Proceedings of IOE Graduate Conference, 2019-Summer
Peer Reviewed
Year: 2019 Month: May Volume: 6
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Evaluating the Effect of Policies, Vehicle Attributes and Charging Infrastructure on Electric Vehicles Diffusion in Kathmandu Valley of Nepal

Sushil Paudel [a], Govinda Raj Pokharel [b], Nawraj Bhattarai [c], Shritu Shrestha [d]

[(a, b, c)] *Department of Mechanical Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[d] *Wuppertal Institute for Climate, Environment and Energy*
Corresponding Email: [a] 069bel344sushil@ioe.edu.np, [b] pokharelgr@gmail.com,
[c] bnawraj@ioe.edu.np, [d] shritu.shrestha@wupperinst.org

Abstract

This paper outlines the electric vehicle development trajectory and examines the principal factors that can uplift the growth of electric vehicles and contribute to future market share of electric vehicle based on public expectations from government in terms of vehicle infrastructure and attributes, situation and policies. Public's expectations, their willingness and attraction towards electric vehicles has been understood based on various questionnaire posed to them in the online public response survey. Current status of electric vehicles has been obtained and policy study in promotion of electric vehicles in India, China and Bhutan has been studied to incorporate the major factor contributing to influence the promotion of electric vehicles in Nepalese vehicle market. In this paper, the System Dynamics Model has been selected for evaluating electric vehicle growth based on vehicle attributes, government policies charging infrastructure. Public and electric vehicle promoter acceptability survey has been performed and the importance and attractiveness of electric vehicles under key factors has been determined. The number of future electric vehicles in market of Kathmandu has been forecasted to reach nearly 10, 00,000 within three years and remains constant. During the course of this research, a unique electric vehicle diffusion model, which is an adaptation of Struben and Sterman model, has been developed. This model is relevant to Nepalese electric vehicle market and social structure and hence is expected to work better than the former one, at least in context of Nepal.

Keywords

System Dynamics Method, Electric Vehicles Forecasting, Electric Vehicles, VENSIM-PLE

1. Introduction

Electric vehicle development in the Kathmandu Valley has begun in 1993 as a response to the urgency of a severe air pollution situation. The dynamics of government intervention, non-governmental organization advocacy, international donor support, and private sector involvement all shaped EV implementation in various ways. Its success led other South and East Asian cities to view it as a model for implementing EVs to alleviate air pollution. Yet despite a promising beginning and intensive proliferation, the EV industry was failing only six years after its inception and till now, the industry has no any significant growth in the country. What went wrong with a development that seemed to have all the makings of success at the beginning? What is the current status? What will be future growth of Electric Vehicles based on different policies and EV features?

In fight against air pollution and greenhouse gas emissions, the electrification of the transport sector is an important goal because widespread electrification would greatly improve the quality of the air we breathe. And in fact, switching to electric vehicles has also been a core target of the Ministry of Forests and Environment since 2015, when Nepal's Nationally Determined Contribution was established [1]. Also, emissions from the transport sector constitutes of 69% of total emissions per year in Kathmandu valley [2, 3].

Nepal has a comparative advantage in terms of production of its own hydroelectricity, a local energy resource, with a huge potential to replace imported fossil fuel in upcoming days resulting the energy security of country. Also, EVs are the cleaner, greener, and quieter alternative money saving and cheaper in the long run and are dependent on domestic energy sources of Nepal.Maharjan [4] outlined the EV development and examines the major factors that hurdled the progress during 2000 AD, but role of polices and vehicle attributes in realization of growth of electric vehicles were not focus of that study. Shakya [5] studied about low carbon development strategies i.e. role of transport sector electrification and carbon tax in Nepal. This study has no relevance in this research as it was made to examine the mid and long term effects of a sectoral low carbon strategy by developing transport electrification scenarios. Still, there are very few research conducted which examines the status of EVs in capital city and estimate the growth by analyzing barriers in different policy scenario. In this context, a study on EV development might shed new light on the dynamics of EV adoption and the barriers it faces in its implementation which ultimately provides policy recommendations for promotion EVs in Kathmandu Valley with realization of potential benefits.

This study is focused on understanding the status of electric vehicle development and examining the role of government policies, vehicle technical features and the development of infrastructure in the private EV promotion in Kathmandu Valley, rather than the exact prediction of the future EV population. Kathmandu is the capital city of Nepal and it's population is projected to double by 2030 [6] and considered as largest among cities of Nepal according to population. About 46.2% of the total vehicles registered in the country are registered in the Bagmati zone [7]. The annual average growth rate of the total registered vehicles in the Valley from 1990-2011 is 14.32% [8]. Introduction of policies favorable to battery powered vehicles could at least replace this incremental rate by EVs. Reduction in purchase and operation costs, charging duration can create a huge acceptability of electric vehicles in Kathmandu Valley. Similarly, construction of charging infrastructure around the valley could provide solution to worries of the general public while purchasing an EV. The study has been undertaken to examine the influence of key factors on growth rate of electric vehicles based on public and promoter aspects and to promote EVs in Nepal in different scenarios.

This research is supported by a customer preference survey which is an inclusive survey, where despite its small sample size, has incorporated people's thoughts from different backgrounds. The word of mouth of EV drivers and EV non-drivers has been taken separately to better analyze the customer preference and situation. Special attention has been paid for this inclusiveness of the survey.

The second section of this paper describes in brief the problem formulation and the general methodology followed in the paper. On the next section, the modeling and mathematical part of the research is included, where details of modified Struben and Stermen model used here, and their mathematical bases are also included. The fourth section of this paper is dedicated towards the survey results and its sample distribution, which, is far more important aspect of this research than meets the eye. Finally, the next two sections describes the results obtained and conclusions of this study respectively.

2. Problem Formulation and Methodology

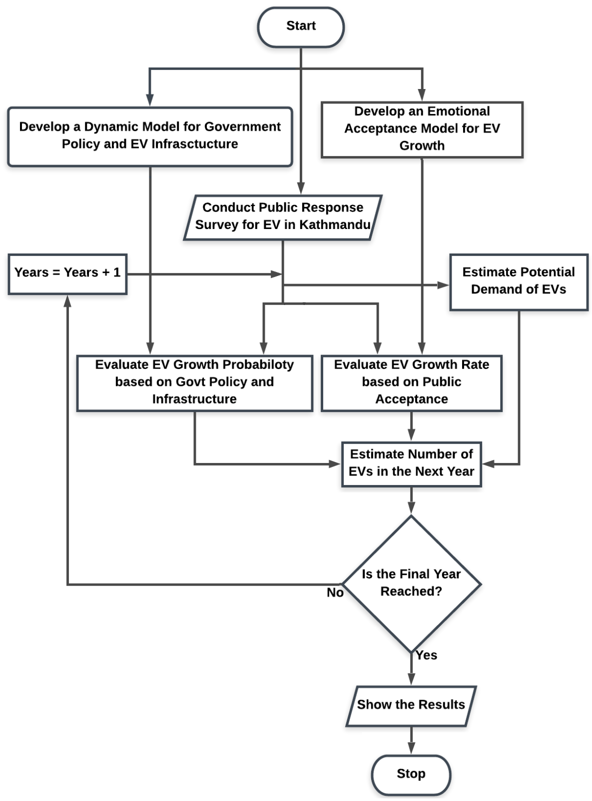

Figure 1: Flowchart Showing the Paper General Methodology

The diffusion model of the Nepalese market based on the model of Struben and Sterman [9] was built with some modification to match research goal. Struben and Sterman emphasize a broad boundary of AFV transition, "including attributes, driver experience, word of mouth, marketing, learning through R&D and experience, innovation spillovers, and infrastructure" [9]. However, the research did not consider the effect of policies, which is a key factor in Nepalese EV promotion. This research has focused on key factor, including policies, charging infrastructure and vehicle attributes. Moreover, the model has considered those factors from consumer preference view. Secondary data has been obtained from governmental and non-governmental organizations. Primary data has been obtained from field visit/questionnaire survey to estimate different parameters of our modified Struben and Sterman Model.

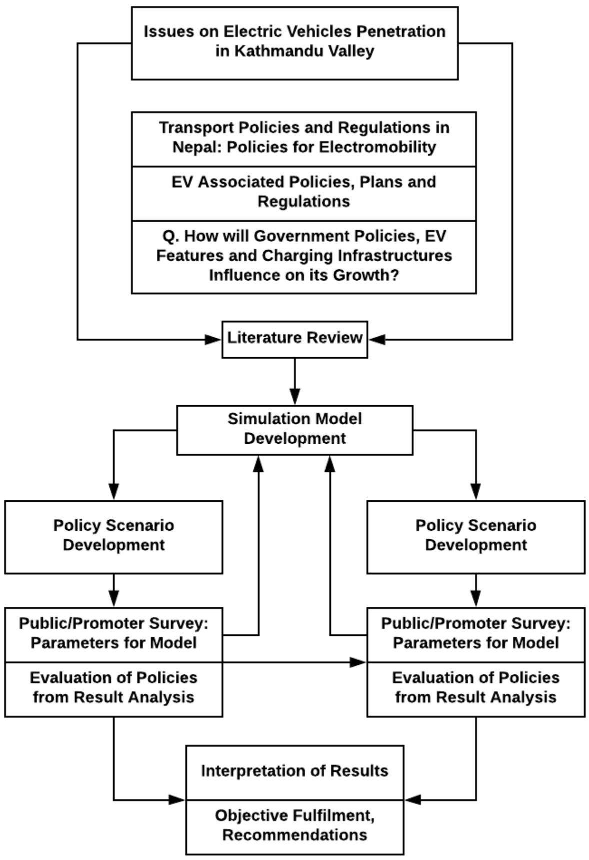

Figure 2: Flowchart Showing the Paper Specific Methodology

In several works, the Struben and Stermen EV Diffusion model has been used. For example, in a study in context of Shenzhen [10], the authors used it to investigate the influence of infrastructure development plans, duration of policies, and phase out strategy of policies. Similarly, System Dynamics Method has been used by Turan and Yücel [11] to evaluate the plausible diffusion patterns of electric vehicles for Istanbul and extent of the diffusion rate in Istanbul after three decades.

The general methodology followed during this method is shown in Figure 1. Development of different models, calculation of different states and their tabulation for a period of 10 years of time in 120 iteration, where one iteration is equivalent to 1 month, is implemented in this paper. In each of the iterations, the model is run completely, updating the values of the variables and recording/tabulating the results as per our requirement.

The general methodology, as seen in Figure 1, includes the development of dynamic models for emotional acceptance of EV diffusion and rational choice, as recommended by [12, 13]

In the next figure, Figure 2, the specific methodology explaining the method of System Dynamics implemented in this paper is shown. Here, the interaction between different aspects, viz. government policy, public emotional aspect, their response, etc are elaborated.

The methodology of the paper, giving special emphasis to the System Dynamics model is provided in the second flowchart, presented here in Figure 2. It includes all the works done in the research, including the literature review, review of government policies in Nepal, China, Bhutan and India, brief structure of policy scenario development, survey structure, and the incorporation of survey results.

The survey questionnaire used are generally relating to the public's response to easy taxation, purchase subsidy, environmental impact of EVs, ease in operation and maintenance of EVs, their willingness to recommend EV to someone else based on these qualities of EV, and in addition to these, the survey collects their expectations from government side for emphasis on growth of EVs.

3. Model Development

The system dynamics model developed in VENSIM-PLE for this study consists of two major parts. The first one, concerning to general public's response to government policy, their understanding of EVs and their general necessity, is termed as Emotional Acceptance part. This part takes the public's response obtained from our survey and using appropriate mathematical procedures, calculates the public's overall willingness to consider buying an

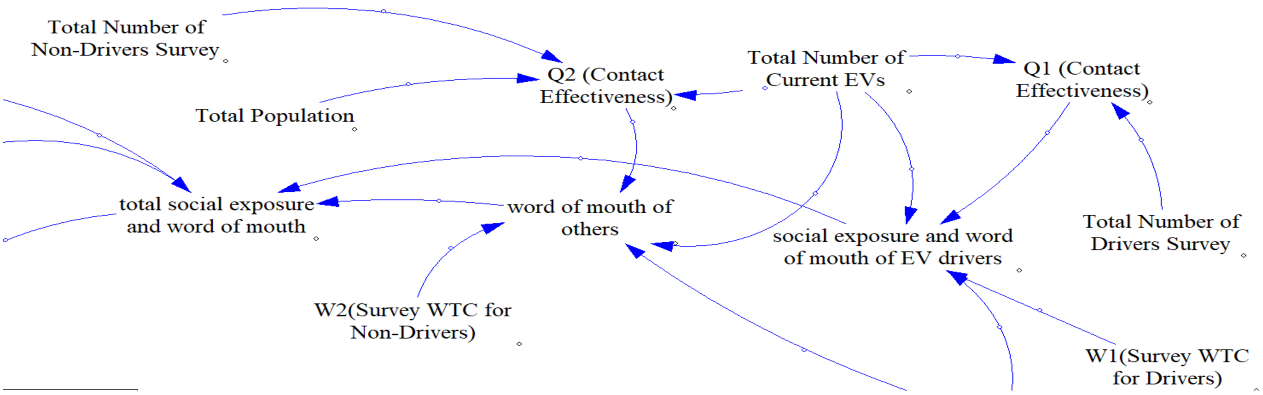

Figure 3: Emotional Acceptance Models

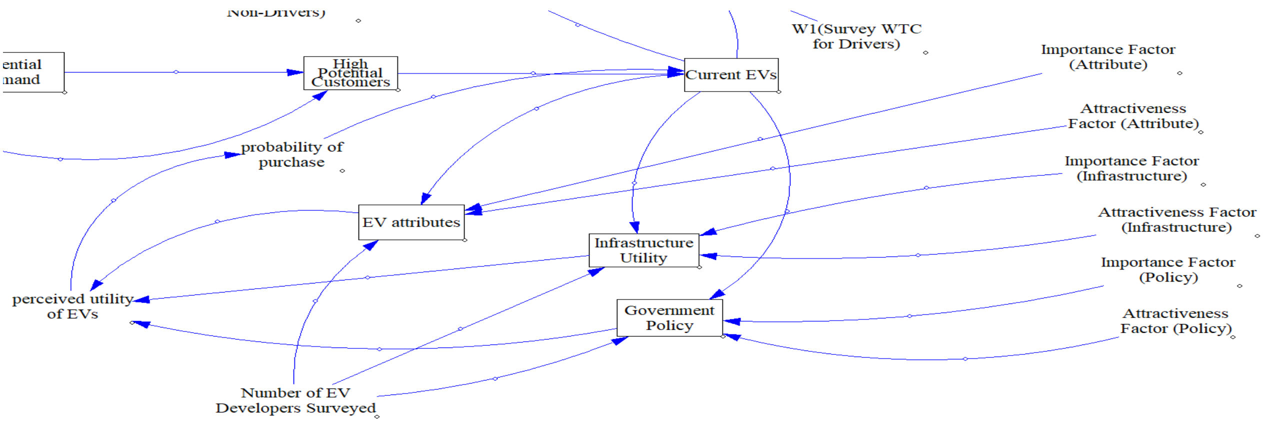

Figure 4: Government Policy and Allied Models

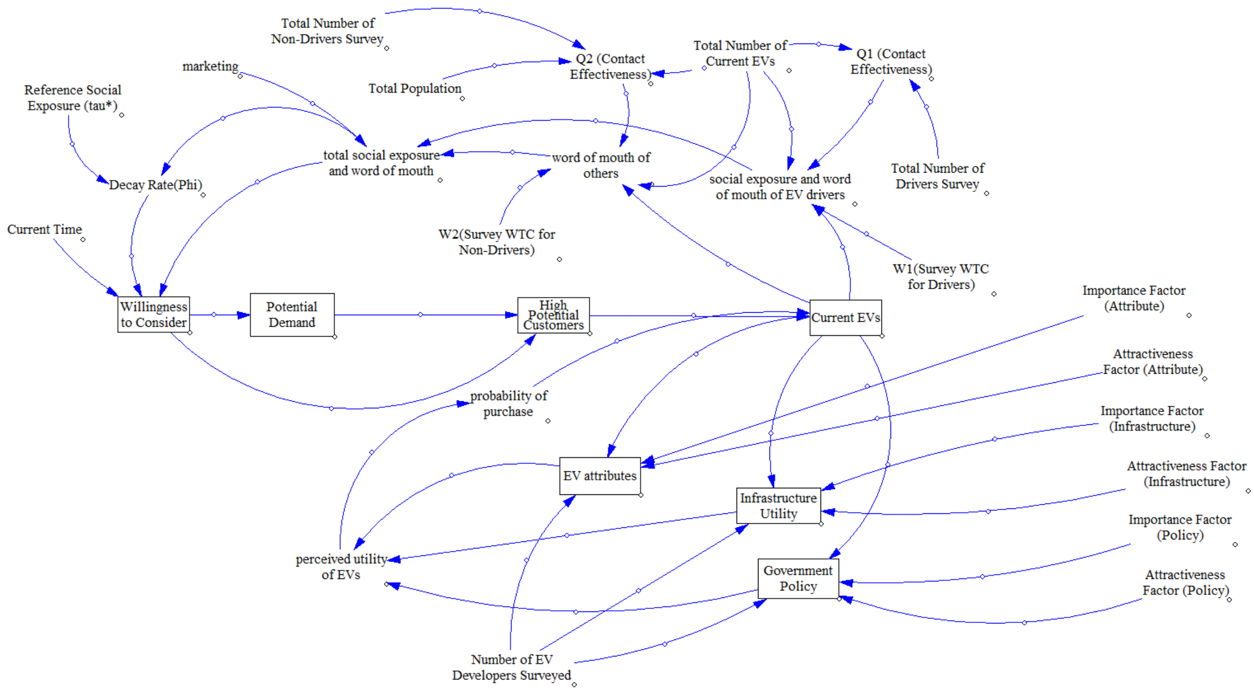

Figure 5: VENSIM Complete Model

electric vehicles. A snap of the model developed in VENSIM-PLE is provided in the following figure, Figure 3.

In order to incorporate the government policy, EV infrastructure and vehicles attributes, the model regarding government policy and related aspects was developed and is shown in Figure 4. This part of the model includes the response of people regarding how important a factor is for them to consider buying an EV. The factor includes the detail of the government policy, charging infrastructure and EV attributes. These are explained in detail in the following table, Table 1.

Table 1: Factors Affecting Rational Choice of EV

Category	Factors
Government Policy	Purchase Subsidy, Taxation
Vehicle Attributes	Purchase Cost, Operation Cost, Charging duration, Driving range
Charging Infrastructure	Number of Charging Stations, Charging place

3.1 Mathematical Models of Different Blocks

While calculating the growth of EVs, the response of public to the government policy obtained by the survey needs to be incorporated into the mathematical models developed. The mathematics behind this incorporation is explained in this section.

The response of EV drivers should contribute more to the results because one who has actually used an EV knows better about its aspects. The survey results of EV drivers is converted to what is known as Word of Mouth, which is calculated as shown in Equation 1[9, 10].

$$WOM_D = Q_1 W_1 (\frac{V}{N}) \quad (1)$$

Similarly, the response of non-EV drivers are quantified using the following formula, Equation:2.

$$WOM_O = Q_2 W_2 (1 - \frac{V}{N}) \quad (2)$$

Where,
q_1 and q_2 are contact effectiveness
W_1 and W_2 are willingness to consider calculated from survey responses
V = Total number of vehicles (EV + CV)
N = Number of EVs
$\frac{V}{N}$ = Share of EVs in Market
$1 - \frac{V}{N}$ = Share of CVs in Market

Another important factor that decides the total social exposure and provides a measure of effect of marketing of EVs is Marketing Effectiveness Factor λ. The complete measure of total social exposure is given as the sum of these three factors, as shown in Equation 3.

$$\tau = \lambda + WOM_D + WOM_O \quad (3)$$

During the EV consideration stage, the willingness to consider or consideration rate varies as shown in Equation 4, the integration of which, gives us the total willingness to consider, W [9, 10].

$$\frac{dW}{dt} = \tau(1 - W) - \phi W \quad (4)$$

Here,
ϕ is the decay rate of W.

The differential equation in 4, after solving it, could also be written as follows.

$$W = \frac{t\tau}{(1 + (\tau - \phi)t)} \quad (5)$$

In order to get a modified Struben and Stermen model, Equation 5 has been used instead of Equation 4. The reason behind using the modified model instead of the original model is that the modified model provides much more relevance to the current condition of vehicles and transportation in Nepal. The discards of any vehicles is very low, the EV drivers' willingness to consider is not always a full hundred percent, and the interrelation between government policy and EV attributes is rarely seen, due to whihch the modified model portrays the condition of Nepal's electricity market more appropriately than the original model.

The calculation of the decay rate ϕ is given as, Equation 6 [9].

$$\phi = \frac{1}{1 + exp(-2(1 - \frac{\tau}{\tau*}))} \quad (6)$$

Where,
$\tau*$ = reference social exposure when WTC decays at the rate of 50%.

The probability of purchase is given as,

$$P = \beta_p * a_p + \beta_c * a_c + \beta_v * a_v \quad (7)$$

Where,
β_p and a_p are government policy importance and attractiveness factors respectively
β_v and a_v are vehicle attributes importance and attractiveness factors respectively
β_c and $a_c$are charging infrastructure importance and attractiveness factors respectively
The constituents of these critical factors are shown in Table 1.

4. Survey Sample Description

During the survey of general public in Kathmandu, the people who contributed to the survey were of different social and educational background. Special attention has been paid to make the inclusive and representative of whole population of Kathmandu. The survey sample description is presented in the table below, Table 2

Table 2: Sample Description

Index	Variable	Percentage
Gender	Male	88.3%
	Female	11.7%
Age (years)	18-22	20.2%
	22-35	73.3%
	35+	6.5%
Occupation	Staff	22.7%
	Advance Management	5.3%
	Private Firm Owner/ Business	13%
	University Student/ Student	43.7%
	R&D Engineer	15.4%
Driving Experience	Less than 3 years	36%
	3-5 years	15.4%
	5-8 years	11.3%
	More than 8 years	18.2%
	Not Applicable	18.2%
Willingness to buy EV in 2 years	Already have an EV	3.6%
	Considering to buy an EV	40.5%
	Not Sure	47%
	Not Considering to buy an EV	8.9%

Here, the surveyed people includes both gender, of various age groups. Also, majority the respondents are from young age group, which is an advantage to us because this age group most determines the growth of EV in the future as this group is the one who will be using the means in the coming future, which is under our study. Also, majority of the respondents comprising of people with driving experience and their high willingness to consider shows that the growth of EV will be considerable in the days to come. Other demographic data also plays important roles in this study, which is expected to have been apparent in the other sections of this paper.

5. Results and Discussion

Based on the model developed in VENSIM, the graphs showing change of different variables such as probability of purchase, high potential customers, and number of EVs were obtained. As seen in the model in Figure 5, it is seen that the Current EVs depends on High Potential Customers and Probability of Purchase. The graph showing the growth of these three variables over the period of 10 years (120 months) is presented in Figure 6. Since the changes in policy over the time period and change in people's response during those times is not considered here, the growth of EV becomes steady after a certain time. Similar effect could be seen from the saturation of probability of purchase and the peak observed in the high potential customer graphs.

Similarly, the change in total social exposure and decay rate, and their effect in willingness to consider is shown in the following figure, Figure 7.

It could be observed that if the current policy and infrastructure regarding EVs is up to customer's expectations, the number of EVs in Kathmandu will grow from 3479 to 950,000 in ten years. But in order to obtain the growth, the government policies, EV attributes, and infrastructures should be as per the customer expectations, as stated above.

6. Conclusion

It was clearly seen from the results that with the choice of policy and infrastructure development from the government side according to consumer preferences, there could be considerable rise in EV in Kathmandu in a short period of time. The rise in number of EVs from 3479 to 950,000 from the start of the simulation to the end (a period of ten years) was a considerable growth regarding the relatively small sample and un-supportive policy status of Nepal. Even though this paper did not implement the changes in policy after certain period of time (since government policy changes continuously based on intermediate status of what the policy affects), high rise in number of EVs was seen vibrantly in the results section. Also, from the survey data, it was inferred that the newer generation (age group 18-35 years) were more interested in buying EVs and

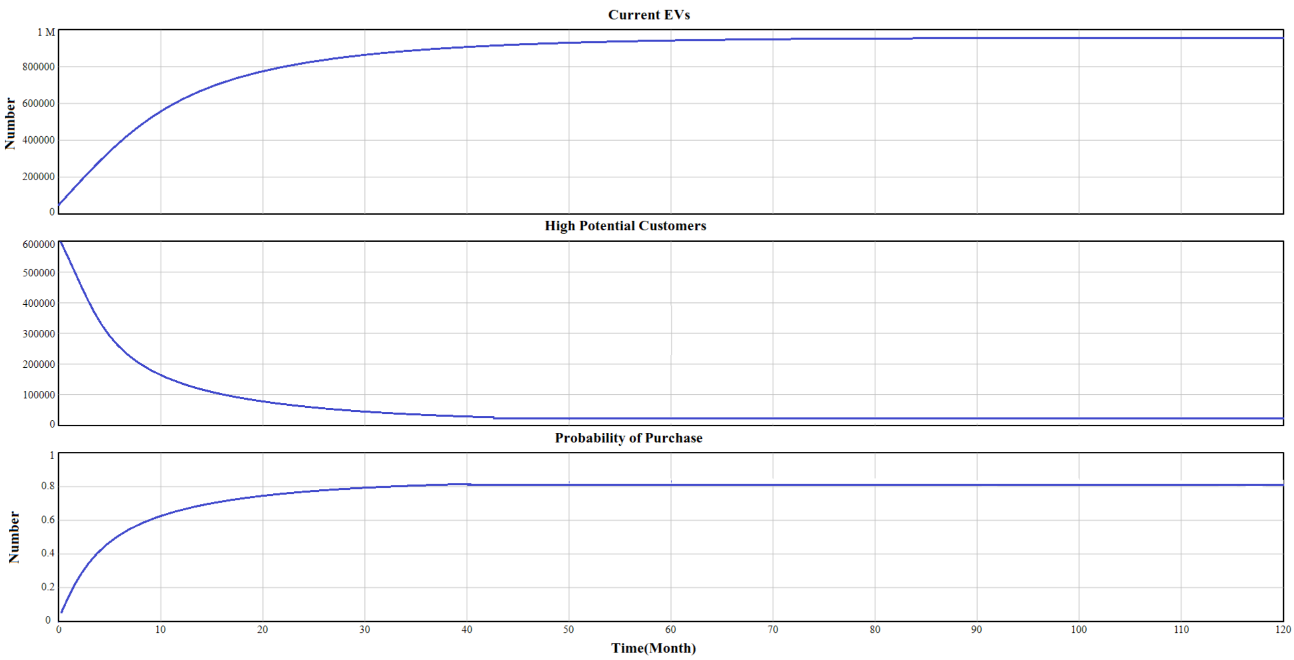

Figure 6: Graph of EV Growth and its Causes

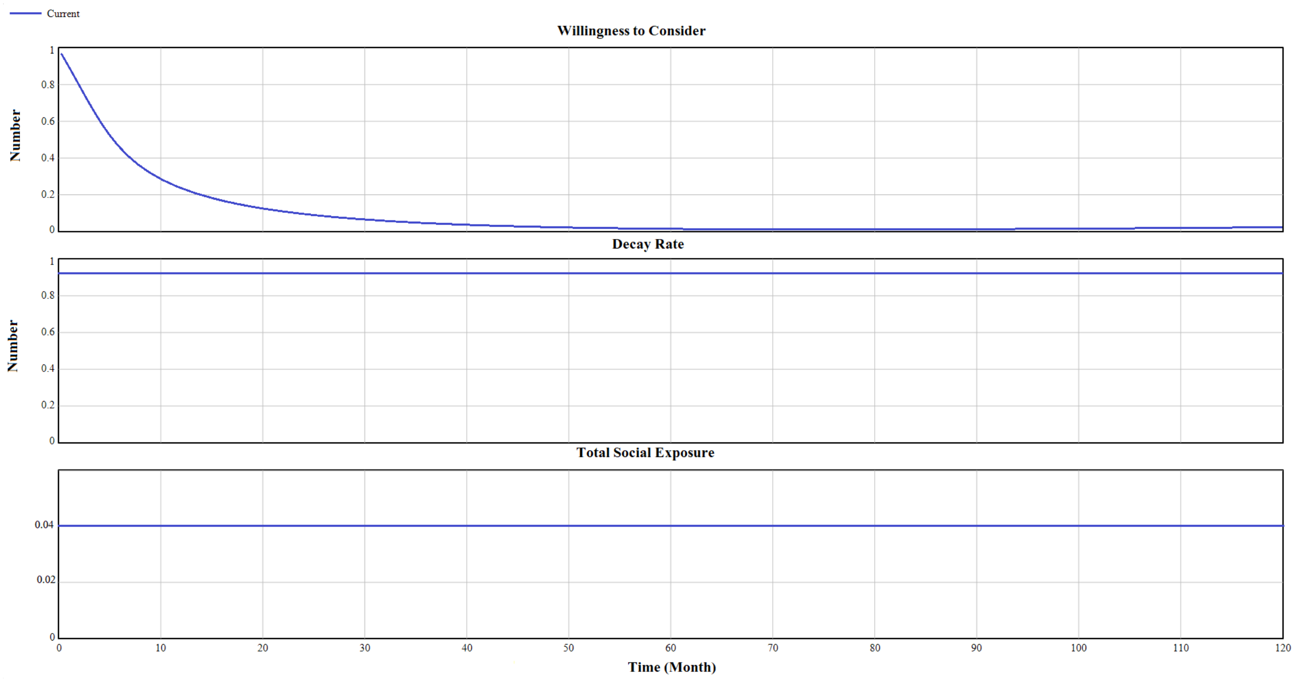

Figure 7: Graph of Willingness to Consider and its Causes

considering this, there could be demographic dividend effect on the growth of EVs in Kathmandu valley too. Hence, using the system dynamics method, the future prediction of EVs based on customer preferences is done in Kathmandu Valley, Nepal.

Acknowledgments

The authors extend their hearty gratitude to the faculties and colleagues at Tribhuvan University, Institute of Engineering, Pulchowk Campus for their constant help, support and recommendations. They owe their gratitude to the people of Kathmandu involved in the survey which gave shape to this whole research.

References

[1] National Planning Commission. Nepal's sustainable development goals status and roadmap: 2016-2030. 2017.

[2] Beatrice Murray, Isabella C. Bassignana Khadka, Andrea Perlis, Amy Sellmyer, Punam Pradhan, and Asha Kaji Thaku. Rapid urban assessment of air quality for kathmandu, nepal. 2012.

[3] Nepal Oil Corporation. Annual report. 2013.

[4] Sushila Maharjan. Electric vehicle technology in kathmandu, nepal: A closer look at development. 2002.

[5] Shreeraj Shakya. Analysis of low carbon development strategies:role of transport sector electrification and carbon tax in nepal. 2012.

[6] Central Bureau of Statistics, Government of Nepal. National population and housing census 2001. 2012.

[7] Shobhakar Dhakal. Urban transportation and the environment in kathmandu valley, nepal: Integrating global carbon concerns into local air pollution management. 2006.

[8] Japan International Cooperation Agency JICA. Data collection survey on traffic improvement in kathmandu valley. 2012.

[9] Jeroen Struben and John D Sterman. Transition challenges for alternative fuel vehicle and transportation systems. January 1, 2008.

[10] Jiali Yu, Peng Yang, Kai Zhang, Faping Wang, and Lixin Miao. Evaluating the effect of policies and the development of charging infrastructure on electric vehicle diffusion in china. 2018.

[11] Özlem Turan and Gönenç Yücel. Analyzing electric vehicle diffusion scenarios for istanbul. 2014.

[12] Zeinab Rezvani, Johan Jansson, and Jan Bodin. Advances in consumer electric vehicle adoption research: A review and research agenda. 2015.

[13] María Yetano Roche, Susana Mourato, Manfred Fischedick, Katja Pietzner, and Peter Viebahn. Public attitudes towards and demand for hydrogen and fuel cell vehicles: A review of the evidence and methodological implications. *Energy Policy*, 38(10):5301 – 5310, 2010. The socio-economic transition towards a hydrogen economy - findings from European research, with regular papers.

[14] A Baral and R Parajuli. Bottlenecks in the proliferation of electric vehicles in nepal. 1999.

[15] Gert Berckmans, Maarten Messagie, Jelle Smekens, Noshin Omar, Lieselot Vanhaverbeke, and Joeri Van Mierlo. Cost projection of state of the art lithium-ion batteries for electric vehicles up to 2030. 2017.

[16] Andrew F. Burke. Batteries and ultracapacitors for electric, hybrid, and fuel cell vehicles. April, 2007.

[17] Department of Customs, Government of Nepal. Foreign trade statistics. 2016-2019.

[18] Gross National Happiness Commission, Government of Bhutan. Eleventh five year plan volume i: Self reliance and inclusive green socio-economic development. 2013.

[19] World Bank Group. Climbing higher: Toward a middle-income nepal, country economic memorandum. 2017.

[20] John Paul Helvestona, Yimin Liu, Elea Mc Donnell Feit, Erica Fuchs, Erica Klampfl, and Jeremy J. Michalek. Will subsidies drive electric vehicle adoption? measuring consumer preferences in the us and china. March 2015.

[21] Hong Chen Wenbo Li, Ruyin Long. Consumers' evaluation of national new energy vehicle policy in china: An analysis based on a four paradigm model. December, 2016.

[22] Ministry of Physical Infrastructure and Transport. Kathmandu sustainable urban transport project. 2013.

[23] Daniel Sperling. Future drive: Electric vehicles and sustainable transportation. 1995.

[24] Govinda Raj Pokharel. Moving towards electromobility for energy security and prosperity. 2018.

[25] Ning Wang, Linhao Tang, and Huizhong Pan. Analysis of public acceptance of electric vehicles: An empirical study in shanghai. 2018.