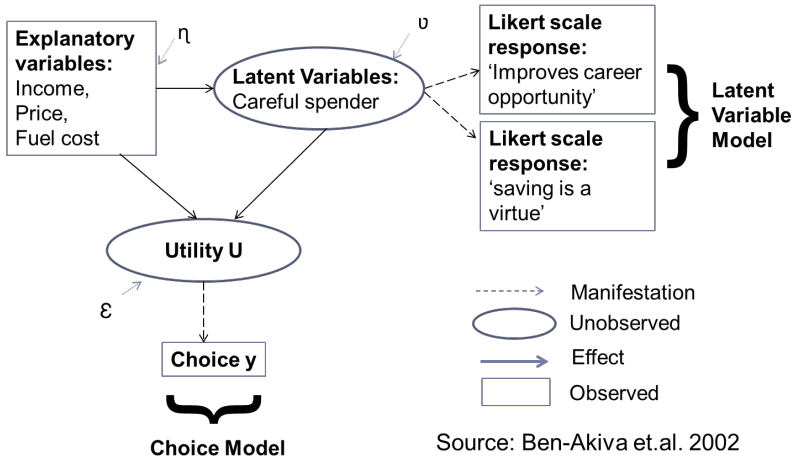

Figure 4.9. Integrated choice and latent variable model

4.5.4 Vehicle Choice

The model estimated is used to reflect the respondents choice among 14 categories of vehicles. The choice set includes new and used vehicles including motorized two-wheelers and the seven size segments of cars namely: *Mini*, *Compact*, *Mid-size*, *Executive*, *Premium*, *SUV*, and *Minivan*, of which the sample of buyers of *Executive* and the *Premium* class surveyed bought new vehicles only. Through this model, we study the effect of different attributes of the vehicle, the socio-demographic characteristics of the households, and the respondents attitudes and perceptions on vehicle choice.

Among the vehicle attributes, we assess the effect of price, fuel cost, size of the vehicle, and engine size on vehicle choice. The vehicle prices used in model estimation are the ex-showroom prices in Surat of all vehicles. These prices exclude subsequent road tax, municipal corporation tax etc. The fuel costs used for the different fuels, namely gasoline, diesel, liquefied petroleum gas (LPG), compact natural gas (CNG), and electricity, are the representative prices of these fuels in Surat in August 2009. The average price in INR over all makes, models and variants for each vehicle segment is calculated for new vehicles. For used vehicles, besides makes, models and variants, the average is also calculated over all vintages starting from year 2000, and over broad ranges of kilometers traveled, when available. The average fuel cost per kilometer is calculated for each segment by dividing the cost per liter or kilogram of the fuel by the fuel efficiency (kilometer per liter) of the vehicles. We use the average number of seats of the vehicle class to represent size. The average engine sizes of each category is also used as an explanatory variable.

As in the previous analyses, we will explore the preferences of vehicle across the 14 vehicle categories mentioned, with increasing income and decreasing household sizes of consumers, the two major changes affecting the Indian society.

The number of buyers surveyed varied across the 14 vehicle categories of the choice set. We estimated cluster-specific coefficients for the groups of choice alternatives that in isolation had inadequate sample for estimating coefficients. Similar size segments are clustered together to have at least 10 respondents in each cluster. For example, since the number of *Mini* car buyers in the sample were less than ten, the sample of *Mini* car buyers were combined with the *Compact* car buyers in estimating the coefficients.

The number of seats of the vehicle is divided by the number of members in the household to explore the effect of varying household size on the preference for vehicle size. Generic coefficients are estimated for the price of the vehicle, fuel cost per kilometer, size of the engine, and for the number of seats per person.

Cluster-specific coefficients are estimated for three of the factors obtained from the factor analysis. In the beta version of the python BIOGEME, the choice and latent variable model was not estimable with more than three latent variables. We tested different combinations of latent variables and used 'monetary and utility con-

sciousness', 'inconvenience of other modes', and 'perception of status' in the final model. In the measurement equations, we specified the dummies for business owning head of household, and those employed in private companies as an explanatory variable for the factor 'monetary and utility consciousness'; the age of the head of household as an explanatory variable for the factor 'inconvenience of other modes'; and the household income for the 'perception of status' variable. Since some of the otherwise complete surveys did not have complete responses to the Likert scale questions, instead of removing those observations for which the Likert scale responses were absent, the density of the missing responses were set to 1. This enabled use of all socio-demographic data in our sample. Finally, since the sample was choice-based, we weighted the log-likelihood function in proportion with the sales at the national level. Table 4.10 shows the model output.

Table 4.10. Choice and latent variable model on the recent vehicle purchase of a household

Name	**Value**	**Robust t-test**
PRICE	-2.59	-2.85
FUELCOSTKM	-3.49	-7.07
SEATING CAPACITY / HHSIZE	-0.865	-1.16
ENGINESIZE	0.004	4.24
$Beta_{MID-SIZE,EXECUTIVE,PREMIUM}$ INCONVENIENCE	-0.337	-0.47
$Beta_{MID-SIZE,EXECUTIVE,PREMIUM}$ STATUS	0.453	0.37
$Beta_{NEWTWO-WHEELER}$ MONETARY-CONSC	-0.750	-1.10
$Beta_{NEWTWO-WHEELER}$ STATUS	1.32	1.41
$Beta_{COMPACT}$ MONETARY-CONSC	1.450	1.78
$Beta_{COMPACT}$ INCONVENIENCE	0.139	0.19
$Beta_{SUV}$ STATUS	1.04	1.05
STRUCTURAL & MEASUREMENT VARIABLES		
beta age	0.016	1.53
beta costbusi	-1.06	-2.58
beta costpriv	-0.755	-2.49
beta income	0.001	5.05
beta mean cost & utility	1.06	3.45
beta inconvenience	-0.628	-1.55
beta mean status	-0.03	-4.44
other structural & measurement variables	0.019-2.590	significant
Dependent variable: Probability of a household having purchased a new or used		
Number of observations	128	
Initial log-likelihood	-24904.68	
Final log-likelihood	-22480.76	
Rho bar	0.096	

The coefficients estimated for the price and the fuel cost are significant and negative, as expected. This is the first indicator that the model is specified adequately, and that it includes attributes that account for vehicle quality. Otherwise it is common to get a positive sign for these attributes, misleadingly indicating that it is the higher price and operating cost that is preferred, rather than the desirable attributes of the vehicles with higher price and operating cost. The coefficient for the average seat-

ing capacity per person in the household has a negative sign, indicating that greater number of seats, a proxy for larger vehicle size, is not preferred. Larger vehicles are not preferred due to lack of maneuverability and difficulty in parking in unmarked parking locations, as in most locations in Surat and India. Additionally, since seat belt laws for the rear seat are not enforced, more occupants than what is mandated may use the car. This again renders additional number of seats unnecessary. However, the magnitude of this coefficient reduces with increase in household size. This indicates that while larger vehicles are not preferred, the disutility for buying larger vehicles reduces for larger households. The coefficient of size of the engine is positive and significant, indicating a preference for bigger and more powerful engines.

The factors on attitudes are not significant in explaining vehicle choice. This is likely the characteristic of the population the data represents for whom the observable attributes are much more significant than the underlying perceptions of status, inconvenience, and on money and utility. Based on our interviews and anecdotal evidence, we had hypothesized the factor 'cost and utility consciousness' to be significant, but did not obtain expected results. Alternatively, it could be due to inadequate or noisy data for the Likert Scale responses, which was the only part of the survey that could not be validated.

The ratio of the coefficient of fuel cost per kilometer to that of vehicle price gives the willingness-to-pay for reduction in fuel cost. The scale is model estimation for the vehicle price is 1/1,000,000. After adjusting the estimated values of the coefficients for their respective units and scale in model estimation, we obtain the willingness-to-pay (WTP) for 1 paise (0.01 INR) reduction in fuel cost per kilometer as INR 13,47,490. The equivalent value obtained in a study conducted in the United States is $522 per cent fuel cost reduction per mile (Martin, 2009). After adjusting the respective units, the WTP for fuel cost reduction in Surat is found to be 42 times that obtained in the United States study. Without placing too much emphasis on the number 42, as this has varied among the different models estimated from the same data possibly due to noise in the data, we can conclude that the Indian consumer is far more sensitive to fuel cost as compared to the consumer in the United States. The ratio of the price of gasoline in India to that in the United States in 2009, with the Indian price converted to USD (2008 PPP), is 4.07. The Indian consumer is thus far more sensitive to fuel cost as compared to the United States consumer than can be accounted for by the difference in fuel prices.

The present research being on car size cateogries does not address the role of vehicle attributes, such as brand name, reliability, resale value, and availability of spares, that affect choice of a particular make and model combination. It is worth emphasizing that these factors repeatedly came up in discussions as respondents explained their choices. Brand name came second to fuel efficiency with 36 percent of the 113 respondents explaining their choice of recent vehicle purchased mentioning it as an important factor. Similar to that at the national level, Maruti is the most popular brand among the households surveyed. While some models are more popular than

others, the same household rarely owned two vehicles of the same make and model. Only two households among those surveyed bought a motorized two-wheeler of the same make and model as one they owned already and none bought a car that was the same. At the level of size categories, *Compact* cars being the most popular, households were more likely to own multiple *Compact* cars but less likely to own multiples of any other size categories. Next, the consumers preferred automotive makes that have been found to be reliable in the past. They frequently cited unreliability as their reason for not buying the recently launched *Nano* by Tata Motors. Others models by the company have earlier been found to be defective which the company corrected in subsequent versions. The resale value is another factor that came up repeatedly. Its importance may be expected to increase with households holding their vehicles less and the size of the pre-owned car market increasing. The resale value also depends on its reliability. Finally, availability of spare parts is an important criterion. Due to availability of cheap labor, broken down cars and motorized two-wheelers are repaired and used longer than in more industrialized countries where they are salvaged and replaced. Authorized and unauthorized repair shops are widely available. However, India is following the trend of the more industrialized nations. The option of repairing and replacing defective parts with spare ones are becoming more expensive with spares becoming increasingly specific to the model, and with mechanics needing more proprietory knowledge of the specific make of the car.

4.5.5 Discussion

In this chapter we discuss the consumer preference among vehicle types. We first study the well-known phenomenon of the shift with increasing income from a motorized two-wheeler-owning to a car-owning household. We observe the effect of changing household size and built environment characteristics. We observe that an increase in income leads to an increase in car ownership. An increase in size of the household only explains ownership of two or more cars, or three or more motorized two-wheelers. Some of the inferences obtained are worth validating with a larger dataset. With increase in car ownership beyond a threshold, household are observed to own less of motorized two-wheelers; typically at this stage, smaller households shift to a car-only fleet. Thus three stages in the motorization process can be demarcated, beginning with owning motorized two-wheelers, moving to owning a mixed fleet of motorized two-wheelers and cars, and finally owning only cars. The role of motorized two-wheelers in the motorization process is similar to that of public transport, as it retards the growth in car ownership by meeting some of the mobility needs of a household.

Analyzing the different car sizes owned by the different households, we find that household size does not affect the size of the largest car owned. We also find that with the increase in car ownership representing an increase in income, households are more likely to own their largest car from the more expensive size categories, such as a *Mid-size*, *Executive*, *Premium*, or *SUV*, rather than from the less expensive *Mini* car,

Compact or a *Minivan* categories. Income again is found to explain car ownership, both number and type, more than anything else.

In vehicle purchase behavior, households preferred smaller cars, although the preference diminished for larger households. They also preferred vehicles with larger engines. Analyses revealed that the Indian consumer is very sensitive to fuel cost. Comparing the findings of the present study with a recent vehicle purchase study conducted in the United States, the willingness-to-pay for reducing fuel cost of the Indian consumer was found to be orders of magnitudes higher than that of the consumer in the United States. Observed vehicle attributes were found to be much more significant than latent attitudes and perceptions supported by socio-demographic attributes, in explaining the type of vehicle purchased.

Chapter 5

Conclusions

This dissertation analyzes the results of a survey of the motorized vehicle owning residents of Surat, a prosperous, rapidly-motorizing city of five million inhabitants. By interviewing new vehicle buyers, this study assesses their choices of newly purchased vehicles. Factors that affect choices between used and new motorized two-wheelers and of cars of different sizes are analyzed. The study also assesses the trends in vehicle ownership, and the perceptions and aspirations that influence the vehicle choice process.

Preliminary data analysis shows that *Compact* cars are bought by households of all income ranges but *Minivans* are only bought by households who are buying their first car, or even their first motorized vehicle. The *SUV* is typically bought by the more affluent households, and is usually not the first motorized vehicle to be purchased. Likewise, the more expensive *Mid-size*, *Executive* or *Premium* cars are usually bought as second cars. Such findings lead to the inference that consumers prefer the luxury, power, and status, associated with larger cars rather than the increased seating capacity. If that is true then there is a niche market for luxury small cars.

The models reveal that household size does not affect either the number of cars or the size of the largest car owned by the household. Overcrowding of vehicles is common because the enforcement of rear seat belt laws is lax. Larger households are thus as likely as smaller ones to own a *Mini* or a *Compact* car as their largest cars, since larger cars are typically more expensive. With increase in income or number of cars owned, households prefer larger cars with higher average prices.

It is found that observable vehicle attributes and socio-demographic characteristics have a greater influence on vehicle purchase behavior than latent attitudes and perceptions. This finding needs to be validated with a larger dataset, but is significant in its implications for the motorized vehicle owning population of Surat. Further analysis reveals that the population surveyed is extremely sensitive to fuel cost. Comparison with findings from a recent study on Chicago and the state of Cal-

ifornia shows the extent to which the Surat consumer is more fuel sensitive than the United States consumer. Similar studies conducted over a greater number of cities will help generalize the findings for the two countries being compared.

Initial data analysis reveals that the more the number of cars a household owns, the more they succumb to a car-based lifestyle. We observe that with increase in the number of cars owned by the households, the ownership of motorized two-wheelerfalls. Car owners also appear to prefer their cars over hired or shared means, given the convenience it offers for the cost of operation. The phenomenon of considering the car as the default option for all trips, including a large number of drive-alone or chauffeur-driven single rider trips, is particularly marked in households that own more than two cars, or in those that do not own any motorized two-wheelers.

5.1 Possible Use of Current Research and its Extensions

There are many policy issues facing a country that is motorizing rapidly. There are many ways to address the issues which will have different bearings on use of infrastructure, congestion, fuel efficiency, emissions, as well as on safety and equity. The results of this research provides useful information on the equity aspect of policies. As households that own motorized two-wheelers and no cars are the least wealthy among owners of motorized vehicles, any policy increasing the cost of ownership and use of motorized two-wheelers is likely to adversely affect their mobility. The research shows that motorized two-wheeler ownership retards car ownership by acting as an intermediate. Because of their use of less road space and potential energy efficiency, policies could be used to encourage their ownership over that of cars, in tandem with improving their emissions and safety aspects. It is also worth considering that, pricing means to reduce car ownership and use will affect lower income car owners more adversely than the higher income households that own multiple cars. That would not help achieve the goal of reducing indiscriminate car use but instead impair mobility and safety. A discussion on the hazards of motorized two-wheelers overloading their vehicles due to lack of purchasing power to own a car follows in a later section.

From the analysis of the attitude factors, we obtain that with increase in age, motorized vehicle owners become sensitive to convenience and comfort. A comfortable and reliable means of transport, that ply on lanes free of the congested mixed traffic might be attractive to those who drive their own cars, as it would also relieve them of maneuvering and parking in the congested city. As such, the bus rapid transit being currently implemented in the city, if well-planned and administered, might succeed in reducing car-dependence.

The fact that *SUV*s are owned by households that are wealthier than those that own *Minivans* is also relevant to equity considerations. The way pricing policies

are framed determines the target population of the policy. Pricing policies aimed to reduce the purchase and use of larger cars would also affect the lower income *Minivan* owners. One approach that has less adverse effect on the mobility of lower income households could be to have a favorable policy based on engine sizes rather than length of the vehicle. It would affect *SUV* owners to a much greater extent than *Minivan* owners.

In an extension of this study, it would be useful to address the classical problem of allocating costs to users. A study across vehicle ownership types and vehicle use, with knowledge of fuel type used can be used to refine the tax structure for vehicle use. Depending on fuel efficiency, possible emissions, size, and extent of use of each vehicle type, a policy can be framed that would most efficiently curb emissions, congestion and fuel use. It can be determined whether pricing should be based on the extent of travel, assuming that was possible to gauge, or on the extent of fuel consumption, and whether the rate should vary across different vehicle types.

Future work involves validation of the findings with a larger dataset. After ascertaining the travel times and costs by alternative modes, a mode choice model calibrated with the present data or a bigger dataset would be informative. Furthermore, a similar study conducted across multiple cities, Indian or international, will capture the effect of the different built forms and varying access to transit, as well as different attitudes given the variations in the cultural make up across the country.

Analyzing trip making behavior and mode choice remains to be addressed in future work. However, since the present research and extensions thereof are intended to be useful for policy making, the next discussion in based on common observations on travel characteristics and on land use. These observations underscore that the culture of the city surveyed is very relevant to the issues in question and suggest the need for innovative policy making.

5.2 Need for Innovative Policy Framework

Cars being relatively expensive and Surat lacking good public transport, there is a chasm between motorized two-wheeler and car ownership, due to the lack of intermediate choices. While the city has an excellent network of informal public transport, hiring motorized three-wheelers without ride sharing is equally or more expensive compared to the fuel cost of taking one's own car for the same trip. Cost-conscious consumers would rather take their children on a motorized two-wheeler or overload it with goods and save money, than spend on expensive informal transport. In a community in which ninety three percent of the households live in residences they own, the importance of owning their means of transport cannot be over stressed. Any intermediate shared or hired option has to be of sufficiently low cost so as to not matter.

Policies could be aimed at reducing indiscriminate car trips, for which alternative modes exist. Usually bulk purchase trips, discretionary trips, and trips for the elderly are best catered to by cars, given the mode options available. Policy initiatives could support those trips and others for which a car offers significantly more convenience compared to available alternative modes. It should also work towards increasing the viability of alternatives available for such trips.

Even with more affordable cars in the market, there will still be a sizable population of such road users. Besides inexpensive and safer means of transportation, these road users also need interventions to improve their safety. Small business owners are typically the violators that transport their goods on their motorized two-wheelers. Regulating them in the name of safety would be to drive them out of their business. Given these considerations, improvement of road infrastructure, vehicle design, and design of inexpensive and climate-appropriate safety gear for vulnerable road users are necessities for Indian cities.

Surat and most Indian cities have high densities and mixed land use generating a lot of walk trips for convenience shopping, social, religious, and even work purposes. But one-stop grocery chains, carrying a range of different brands and alternatives have been introduced. As more people own cars, they can access those stores located further from home, and transport large quantities of grocery at lower prices. Over time these stores could adversely affect the business of the neighborhood stores, driving their owners out of business, and creating further dependence on car ownership. Policies promoting high-densities and supporting small businesses need to be adopted.

5.3 Contributions

Ironically, the lack of affordability to own motorized vehicles had made the transport system of the country reliant on non-motorized and public modes, and hence sustainable by default. Improvement of the economy, otherwise a necessity, can be a threat to the inherently sustainable culture of the country. Our research findings can be useful to policymakers looking for means of continued sustainability, while improving the quality of life of its citizen perceptively. This dissertation is the only study to the author's knowledge, that makes a comprehensive assessment of the choices between motorized two-wheelers and different size categories of cars, along with new and used vehicles. Its contribution also lies in studying the vehicle purchase in developing countries and in quantifying the extent to which a consumer is more sensitive to fuel cost than to the purchase price of a vehicle. It makes a timely comparison of preferences across car size categories in a country in which car ownership is poised to grow rapidly. The findings about the future composition of motorized two-wheelers and various size categories of cars are useful as inputs to infrastructure building, fuel use, and emission studies. Along with the findings on the willingness to pay for saving fuel

cost, the research provides important inputs to policy for encouraging non-motorized and public modes, as well as for encouraging clean motorized two-wheelers over cars.

Automobility of a country is a vast topic that needs extensive research. The present dissertation, while answering some key relevant questions, finds several more that needs further study. We hope the present dissertation is the beginning of many studies aimed at directing car growth in India in an environmentally-friendly manner. With availability of improved data, there is a promising future for policy related studies and policy making for India.

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Appendix A

Car Size Categories

	Segment/Subsegment	**Basis**	**Models**
	/Manufacturer		
I	**Passenger Vehicles (PV)**		
A		**Number of**	
		seats	
		including	
		driver not	
		exceeding 6	
A1	**Mini**	**Upto 3400 mm**	
	Maruti Suzuki India Limited		Maruti 800
	Tata Motors Limited		Nano
A2	**Compact**	**3401-4000mm**	
	Fiat India Automobiles		Palio, Fiat 500,
	Private Limited		Grande Punto
	Ford India Private Limited		Fusion
	General Motors India		Spark, U-VA
	Private Limited		
	Honda Siel Cars Limited		Jazz
	Hyundai Motor India Limited		Santro, Getz, i10, i20
	Maruti Suzuki India Limited		Alto, Wagon R, Zen,
			Swift, A Star
	SkodaAuto India Private		Fabia
	Limited		
	Tata Motors Limited		Indica

	Segment/Subsegment	**Basis**	**Models**
	/Manufacturer		
I	**Passenger Vehicles (PV)**		
A3	**Mid-size**	**4001-4500mm**	
	Ford India Private Limited		Fusion
	General Motors India		Chevrolet Aveo (NB)
	Private Limited		
	Hindustan Motors Limited		Ambassador, Lancer,
			Cedia
	Honda Siel Cars India Limited		City
	Hyundai Motors India Limited		Accent, Verna
	Mahindra Renault Private		Logan
	Limited		
	Maruti Suzuki India Limited		SX4, Dzire
	Tata Motors Limited		Indigo, Indigo Marina
A4	**Executive**	**4501-4700mm**	
	BMW India Private Limited		3 series
	Fiat India Automobiles		Linea
	Private Limited		
	General Motors India		Chevrolet Optra (NB)
	Private Limited		
	Honda Siel Cars Private		Civic
	Limited		
	Hyundai Motor India Limited		Elantra
	Mercedes-Benz India Private		C-Class
	Limited		
	SkodaAuto India Private		Octavia, Laura
	Limited		
	Toyota Kirloskar Motor		Corolla
	Private Limited		
A5	**Premium**	**4701-5000mm**	
	BMW India Private Limited		5 & 6 series
	Honda Siel Cars India Limited		Accord
	Hyundai Motor India Limited		Sonata
	Mercedes-Benz India Private		E-Class
	Limited		
A5	**Premium**	**4701-5000mm**	
	Nissan Motor India Private		Teana
	Limited		
	SkodaAuto India Private		Superb
	Limited		
	Toyota Kirloskar Motor		Camry
	Private Limited		

	Segment/Subsegment	**Basis**	**Models**
	/Manufacturer		
I	**Passenger Vehicles (PV)**		
A5	**Premium**	**4701-5000mm**	
	Volkswagen - Audi		A4, A6
	Volkswagen India Private		Passat
	Limited		
A6	**Luxury**	**5001mm up**	
	BMW India Private Limited		7 series
	Mercedes-Benz India Private		S-class
	Limited		
	Volkswagen - Audi		Q7, A8
B	**Utility Vehicles (UV)**		
B1		**Max Mass**	
		upto 3.5	
		tonnes	
		M1(B1)	
		Number of	
		seats	
		including	
		driver not	
		exceeding 7	
	BMW India Private Limited		X3, X5
	Force Motors Limited		Trax, Traveller
	Ford India Private Limited		Endeavour
	General Motors India		Tavera, Captiva
	Private Limited		
	Hindustan Motors Limited		Pajero
	Honda Siel Cars Limited		CR-V
	Hyundai Motors India Limited		Tucson, Terracan
	Mahindra & Mahindra Limited		Scorpio, Bolero,
			Invader, Commander
			650, CL 500/550,
			Maxx, Marshal,
			Ambulance, Xylo
	Maruti Suzuki India Limited		Vitara
	Mercedes-Benz India Private		
	Limited		
	Nissan Motor India Private		X-Trail
	Limited		
	Tata Motors Limited		Safari
	Toyota Kirloskar Motor		Fortuner, Innova,
	Private Limited		Prado

	Segment/Subsegment	**Basis**	**Models**
	/Manufacturer		
I	**Passenger Vehicles (PV)**		
		M1(B2)	
		Number of	
		seats	
		including	
		driver	
	Force Motors Limited	**exceeding 7**	Trax
	General Motors India	**but not**	Tavera
	Private Limited	**exceeding 9**	
	International Cars & Motors	**(7+1 & 8+1)**	Rhino
	Limited		
	Mahindra & Mahindra Limited		Scorpio, Bolero,
			Invader, Maxx,
			Marshal, Xylo
	Maruti Suzuki India Limited		Gypsy
	Tata Motors Limited		Sumo, Safari, Winger
	Toyota Kirloskar Motor		Innova
	Private Limited		
B2		**Max Mass**	
		upto 5	
		tonnes	
		M2(A1)	
		Number of	
	Force Motors Limited	**seats**	Trax, Traveller
	General Motors India	**including**	Travera
	Private Limited	**driver not**	
	Mahindra & Mahindra Limited	**exceeding 13**	Bolero, Commander
			650, Maxx, Marshal,
			Rakshak, Savari
	Tata Motors Limited		Sumo, Winger
	Total Utility Vehicles (UV)		
C	Multi Purpose vehicles	**M1(C) Van**	
	(MPV)	**Type vehicles**	
		and Max	
		Mass not	
		exceeding 3.5	
		tonnes	
	Maruti Suzuki India Ltd		Omni, Versa
	Tata Motors Ltd		ACE Magic

Appendix B

Secondary Data on Socio-Economics, Vehicle Ownership and Use Characteristics in Surat

Distribution of Households by Size

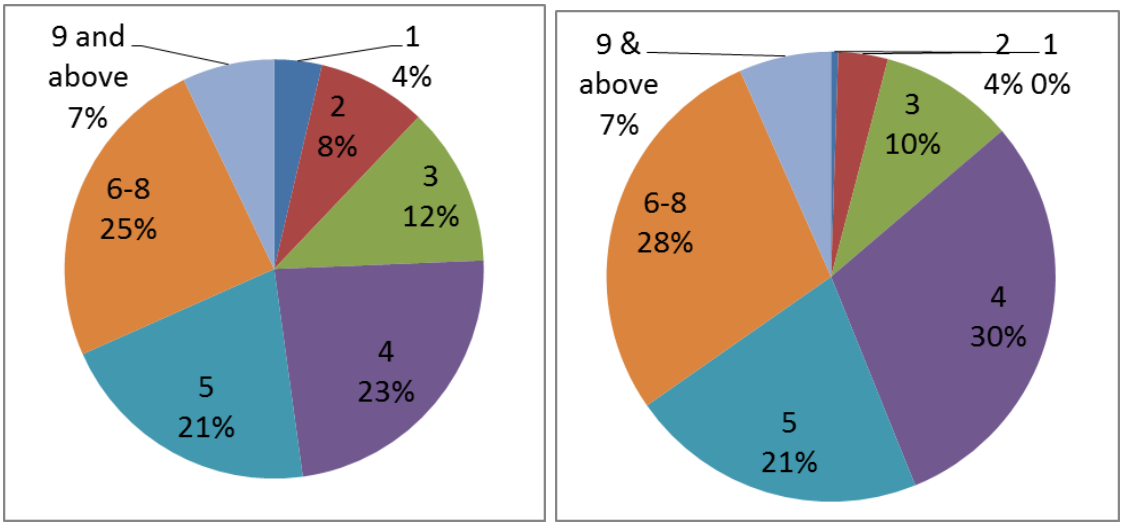

Figure B.1. Distribution of households by sizes: i) in state of Gujarat from Census 2001, ii) in sample

Figure B.1 compares the distribution of households by household size in the state of Gujarat and in the survey sample. The share of three to nine person households in

the survey sample are roughly representative of that in the state of Gujarat as per Census 2001, except that the survey sample includes a larger share of four person households. The one and two person households are slightly under-represented in the survey sample.

Distribution of Households by Home Ownership Status

Table B.1. Distribution of households by home ownership status: i) in state of Gujarat from Census 2001, ii) in survey sample

Ownership Status	Gujarat 2001 Households	Gujarat 2001 Percent	Survey Sample 2009 Households	Survey Sample 2009 Percent
Owned	2,749,173	73.2	179	94.7
Rented	856,636	22.8	9	4.8
Employer provided	152,219	4.1	1	0.5
Total	3,758,028	100	189	100

Table B.1 compares the distribution of home ownership status in the state of Gujarat as per Census 2001, and in the survey sample. The survey sample consists a much larger share of households that own their homes as compared to that in the state of Gujarat. Simulatanously, households that rent their homes are under-represented. While the share of hosueholds that live in emplyer provided housing is small in the state of Gujarat, it is even lower in the survey sample of motorized vehicle owners.

Per Capita Daily Trip Rate

Table B.2. Per capita daily trip rate from i) CRRI 1988, ii) CRRI 2004, iii) CES 2005, iv) WS 2008 Studies

Trip rate	1988	2004	2005	2008
Total	1.02	1.31	1.13	1.28
Motorized	0.55	0.78	0.73	-

Table B.2 shows the per capita daily trip rate of Surat residents. The recent studies roughly concur on the trip rate: 0.78 motorized trips per person per day and 1.31 trips overall (including non-motorized, i.e. walk and bike) trips per person per day. The per capita daily trip rate of Surat has been growing in the last 20 years that the

studies span. There is a discrepancy in the 2004 and 2005 numbers obtained by two different consultants, possibly due to the different methodologies and assumptions followed by them. The trip rate by motorized modes have also been growing.

Mode Split in Surat

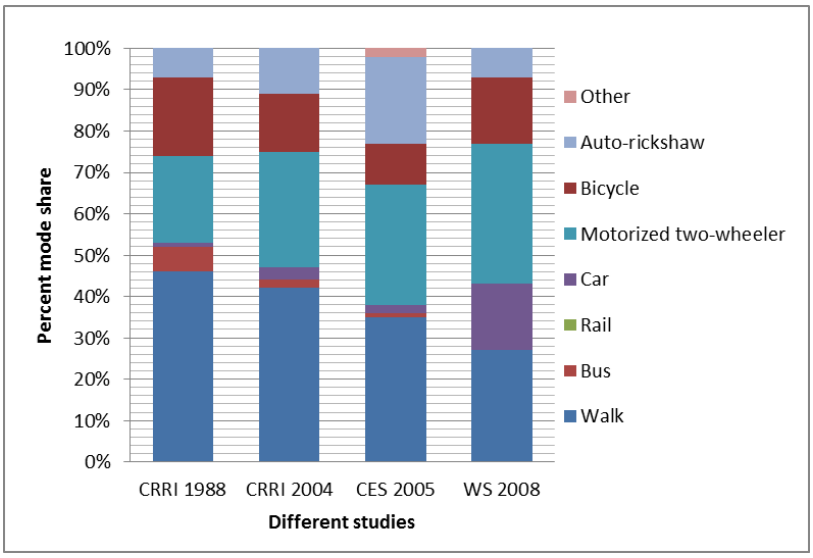

Figure B.2. Average trip length by modes in Surat based on i) CRRI 1988 ii) CRRI 2004 iii) CES 2005 iv) WS 2008

Figure B.2 shows the mode split in Surat as studied by different consultants over the span of 20 years. Once more, while the details of assumptions and methodologies are unknown to us for more accurate comparisons, the figure gives an overall view of the share of different modes. Walk trips occupied the largest share in 1988, but its share has reduced significantly. While the share of bus trips was minimal, its share has now reduced to be negligible. The share of motorized two-wheeler trips is growing and similarly for car trips. The mode shares indicate an increase in the use of personal motorized vehicles possibly owing to the inadequacy in public transport and facilities for non-motorized modes.

Average Trip Length by Modes in Surat

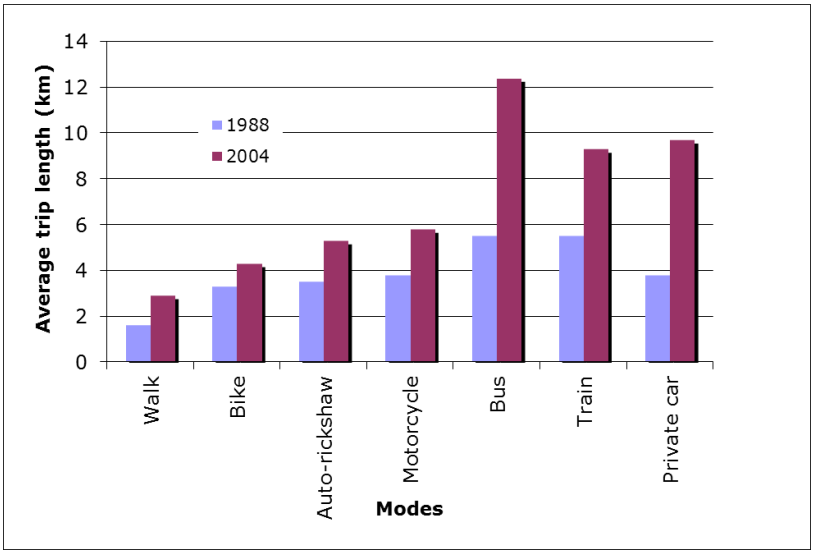

Figure B.3. Average trip length by modes in Surat based on i) CRRI 1988 ii) CRRI 2004 Studies

Figure B.3 shows the average trip length by all modes based on two different studies by the same consultant in 1988 and 2004. It is evident that trip lengths by all modes had increased, especially those by bus, train, and private car.

Average Vehicle Occupancy

Table B.3. Average vehicle occupancy in Surat: CRRI 2004 Study

Mode	Number of passengers
Car	1.25
Motorized two-wheeler	1.11
Bicycle	1.05
Auto-rickshaw	2.65
Auto-rickshaw (pooled)	3.42

Figure B.3 shows the occupancy of different modes in Surat as per the CRRI 2004 study. The auto-rickshaws or motorized three-wheelers have the highest occupancies, especially the 'shuttle' or pooled auto-rickshaws. The occupancy value of cars indicate the presence of a large share of drive-alone auto trips similar to more industrialized countries.

Appendix C

Survey Proforma

HOUSEHOLD TRANSPORTATION CHOICES IN INDIA
University of California, Berkeley
Curve Concepts, Surat
Date: **Surveyor:**
Time: **Form No:**

This is a survey on vehicle ownership and trip mode choices of the residents of Surat. Statistical analysis will be conducted on your responses along with those of others surveyed, to help inform policy. Your responses will be anonymous. First, we will ask you a couple of screening questions.

Screening Questions:

1. Do you own any motor vehicles in your household?
   a. Yes
   b. No (Do not survey)
2. Did you acquire any two-wheeler or car since April 2009?
   a. Yes (Group A)
   b. No (Within January to March 2009? Yes (Do not survey)
      No (Group B)

SECTION A: TO BE FILLED BY SURVEYOR

1. Residence Information

1. Address:_____

2. Contact number:_____

3. Type of Residence
   Bungalow ☐
   Row house ☐
   Building ☐
   Gala type ☐

5. Is this your:
   Own house ☐
   Rented house ☐
   Government Quarters ☐
   Company house ☐

4. Land use:
Residential/Commercial/RC/Other, please specify_____

GROUP A ONLY:

2. Vehicle Acquisition details

1. Car/2W
2. Make/model?_____/_____

3. Kilometres on vehicle_____

4a. Petrol/ diesel/ CNG / LPG/Battery
4b. Km/L or Km/Kg or Km/charge_____

5a. Company lease? Yes/No
5b.Company fuel reimbursement?Yes/No

6a. Street parking? Yes/No 6b.Fees_____

7. Second hand? Yes/No
7a. **If second hand**, year of manufacture?_____

8. Car only: Driver? Yes/No
8a. If Driver: Company employed? Yes/No

9. Insured Yes/No
9a. Insurance: 1. Comprehensive/Full 2. Third party 3. Other, please specify _____

10 a) Vehicle need? Work ☐ Family use ☐ Other_____

b) Some people buy a new vehicle when existing vehicles or public transport system are inadequate for the purpose. Others buy a new vehicle because of their strong liking for that vehicle. What were the reasons in your case?

Status	☐	Maneuverability in traffic	☐	Time flexibility	☐	Replace old veh.	☐
Safety	☐	Multiple passengers	☐	Carry things	☐		
Speed	☐	Auto/bus inadequate	☐	Comfort	☐		

Others (please specify):_____

c) Which factors were important in your decision to buy the new vehicle?

Easy maintenance ☐ Value for money ☐ Brand name ☐ Nice features ☐

Others_____

d) CAR ONLY Reason for choosing a vehicle of this size_____

GROUP A & GROUP B:

3. Other Vehicle Ownership Detail

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6
1. Car-**C**/**2W**/Cycle-**O**						
2. Make/model						
3. Second hand	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
4. Purchase year						
5. Kilometers on vehicle						
6. Car only: driver?	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
6a.If driver company employed	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
7. Easy maintenance?	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
8. Insured	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
9. Insurance type	1 / 2 / ?	1 / 2 / ?	1 / 2 / ?	1 / 2 / ?	1 / 2 / ?	1 / 2 / ?
10. Street parking?	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
11. Parking fees amount (Rs.)						

3a. Have you booked any new vehicle? Yes/No. If yes, what vehicle?_____

4. Miscellaneous

a. Walk time to nearest auto stop_____

b. Walk time to nearest bus stop_____

c. Do you make regular out of town trip using private vehicle? Yes/No

5. Vehicle Ownership profile of peers

Now I will ask you about the vehicle ownership profiles of your relatives/friends/ neighbors

Out of 10 of your closest relatives how many have cars/two wheelers?_____/_____

Out of 10 of your neighbors how many have cars/two wheelers? _____/_____

Out of 10 of your closest friends how many have cars/two wheelers? _____/_____

6. Personal Information: Please mention husband, wife and children consecutively

		Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Person 7	Person 8	Person 9	Person 10	Person 11
1	Relationship											
	Self											
	Spouse											
	Son											
	Daughter											
	Daughter-in-law											
	Uncle											
	Aunt											
	Father											
	Mother											
	Brother											
	Sister											
	Others (please specify):											
2	Age											
3	Gender	M / F	M / F	M / F	M / F	M / F	M / F	M / F	M / F	M / F	M / F	M / F
4	Drives car	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
	License	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
5	Drives 2W	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
	License	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
6	Occupation:											
	Student											
	Housewife											
	Retired											
	Unemployed											
	Government sector											
	Private sector											
	Self-employed											

7. Yesterday's trip information (working day) Please start with trips made using the new vehicle, followed by car & two wheeler trips. Next, any trips made using public transport.

		Person Trip	Person Trip	Person Trip	Person Trip	Person Trip	Person Trip	Person Trip	Person Trip	Person Trip
1.	Purpose Work									
	Education									
	Maintenance									
	Shopping									
	Social									
	Recreation									
	Religious									
	Drop off/pick up									
	Return									
	Other(please specify)									
2	Mode Walk									
	Auto									
	Bus									
	Cycle									
	Two-wheeler (please specify)									
	Car (please specify)									
3	Start location									
4	End location									
5	Distance in km									
6	Start time									
7	End time									
8	How many times a week									
9	**Private Transport** : Driver									
	Co-passengers									
	Street parking? *(Wait time)*									
	Parking Fee *(No. of transfers)*									
10	*For Public Transport: Fare*									
	Walk time start location									
	Walk time end location									

7. TRIP INFORMATION CONTINUED

GROUP A ONLY
For trips made with new vehicle:
Person No_____ Trip No:_____

How did you make this trip before?

- ☐ Did not make part/whole of the trip
- ☐ Went to a different location
- ☐ Traveled separately
- ☐ Different mode, please specify_____

Others, please specify_____

GROUP B ONLY
Person No_____ Trip No: _____
Some people use their personal vehicle when existing vehicles or public transport system is inadequate for the purpose. Others use their personal vehicle out of habit, for status etc. In your case, why was this vehicle the most appropriate for your trip?

- ☐ Speed
- ☐ Maneuverable in traffic
- ☐ Weather
- ☐ Safety
- ☐ Comfort
- ☐ Time flexibility
- ☐ Status
- ☐ Multiple Passengers
- ☐ Carry things
- ☐ Inadequate public transport: Please specify_____

Others, please specify_____

Section B:To be filled by survey respondent **Form No:_____** **Person no. _____**

1. Please state the extent to which you agree/disagree with the statements.
DD-Definitely Disagree D-Somewhat Disagree N-Neither A-Somewhat Agree DA-Defintiely Agree N/A Not Applicable

	DD	D	N	A	DA	N/A
A car is a status symbol	☐	☐	☐	☐	☐	☐
A vehicle improves my career opportunities	☐	☐	☐	☐	☐	☐
A vehicle improves my personal life	☐	☐	☐	☐	☐	☐
It is inconvenient to be a pedestrian	☐	☐	☐	☐	☐	☐
It is inconvenient to be a bus rider	☐	☐	☐	☐	☐	☐
It is inconvenient to ride a bicycle	☐	☐	☐	☐	☐	☐
A personal vehicle is a status symbol	☐	☐	☐	☐	☐	☐
The loan is important for my vehicle purchase	☐	☐	☐	☐	☐	☐
The operating cost of the vehicle is important in my vehicle purchase decision	☐	☐	☐	☐	☐	☐
Cars are expensive	☐	☐	☐	☐	☐	☐
Saving is a virtue and we should not spend too much	☐	☐	☐	☐	☐	☐
It is important to support India's economy by buying Indian brand	☐	☐	☐	☐	☐	☐
Be it of Indian or foreign brand, we should buy that which gives value for money	☐	☐	☐	☐	☐	☐
Finding parking is a hassle	☐	☐	☐	☐	☐	☐
Being a car owner is a hassle	☐	☐	☐	☐	☐	☐
Driving in congestion is a hassle	☐	☐	☐	☐	☐	☐
I don't want to be seen riding bus/shared auto	☐	☐	☐	☐	☐	☐
I don't want to be seen walking/bicycling	☐	☐	☐	☐	☐	☐
I consider buying a vehicle for infrequent need	☐	☐	☐	☐	☐	☐
On hot/rainy days I wish I had my own car	☐	☐	☐	☐	☐	☐
When many of my friends/family/neighbors own a certain type of vehicle I have to buy it	☐	☐	☐	☐	☐	☐
I like to be the first among my peers to do something new	☐	☐	☐	☐	☐	☐
When something new hits the market, I have to buy it	☐	☐	☐	☐	☐	☐
I feel the need for some time to myself	☐	☐	☐	☐	☐	☐
I want people to look at me	☐	☐	☐	☐	☐	☐
The vehicle that I own must be of an expensive brand	☐	☐	☐	☐	☐	☐

2. Questions for new vehicle

Price_____ Loan/interest_____

EMI amount_____ Insurance premium_____

3. Price questions for other vehicles

	Vehicle 1	**Vehicle 2**	**Vehicle 3**	**Vehicle 4**	**Vehicle 5**	**Vehicle 6**
EMI amount						

4. Please check the appropriate personal income category of main earner in the household:

Below 10,000	☐
10,000-30,000	☐
30,000-50,000	☐
50,000-1,00,000	☐
1,00,000-5,00,000	☐
5,00,000-10,00,000	☐
10,00,000-20,00,000	☐
20,00,000 and above	☐

5. Please check the appropriate household income category.

Below 10,000	☐
10,000-30,000	☐
30,000-50,000	☐
50,000-1,00,000	☐
1,00,000-5,00,000	☐
5,00,000-10,00,000	☐
10,00,000-20,00,000	☐
20,00,000 and above	☐

Thank you!

If you have any questions or comments about this survey, please contact me at survey.surat2009@gmail.com

Appendix D

Exploratory Factor Analysis

The responses to the Likert scale questions represented attitudes to be used as explanatory variables in the vehicle purchase model. Each of these responses are indicators of underlying attitudes. The responses are often indicators of a mix of underlying attitudes. An exploratory factor analysis is conducted on the five point responses to obtain the the underlying orthogonal factors or attitudes from the correlated responses. This is a method of dimension reduction aimed to reduce the number of explanatory variables that are used in the vehicle choice model. The method used is principal axis factor analysis using the package SPSS 17. The output tables from the factor analysis process are displayed in this Appendix.

Table D.1. KMO Measure of Sampling Adequacy & Barlett's Test of Sphericity

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.707
Bartlett's Test of Sphericity	Approx. Chi-Square	665.119
	df	325
	Sig.	.000

Table D.1 represents the outputs of the Kaiser-Meyer-Olkin measure of sampling adequacy and the Barlett's Test of Sphericity. The KMO measure of sampling adequacy was 0.707 which is rated as 'middling'. The significance of the Barlett's Test of Sphericity is 0.00, which means that there are underlying factors in the Likert Scale responses.

Table D.2. Communalities

Communalities

	Initial
car_st_symb	.660
veh_career	.533
veh_pers_life	.597
inc_pedestr	.532
inc_bus_rider	.546
inc_bicycle	.528
pers_veh_st	.586
loan_imp	.345
op_cost_imp	.616
cars_expensv	.358
save_virtue	.606
Indian_brand	.399
value_money	.482
parking_hassle	.475
car_own_hassle	.318
dr_cong_hassle	.497
seen_bus_auto	.635
seen_walk_cyc	.600
infreq_need	.625
hot_rainy	.457
peer_have_to_buy	.541
1st_peer_new	.446
new_mkt_buy	.509
time_myself	.350
look_at_me	.401
exp_brand	.525

Extraction Method:
Principal Axis Factoring.

Table D.2 shows the initial communalities for the variables. The initial communalities are high for all of the variables. As such, all variables were retained for the factor analysis.

Table D.3 shows the initial eigenvalues and the rotation sums of squared loadings of the factors. The rotated factors are preferred since they are easier to interpret with a greater difference in value between the high and the low loadings. 26 factors were extracted through Principal Axis Factoring and Orthogonal Varimax Rotation was applied. The initial eigenvalues were greater than 1 for the first 8 factors. As preliminary runs of the factor analysis had shown the five topmost factors to be the

most meaningful conceptually, we specified 5 factors to be extracted which took 11 iterations. The eigenvalues of the 5 extracted factors are shown under the rotation sums of squared loadings and they cumulatively explain 43.62 percent of the variance in the data.

Table D.3. Total Variance Explained

Total Variance Explained

	Initial Eigenvalues			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.195	19.979	19.979	3.345	12.865	12.865
2	3.595	13.828	33.807	2.149	8.265	21.130
3	2.047	7.871	41.678	2.027	7.795	28.925
4	1.638	6.301	47.979	1.935	7.442	36.367
5	1.537	5.910	53.889	1.886	7.253	43.620
6	1.285	4.941	58.831			
7	1.140	4.384	63.215			
8	1.008	3.875	67.090			
9	.975	3.752	70.842			
10	.842	3.237	74.079			
11	.778	2.992	77.071			
12	.711	2.734	79.805			
13	.664	2.553	82.359			
14	.608	2.337	84.696			
15	.526	2.022	86.718			
16	.488	1.876	88.594			
17	.461	1.775	90.369			
18	.416	1.598	91.968			
19	.367	1.411	93.379			
20	.326	1.256	94.634			
21	.313	1.203	95.837			
22	.278	1.068	96.905			
23	.268	1.030	97.935			
24	.204	.784	98.720			
25	.173	.667	99.387			
26	.159	.613	100.000			

Extraction Method: Principal Axis Factoring.

All loadings with a value greater than 0.5 are considered in identifying each factor

from the rotated factor matrix, Table D.4. High loadings are obtained for the following statements:

Table D.4. Rotated Factor Matrix

Rotated Factor Matrix[a]

	Factor				
	1	2	3	4	5
car_st_symb	.183	.424	.567	.140	.134
veh_career	.511	.133	.347	.236	.008
veh_pers_life	.493	.155	.424	.035	.115
inc_pedestr	-.004	.785	.034	.069	.038
inc_bus_rider	.243	.691	-.018	.100	.026
inc_bicycle	-.020	.578	.194	.043	.198
pers_veh_st	.187	.380	.582	-.021	.287
loan_imp	.518	.003	.023	.017	.133
op_cost_imp	.732	.020	.216	-.034	-.050
cars_expensv	.525	-.069	-.223	-.100	-.099
save_virtue	.606	-.014	.317	-.125	-.209
Indian_brand	.428	.119	.087	-.181	.081
value_money	.173	.345	.285	.038	-.100
parking_hassle	.597	.100	.084	-.176	-.018
car_own_hassle	.046	-.202	-.089	.355	.124
dr_cong_hassle	.623	.091	.208	.071	.078
seen_bus_auto	-.148	.205	-.030	.728	.083
seen_walk_cyc	-.139	.216	-.010	.592	.076
infreq_need	.027	.004	.317	.666	.207
hot_rainy	.084	.029	.604	-.106	.034
peer_have_to_buy	-.038	.136	.081	.440	.566
1st_peer_new	.130	-.055	-.055	.104	.554
new_mkt_buy	-.011	.132	.031	.035	.750
time_myself	.118	-.003	.353	.064	-.058
look_at_me	-.181	.020	.286	.245	.440
exp_brand	.438	.172	-.008	.120	.419

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Factor 1:

The operating cost considerations are important in my vehicle purchase*

Saving is a virtue*
Driving in congestion is a hassle
Finding parking is a hassle
The personal vehicle is important for my career opportunities*
The loan is important for my vehicle purchase*
Cars are expensive

Factor 2:
It is inconvenient to be a bus rider
It is inconvenient to be a pedestrian
It is inconvenient to ride a bicycle

Factor 3:
A car is a status symbol
A personal vehicle is a status symbol
On hot or rainy days I wish I had my own car*

Factor 4:
I consider buying a vehicle for infrequent need*
I don't want to be seen riding a bus or an auto
I don't want to be seen walking or cycling

Factor 5:
When there is something new in the market I have to buy it
I have to be the first among my peers to get something new
When my peers have a certain type of vehicle, I have to own it
*(Ni, 2008)

Accordingly, the factors are names as follows:

1. Monetary and utility considerations
2. Inconvenience of non-motorized and public modes
3. Perception of status
4. Negative image of non-motorized and public modes
5. Peer influence

These factors are used for the confirmatory factor analysis in the choice and latent variable model.

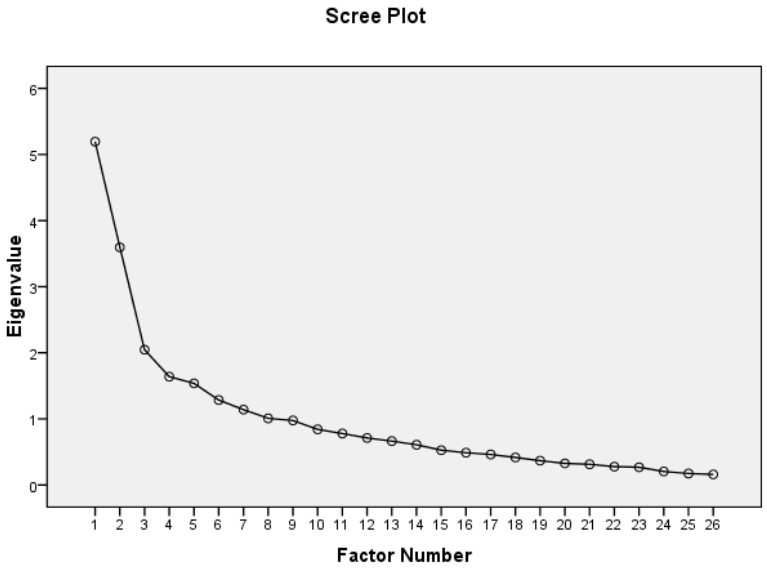

Figure D.1. Scree plot

Figure D.1 shows that the largest drop in eigenvalue are between the first and the second, and the second and the third factor. This is also evident from the eigenvalues in Table D.3.