INDIAN VEHICLE OWNERSHIP AND TRAVEL BEHAVIORS: A CASE STUDY OF BANGALORE, DELHI AND KOLKATA

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ABSTRACT

As the second most populous country in the world, the travel behaviors and vehicle fleet of India will have enormous consequences to the world's economy and environment. This study developed a survey for over 1000 Indians on topics of vehicle ownership and travel behavior in the key cities of Bangalore (India's "Silicon Valley"), Kolkata (India's third most-populous metro area, formerly known as Calcutta) and Delhi (India's capital city). The data were then used to model vehicle ownership and use decisions, and other trip-making choices in those three regions, versus other parts of India. It would also be very helpful to have some discussion of what this means about the relationship between projected vehicle ownership levels in these three cities, versus those in other Indian cities or in the country as a whole. Covariates of personal income, household size and residence location were all found to be statistically and practically significant in models of vehicle distances traveled. A multinomial logit model was used to predict vehicle types owned (including motorized two-wheel and four-wheel vehicles), and a Poisson model was used for vehicle ownership counts, income and other household assets were valuable predictors. An origin model for vehicle manufacture was also calibrated, to help deliver future-year projections; while the majority of vehicles owned by respondent households were manufactured domestically, in India, other Asian countries provided the second highest share.

Using these new models of behavior, alongside various forecasts of model covariates, predictions were produced for India's vehicle ownership through year 2030. The number of vehicles per capita in the regions surveyed is forecast to rise from just 0.238 in year 2015 to 0.718 in 2030. Moreover, if this data set's resulting model parameters remain appropriate over time, higher shares of vehicles will be imported from the EU/US, and the share of passenger cars will rise (as opposed to those of vans, trucks and SUVs). Finally, summary statistics of trip frequency and mode by purpose are provided.

BACKGROUND

Bansal and Kockelman's (2016) recent literature review of vehicle ownership in the Indian context found predictive models for the regions of Mumbai (formerly Bombay) (Kumar and Krishna Rao 2006, Shirgaokar et al. 2012), Chennai (formerly Madras) (Srinivasan et al. 2007, Gopisetty and Srinivasan 2013), Pune (Padmini and Dhingra 2010), and Surat (Banerjee et al. 2010). Surprisingly, there appears to be no individual- or household-level vehicle ownership models available/publicly accessible for key metropolitan areas like Delhi (India's capital city), Bangalore (India's "Silicon Valley"), and Kolkata (India's third most-populous metro area, formerly known as Calcutta). In such a diverse country, it is not reasonable to generalize the results of vehicle ownership models developed in other regions of India to these major cities.Bansal and Kockelman (2015) also sought many experts' opinions on Indians' travel and vehicle ownership behaviors. Purchase price was cited as the top factor in car ownership decisions by all experts. Additionally, four experts stated that, if an Indian household could afford a four-wheel vehicle, they would buy the four-wheeler, irrespective of a two-wheeler's (motorcycle's or moped's) price.

Among other recent studies, Dash et al. (2013) created a disaggregate model of vehicle ownership of India based on expenditure census data. Vehicle ownership was modeled using a multinomial logit (MNL) with the four choices of no vehicle, two-wheel vehicle only, four-wheel vehicle only or both two- and four-wheel vehicle. The study made no attempt to quantify when households have multiple vehicles. Expenditures, household size, children and age were found to be statistically significant in predicting these four categories/types of ownership, in a dataset of 89,503 households. Among similar studies, Srinivasen et al. (2007) and Gopisetty and Srinivasan (2013) estimated ownership of two-wheel and four-wheel vehicles in Chennai using ordered probit and three-stage least squares models, respectively. Please see Bansal and Kockelman (2016) for detailed literature review of vehicle ownership models.

Additionally, except Banerjee et al. (2010), none of the previous studies explored the Indians' preference for vehicle body type and very few provided insights about Indians' vehicle usage (vehicle-kilometers-traveled). While automobile industry contributes 22% of India's manufacturing GDP and also ranks sixth globally in sales, it is important to understand Indian's future vehicle adoption.

To this end, this study conducted a survey of 1,594 Indians (n=1,001 after data cleaning) across Delhi, Bangalore and Kolkata, and estimated: a) annual vehicle kilometers traveled (VKT) b) vehicle ownership of two-wheelers and four-wheelers, and c) vehicle body type preferences. Subsequently, we used these model parameters, GDP, and cell phone ownership data to forecast

Indians' future (e.g., year 2030) vehicle adoption (for each vehicle type and brand) in these cities.

DATA SET

In developing countries such as India, household data can be difficult to obtain. The Indian census does not provide cross tabulated data on households, making multivariable modeling impossible. Unavailability of household-level travel survey data creates difficulties in calibrating vehicle ownership and use models. Therefore, as a first step, the team designed and disseminated a survey in Delhi, Bangalore, and Kolkata during July and August 2015 using Qualtrics, a web-based survey tool. The Survey Sampling International (SSI, an internationally recognized and highly professional survey firm) continuous panel of respondents served as the sampling frame for this survey.

To explore respondents' preferences for vehicle types and their travel patterns, the survey asked 77 questions, divided into four sections. Respondents were asked about their household's current vehicle inventory (e.g., make, model, fuel type, and odometer reading), vehicle usage frequency (weekly and annually), vehicle-kilometers traveled (VKT) by each vehicle, household vehicles sold in the past 10 years (e.g., year of acquisition, year of sale, and model), future vehicle preferences (e.g., willingness to pay for next vehicle, desired fuel economy, body type, and preference for used vehicles), and inclination toward electric vehicles. Respondents were also asked about behavioral changes due to gasoline prices, their opinions on helmet laws (for users of two-wheelers), the importance of vehicle brand and operating costs during their purchase decisions, travel choices (e.g., number of trips by purpose, travel distances, transit use, and recent long-distance trips), and demographics (e.g., household size, household and personal income, and education level).

While 1,594 Indians completed the survey, those who responded too quickly or provided inconsistent responses were removed, leaving a total of 1,001 reasonably reliable respondents. Respondents who completed the survey in less than 13 minutes were assumed to have not read questions thoroughly, and their responses were discarded. Others considered ineligible for further analysis where those reporting themselves to be younger than 18 years, their households to have more workers or children than represented in the household size, those having a higher personal income than household income, those who reported having bought a car in the future (more than one year in advance), and other combinations of conflicting/inconsistent answers. Tables 1 and 2 provide these types of summary statistics.

TABLE 1 Summary Statistics of Most Model Covariates (n = 1,001)

Variable	Mean	Standard Deviation	Min	Max
Household Income (Rupees)	1,005,000	797,000	5000	2500000
Respondent Income (Rupees)	597,000	708,000	5000	2,500,000
Household Size (#Persons)	4.137	1.487	1	12
Married Couples in Household (#)	1.115	0.607	0	4
Workers in Household	1.587	1.068	0	7
Children in Household	0.838	0.842	0	7

Age of Respondent (years)	35.87	11.82	21.5	70
Cell Phones in Household (#)	3.499	1.572	1	7+
Refrigerators in Household	1.138	0.475	0	4
LPG Stoves in Household	1.418	0.703	0	6
Air Conditioners in Household	1.181	1.202	0	7+
Televisions in Household	1.586	0.781	0	7+
Computers in Household	1.752	0.919	0	7+
Bicycles in Household	0.729	0.775	0	7+
Internet Connections in Household	1.938	1.289	0	7+
Credit Cards in Household	1.647	1.546	0	7+
Number of Four-Wheel Vehicles owned or leased Household	0.997	0.852	0	5+
Out of 10 Closest Relatives that own Four-Wheel Vehicles	2.395	1.678	0	5+
Out of 10 Closest Friends that Own Four-Wheel Vehicles	2.368	1.757	0	5+
Out of 10 Neighbors that own Four-Wheel Vehicles	2.358	1.747	0	5+

TABLE 2 Summary Statistics for Indicator Variables (n = 1,001)

Variable of Interest	% Respondents
Gender	
Male	64%
Female	36%
Home Ownership	
Own Home	75%
Do Not Own Home	25%
Education	
No College	7%
Bachelor's Degree	53%
Master's Degree or Higher	40%
Occupation	
Unemployed	20%
Employed	80%
Residence Region	
Bangalore	41%
Delhi	32%
Kolkata	25%
Other	2%

Table 1 and 2's summary statistics suggest a strong sampling bias in the data towards India's more educated and wealthier citizens, which may be due to the regions sampled and the fact that

the respondents needed Internet access to receive word of and then complete the survey. Of the 1001 final respondents, 931 held a bachelor's degree or higher, while the Indian census (2011) states that only 79.9% of the population was literate in 2011. Additionally, just three percent of respondents indicated that they have no LPG stoves in their home, while the Indian census (2011) states that 20% of urban households still cook using wood. While these three regions are special (highly urban, relatively developed and economically vital for the nation) and these respondents are just 1 representative of larger households (that will include many more women, older people, and many less educated members), it seems likely that lower-income and/or less-educated households are under-represented in the survey. Such sampling biases may be largely due to the survey being delivered online and in English, via a panel that SSI is probably still building for this developing country, where most households are not regularly connected to the Internet. Since India does not provide publicly-available or open-source Census data on income versus household size, education, age, gender and/or other cross-classifications, and even marginal (single-variable) distributions of basic demographics remain very difficult to obtain, no reliable bias correction was feasible in the following analysis.

RESULTS

As noted earlier, 77 questions were asked of respondents, covering various vehicle ownership and travel behaviors. The results were analyzed by topic, to identify meaningful conclusions, and ultimately deliver forecasts for future-year vehicle ownership levels. First, annual vehicle travel distances were analyzed using ordinary least squares (OLS) linear regression. Then, household-level vehicle ownership choices were analyzed using an MNL model for vehicle types owned and a Poisson count model for the number of four-wheeled vehicles owned (or leased), Vehicle body types and then origin/region of manufacturers were also modeled using MNL specifications.

Using the count model results, the vehicle type MNL results, the vehicle brand region MNL, and outside forecasts, a forecast was developed to anticipate rate of motorization for the sampled households, which are presumed to reflect the rates of change in vehicle ownership for larger region or entire country. Finally, summary statistics of trip generation were created to offer readers insights on Indians' typical trip-making and mode choice behavior.

Four-Wheel Vehicle Travel Distances

Congestion levels, air quality, crash counts, economic activity, and vehicle scrappage/retirement depends a great deal on vehicle usage levels or travel distances. For this reason, several survey questions tackled use frequency and distance, per trip, per week, or per year. Table 1 shows several summary statics based upon the questions "How many days (per week, on average) do you use this vehicle?" and "How many kilometers per year is this vehicle probably driven?" Statistics are based upon only on respondents who were not residing in the "other" regions.

TABLE 3 Vehicle Usage Frequencies and Intensities

	Usage Frequency (Days) Per Year (by respondent)				Vehicle-Kilometers Driven Per Year (by household)			
	Total	**Bangalore**	**Delhi**	**Kolkata**	**Total**	**Bangalore**	**Delhi**	**Kolkata**
Average	226	212	235	229	8817	8634	9594	7230

Std. Dev.	96	97	95	89	6278	5979	6251	6181
Maximum	350	350	350	350	22,500	22,500	22,500	22,500
Minimum	0	10	10	10	250	250	250	250
$\mathbf{N_{obs}}$	949	345	323	196	949	345	323	196

Vehicle usage frequency was largely the same with the different locations. However, the vehicle kilometers driven per a year was slightly more in Delhi. This appears reasonable, since Delhi is a much larger region of 2163 square kilometers, than Kolkata which has a physical size of just 465 square kilometers (Demographia, 2016); presumably, many Delhi travelers' work destinations are more distant than those in Kolkata leading to more vehicle distance travel (Gonzalez, 2007).

Ordinary least squares (OLS) regression was used to appreciate which demographic and related factors are most useful in predicting the households' four-wheel vehicles' annual VKT estimate, with result shown in Table 2. Only 880 observations were usable for this regression due to respondents who did not fill all information necessary. Parameters run in the regression were selected based on both their effectiveness in predicting travel behavior as well as their accuracy when reported by the respondent.

The daily vehicle miles traveled per a day by a vehicle in the US was 58.05 (NHTS 2009) converting to 31,942 kilometers per year. This is significantly more than the value observed in the survey. It appears that the vehicle usage in the surveyed areas of India is significantly less than that in the US. This could be largely due to the US not being completely urban, while the surveyed area is.

TABLE 4 Vehicle Travel OLS Regression Results

Covariates	Coefficient Estimate	Standardized Coefficient	t-Stat	p-value
Intercept	6720	n/a	4.81	0.000
Age (of respondent)	49.15	0.092	2.64	0.008
Personal Income (Rupees)	0.001145	0.139	4.04	0.000
Household Size	166.3	0.065	2.05	0.041
Employed	941.4	0.056	1.70	0.089
Reside in Delhi	670.4	0.037	1.43	0.154
Reside in Kolkata	-1838	-0.058	-3.32	0.001
Respondent Holds Master's Degree or Higher	-1677	-0.133	-1.43	0.154
Respondent Holds Bachelor's Degree	-2360	-0.189	-2.06	0.040
$\mathbf{N}_{observations} = 880$		$R^2 = 0.064$	$R^2_{adj} = 0.056$	

As reflected by these parameter values, respondent's income and education provide the strongest predictive power in estimating annual VKT of their households' four-wheelers. In other words,

due to their relatively large standardized coefficient values (which measure the number of standard deviation shifts in VKT that a 1-standard-deviation shift in each covariate is predicted to produce), a respondents personal income and education are the most practically significant variables found in the dataset. Rising Indian income and education levels may be essential to anticipate, when predicting India's future vehicle ownership levels and associated travel patterns. As expected, those with higher income tend to reside in households with higher travel distances on their vehicles (due to greater affordability of gasoline, and possibly more recreational travel). Household income was also statistically significant when personal income was removed. Interestingly, those with graduate education appear to reside in households that use any four-wheelers they own less intensively (after controlling for age, income, and city/region). Perhaps they tend to live closer to their destinations, or they (and others in their household) are working much of the day and have less time available to travel than others, everything else constant (including income). Higher incomes are regularly associated with greater education, so there is an offset in these variables. One respondent cannot reflect the attributes of all those residing in his/her household, with access to all reported vehicles.

Age and household size are next in order of practical importance. Older respondents living in households with more persons are associated with higher-VKT vehicles. Location of residence (Kolkata and Delhi, versus Bangalore and other locations) is also important, with those residing in Kolkata reporting much lower annual VKT for their households' four-wheelers than those residing in Delhi. This appears reasonable, since Delhi is a much larger region (of 1484 square kilometers), with nearly eight times the population of Kolkata (just 184 square kilometers); presumably, many Delhi travelers' destinations are more distant than those that attracted trip-making in Kolkata.

Vehicle Ownership Decisions

In addition to 4-wheel vehicle distances traveled, the size of India's personal fleet will have major repercussions for Indians' mobility, economy, and infrastructure. Here, vehicle ownership is modeled using two different techniques: a categorical model of vehicle types owned, and a count model for the number of four-wheelers owned.

Vehicle Type

Two-wheelers remain very popular in India, due to their lower ownership and use costs, maneuverability in India's congested city-traffic conditions, and ease of parking in congested downtowns. In order to evaluate and anticipate ownership of two-wheeler versus four-wheeler vehicles, an MNL model specification was used, as recommended by Bhat and Pulug (1998).

Dash et al. (2013) modeled household vehicle ownership in all of India as an MNL with the following four alternatives:

1. No motor vehicles owned by household
2. Only two-wheeler(s) owned by household
3. Only four-wheeler(s) owned by household
4. Both two- and four- wheelers owned by household

The survey asked: "What kind of motorized vehicles does your household currently own or lease?" with options mirrored in Dash et al (2013) survey, and with results summarized in Table 5.

TABLE 5 Current Vehicle Inventory of Households (% of Respondents)

	Total	Bangalore	Delhi	Kolkata
No vehicles owned	9.30%	10.95%	6.90%	20.65%
2-wheelers only	16.6%	17.76%	9.09%	16.19%
4-wheelers only	20.50%	21.17%	22.88%	29.96%
2-wheelers and 4-wheelers	53.60%	50.12%	61.13%	32.20%
$\mathbf{N_{obs}}$	1001	411	319	247

The majority of respondents stated that their household own (or lease) a four-wheel vehicle, yet the Indian census (2011) states that for urban environments only 9.75% of households own a four-wheel vehicle. This bias may be due to the relatively educated nature of survey respondents.

Dash et al. (2013) also examined the question of vehicle type and found the following covariates to be statistically significant and have a positive effect on vehicle ownership over all of India: household size, wealth/expenditures, number of children, and number of elderly household members. Similarly, an MNL model was used here, to predict ownership of different vehicle types, as shown in table 6, with similar results. To create the model, the data was regressed using all household parameters using VGAM library in R. Parameters including household size and assets with high p-values (over .2) for all alternatives were removed and the model was regressed. This procedure was repeated to arrive at Table 6's model results.

TABLE 6 Vehicle Types Owned (MNL Specification, with No Motorized Vehicles Owned is Base Alternative)

Variable	Option	Estimate	Z-statistic	p-value
Alt. Specific Constants (Intercepts)	2 & 4 Wheeler	-0.0275	-0.08	0.933
	2 Wheeler	0.278	0.81	0.420
	4 Wheeler	-1.22	-3.42	0.001
Household Income	2 & 4 Wheeler	2.08E-06	6.33	0.000
	2 Wheeler	1.21E-06	3.53	0.000
	4 Wheeler	2.14E-06	6.41	0.000
Children in Household	2 & 4 Wheeler	0.533	2.88	0.004
	2 Wheeler	0.419	2.11	0.035
	4 Wheeler	0.311	1.58	0.114
Married Couples in Household	2 & 4 Wheeler	0.757	3.14	0.002
	2 Wheeler	0.359	1.36	0.175
	4 Wheeler	0.695	2.81	0.005
Reside in Delhi	2 & 4 Wheeler	-0.317	-0.95	0.345
	2 Wheeler	-1.12	-2.99	0.003
	4 Wheeler	0.0502	0.14	0.890

Reside in Kolkata	2 & 4 Wheeler	-1.96	-6.48	0.000
	2 Wheeler	-1.80	-5.55	0.000
	4 Wheeler	-0.663	-2.07	0.039

As expected, household income is predicted to have a positive impact on all three types of motorized-vehicle ownership. Wealthier households can afford more vehicles, and may have more jobs and activities to attend to outside the home. The number of children and married couples in a household also increase all three likelihoods of owning motorized-vehicles. This can be reasoned that with more members in a household, there is more travel demand and thus more of a requirement for a vehicle. Interestingly, the likelihood of having at least one two-wheel vehicle rose with the number of children, at approximately the same rate as four-wheel vehicle ownership. This may be due to the presence of teenage children wanting or needing to travel on such vehicles as in Dash et al. (2013).

Those residing in Delhi or Kolkata were also found to have practically and statistically different motorized-vehicle ownership, everything else constant (relative to Bangalore and elsewhere in India). Living in Kolkata significantly reduces the probability of a household owning a vehicle. Perhaps this is due to Kolkata having the smallest population of the set of cities sampled. Living in Delhi reduced a household's probability of owning a two-wheel vehicle.

In summary, the results largely mirrored those found by Dash et al. (2013). However, the number of vehicles a household may own is ignored by this categorical model structure. This is not very useful for forecasting the size of India's vehicle fleet and thus a count model was created.

Number of Four-Wheel Vehicles Owned

The above model specification was useful for predicting what types of vehicles are likely to exist in any household's fleet, but it lacks the quantity of vehicles. A negative binomial model was first estimated here, using the survey data; however, there was no evidence of overdispersion, so a Poisson model was ultimately selected. Regression was performed using R's GLM library, and a stepwise algorithm added and subtracted variables to arrive at the best model fit, using the Akiake Information Criteria (AIC). Additionally, variables were removed if they were not found to be practically significant by hand, resulting in Table 7's specification and parameter estimates.

TABLE 7 Poisson Model for Count of Four-Wheel Vehicles Owned

Variable	Estimate	Z-statistic	p-value
Intercept	-0.870	-8.25	0.000
Household Income (rupees)	2.02E-07	4.90	0.000
Cellphones in Household	0.0375	1.76	0.078
Married Couples in Household	0.149	2.79	0.005
Credit Cards in Household	0.111	5.55	0.000
Owns Home	0.159	1.93	0.054

AIC: 2343.2; McFadden's R^2: 0.0568; $N_{obs} = 1001$

Surprisingly, region of residence was not found to be statistically significant in this count model for four-wheel vehicle ownership, even when it was the sole predictor variable. Evidently, region may be much more relevant for simply needing to own a car or other 4-wheeler (as evident in Tables 5 and 6), but not so relevant for the total number of cars owned.

Also surprising was that variables of household size and number of children were not found to be statistically significant, after controlling for household income. This could be due to the fact that the number of cell phones and credit cards available to a household better represent the number of members with independent travel needs better than the total number of members in the household, since, for example, children are unable to drive. Indeed, when household income, cellphones, and credit cards are removed from the model, the number of children and household size become statistically and practically significant predictors.

Vehicle Body Type

Respondents were also asked to identify the makes and models of their households' vehicles. 295 unique models were listed, and these were classified by hand into three body-type categories: Cars, Trucks or SUVs, and Vans.

TABLE 8 Vehicle Body Types (n = 873)

Type	Number	India Survey Percentage	US Values from (NHTS 2009)
Car	538	62%	50%
Truck or SUV	83	10%	37%
Van	252	29%	8%
Total	*873*	*100%*	*95%*

As shown in Table 8, 62 percent of four-wheel vehicles owned by respondents' household are cars. Trucks and SUVs made up a small share, far fewer than found in US households (10% vs. 37% in the U.S. (NHTS 2009), while vans made up a much larger share (29% vs. 8% [NHTS 2009]). The US fleet is not as urbanized and US regions not as dense as those studied here, which may be one key reason for such discrepancies. Trucks and SUVs (and vans) also typically cost more than passenger cars, which may be another reason, arising from wealth differences between India and the US.

An MNL model was used to appreciate what factors are most important in predicting vehicle body type owned in India, with results shown in Table 9.

TABLE 9 Vehicle Body Type Model Results (MNL Specification with Passenger Car as Base Body Type)

Variable	Option	Estimate	Z-statistic	p-value
Alt. Specific Constant	Trucks & SUVs	-2.396	-4.3	0.000
	Vans	-0.651	-1.6	0.116
Household Size	Trucks & SUVs	0.153	0.6	0.562
	Vans	-0.144	-2.5	0.014
Employed	Trucks & SUVs	-0.166	-0.4	0.720
	Vans	-0.484	-3.3	0.001

Household Income	Trucks & SUVs	5.26E-08	0.4	0.722
	Vans	-3.77E-07	-2.4	0.016
Bangalore	Trucks & SUVs	0.145	0.5	0.642
	Vans	0.813	2.0	0.047
Delhi	Trucks & SUVs	-0.194	-1.1	0.277
	Vans	0.674	2.1	0.033
Kolkata	Trucks & SUVs	-0.525	-2.1	0.033
	Vans	0.753	0.3	0.782

Of interest here is the fact that larger households appear to be less likely to own a van, which is unexpected, but trucks or SUVs and vans do appear to be preferred or more likely in Bangalore (and other locations, outside of Delhi and Kolkata) households. Additionally, home ownership was not found to be statistically significant, even when used as the sole predictor variable.

Region of Vehicle Origin

A vehicle's manufacture origin is also of interest, for industry competitors and regional economies, since vehicle production is a major industry. Makes of vehicles were grouped together into those of Indian origin, other Asian producers, and European or United States (EU/US) manufacturers. An MNL model specification was used here, for this 4-alternative setup, to reveal which factors may be most significant in predicting region of manufacturer headquarters for 4-wheel vehicles owned by the surveyed households. Table 10 shows the exact grouping of brands along with the number of observations in the vehicle data set.

TABLE 10 Manufacturers of 4-Wheel Vehicles Owned

Region	Vehicle Make	Observations	Percentage
Asia	Datsun	3	0.3%
Asia	Honda	81	9.3%
Asia	Hyundai	189	21.6%
Asia	Mitsubishi	4	0.5%
Asia	Nissan	9	1.0%
Asia	Toyota	40	4.6%
Asia	***Total***	***326***	***37.3%***
EU/US	Audi	35	4.0%
EU/US	BMW	1	0.1%
EU/US	Chevrolet	36	4.1%
EU/US	Fiat	15	1.7%
EU/US	Ford	49	5.6%
EU/US	Renault	8	0.9%
EU/US	Skoda	5	0.6%
EU/US	Volkswagen	14	1.6%
EU/US	***Total***	***167***	***19.1%***
India	Force	1	0.1%
India	Hindustan Motors	3	0.3%

India	Mahindra	25	2.9%
India	Maruti	309	35.4%
India	Tata	46	5.3%
India	***Total***	***380***	***43.5%***

The most popular region of manufacturer is the domestic market, or Indian brands, with Maruti/Suzuki being the largest single manufacturer - by more than a 10-percent margin over the next biggest seller of 4-wheelers (Hyundai, from South Korea). The other Indian manufacturers do not provide large shares of 4-wheelers in the data set, but this could be due to the sample bias towards wealthier, urban, and more educated Indian households.

An MNL regression was performed to observe what variables were significant in predicting a vehicle's manufacturer region. Household size was not a statistically significant predictor in this model, even when regressed alone. Vehicle body type was a valuable predictor here, with vans and trucks were often produced by domestic manufacturers. Additionally, those residing in Kolkata and those of lower household income appear more likely to select Indian makes of 4-wheel vehicles, while the variable of home ownership increased the likelihood of owning a vehicle produced by a foreign manufacturer (though very possibly produced within the nation of India). It seems that the highest income households are most likely to select vehicles designed by EU/US manufacturers, and other Asian producers may cater best to middle-income categories.

FORECASTING FUTURE YEAR VEHICLE OWNERSHIP LEVELS

A forecast was generated for the number and type of vehicles that India will have in the future. A static model was decided upon due to the small dataset available (N~1000) and the possibility of biased data towards the more educated and wealthier Indians. Two input forecasts were found, a GDP per capita forecast from the International Monetary Bank and a forecast of cell phone ownership in India from eMarketers (2014) that was extrapolated to the levels seen in the US (91% from Pew Research 2013). While cell phones are likely not a direct causation of a desire to buy a car, they could be interpreted as a proxy of independent travel needs. With a cell phone comes outside connections and responsibilities outside of the immediate area and thus a need for transportation. Additionally, the number of cell phones is highly correlated with the size of the household, the more commonly used figure.

The framework consisted of using the sampled households' demographics and other attributes for key model inputs, to predict whether the household owned any four wheelers (i.e., any passenger cars, light-duty trucks, SUVs, or vans). Then, the expected number of vehicles owned by each household was estimated using the vehicle count model. These vehicles were then classified by type and manufacturers' headquarters region.

Expected values for all responses were tabulated. For example, for Household #3, with its given wealth and number of cellphones, is estimated to have 2.3 vehicles. These vehicles are predicted to have an 80% chance of being a car, 15% chance of being a van and a 5% chance of being a truck or SUV. For each permutation of vehicle body type and manufacturer location, the probabilities are assessed using the MNL model results. This was done for every respondent's household.

The sampled households were adjusted for income and cell phone ownership changes over time, based on predictions by the United Nations (2015) and Wilson (2003), resulting in Table 11's forecasts.

TABLE 11 Vehicle Ownership Forecasts for Indians in Regions of Study Over Time

Year	2015	2020	2025	2030
GDP per Capita across India (Dollars)	$1,149	$1,622	$2,331	$3,473
India's Population	1.311 Billion	1.389 Billion	1.462 Billion	1.528 Billion
Cellphone Ownership	51%	65%	75%	85%
#Four-Wheel Vehicles per Capita (in regions of study)	0.238	0.303	0.419	0.718
% Cars	59%	62%	66%	72%
% Trucks & SUVs	9%	10%	12%	14%
% Vans	32%	28%	22%	14%
% Indian Manufacturer	51%	50%	46%	36%
% Asian Imports	28%	27%	24%	18%
% EU/US Manufacturer	21%	23%	30%	46%

Note: GDP per Capita forecasts come from Wilson (2003), and Population forecasts come from United Nations (2015).

The number of four-wheel motorized vehicles per person for the three regions of study (plus those responding from other regions, who may have previously resided in those regions) is higher than that which can be imputed from vehicle registration data. According to the Indian government, in 2012 there were 2.17 million vehicles registered in Delhi (data.gov.in 2016) and 17 million people according to India's 2011 census (Government of India 2011). This implies 0.13 vehicles per person in Delhi as opposed to the found 0.238 rate found for the surveyed region. This discrepancy is presumably due to the relatively high income and educational status of survey respondents.

Regardless of the starting levels of vehicle ownership, the simulation suggests that the vehicles-per-person statistic will grow by 27% between 2015 and 2020, and another 137% by 2035 - or 202% total over the 20-year period, which is an average growth rate of 5.7 percent per year in vehicles owned per capita – at least in the regions of sampled data. Such strong growth rates suggest an active and presumably profitable market for manufacturers, along with added roadway congestion, emissions, and crash injuries. These downsides may directly stifle ownership, via network gridlock, and/or policymaking, designed to curb vehicle ownership and use. Finally, it is worth nothing that passenger cars are expected to make up a larger percentage of those vehicle body types, over time, and the share of vehicles designed and sold by foreign

EU/US manufacturers is expected to grow to a healthy share of 46% in 2030. Such forecasts may be of interest to Indian policymakers and manufacturers throughout the world.

TRIP GENERATION RATES AND MODE CHOICE

The survey also asked questions about individuals' trip making rates, or "trip generation". This included how many round trips they believe they made over the past 7 days for each of various purposes (activity types). Responses were limited by options in a drop-down menu on the online survey page, with answer options as follows: 0 trips, 1-2 trips, 3-4 trips, 5-6 trips, 7-8 trips, or more than 9 trips (of that purpose over the past week). By treating the "1-2 trips" response as 1.5, 3-4 as 3.5, 5-6 as 5.5, 7-8 as 7.5, and 9 or more as 9.5, the responses could be numerically averaged to arrive at Table 13's values (second column). Respondents were also asked what travel mode they used for that trip type in the last seven days, with mode shares shown across remaining columns in Table 12.

TABLE 12 Weekly Trip Counts and Mode Choices by Activity Type (n = 1,001)

Purpose	Avg. # Trips per Week	Drive Alone, 2-wheeler	Drive Alone, 4-wheeler	Drive/ride with Others	Walk	Bicycle	Public Transport	Employer's Bus or Taxi	Private Taxi or Rickshaw
Work	4.376	29%	37%	8%	4%	2%	8%	7%	3%
School	2.776	21%	36%	27%	4%	1%	5%	0%	6%
Personal	2.580	28%	22%	13%	5%	7%	18%	3%	4%
Social	2.422	23%	40%	12%	3%	2%	7%	5%	7%
Other	2.092	21%	36%	27%	4%	1%	5%	0%	6%
Shop	2.661	29%	28%	16%	5%	2%	8%	1%	10%

Overall, respondents generated an average of 2.42 round-trips each day, on average (or 16.9 round-trips per a week) for various purposes. According to the US National Household Travel Survey (NHTS 2009), the average American reported 3.79 trips per day in 2009, though this is one way trips and not just limited to survey respondents who are educated. These respondents are younger and more educated, and perhaps working hard at full-time jobs much of the day, than the average American (which includes children and retirees). This is underscored by the fact that 25.9% of respondents' trips or out-of-home activities are for work, while just 15.6% of person-trips are for work in the 2009 NHTS. The online survey format used here also enables more forgetting of trips made, and non-counting of short trips is a common issue in most travel surveys.

CONCLUSIONS

Motivated by the need to understand vehicle ownership and travel behaviors of the world's second most populated country, this research surveyed 1,001 Indians living primarily in the Bangalore, Delhi and Kolkata regions. MNL models of vehicle types (2 vs. 4 wheelers) and 4-wheeler body types (car vs. truck or SUV vs. van) and manufacturer region of origin, along with a Poisson model of four-wheelers owned, allowed for future-year forecasts (through 2030) of ownership decisions, at least for the sampled households. Results suggest that the likelihood of four-wheel vehicle ownership rises with incomes and household size, as well as residence in

Delhi or Bangalore. But region of residence was not found significant when predicting four-wheel vehicle count. Vehicle distance traveled models found that vehicles were being driven significantly less in the surveyed areas than the average US.

Pivoting off of GDP-per-capita and cellphone ownership forecasts, a sequence of these models predicts a 202-percent increase in vehicle counts per capita by year 2035. Foreign-brand cars are expected to become a larger part of the fleet over time, through these forecast models' predictions. Of course, the emergence of shared self-driving or autonomous vehicles (SAVs [Fagnant and Kockelman 2014, Fagnant et al. 2015]) could drive actual vehicle-per-capita values down, and affect manufacturer choices dramatically, while still bringing vehicle access to even greater numbers of Indians.

Finally, trip generation rates, travel distances, and mode choices was provided in the survey data, with the sampled Indians having activity-participation rates below those of Americans, traveling less distance, and relying significantly more on transit and active (walk + bicycle) modes than Americans – though driving or being in a private motorized vehicle was still the most common mode choice. The world wonders how Indians' travel choices will evolve over time, along with vehicle ownership rates, congestion, air quality, crash counts, and other key statistics. Such outcomes are key for this major world country, global climate change, human health, and other metrics of serious interest. This survey and its results seek to shed light on these important issues.

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