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Ph. D. Dissertation in Engineering

Two Essays on Electric Vehicle Use in Nepal

- Consumer Preferences and Barriers Analysis-

August-2019

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Abstract

Two Essays on Electric Vehicle Use in Nepal

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Electric vehicles (EVs) can be considered an alternative technology to reduce greenhouse gas emission in the transportation sector. The government of Nepal also aims to accelerate the use of EVs. Nepal does not have any proven fossil fuel reserves; however, it does have a high potential for hydroelectricity, which could be sufficient to meet the demand for EVs. The share of petroleum products could be reduced if the country can increase its hydroelectricity production and its use in the vehicle sector.

Thus, the first part of this study examines consumer preferences and conducts market simulations based on different scenarios for electric vehicle use in the context of Nepal. Stated preference data is collected by conjoint designed survey. Then mixed logit and latent class model are applied for estimation. Results show that potential consumers having small family size, lower monthly travel distance, environmentally aware, and electric vehicle knowledge are more likely to adopt the electric vehicle. We find that the reduction in purchase price is most effective to increase consumers' likelihood to purchase battery electric vehicle and plug-in hybrid electric vehicle. Market simulation result suggests that policy mix scenario is more effective than single policy support for EVs. Finally, latent class estimation pointed out three distinct classes of consumers in Nepal implying significant heterogeneity among potential vehicle users. This variation should be addressed within the policies to increase the demand for electric vehicles.

The second part of this study attempts to identify the barriers to electric vehicles diffusion in the context of Nepal and to rank them. Seventeen barriers were identified from previous studies, reports, policy documents, and interaction with stakeholders. Identified barriers were classified into five categories; technical, policy, economic, infrastructure, and social. Then, the comparative survey was performed to get experts' opinion on identified barriers and analytical hierarchical process (AHP) was used for estimating and ranking the barriers. Results reveal infrastructure, policy, economic, and technical barriers are important barrier categories with the comparison to social barrier category. Likewise, lack of charging stations, higher purchase price, and lack of government long-term plan and goal is ranked top three in overall barriers.

Keywords: Electric vehicles, Nepal, Barrier, Consumer preferences, Mixed logit, AHP

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Chapter 1. Overview

1.1 Background

Transportation sector is one of the top contributors for climate change with an increasing trend (Jansson, Pettersson, Mannberg, Brännlund, & Lindgren, 2017); however, it has received attention, discussions are going on worldwide in order to identify effective and efficient measures. Reduction in greenhouse gas emission from transportation sector can be addressed in two areas: changes in travel behavior and changes in vehicle technology (Kihm & Trommer, 2014). In order to mitigate climate change and secure petroleum products supply, governments and other authorities have given priority for the development of alternative fuel vehicles (AFVs) (Vassileva & Campillo, 2017).

AFVs can be fueled by alternative fuels, are developed and diffused in the vehicle market. Environmental impact of the vehicle can be reduced if internal combustion vehicles (ICVs) are replaced by AFVs. Consumer preferences and adaptations are important factors for the long term success of less environmentally harmful AFVs (Axsen & Kurani, 2011).

Among different types of AFVs, electric vehicles (EVs) are gained high interest in recent years. EVs use electric motors for propulsion. EVs contain batteries to supply power that can be charged from electricity. EVs are three types: hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs). EVs generate much fewer emissions compared to ICVs, more specifically when the electricity for battery charging is produced by renewable energy sources. EVs can be also charged in off-peak hours (Jochem, Babrowski, & Fichtner, 2015; N. Wang, Tang, & Pan, 2017). Moreover, emission reduction from EVs mainly depends on the sources of electricity generation. EVs also provide an advantage in terms of energy efficiency, energy security, travel cost, and local pollutions (Grauers, Sarasini, & Karlström, 2013). From the perspective of government, EVs use is an effective alternative for improving the efficiency and mitigate the environmental issue, and from a private sector perspective, it is green and new business opportunity (Ko & Hahn, 2013).

In order to stimulate the demand for EVs, it is important to take into consideration how the consumers perceive EVs. Most of the previous studies, consumer preferences for EVs, have performed a conjoint-based discrete choice survey and collected stated preferences data. Stated preference approach is popular because of the limitation on revealed preferences data. Consumers consider many factors such as purchase subsidy, charging infrastructures, fuel cost, purchase price, operating cost, technical performance, range, fuel type, incentives, tax, brands, and models before purchasing EVs (Chorus, Koetse, & Hoen, 2013; Hahn, Lee, & Choi, 2018; Ko & Hahn, 2013; Qian & Soopramanien, 2011; Rudolph, 2016; Sheldon, DeShazo, & Carson, 2017).

Subsequently, analysis of consumer preferences on these factors would be the important information in analyzing and formulation of government policies. From automakers perspective, consumer preferences analysis is a crucial factor for the development of different kinds of AFVs (Chorus et al., 2013). To best of our knowledge from literature reviews, consumer preferences studies focused on a specific country or region. The choice of the vehicle does not necessarily only depend on the attribute of the vehicle (Hahn et al., 2018); however, other variables such as socio-demographic, travel characteristics, and environmental concerns might better explain consumers' preferences (Rudolph, 2016; Sheldon et al., 2017).

Despite the considerable benefits of EVs, many barriers have been reported against their wider acceptance. While consumers give positive feedback about EVs, many barriers/issues remain such as lack of government policies and supports, higher pricing compared to ICVs, limited choice models, low resale value, long charging time, limits with regard to the driving distance, and economic concerns (Kihm & Trommer, 2014; Vassileva & Campillo, 2017; N. Wang et al., 2017). Adequate public charging networks, government planning, awareness-raising, and enabling laws could foster the diffusion of EVs (Broadbent, Drozdzewski, & Metternicht, 2018). Even though EV manufacturers have progressed in technological terms, manufacturers still limit EV production due to higher battery price and performance issues (Quak, Nesterova, & van Rooijen, 2016). Conflicts of interest between stakeholders and poor implementation limit the development of EV-related standards and infrastructures (Xue, You, & Shao, 2014). The relatively higher price of an EV compared to that of an ICV serves as a crucial barrier; however, environmental benefits could be the main enabler for EV uptake among consumers (Van Der Straten, Wiegmans, & Schelling, 2007). Thus, results from prior research show potential consumers have various concerns about barriers and addressing these barriers is crucial to the diffusion of EVs. A better understanding of EV use drivers and barriers is important to identify the impact and to develop the sustainable integration plan (Vassileva & Campillo, 2017).

Governments around the globe are setting various policies in order to increase the EVs market and to accelerate the market transition (J.-H. Kim, Kim, & Yoo, 2019); however, the adoption rate is still low. Government policies are directed towards infrastructure development, purchase price subsidy, research and development support, and awareness campaign. Some prior studies indicated that great efforts on the technological innovation from automakers and a wide package of policies, environmental awareness campaign, and proper information flow about EVs to the potential consumers from the government should come into account in order to stimulate the demand of EVs (Hackbarth & Madlener, 2013; S. Wang, Li, & Zhao, 2017).

Likewise, studies also suggested that a single policy cannot aid such diffusion; rather, a mixture of enabling policies, considering the context of the country, is likely to be effective for the widespread diffusion of EVs. Such policies should consider important aspects such as the development of EV charging infrastructure, tax rebates, and subsidies for purchasing EVs (Steenberghen & Lopez, 2008; Yong & Park, 2017).

1.2 Motivation and Problem Description

1.2.1 Context of Nepal

Nepal is a landlocked country in South Asia situated between India and China. It is 48th largest country by population and 93rd largest country by area. Some demographic information of Nepal is presented in table 1.1.

Nepal's top imports are presented in table 1.2. Fuel shares about 15.2% followed by semi-finished iron or non-alloy steel products. Vehicle also shares about 7.1% on Nepal's total import. In 2017, Nepali importers spent the most on the following 10 subcategories of mineral fuels including processed petroleum oil presented in table 1.3. Table 1.4 presents the top 10 vehicle imports in 2017.

Table 1.1 Some demographic information of Nepal-2017

Area (sq.km)	147181
Population (millions)	29.30
Population growth (%)	1.1
Life expectancy (years)	71
GDP (Current- Billion Dollar)	24.88
GDP growth (%)	7.9
GNI per capita, PPP (dollar)	2730
Import (billion dollars)	10.04
Export (billion dollars)	0.74
Forest area (sq.km)	36.4
Number of provinces	7
Number of municipalities	753
Energy use (kg of oil equivalent/capita)	139
Electricity consumption(kWh/capita)	139
CO2 emission(metric tons/capita)	0.28

Source: World Bank (https://databank.worldbank.org)

Out of 77 districts of Nepal, 75 districts center are connected to the road and 71 districts are connected with blacktopped road. Altogether 29639 km road was constructed by the central government up to 2018, the portion of blacktopped, graveled, and earthen road is 44.3 percent, 23.5 percent, and 32.2 percent, respectively as shown in table 1.5 (Ministry of Finance, 2019).

Likewise, out of 58398 km road constructed in the local level, the shares of blacktopped, graveled, and earthen roads are 4.6 percent, 22 .0 percent, and 73.4 percent respectively. The share of the blacktopped road at the local body is very low. Access to the safe and quality road has not been increased due to the fact that most of the constructed roads are earthen road at the local level. Details of road construction under local bodies are presented in table 1.6.

Table 1.2 Nepal's top 10 imports-2017

Products	Value (million dollar)	Share (%)
Mineral fuels including oil	1500	15.2
Iron, steel	947	9.4
Machinery including computers	914	9.1
Vehicles	714	7.1
Electrical machinery	658	6.6
Cereals	410	4.1
Gems, precious metals	370	3.7
Plastics	367	3.7
Salt, Sulphur, stone, cement	318	3.2
Animal/vegetable fats, oils, waxes	298	3

Source: http://www.worldstopexports.com/nepals-top-10-imports/

Table 1.3 Nepal's top 10 fuel imports

Products	Value (million dollar)
Processed petroleum oils	1100
Petroleum gases	232
Coal	145
Oil residues	32
Coke	22
Petroleum jelly	0.78
Coal tar oils	0.27
Natural bitumen	0.23
Asphalt/petroleum bitumen mixes	0.17
Crude oil	0.08

Source: http://www.worldstopexports.com/nepals-top-10-imports/

Table 1.4 Nepal's top 10 vehicle imports

Products	Value (million dollar)
Motorcycles	202
Cars	133
Trucks	103
Tractors	90
Chassis fitted with engine:	73
Automobile parts/accessories	37
Public-transport vehicles	29
Motorcycle parts/accessories	21
Bicycles	12
Special purpose vehicles	8

Table 1.5 Road expansion from central level

Description	Road Length (km)
Blacktopped	13149
Graveled	6956
Earthen	9534
Total	29639

Source: Ministry of Physical Infrastructure and Transport

Table 1.6 Details of road construction under local bodies

Description	Road Length (km)
Earthen	42892
Graveled	12840
Black topped	2666
Total	58398

Source: Department of local infrastructure and development and agriculture road

Although the government has provided custom duty and value-added tax relief measures for EVs, there is a lack of subsidy and other government incentives. Nepal do not have government-led financing for electric mobility. The government of Nepal has minimized disincentives through reform of the customs and value-added tax regimes for EV. This is a positive development. However, the government currently does not provide any proactive incentive for switching to EV such as an incentive in the form of a subsidy, would be useful. Spare parts for EVs do not enjoy the same low customs tax and exemption from value-added tax.

The government of Nepal also aims to accelerate the use of EV. EV has important considerations in the context of Nepal. Ministry of Energy, Water Resources and Irrigation of Nepal[1] mentioned the at least two charging stations will be constructed in each municipality within four years. In addition, 2019's budget speech of government of Nepal[2] also highlighted the construction of necessary charging stations for EVs and mentioned the necessary budget is allocated.

It will be difficult to have electric buses, trucks, and off-road vehicles compared to small vehicle. In this regard, this study is limited to electric car and jeep. Summary of vehicles registration in Nepal till 2018 is presented in table 1.7. Car/Jeep category contributes about 34.43% of vehicles registered in Nepal. In addition, the study is confined in province 3, where about 65% of car/jeep are registered till 2018.

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[1] http://www.moewri.gov.np/images/category/FY-2075-76-Policy-Budget-and-Program-Implementation-Action-Plan.pdf

[2] https://www.mof.gov.np/en/archive-documents/budget-speech-17.html?lang=

Table 1.7 Summary of vehicle registration until 2018 in Nepal

Type	Number	Share (%)	Province 3	Province 3 (%)
Bus	49318	7.14	12617	25.583
Minibus/Minitruck	25595	3.71	13343	52.131
Crane/Roller/ Excavator/Truck	90411	13.1	32967	36.463
Car/Jeep	**237658**	**34.43**	**154433**	**64.981**
Pickup	55973	8.11	23374	41.759
Microbus	7658	1.11	3802	49.647
Tempo	45672	6.62	2528	5.535
Tractor	143962	20.85	2908	2.020
Rickshaw	26466	3.83	3890	14.698
Others	7607	1.1	634	8.334
Total	**690320**			
Motorcycle	2530722		921917	
Grand Total	3221042		1172413	

Source: (https://dotm.gov.np/en/vehicle-registration-record/)

Nepal does not have any fossil fuel reserves such as coal, natural gas, and petroleum. The country has a high potential for hydropower (approximately 83 GW) despite its current installed capacity being very low (Gurung, Ghimeray, & Hassan, 2012; Gurung, Gurung, & Oh, 2011; Sovacool, Bambawale, Gippner, & Dhakal, 2011). In Nepal, the generation of electricity mainly comes from hydropower.

The proportion of traditional (wood and biomass), commercial (oil, coal, and electricity), and renewable energy (solar, wind, and small hydro) consumption in the total energy consumption were 68.6 percent, 28.2.percent, and 3.2 percent respectively in 2018. Petroleum products provide approximately 13% of the country's total energy supply that is imported from neighboring countries.

The share of petroleum products could be reduced if the country can increase its hydroelectricity production and its use in the vehicle sector, this also might be expected to limit on increasing its petroleum imports (Ministry of Finance, 2019). According to the National Oil Corporation Limited (NOCL)[3], 488,675 kiloliters and 1,588,869 kiloliters of petrol and diesel were imported in the fiscal year 2017–2018, amounting to an increase of approximately 20% over last year. Production of electricity reached to 1,142 MW in Nepal by the end of 2018. Summary of electricity production with source-wise is given in table 1.8. As shown in figure 1.1, domestic electricity production in Nepal is not sufficient in order to meet the demand. Due to the shortage of electricity, currently, the government of Nepal is importing electricity from India to reduce the gap between supply and demand. Imported electricity contributed to limit the demand and supply gap of electricity as shown in figure 1.2.

Table 1.8 Summary of electricity production in Nepal-2018

Type	Capacity (MW)	Share (%)
Hydropower	1061.58	93.00
Thermal power plant	53.40	4.60
Solar PV	27	2.40
Total	1142	

Source : (Ministry of Finance, 2019)

[3] www.nepaloil.com.np/import

Households and business sectors are the main sectors for electricity consumption in Nepal. Sector-wise electricity consumption figures are presented in table 1.9.

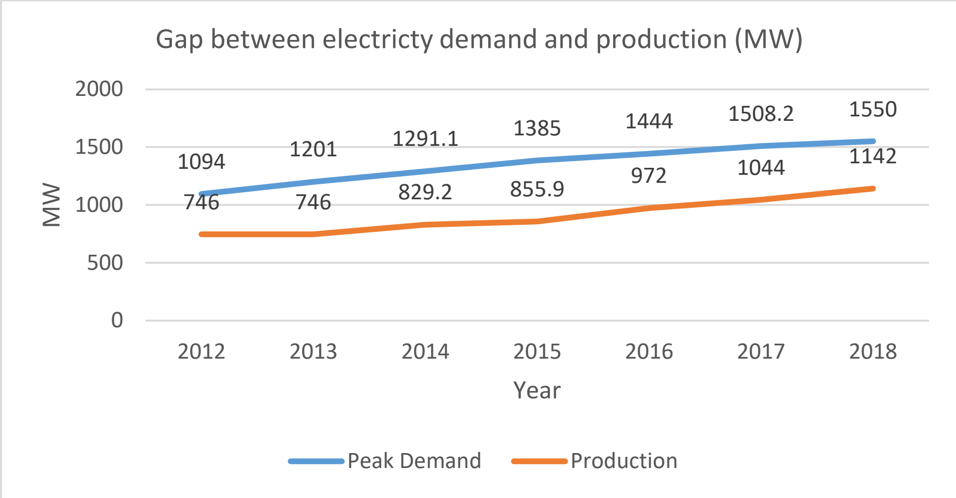

Figure 1.1 Electricity demand and production gap

Source: Ministry of Energy, Water Resources and Irrigation (Ministry of Finance, 2019)

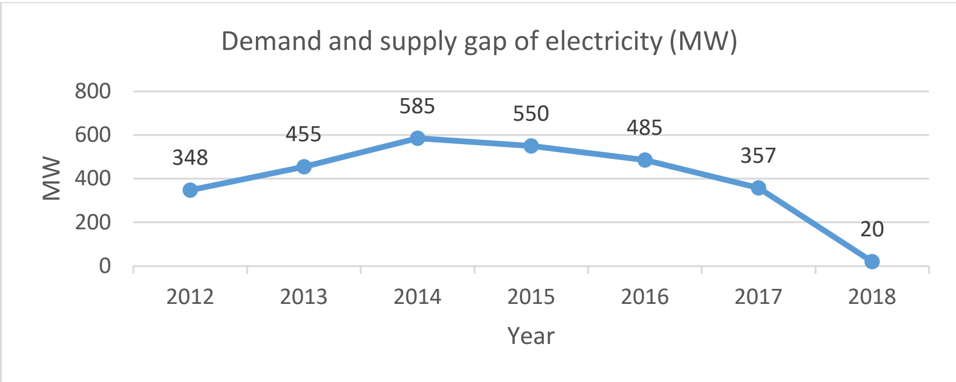

Figure 1.2 Supply and demand gap electricity

Source: Ministry of Energy, Water Resources and Irrigation (Ministry of Finance, 2019)

Table 1.9 Sector wise electricity consumption-2018 (GW hour)

Sector	Consumption (GW hour)	Share (%)
Households	2403.63	42.81
Business	2074.16	36.94
Industrial	407.59	7.26
Others	729.21	12.99
Total	5614.59	100

Source Nepal Electricity authority (www.nea.org.np)

Table 1.10 shows the current status of hydropower, indicating a large number of hydropower projects at different stages of construction. Many hydropower projects that are in different stages of development could provide sufficient electricity for battery charging requirement of EVs in future. According to the Government of Nepal, additional 1264 MW of electricity will be generated by the end of 2019. Out of this, 1239 MW will be from hydropower and 25 MW from Solar PV.

Table 1.10 Summary of hydroelectricity status

Type	Number	Total Capacity (MW)
Operation (installed)	81	1038.07
Under construction	203	7780.563
Applied for generation License	30	1519.24
Survey certificated issued	301	18193.55
Apply for survey certificate	33	1046.36
Total	643	29577.80

Source: Ministry of Energy, Water Resources and Irrigation (Ministry of Finance, 2019)

1.2.2 Research Gap

For instance, countries might differ in terms of potential for EV uptake depending on their economic situation, geographic condition, and energy resource availability (L.P. Ghimire & Kim, 2018). Thus, the results of a particular study may not necessarily apply to another country; a country-specific analysis is important. Various previous studies presented their findings based on the country-specific context. However, we could not find a consumer preference study for EVs in Nepal. In addition, we might expect preference heterogeneity among potential consumers. It is important to identify the consumer segments in order to address the heterogeneity in policies and strategies. The current study attempts to overcome these gaps by considering relevant attributes in the context of Nepal.

Some of the barriers for EVs uptake are common globally and others tend to be country-specific (Haddadian, Khodayar, & Shahidehpour, 2015; Onat et al., 2017). Previous studies have identified and reported various barriers/factors/issues affecting to the use of EVs. However, they did not report all barriers within one framework. Nor were the barriers ranked in order of their importance. The current study attempts to overcome these gaps by considering all relevant barriers in the context of Nepal and rank them based on experts' opinions.

1.3 Research Objectives

Two main objectives of this research are the analysis of consumer preferences and barriers for EVs in the context of Nepal, especially in urban areas. Thus, it is divided into two parts: 1) Consumer preferences analysis 2) Analysis of barriers. The objectives are as follows.

A. Consumer preferences analysis (Chapter 2)

1. Analyzing the relative importance of EV's attributes based on the stated preference.

2. Analyzing the effects of consumers' socio-demographic, travel characteristics, and environmental concerns on preferences for EVs.

3. Conducting scenarios based market simulations to analyze the effectiveness of policies in order to stimulate the demand for EVs.

4. Latent class model (LCM) formulation in order to identify an optimal number of classes among consumers.

B. Analysis of barriers (Chapter 3)

1. To identify the various barriers against the diffusion of EVs in Nepal.

2. To estimate the importance of the barriers, and to rank them.

Chapter 2. Literature Review

2.1 Alternative Fuel Vehicles

Use of petrol or diesel for transportation sector is the most common. However, some alternative fuel vehicles are available in the current market. Propane, natural gas, electricity, fuel cell, and biodiesel are examples of alternative fuels used in the transportation sector. AFV is defined as any kind of vehicle that is not only entirely operates with gasoline or diesel. The development of AFV mainly came by environmental issues caused by traditional vehicles, efficiency improvement, and depleting of fossil fuels. Because of these concerns, development and use of cleaner AFVs became a priority sector for the governments and vehicle manufacturers around the globe. Reduction in the cost of fuel due to the improvement of efficiency, reduction in carbon emission, and reduction in environmental impacts are major benefits of AFVs. There are different types of AFVs, some of them are explained briefly, for more details please refer to (DOE, 2014).

Methanol vehicle: Methanol can be produced from gas, coal, residues of oil, and biomass. Vehicles can be operated only from methanol; however, methanol blended with petrol is becoming popular and practical. As we know that methanol is liquid, it does not demand major change in vehicle engine.

Propane vehicle: Propane is considered as high energy intensity fuel, and often called as liquefied petroleum gas (LPG). Propane is nonrenewable and can be obtained as a byproduct during the refining of petroleum or natural gas. It will save about 5 to 30 percent cost of fuel while using in vehicle.

Ethanol vehicle: Ethanol is colorless alcohol. It can be made by fermenting the sugars from grains. But there are many procedures that can produce ethanol from biomass. Ten percent mix of ethanol in gasoline draws attention to the transportation sector. It is expected that use of ethanol results up to 25% reduction in carbon monoxide emission in the transportation sector.

Biodiesel vehicle: Biodiesel is fuel can be produced by the chemical reaction of an alcohol with oils of vegetable, fat, or grease. It is often used in blends of 2 percent to 20 percent to diesel. Biodiesel fuels are compatible with diesel and can be used in unmodified diesel engines with the existing fueling infrastructures.

Electric vehicle: Electric vehicles (EVs) can be operated from energy stored in batteries. Batteries of EVs can be charged from electricity. EVs are becoming more popular than other AFVs; however, researchers are working on the improvement of batteries. The capacity of the battery as stored energy will determine the range of EVs. Adding batteries can increase the capacity of storing energy, but it can increase the weight of a vehicle, reducing its load-carrying capacity and range. Three types of vehicle that can be operated with electric power storage are as follows.

1. **Hybrid electric vehicle (HEV):** HEV uses an internal combustion engine for gasoline or diesel and an electric motor for electric power stored in batteries. HEV cannot be charged from the grid of electricity. Instead, batteries are charged from the regenerative braking system.

2. **Plugin hybrid electric vehicle (PHEV):** PHEV can be operated from the internal combustion engine and batteries which can be recharged from grid power. PHEV contains more powerful batteries compared to HEV. PHEVs offers flexibility in fuel selection.
3. **Battery electric vehicle (BEV):** BEV will be exclusively operated from batteries embedded with the vehicle. Batteries can be charged from an electrical outlet. BEV can be called complete electric vehicle compared to PHEV and HEV because it does not require any fossil fuel. BEV is a zero-emission vehicle.

Hydrogen fuel cell vehicle: It uses hydrogen fuel for operation through the reaction of hydrogen with oxygen in a fuel cell to provide motive power to motors. Thus, hydrogen and oxygen are used to produce electricity without harmful emissions in hydrogen fuel cell vehicle. Hydrogen is a gas at normal temperature and pressure, which shows greater transportation and storage hurdles than other fossil fuels.

2.2 Consumer Preference Studies

Consumer preferences study can be applied to forecast the demand for a new product that does not exist with sufficient numbers in the market. EVs can be considered as a new product compared with ICVs, especially in Nepal. In consumer preferences studies, individuals make decisions by considering the trade-off between attributes with the assumption of chosen alternative will maximize the utility ((Liao, Molin, & van Wee, 2017). We might expect that better understating of consumer preferences for EVs can contribute to design effective and efficient policies. Many studies on consumer preferences for AFVs have been published over the last decades. Among different types of AFVs, more studies were on the EVs. We might expect that a comprehensive literature review would be useful to synthesize findings and to identify the knowledge gap that needs to be addressed. Consumer preferences study assumes that the decision maker will choose alternative among a set of alternatives that maximize the utility. Prior studies on EV preferences used stated preference or revealed preference data.

2.2.1 Revealed Preference

Revealed preference (RP) is one method to analyze the consumer preferences for any product or service based on the choice made by consumers. It is based on the economic theory of individuals' purchase behavior to observe their preferences. RP is applied on the assumption that individuals have considered available alternatives before considering the purchasing decision. RP is mostly used to identify the impact of policies or strategies on consumers' purchase behaviors. RP models are to understand the preferences of consumers among available choices in the market within their budget constraint.

However, there is a limitation on the availability of sufficient choice data in order to estimate preferences of new product or service. Even if we have a larger RP sample, RP data would still be afflicted by multicollinearity and difficulties with measuring vehicle attributes (Brownstone, Bunch, & Train, 2000).

2.2.2 Stated Preference

Stated preference (SP) method is a survey-based economic technique for analyzing the consumer preferences on new product or service. There would be the limitation on choice data for any new products, thus, many researchers attempt to overcome this issue by constructing hypothetical alternatives to conduct SP survey and to observe the individuals' preferences. SP data can eliminate the issue of multicollinearity. However, SP choices have been subject to criticize by some experts due to an understating that individuals behave differently in hypothetical choices than observing in a real situation market. Researchers highlighted that some attributes of the new product might be innovative enough that consumers do not properly understand. Thus, this would differ the results of SP choice modeling than RP choice modeling (Brownstone et al., 2000).

Most of the previous studies were on stated preferences data because of the limitation of a sufficient number of EVs in the real market. Preceding studies on EVs, SP data were collected by conjoint based choice experiments in which respondents were making a choice in each given set of alternatives. Attribute's value might vary between alternatives.

2.2.3 Stated Preferences Studies

Various studies analyzed the consumer preferences for AFVs using stated preference method with a conjoint survey for different countries/regions. Some of them are summarized in table 2.1. This summary briefly shows the main objective, main results, the model used, and attributes considered. We used several kinds of literature searching platform such as Google Scholar, Science Direct, Jastor, and Springer in order to gather SP studies on AFVs.

AFVs preferences studies varied with different attributes. However, generally can be categorized into four categories of attributes; technical, infrastructure, economic, and policy. In addition, most of the studies also considered alternative specific constant (ASC), can be called fuel type, which can capture the joint effect of attributes and factors not considered in the study. Mostly, estimated coefficients of ASC is interpreted as relative preferences of AFVs compared to ICVs when other remains constant. However, ASC considered in each study covers different factors. So, the results of ASC cannot be compared between studies. ASC can be interpreted based on each study context. The following section presents the results obtained for different attributes of AFVs. Summary of reviewed studies is presented in table 2.1.

2.2.3.1 Economic Attributes

Economic attributes are refereeing various monetary costs of purchase and operation. The purchase price is considered in all studies presented in table 2.1. Price is customized with different levels taking reference with the real market. Coefficient of the purchase price is highly significant and showing a negative impact on the utilities in all studies.

Operation costs do not appear in every study as seen in table 2.1. Operation costs inclusion is also not consistent in all studies; however, appeared in the different name of attributes. Fuel cost is included in most of the studies (Caulfield, Farrell, & McMahon, 2010; Hackbarth & Madlener, 2013; Ida, Murakami, & Tanaka, 2014; Rudolph, 2016; Sheldon et al., 2017). Likewise, the annual cost in another study (Qian & Soopramanien, 2011), and battery price in (Ko & Hahn, 2013). These all cost have a negative effect to purchase a car. Fuel cost gives EV an edge over ICV since EV generally has lower fuel cost.

2.2.3.2 Technical Attributes

Technical attributes can be defined as the technical characteristics associated with the vehicle. Vehicle power, range, recharging time, brand and models, size, warranty, emissions, and performance issues are considered in technical attributes (Liao et al., 2017). Range is mostly used technical attribute followed by the recharging time in vehicle preference studies. The short driving range is one of the major barriers to increase demand for EVs. Range issue can be compensated with shorter charging time and increasing the capacity of the battery. Range increment has a positive impact on the preferences of the vehicle in all studies. Emission reduction results are not significant in all studies, but in some studies have a positive impact on the choice of vehicle (Y. Kim, Jeong, Ahn, & Lee, 2007). Performance of vehicle generally represented by power, acceleration time, and maximum speed. Individuals are generally showed their positive preferences for better performance.

2.2.3.3 Infrastructure Attributes

Presence of charging/fuel stations and repair and maintenance workshop can be considered in infrastructures attributes. Results of infrastructure attributes showed significantly positive effect because more charging facilities will save time and relieving consumer range anxiety. In general, increment in the infrastructure for the vehicle improved the choice probability of EV in reviewed studies.

2.2.3.4 Policy Attributes

Policy instruments for promoting the diffusion of EVs can be considered in policy attributes. Some policy instruments can be varied in each country/ region based on the context. There are different types of policy attributes considered in different studies. Subsidy policy to reduce the purchase price, lower electricity price for operation cost reduction, reduce/exemption of taxes (custom tax, road tax, purchase tax, and annual tax), free parking, access to high occupancy vehicle (HOV), and public infrastructure development are examples of policy attributes. All studies did not consider the policy attributes during the stated preference survey; however, conducted policy simulations after estimation.

Table 2.1 Summary of preceding SP studies

Reference/Country	Main Objective	Attributes	Model	Main Results
(Y. Kim et al., 2007) -South Korea	Analyzing consumer preferences for alternative fuel vehicles.	Fuel type Fuel cost Price Service stations Power Emission rate	Mixed Logit	The fuel and maintenance costs are the most influential factors. Positive Network externality exists. Exists of the indirect network effect.
(Sheldon et al., 2017) - California/ USA	How large are the differences in consumer demand for BEV, PHEV, and (ICVs)	Brand-Model Fuel cost Price Range Fuel Type	Mixed Logit ASC Logit Latent Class	Shorter ranges are commercially viable than more expensive longer-ranged PHEVs. Three distinct consumer segments.
(Khan, Fatmi, & Habib, 2017) - Canada	Latent class model to investigate the choice vehicles with 100%	Fuel Type	Latent Class MNL	Strong variations in the effects of magnitude exist among the households across the two classes.

	increase in gas price.			
(Hahn et al., 2018) - Seoul- South Korea	Assessing the relative impacts of green vehicles' attributes.	Price Operating cost Range Fuel stations Fuel type	MNL Nested Logit	Choice probabilities of green vehicles differed for the size of vehicles. The purchase price is the most effective approach to increasing demand.
(Hackbarth & Madlener, 2013) - Germany	To assess the relative impact of vehicle attributes on the choice probabilities.	Fuel type Price Fuel cost Charging time Incentive	MNL Mixed Logit	BEVs and FCEVs only gain in demand if multiple policy measures are implemented. PHEV are less like to be rejected for younger, highly educated, and environmentally aware.
(Qian & Soopramanien, 2011) - China	How consumers perceive when modeling consumer preference for green versus ICVs.	Fuel type Price Annual Cost Stations Range Incentives	MNL Nested Logit	Petrol cars and hybrid cars to be more similar. Car owners are more likely to switch to alternative fuel vehicles compared to non-car owners

(Rudolph, 2016) - Germany	Insights about possible ecological effects incentives combination with the mobility behavior	Fuel type Price Fuel cost Tax subsidy Parking fee	Mixed Logit	The choice strongly depends on the magnitude of the incentive.
(Chorus et al., 2013) - Netherland	Consumer preference analysis for AFVs comparing utilization maximum and regret minimization model	Price Fuel type Tax Range Recharge time Brand/model Policy	Mixed Logit	Two models achieve almost identical fit with the data and differ only marginally in terms of predictive ability. Probabilities between two models are of a non-trivial magnitude
(Javid & Nejat, 2017) - USA	To explore the factors that are deemed to be associated with PEV adoption and estimate the PEV penetration.		Logistic Regression Probit	Charging stations and gas prices are tools for transportation planners and city authorities to regulate PEV technology.

(Caulfield et al., 2010) - Ireland	Attempt to ascertain whether the reduction of fuel cost, vehicle registration tax or greenhouse gas emissions would encourage to purchase AFVs	Fuel type Fuel cost	Logit	Majority of respondents agreed that HEVs are better for the environment and cheaper to run than conventional vehicles but expensive to buy.
(Ko & Hahn, 2013)- Korea	Consumer preferences for the important attributes that influence the purchase of EV using	Battery price Holding tax Subsidy Battery swap Infrastructure	Mixed Logit	Consumers endow greater value for EV with a swappable battery than EV with unswappable battery.
(Tanaka, Ida, Murakami, & Friedman, 2014) Japan and USA	Comparative analysis between the US and Japan with policy simulations	Price Fuel cost Range Emission Charging stations	Mixed Logit	US consumers are more sensitive to fuel cost reductions and to alternative fuel station availability. Innovation scenario with a significant purchase price reduction observed a high penetration.

(Shim, Kim, Altmann, Yoon, & Kim, 2018) - Korea	Analyzing key features for electric vehicle diffusion and its impact on the Korean power market	Fuel Type Accessibility Range Fuel Cost Price	Mixed Logit	Electric vehicles can increase to around 40% of the total market share if the key features of electric vehicles reach a similar level to ICV
(Rahmani & Loureiro, 2019) - Spain	Analyzing preferences for hybrid electric vehicles.	Price Fuel cost Emissions Fuel Type	Latent Class	Lack of interest in the adaptation of hybrid electric vehicle is because of the lack of information and false belief of the vehicle's quality. Informative campaigns and additional economic incentives policies is recommended to increase demand.
(Guerra, 2017) - Indonesia	To evaluate the potential of electric motorcycles in a small Indonesian city.	Price Fuel price Range Charge time Max speed	Mixed Logit	Identified variation in preferences for motorcycle features. Speed, range, charge time, and price all mattered substantially.

2.2.4 Review on Modeling Techniques

Discrete choice models are used as a methodology in all reviewed stated preference studies presented in table 2.1. Discrete choice models have widely applied methodologies in economic research. Discrete choice models focus to estimate coefficients of taste parameters that describe preference or weight in decision making process.

Discrete choice models are contrasted with standard consumption models in which the quantity of good consumption will be the continuous variable. These models allow predicting the choice between discrete alternatives such as choosing between types of job or choosing between modes of transportation. Instead of estimating how much, discrete choice models examines which one with a given number of alternatives. The models will estimate the probability that a person chooses each alternative among available alternatives. Discrete choice models are also widely applied in marketing research to analyze consumer demand and to predict market demand. In addition, transportation researchers are using discrete choice models to predict the demand for different types of AFVs.

Discrete choice models are considered in many different ways including multinomial logit, multinomial probit, nested logit, generalized extreme value models, mixed or random parameters logit model, and latent class choice model. However, all these models have some common features as follows.

Choice set: It is the set of alternatives that are available to the individuals to provide their preferences. The choice set should maintain three conditions:

1. Alternatives included must be **collectively exhaustive**, that means choice set should include all possible alternatives.

2. All alternatives should be **mutually exclusive**, selecting one alternative means not selecting any other alternatives.
3. Number of alternatives must be **finite**.

Choice Probabilities: All discrete choice models estimate the probability that an individual chooses a specific alternative. Choice probability can be expressed in a function of observed attributes that will be related to alternatives and individual's characteristics. For example, selection of transportation mode, travel time and cost of travel could be included in attributes and income, age, and gender can be included in individuals' characteristics. Two properties of choice probabilities are as follows.

1. The choice probability must be between 0 and 1
2. For every person, the sum of choice probabilities of alternatives must be 1.

Consumer Utility: All discrete choice models are derived from consumer utility theory. Utility can be explained as a benefit or wellbeing of a person obtains from choosing a specific alternative. The behavior of the consumer is utility maximization, the person will choose the alternative that gives the highest utility. The utility that the individual obtains from the alternative can be divided into two parts: observed by researcher and unobserved by the researcher. Discrete choice models imply two properties based on utility theory.

1. Only difference in utility matter: We might expect that consumer will choose an alternative with the highest utility. That means the consumer will compare utilities of each alternative and make a decision based on the highest utility can be achieved from the chosen alternative.
2. Scale of utility must be normalized. Utility has no units to compare. Thus, the scale of utility needs to normalize to compare.

Among the reviewed articles, multinomial logit, nested logit, mixed logit, and latent class models are used. Brief description of each model is as follows.

2.2.4.1 Multinomial Logit Model (MNL)

Multinomial logit model is the most widely used model in the discrete choice analysis. MNL is popular due to its probability can be expressed in closed form. There are three power and limitations of MNL (Revelt & Train, 2000; Train, 2009).

1. MNL can explain only systematic taste variation that relates to only observed characteristics of respondents. But, random taste variation cannot be accounted.
2. MNL represents proportional substitution properties across alternatives. For any two alternatives, the ratio of choice probabilities does not depend on other alternatives. This property of MNL is called as independence from irrelevant alternative (IIA). But, IIA does not hold in real situations.
3. MNL can only account unobserved factors if they are independent over time. However, MNL cannot consider the case where unobserved factors are correlated over time and alternatives.

2.2.4.2 Nested Logit Model

Some studies applied the nested logit model to incorporate the restriction of IIA in MNL. The nested logit model relaxes the limitation of MNL to some extent. Alternatives in the same nest should be similar so that they can compete with each other. It is appropriate when alternatives can be decomposed in nests in a way that following properties hold.

1. IIA property holds within the nest. That is, the ratio of choice probabilities of alternatives from the same nest is independent with all other alternatives.

2. IIA does not hold between two alternatives from a different nest. That is, IIA property does hold for alternatives presented in a different nest.

2.2.4.3 Mixed Logit models

The estimated coefficients in multinomial logit and nested logit model are fixed which implies coefficients do not vary across individuals. This is unrealistic in many situations because of individuals heterogeneity presents in terms of preferences. Mixed logit can account random taste variation over individuals and the correlation between alternatives. Thus, mixed logit relaxes the IIA property of MNL. In a more specific way, mixed logit overcomes three limitations of standard logit models as follows (Brownstone et al., 2000; McFadden & Train, 2000; Train, 2009).

1. Allows random taste variation.
2. Overcome the unrestricted the substitution properties, IIA property does not hold.
3. Accommodates correlation of unobserved factors over time.

Because of these flexibilities, it is becoming more popular in recent years. However, choice probabilities do not remain in closed form, so the probabilities are needed to be approximated by simulations.

2.2.4.4 Latent Class Model

Latent class model (LCM) resembles the mixed logit models; however, LCM relaxes the mixed logit model's requirement that researcher needs to consider prior assumption on the distribution of parameters across decision makers (Greene & Hensher, 2003). However, LCM is less flexible than mixed logit as it estimates parameters with a discrete one. LCM posits decision makers' behavior depends on the observed attributes of alternatives and on latent heterogeneity that can be appeared from various factors.

LCM can accommodate the unobserved heterogeneity of individuals by categorizing them into different segments or latent classes (Khan et al., 2017). LCM helps to identify the consumers in a certain number of segments. Thus, researchers can recommend segment specific strategies and policies.

2.3 Analysis of Barriers

2.3.1 Previous Studies on Barriers

Although EVs have an environmental advantage, some barriers are limiting the wider adaptation. Previous studies have examined the barriers considering opinions of vehicle manufacturers, consumers, and policymakers. Some previous studies attempted to identify the barriers; however, most of the studies were country-specific. Previous four studies on EV barriers analysis are summarized in table 2.2.

She et al. (2017) listed and analyzed the barriers for the context of China in three categories; financial, performance, and infrastructure. Financial barriers include monetary barriers such as higher purchase price, higher battery cost, poor understanding of fuel cost, and maintenance cost. Likewise, performance barriers include reliability, range, battery charging time, and power of the vehicle. Lack of infrastructures at public places, at working place, at home, and at highway are considered in the infrastructure barrier category. A study conducted for the context of UK and Germany (Steinhilber et al., 2013) explained barriers in six dimensions; regulation and governance, infrastructure, R&D incentives, technology, business models, and consumer incentives. Browne, O'Mahony, & Caulfield (2012) suggests that barriers to the EVs can be classified into the seven dimensions including financial, technical or commercial, institutional and administrative, public acceptability, legal, policy failures, and physical barriers. A similar study (Haddadian et al., 2015) listed challenges for global adaptation of EVs in four main categories; technology, economic, social and consumer perception, and innovative business models.

Table 2.2 Summary of barriers studies

Source	Categories of barriers
(She, Qing Sun, Ma, & Xie, 2017)	1. Financial
	2. Performance
	3. Infrastructure
(Steinhilber, Wells, & Thankappan, 2013)	1. Regulation and governance
	2. Infrastructure
	3. R&D incentives
	4. Technology
	5. Business models
	6. Consumer incentives
(Browne, O'Mahony, & Caulfield, 2012)	1. Financial
	2. Technical or commercial
	3. Institutional /administrative
	4. Public acceptability
	5. Legal or regulatory
	6. Policy failures
	7. Physical barriers
(Haddadian et al., 2015)	1. Technology
	2. Economic
	3. Social perception
	4. Innovative business models

2.3.2 Identification of Barriers

2.3.2.1 Literature Review

An extensive review of previously published studies, reports, policy documents was the initial step in framework development. This step can potentially indicate the various issues/challenges/shortcomings with reference to EVs. Country-specific energy/transportation strategy and plans, market potential, geography, economic condition, and energy resource availability may be suitable factors in the identification of the barriers. In addition to this, case studies at local, regional, country, and global levels can be referred to, and 'lessons learned' can be taken into account for further refinements in the categorization of these factors.

2.3.2.2 Interaction with Stakeholders

Stakeholders may include EV manufacturers, policymakers, NGOs, experts, potential consumers/users, early adopters, and related institutions. Their opinion/perception should be taken into account, which is crucial not only for identifying the barriers but also for determining the lacunae in policies and measures to overcome these barriers. The identification of barriers and the implementation of policies pertaining to them are highly inter-related. Therefore, it is recommended that preferably, both methods, literature review and interaction with stakeholders, are used for the identification of barriers against EVs use.

2.3.2.3 Categorization of Barriers

Post identification, the barriers can be classified into categories such as social, technical, economic, policy, and infrastructure based upon their nature in the use of

EVs. The categorization of these barriers can be further refined based on the considered EVs technology and the country/region/locality of study.

2.3.3 Selection of Method

Multi-criteria decision method (MCDM) is widely used in various decision-making problems and ranking barriers. There are three steps to apply MDCM (Triantaphyllou, 2000).

1. Identify relevant criteria and alternatives for the study.
2. Measures for relative importance. It must be for the criteria and alternatives.
3. Estimation to examine weights/ranking of criteria/factors.

Many MCDM methods can be found in previous research. Each approach has its own merits and demerits. In this section, weighted sum model, weighted product model, and analytical hierarchy process are presented briefly. We can also find some other MCDM techniques such as revised AHP, ELECTRE method, and TOPSIS method (Triantaphyllou, 2000).

2.3.3.1 Weighted Sum Model (WSM)

WSM is a widely used method, specifically in one-dimensional decision-making problems. If there are I alternatives and J criteria, the best alternative can be identified from the following equation (2.1) (Triantaphyllou, 2000).

$$A_i = \sum_{j=1}^{J} a_{ij}\, w_j \quad (2.1)$$

Where A_i is the score for each alternative, a_{ij} is the weight of i-th alternative in terms of j-th criteria and w_j is the weight of j-th criteria. An alternative with the highest score is considered as the best alternative.

2.3.3.2 Weighting Product Model (WPM)

It is similar to WSM. However, the major difference is multiplication instead of addition in WSM. Best alternative can be identified from the following equation (2.2).

$$R\left({}^{A_k}/_{A_l}\right) = \prod_{j=1}^{J}\left({}^{a_{kj}}/_{a_{lj}}\right)^{w_j} \quad (2.2)$$

Where is J is the total number of criteria and a_{kj} and a_{lj} is the value of k-th and l-th alternative in terms of j-th criteria. If the term $R\left({}^{A_k}/_{A_l}\right)$ is greater than one, then it indicates that alternative A_k is more desirable than the alternative A_l.

2.3.3.3 Analytical Hierarchy Process (AHP)

AHP is applicable to decompose a complex decision-making problem into a hierarchical structure. AHP allows pairwise comparison to the decision maker. The AHP is based on the relative values for criteria and alternatives; however, WSM uses actual one. It is applicable to single to multiple dimensional problems.

AHP is the most popular (Pohekar & Ramachandran, 2004) because it allows the estimation of the inconsistency index. This index is important for ensuring the decision made is consistent and unbiased (T. L. Saaty, 1994). If the inconsistency index is higher than 0.10, the researcher may either ask re-evaluation of pairwise comparisons to respective respondent or can exclude inconsistent opinion. Thus, the inconsistency checking provision may increase the persuasiveness of results. Details of AHP is presented in chapter 4.

Chapter 3. Consumer Preferences Analysis on Electric Vehicle use in Nepal

3.1 Introduction

Transportation is one of the major contributors to greenhouse gas emission. Electric vehicles (EVs) have come into greater focus to mitigate the environmental effect. EVs, are a green car, might be an alternative for fuel substitution (Byun, Shin, & Lee, 2018); however, EVs have not massively penetrated globally (Hackbarth & Madlener, 2013). Automobile makers are targeting for the development of alternative fuel vehicles (AFVs), and governments are setting different policies to support in different areas such as infrastructure development, purchase price subsidy, research and development support, and awareness campaign. Even though EVs emit lower pollution, they have some disadvantages such as higher purchase price than internal combustion vehicles (ICVs), lack of infrastructures, lack of massive development, and low-level market penetration (Y. Kim et al., 2007; Yacobucci, 2005). EVs use electricity to charge batteries, thus, reduction of emission indirectly depends on the primary source of electricity.

Governments around the globe are setting various policies in order to expand the EVs market and to accelerate the market transition (J.-H. Kim et al., 2019). In this context, many previous studies have been conducted consumer preferences studies for EVs and analyzed various policy scenarios. It is important to examine how consumers perceive EVs together with attributes. Consumers consider various aspects before purchasing vehicles such as purchase price, fuel cost, purchase subsidy, the presence of infrastructures, technical performance, and many others.

Consequently, consumers' preference analysis on these factors might provide relevant information to policy makers in formulating and analyzing policies. In order to stimulate the use of EVs, great efforts on the technological innovation from automakers, and a wide package of policies from the government should come into account (S. Wang et al., 2017). In addition, environmental awareness and proper knowledge of EVs to the potential consumers will increase the likelihood of choosing EVs (Hackbarth & Madlener, 2013).

The government of Nepal also aims to accelerate the use of EVs. EVs have important considerations in the context of Nepal. Nepal does not have any fossil fuel reserves such as coal, natural gas, and petroleum. The country has a high potential for hydropower (approximately 83 GW) despite its current installed capacity being very low (Gurung et al., 2012, 2011; Sovacool et al., 2011). In Nepal, the generation of electricity mainly comes from hydropower. Petroleum products provide approximately 13% of the country's total energy supply that is imported from neighboring countries. The share of petroleum products could be reduced if the country can increase its hydroelectricity production and its use in the vehicle sector (Ministry of Finance, 2019).

The country might differ in terms of potential for EV uptake depending on their economic situation, geographic condition, and energy resources availability (L.P. Ghimire & Kim, 2018). Thus, the results of a particular study may not necessarily apply to another country; a country-specific study is required. Various previous studies presented their findings based on the country-specific context. However, we could not find a consumer preferences study for EVs considering the case of Nepal. The current study attempts to overcome these gaps by considering all relevant attributes together with other interactions variables in the context of Nepal.

The main objective of this study is to analyze consumer preferences for EVs in Nepal. This study contributes to the extension of existing studies in four ways. First, we analyzed the relative importance of EVs' attributes based on the stated preference conjoint survey data. Internal Combustion Vehicle (ICV), Plug-in Hybrid Electric Vehicle (PHEV), and Battery Electric Vehicle (BEV) were considered. Moreover, attributes considered were the purchase price, infrastructure availability, fuel cost, and range. We used the mixed logit model for the estimation. Second, this study accommodated the effects of socio-demographic, travel characteristics, and environmental concerns. Third, different scenarios based market simulations were performed to analyze the effectiveness of different policies in order to stimulate the demand for EVs. Fourth, another key feature of this study is the latent class model (LCM) formulation in order to identify the consumer heterogeneity among the class. Class segments were explained based on possible membership variables.

3.2 Research Design

3.2.1 Conjoint Method

The conjoint method is a statistical method that can be applied to consumer preferences study for any products. This method is from the idea that any product or service can be described with a certain number of attributes. It has been widely used to measure how consumers provide value to each attribute. In addition, it is a popular method to analyze new products based on the stated preference survey because there is a limitation on the availability of revealed preferences data. We adapted the conjoint method approach to this study in the following steps (Green & Srinivasan, 1978, 1990; Ko & Hahn, 2013).

Step I: Attributes Selection

Vehicles can be described on the basis of attributes, then, each attribute can be decomposed into a certain number of levels. We considered three types of vehicle for the context of Nepal; internal combustion vehicle (ICV), battery electric vehicle (BEV), and plug-in hybrid electric vehicle (PHEV). Then three vehicle type is described by four attributes. We set four attributes; purchase price, infrastructure availability, fuel cost, and range. Furthermore, each attribute is decomposed into a certain number of levels. Table 3.1 shows the summary of attributes with levels.

Table 3.1 Overview of attributes with levels

Fuel Type	ICV	BEV	PHEV
Purchase price ($1000)	20 30	25 32.5 40	25 32.5 40
Infrastructure availability (% of ICV)	100	25 50 75	25 50 75
Fuel cost ($/100km)	10 15	5 8 10	5 8 10
Range (km)	500	100 200 300	100 300 500

The purchase price is considered in almost all previous studies on consumer preferences for AFVs. The purchase price is relatively higher for EVs than ICVs. We considered the purchase price attribute with two levels for ICV and three levels for the BEV and PHEV. This study defines infrastructure availability is the availability of gasoline stations and maintenance workshops for the ICV. We fixed current status at 100% for the ICV. For BEV and PHEV, infrastructure availability is defined considering charging stations and maintenance workshops compared to ICV with three levels. Fuel cost is defined as the cost of diesel/petrol/electricity per 100km travel. Furthermore, the range is defined as distance can be traveled after one time full petrol or diesel or charging of the battery. We fixed 500km for ICV; however, defined in three levels for BEV and PHEV.

Step II: Choice Cards Design

Attributes with levels presented in table 3.1, the maximum number of cards can be created is 166. However, it is unrealistic for the respondents to provide preferences for 166 cards. Thus, we used orthogonal fractional factorial design to obtain 20 choice cards, greatly reduced complexity to respondents. Then, four sets having five alternative cards in each set were constructed for the survey questionnaires.

3.2.2 Variables

The choice of the vehicle does not necessarily only depend on the attributes of the vehicle (Hahn et al., 2018); however, other variables might better explain consumer preferences. These variables can be integrated with the introduction of interaction variables (Rudolph, 2016; Sheldon et al., 2017). Accordingly, this study considers the socio-demographic, travel characteristics, and environmental concerns variables. These variables can be also used for membership variables to identify consumer segments (Khan et al., 2017; Kormos, Axsen, Long, & Goldberg, 2018). Gender, age, education, family members, and income are considered within socio-demographic variables. Likewise, monthly travel distance, intention to buy a new vehicle within five years, current vehicle ownership, and frequent mount travel are taken in travel characteristic variables. Finally, environment consideration while purchasing a new vehicle, electric vehicle knowledge, and working sector are considered under environmental concerns variables. Summary of variables used in this study is shown in table 3.2. Based on the above description, the overall research framework is depicted in figure 3.1.

Table 3.2 Summary and definitions of variables

Variables	Definition
Gender (male)	1 if the respondent is male, 0 otherwise
Age (≤ 40 years)	1 if the respondent's age is within 40 years, 0 otherwise
Education(≥ Bachelor)	1 if the respondent's education is at least bachelor, 0 otherwise
Family (≤ 4 persons)	1 if the number of family members is
Middle income	1 if income is in between $ 5000 and $10000
High income	1 if income is higher than $10000
Monthly travel distance	1 if monthly travel distance is up to 600km, 0 otherwise
Intention to buy a new vehicle	1 if the intention to buy a new vehicle in five years, 0 otherwise
Vehicle available	1 if the respondent holds vehicle, 0 otherwise
Mountain travel	1 if the respondent has frequent mountain travel, 0 otherwise
Environment consideration	1 if yes, 0 otherwise
Vehicle knowledge (Medium)	1 if respondent has medium EV knowledge, 0 otherwise
Vehicle Knowledge (High)	1 if respondent has high EV knowledge, 0 otherwise
Working sector	1 if respondent is working in energy/environment , 0 otherwise

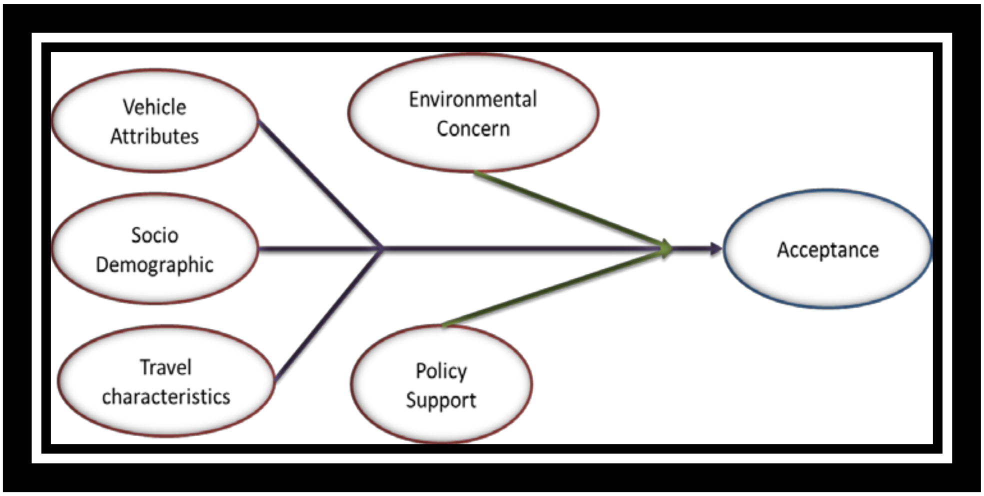

Figure 3.1 Research framework for EV consumer preference analysis

3.2.3 Survey and Data

The data were collected through the survey questionnaires in January/February 2019. We conducted a survey in Kathmandu, Nepal. The first part of this survey consists choice of cars with four sets of cars, each set consists of five cars with attributes. In the second part, socio-demographic, travel characteristics, and environmental concerns of respondents were asked.

Table 3.3 Demographic profile of respondents

Demographics	Frequency	Percentage (%)
Gender		
Female	87	32.46
Male	181	67.54
Age		
Under 20	**10**	**3.73**
20-39	198	73.88
40-59	58	21.64
60 and above	**2**	**0.75**
Education		
Less than Bachelor	84	31.34
At least a bachelor	184	68.66
Family size		
Up to 4	114	42.54
Above 4	154	57.46
Income		
Low income (less than $5000)	122	45.52
Middle income ($5000 to $1000)	95	35.45
High Income (above $1000)	51	19.03
Monthly travel distance		
Up to 600km	191	71.27
Above 600km	77	28.73
Frequent mountain travel		
Yes	175	65.30
No	93	34.70
Vehicle available		
Yes	112	41.79
No	156	41.79

According to the transportation management directives of Nepal[4], a person should not be younger than 18 years in order to apply for a driving license for a small vehicle. But for the medium and large vehicles, the person should not be younger than 21 years. In addition, a person should not be older than 60 years for medium and large vehicles. The survey was carried out face to face interview in order to improve reliability. In total, 268 respondents provided the completed questionnaires resulting in 5360 observation. The statistics of respondents such as gender, age, education, family size, income, monthly travel distance, mountain travel, vehicle available, and environmental consideration are shown in table 3.3. More specifically, a frequency distribution of the age of the respondents that are participated in the survey is presented in figure 3.2. It indicates that most of the respondents were between 20 and 45 years of age. The survey questionnaire is presented in appendix A.

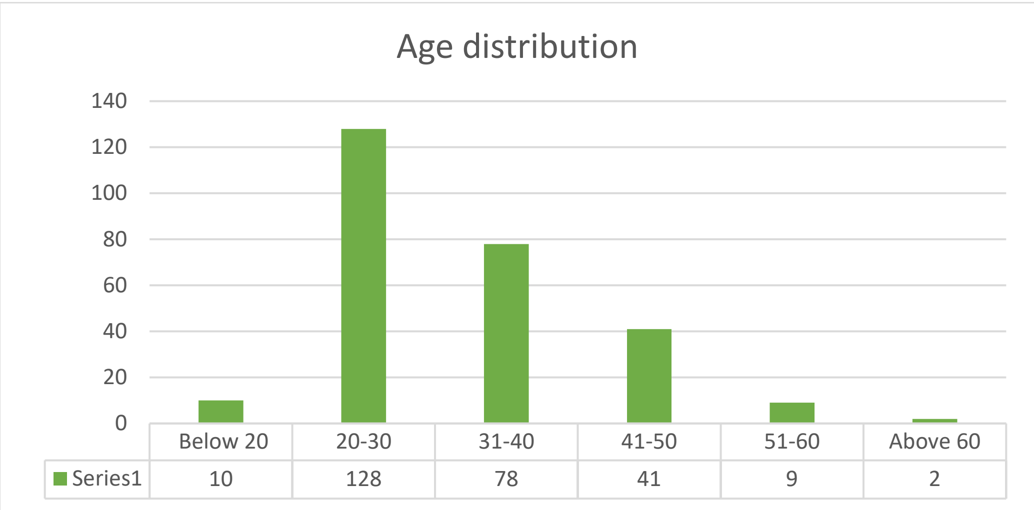

Figure 3.2 Frequency distribution of the age of respondents

[4] https://dotm.gov.np/en/act-regulationdirectives/

3.3 Model Specifications

3.3.1 Mixed Logit

Mixed logit model can reflect the heterogeneity of the consumers and highly flexible to accommodate other random utility models (McFadden & Train, 2000). It overcomes three limitations of logit model estimation; random taste variation, restricted substitution patterns, and correlation in unobserved factors (Train, 2009). The utility of person n from alternative j in the choice set t is given by equation (3.1).

$$\boldsymbol{U_{njt} = \beta_n x_{njt} + \varepsilon_{njt}} \quad (\mathbf{3.1})$$

Where $\boldsymbol{x_{njt}}$ is observed variables, β_n is a vector of coefficients of these variables and ε_{njt} random term with iid extreme value. Then the probability of a sequence of choices is given by equation (3.2)

$$\mathbf{S_n} = \int \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{\exp(\mathbf{x'_{njt}}\,\boldsymbol{\beta})}{\sum_{j=1}^{J} \exp(\mathbf{x'_{njt}}\,\boldsymbol{\beta})} \right]^{y_{njt}} \mathbf{f}((\boldsymbol{\beta}|\boldsymbol{\theta}))\, \mathbf{d}\boldsymbol{\beta} \quad (\mathbf{3.2})$$

Where $f\left(\frac{\beta}{\theta}\right)$ is the density function of β and y_{njt} = 1 if the individual chose alternative j in choice situation t and 0 otherwise. Allowing the coefficients to vary implies that we allow for the fact that different decision makers may have different coefficients. Then θ parameters can be estimated by maximizing the simulated log-likelihood function presented in equation (3.3).

$$\mathbf{SLL} = \sum_{n=1}^{N} \ln \left\{ \frac{1}{R} \sum_{r=1}^{R} \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{\exp(x'_{njt}\beta_n^r)}{\sum_{j=1}^{J} \exp(x'_{njt}\beta_n^r)} \right]^{y_{njt}} \right\} \qquad (3.3)$$

Where β_n^r is the r[th] draw for decision maker n from the distribution of β and R is total number of draws. In addition, the mixed logit model can be applied to estimate each respondent's coefficients. The expected value of β conditional choice pattern y_n and set of alternatives characterized by x_n for person n is given by equation (3.4).

$$E(\boldsymbol{\beta}|y_n, x_n) = \frac{\int \boldsymbol{\beta} \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{exp(x'_{njt}\beta)}{\sum_{j=1}^{J} xp(x'_{njt}\beta)} \right]^{y^{njt}} f(\boldsymbol{\beta}|\boldsymbol{\theta})\, d\beta}{\int \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{exp(x'_{njt}\beta)}{\sum_{j=1}^{J} xp(x'_{njt}\beta)} \right]^{y^{njt}} f(\boldsymbol{\beta}|\boldsymbol{\theta})\, d\beta} \qquad (3.4)$$

$E(\beta|y_n, x_n)$ can be estimated using simulation (Revelt & Train, 2000). For the detailed explanation of mixed logit model estimation please find in (Hole, 2007, 2013; Train, 2009).

3.3.2 Latent Class Model (LCM)

LCM resembles the mixed logit model and it is somewhat less flexible for random taste variation than mixed logit. However, it provides flexibility to the researcher that it does not require to have a prior assumption of distributions of coefficients. LCM treats coefficient parameters as a discrete one. This model is based on the fact that each consumer's choice depends on attributes and latent heterogeneity that is unobserved by the researcher. Instead, we can assume consumers can be categorized in Q classes, but a researcher does not know which consumer belongs to which class.

Details of LCM is presented in (Greene & Hensher, 2003). In this case, the sequence of choices' probability of respondent is given by equation (3.5)

$$\boldsymbol{S_n} = \sum_{q=1}^{N} \boldsymbol{H_{nq}} \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{\exp\left(\boldsymbol{x'}_{njt}\,\boldsymbol{\beta}_q\right)}{\sum_{j=1}^{J} \exp\left(\boldsymbol{x'}_{njt}\,\boldsymbol{\beta}_q\right)} \right]^{y_{njt}} \qquad (\mathbf{3.5})$$

Then the probability of respondent n belonging to class q can be specified as equation (3.6).

$$\boldsymbol{H_{nq}} = \frac{\exp(\boldsymbol{z'_n}\boldsymbol{\gamma_q})}{\sum_{q=1}^{Q} \exp(\boldsymbol{z'_n}\boldsymbol{\gamma_q})} \qquad (\mathbf{3.6})$$

Where z_n is a set of observable characteristics of respondents, can be also called class membership variables. The γ_Q parameter is normalized to zero to obtain the identification of the model (Greene, 2003). Then, log likelihood for this model is given by equation (3.7).

$$\boldsymbol{LL} = \sum_{n=1}^{N} \boldsymbol{ln} \left\{ \sum_{q=1}^{Q} \boldsymbol{H_{nq}} \prod_{t=1}^{T} \prod_{j=1}^{J} \left[\frac{\exp(\boldsymbol{x'}_{njt}\boldsymbol{\beta}_q)}{\sum_{j=1}^{J} \exp(\boldsymbol{x'}_{njt}\boldsymbol{\beta}_q)} \right]^{y_{njt}} \right\} \qquad (\mathbf{3.7})$$

Then β_q and Q-1 latent class parameters γ_q, can be estimated by maximizing the log-likelihood equation (3.7). For the details about LCM with its estimation procedure, the interested reader is referred to (Greene & Hensher, 2003; Pacifico & Yoo, 2013). In addition, previous studies with LCM, please refer to (Ferguson, Mohamed, Higgins, Abotalebi, & Kanaroglou, 2018; Khan et al., 2017; Kormos et al., 2018; Sheldon et al., 2017).

3.4 Results and Discussion

3.4.1 Mixed Logit Estimation

Mixed logit model estimation contains two part. Firstly, only the random coefficients of the attributes that describe the importance of the attributes. Secondly, interaction variables with BEV and PHEV that describe the effect of socio-demographic, travel characteristics, and environmental concerns on consumer preferences of EVs. It might be reasonable that most consumers do not prefer higher price, thus, we assumed the price attribute as log-normal distribution (Shim et al., 2018). However, all other attributes are considered normal distribution for the estimation. Coefficients are estimated based on maximum simulated likelihood (MSL) approach, same as maximum likelihood except that simulated probabilities are used (Train, 2009).

The results of attributes only model are presented in table 3.4. Internal combustion vehicle (ICV) was considered as a base to compare with BEV and PHEV. In general, the results to alternative specific attribute show that consumers prefer BEV and PHEV than ICV while all other variables remain constant. This implies that potential consumers have a clear distinct preference for EVs than gasoline/diesel vehicles in Nepal. As expected, infrastructure and range show a positive impact on purchase implying that consumers prefer an increase in the infrastructure and range. Likewise, results show the expected negative impact of fuel cost and purchase price; however, fuel cost is not statistically significant. Alternatively, we can say that consumers prefer lower purchase price and lower fuel cost. We also estimated the individual respondents' coefficients using sampling method explained by Train (Revelt & Train, 2000; Train, 2009), which can be used for simulation.

The respondents' socio-demographic, travel characteristics, and pro-environment behaviors are integrated into a mixed logit model by creating interaction variables with BEV and PHEV. Estimation result presented in table 3.5 shows BEV and PHEV coefficients are no more statistically significant. This is because interaction variables might explain the consumers' preferences for BEV and PHEV.

Only some of the interaction variables are statistically significant in our model. Results show male is less likely to buy PHEV than female. Smaller household tends to prefer BEV, which is the opposite result with the previous study (Qian & Soopramanien, 2011). This may reflect the limitations of the different size of BEV to accommodate a larger family.

Table 3.4 Estimation results of attributes only model

Mixed logit model				Number of observation	=	5360
Log likelihood = -1389.1308						
	Mean			**Standard Deviation**		
Variables	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
BEV	**3.242**	**0.323**	**0.000**	1.706	0.246	0.000
PHEV	**2.725**	**0.244**	**0.000**	-1.005	0.234	0.000
Infrastructure	**0.019**	**0.003**	**0.000**	-0.023	0.004	0.000
Range	**0.008**	**0.001**	**0.000**	-0.004	0.001	0.000
Fuel Cost	-0.042	0.030	0.156	0.186	0.039	0.000
Price	**-2.573**	**0.138**	**0.000**	0.687	0.154	0.000

With regard to the effect of travel characteristics, a person having lower monthly travel distance prefers BEV and PHEV. This may be because of a shorter travel distance would reduce range anxiety of EVs. Respondent had the intention to buy a new vehicle within the five years is more likely to purchase BEV. This indicates, there is a market potential of BEV among potential new vehicle buyers. The negative coefficient of vehicle available suggests that respondents are inherent to change their current vehicle fuel type to BEV.

Further, the demand of BEV and PHEV would be higher for individuals who consider the environmental impact while purchasing a vehicle. Environmentally aware vehicle consumers have an increased preference for EVs. This demands the environmental awareness policy campaign to accelerate the adaptation rate of EVs to environmentally unaware consumers. Furthermore, the result reveals high electric vehicle knowledge increases the probability of choosing BEV implying dissemination of information about the EV and their importance would significantly contribute to the adaptation. As expected, respondents working on energy/environment sector have a positive relationship to choose the PHEV.

3.4.1 Elasticity

Estimated coefficients of attributes imply a marginal change in utility, the changes in utility due to the attribute changed by one unit. However, units are different for attributes, the magnitude of coefficients are not directly comparable. Therefore, we considered estimating the elasticity effect. We used the following equation (3.8) for the estimation of elasticity (Y. Kim et al., 2007).

$$\boldsymbol{Elasticity} = \left(\frac{\Delta \boldsymbol{P}}{\Delta \boldsymbol{Q}}\right) * \frac{\boldsymbol{Q}}{\boldsymbol{P}} \qquad (\mathbf{3.8})$$

Where ∆P is changed in choice probability and ∆Q change in an attribute.

Table 3.5 Interaction model- Demographic, travel and environment behaviors

Mixed logit model	Number of observation = 5360					
	Mean			**Standard Deviation**		
Attributes	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
BEV	0.070	0.495	0.444	1.479	0.238	0.000
PHEV	-0.431	0.790	0.585	0.877	0.250	0.000
Infrastructure	**0.018**	**0.003**	**0.000**	**0.022**	**0.004**	**0.000**
Range	**0.007**	**0.001**	**0.000**	**0.146**	**0.040**	**0.000**
Fuel Cost	**-0.053**	**0.028**	**0.060**	**0.004**	**0.001**	**0.000**
Price	**-2.631**	**0.142**	**0.000**	**0.716**	**0.141**	**0.000**
	BEV			**PHEV**		
Interaction Variables	Coef.	Std. Err.	P>z	Coef.	Std. Err.	P>z
Gender (male)	-0.234	0.379	0.536	**-0.592**	**0.301**	**0.049**
Age (≤ 40 years)	-0.043	0.481	0.929	0.513	0.389	0.188
Education(≥ Bachelor)	-0.313	0.441	0.478	-0.193	0.354	0.585
Family (≤ 4 persons)	**0.633**	**0.369**	**0.087**	0.437	0.301	0.146
Middle Income	0.212	0.584	0.717	0.649	0.479	0.176
High Income	-0.629	0.464	0.175	0.251	0.373	0.500
Monthly travel distance (≤ 600 km)	**1.678**	**0.431**	**0.000**	**0.876**	**0.336**	**0.009**
Intention to buy new vehicle	**1.024**	**0.529**	**0.053**	0.590	0.421	0.161
Vehicle available	**-0.373**	**0.390**	**0.039**	0.015	0.316	0.962
Mountain travel	-0.015	0.395	0.970	0.155	0.323	0.331
Environment Consideration	**1.176**	**0.488**	**0.016**	**1.555**	**0.387**	**0.000**
Vehicle Knowledge (Medium)	0.106	0.640	0.869	0.210	0.504	0.677
Vehicle Knowledge (High)	**1.476**	**0.734**	**0.044**	0.318	0.581	0.584
Working (Energy/Environment)	-0.029	0.511	0.954	**0.669**	**0.418**	**0.100**

We have calculated elasticity with 50% change in each attribute in order to make an equal proportion. The elasticity results presented in figure 3.3 is calculated based on each attribute change of BEV and PHEV. We can see from figure 3.3 that purchase price is the most influential attribute followed by range for both BEV and PHEV. Alternatively, the reduction of the purchase price is most effective to increase consumers' likelihood to purchase BEV and PHEV. The result also indicates that a reduction in fuel cost has a moderate impact, and infrastructure development is the least effective.

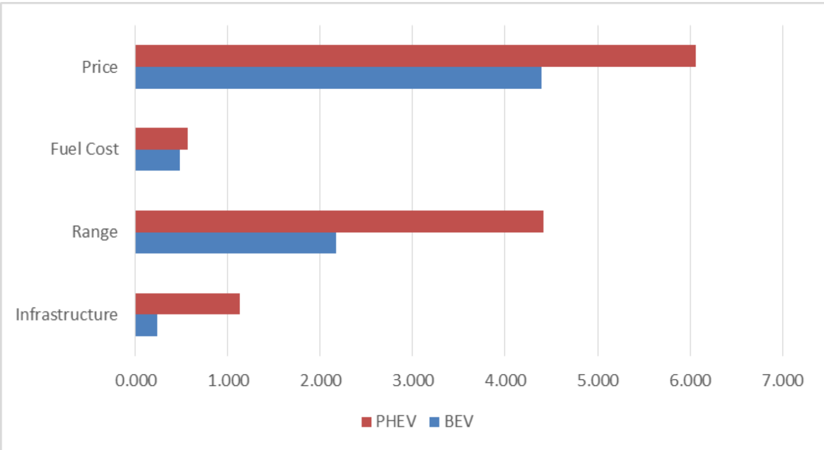

Figure 3.3 Elasticity calculation for each attribute

3.4.2 Market Simulations with Different Scenarios

In order to estimate the effects of the policy change and technological advancement, we conducted the market simulations on the BEV considering estimated individual coefficients from attributes only model. We formulated the base case scenario considering relatively realistic attributes based on Nepal's market. Scenario 1 introduces purchase subsidy in order to reduce the purchase price of BEV while other attributes remain constant from the base case. Scenario 2 considers infrastructure development such as charging stations and service stations for BEV and PHEV in percentage compared to the ICVs. The technological innovation of BEV is considered under scenario 3 as range increment. Policy mix scenario (mix of scenario 1 and scenario 3) is constructed as a scenario 4. Scenario 5 considers combining policies and technological innovation. Finally, scenario six is with EVs' attributes are the same with ICVs. The details of the six scenarios can be seen in Table 3.6.

Market simulations are based on the sample enumeration method from equation (3.9) (Y. Kim et al., 2007; Train, 2009).

$$\boldsymbol{Market\ share = \frac{1}{N} * \sum_{n=1}^{N} P_{ni}} \quad \mathbf{(3.9)}$$

Where P_{ni} is the probability that decision maker n chooses alternative i from a set of alternatives and N is a total number of decision makers.

Table 3.6 Scenarios with government intervention and technological innovation

Scenarios	Infrastructure (% ICV)	Range (km)	Fuel cost ($ /100km)	Price ($ 1000)
Base (Current- Realistic)				
ICV	100	500	15	20
BEV	10	150	10	32
PHEV	50	400	12	40
Scenario 1: Purchase subsidy ($10000) to BEV				
ICV	100	500	15	20
BEV	10	150	10	**22**
PHEV	50	400	12	40
Scenario 2: Infrastructure Development (BEV and PHEV)				
ICV	100	500	15	20
BEV	**50**	150	10	32
PHEV	**70**	400	12	40
Scenario 3: Technological innovation (BEV range= 300km)				
ICV	100	500	15	20
BEV	10	**300**	10	32
PHEV	50	400	12	40
Scenario 4: Policy mix (combinations of scenarios 1 and 2)				
ICV	100	500	15	20
BEV	**50**	150	10	**22**
PHEV	**70**	400	12	40
Scenario 5: Policy mix and innovation (Combination of scenarios 1,2 and 3)				
ICV	100	500	15	20
BEV	**50**	**300**	10	**22**
PHEV	**70**	400	12	40
Scenario 6: EVs' attributes same with ICVs				

The results are presented in table 3.7 show that in the base case (reference scenario), the market share of ICV is about 92.8%. The market share of BEV is only 2.3%, and for PHEV is about 4.9%. In the base case scenario, ICVs still dominate the vehicle market of Nepal.

Next to each scenario, the market share of BEV is increased. Purchase subsidy, infrastructure development, and technical innovation scenarios increased the market share of BEV. Scenario 4 (a combination of scenario 1 and 2) result shows that increased BEV market share is 3.10%, which is more than the sum of scenario 1 and 2 (3.10> 2.45+.20 = 2.55). This might be explained as a synergy effect of both policies. It would be a plausible argument that some consumers will adopt BEV only after reduced price and increased infrastructure. This tells us a combination of policies would be more effective than a single policy for the EV use in Nepal.

Further, we combined policies and innovation in scenario 5, BEV share is increased by 9.22%. We find that market share of BEV is 11.57% in scenario 5, this is worthwhile noting that a combination of policies and innovation would give more increment in market share of BEV than summed effect of each scenario (9.22 >2.45+.20+2.42=5.07). It might be explained that some potential consumers will give preference to BEV only after the technological innovation with supporting policies. Form scenario 6, EVs' attributes are same with ICV, the market share of EVs is about 59.60%.

Table 3.7 Results of market shares in different scenarios (%)

Scenarios	Predicted Market share			**Δ BEV Share**
	ICV	BEV	PHEV	
Base - Realistic	92.78	2.35	4.87	.
Scenario 1: Purchase subsidy	90.64	4.80	4.56	**2.45**
Scenario 2: Infrastructure Development	91.57	2.55	5.89	**0.20**
Scenario 3: Technological innovation	90.66	4.77	4.58	**2.42**
Scenario 4: Policy mix	88.97	5.45	5.58	**3.10**
Scenario 5: Policy mix and innovation	83.40	11.57	5.02	**9.22**
Scenario 6: EV attributes same with ICV	40.50	**30.40**	**29.10**	

Our simulation result is limited with changes in four attributes that we have considered for the consumer preferences survey. However, if we include other attributes such as battery replacement cost, and vehicle size, we might expect different results in simulation. In addition, we know that battery replacement costs in EVs, which are incurred every 3 to 5 years, is one of the important variables limiting preferences of EVs.

3.4.3 Latent Class Estimation

An optimal number of classes of consumers might not be known to the researcher, different statistical measures can be used to identify (Kormos et al., 2018). This study considers the Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) to determine an optimal number of classes (Pacifico & Yoo, 2013). Estimation was performed up to ten numbers of classes, estimated results for the BIC and AIC are reported in table 3.8. Log-likelihood function (LLF) value and number of parameters (Nparam) are also shown. CAIC and BIC are minimized in 3 class model. In the remainder of the latent class model estimation, our estimation and analysis focus on 3 class LCM.

Table 3.8 Latent class identification with BIC and CAIC

Classes	LLF	Nparam	AIC	BIC
2	-1439.83	15	2978.524	2963.524
3	**-1393.38**	**23**	**2938.352**	**2915.352**
4	-1371.06	31	2946.438	2915.438
5	-1356.86	39	2970.767	2931.767
6	-1347.33	47	3004.434	2957.434
7	-1328.27	55	3019.052	2964.052
8	-1331.05	63	3077.337	3014.337
9	-1320.44	71	3108.836	3037.836
10	-1307.04	79	3134.774	3055.774

Results of LCM with three classes are presented in table 3.9. We used socio-demographic variables (gender, age, education, family size, and income), travel characteristics (monthly travel distance, intention to buy a vehicle, availability of vehicle and frequent mountain travel), and environment concerns (environment consideration, electric vehicle knowledge, and working sector) to explain the class membership. Not all membership variables are statistically significant, only significant membership variables are explained. Results reveal three distinct groups of consumers exist and intuitive meaning for each class.

Class 1 is most receptive to BEV adaptation and its share is about 37.9%. This class has a positive coefficient for PHEV; however, less than the BEV. This class is least sensitive to infrastructure development for EVs. In addition, this class has a less strong preference for range increment compared to class 3. Membership results show that consumers having lower average monthly travel distance, environmental concern, and high electric vehicle knowledge are more likely to be in class 1. Further, consumers having high income and current vehicle ownership are less likely to be in class 1.

Table 3.9 shows class 2 is most receptive to PHEV preference and its share is about 32.4%. Results tell that this class is least sensitive to price and range. Membership variables results tell that consumers having lower monthly travel distance and frequent mountain travel are likely to be in class 2. Likewise, gender (male) consumers are less likely to be in this class. Consumers those need to travel frequently to the mountain might compensate range anxiety and limitation of infrastructures by choosing PHEV, as PHEV offers a choice of fuels. PHEVs have both internal combustion engine for gasoline and an electric motor for the battery.

Class 3 shares about 29.7% and have less preference for BEV and PHEV compared to class 1 and 2. Results tell this class is the most sensitive to price, infrastructure, and range. This implies this group is mostly attributes oriented group. This class is referenced in our estimation. Consumers having low income, longer average monthly travel distance, the current owner of the vehicle, and limited knowledge about EVs and theirs's environmental benefits are more likely to be in class 3. In summary, results show that class 1 seems to BEV oriented, class 2 as a PHEV oriented, and class 3 as attributes oriented. Class 3 consumers demand environmental awareness and knowledge of EVs in order to increase their preference for PHEV and BEV.

Table 3.9 Class membership model parameters: Class3 = Reference class

	Class 1		Class 2		Class 3	
Attributes	Coef.	P>z	Coef.	P>z	Coef.	P>z
BEV	**4.055**	**0.000**	**2.695**	**0.000**	1.296	0.167
PHEV	**2.021**	**0.000**	**3.532**	**0.000**	**1.522**	**0.015**
Price	**-0.097**	**0.000**	**-0.042**	**0.010**	**-0.111**	**0.000**
Infrastructure	**0.006**	**0.100**	**0.014**	**0.012**	**0.028**	**0.000**
Fuel cost	-0.057	0.134	0.006	0.932	-0.076	0.386
Range	0.007	0.000	0.005	0.000	0.009	0.000
Class Share	**0.379**		**0.324**		**0.297**	
Class membership Variables						
Gender	-0.327	0.468	**-1.564**	**0.008**	-	-
Age (≤ 40 years)	-0.555	0.306	-0.295	0.640	-	-
Education(≥ Bachelor)	-0.416	0.453	-0.486	0.440	-	-
Family (≤ 4 person)	0.424	0.325	0.072	0.884	-	-
Middle Income	-0.105	0.871	0.346	0.637	-	-
High Income	**-0.982**	**0.065**	-0.445	0.437	-	-
Monthly travel distance (≤ 600 km)	**1.730**	**0.000**	**1.239**	**0.023**	-	-
Intention to buy new vehicle	0.690	0.302	0.376	0.597	-	-
Vehicle available	**-0.660**	**0.036**	-0.359	0.482	-	-
Mountain travel	-0.124	0.800	**0.492**	**0.067**	-	-
Environment Consideration	**1.203**	**0.023**	14.652	0.855	-	-
Vehicle Knowledge (Medium)	0.014	0.985	-0.188	0.839	-	-
Vehicle Knowledge (High)	**1.460**	**0.087**	0.455	0.656	-	-
Working (Energy/Environment)	-0.218	0.738	0.558	0.395	-	-
Constant	-1.291	0.281	-13.718	0.864	-	-

3.5 Conclusion

Nepal does not have any fossil fuel reserves such as coal, natural gas, and petroleum. The country has a high potential for hydropower. The share of petroleum products could be reduced if the country can increase its hydroelectricity production (Ministry of Finance, 2019). This scenario shows that the use of EVs can not only provide environmental benefits but also reduce the imports of oil for Nepal.

Thus, this study explored consumer preferences analysis for EVs. Stated preference data were obtained through a survey using the conjoint method in Nepal. Then, the mixed logit model is used for the estimation. We find potential vehicle users, in general, prefer BEV and PHEV compared to ICV in Nepal. Moreover, the results show that consumers have positive preferences towards infrastructure development and range increment. As expected, the negative coefficient for the purchase price and fuel cost indicating a preference towards the lower purchase price and lower fuel cost.

Further, the mixed logit model with the interaction of socio-demographic, travel characteristics, and environmental concerns are analyzed. The result indicates that potential consumers having small family size, lower monthly travel distance, environmental awareness, and electric vehicle knowledge are more likely to adopt the EVs. But, current vehicle users are inherent to adopt BEV and PHEV.

Our elasticity estimation suggests that the reduction of the purchase price is most effective to increase consumers' likelihood to purchase BEV and PHEV. Then, range increment is found a second important attribute. In addition, results also tell that fuel cost reduction and infrastructure development is moderately important attributes in terms of the increased likelihood of choosing BEV and PHEV.

Market simulations with different scenarios suggest that policies mix scenario is effective than single policy support for EVs. Our findings also suggest that technological innovation with multiple policies could be more effective to increase the market share of EVs. Furthermore, just improvement in one attribute might not significantly contribute to increasing demand for EVs.

Another key feature of our study is that a latent class model estimation in order to identify and analyze latent heterogeneity among potential consumers. This model's estimation suggests three distinct class of consumers exist in Nepal implying significant heterogeneity among potential vehicle users. Result suggests that class 1 is most receptive to BEV which accounts for about 38% consumers. Class 1 tends to include consumers with lower monthly travel distance, awareness of EVs and, pro-environmental behavior. Results clearly indicate that proper information flow to potential consumers about EVs and its environmental benefits should be one approach to stimulate the market demand for EVs.

Consumers belonging to class 2 insight a higher probability to choose PHEV and can be called a PHEV oriented group. These group of consumers are least sensitive to purchase price and limited range problem. Consumers having frequent mountain travel likely to be in this PHEV oriented group. PHEV might provide an alternative to accommodate the range of anxiety and infrastructure barriers compared to BEVs. Moreover, class 3 consumers are attributes oriented and have less preference for BEV and PHEV than class 1 and 2. Low-income, higher monthly travel distance, and unaware of EVs lead to consumers to be in class 3. It might be concluded that this group needs more environmental awareness and information flow to stimulate EVs demand. We believe that awareness campaign policy must be targeted to this class of consumers.

The results of this study would be an insightful background to the policymakers and automakers. We expect this study provides some fundamentals for the consideration while formulating different policies from the government. Market simulations with a number of scenarios could provide relevant information to decision makers while designing different strategies in order to accelerate the market demand of BEV and PHEV. We acknowledge that our estimation is based on the stated preference hypothetical choice experiment method, which can be compared to revealed preference in the future. However, this study contributes in-depth knowledge of the attributes and socio-demographic, environmental concerns, and travel characteristics variables affecting the demand for EVs. Finally, our estimation is based on the current market based stated preference approach. As time being, consumers might be better informed, and technical innovation could be achieved, preference will be changed in the future.

Chapter 4. Analysis of Barriers against Electric Vehicle Use in Nepal

4.1 Introduction

As the name suggests, electric vehicles (EVs) run either fully or partially on electric energy supplied by the electric grid. EVs mainly comprise battery electric vehicles (BEVs) and plug-in electric vehicles (PHEVs). BEVs run on electric energy charged by plugging the vehicle into a source of electricity or an electric grid. The energy is stored in batteries. They do not consume any petroleum-based fuels. However, PHEVs use batteries to store the electrical energy from the grid and use petroleum-based fuels to power their combustion engines. EVs can be considered as an alternative to conventional vehicles (CVs), which use a combustion engine, burn petroleum-based fuels, and thus emit greenhouse gases (Egbue & Long, 2012).

Worldwide, the transportation sector is gradually maturing to respond to environmental issues and energy security concerns (Tsita & Pilavachi, 2012). In response to climate change, many nations are considering the adoption of EVs. However, their diffusion rates vary widely. A single policy cannot aid such diffusion; rather, a mixture of enabling policies, bearing in mind the context of the country, is likely to be effective for the widespread diffusion of EVs. Such policies should consider important aspects such as the development of EV charging infrastructure, tax rebates, and subsidies for purchasing EVs (Steenberghen & Lopez, 2008; Yong & Park, 2017).

Despite the considerable benefits of EVs, many barriers have been reported against their wider acceptance. One of the reasons for this slow uptake relates to consumer perceptions about EVs (Rezvani, Jansson, & Bodin, 2015; Schuitema, Anable, Skippon, & Kinnear, 2013); the penetration of EVs is significantly dependent on user acceptance. Likewise, travel behavior, government policies and support, higher pricing compared to CVs, limits with regard to the driving distance with a single charge, and economic and unaware of environmental issues are key detrimental factors affecting the uptake of EVs (Vassileva & Campillo, 2017). Adequate public charging networks, government planning, awareness raising, and enabling laws could foster the diffusion of EVs (Broadbent et al., 2018). Even though EV manufacturer has progressed in technological terms, manufacturers still limit EV production due to their higher battery price and performance issues (Quak et al., 2016). Conflicts of interest between stakeholders and poor implementation limit the development of EV-related standards and infrastructure necessary for their diffusion (Xue et al., 2014). The relatively higher price of an EV compared to that of a CV serves as a crucial barrier; however, environmental benefits could be the main enabler for EV uptake among consumers (Van Der Straten et al., 2007). Addressing these barriers is crucial to the diffusion of EVs.

Some of these barriers are common globally and others tend to be country-specific (Haddadian et al., 2015; Onat et al., 2017). For instance, countries might differ in terms of potential for EV uptake depending on their economic situation and geographic conditions (L.P. Ghimire & Kim, 2018). Thus, the results of a particular study may not necessarily apply to another country; a country-specific analysis is important. The primary objective of this study is to identify the various barriers against the diffusion of EVs in Nepal. This study was conducted via an extensive literature review with regard to EV deployment in Nepal. Analyses of reports and policies, as well as interactions with stakeholders, formed the foundation of this review. Seventeen specific barriers were identified and then categorized into five categories, namely, social, technical, infrastructure, financial, and policy. The analytical hierarchy process (AHP) was used to estimate the importance of the barriers and rank them (T. L. Saaty, 1980). AHP is a multi-criteria decision method and a popular tool for formulating and analyzing factors or decisions. It is used to rank alternatives by identifying criteria weights through the pairwise comparison method. The comparison values may be sourced from surveys or opinions of experts in the relevant field by using a fundamental nine-point scale (Buwana, Hasibuan, & Abdini, 2016; Ramanathan, 2006; Tsita & Pilavachi, 2012; Velasquez & Hester, 2013).

4.2 Literature Review

Traditionally, most transportation modes are highly dependent on fossil fuel consumption, which accounts for approximately 22% of carbon dioxide emissions worldwide (IEA, 2012). EVs have been receiving increasing attention as an alternative to lower carbon dioxide emissions attributable to the transportation sector (Vassileva & Campillo, 2017). Thus, given the urgent need to undertake climate change mitigation efforts, nations have adopted different policies to stimulate the uptake of EVS (Brady & O'Mahony, 2011). However, such policy instruments are not consistent and differ from one country to another. Thus, the use of BEVs and PHEVs varies globally (Christensen, Wells, & Cipcigan, 2012; Wikström, Hansson, & Alvfors, 2016). Nonetheless, market penetration is still very low compared to CVs due to the various cost and non-cost factors (Yavuz, Oztaysi, Onar, & Kahraman, 2015). The amount of emissions reduction due to EVs mainly depends on the source of electricity generation, that is, the source used to charge the batteries of EVs

(Haddadian et al., 2015; Krupa et al., 2014; Lewis, Kelly, & Keoleian, 2012; Samaras & Meisterling, 2008). Distributed or isolated energy can be used by EVs to store energy produced from renewable energy sources such as solar and wind power (Bellekom, Benders, Pelgröm, & Moll, 2012).

Previous studies reported different kinds of barriers against EVs uptake in the market. Sovacool & Hirsh (2009) pointed out that while decision makers and technologists recognize the importance of both technical and social barriers, the latter are likely to pose bigger challenges, and thus, it would be prudent to analyze socio-technical barriers jointly to enable the adoption of EVs. Yong & Park (2017) identified the factors affecting the adoption of EVs using a fuzzy set procedure. The authors concluded that economic issues and charging infrastructure should be included by governments in the consideration of financial and tax exemption policies. Prior works have highlighted many concerns, such as poor distance range, lack of recharging networks, long charging times, expensive purchase price, fuel cost, as well as brand and model availability (Figenbaum, Kolbenstvedt, & Elvebakk, 2014; Geels, 2002; Lane & Potter, 2007). Thomas Stevens (2013) ranked non-cost barriers and showed that limited awareness is the most important factor affecting EV uptake, followed by the perceptions of users, standardization limitations, lack of different models, and absence of enabling regulations. A similar study by Browne, Mahony, & Caulfield (2012) classified non-cost barriers into six categories: commercial, administrative and institutional, public acceptance, regulatory or legal, policy failures, and infrastructure-related. Another study classified barriers across three categories only: technological developments, fueling infrastructure availability, and elements of institutional infrastructure (Farla, Alkemade, & Suurs, 2010). Improvement in technical performance was cited as a crucial factor to overcome behavioral, cultural, infrastructure-related, and economic barriers (Gan, 2003).

Previous research on the transportation sector has used AHP. Tsita & Pilavachi (2012) evaluated the best alternative fuels for the transport sector using AHP while considering cost and policy criteria. Buwana et al. (2016) studied the selection of a sustainable transportation system using AHP and considering social, economic, and environmental aspects, and they reported the social aspect as the main deciding factor. Likewise, Zhang et al. (2016) used the fuzzy AHP to analyze the future of fuel cell vehicles in the Chinese market and reported that fuel availability, vehicle performance, and economic costs are the most important features with regard to vehicle selection. Ghimire & Kim (2018) also applied the AHP method to rank the barriers against renewable energy development in Nepal and found economic and policy barriers to be the most important categories. While their study is specific to EVs, some of the barriers considered by them share common ground with renewable energy development.

4.3 Identification of Barriers

The diffusion of EVs in Nepal depends on several real and perceived barriers. As noted previously, these barriers were identified through a thorough literature review, including analysis of relevant online content, previously published studies, and interactions with stakeholders such as EV manufacturers, policymakers, technical experts, consumers/users, and related institutions. This approach resulted in the identification of 17 barriers relevant to EV diffusion in Nepal. Then, the barriers were classified into five categories based on the nature of barriers explained in some previous studies (Browne et al., 2012; Buwana et al., 2016; L.P. Ghimire & Kim, 2018; Heo, Kim, & Boo, 2010; Tsita & Pilavachi, 2012): technical, policy, economic, infrastructure, and social. Browne et al. (2012) suggest that barriers to sustainable transportation can be divided into seven main criteria; however, this study dropped the policy failure criteria, and administrative and legal or regulatory are combined into policy category. Notably, a previous study concerning renewable energy development in Nepal had classified the identified barriers into six categories (L.P. Ghimire & Kim, 2018); however, the current study does not consider the administrative nature of barriers as EVs are new to the Nepalese market and the vehicle industry is currently run by private companies. The barriers and their respective classifications are presented in Table 4.1. Brief descriptions of each category of barrier appear in Sections 4.3.1–4.3.5.

4.3.1 Technical Barriers

Technological advancements in the vehicle industry can play a crucial role in emission reduction and the energy efficiency of vehicles (Gan, 2003). Lack of standardization, limited availability, lack of model choices, and performance issues are important factors for the diffusion of EVs (Schuitema et al., 2013; Xue et al., 2014). EVs are relatively new compared to CVs, and their quality can be compromised by financial constraints at the manufacturing stage. The four technical barriers identified in this study for Nepal are explained below.

4.3.1.1 Limited Range (one-time travel distance at full charge)

EV batteries must be charged for the vehicle to run and their storage capacities determine the distance that can be traveled on a single charge. One of the major user concerns for EVs is range anxiety (Bonges III & Lusk, 2016; Franke, Neumann, Bühler, Cocron, & Krems, 2012; Jensen, Cherchi, & Mabit, 2013). Users who do not need to travel long distances for their daily routines are likely to show more interest in EVs (Quak et al., 2016). Thus, limited range can be considered as an important technical barrier.

4.3.1.2 Lack of Evidence on Reliability and Performance

EVs are a relatively new technology compared with CVs, and potential users tend to be concerned about their technological performance, which increases their unwillingness to use EVs (Quak et al., 2016). Lack of performance is known to affect user perception of BEVs (Carley, Krause, Lane, & Graham, 2013), whereas system stability is an important detrimental factor against increased deployment of EVs (Xue et al., 2014). Thus, lack of evidence regarding reliability and performance can be considered as another technical barrier.

4.3.1.3 Limited Battery Life

EVs run on the power provided by charged batteries. However, the typical warranty for an EV battery lasts three to five years only. The batteries are also sensitive to overcharging, which poses a problem to EV users (Pelletier, Jabali, & Laporte, 2014; Taefi et al., 2014). Limited battery life requires frequent replacements, which is a major burden on EV users (Cairns & Albertus, 2010; Haddadian et al., 2015).

4.3.1.4 Fewer EV Models

EV uptake is affected by the limited number of design models. A wider range of car models can appeal to a broader consumer segment (Energy, 2013; Lutsey, Searle, Chambliss, & Bandivadekar, 2015). Thus, limited EV model availability poses another challenge in that it narrows down choices for users (Haddadian et al., 2015; Quak et al., 2016). The EV manufacturing industry is responsible for the research, development, and production of EVs. However, the production of different EV models is typically limited (Xue et al., 2014).

4.3.2 Social Barriers

Social factors, particularly consumer understanding of the attributes of EVs, are being recognized as significant influencing variables for users choosing EVs over CVs. Communication of related information is crucial in this regard (Cherchi, 2017). Egbue & Long (2012) reported that social barriers may pose obstacles equivalent to technical factors with regard to the adoption of EVs. Consumer knowledge, experience, environmental considerations, and perceived quality of EVs affect a consumer's decision to purchase EVs. This study considers the following three social barriers against EV diffusion in Nepal.

4.3.2.1 Lack of Knowledge on EVs

Market failures can occur when users have incomplete information about a product. Thus, correct information provision is crucial to aid the transition towards products such as EVs (Broadbent et al., 2018; M Rogers, 1983). Potential users' awareness of the benefits of an EV, financial incentives, infrastructure availability, and potential fuel-related savings are likely to be essential factors affecting the uptake of EV (Sovacool & Hirsh, 2009). Notably, this barrier is limited to the provision of general information about EVs to potential users. It does not consider users' understanding of the product quality of EVs.

4.3.2.2 Lack of Environmental Awareness Regarding EVs

Emission reduction is one of the key advantages of using EVs. Ninety-eight percent of electricity is generated from the hydropower in Nepal, which is emission-free.

However, consumers are often uncertain about the possible emission reductions due to EVs, and at times, they are environmentally unaware about the possible harm caused by greenhouse gas emissions due to the use of CVs (Haddadian et al., 2015). Environmental awareness regarding EVs enhances adaptation rate of EVs (M.-K. Kim, Oh, Park, & Joo, 2018).

4.3.2.3 Consumers' Limited Understanding of the Product Quality of EVs

Consumers' perceptions of the quality of EVs as a product may influence their decision to purchase EVs. Uninformed or wrongly informed consumers are likely to be unwilling to purchase EVs (Carley et al., 2013). Actual versus perceived product quality limitations such as those related to performance/reliability, range capacity, and other technical issues may create a perception gap among potential EV users (Haddadian et al., 2015). Thus, it appears that consumers must be informed about the quality of EVs as this particular social factor serves as a prerequisite for their acceptance. Notably, this barrier is limited to product quality concerns about EVs as this technology is relatively new in the Nepalese market.

4.3.3 Economic Barriers

CVs enjoy an economic advantage, which increases consumer resistance to purchasing EVs, which are typically priced higher (Mock & Yang, 2014). This relative advantage (i.e., the lower purchase price of internal combustion vehicles) is recognized as a major barrier against the uptake of EVs (Van Der Straten et al., 2007; Weiller & Neely, 2014). Other economic factors such as battery replacement cost, fuel cost, and access to credit can be considered as disadvantageous to the diffusion of EVs. Many countries now provide different kinds of financial incentives to create a competitive market for EVs. These experiences have proved that economic barriers can be addressed to a certain extent through such incentives (M.-K. Kim et al., 2018; Lévay, Drossinos, & Thiel, 2017). This study identified four economic barriers against the diffusion of EVs in Nepal.

4.3.3.1 Higher Purchase Price

Consumers view the higher purchase price of EVs as a major concern (Allcott & Wozny, 2014; Mock & Yang, 2014). Subsidizing EV purchase is becoming a popular tool in many countries to promote their diffusion. PHEVs tend to be even costlier due to the complexity of their dual operations (Axsen, Burke, & Kurani, 2008; Livay, Drossinos, & Thiel, 2017).

4.3.3.2 Battery Replacement Cost

As mentioned previously, the battery life of an EV is limited to three to five years (Pelletier et al., 2014; Taefi et al., 2014), and the consumer must bear the cost burden of its replacement. This aspect serves as a key barrier against EV uptake (Nykvist & Nilsson, 2015). Previous research has also pointed out that the cost of the battery accounts for a significant proportion of an EV’s total purchase price (Egbue & Long, 2012; Lemoine, Kammen, & Farrell, 2008).

4.3.3.3 Higher Electricity Price for Charging

EVs utilize electrical energy to run compared to CVs, which use petrol or diesel. Consumers are sensitive to the cost of fuel, and thus, a higher electricity price reduces demand for EVs (Tanaka et al., 2014; Y. Zhang, Yu, & Zou, 2011). The daily operating cost of an EV is mainly dependent on the electricity price for charging the

EV, and thus, lower electricity prices could persuade potential EV users to purchase an EV.

4.3.3.4 Lack of Credit Access for EVs

Consumers are hesitant to invest in new technologies as they typically pose some measure of risk, and therefore, policymakers can play a vital role by facilitating the purchase of EVs by providing users subsidized interest rate credit mechanisms (Wikström et al., 2016). Difficulty in obtaining credit access due to a weak or absent credit mechanism serves as another barrier against the diffusion of EVs (Gan, 2003).

4.3.4 Infrastructure Barriers

In the transportation sector, the lock-in possibility is relatively high for new technologies such as EVs, which are dependent on the available infrastructure for charging. Thus, the absence of sufficient infrastructure will create a negative network externality for the deployment of EVs (Xue et al., 2014). Private vehicle manufacturers are of the view that construction of the relevant infrastructure, such as charging stations and repair maintenance workshops, should be undertaken solely by the government, and vice versa (Sovacool & Hirsh, 2009). This study identified three specific infrastructure-related barriers for Nepal, as explained below.

4.3.4.1 Lack of Charging Stations

A sufficient number of charging stations is a prerequisite for EV diffusion. Lower numbers of charging networks have been recognized as a limiting factor for consumers to buy EVs (Egbue & Long, 2012; Harrison & Thiel, 2017; M.-K. Kim et al., 2018). The public and private sectors are reluctant to invest in the charging stations as the number of EV users are still insufficient, and conversely, potential EV users hesitate from purchasing an EV due to the insufficient number of charging stations (Bonges III & Lusk, 2016; Haddadian et al., 2015).

4.3.4.2 Lack of Repair and Maintenance Workshops

Current EV owners are disappointed about the low number of support centers or workshops for EV repair and maintenance in comparison to those for CVs (Quak et al., 2016). Further, EV-related repair and maintenance procedures can be complicated, and only a few trained mechanics are available to fix such issues when they arise (Ninh, Bentzen, & Laugesen, 2014).

4.3.4.3 No Domestic Industry

Sierzchula et al. (2014) showed that the EV adaptation is correlated to local vehicle production facilities, and that consumers' confidence in a product can increase provided the industry is well-established in the country/region and they are assured that their complaints will be resolved should a problem occur with the product. Notably, Nepal does not have a domestic EV production industry at this time, and therefore, this lack of industry can be viewed as an infrastructural barrier.

4.3.5 Policy Barriers

In Nepal, EVs are regarded as a relatively new technology compared to CVs. However, a complete policy framework for EVs in Nepal is still under discussion among various stakeholders (policy makers, users, manufacturers, and other relevant experts). The government can implement different policies to encourage the uptake of EVs, including awareness raising, tax exemption, and long-term goal-based planning (Hussey et al., 2013; Vergis, Turrentine, Fulton, & Fulton, 2014). A recent study conducted by Harrison and Thiel (Harrison & Thiel, 2017) pointed out that purchase subsidies may not be able to increase EV adoption in the absence of an effective policy package and political willingness.

We did not include lack of the subsidy or grant policy because higher purchase price mentioned in economic barriers might be correlated. In other words, if there is subsidy or grant policy, purchase price will be lower. Thus, Some policies (such as subsidies and tax exemption) might be related to economic barriers, but given that EVs are new to Nepal, the absence of a comprehensive policy framework cannot be overlooked. This study identified three policy barriers against the uptake of EVs in Nepal.

4.3.5.1 Lack of Long-term Planning and Goals on the Government's Part

Governments should connect the increase in EV usage at the national level to their respective sustainable development visions (Rotmans et al., 2001). Long-term planning and goal development by the government could foster faster EV diffusion. Appropriate legislation geared toward the provision of a sufficient number of charging networks, government procurement strategies, environmental awareness, subsidized purchasing, and the like should be included in long-term plans and goals for accelerated EV uptake (Broadbent et al., 2018). Given that EV diffusion is still in its nascent stage in Nepal, the lack of long-term planning and goal setting by the government is an important policy barrier.

4.3.5.2 Absence of an Annual tax Exemption Policy

Vehicle owners pay mandatory annual vehicle, road, and route permit taxes. Providing such tax benefits to users can help the diffusion of EVs over their conventional counterparts (Council, 2013; Farla et al., 2010; Gallagher & Muehlegger, 2011; Steenberghen & Lopez, 2008). Currently, Nepal does not exempt EV owners from such taxes[5].

4.3.5.3 Absence of Awareness Raising about EVs

According to Rogers, the diffusion of any new technology can be accelerated by providing potential users the needed information about the technology (M Rogers, 1983). Educational programs, advertisements, and media communications can play a crucial role in the diffusion of EVs (Broadbent et al., 2018). Thus, designing and implementing awareness-raising campaigns is crucial to foster the diffusion of EVs in Nepal. Such campaigns are likely to reduce consumers' hesitation about purchasing EVs. As EVs are new to Nepal, this study considered the absence of awareness raising as a policy barrier against diffusion of EVs in the country.

[5] https://www.dotm.gov.np/en/ Tax rate for Fiscal year 2075/76

Table 4.1 Summary of barriers to electric vehicles adoption in Nepal

Categories	**Barriers**	**Literature Reference**
Technical Barriers	Limited range (one-time travel distance at full charge)	(Bonges III & Lusk, 2016; Jensen et al., 2013; Quak et al., 2016)
	Lack of evidence on reliability and performance	(Carley et al., 2013; Quak et al., 2016; Xue et al., 2014)
	Limited battery life	(Cairns & Albertus, 2010; Haddadian et al., 2015; Pelletier et al., 2014; Taefi et al., 2014)
	Fewer EV models	(Energy, 2013; Haddadian et al., 2015; Lutsey et al., 2015; Quak et al., 2016)
Social Barriers	Lack of knowledge on EVs	(Broadbent et al., 2018; M Rogers, 1983)
	Lack of environmental awareness regarding EVs	(Haddadian et al., 2015; Mairesse, Macharis, Lebeau, & Turcksin, 2012)
	Consumers' limited understanding of the product quality of EVs	(Carley et al., 2013; Haddadian et al., 2015)

Economic Barriers	Higher Purchase price	(Allcott & Wozny, 2014; Axsen et al., 2008; Mock & Yang, 2014)
	Battery replacement cost	(Egbue & Long, 2012; Lemoine et al., 2008; Nykvist & Nilsson, 2015; Pelletier et al., 2014)
	Higher electricity price for charging	(Tanaka et al., 2014)
	Lack of credit access for EVs	(Gan, 2003; Wikström et al., 2016)
Infrastructure Barriers	Lack of charging stations	(Bonges III & Lusk, 2016; Egbue & Long, 2012; Haddadian et al., 2015)
	Lack of repair/maintenance workshops	(Ninh et al., 2014; Quak et al., 2016)
	No domestic industry	(Sierzchula et al., 2014)
Policy Barriers	Lack of long-term planning and goals on the government's part	(Broadbent et al., 2018; Rotmans et al., 2001)
	Absence of an annual tax exemption	(Council, 2013; Farla et al., 2010; Gallagher & Muehlegger, 2011; Steenberghen & Lopez, 2008)
	Absence of awareness raising about EVs	(Broadbent et al., 2018; M Rogers, 1983)

4.4 Method

4.4.1 Analytical Hierarchy Process (AHP)

AHP is used to estimate subjective judgment while making decisions or ranking factors/barriers. Thus, it is a decision-making model that analyzes the hierarchical structure of a research problem. In AHP, comparative values can be sourced either from an expert survey or from actual measurements using a nine-point fundamental scale (L.P. Ghimire & Kim, 2018; R. W. Saaty, 1987; T. L. Saaty, 1990, 1994; Wind & Saaty, 1980).

Step I: The goal of this research is to rank the abovementioned barriers. Accordingly, the hierarchical tree was formulated considering the 17 barriers within their respective classifications (i.e., 5 categories). This step decomposes the decision-making problem into a hierarchical structure (T. L. Saaty, 1994). Figure 4.1 shows the hierarchical tree for ranking the barriers.

Step II: Pairwise comparison questionnaires, presented in appendix B, were formulated with respect to the goal of the study as well as the categories of the barriers. These questionnaires were provided to experts in the field to obtain their views on a nine-point scale (R. W. Saaty, 1987).

Step III: Based on the experts' opinions collected through the survey in Step II, a comparison matrix was created at the category level with respect to the goal of the study, and at barrier level with respect to each category. Next, the combined comparison matrix was created by using the geometric mean of all the respondents' opinions (T. L. Saaty, 1986).

Step IV: At this stage, the weights for each category of barriers and specific barriers within each category were estimated using the formula $Aw = \lambda max \times w$, where A is the comparison matrix or priority matrix, w is the eigenvector (also called the priority weight), and λmax is the maximum eigenvalue (T. L. Saaty, 1994). The maximum eigenvalue and eigenvector can be obtained by solving the principle eigenvector. Various approximation methods exist, and one of the easier ways is to normalize the rows of the combined comparison matrix (R. W. Saaty, 1987).

Step V: The final step involves calculating the consistency of the estimation.

$$CI = (\lambda max-n)/(n-1)$$

Where CI is the consistency index and a zero CI value denotes perfectly consistent judgment among all respondents. However, some inconsistencies are acceptable.

$$CR = CI/RI$$

Where CR is the consistency ratio, and RI is the random index. The standard values of RI are shown in table 4.2. CR ≤ 0.1 denotes an acceptable range (Day & Wensley, 1983).

Table 4.2 Random index (RI) values

Criteria Numbers	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.40	1.49

Source: (T. L. Saaty, 1994)

4.4.2 Survey and Data

This study considered experts working in the fields of energy, environment, and transport in the government sector. Experts in vehicle-related institutions, as well as people using a vehicle or intending to use one, were also considered. We expected experts from the energy and environment sectors to be aware of the importance of EVs to a better extent than a layperson. The respondents were provided detailed information about the barriers against the diffusion of EVs in Nepal, and were requested to compare all the barriers in terms of their perceived importance on the aforementioned nine-point scale. We requested more than 60 experts to participate in the survey. We received 53 complete and consistent datasets for the estimation. Among these 53 respondents, 19, 19, and 15 belonged to the energy, energy and environment, and government sectors respectively. Thirty-four respondents were conversant with using a vehicle, and 19 intended to buy one.

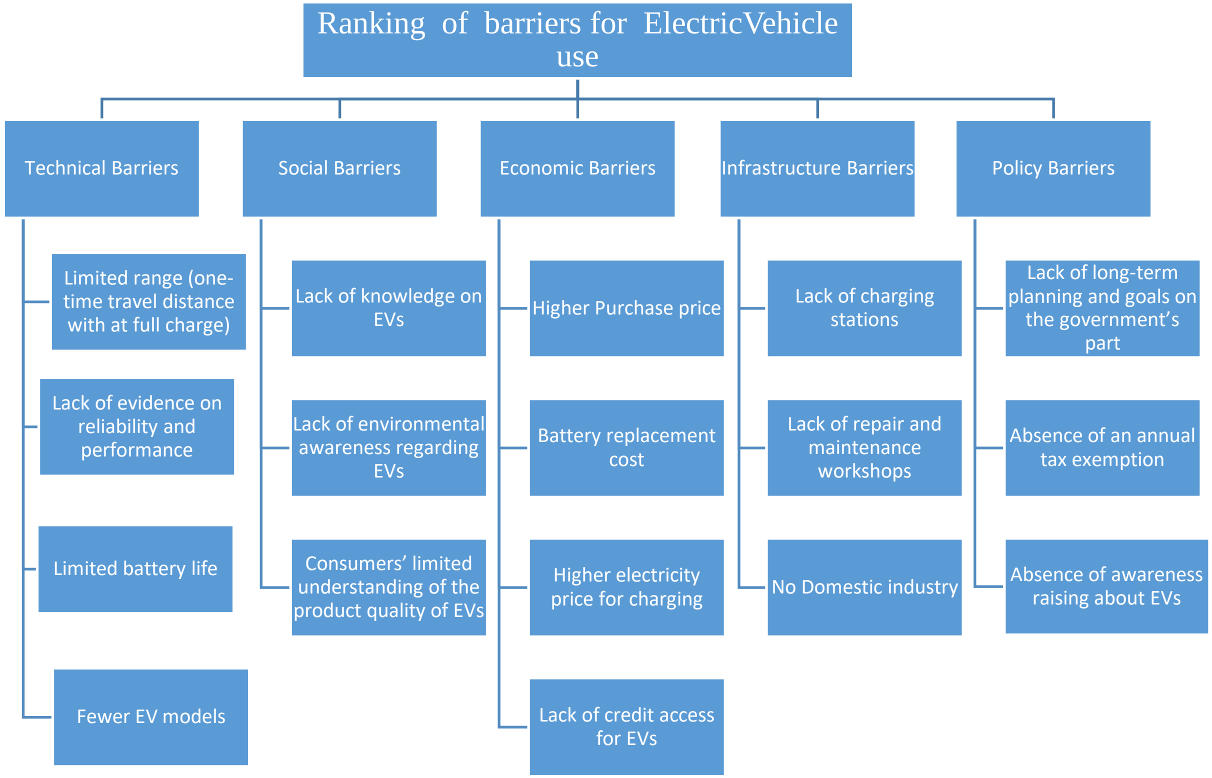

Figure 4.1 Hierarchical tree of barriers to electric vehicle use in Nepal

4.5 Results and Discussion

4.5.1 Ranking Barrier Categories

The results of the AHP estimation are shown in Table 4.3. Among the five categories of barriers, these results, derived from experts' opinions, rank infrastructure barriers (24.60%) as the most crucial category of barriers against EV diffusion in Nepal, followed by policy barriers (24.07%), economic barriers (23.74%), technical barriers (19.38%), and social barriers (8.21%). Notably, the infrastructure, policy, and economic barriers are not significantly different in terms of weight, which means that all three categories pose significant challenges. The results show that while social barriers pose a challenge, they affect the uptake of EVs to the lowest extent compared to the other four barrier categories.

Table 4.3 Categories of barriers ranking for electric vehicle use

Barrier Categories	**Priority Weight**	**Priority Weight (%)**	**Rank**
Technical Barriers	0.194	19.38	**4**
Policy Barriers	0.241	24.07	**2**
Economic Barriers	0.237	23.74	**3**
Infrastructure Barriers	0.246	24.60	**1**
Social Barriers	0.082	8.21	**5**

Consistency Ratio (CR) = 0.00247

4.5.2 Ranking within Categories

Next, the ranks of the barriers within each category, in terms their percentage weights, were estimated. Table 4.4 shows that limited range (namely, one-time travel distance with a fully charged battery) is ranked first (31.34%), which implies that the greatest obstacle to using the EVs in Nepal is technical in nature. Limited range was followed by limited battery life (28.16%), lack of evidence regarding reliability and performance (23.66%), and absence of different models (15.90%).

Table 4.4 Technical barriers ranking

Technical Barriers	**Priority Weight**	**Priority Weight (%)**	**Rank**
Limited range	0.313	31.34	**1**
Lack of evidence on reliability and performance	0.237	23.66	**3**
Limited battery life	0.282	28.16	**2**
Fewer EV models	0.169	16.91	**4**

Consistency Ratio (CR) = 0.03

Table 4.5 indicates that consumer understanding regarding quality (42.42%) is the most influential social barrier, followed by lack of knowledge about EVs (31.14%), and lack of environmental awareness about using EVs (27.52%).

Table 4.5 Social barriers rankings

Social Barriers	**Priority Weight**	**Priority Weight (%)**	**Rank**
Lack of knowledge on EVs	0.311	31.14	**2**
Lack of environmental awareness regarding EVs	0.275	27.52	**3**
Consumers' limited understanding of the product quality of EVs	0.414	41.42	**1**

Consistency Ratio (CR) = 0.02

Table 4.6 indicates that higher purchase price (54.83%) is ranked as the most crucial economic barrier against EV uptake in Nepal, followed by the battery replacement cost (24.01%), lack of credit access (12.14%), and higher electricity price for charging (9.02%).

Table 4.6 Economical barriers rankings

Economical Barriers	**Priority Weight**	**Priority Weight (%)**	**Rank**
Higher Purchase price	0.548	54.83	**1**
Battery replacement cost	0.240	24.01	**2**
Higher electricity price for charging	0.090	9.02	**4**
Lack of credit access for EVs	0.121	12.14	**3**

Consistency Ratio (CR) = 0.04

Likewise, with regard to the infrastructure barriers, table 4.7 shows that lack of charging stations (55.89%) is ranked as the most important obstacle against EV use in Nepal, followed by lack of repair and maintenance workshops (27.80%) and absence of a domestic industry in Nepal (16.28%).

Table 4.7 Infrastructure barriers rankings

Infrastructures Barriers	**Priority Weight**	**Priority Weight (%)**	**Rank**
Lack of charging stations	0.559	55.89	**1**
Lack of repair and maintenance workshops	0.278	27.80	**2**
No domestic industry	0.163	16.28	**3**

Consistency Ratio (CR) = 0.01

As per Table 4.8, within the policy barriers category, lack of long-term planning and goal setting by the government (50.93%) is estimated to be the most important barrier, followed by the absence of a tax exemption policy (28.14%) and lack of awareness raising about EVs (20.87%).

Table 4.8 Policy barriers rankings

Policy Barriers	**Priority Weight**	**Priority Weight (%)**	**Rank**
Lack of long-term planning and goals	0.509	50.93	**1**
Absence of an annual tax exemption	0.281	28.14	**2**
Absence of awareness raising about EVs	0.209	20.87	**3**

Consistency Ratio (CR) = 0.001

4.5.3 Overall Ranking

The global weight of the barriers was calculated by multiplying the priority weight of each category with the relevant priority weight of the barrier within that category. The global weight of the barriers is presented in Figure 4.2 in terms of the degree to which each barrier hinders EV diffusion in Nepal. Lack of charging stations (13.6%), higher purchase price (12.6%), and absence of long-term planning and goal setting by the government (12.1%) were ranked as the top three barriers, followed by lack of repair and maintenance workshops (6.9%), absence of a tax exemption policy (6.7%), limited range (6.1%), limited battery life (5.7%), battery replacement cost (5.5%), and lack of evidence with regard to reliability and performance (5.2%). The overall ranking results indicate that higher electricity price (2.1%) is the least important barrier, followed by lack of environmental awareness about EVs (2.3%), lack of knowledge about EVs (2.6%), and absence of credit access to purchase EVs (2.8%).

4.5.4 Discussion

As this study was conducted in the context of Nepal, the abovementioned results are likely to have significant implications for decision makers in the government, EV manufacturers, and other interested stakeholders who wish to understand the barriers against EV use in Nepal as well as their relative importance. Our results show that the infrastructure, policy, economic, and technical barrier categories present considerable challenges in this regard, whereas social barriers are less important in comparison. A similar study conducted for Kasongan city of South Korea showed poor social acceptance of EVs as the main barrier (Buwana et al., 2016), but our work suggests otherwise. This difference can be attributed to the fact that such studies are always very location- and case-specific. Our results are similar to those of another study conducted for fuel cell vehicles, wherein infrastructure, technical, and economic challenges were identified as the most important dimensions affecting consumer attitudes towards fuel cell vehicles (L. Zhang et al., 2016). Our results also indicate that the top three ranked categories of barriers had similar weights, which shows that while the origins of the barriers are diverse, it is crucial to address them simultaneously to ensure successful EV diffusion in Nepal. Thus, adopting an integrated approach, rather than focusing on a specific barrier, is a must.

As EVs are a relatively new technology in comparison with CVs, consumers are unlikely to invest in EVs unless the supporting infrastructure exists. Thus, policy makers and EV manufacturers should work together to facilitate the creation and maintenance of the relevant infrastructure (Sovacool & Hirsh, 2009). Among the four barriers listed in the infrastructure category, lack of charging stations was ranked the highest, followed by lack of repair and maintenance workshops, and absence of a domestic industry. The results indicate the relatively higher importance of charging stations in comparison with the other two barriers. Our results support previous findings that showed the existence of an indirect network effect pertaining to charging and service stations. Thus, government intervention and partnerships with the private sector toward infrastructure creation are crucial to achieve any targets for EV diffusion (Y. Kim et al., 2007; Yu, Li, & Tong, 2016).

Policy barriers were ranked as the second-most important barrier category. As EVs are new to Nepal, the government is yet to devise EV-specific policies for their promotion. Different policy instruments would likely be needed to promote EV usage based on specific government plans and goals. Such policies would include tax exemption and awareness creation. Our results show that long-term planning and goal setting by the government is the most important policy-related factor affecting EV use. Policies on tax exemption and awareness creation will play a supporting role in the deployment of EVs in Nepal. For instance, awareness raising will provide important information to potential consumers regarding the incentives of purchasing and using EVs, the infrastructure needed for EVs, their quality, and role in emissions reductions (Broadbent et al., 2018). These results are in agreement with the findings of Yong and Park, who also suggested that a policy mix is crucial for EV diffusion (Yong & Park, 2017).

Economic barriers against EV diffusion in Nepal also deserve attention. Experts' opinions revealed that the relatively higher purchase price of EVs was ranked the highest in this category, followed by battery replacement cost, lack of credit access, and higher electricity price. Previous studies also identified the higher purchase price as a crucial factor and suggested that purchase subsidies could provide a competitive edge to EVs over CVs (Steenberghen & Lopez, 2008; Xue et al., 2014; Yong & Park, 2017). In addition, battery replacement cost and credit access mechanisms need to be considered. Electricity price for recharging the batteries of EVs was shown to be the lowest ranked barrier. This result may be attributed to the low price of electricity compared to gasoline in Nepal, where 98% of electricity is generated by hydropower, which is a relatively cheap source of electricity.

Technical barriers were ranked as the fourth most important barrier category in this study. The findings show that experts continue to have doubts about the technical performance of EVs. Within the technical barriers category, the limited range problem was ranked the most crucial barrier, whereas the lack of different models was ranked the lowest. Number of charging stations can reduce limited range problem (Shi, Pan, Wang, & Cai, 2019). The results also revealed that limited battery life and lack of evidence regarding EV reliability and performance were the second and third barriers in the technical category respectively, with their weights being similar to that of the limited range problem. Thus, the results indicate that these technical issues need to be resolved in order to encourage the uptake of EVs in Nepal.

Social barriers were considered to be the least important as the experts did not perceive these features as vital as the other challenges. Within the social barrier category, consumer understanding on quality was ranked as the most important followed by lack of knowledge regarding EVs and lack of environmental awareness. Thus, the results reveal that the average consumer is likely to be uninformed about the advantages of using EVs as well as their quality and actual performance. Thus, it is vital that information about EVs be disseminated to heighten consumer understanding and awareness.

The global weights presented in figure 4.2 point to the lack of charging stations, higher purchase price, lack of long-term planning and goal setting by the government, absence of repair and maintenance workshops, and absence of a tax exemption policy as the top five ranked barriers against diffusion of EVs in Nepal. Moreover, the higher electricity price, lack of environmental awareness with regard to EVs, poor knowledge about EVs, and lack of credit access were ranked as less important barriers against the deployment of EVs in Nepal. It is evident that the top-ranked barriers should be addressed first.

4.5.5 Group Results

Among, 53 respondents, 34 respondents were conversant with vehicle and 19 were intended to buy one. We also attempt to examine the barriers ranking considering these two categories of respondents. There is some difference in terms of weight and ranking. Conversant vehicle users ranked slightly higher weight for infrastructure barriers as the most crucial category of barriers against EV diffusion in Nepal. However, intended to buy users ranked policy barriers as the most crucial category. Likewise, overall weights of conversant users reveal the lack of charging stations, higher purchase price, and lack of long-term planning as the top three ranked barriers against diffusion of EVs in Nepal. However, intended to buy users pointed lack of long-term planning, higher purchase price, and lack of chagrining stations as the top three ranked barriers. These two groups’ results are presented in appendix C.

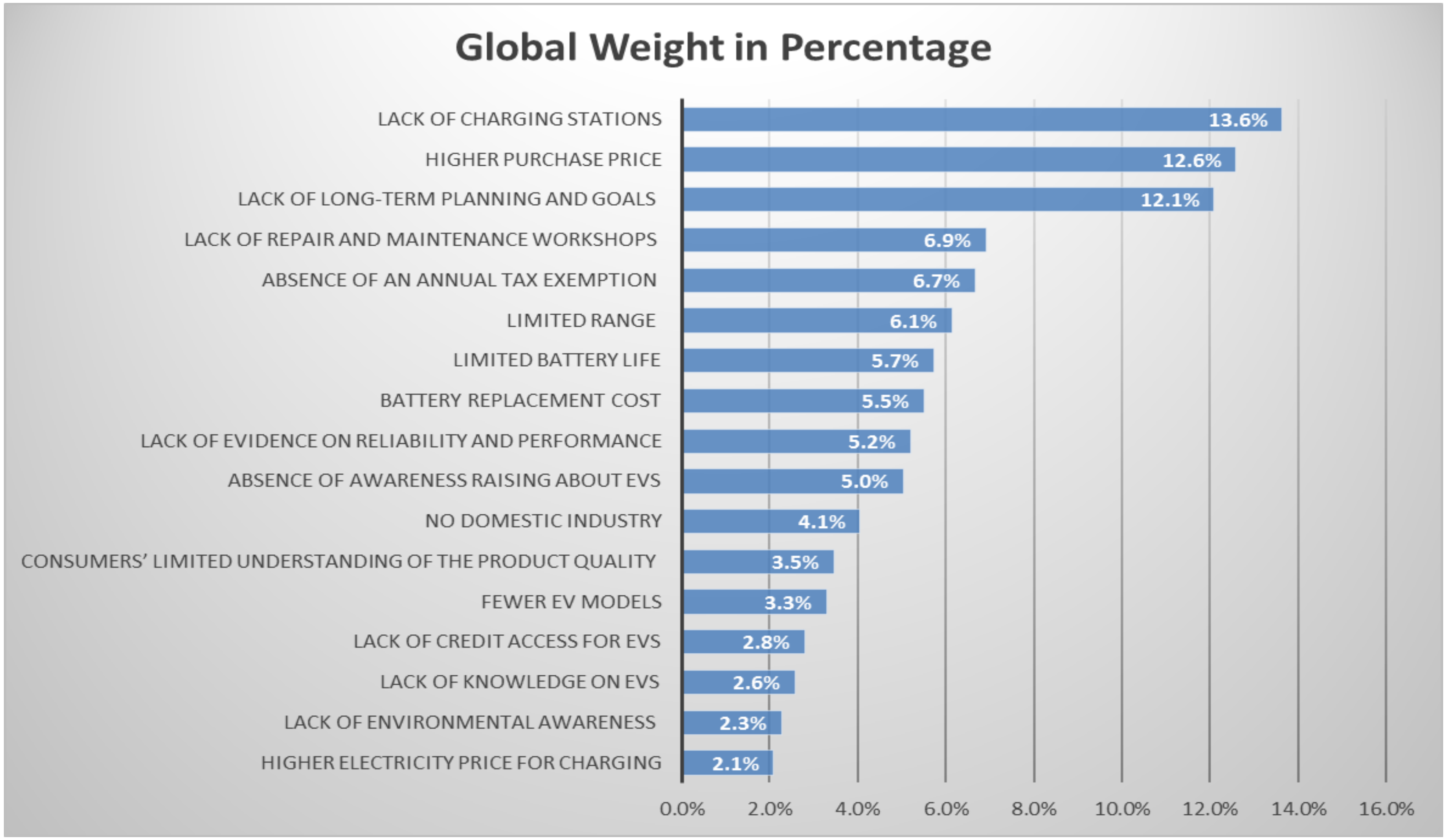

Figure 4.2 Overall rankings of barriers (Global weight in percentage)

4.6 Conclusion

Diffusion of EVs in Nepal is important given that concerted EV uptake will serve as an effective climate change mitigation measure. Moreover, it can help reduce the country's import with regard to petroleum products. While Nepal does not have fossil fuel reserves, unlike other countries, its hydropower potential is very high. Electricity produced using hydropower will help provide the needed electricity for charging EV batteries.

This study identified 17 barriers against EV uptake in Nepal from an extensive review of previous research, reports, and interactions with experts. Then, the barriers were classified into five categories: technical, policy, economic, infrastructure, and social. Importantly, this study presents the first attempt, in the context of EV usage in Nepal, at ranking such barriers using AHP and experts' opinions on their relative importance. Insufficient infrastructure was the highest-ranked barrier category followed by policy, economic, technical, and social barriers. The global weight analysis pointed to the lack of charging stations, higher purchase price, lack of long-term planning and goal setting by the government, absence of repair and maintenance workshops, and absence of a tax exemption policy as the top five ranked barriers against the diffusion of EVs in Nepal.

The findings of this study will provide guidance to decision-makers, EV manufacturers, and other stakeholders towards promoting EV diffusion in the country. Moreover, the study demonstrated the successful use of the AHP towards such an analysis. However, given that some barriers are common globally whereas others tend to be country-specific, the results of one study will likely not be applicable to another country. Thus, a customized analysis is important for a region/country.

Moreover, it is possible that other barriers against EV promotion may exist or arise in the future. Thus, frequent and continued interactions with users, manufacturers, experts, and policy makers are necessary to identify such issues in a proactive manner.

Chapter 5. Conclusions and Implications

5.1 Summary of Results

Use of EVs in Nepal is an important consideration; EV uptake will serve as an effective climate change mitigation and can help reduce the country's import with regard to petroleum products. While Nepal does not have fossil fuel reserves; however, hydropower potential is very high. This thesis deals on analysis of consumer preferences and barriers for electric vehicle use in Nepal. EVs might be an alternative in order to address the climate change issue in the transportation sector. Many governments around the globe have introduced different policies in order to stimulate the consumers' demand for EVs. Previous studies also reported that government intervention in the form of subsidy and tax exemption might contribute to creating a market for EVs.

Chapter 3 examines consumer preferences for EVs. We also conducted market simulations in order to obtain the impact of different policy measures and technological advancement on EVs. The coefficients of monetary attributes such as price and fuel cost have negative signs indicating potential users prefer lower price and lower fuel cost for cars. The positive coefficients of infrastructure development and range implying the importance of charging stations and service center, and prefer the design of EVs with longer range battery capacity. Furthermore, the interaction model results show significant heterogeneity among potential consumers for EVs preferences. Potential vehicle consumers with small family size, lower monthly travel distance, environmental awareness, and electric vehicle knowledge are more likely to adopt the EVs.

Elasticity estimation suggests that the reduction of the purchase price is most effective to increase consumers' demand to BEV and PHEV followed by range increment. However, fuel cost reduction and infrastructure development are moderately important attributes in order to stimulate the demand for EVs. Market simulations results indicate that policies mix scenario would be more effective due to the synergy effect. Alternatively, some consumers will adopt BEV only after reduced price and increased infrastructure.

LCM estimation suggests three distinct class of consumers exist in Nepal implying class 1 -BEV oriented, class 2- PHEV oriented and class-3 attributes oriented. Results show that class 3 group consumers need more awareness and information flow to stimulate their EVs' demand. In this regard, consumer preference study is from the consumer perspective or demand side as the study considers the opinions of the potential electric vehicle consumers. However, the result obtained from a demand perspective might provide some useful information to the supply side stakeholders (automakers, and policymakers) in order to increase the supply and demand of EVs.

Chapter 4 attempts to identify the barriers and rank them for EV use in Nepal. We identified seventeen specific barriers for EV use from an extensive review of the literatures. Seventeen barriers then classified into five categories: technical, policy, economic, infrastructure, and social.

Moreover, collected experts' opinions on their relative importance and AHP was used to rank the identified barriers.

Barriers analysis results presented in chapter 4 show that insufficient infrastructure was the highest-ranked barrier category followed by policy, economic, technical, and social barriers. The global weight analysis pointed to the lack of charging stations, higher purchase price, and lack of long-term planning and goal setting by the government as the top three ranked barriers against the diffusion of EVs in Nepal.

In this regards, barriers ranking and analysis is obtained through the experts' opinion, can be called a supply perspective study. However, consumers' opinion may not necessarily provide a similar result. Thus, this study was aimed to identify all barriers and rank them in order of their importance considering experts' opinion. Based on the ranking of barriers, decision makers/policymaker might focus to overcome the highest ranked barriers first.

5.2 Contributions and Implications

We expect that the quantitative results of this study will inform policymakers when its goal is to increase consumer demand for EVs for the sake of reducing oil consumption and protecting the environment. In addition, in Nepal, EVs use can contribute to reducing the country's import to petroleum products. Nepal does not have any proven fossil fuel reserves for domestic production. Automakers companies should benefit as well to set business and research-and-development Strategy.

Elasticity estimation and market simulations with a number of scenarios could provide relevant information to decision makers while designing different strategies in order to accelerate the market demand of BEV and PHEV. Significant preference variation across the classes should be addressed within the policies to increase the demand for EVs. Furthermore, just improvement in one attribute might not significantly contribute to stimulating demand for EVs.

Given that some barriers are common globally whereas others tend to be country-specific, the results of one study will likely not be applicable to another country. Thus, a customized analysis is important for a region/country. Moreover, it is possible that other barriers against EV promotion may exist or arise in the future. Thus, frequent and continued interactions with users, manufacturers, experts, and policymakers are necessary to identify such issues.

Isolate or distributed renewable energy technologies such as micro/mini-hydropower, solar, wind, and biomass are suitable energy resources for households situated in rural and remote areas of Nepal (Ghimire, 2016). In addition, these technologies could play an important role to provide electricity for battery charging of EVs.

5.2.1 Synthesis Results of Two Studies

First, consumer preference study, demand perspective, deals with only key attributes of the vehicle such as price, infrastructure, range, and fuel cost. However, barriers study, supply perspective, aimed to list barriers and ranks them in order of their importance from experts' opinion. Though the objectives of the two studies are different, both studies' results provide some common inference. From Consumer preference elasticity estimation result suggests that purchase price attribute is most influential to increase demand for EVs followed by range increment and infrastructure development. Likewise, barriers ranking results also suggest that lack of infrastructure, higher purchase price, and limited range problem are key barriers for the uptake EVs. In addition, specific inferences from each study are as follows:

<u>Consumer preferences</u>

- Consumer socio-demographic, travel characteristics, and environmental concerns impact on the EVs demand are analyzed.
- Effectiveness of policies in order to increase the market demand for EVs are examined.

- Latent class estimation provides consumer segments. Heterogeneity among consumers can be addressed in policies and strategies.

Barriers Analysis

- Listed all the barriers for the context of Nepal, seventeen barriers are briefly explained.
- Barriers are ranked considering the experts' opinion.

5.2.2 Policy Implications

Based on two studies, consumer preferences and barriers analysis, following specific points can be considered as the policy implications in order to increase the demand for EVs.

- In general, consumers prefer EVs compared to ICV when all other remains constant in Nepal. This approach can be applied considering a large sample to verify the results.
- Purchase price reduction is the most effective way to increase the demand for EVs. There might be different strategies to reduce purchase prices such as purchase subsidy, and customs tax exemption.
- Preference study indicates that long term market could be achieved about 60% if attributes of EVs will be similar with ICVs.
- Simulation result shows the synergy effect while multiple policies are in place. It is recommended to implement multiple policies to create more demand for BEV and PHEV.
- Public education about EVs should be seriously considered to increase demand. Despite we identified the three consumer segments, class three

demands high environmental awareness to increase their preferences towards BEV and PHEV.

- We identified and listed seventeen barriers against EV use in Nepal; however, lack of charging stations, higher purchase price, and lack of government long term plan are top-ranked barriers. Strategies and policies should be focused on top-ranked barriers first.

5.3 Limitations and Future Research

We acknowledge that our estimation is based on the stated preference hypothetical choice experiment method, which can be compared to revealed preferences in the future. Consumer preferences analysis contributes in-depth knowledge of the attributes, socio-demographic, environmental concerns, and travel characteristics variables' impact on demand of EVs. However, we limited this study only with certain attributes, thus, future research can be conducted adding other attributes such as battery replacement cost, vehicle size, brand/model, recharging time, tax, and incentives. Battery replacement costs in EVs, which are incurred every 3 to 5 years, is one of the important variables limiting preferences of EVs. The inclusion of such costs might influence the simulations results.

Our estimation is based on the current market based stated preference approach. As time being, consumers might be better informed, and technical innovation could be achieved, preference will be changed in the future.

We limited our survey in urban areas of Nepal. We might expect other barriers and different perception if we consider all the area of Nepal. This study is based on consumers' opinions and views from urban areas perspective, thus, results implication could be limited to urban areas of Nepal.

Likewise, we believe that barriers may arise or some other barriers exist that is not covered in this study. Continued interactions with EVs stakeholders seem important to identify and to list barriers/challenges and to rank them. Barriers ranking in this study is limited to experts' opinion; however, analysis can be elaborated to the consumer level. We might expect different ranking of barriers form a different group.

One of the objectives of the diffusion of EVs is to reduce imports of petroleum products in Nepal. Petroleum products are top import products, which enlarging the country's trade deficit. However, imports of EVs to replace ICVs might increase the trade deficit, as EV is more expensive than the ICV. In addition, infrastructure developments to facilitate the diffusion of EVs might also affect trade deficit as parts of the equipment will be imported from other countries. This scenario tells that the overall impact in trade deficit while using EVs in Nepal should be assessed in detail.

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Appendix A: Survey questionnaires for consumer preferences study

Survey on Consumer Preference study on Electric Vehicle (EV)

Survey on Implementation of Battery Electric Vehicle (BEV) and Plug-in Hybrid Electric Vehicle (PHEV).

Very Important Information

Internal Combustion Vehicle (ICV): Car that will use petrol or diesel as fuel.

Battery Electric Vehicle (BEV): BEV is a type of electric **vehicle** (EV) that uses chemical energy stored in rechargeable battery packs. The battery will be charged from the external source of electricity.

Plug-in Electric Vehicle (PHEV): PHEV is a vehicle with batteries that can be charged externally to run as BEVs during their charge-depleting mode and can be used with petrol or diesel.

Infrastructure Availability: Availability of petrol pump and maintenance workshop for the ICV. Availability of charging stations and workshop with comparison to petrol or diesel car (ICV).

Range: Distance can be travelled after one time full petrol or diesel or charging of battery.

This survey questionnaire is to identify the willingness to adopt Electrical and hybrid electric vehicle by the consumers through government intervention. We have formulated with the hypothetical alternative of cars and have included the petrol or diesel car together with BEV and PHEV for the alternatives.

No individual responses will be disclosed rather will be processed using statistical application and only implications will be drawn from the responses. Moreover, the information will be kept strictly confidential and the result will be used only for academic research purpose, not for any commercial or other purposes.

Should you have any comments, suggestions or questions about this survey, kindly contact us via email at

Kindly read the attributes used and their levels of vehicles.

Attributes and Levels

Fuel type	ICV (Petrol or Diesel)	BEV Battery Electric Vehicle	PHEV Plug-In Hybrid Electric Vehicle
Purchase Price	1. $20000 2. $ 30000	3. $ 25000 4. $ 32500 5. $40000	1. $ 25000 2. $ 32500 3. $ 40000
Infrastructure Availability	Current Status	1. 25% with compare to ICV 2. 50% with compare to ICV 3. 75% with compare to ICV	1. 25% with compare to ICV 2. 50% with compare to ICV 3. 75% with compare to ICV
Fuel Cost per 100 km	1. $10 2. $15	1. $ 5 2. $ 8 3. $10	1. $ 5 2. $ 8 3. $10
Range	500km	1. 100 km 2. 200 km 3. 300 km	1. 100 km 2. 300 km 3. 500 km

Section A. In this section, hypothetical cars are presented and each car is differed with others. Each set consists of five alternative cars with attributes are presented in the table. The first part of this survey, the respondent must choose one best option. We have included the petrol or diesel car for the alternatives to compare with BEV and PHEV.

Example Question. Please select one best car in your view.

Car Type	Purchase Price	Infrastructure Availability	Fuel Cost	Range Around	Your Preference
ICV 1 (Petrol or Diesel Car)	$ 40000	Current Status	$15	500 Km	
BEV 1	$40000	25%	$5	200 Km	
BEV 2	$25000	50%	$5	300 Km	
PHEV 1	$40000	25%	$10	100 Km	
PHEV 2	$25000	50%	$5	300 Km	**Selected**

From above, PHEV (2) is selected among five car alternatives.

Survey

Please select the best car in each set of five cars.

Set A:

Car Type	Purchase Price	Infrastructure Availability	Fuel Cost (100km)	Range Around	Your Preference
ICV 1 (Petrol or Diesel Car)	$ 20000	Current (100%)	$10	500 Km	
BEV 1	$25000	25%	$5	100 Km	
BEV 2	$32500	75%	$5	100 Km	
PHEV 1	$40000	75%	$5	500 Km	
PHEV 2	$25000	50%	$8	100 Km	

Set B

Car Type	Purchase Price	Infrastructure Availability	Fuel Cost (100km)	Range Around	Your Preference
ICV 2 (Petrol or Diesel Car)	$ 20000	Current (100%)	$15	500 Km	
BEV 3	$25000	25%	$5	300 Km	
BEV 4	$25000	50%	$10	300 Km	
PHEV 3	$32500	25%	$8	500 Km	
PHEV 4	$32500	25%	$10	100 Km	

Set C

Car Type	Purchase Price	Infrastructure Availability	Fuel Cost (100km)	Range Around	Your Preference
ICV 3 (Petrol or Diesel Car)	$ 30000	Current (100%)	$10	500 Km	
BEV 5	$40000	25%	$8	200 Km	
BEV 6	$25000	75%	$8	100 Km	
PHEV 5	$40000	50%	$5	100 Km	
PHEV 6	$25000	25%	$5	300 Km	

Set D

Car Type	Purchase Price	Infrastructure Availability	Fuel Cost (100km)	Range Around	Your Preference
ICV 4 (Petrol or Diesel Car)	$ 30000	Current (100%)	$15	500 Km	
BEV 7	$32500	50%	$5	200 Km	
BEV 8	$40000	25%	$10	100 Km	
PHEV 7	$25000	75%	$10	300 Km	
PHEV 8	$25000	25%	$5	100 Km	

Section B: In this section, socio-demographic information will be collected.

1. Gender:

2. You Age: ------ years

3. Education:
   a. SLC
   b. Intermediate
   c. Bachelor
   d. Master
   e. PhD
   f. Some Training

4. Family Members
   …….. Persons

5. Tentative Annual Income:
   ………… Nepali Rupees

6. Average Monthly Travel Distance
   .... Km

7. Do you have the intention to buy a new vehicle within next 5 years
   Yes
   No

8. Do you have your own vehicle?
   Yes (if yes, which fuel type vehicle:……..)
   No

9. How many Vehicles are there in your family?
   …..numbers

10. Do you have a vehicle driving license, if yes how many years of experience?
    Yes (.....years)
    No

11. Do you travel frequently to the mountain location?
    Yes
    No

12. Do you consider the environment effect during the vehicle purchase and use?
    a. Yes
    b. No

13. Do you have knowledge of the importance of electrical vehicle? Please select one.
    a. Do not know
    b. A little bit know
    c. Well known

14. Your working Sector
    a. Energy Sector/ Environment Sector
    b. Others

THANK YOU VERY MUCH!

Appendix B: Survey questionnaires for barriers analysis

Survey on barriers against electrical vehicle diffusion –Context of Nepal

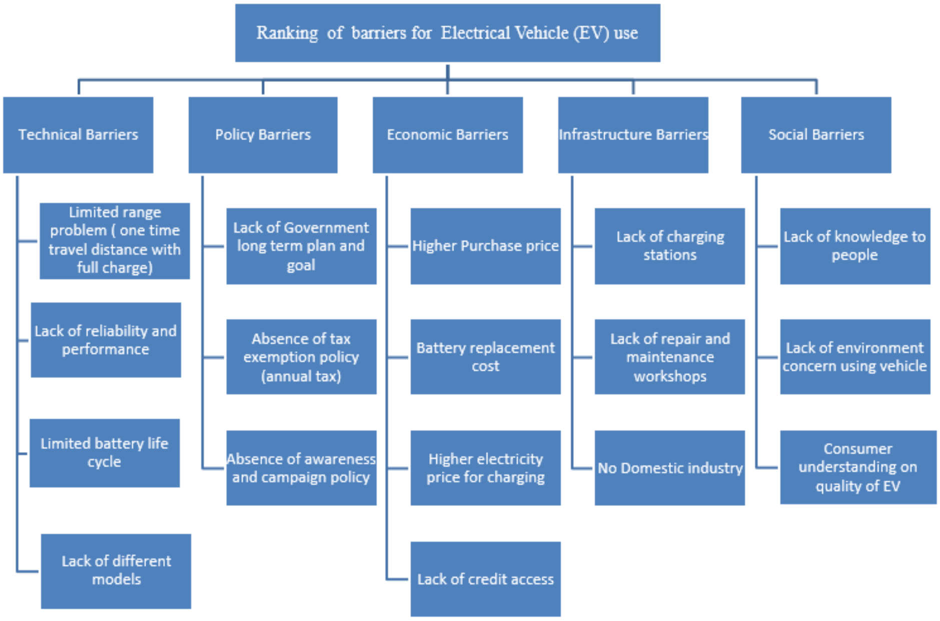
Researcher Mr. Laxman Prasad Ghimire is performing this research under the supervision of Professor **Yeonbae Kim.** This survey is in order to study barriers electrical vehicle diffusion and for the purpose of the ranking. This questionnaire attempts to raise the question of "their rank in the context of Nepal.

This questionnaire includes pair-wise comparison questions addressed to experts who are familiar with electrical vehicle, to seek their judgments identified barrier dimensions and sub dimensions.

All your response to this survey will be confidential and used only for academic research purpose. The information provided by participants will not be disclosed. The answers s/he gives will be only used for research purpose.

If you have any comments, suggestions or questions about this survey, kindly contact us via e-mail at

Barrier Type	**Barriers**
Technical Barriers	1. Limited range problem (one time travel distance with full charge) 2. Lack of evidence on reliability and performance 3. Limited battery life cycle 4. Lack of different models
Policy barriers	1. Lack of Government long term plan and goal 2. Absence of tax exemption policy (annual tax) 3. Absence of awareness and campaign policy
Economic Barriers	1. Higher Purchase price 2. Battery replacement cost 3. Higher electricity price for charging 4. Lack of credit access for EVs
Infrastructure Barriers	1. Lack of charging stations 2. Lack of repair and maintenance workshops 3. No domestic industry
Social barriers	1. lack of knowledge of EV 2. Lack of environment concern using vehicle 3. Consumer understanding on quality



Example: Pairwise comparison of barriers for Electrical vehicle use in Nepal.

Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Technical Barriers	9	7	5	3	1	3	5	7	9	Social Barriers

Option B (Social barriers) is strongly important than option A (Technical barriers) for Electrical Vehicles use in Nepal.

Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Economic Barriers	9	7	5	3	1	3	5	7	9	Policy Barriers

Option A (Economic barriers) is very strongly Important than option B (Policy barriers) for Electrical Vehicles use in Nepal.

Please indicate your opinion like in example above.

With respect to Barrier Type										
Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Technical Barrier	9	7	5	3	1	3	5	7	9	Policy Barriers
Technical Barriers	9	7	5	3	1	3	5	7	9	Economic Barriers
Technical Barriers	9	7	5	3	1	3	5	7	9	Infrastructure Barriers
Technical Barriers	9	7	5	3	1	3	5	7	9	Social Barriers
Policy Barriers	9	7	5	3	1	3	5	7	9	Economic Barriers
Policy Barriers	9	7	5	3	1	3	5	7	9	Infrastructure Barriers
Policy Barriers	9	7	5	3	1	3	5	7	9	Social Barriers
Economic Barriers	9	7	5	3	1	3	5	7	9	Infrastructure Barriers
Economic Barriers	9	7	5	3	1	3	5	7	9	Social Barriers
Infrastructure Barriers	9	7	5	3	1	3	5	7	9	Social Barriers

With respect to Technical Barriers										
Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Limited range problem	9	7	5	3	1	3	5	7	9	Lack of evidence on reliability and performance
Limited range problem	9	7	5	3	1	3	5	7	9	Limited battery life cycle
Limited range problem	9	7	5	3	1	3	5	7	9	Lack of different models
Lack of evidence on reliability and performance	9	7	5	3	1	3	5	7	9	Limited battery life cycle
Lack of evidence on reliability and performance	9	7	5	3	1	3	5	7	9	Lack of different models
Limited battery life cycle	9	7	5	3	1	3	5	7	9	Lack of different models

With respect to Policy Barriers										
Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Lack of Government long term plan and goal	9	7	5	3	1	3	5	7	9	Absence of tax exemption policy (annual tax)
Lack of Government long term plan and goal	9	7	5	3	1	3	5	7	9	Absence of awareness and campaign policy
Absence of tax exemption policy (annual tax)	9	7	5	3	1	3	5	7	9	Absence of awareness and campaign policy

With respect to Economic Barriers										
Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Higher Purchase price	9	7	5	3	1	3	5	7	9	Battery replacement cost
Higher Purchase price	9	7	5	3	1	3	5	7	9	Higher electricity price for charging
Higher Purchase price	9	7	5	3	1	3	5	7	9	Lack of credit access for EVs
Battery replacement cost	9	7	5	3	1	3	5	7	9	Higher electricity price for charging
Battery replacement cost	9	7	5	3	1	3	5	7	9	Lack of credit access for EVs
Higher electricity price for charging	9	7	5	3	1	3	5	7	9	Lack of credit access for EVs

With respect to Infrastructure Barriers										
Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Lack of charging stations	9	7	5	3	1	3	5	7	9	Lack of repair and maintenance
Lack of repair and maintenance workshops	9	7	5	3	1	3	5	7	9	No domestic industry
Lack of repair and maintenance workshops	9	7	5	3	1	3	5	7	9	No domestic industry

With respect to Social Barriers										
Options A	Extremely	Very Strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very Strongly	Extremely	Options B
Lack of knowledge of EV	9	7	5	3	1	3	5	7	9	Lack of environment concern using vehicle
Lack of knowledge of EV	9	7	5	3	1	3	5	7	9	Consumer understanding on quality
Lack of knowledge of EV	9	7	5	3	1	3	5	7	9	Consumer understanding on quality

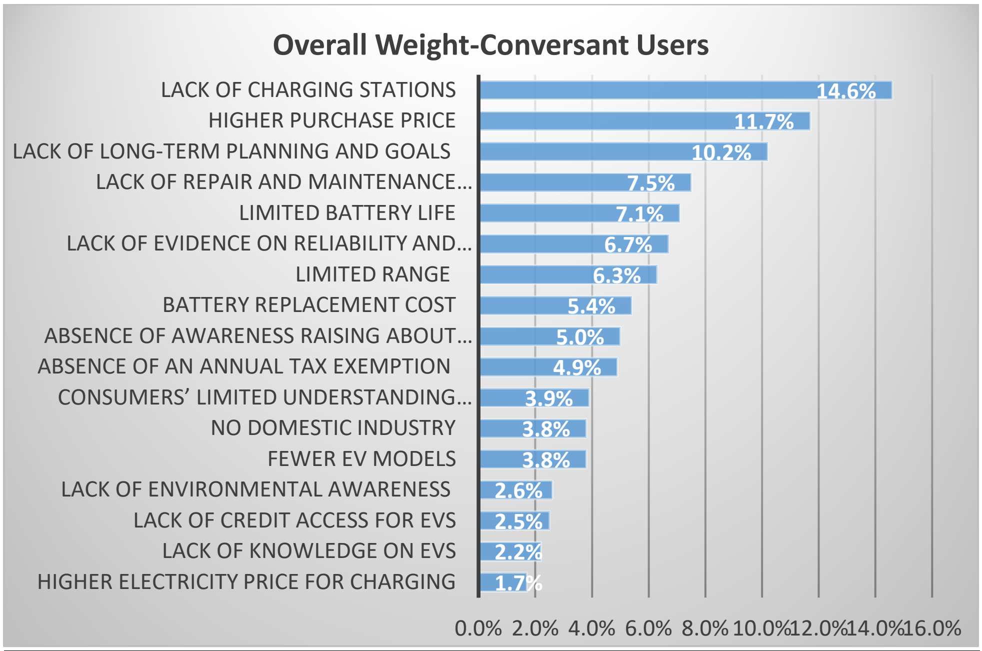
Name:
Email:
Working Area: A. Energy B. Energy/ Environment C. Government
Do you have your own vehicle? Yes or No

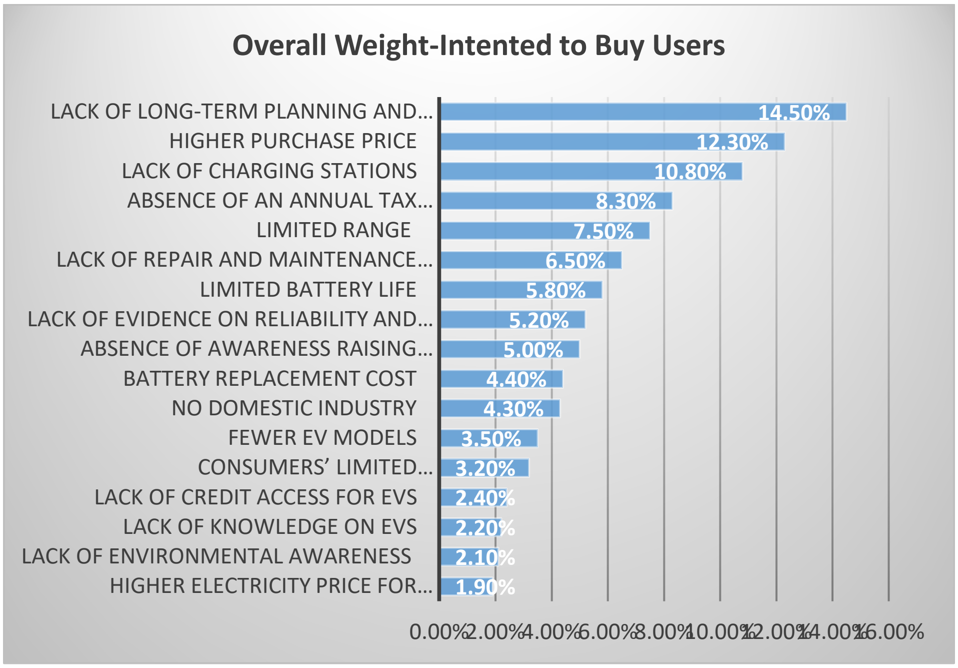
Thank you very much for your time and cooperation!

Appendix C: Barriers Analysis- Conversant and Intended to Buy Vehicle Users

Categories of barriers ranking for conversant and intended to buy users

Barrier Categories	Conversant users		Intended to buy users	
	Weight (%)	Rank	Weight (%)	Rank
Technical Barriers	22.40	**2**	20.00	**4**
Policy Barriers	20.30	**4**	26.90	**1**
Economic Barriers	21.20	**3**	23.00	**2**
Infrastructure Barriers	26.60	**1**	22.70	**3**
Social Barriers	9.50	**5**	7.50	**5**





Overall Weight-Intented to Buy Users
LACK OF LONG-TERM PLANNING AND...
HIGHER PURCHASE PRICE
LACK OF CHARGING STATIONS
ABSENCE OF AN ANNUAL TAX...
LIMITED RANGE
LACK OF REPAIR AND MAINTENANCE...
LIMITED BATTERY LIFE
LACK OF EVIDENCE ON RELIABILITY AND...
ABSENCE OF AWARENESS RAISING...
BATTERY REPLACEMENT COST
NO DOMESTIC INDUSTRY
FEWER EV MODELS
CONSUMERS' LIMITED...
LACK OF CREDIT ACCESS FOR EVS
LACK OF KNOWLEDGE ON EVS
LACK OF ENVIRONMENTAL AWARENESS
HIGHER ELECTRICITY PRICE FOR...
14.50%
12.30%
10.80%
8.30%
7.50%
6.50%
5.80%
5.20%
5.00%
4.40%
4.30%
3.50%
3.20%
2.40%
2.20%
2.10%
1.90%
0.00%
2.00%
4.00%
6.00%
8.00%
10.00%
12.00%
14.00%
16.00%

Abstract in Korean (초록)

전기자동차 (EV)는 운송부문에서 온실가스배출을 줄이기 위한 대안기술 중 하나입니다. 또한 네팔 정부는 전기자동차 사용의 확대를 주요한 정책목표로 하고 있습니다. 네팔은 화석연료의 매장량은 적지만 수력발전에 대해서는 높은 가능성을 가지고 있으며, 이는 전기자동차에 대한 수요를 충족시키기에 충분한 양입니다.

본 논문의 첫 번째 부분(에세이)에서는 전기자동차에 대한 네발 소비자의 선호도를 조사하고 다양한 시나리오를 기반으로 수요시뮬레이션을 실시하였습니다. 소비자 선호 자료는 네팔 소비자를 대상으로 한 설문을 통해 수집되었습니다 (진술선호분석). . 그런 다음 수집된 자료를 혼합로짓모형 (Mixed Logit Model)과 Latent Class Model 을 이용하여 통계분석을 하였습니다. 분석결과는 작은 가족, 더 낮은 월간 이동 거리, 환경문제에 대한 높은 인식 및 전기자동차 지식을 가진 소비자가 전기자동차를 채택 할 가능성이 높음을 보여줍니다. 또한 수요 시뮬레이션 결과는 단일 정책 보다는 동시에 사용하는 정책믹스의

경우가 전기자동차 확대에 더 효과적임을 보여주고 있습니다. 마지막으로 Latent Class Model 결과는 네팔 소비자가 세가지 크게 다른 (이질적인) 그룹으로 나뉠 수 있음을 보여 주었습니다.

이 논문의 두 번째 부분 (essay)은 네팔의 전기 자동차 보급에 대한 다양한 장벽 (Barriers)을 식별하고 그 장벽들 사이의 중요도 순위를 매기는 분석입니다. 기존 관련 연구의 분석을 통해 17 가지의 장벽이 확인되었고, 확인 된 장벽들은 다섯가지 범주로 분류되었습니다 (기술, 정책, 경제, 인프라 및 사회). 그런 다음 분석적 계층프로세스 (AHP) 방법을 사용하여 해당분야의 전문가들의 장벽의 중요도에 대한 의견을 파악했습니다. 분석결과는 인프라, 정책, 경제 및 기술 장벽 모두가 상대적으로 중요한 장벽 범주 들임을 보여줍니다. 즉 네팔의 전기자동차 확대를 위해서는 특정 부문에 집중된 지원보다는 인프라, 정책, 경제 및 기술에 걸친 종합적인 (comprehensive) 접근이 필요함을 보여 주고 있습니다.

주요어 : 전기자동차, 네팔, , 소비자 선호도, 혼합 logit 모형, 장애요인, AHP 학

번 : 2017-35348

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I would like to dedicate this study to my dearest family members, particularly my parents (Ram Prasad Ghimire, Sabitri Ghimire, Basudev Timalsina, and Goma Ghimire), my brothers (Bhim and Sanjaya). Likewise, I put my sincere thanks to my sister (Indira), sister-in-law(Sarita), and sister-in-law(Rina) for their continous support.

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