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Projection of private vehicle stock in India up to 2050

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Abstract

The study presents projections of private vehicles in India up to 2050. Private vehicles include two-wheelers and cars which run on petrol and diesel. The population of private vehicles increases with the economic development of the country. Therefore, in the current study forecast of vehicle ownership is done with per capita GDP using Gompertz function. The result gives future vehicle stock values of two-wheelers and cars based on different GDP growth rates and saturation levels for vehicle ownership per 1000 people in India. Our study projects that, total two-wheeler population increases by ~3-fold in conservative growth scenario and by ~4-fold in aggressive growth scenario, giving 420 million and 562 million vehicles respectively for each scenario in the year 2050. Similarly, for cars, total vehicle population increases by ~9-fold in conservative growth scenario and ~14-fold in aggressive growth scenario, giving 262 million and 432 million vehicles respectively for each scenario in the year 2050. The point of inflection starts after 2030 for private vehicles in India. The result also indicates that India is at the initial stage of Gompertz curve and follows an 'S' shaped growth pattern like developed countries. The study also suggests few suitable policy recommendations for reduction in vehicle population which will eventually affect vehicular emissions and oil dependency.

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Keywords: Vehicle ownership; per capita GDP; Gompertz curve; policy recommendations

1. Introduction

India is a developing country which relies on the transport sector for its development. It is considered as the backbone of the country. It not only caters to the traveling demand of the people but also provides better connectivity and infrastructure. This has led to its rapid expansion and unfortunately created a trend where the modes which are experiencing the most growth are also the most polluting. The population of private vehicles such as two-wheelers

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and cars has increased with the economic development of the nation. Developed countries have shown this relationship and it has been recently observed in developing countries too (Dargay et al., 2007).

Road transport sector contributes around 3% to India's GDP (GOI, 2016b). The percentage of private vehicles (two-wheelers and cars) in the total registered vehicles has approximately increased from 55% in 1960 to 85% in 2016. On the other hand, the population of registered buses has decreased from approximately 9% in 1960 to around 1 % in 2016 among the total registered vehicles in India.

Nomenclature

BAU	Business As Usual
GDP	Gross Domestic Product
GHG	Greenhouse Gas
CO_2	Carbon Dioxide
OECD	Organization of Economic Co-operation and Development
CAGR	Compound Annual Growth Rate
PPP	Purchasing Power Parity
IEA	International Energy Agency
WBI	World Bank Indicator
HWV	Highway Vehicles
TERI	The Energy and Resource Institute
MORTH	Ministry of Road Transport and Highways
RBI	Reserve Bank of India
CNG	Compressed Natural Gas
NEMMP	National Electric Mobility Mission Plan
FAME	Faster Adoption and Manufacturing of Electric vehicles

1.1. Travel Characteristics of India

Trend analysis of registered private vehicles in Fig.1 indicates linear growth in the log of registered population of two-wheeler (2w) and cars in India. Increase in household income and poor public transport are the main causes for the rampant growth in private vehicles. The concentration of air pollutants and Greenhouse gases (GHG) gases emitted from the exhaust of the vehicles has increased with an increase in vehicle number (Pucher et al., 2005). Buses are a popular mode of public transport and are available in all the cities of India irrespective of their sizes, number of people and economic development. But their conditions are deteriorating due to lack of proper infrastructure and maintenance. In such a scenario, people have preferred private vehicles and with the rise in household income, private vehicle ownership has increased (Wu et al., 2014).

Even with increasing private vehicles in India, vehicle ownership is still below that in developed countries. In 2015, India has 19 passenger cars per 1000 people, whereas, there were 300-400 cars per 1000 people in Organization of Economic Co-operation and Development (OECD) countries (Paladugula et al., 2018).

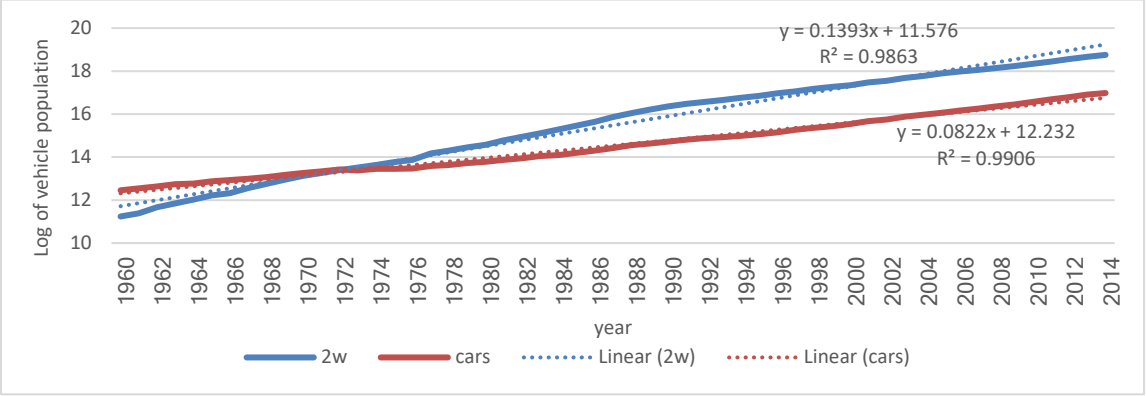

Fig. 1 Trend analysis of registered private vehicles in India from 1960 to 2014

India is still in the developing stage and with an increase in the country's GDP, private vehicle ownership will continue to increase. This growth will automatically affect the on-road vehicle population and will add up to the already existing significant problems of congestion, air pollution, greenhouse gas emissions, increase in oil demand and the health of the people. Table 1 gives the change in travel characteristics of India over the years along with GDP.

Table 1: Travel characteristics of India

source		**Year**		
		2011	2013	2015
IEA, WBI	Population (Millions)	1247	1279	1311
WBI	Population Density (people per square km of area)	419.56	430.35	440.96
WBI, Data.Gov.in, MoRTH	2Ws/ 1000 people	81.7	99.9	117.7
	cars/1000 people	14.0	16.9	19.6
	CAGR of 2w (2001- final year)	10.2%	10.5%	10.4%
	CAGR for cars (2001-final year)	11.3%	11.5%	11.1%
	CAGR for buses (2001- final year)	6.9%	9.2%	8.4%
	CAGR for goods vehicles (2001- final years)	9.1%	9.0%	8.6%
IEA, WBI	GDP (billion 2010 USD)	1766	1985	2296
IEA, WBI	GDP PPP (billion 2010 USD)	5665	6366	7365

2. Past projection studies on India

The projection studies for Indian transport sector analyzed vehicle stock population and also estimated its impact on oil demand, energy consumption and on vehicular emissions. The study done by IEA/SMP model projected population of light-duty vehicles (cars and utility vehicles), along with two- and three-wheelers populations using Gompertz function with GDP per capita (Fulton and Eads, 2004). Whereas, Singh (2006) projected passenger kilometers demand per capita using both Gompertz and logistic function to calculate energy demand and carbon dioxide (CO_2) emissions up to 2021. Another study done by Bouachera and Mazraati (2007) examined car ownership to estimate fuel demand up to 2030 using growth models such as logistic, quasi-logistic, and Gompertz functions for India assuming high saturation level of 850 vehicles per 1000 persons. The study by Banerjee and Schipper (2009) estimated CO_2 emissions from forecasted vehicle population of cars and suggested that vehicle ownership of India in 2030 would be similar to South Korea in the early 1990s. Arora et al. (2011) projected two-wheeler and highway vehicle (HWV) stock (which includes cars, taxi, multi-utility vehicles, three-wheelers, multipurpose vehicles, buses and goods vehicle like trucks) using Gompertz function to estimate the oil demand and CO_2 emission for 2040.The study projected future stock population based on different growth scenarios, different saturation levels and expected GDP growth rate in India.

Saturation level (γ) is an important parameter in the estimation but there is no standard technical method to define it. According to the literature review, the saturation level (γ) for UK and other industrialized countries lie between 0.4 and 0.7 (vehicle ownership/1000 people i.e. 400 to 700 vehicles) (Button K et al., 1993). Car ownership rates in most of the OECD countries was estimated as 0.62 in 2015 based on the Gompertz model built using time series data of 26 countries (Dargay et al., 2007). Saturation level for China was defined to be 0.292 (Kobos et al., 2007). Huo et al., (2007) reviewed the literature data of 18 countries and indicated that the saturation level of the United States as the representative of North America was 0.8 (vehicle ownership/1000 people). For European counties saturation level was 0.6 and for Japan as the representative of Asian countries was 0.55. The study done for India conducted analysis of the historical Highway vehicles (HWV) which along with cars included other four wheelers on the road with per capita GDP. The results of this study were in coherence with the above analysis for US (OECD North America). Whereas Europe was divided into two groups OECD- Europe (France & Germany) having $\gamma = 650$ vehicles per 1000 vehicles and OECD- Europe low pattern (UK, Netherland and Norway) having $\gamma = 550$ vehicles per 1000 people. For Asian countries (China, India and Indonesia) γ = 400-450 vehicles per 1000 people (Arora et al., 2011). From the literature study it can be understood that saturation level depends on the average household size, increase in urbanization and reduced fertility rates. It is affected by different socio-economic situation and policy restrictions which impact population density and lifestyle.

3. Purpose of the study

The aim of our study was to project the private vehicle stock of India up to 2050 using per capita GDP of India. The current study examined the business as usual (BAU) scenario for two-wheelers and cars separately running on fossil fuels (petrol and diesel) under two growth scenarios (conservative and aggressive having different saturation level) and compared results with the studies done in past for India. In the latest study done for India on vehicle projections (Arora et al., 2011) cars were grouped together with intermediate transport vehicles (three-wheelers), public vehicles (buses) and goods vehicles (trucks). All these vehicles have different growth rates with private vehicle like cars dominating among them in India. Therefore, separate analysis for cars and other vehicle modes should be done. Hence the current study analyzed two-wheelers and cars (not including other vehicle types with cars) stock projections for 2050. This type of study is useful for future analysis of energy consumption and vehicular emissions from India and

helps in suggesting suitable mitigation options for emission reduction. Such studies help policy makers to make proper strategies for limiting vehicle population and vehicular emissions.

4. Data for the study

The data used in the analysis were secondary data from the period 1966 to 2011 for India. The historical registered vehicle population was taken from MORTH (2015). GDP in Indian currency was obtained from RBI website at factor cost (2004-05) and was converted into GDP at Purchasing Power Parity (PPP) US$. The conversion rate was obtained from World Bank Indicator (WBI) for 2004-05 for India. The saturation values for two-wheeler ownership per 1000 people and car ownership per 1000 people were assumed from Arora et al. (2011). Here, GDP and population are the important parameters for future vehicle stock assessment. Population growth rate was assumed from the UN population projection for India (UN, 2015). According to this assumption, India's population will reach 1.5 billion in 2030 and 1.7 billion by 2050. For the current study, population growth rate was assumed to be 1.5% per year till 2050. Annual GDP growth rate reported by 'The Energy and Resource Institute (TERI)' from 2015 to 2050 was assumed from the study by Paladugula et al. (2018) is shown in table 2:

Table 2: Annual GDP growth rate given by TERI

year	Annual GDP growth rate reported by TERI (in %)
2015	7.2
2020	8.3
2025	8.8
2030	9.2
2035	8.9
2040	8.2
2045	7.4
2050	6.7

The growth rate assumed by TERI was on the higher side compared to values reported by other organizations in the study by Paladugula et al (2018). Annual GDP values given by TERI were selected for the analysis as its transport demand model was built from input data of various transport ministry publications. Vehicle registered data used here was also obtained from transport ministry publications (MORTH, 2015). So, in order to have consistency in the data used in our study, GDP values given by TERI were used for the analysis.

5. Methodology

The change in vehicle ownership is directly related to per capita GDP in a country. This relationship is not linear (Arora et al, 2011). In developed countries, this relationship follows 'S' shaped curve which implies that vehicle ownership increases slowly at the lowest income levels, and then more rapidly as income rises, and finally slows down as saturation is approached (Dargay et al., 2007; Wu et al., 2014).

Logistic, log-logistic, and Gompertz functions have been used in previous studies. The inclination for a specific functional form is based on the goodness of fit of the data as there is no theoretical basis for selection of a specific model over other (Dargay et al., 1997). Among them, the Gompertz function was deemed as more flexible and fits the historical data better than the rest of the models (Wu et al., 2014).

The model used for current analysis is assumed from Dargay et al (2007), where V* denote the long-run equilibrium level of vehicle ownership (vehicles per 1000 people), and GDP denotes per capita income (expressed in constant 2005 US $ evaluated at Purchasing Power Parities). The model shown in equation (1), where γ is the saturation level (measured in vehicles per 1000 people) and α and β are negative parameters defining the shape of the curve.

$$V^* = \gamma e^{\alpha e^{\beta GDP_t}} \quad (1)$$

Here, equation (1) V* denotes the long-run equilibrium relationship between private vehicle ownership and per capita GDP. To account for lags in the adjustment of vehicle ownership to per capita GDP, equation (2) is formulated as shown below.

$$V_t = V_{t-1} + \theta (V_t^* - V_{t-1}) \quad (2)$$

In the equation (2), V_t is vehicle ownership in year t (vehicles per 1000 people); V* is equilibrium vehicle ownership level defined in equation (1). θ is the speed of adjustment for vehicle ownership with respect to GDP growth ($0< \theta <1$). Lags have been included to depict slow adjustment of vehicle ownership to increase in GDP. Substituting equation (1) into (2), would give equation (3), where, γ (saturation level) is an important input value for future analysis of private vehicle stocks.

$$V_t = \gamma\theta e^{\alpha e^{\beta GDP_t}} + (1-\theta)V_{t-1} \quad (3)$$

Here, saturation levels are important input values for the future analysis of private vehicle stocks. According to Arora et al (2011), historical data analysis of Highway vehicle (HWV) ownership reveals five different HWV saturation patterns which are shown in table 3:

Table 3: Saturation level in different countries

	Saturation level of vehicles at GDP per capita US$ 43,000
OECD North America	850
OECD Pacific	700-750
OECD Europe (France and Germany)	650
OECD Europe-Low (United Kingdom, Netherlands and Norway)	550
Asia	400-450

In the current study, saturation values for two-wheelers and cars are assumed from Arora et al (2011). The saturation level for car ownership is assumed to be 150 (conservative growth scenario) and 250 (aggressive growth scenario) vehicles per 1000 person considering GDP per capita for urban and rural India to be in the range of 7,500-20,000 US$- PPP and 9,000-10,000 US$-PPP respectively. Whereas for two-wheelers, 250 (conservative growth scenario) and 350 (aggressive growth scenario) vehicles per 1000 persons are assumed as the saturation levels considering high sales value and ownership rates in other Asian countries for two-wheelers (Arora et al., 2011).

6. Result and Discussion

Projection of two-wheeler and car stock population was done using equation (3) up to the year 2050. After the simulation, it was observed that both two-wheelers and cars at conservative and aggressive growth scenario follow ‘S’ shaped curve with per capita GDP. The results are shown in Fig. 2 and Fig. 3 indicating that India’s vehicle stock

will follow the OECD or Europe trend of the S-shaped curve.

The other parameters of the model α, β and θ were iterated for different saturation levels. α and β parameters determine the shape of the curve. These parameters are negative. The increase in α and β would lead to a steep S shape curve against the economic factor (per capita GDP). In the Gompertz curve smaller absolute values of α and β would best fit the case of lower levels of per capita GDP. Speed of adjustment (θ) affected by rising income and falling income. But for the long run income elasticity, θ is same for income increase and decrease. The values of the parameters obtained for the estimation are shown in the table 4. For the projection study where, different models were created to obtain the final output, adjusted R squared has been used. It is a modified version of R-squared that has been adjusted for the number of predictors in the model (predictors are the variables which are likely to influence the future results). Adjusted R square gives the fit for the model of vehicle ownership with per capita GDP at different saturation levels. For two-wheelers adjusted R squared was 0.88 and for cars adjusted R squared was 0.6.

Table4: Values of α, β and θ for the model

Vehicle	Growth scenario	Saturation level (γ)	α	β	θ
Two-wheelers	conservative	250	-9.39	-0.00035	0.093
	aggressive	350	-9.59	-0.00032	0.092
Cars	conservative	150	-9.32	-0.00014	0.671
	aggressive	250	-9.80	-0.00013	0.664

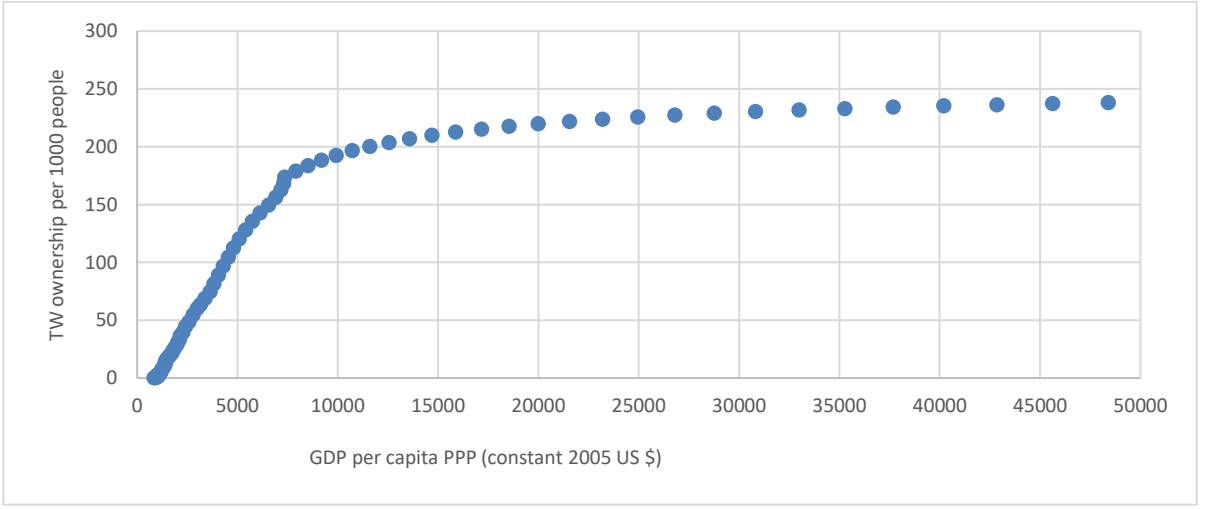

Fig. 2 Future projection of TW ownership per 1000 people with GDP per capita PPP (at constant 2005 US $)

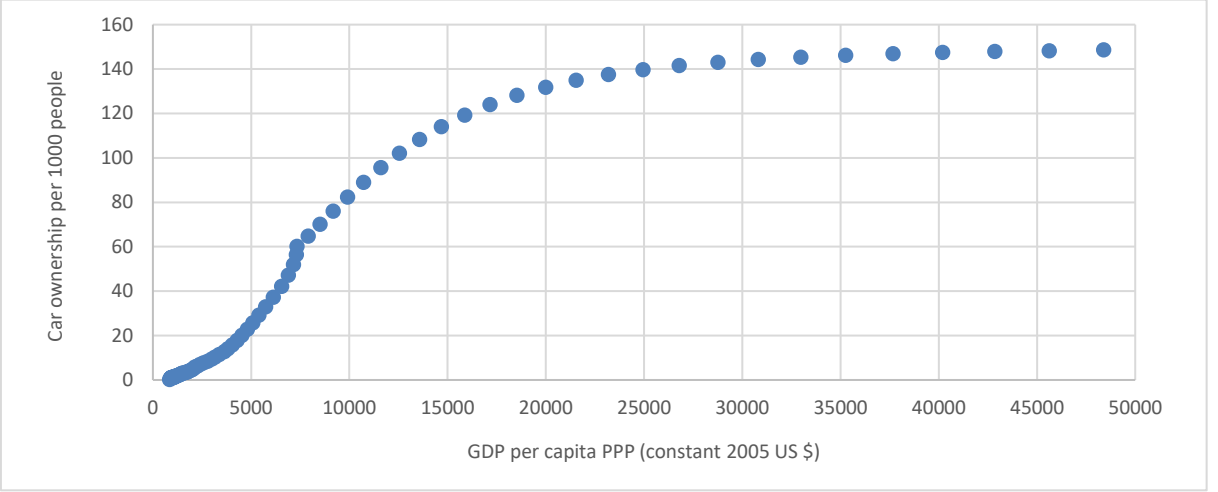

Fig.3 Future projection of Cars ownership per1000 people with GDP per capita PPP (at constant 2005 US $)

This model gives future stock values of two wheelers shown in Fig.4 to be around 420 million to 562 million (considering both conservative and aggressive growth scenarios). The projected future stock of cars shown in Fig.5 in 2050 for India is around 262 million to 432 million (considering both conservative and aggressive growth scenarios).

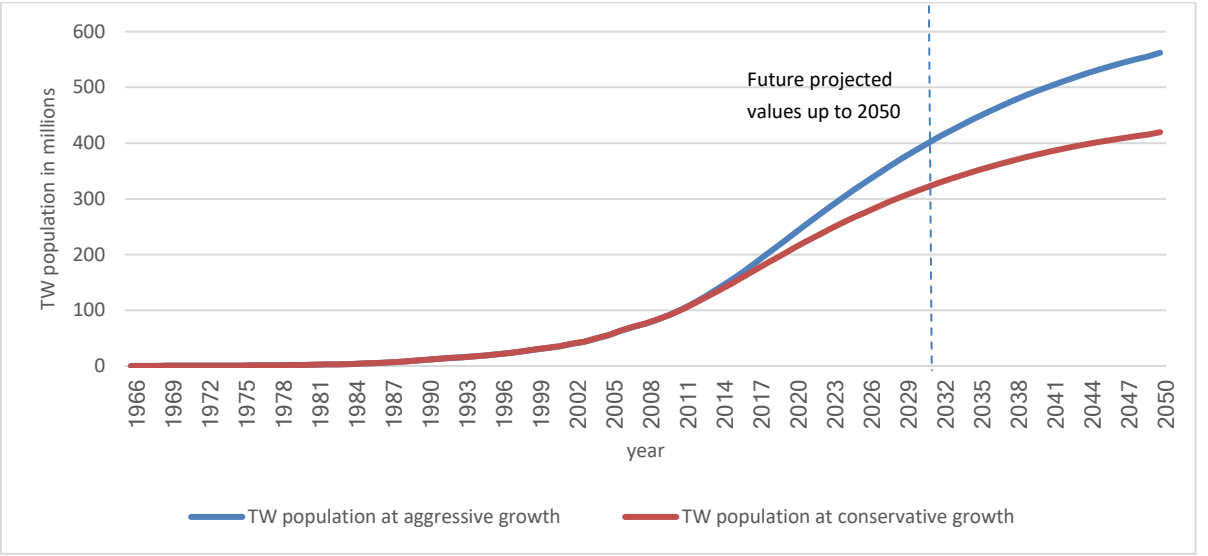

Fig. 4 Two-wheeler population projection up to 2050 for India

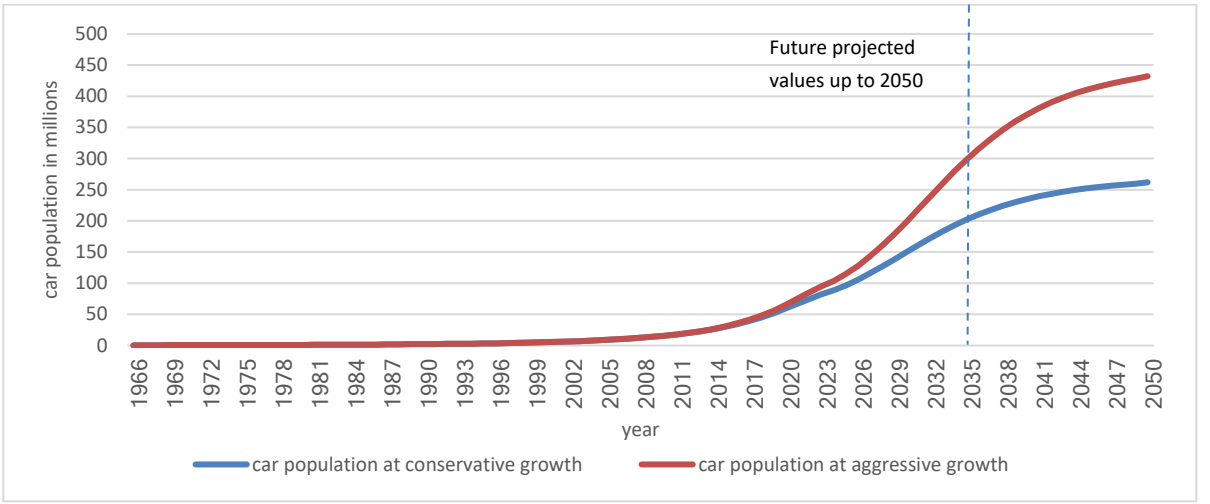

Fig. 5 Car population projection up to 2050 for India

In both the scenarios (conservative and aggressive growth scenarios) the private vehicle population will be very high in the future (2050). This is a BAU scenario where no measures are taken to control the situation. This will lead to an increase in pollution level and oil demand from the transport sector and will also worsen the traffic congestion on road. In order to improve this situation, necessary policies should be introduced or implemented now to benefit the environment and people in the future.

The results of the past studies showed that: Fulton and Eads (2004) projected car and two-wheeler population under low growth scenario until 2040 to be around 109 million and 107 million respectively. But the study did not examine the condition under high economic growth scenario for India. The study done by ADB (2006) projected Indian car population to be 80 million and two-wheeler population to be 236 million by 2035. Dargay et al (2007) included cars in highway vehicle category and projected their population to be 156 million by 2030. Arora et al (2011) also included cars in HWV category but reported them separately as well. The projected car population in their study was 144 million and two-wheeler population was 301 million under conservative growth scenario for 2040. Whereas, the projected car population in aggressive growth scenario was 215 million and two-wheeler population was 359 million for 2040. Our study projected vehicle stock projections up to 2050, which is shown in table 4 and 5. Here, projections were done for both conservative and aggressive growth scenarios. As per our study, by 2030 Indian car would be more than US car stock in 2007 which is 136 million (US EIA, 2006). Whereas, two-wheeler population in India by 2020 would exceed China's two-wheeler population. According to Arora et al (2011), on exceeding China's two-wheeler population, India will have the largest two-wheeler population in the world.

Table 4: Projections for conservative growth scenario

year	2015	2020	2030	2040	2050
Two-wheeler population (million)	147	210	313	380	420
Car population (million)	30	60	149	235	262

Table 5: Projections for aggressive growth scenario

year	2015	2020	2030	2040	2050
Two-wheeler population (million)	154	236	386	494	562
Car population (million)	31	65	198	371	432

The results of our study are on the higher side compared to the past studies. This can be due to difference in assumptions and data used in the study. The saturation levels used are also different in different studies. Uncertainty in the results can be due to lack of data accuracy. This study will be further used to estimate energy consumption and CO_2 emission from the private vehicles up to 2050 and the impact of suitable policies on its emission reduction.

7. Conclusions and policy recommendations

The study projects the private vehicles stock for the future year 2050 for India using two growth scenarios- conservative and aggressive. The results of the study imply that India follows the 'S' shaped curve and is currently in the initial stage of the Gompertz curve. Two-wheeler population increases by ~3 fold for conservative growth scenario and ~4 fold for aggressive growth scenario. The point of inflection is around the year 2030-2032. For cars, stock population increased tremendously by 9-fold in conservative growth scenario and by 14-fold in aggressive growth scenario. The inflection point for cars growth in India is around the year 2030-2035 (similar to two-wheeler).

The values of the parameters α, β and θ for the Gompertz curve in India (for private stock) are different compared to the ones given by study Dargay et al., 2007; and Wu et al., 2014). The reason could be relationship between the vehicle ownership and per capita GDP data of India (1966-2011) analysed for the study. As the future work, sensitivity analysis can be conducted for different values of input parameters (GDP growth rate, saturation level and other parameters of the model and population growth rate) for future stock analysis.

The analysis also implied that stock of private vehicles will be high in 2050 and further measures are needed to control the negative externalities caused by them. Below are the few policy recommendations to control automobile population and pollution According to the results of our analysis, India is in the initial stage of the Gompertz function today. With the booming automotive industry, vehicle population will continue to increase and this will negatively impact the environment and health of the people (Wu et al, 2014). Therefore, suitable policy recommendations are required to control the automobile population and pollution, which are:

- Private vehicles in India run on petrol and diesel. In 2009, Compressed Natural Gas (CNG) was introduced as fuel in three-wheelers and taxis. CNG has lower CO_2 emission factor compared to petrol and diesel, therefore, higher CNG share as fuel in cars will reduce emission in future.
- Vehicular emission can also be controlled by improving vehicle and fuel efficiency. Auto fuel policy in India has already regulated measures asking automobiles companies to ensure 20% reduction by 2017 and 40% reduction in 2020 (Chandola and Sen, 2008). The purpose of such a program is to improve the quality of fuel and apply strict emission standards on automobile industries.
- Electric vehicles are already introduced but they are yet to be the front-runner in the Indian market. Indian government provides incentives through programs like National Electric Mobility Mission Plan (NEMMP) and Faster Adoption and Manufacturing of Electric vehicles (FAME) for electric vehicle diffusion in the

Indian market. Since electric vehicles have zero on-road emissions they can be considered as an alternative to petrol and diesel vehicles.

- Increasing vehicle stock population can also be controlled by improving the condition of public transport in India. Providing better connectivity (from home to bus or metro station), carpooling and strict standards for private vehicle purchase and maintenance can boost the use of public transport in India.

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