Identification of Priority Attributes Influencing the Choice of Plug-in Hybrid Electric Vehicle in Indian Megacities

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Abstract: The present study aims to identify the priority attributes influencing the choice of Plug-in Hybrid Electric Vehicle in urban India. 1000 responses were collected from car owners in two megacities, namely Delhi and Kolkata using Computer Assisted Personal Interview (CAPI). The data were analyzed using RIDIT analysis, a Multiple Attribute Decision Making (MADM) approach to identify the priority attributes influencing consumers’ choice of PHEV. Results indicate that in addition to the attributes specific to PHEV technology such as battery warranty, electric range and charging infrastructure, attributes for general vehicle use such as safety, security, seating comfort, and air conditioning were also considered equally important by car owners in two cities. Although the results are case specific, it is expected to be of interest to PHEV manufacturers and the larger community of researchers and policymakers, working on electric mobility as an instrument to reduce vehicular emission in urban areas.

Keywords: Plug-in Hybrid Electric Vehicle, heterogeneity, RIDIT analysis, priority attributes

1. INTRODUCTION

Climate change has emerged as a global issue posing considerable stress on human health and environment (Musti and Kockelman, 2011). It is well proven in the scientific literature that the anthropogenic activities have been the primary source of global warming since mid-20th century (Cook et al., 2013). Global warming occurs due to increase in greenhouse gas (GHG) emissions, primarily due to the release of carbon dioxide (CO2) (Allen et al., 2009). CO2 is mainly produced by burning of fossil fuel, which is responsible for 60% of the global anthropogenic GHG emission (Achtnicht, 2012). Moreover, due to this higher dependency on fossil fuels, transportation sector is one of the major sources of CO2 emission. The transportation sector is solely responsible for 23% of global CO2 emission, where road transport is the primary contributor (IEA, 2017).

In the past trends, the developed countries were the major emitters of CO2. However, more recently, the share of emission from developing countries such as India has surpassed those of developed countries, which is evident from the list of top ten emitters, where India ranks third (IEA, 2017). Rapid urbanization, increase in disposable income, improved standard of living, and easy availability of car finance options have led to exponential growth of passenger car ownership in urban India (Shende, 2014). The total count of registered passenger cars in India has increased from 8.6 million in 2003 to 28.6 million in 2015 (MoRTH, 2016). However, the increase in car ownership is mainly concentrated in the Indian
megacities such as Delhi, Kolkata, Mumbai, etc. (Singh, 2005). On the other side, the availability of urban space for road transport in Indian cities is very limited (Maitra et al., 2014). As a result, such unprecedented vehicular growth is generating an imbalance in demand and supply, which is further aggravating negative externalities such as traffic congestion, delay and vehicular emission (Cheranchery and Maitra, 2017). Urban air pollution has emerged as a major concern in the country where vehicular emission accounts for more than 60% of greenhouse gas (GHG) emission (Ramachandra, 2009). In India, emission from road transport accounts to 93% of the total emission from the transportation sector (IEA, 2017). Therefore, the prevailing dependency on fossil fuel-based transport is highly unsustainable, and there is a need to shift towards cleaner and low carbon emitting alternative. An important step to initiate such a shift is the introduction of Plug-in Hybrid Electric Vehicle.

Plug-in Hybrid Electric Vehicle (PHEV) shows a strong potential to reduce GHG emission, increase fuel economy, and provide driving range comparable to that of a conventional vehicle (CV) (Smith, 2010). The major factor, which encourages the use of PHEV as compared to Battery Electric Vehicle (BEV) and Hybrid Electric Vehicle (HEV) is its readily available fuel for long distance travel, reducing range anxiety among consumers, and an external charging facility to recharge the battery (Simpson, 2006). Chevrolet Volt and Toyota Prius Plug-in Hybrid are the two well-known examples of PHEV currently in the market. For every one kilometer of travel, PHEV can reduce GHG emission by 32 percent as compared to CV (Samaras and Meisterling, 2008). Comparative environmental assessment of different vehicle technologies such as Compressed Natural Gas (CNG), Liquid Petroleum Gas (LPG), PHEV, BEV and conventional fossil-fuel vehicles using Life Cycle Assessment (LCA) reveal that BEV and PHEV have the lowest carbon emission as compared to other vehicle technologies (Mierlo et al., 2017). However, reduction in emission depends largely on the current sources of electric power generation, ability of smart grid technology to increase the efficiency of electric transmission and reduce peak demands (Mwasilu et al., 2014), and shift in power generation sources from coal to renewable energy sources such as photovoltaic solar, biomass, wind, etc. (Hoen and Koetse, 2014; Bicer and Dincer, 2018). PHEV also reduces petroleum consumption by 40 to 60 percent as compared to CV, offering fuel savings to the consumers (Elgowainy et al., 2009). Hence, looking into the benefits to the consumers and environment, the introduction of PHEV holds great promises to decarbonize urban transport and gradually shift towards sustainable urban transportation (Axsen and Kurani, 2009). However, the benefits may be realized only if the consumers are willing to purchase the new technology (Krupa et al., 2014).

Past literature suggests that limitations in battery technology and high battery cost are the two major barriers to widespread adoption of electric vehicles (EVs) (Simpson, 2006). As a result, extensive research is initiated in this direction to alleviate the limitations placed on the performance due to bulk, weight and storage capacity of the batteries (Sovacool and Hirsh, 2009). However, it may be noted that it is not only important to overcome the problems related to battery technology but also to identify consumer expectations from such technology to ensure significant market penetration (Egbue and Long, 2012). Efforts laid by the engineers, researchers, and policymakers towards technological interventions in EVs may fail if consumers do not accept the new technology (Sovacool, 2009). Hence, along with the ‘technical concerns,’ it is equally important to keep ‘social concerns’ in the mind before bringing such vehicles in the real market to ensure its commercial success (Ozaki and Sevastyanova, 2011). Extensive research has already been initiated in this direction to understand the perception of consumers towards EVs. Greene (2001) found that consumers are more sensitive to price while choosing EVs than when choosing CVs, reflected by higher price elasticity between EVs and CVs than between two CVs. Price preference for EVs also
depends on the socioeconomic characteristics of the population. People with low income are more sensitive to the purchase price of EVs as compare to high-income groups (Potoglou and Kanaroglou, 2007; Achtenh, 2012; Hackbahr and Madlener, 2013). However, Jensen et al. (2013) found no effect of income on preference for EVs. Driving range has a positive and highly significant impact on the purchase of EVs (Ewing and Sarigollu, 2000; Dagsvik et al., 2002; Hirdue et al., 2011; Lebeau et al., 2012; Hackbarth and Madlener, 2013; Jensen et al., 2013). However, for consumers with lower annual vehicle miles of travel, driving range is found to be less important (Hoen and Koetse, 2014). Charging time of the battery has a negative and substantial influence on the choice of EVs (Hirdue et al., 2011; Lebeau et al., 2012; Hackbarth and Madlener, 2013). On the contrary, Axsen and Kurani (2009) found that due to availability of home-based charging facility, decrease in charging time was the least chosen upgrade by the U.S respondents. Environmental concern is a powerful predictor of willingness to purchase EVs (Egbue and Long, 2012). Ewing and Sarigollu (2000) found that ‘Actively Concerned’ respondents are more likely to purchase clean-fuel vehicles as compared to ‘Unconcerned’ respondents. Purchase of EVs is also driven by the motive to present an image of higher environmental concern. Turrentine and Kurani (2007) found that setting an example of higher environmental values was the key reason for several U.S households who already purchased HEVs. Consumers also value acceleration characteristics of EVs. Male respondents are found to prefer faster acceleration in contrast to female who prefer slower acceleration (Potoglou and Kanaroglou, 2007). Respondents with household type-single prefer shorter acceleration more as compared to multiple household residents. It may be noted that literature and their findings discussed, majorly presents the investigation carried out in the developed countries. Practically, no investigation has been done, especially in developing countries such as India to primarily identify the importance of attributes related to EVs from consumers’ perspective. Identification of attributes of higher priority to the consumers’ may guide the manufacturers and policymakers to bring EVs as per the requirements of the consumers. Furthermore, it may be mentioned that as an EV is like any other conventional car, with just a difference in propulsion technology, it is also important to identify attributes for general vehicle use which influence consumer decisions while choosing a car. Identification of these attributes and its incorporation while manufacturing EVs may further attract consumers to buy such vehicles. Therefore, in the context of present study, it is necessary to understand the perception of consumers for functional attributes of PHEV such as purchase price, driving range, charging time, etc. as well as the attributes for general vehicle use to identify priority attributes influencing consumers’ choice of PHEV. The attributes of higher priority to the consumers may be subsequently used in designing stated-choice experiment to estimate users’ Willingness to Pay (WTP) for the attributes. It is particularly important to identify priority attributes, because if a long list of attribute is included in the stated choice experiment, respondents may find it difficult to answer the questions due to cognitive burden, which is further likely to introduce noise in the data (Hensher et al., 2005). Hence, the present study aims to identify the priority attributes influencing the choice of Plug-in Hybrid Electric Vehicle in urban India. The two megacities, Delhi and Kolkata, were selected as case cities to identify the priority attributes of PHEV.

**Delhi**

Delhi is the national capital of India, which comprises of an area of 1483 sq. km. (Census, 2011), sharing its border with the states of Haryana and Uttar Pradesh. Delhi has a population of 16.36 million persons with 2.34 million passenger car ownership (Census, 2011). The national capital has the highest number of car ownership as compared to other megacities.
such as Mumbai, Chennai, Kolkata, etc. (CPCB, 2010). Delhi has been consistently ranked as one of the top most polluted cities in the world over the last few years (Chowdhury et al. 2017). The city has an estimated GHG (CO₂ equivalent) emission of 10867.51Gg from its transportation sector (Ramachandra et al. 2015).

**Kolkata**

Kolkata, the cultural capital of India is a major commercial and financial hub in the eastern part of India. Kolkata Municipal Corporation (KMC) covers an area of 187 sq. km. (Census, 2011) and is located on the east bank of Hooghly river. Kolkata has a population of 4.49 million persons with 0.19 million passenger car ownership (Census, 2011). Kolkata is also considered to be one of the worst polluted cities in the world (Das et al., 2015). The city has an estimated GHG (CO₂ equivalent) emission of 1886.6 Gg from its transportation sector (Ramachandra et al. 2015).

The remainder of the paper is divided into five sections. Theoretical background is discussed in section 2. Section 3 illustrates the design of survey instrument. Section 4 provides detailed description of data collection and database development. Section 5 presents selection of priority attributes using RIDIT analysis. Finally, section 6 summarises the key findings of the present study, recommendations to the policymakers, and scope of further investigation.

2. **THEORETICAL BACKGROUND**

Several scientific approaches are available in the literature to prioritize attributes based on importance rating data. Analytical Hierarchy Process (AHP) has been widely used in past studies for prioritization of attributes (Cheung et al., 2001; Wong and Li, 2008). However, research shows that AHP is particularly useful for analyzing expert opinion for attribute prioritization, especially when the sample size is small, and the experiment is comparatively controlled (Cheng and Li, 2002). Furthermore, the AHP technique is also found to be associated with the problem of rank reversal (Dyer, 1990). As the present work aims to analyze consumers’ perception towards attributes of PHEV, techniques extensively used for handling large volume of rating data are found more appropriate. In general, for user perception, user ranking based on mean score can be used as a tool for prioritization of attributes (Chowdhary and Prakash, 2007). However, since mean score cannot be used as a measure of central tendency for Likert-type data, appropriate Multiple Attribute Decision Making (MADM) technique capable of handling such data should be used (Sullivan and Artino, 2013). MADM techniques such as RIDIT analysis (Wu, 2007; Panda and Sreekumar, 2012), Gray Relation Analysis (GRA) (Kuo et al., 2008; Wei, 2011) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Lai et al., 1994; Tong et al., 2005) are widely used by researchers as a tool to analyse Likert-type data to investigate importance of service attributes. Research also shows that the user perceived importance ranking of attributes as obtained from RIDIT, GRA and TOPSIS are consistent and are not statistically significantly different (Sadhukhan et al., 2014). However, as compared to GRA and TOPSIS, RIDIT analysis is the only technique which is additionally associated with Kruskal–Wallis (W) statistics which ensures statistical goodness of fit of the results obtained (Wu, 2007; Xu et al., 2015). Hence, for the present study, RIDIT analysis is used to analyze the rating data to identify the priority attributes influencing the choice of PHEV in urban India.

**RIDIT Analysis**
RIDIT analysis is a statistical technique useful for analyzing ordered categorical data such as Likert-type ordinal scale data (Pouplard et al., 1997). I. Bross first introduced RIDIT analysis in 1958. RIDIT analysis is ‘distribution free’ i.e. it makes no assumption regarding the distribution of the population under study (Fleiss et al., 2003). The name ‘RIDIT’ was chosen due to its similarity with ‘probit’ and ‘logit’ as a type of data transformation (Pouplard et al., 1997). However, ‘probit’ and ‘logit’ refer to theoretical distribution, whereas ‘ridit’ refer to relative to an identified distribution, which may be an empirical distribution chosen by the analyst (Fleiss et al., 1979). Therefore, RIDIT analysis is closely associated with the principle of probability transformation. RIDIT analysis shares its widespread application in the field of medical science (Belloc et al., 1971); business management (Bikash et al., 2010); behaviour studies (Badami and Haider, 2007). The methodology to perform RIDIT analysis is briefly discussed below in the context of present work (Wu, 2007).

1. Computation of ‘ridit’ for reference population

a) Select a group of data with responses in ordered categorical scale to serve as the reference population. For the present study, reference population refers to the total number of responses given by car owners using Likert-type ordinal scale survey.

b) Compute frequency of response \(f_i\) for each categorical scale, where \(i = 1\) to \(n\).

c) Compute mid-point accumulated frequency \(F_i\) for each category of responses by taking cumulative frequency of categories lower in the degree of seriousness as compare to the category of interest, plus half the frequency of category of interest.

\[
F_1 = \frac{1}{2} f_1 \tag{1}
\]

where,
\(F_1 = \) Mid-point accumulated frequency for lowest category of response
\(f_1 = \) Frequency of lowest category of response

\[
F_i = \frac{1}{2} f_i + \sum_{k=1}^{i-1} f_k , \text{ where } i = 2 \text{ to } n \tag{2}
\]

d) Compute ‘ridit’ \(R_i\) for each category of responses for the reference population

\[
R_i = \frac{F_i}{N} , \text{ where } i = 1 \text{ to } n \tag{3}
\]

where,
\(N=\) Total response or reference population size. By definition, \(R_i\) for reference population is always equal to 0.5

2. Computation of ‘ridit’ for comparison data set

a) Compute ‘ridit’ \(r_{ji}\) for each category of scale item

\[
r_{ji} = \frac{R_i \cdot p_{ji}}{p_j} \tag{4}
\]
where,
\[ j = 1 \text{ to } p, \]
\[ P_{ji} = \text{frequency of category } i \text{ for } j\text{th scale item}, \]
\[ P_j = \text{summation of the frequency of all categories for } j\text{th scale item} \]
\[ P_j = \sum_{k=1}^{n} p_{jk} \]  
(5)

b) Compute ‘mean ridit’ \( \bar{r}_j \) for each category of scale item
\[ \bar{r}_j = \sum_{k=1}^{n} r_{jk} \]  
(6)

3. Compute confidence interval (CI) for \( \bar{r}_j \). For reference data set with relatively larger size as compared to comparison data set, 95% CI of any \( \bar{r}_j \) is given by:
\[ CI = \bar{r} + \frac{1}{\sqrt{3p}_j} \]  
(7)

4. Compute Kruskal-Wallis (\( W \)) statistics to test the following hypothesis.
\[ H_0: \bar{r}_j = 0.5 \text{ (for all } j) \]
\[ H_1: \bar{r}_j \neq 0.5 \text{ (for all } j) \]
\[ W = 12 \sum_{j=1}^{p} P_j (\bar{r} - 0.5)^2 \]

Kruskal-Wallis (\( W \)) follows chi-squared (\( \chi^2 \)) distribution with \( p-1 \) degrees of freedom. Reject the null hypothesis (\( H_0 \)) if the Kruskal-Wallis (\( W \)) statistic is greater than critical chi-square value. If \( H_0 \) is rejected, the general rules to interpret \( \bar{r} \) is discussed below.

i. If \( \bar{r} \neq 0.5 \), it indicates a significant difference in response pattern of reference and comparison data set for a particular scale item. However, if CI of \( \bar{r}_j \) contains 0.5, then \( \bar{r}_j \) does not significantly deviate from 0.5.

ii. Lower value of \( \bar{r} \) is preferred over higher value because \( \bar{r} < 0.5 \) indicates a low probability of being in negative propensity.

iii. If confidence interval of \( \bar{r} \) is overlapped, it indicates that the response pattern of scale items, among the respondents, are statistically indifferent from each other.

3. DESIGN OF SURVEY INSTRUMENT

In order to collect responses from Delhi and Kolkata, a survey instrument was designed. The target group to collect sample data from both the cities were the private car owners of 18 years of age or older possessing a valid driving license, who intend to purchase a new car or replace the existing car in the near future. Urban areas were selected because i) car ownership is highly predominant in the urban centers (Singh, 2005); ii) vehicle kilometers traveled are lesser than rural areas, hence driving range of batteries in PHEV could easily accommodate the daily kilometers travel by the car owners reducing emission in urban areas (assuming batteries are charged daily); iii) megacities are the primary target areas of car manufacturers to introduce electric vehicles (Carley et al., 2013). Initially, an extensive literature survey was
done to identify the functional attributes influencing the choice of PHEV. Attributes such as electric range, battery warranty, charging time, charging infrastructure, purchase price, annual travel cost, annual maintenance cost, emission, gasoline range, fuel type, engine power, acceleration time and top speed, considered in most of the studies related to EVs (Potoglou and Kanaroglou, 2007; Hidrue et al., 2011; Achtnicht, 2012; Lebeau et al., 2012; Hackbarth and Madlener, 2013; Higgins et al., 2017) were found to be pertinent in the context of PHEV for the present study. Furthermore, attributes influencing general vehicle use such as advanced vehicle technology options, appearance/style, air conditioning, gadgets, safety, security, vehicle class and seating comfort were also included in the study based on literature (Egbue and Long, 2012; Kabaday et al., 2013; Shin et al., 2015; Hafner et al., 2017), discussion with subject experts, and interaction with car owners. Finally, an exhaustive set of 21 attributes were selected for the present study. The attributes and their description are presented in Table 1. After the selection of attributes, a questionnaire was designed to collect responses from car owners in Delhi and Kolkata. The questionnaire was divided into three parts. The first part collected respondents’ importance of attributes in a seven-point Likert-type ordinal rating scale (Schiffman et al., 2008). The second and third part collected information on respondents’ trip characteristics and socioeconomic characteristics respectively. Thereafter, a pilot study was conducted to check the adequacy of the questionnaire. After each interview, the respondents were asked to comment on the questionnaire design and to indicate problems, if any, faced while answering the questions. The feedback from the respondents was positive, confirming that the respondents answered the questions very carefully. After incorporating the modifications in response to the suggestions from the respondents and observations from the pilot study, the questionnaire was ready to perform the main survey.

Table 1. Description of selected attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
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<tbody>
<tr>
<td>Purchase price</td>
<td>Cost of the vehicle</td>
</tr>
<tr>
<td>Fuel type</td>
<td>Fuel used to run a vehicle such as diesel, petrol, electricity, etc.</td>
</tr>
<tr>
<td>Advanced vehicle technology options</td>
<td>Real-time vehicle guidance and traffic forecasting systems, battery management system, advance driver assistance systems, etc.</td>
</tr>
<tr>
<td>Gasoline range</td>
<td>Number of kilometers a vehicle can travel without refueling the gas tank</td>
</tr>
<tr>
<td>Annual travel cost</td>
<td>Annual cost to run the vehicle</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>Cost incurred by the owner annually to keep the vehicle in good condition</td>
</tr>
<tr>
<td>Electric range</td>
<td>Number of kilometers a vehicle can travel on fully charged battery</td>
</tr>
<tr>
<td>Gadgets</td>
<td>Electronic device such as cell phone charger, Bluetooth stereo with display system, hands-free calling system, etc.</td>
</tr>
<tr>
<td>Appearance/style</td>
<td>Looks (both interior and exterior), shape and colour of a vehicle</td>
</tr>
<tr>
<td>Emission</td>
<td>Emission of pollutants such as carbon dioxide, carbon monoxide, etc. from the exhaust pipe of a vehicle</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>Air conditioning system inside a vehicle</td>
</tr>
<tr>
<td>Battery warranty</td>
<td>A written guarantee, issued to a vehicle buyer by its manufacturer, promising to replace the battery if necessary within a specified period</td>
</tr>
<tr>
<td>Safety</td>
<td>Ability of a vehicle to minimize the occurrence as well as the consequence of a traffic collision</td>
</tr>
<tr>
<td>Security</td>
<td>Protection of a vehicle against any form of danger or threat</td>
</tr>
<tr>
<td>Engine power</td>
<td>Maximum power that an engine of a vehicle can provide</td>
</tr>
<tr>
<td>Charging time</td>
<td>Time taken to charge the battery</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>Time in seconds required by a vehicle to accelerate from 0 to 100 km/h</td>
</tr>
<tr>
<td>Top speed</td>
<td>Maximum speed that can be attained by a vehicle</td>
</tr>
<tr>
<td>Charging infrastructure</td>
<td>Availability of charging facility</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Vehicle class</td>
<td>Vehicle body type such as hatchback, sedan, SUV, etc.</td>
</tr>
<tr>
<td>Seating comfort</td>
<td>Degree of comfort experienced during travel</td>
</tr>
</tbody>
</table>

4. DATA COLLECTION AND DATABASE DEVELOPMENT

The designed survey instrument was programmed as a Computer Assisted Personal Interview (CAPI) (Baker et al., 1995) to collect responses from car owners in Delhi and Kolkata. A simple random sampling technique (Kothari, 2004) was used to identify car owners at several locations such as residential complexes, offices, schools, universities, and colleges in both the cities. The car owners were questioned regarding their future car purchase plan. The car owners who said ‘yes’ for intended ownership of a new car or replacement of an existing car in the near future were interviewed further for the present study. An interviewer was assigned to each respondent, who guided him/her through the survey screens of CAPI. All the data collected were automatically stored in the database. First, the respondents were given a brief description regarding the selected attributes and requested to give importance of attributes on a seven-point Likert-type scale (where 1 indicated least important, and 7 indicated most important) (Schiffman et al., 2008). Next, the respondents were asked about their trip characteristics (i.e., trip frequency for journey to work and trip length for journey to work) followed by questions on socioeconomic characteristics (i.e., gender, age, education, occupation, monthly family income, car ownership, vehicle class owned and availability of home-based parking facility). For the respondents who owned more than one car, further information was collected regarding their most preferred car, with higher vehicle kilometers traveled (VKT). Survey responses were collected until 500 responses were obtained from each city which satisfies the minimum sample size of 384 recommended by Krejcie and Morgan (1970). In order to acknowledge participation, each respondent was gifted with a pen after they completed the entire survey. During initial data processing and refinement, the individual survey was removed if (i) responses to some of the questions were incomplete (ii) respondents rated most of the attributes with a specific categorical response, indicating that the respondent did not think while answering the questions (iii) respondents completed the survey in <300s. During the pilot study, it was found that the questionnaire survey required at least 300s for its completion. Hence, the responses with completion time <300s were removed, and respondents with completion time >300s, an additional time of 60s was given to complete the survey. After initial data processing and necessary refinement, 470 responses from car owners in Delhi, and 465 responses from car owners in Kolkata were found usable for further study.

Before identifying the priority attributes, it was necessary to investigate heterogeneity in perception of attributes across different user groups. Literature suggests that the socioeconomic profile of consumers interested in different vehicle class (such as hatchback, sedan, Sports Utility Vehicle (SUV), Multi Utility Vehicle (MUV), etc.) varies significantly, and the existing differences further reflect in their stated importance of electric vehicle attributes (Jensen et al., 2013; Higgins et al., 2017). Therefore, it was necessary to investigate heterogeneity in the perception of attributes across consumers with different vehicle class preferences. Users’ perception of attributes is also likely to vary across cities due to differences in city size, economy, etc. (Majumdar et al., 2015). The two case study cities selected for the present study vary significantly in their city size, as already mentioned in section 1. Also, during database development, a substantial variation was observed in the socioeconomic characteristics such as monthly family income, car ownership and availability of home-based parking facility, and trip characteristics such as trip length for journey to work.
across the two cities. Hence, it was necessary to investigate heterogeneity in perception of attributes across users of different vehicle class, and across users of the two different cities before identifying the priority attributes for PHEV.

The heterogeneity in perception of attributes across different user groups was investigated using Kruskal-Wallis H-test. Kruskal-Wallis H-test is a non-parametric test used to compare two or more than two independent groups. The test is also popularly known as, one-way ANOVA on ranks, as the test uses ranks instead of actual data to compare independent groups (Kruskal and Wallis, 1952). The test investigates whether or not the median for any variable follow the same distribution across different population subgroups. The test statistics $H$ is defined as:

$$H = \frac{12}{n(n+1)} \sum \frac{R_j^2}{n_j} - 3 \left( n + 1 \right)$$ (8)

where, $n =$ total sample size, $n_j =$ sample size of $j$th sample, $R_j =$ sum of ranks for $j$th sample

Figure 1. Vehicle class composition: (a) Delhi and (b) Kolkata

Figure 1 (a) and Figure 1 (b) shows segmentation of car owners based on their choice of vehicle class for Delhi and Kolkata respectively. The figure shows that among different vehicle classes such as hatchback, sedan, Sports Utility Vehicle (SUV), luxury car, Multi Utility Vehicle (MUV) or Multi Purpose Vehicle (MPV), etc. the car owners in both the cities largely own hatchback and sedan cars. As the sample size of SUV, luxury car and MUV/MPV for both the cities were insufficient to perform any statistical tests, these vehicle classes were not included in further analysis. Therefore, Kruskal-Wallis H-test was used to investigate (i) heterogeneity in the perception of attributes across hatchback and sedan users for both Delhi and Kolkata, and (ii) heterogeneity in users’ perception across Delhi and Kolkata. Asymptotic significance or p values obtained against each attribute (shown in Table 2) was used to interpret the outcomes of the tests. If the p-value is $\leq .05$, there exists a significant difference in users’ perception for an attribute across a specific population subgroup. The cells highlighted in Table 2 represent the cases with evidence of heterogeneity at 95% confidence level.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>p values</th>
</tr>
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<tbody>
<tr>
<td>Hatchback</td>
<td></td>
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<tr>
<td>Sedan</td>
<td></td>
</tr>
<tr>
<td>SUV</td>
<td></td>
</tr>
<tr>
<td>Luxury car</td>
<td></td>
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<tr>
<td>MUV/MPV</td>
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</table>

Table 2. Heterogeneity investigation using Kruskal-Wallis H-test
Results presented in Table 2 reveal that there exists no significant heterogeneity in the perception of car owners across the two segments for both the cities. Therefore, the responses from the two segments were combined to further investigate between city heterogeneity.

**Heterogeneity investigation across Delhi and Kolkata**

The results in Table 2 show that there exists a significant difference in perception for most of the attributes across two cities.

Hence, from heterogeneity study, it is found that there exists no significant difference in perception of attributes across hatchback and sedan users in both the cities, while there exists a significant difference in perception of attributes across car owners in two cities. Therefore, clear evidence of heterogeneity across two cities highlights the need to derive the priority attributes separately for two cities. A total of 428 responses from Delhi and 437 responses from Kolkata were included in the study for subsequent analysis. Table 3 shows the descriptive statistics of the responses for both the cities.
Several differences may be observed across the car owners in two cities from Table 3. In Delhi, 58% of the car owners belong to the age group ≤35 years, and 42% of the car owners belong to the age group >35 years. However, in Kolkata, 41% of the car owners belong to the age group ≤35 years, and 59% of the car owners belong to the age group >35 years. This indicates that Delhi has higher percentage of young car owners as compared to Kolkata. In Delhi, 36% of the car owners have monthly family income over 1.5 lakh, whereas only 17% of the car owners in Kolkata have monthly family income over 1.5 lakh. This shows the existing differences in income profile of car owners across two cities. Difference in income profile is also reflected in car ownership characteristics of two cities. Table 3 indicates that the percentage of single car ownership is higher in Kolkata (78%) as compared to Delhi (64%). However, the percentage of multiple car ownership is higher in Delhi (36%) as compared to Kolkata (22%). Although multiple car ownership is higher in Delhi as compared to Kolkata, 51% of the car owners in Delhi do not have home-based parking facility. However, in Kolkata, only 15% of the car owners do not have a parking facility at home. Substantial variation is also observed in the trip characteristics of the car owners across two
In Delhi, 31% of the car owners have average trip length of journey to work ≤30km, and 69% of the car owners have average trip length of journey to work >30km. Whereas, in Kolkata, 68% of the car owners have average trip length of journey to work ≤30 km, and 32% of the car owners have average trip length of journey to work >30km. The statistics appear logical since Delhi has a city size of 1483 sq.km., which is much larger than Kolkata, with a city size of just 187 sq.km. (Census, 2011). Hence, work destinations for majority of the car owners in Delhi are more distant than the car owners in Kolkata leading to higher trip length.

5. SELECTION OF PRIORITY ATTRIBUTES USING RIDIT ANALYSIS

This section presents the results and discussion on the selection of priority attributes for Delhi and Kolkata using RIDIT analysis. Table 4 summarizes the priority ranking of attributes by the car owners in Delhi and Kolkata, along with their corresponding RIDIT scores. For 20 degrees of freedom, critical chi-squared value $\chi^2_{21-1} = 31.41$ is less than Kruskal Wallis (W) value of 524.24 and 1085.14 for Delhi and Kolkata respectively at 95% confidence level. This indicates that for both the cities the responses towards the 21 attributes are statistically significantly different at 95% confidence level.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Delhi Rank</th>
<th>Mean ridit</th>
<th>Kolkata Rank</th>
<th>Mean ridit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price</td>
<td>8</td>
<td>0.572</td>
<td>8</td>
<td>0.566</td>
</tr>
<tr>
<td>Fuel type</td>
<td>18</td>
<td>0.438</td>
<td>13</td>
<td>0.458</td>
</tr>
<tr>
<td>Advance vehicle technology options</td>
<td>13</td>
<td>0.490</td>
<td>14</td>
<td>0.457</td>
</tr>
<tr>
<td>Gasoline range</td>
<td>17</td>
<td>0.439</td>
<td>12</td>
<td>0.475</td>
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<tr>
<td>Annual travel cost</td>
<td>11</td>
<td>0.522</td>
<td>9</td>
<td>0.563</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>16</td>
<td>0.442</td>
<td>16</td>
<td>0.454</td>
</tr>
<tr>
<td>Electric range</td>
<td>6</td>
<td>0.593</td>
<td>3</td>
<td>0.659</td>
</tr>
<tr>
<td>Gadgets</td>
<td>15</td>
<td>0.446</td>
<td>19</td>
<td>0.366</td>
</tr>
<tr>
<td>Appearance/style</td>
<td>12</td>
<td>0.518</td>
<td>17</td>
<td>0.450</td>
</tr>
<tr>
<td>Emission</td>
<td>10</td>
<td>0.524</td>
<td>5</td>
<td>0.645</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>9</td>
<td>0.559</td>
<td>10</td>
<td>0.527</td>
</tr>
<tr>
<td>Battery warranty</td>
<td>3</td>
<td>0.616</td>
<td>2</td>
<td>0.671</td>
</tr>
<tr>
<td>Safety</td>
<td>1</td>
<td>0.679</td>
<td>1</td>
<td>0.706</td>
</tr>
<tr>
<td>Security</td>
<td>2</td>
<td>0.623</td>
<td>4</td>
<td>0.653</td>
</tr>
<tr>
<td>Engine power</td>
<td>14</td>
<td>0.486</td>
<td>15</td>
<td>0.456</td>
</tr>
<tr>
<td>Charging time</td>
<td>7</td>
<td>0.583</td>
<td>11</td>
<td>0.491</td>
</tr>
<tr>
<td>Acceleration time</td>
<td>19</td>
<td>0.387</td>
<td>20</td>
<td>0.342</td>
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<tr>
<td>Top speed</td>
<td>21</td>
<td>0.307</td>
<td>21</td>
<td>0.232</td>
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<tr>
<td>Charging infrastructure</td>
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<td>0.600</td>
<td>6</td>
<td>0.635</td>
</tr>
<tr>
<td>Vehicle class</td>
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<td>0.374</td>
<td>18</td>
<td>0.379</td>
</tr>
<tr>
<td>Seating comfort</td>
<td>4</td>
<td>0.603</td>
<td>7</td>
<td>0.603</td>
</tr>
</tbody>
</table>

A set of priority attributes for car owners in both the cities were selected by evaluating the average of the mean ridits of all the attributes for each city. The attributes with mean ridit greater than the average of the mean ridits were identified as the priority attributes. Table 5 presents the list of priority attributes for Delhi and Kolkata with mean ridits greater than 0.514 i.e. the average of the mean ridits for both the cities. A list of ‘twelve’ attributes for Delhi and a list of ‘ten’ attributes for Kolkata were identified as the priority attributes for car owners in two cities.
It is interesting to note that ‘Safety’ is the attribute of highest importance for car owners in both cities. The results are in contrary to the observations from the previous studies in India, where safety is identified as one of the least important attributes (Gupta, 2013; Shende, 2014). However, the results are in line with earlier research conducted in developed countries, where it is found that the consumers rate ‘Safety’ as the attribute of top priority while purchasing a new car as compared to other attributes such as price, fuel cost, appearance, comfort, air conditioning, etc. (Whitelegg and Haq, 2006; Koppel et al., 2008). The data collected on vehicle class ownership revealed that the majority of the car owners (hatchback and sedan users) in both the cities own entry-level models (low-cost models) which lack adequate safety features such as airbags, Anti-lock Braking System (ABS), etc. The increasing rate of car accidents in the megacities with higher risk of accident severity due to absence of adequate safety features might have raised the concern of car owners towards safety (Rajaraman et al., 2017). A crash test conducted by Global NCAP revealed the risk of accident severity associated with these entry-level cars sold in India, where all the cars failed the crash test receiving zero-star adult protection rating (Global NCAP, 2014). It may also be observed from Table 5 that the attributes specific to PHEV technology such as ‘Electric range,’ ‘Battery warranty,’ and ‘Charging infrastructure’ are perceived as highly important by car owners in both the cities, indicating significant influence of battery technology and availability of charging facility on the adoption of PHEVs. Similar results are also reported by other literature (Hirdue et al., 2011; Caperello and Kurani, 2012; Krupa et al., 2014), where it is found that the battery performance in terms of driving range on full charge, battery warranty, availability of charging facility (at home, work or public charging stations), etc. are the major concerns of consumers for BEVs and PHEVs. However, along with the attributes specific to PHEV technology, attributes for general vehicle use such as safety, security, seating comfort, and air conditioning are all considered equally important by the car owners in both the cities. It is found that often, such attributes are either neglected or compromised while manufacturing cars for developing countries such as India, where the primary concern of manufacturers while producing cars is its purchase price (Ray and Ray, 2011). Hence, the manufacturers should also focus on such attributes, to promote significant market penetration of PHEVs in urban India. As expected, ‘Purchase price’ and ‘Annual travel cost’ are among the priority attributes for car owners in both the cities. The results are in line with the previous studies done by Krupa et al. (2014); Musti and Kockelman (2011); Egbue and long (2012), where consumers are found highly sensitive to monetary factors such as purchase price,

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Delhi Rank</th>
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<th>Attribute</th>
<th>Kolkata Rank</th>
<th>Mean ridit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>1</td>
<td>0.679</td>
<td>Safety</td>
<td>1</td>
<td>0.706</td>
</tr>
<tr>
<td>Security</td>
<td>2</td>
<td>0.623</td>
<td>Battery warranty</td>
<td>2</td>
<td>0.671</td>
</tr>
<tr>
<td>Battery warranty</td>
<td>3</td>
<td>0.616</td>
<td>Electric range</td>
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<td>0.659</td>
</tr>
<tr>
<td>Seating comfort</td>
<td>4</td>
<td>0.603</td>
<td>Security</td>
<td>4</td>
<td>0.653</td>
</tr>
<tr>
<td>Charging infrastructure</td>
<td>5</td>
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<td>Emission</td>
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<td>0.645</td>
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<tr>
<td>Electric range</td>
<td>6</td>
<td>0.593</td>
<td>Charging infrastructure</td>
<td>6</td>
<td>0.635</td>
</tr>
<tr>
<td>Charging time</td>
<td>7</td>
<td>0.583</td>
<td>Seating comfort</td>
<td>7</td>
<td>0.603</td>
</tr>
<tr>
<td>Purchase price</td>
<td>8</td>
<td>0.572</td>
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<td>8</td>
<td>0.566</td>
</tr>
<tr>
<td>Air conditioning</td>
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<td>0.559</td>
<td>Annual travel cost</td>
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<td>0.563</td>
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<tr>
<td>Emission</td>
<td>10</td>
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<tr>
<td>Annual travel cost</td>
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<tr>
<td>Appearance/style</td>
<td>12</td>
<td>0.518</td>
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</tr>
</tbody>
</table>
annual fuel cost, and annual maintenance cost while choosing a PHEV. A substantial variation in the priority ranking of several attributes by the car owners in two cities may also be observed in Table 5, which is justifying the need to analyze the importance data separately for two cities. This is also in line with the results of heterogeneity investigation carried out during database development, where a significant difference is observed in perception of car owners across two cities. Interestingly, perceived importance of ‘Charging time’ is relatively higher for car owners in Delhi as compared to car owners in Kolkata which is indicated by the absence of ‘Charging time’ in the list of priority attributes for car owners in Kolkata. As already discussed in section 4 that 51% of the car owners in Delhi do not have home-based parking facility, whereas 85% of the cars owners in Kolkata possess parking facility at home. Therefore, the absence of home-based parking facility for majority of the car owners in Delhi may be responsible for raising their concern for ‘Charging time’ of PHEVs. The results are in line with a study done by Axsen and Kurani (2009); Sundstrom et al. (2012); Caperello and Kurani (2012); Krupa et al. (2014), where it is found that consumers prefer charging their vehicle overnight at home than at public charging station for both convenience, and safety and security of vehicle and charging cables. Surprisingly, though Delhi is among the most polluted cities in the world (Chowdhury et al. 2017), perceived importance of ‘Emission’ is lower among car owners in Delhi and relatively higher among car owners in Kolkata. This reveals the existing differences in the environmental concern of car owners across two cities, as it is well documented in several literatures (Hackbarth and Madlener, 2013; Krupa et al., 2014) that the higher concern for vehicular emission represents the consumers with higher environmental awareness. Similar results on difference in perception for emission are also reported by Tanaka et al. (2014), where comparative discrete choice analysis across four states in U.S reveal that the WTP for emission reduction is much higher in Michigan ($44.6) as compared to California, Texas and New York ($26.5-$34.1). Car owners in Delhi also give higher priority to ‘Appearance/style’ as compared to car owners in Kolkata which is again indicated by the absence of ‘Appearance/style’ in the list of priority attributes for car owners in Kolkata. This reflects the existing difference in consumer perception towards aesthetical aspects of a car across the two cities. Hence, it is evident from the results that the existing differences in perception, attitude, and circumstances lead to the differences in priority ranking of several attributes across two cities. The priority attributes identified for the two cities may be subsequently used in designing stated choice experiment to carry out comparative discrete choice analysis to estimate the difference in WTP for the attributes across two cities.

6. CONCLUSION

The present study reports an investigation on identification of priority attributes influencing the choice of Plug-in Hybrid Electric Vehicle by analyzing the perception of car owners in two megacities, namely Delhi and Kolkata. The heterogeneity in perception of attribute was investigated using Kruskal Wallis H-test. Within city heterogeneity revealed no significant difference in perception of attributes across hatchback and sedan users for both the cities. Hence, the responses from the two segments were combined to further investigate between city heterogeneity. Investigation of between city heterogeneity revealed a significant difference in perception for most of the attributes across the car owners in two cities. Therefore, the evidence of heterogeneity highlighted the need to obtain the priority attributes separately for two cities. RIDIT analysis, a Multiple Attribute Decision Making (MADM) approach was used to identify the priority attributes. The analysis derived a set of ‘twelve’
attributes for Delhi and a set of ‘ten’ attributes for Kolkata as priority attributes. ‘Safety’ was identified as the attribute of highest importance for car owners in both the cities. Interestingly, the results obtained are in contrary to the observations from the past studies in India, but in line with the studies carried out in other country context. The increasing rate of car accidents in the megacities with higher risk of accident severity due to lack of adequate safety features in the car are the primary factors raising concern of car owners towards safety. Attributes specific to PHEV technology such as ‘Battery warranty,’ ‘Electric range’ and ‘Charging infrastructure’ were perceived as highly important by car owners in both the cities. Findings are consistent with the results obtained in other developed and developing countries. However, in addition to the attributes specific to PHEV technology, attributes for general vehicle use such as safety, security, seating comfort, and air conditioning were also considered equally important by car owners in both the cities. It is found that often, such attributes are not given due consideration while manufacturing cars for developing countries such as India, where the primary concern of manufacturers while producing cars is its purchase price. Hence, it is important for PHEV manufacturers to also lay more emphasis on attributes for general vehicle use along with the attributes specific to PHEV technology to increase its market penetration in urban India. A substantial variation was also observed in the priority ranking of several attributes across two cities. For instance, ‘Emission’ was perceived as relatively less important among car owners in Delhi as compared to car owners in Kolkata, indicating a difference in perception towards environmental concern across two cities. Similar observation on city to city-specific variation with a significant difference in WTP for emission reduction is also reported in other literatures. Interestingly, ‘Charging time’ was perceived as relatively more important among car owners in Delhi as compared to car owners in Kolkata. Absence of home-based charging facility for 51% of the car owners in Delhi might be the reason for higher concern of ‘Charging time’ among car owners in Delhi. Findings are in line with the past studies, where charging the vehicle overnight at home is preferred against charging the vehicle at public charging station for both convenience, and safety and security of vehicle and charging cables. The perceived importance of ‘Appearance/style’ was higher among car owners in Delhi, and relatively lesser among car owners in Kolkata, reflecting the difference in perception for aesthetical aspects of a car across two cities. Hence, it was clear that the differences in perception, attitude, and circumstances were the primary factors leading to the difference in the priority ranking of several attributes across two cities.

While the present study provides a rational basis for selection of priority attributes influencing users’ choice of PHEV, it also indicates the need for future work to examine users’ willingness to pay for the attributes and develop demand model to analyze the change in mode choice behaviour with the introduction of PHEVs. Although the results are case specific, it is expected to be of interest to PHEV manufacturers and the larger community of researchers and policymakers, working on electric mobility as an instrument to reduce vehicular emission in urban areas.

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