

Abstract

Plug-in Hybrid Electric Vehicles (PHEVs) can help decarbonize road transport in urban India. To accelerate the diffusion of PHEVs, investigation of consumer preferences towards the attributes of PHEVs is necessary. Therefore, the broad objective of the present work is to investigate i) consumer preference towards Plug-in Hybrid Electric Vehicle (PHEV) in the Indian scenario in terms of their a) perception towards PHEV-related attributes, b) perceived benefit due to improvement in these attributes and c) potential demand shift from conventional vehicle (CV) to PHEV due to improvement in these attributes, and ii) use the derived knowledge to formulate suitable policy interventions to increase the attractiveness/penetration of PHEVs in the Indian market. The car-owning population, i.e., the current owners of conventional four-wheelers/CVs are considered consumers of PHEVs, and the work is demonstrated with reference to consumers in two Indian megacities, namely Delhi and Kolkata.

The present work is divided into three major components. In the first component, using a fairly exhaustive list of 22 attributes influencing PHEV choice, a seven-point Likert-type ordinal scale rating survey instrument was designed to collect importance rating of PHEV-related attributes, and satisfaction rating for attribute performance of vehicle owned by the respondents in Delhi and Kolkata. First, the importance rating data were analyzed using Exploratory Factor Analysis (EFA) to identify the latent factors influencing PHEV choice in two cities. Further, to select the most important attributes from each latent factor, two Multiple Attribute Decision Making (MADM) techniques, namely RIDIT analysis and Grey Relation Analysis (GRA) were used. Thereafter, Revised Importance-performance Analysis (Revised IPA) was used to identify the priority areas of improvement in CVs by analyzing consumers' importance and satisfaction rating for related attributes. Finally, by combining the findings from EFA and MADM techniques, and Revised IPA, priority attributes were identified. The results reveal that purchase price, fuel cost, safety, security, air conditioning, appearance/style, public charging infrastructure, charging time, battery warranty, electric range, emission, Advance Vehicle Technology (AVT) option, and gadgets are the priority attributes influencing the choice of PHEVs in the Indian context.

In the second component, a Stated Preference (SP) survey instrument was designed using a key set of priority attributes, namely purchase price, fuel cost, AVT option, electric range, public charging infrastructure, charging time, battery warranty, and emission to collect choice responses from the consumers in Delhi and Kolkata for travel behavior analysis. The

data collected were analyzed in two stages. In Stage-I analysis, Multinomial Logit (MNL) and Mixed Logit (ML) model were developed for the total sample to estimate consumers' perceived benefit towards PHEV-related attributes in terms of willingness to pay (WTP) values. Additionally, ML models considering heterogeneity around the mean estimates of random parameters were developed to investigate the impact of sociodemographic, socio-psychological, and trip-related characteristics on consumers' WTP for improvement in PHEV attributes. In Stage-II analysis, MNL and ML models were developed for the total sample to estimate potential demand shifts from CV to PHEV by developing demand models. The results indicate the need for an added emphasis on PHEV-specific attributes such as charging time and battery warranty and attribute for general vehicle use such as AVT option by vehicle manufacturers to make PHEV attractive to consumers in Indian megacities. Consumers' income, car ownership, availability of home-based parking facility, education, environmental concern, and average daily trip length (journey to work) are found to significantly influence their WTP for improvement in PHEV-related attributes.

In the third component, the demand models developed for Delhi and Kolkata were used for the evaluation of alternative PHEV specifications/models for policy intervention through (i) scenario analysis and (ii) impact assessment of likely penetration on vehicular emission. The five-best alternative PHEV specifications/models that would attract consumers to choose PHEV in Delhi and Kolkata are identified through scenario analysis. Also, the scenario analysis reveals that the relative importance of subsidizing the purchase price is higher than providing public charging facility for promoting PHEVs in the Indian market. High purchase price is identified as the major bottleneck for the penetration of PHEVs. Policy interventions from the government in terms of higher subsidy are necessary to increase the market penetration of PHEVs and for subsequent reduction in gasoline consumption and CO₂ emission from the passenger car segment in the Indian megacities.

Overall, the present work demonstrates a comprehensive approach for investigating consumer preference towards PHEVs in the context of Indian megacities. The approach could be applied in the megacities of other developed and developing countries for deriving suitable policy interventions by vehicle manufacturers and the government to promote the market penetration of electric vehicles.

Keywords: Plug-in Hybrid Electric Vehicle; Exploratory Factor Analysis (EFA); RIDIT; GRA; Revised Importance-performance Analysis (Revised IPA); Stated Preference (SP); Willingness to Pay (WTP); Multinomial Logit-MNL; Mixed Logit-ML; Demand Model