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Techno-Environmental and Financial Aspect of Three Wheeler Vehicles: A Case Study of Electrical and Gasoline Three Wheelers in Hetauda, Nepal

by

Sabina Uprety

A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Techno-Environmental and Financial Aspect of Three Wheeler Vehicles: A Case Study of Electrical and Gasoline Three Wheelers in Hetauda, Nepal"** submitted by Sabina Uprety in partial fulfillment of the requirements for the degree of Master of Science in Renewable Energy Engineering.

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Supervisor, Prof. Ramchandra Sapkota
Department of Mechanical Engineering
Institute of Engineering, Pulchowk Campus

____

External Examiner, Prof. Dr.Bhakta Bahadur Ale

____

Committee Chairperson, Assoc. Prof. Dr. Nawraj Bhattarai
Head of Department
Department of Mechanical Engineering

November13, 2019
____

Date

ABSTRACT

This study aims to analysis scenarios of the energy situation of three wheeler vehicles i.e. gasoline and electric in Hetauda. The transport sector is one of the major consumers of fossil fuels and uses a significant amount of the global energy supply. Several energy vectors have been discussed in the past, including hydrogen and electricity. The uptake of electric vehicle in the existing fleet of vehicles has positive impacts in the reduction of emissions and reduces the carbon footprints by moving in to greener transport. In a country like Nepal, where there is huge hydropower potential, we can allocate a substantial amount of that production in the transportation sector. A continuous increment in the petroleum price and looming uncertainty of supply can be considered as another reason to switch to the home-based energy system in Nepal.

The three types of scenarios including one Business as usual scenario and other two different replacement scenarios, namely, ETRM 75, ETRM 100 for the period 2018-2035 are analyzed in this study. At BAU the total energy consumption is increased from 230.4 TJ in 2018 to 333.5 TJ in 2035.At ETRM 75 the total energy consumption is decreased from 230.4 TJ to 225.5 TJ by the year 2018 to 2035 .Similarly in the scenarios ETRM 100 the total energy consumption is decreased from 230.4 GJ to 75.5 TJ by the year 2018 to 2035.The cumulative cost saved from avoided energy is NRs. 1.1 million and NRs. 2.5 million constant prices of 2018 under ETRM 75 and ETRM 100 scenarios respectively in comparison to BAU scenario. Since net social benefit of replacing by both ETRM 75 and ETRM 100 is positive, ETRM 100 scenario is the best option.

This thesis outlines the electric vehicle development and examines the diffusion pattern or growth of electric vehicles and contributes to future market share of electric vehicle based on two different scenarios from government in terms of vehicle infrastructure and attributes, situation and policies. Public’s expectations, their willingness and attraction towards electric vehicles have been understood based on various questionnaires posed to them. 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.

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LIST OF ABBREVIATIONS

Ah	Ampere Hour
BAU	Business as Usual
CBS	Central Bureau of Statics
CGE	Computable General Equilibrium
CO	Carbon Monoxide
CO2	Carbon Dioxide
DOTM	Department of Transport Management
ESM	Energy System Model
ETRM	Electric Tempo Replacement
EV	Electric Vehicle
G J	Giga Joules
GDP	Gross Development Product
GHG	Green House Gas
ICEVs	Internal Combustion Vehicle
kWh	Kilo Watt Hour
LEAP	Long Range Energy Alternative Planning
MJ	Mega Joules
MW	Mega Watt
NMVOC	Non-Methane Volatile Organic Compounds
NO_2	Nitrogen Oxide
NOC	Nepal Oil Corporation
NRB	Nepal Rastra Bank
NRs	Nepali Rupee
Pkm	Passenger Kilometer
PM	Particulate matters having size less than 10 microns
SEI	Stockholm Environment Institute
SKD	Semi Knock Device
SO_2	Sulphur dioxide
TJ	Tera Joules
V-km	Vehicle Kilometer

CHAPTER ONE: INTRODUCTION

The global shifting away from petroleum fuels and towards more renewable energy sources has resulted in a significant progress in favor of vehicle electrification. The development of electric vehicles (EVs) is an emergent solution to green the existing transportation systems and to reduce the issues of climate change. In recent years, scholars, policy-makers, and the general public in many parts of the world have become increasingly concerned over health and environmental damages associated with air pollution. As urban transport is among the most important contributors to urban air pollution, this concern has led to a heightened interest in Electric Vehicles (EVs) as well as other environmentally friendly alternative forms of transport. Consequently, many industrialized countries have revised the policies to encourage the use of alternative-fuel vehicles. Also, motivated by the increasing environmental concerns and the available resource limitations of oil, the automobile industry has continued to develop different alternative fuel vehicles. In the United States, for example, California, New York and a few other states had mandates that required 10% of all motor vehicles sold after 2003 to be zero-emissions vehicles or, in other words, EVs. California, in particular, provides certain sales credit to encourage the purchase of EVs (Bhatta & & Joshi, 2004).Out of all the potential solutions that do not utilize petroleum, battery electric vehicles (BEVs) are among the widespread and most popular option these days. One of the main advantages of BEVs is that these vehicles have zero emissions (generating no greenhouse gases or pollutants) and contains fewer moving parts which results lesser maintenance and operating costs/expenses. Hence, BEVs help contribute to cleaner air and they are better for the environment. Also, these vehicles run on electricity, which can be generated through more renewable and environmentally friendly resources. Decreasing air quality and rapidly increasing fuel price with frequent fuel strikes has increased the interest of people of towards electrical vehicle. Public awareness about benefits of reducing air pollution level by replacing ICEVs by EVs is in increasing rate. Many researchers, advocates and environmentalists are encouraging government to make favorable policies to expand electrical vehicle system. Furthermore, as there have been great investments in support of infrastructure, battery electric vehicles have become greatly viable and seem to be feasible option in automotive market for consumers. Electric vehicles can help to alleviate one of the major problems in megacities like – the air and noise pollution. There has been significant increase of commercial energy (which includes petroleum, coal and grid) in total energy mix in Nepal. In Nepal, transport sector consumes about 63% of total imported petroleum fuel (NOC, 2013). Furthermore, the high use of petroleum in the transportation sector generates a high level of greenhouse gases and aggregates the air pollution. Especially, automobile emissions generate significant amounts of particulate matter, such as PM 2.5, which pose a substantial risk to public health.

Nepal is a hydropower resource rich developing country. Since most of the electric vehicle use electricity for charging at off-peak time in Nepal, utilization of electricity for clean transportation purpose will not have much impact on increasing load shedding. Since Nepal has huge hydroelectricity potential, it will be an added advantage to use electrical vehicle instead of fuel vehicle

1.1. Background

Energy is the core of the economy, and emissions of greenhouse gases from energy use are the principal contemporary contributor to human-induced climate change. Transportation is one of the major consumers of fossil fuel, consuming about one fifth of the global energy supply (Suresh, Blythe, Hill, Huebner, & Robinson, 2012).

All over the world, transportation has been an important sector, which accounts major portion of the global greenhouse gas emission growing in faster pace to cater economic activities. Transport alone was responsible for around 17% of global energy related CO_2 emissions in 2015 (EEA, 2016).Almost three-quarters of the emissions from transport were due to road. Particulate Matter (PM_{10}) is associated with a 2.57 % increase in all cause of mortality accounted for 20 days lag effect which is about 2.3 times higher than observed for one day lag and demonstrates the existence of an extended lag effect of ambient PM_{10} on all cause deaths (Shrestha, 2012) (Joshi S. , 2003).

The word rickshaw's origins lie in the Japanese language, and it literally translates to "a human-powered vehicle". The rickshaw is one of the oldest modes of transport, and was first introduced in the late 19th century. It is used all across the world, but more common in the Asian countries, especially in India and Bangladesh. The various types of rickshaws have also evolved over time with the earliest ones being the pulled-rickshaws. Other variations of the mode of transport include the cycle-rickshaw, the auto-rickshaw and the relatively newer iteration of the e-rickshaws. Historically, Nepal's urban as well as rural areas have depended on the various rickshaw types for their travel requirements. Electric rickshaws have been becoming more popular in some cities since 2008 as an alternative to auto rickshaws and pulled rickshaws because of their low fuel cost, and less human effort compared to pulled rickshaws. They are being widely accepted as an alternative to petrol/diesel/CNG auto rickshaws. They are 3 wheels pulled by an electric motor ranging from 650-1400 Watts. Battery-run rickshaws could be a low-emitter complementary transport for the low-income people, who suffer most from a lack of transport facility, if introduced in a systematic manner according to experts.

These rickshaws have a M.S (Mild Steel) tubular Chassis, consist of 3 wheels with a differential mechanism at rear wheels. The motor is brushless DC motor manufactured mostly in India and China. The electrical system used in Indian version is 48V and Bangladesh is 60V. The body design from most popular Chinese version is of very thin iron or aluminum sheets. Vehicles made in fiber are also popular because of their strength and durability, resulting in low maintenance, especially in India. Body design is varied from load carriers; passenger vehicles with no roof, to full body with windshield for driver's comfort. It consists of a controller unit. They are sold on the basis of voltage supplied and current output, also the number of MOSFET (metal oxide field effect transistor) used. The battery used is mostly lead acid battery with life of 2-3 years. Deep discharge batteries designed for electric vehicles are rarely used. Weight of the electric car has also been a recurring design difficulty in them.

1.2. Problem statement

Motor vehicle numbers have grown more rapidly in the cities which increase traffic congestion and environmental emissions daily. 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. 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 is dependent on domestic energy sources of Nepal. However, there are very few researches conducted which examines the influence of policies for promotion of EVs in capital city and estimate the development pattern in different 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 most effective policy recommendations for promotion EVs with realization of potential benefits.

1.3. Objectives

1.3.1. Main objective

The main objective of this project is to compare "Technical- environmental and financial aspect of three-wheeler (Electric and gasoline) vehicles of Hetauda city of Nepal.

1.3.2. Specific objectives

- To conduct survey for estimating maintenance/repair cost passenger/trip, trip distance and no. of trips/day in Hetauda.
- To forecast the EV demand in future energy demand without using gasoline vehicles in that area.
- To develop and analyse the different scenarios of energy consumption, local emissions and GHG emissions.
- To conduct financial analysis.

1.4. Limitation

1. The project topic is limited to three wheelers electrical and gasoline only.
2. Survey was carried out during Bhadra of F/Y 2073/74.
3. The study site in this research covers Hetauda only.
4. For the calculation of financial analysis following assumptions was taken.
    - Life time of vehicles was taken as 10 years.
    - Interest rate for bank was 10%.
    - Discounted rate for cost benefit analysis was 6%.

CHAPTER TWO: LITERATURE REVIEW

2.1 Transition trend of the world towards greener transportation system

European commission aims to reduce the emissions of road transportation in 2050 by about 70% compared with today's levels. Passenger cars can relatively easily switch to electricity, whereas this is much more complicated for heavy-duty road transport. The EU is setting up legally binding emission targets for new cars. Rapidly increasing efficiency of Internal Combustion Engine (ICE) vehicles may limit the introduction of electric and hydrogen vehicles. Road transportation is the second biggest source of greenhouse gas emissions in EU after power generation (de Wilde & Kroon, 2013), (GreenPeace, 2013). United States of America is also trying to move towards greener transportation system, President Obama has challenged the automotive industry and consumers alike to have 1 million plug-in hybrid electric vehicles on the road by 2015 (EEA, 2016).

2.2 Electric vehicle in Nepal

The history of an Electric Vehicle (EV) in Nepal is relatively new. In 1975 trolley bus system was introduced by Chinese Government along 13km route between Tripureshwor and Surya Binayak was first EV in Nepal. In 1989, after the embargo imposed by India and consequent fuel scarcity in Nepal has prompted a certain group of intellectuals, engineers and entrepreneurs to explore alternative sources for transportation so that Nepal can manage during such period which led the innovation in this field (Roy, Gurung, & Bam, 2001). Now we have different EVs that are running on the roads of Nepal, especially like motorbikes, small cars, etc., but by far tempo dominates the electric vehicles share in Nepal. Every year new products are launched we can say that there is growing public interest in EVs.

2.3 Growth of three wheelers

As three-wheeler growth in Nepal we can see that it was first officially registered in F/Y 2046/47 with 2359 numbers of tempos. Finally, in F/Y 2073/74 their number was increased to 17,782. The total number of tempi till now is 29,463. But here in this tempo it includes all i.e. diesel, gasoline and safe tempo. Similarly, electric three wheeler it was officially registered in F/Y 2072/73 with number of 11894 and in F/Y

2073/74 it was 2247 and the total of till now the total three wheeler electric vehicles are 14141.

2.4 Fuel consumption scenario

Nepal has no known oil, gas or coal deposits. All commercial fossil fuels (mainly oil and coal) are either imported from India or from international markets routed through India have raised the concern of Energy Security and economic impact. In figure 2.1 shows the increasing patterns of imported petroleum product from India accept in the year 2017, due to the embargo imposed by India.

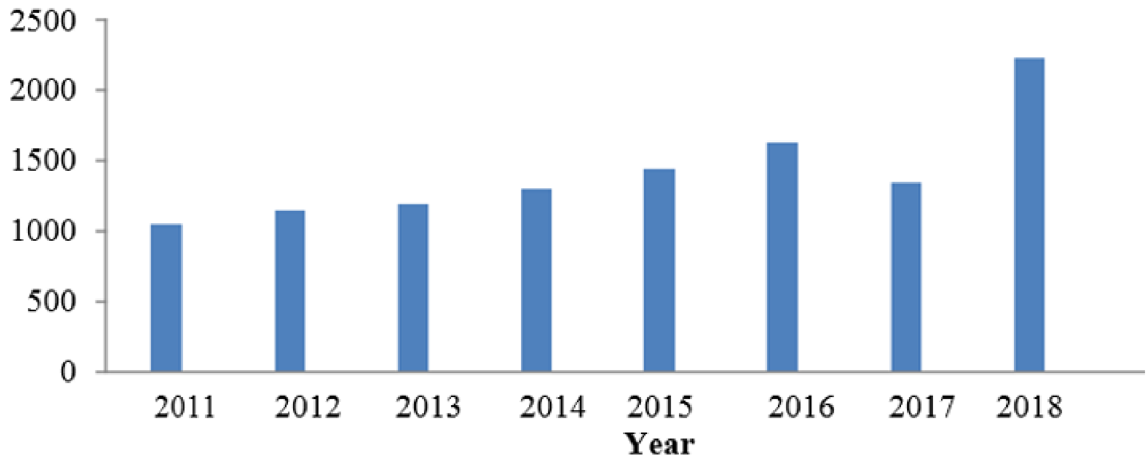

Figure 2.1: Import of Petroleum Product (NOC, 2018)

In the current year, the expenditure made on imported fossil fuels is far more than the revenue Nepal generates from the export of all commodities. Nepal is in the list of rare countries which cannot finance the import of fossil fuels by exporting its total commodities (CBS, 2018). The comparison between expenditure on petroleum products and total value from the export of commodities is illustrated in Figure 2.2

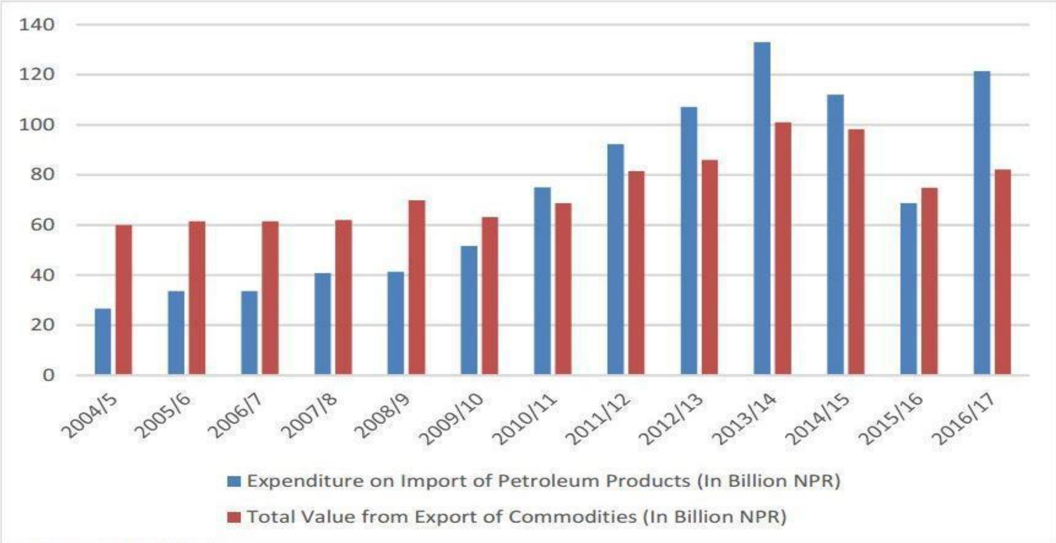

Figure 2.2: Total expenditure on import and export (NRB, 2018).

2.5 Vehicle registered in Nepal

As official the vehicles registration system was introducing in F/Y 2046/47 in Nepal so at that time total number was 46,147 and in the end of F/Y 73/74 was 73,174. Till F/Y 73/74 its number is 2,783,428.

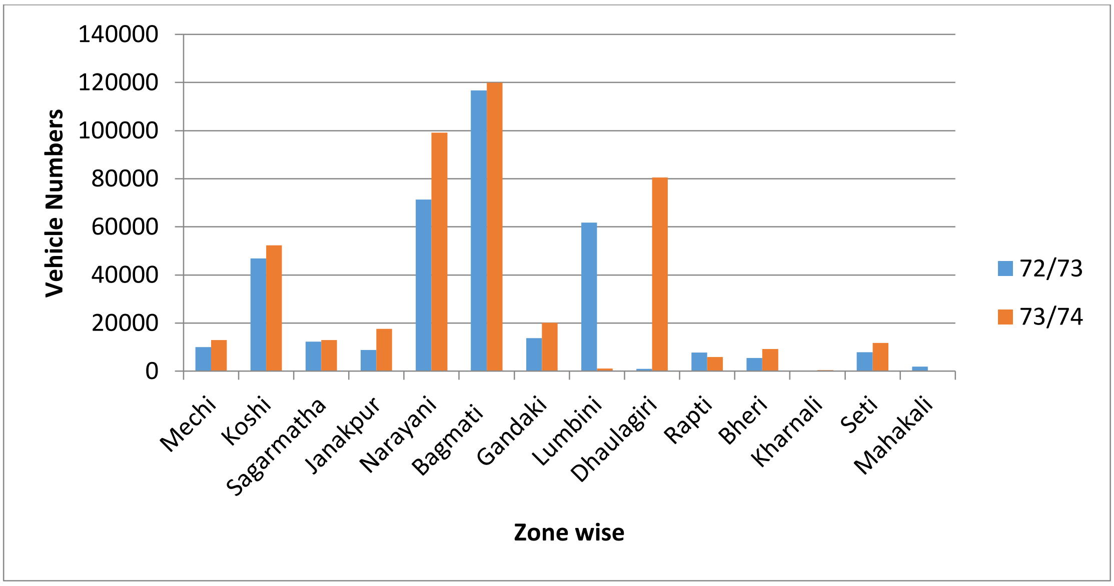

Figure 2.3:Vehicles registration F/Y 72/73 and 73/74 in Nepal (DOTM, 2017)

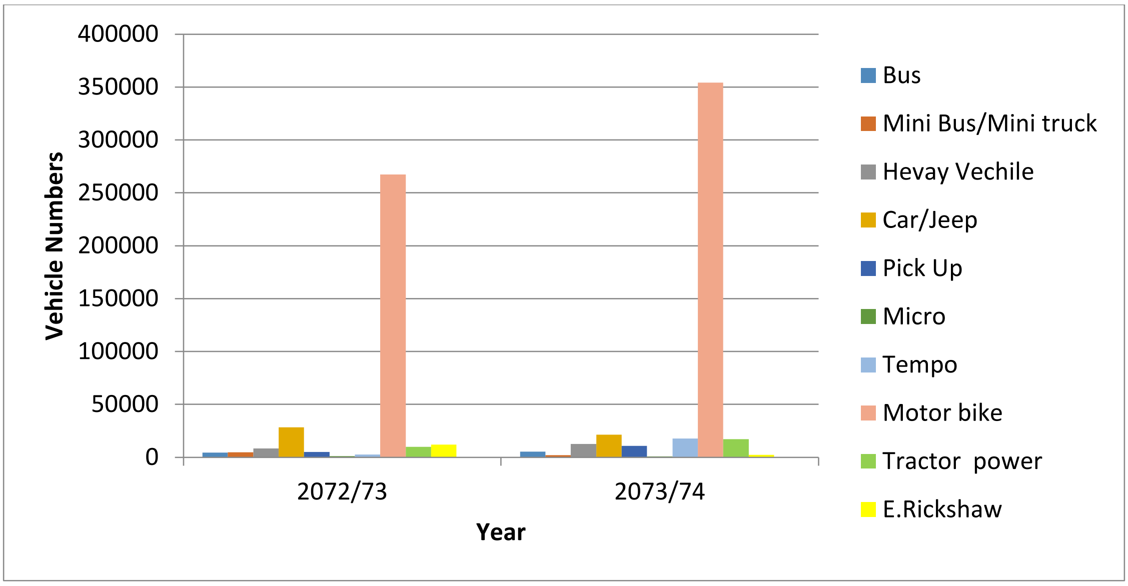

Figure2.4: Vehicles registration type wise for the F/Y72/73 and 73/74 in Nepal (DOTM, 2017)

2.6 Vehicle registered in Naryani zone

The vehicles registered in Narayani are the highest after Bagamati zone in Nepal. While registering first period in F/Y 46/47 its number was 21,368. Similar in F/Y 203/74 it was 99,147. Now till F/Y 203/74 now total number of the vehicles registered in the Narayani zone is 625,089.

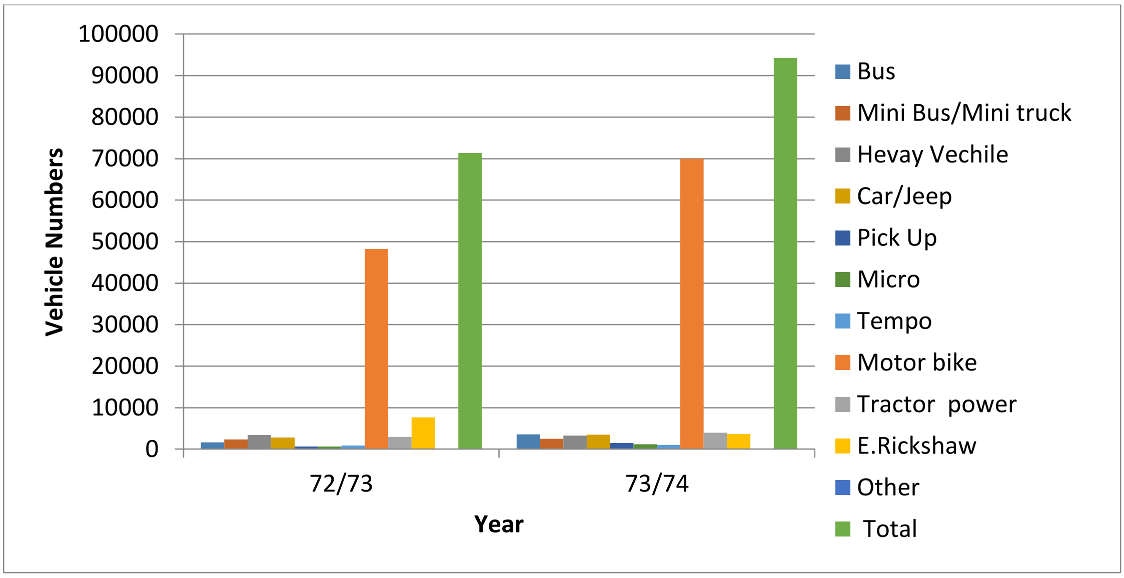

Figure 2.5: Vehicles registration type wise for the F/Y72/73 and 73/74 in Narayani (DOTM, 2017)

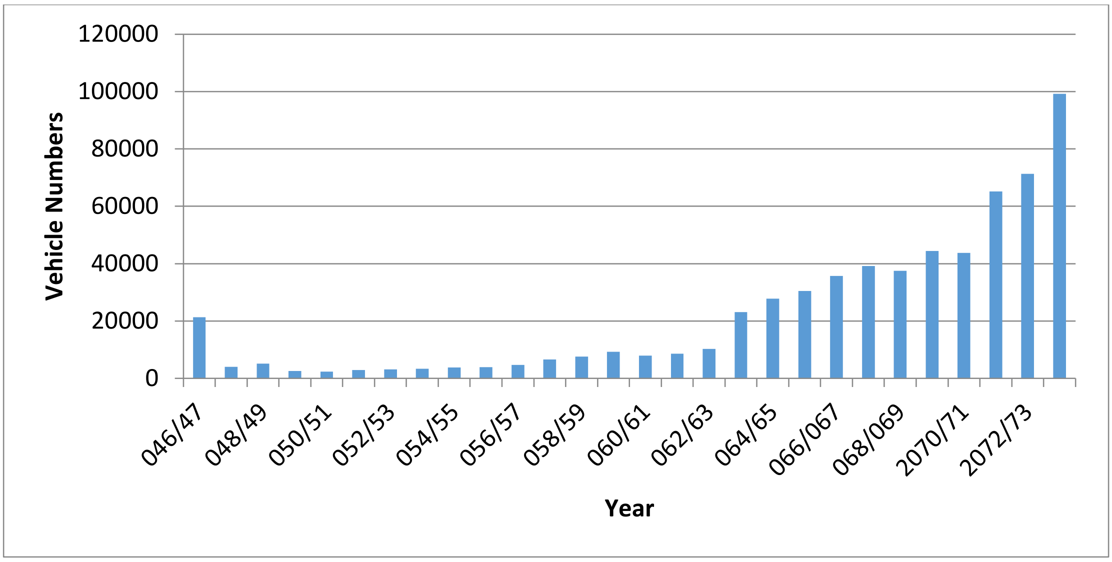

Figure 2.6: Trend of vehicles increment in Narayani zone for different F/Y (DOTM, 2017)

2.7 Existing number of three-wheeler electric vehicles in Hetauda

The total no of electric vehicle in registered in Narayani zone was 7,686 in F/Y 72/73 and F/Y 2073-2074 was2,247 for as it was the highest number tobe registered in Nepal at that period because for its new vehicles as well as there was free to registered in any zone by Nepal government. And this place is close to the Indian boarder. The total number were 998and 1,223 respectively for the F/Y 2072-7073 and F/Y 2073-2074 respectively.

2.8 Existing number of three-wheeler gasoline vehicles in Hetauda

The total no tempo (with others fuel) registered in Narayani zone was 890 only in F/Y 72/73 and this was very less in number as compared to electric tempo because at the high rate electric vehicle was introduced. But the running number of the gasoline was 837 in F/Y 2072-7073 of Hetauda. Similarly, in F/Y 2073-2074 there were 1037.

2.9 Main component of three wheeler electric and gasoline

Here the figures 2.7 and 2.8 show the difference of power flow in EV and the gasoline tempo in simple block diagram respectively. Electric vehicles or EVs are defined as vehicles that use an electric motor for propulsion. The electricity used to run the motor could come either through transmission wires, or through a single or a series of connected batteries. Several literatures have mentioned that if the electricity generated is from clean source, then electric vehicles can be considered as almost zero emission vehicles. Also, such vehicles reduce the CO_2 emissions of the country as they replace conventional fuel engine propelled vehicles and contribute towards reduction of greenhouse gases.

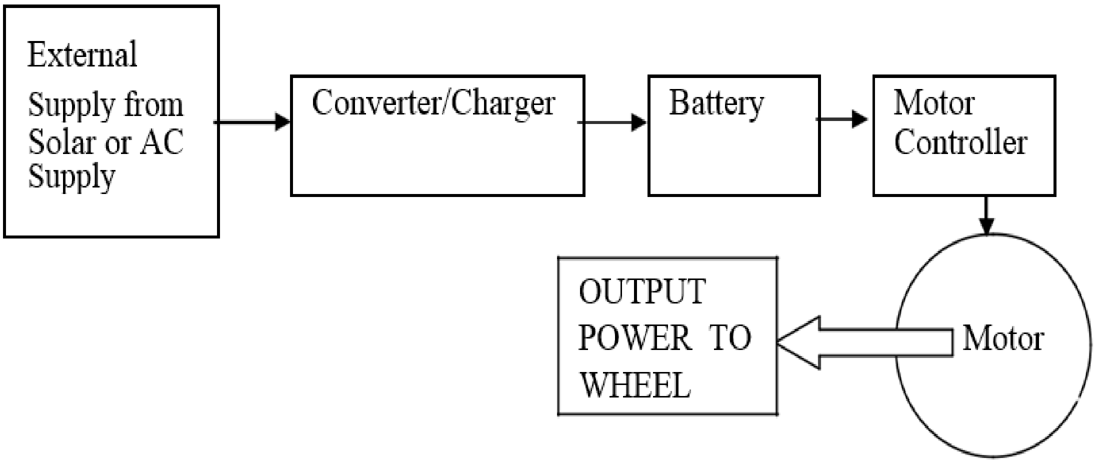

Figure 2.7: Block diagram of power flow in an electric vehicle

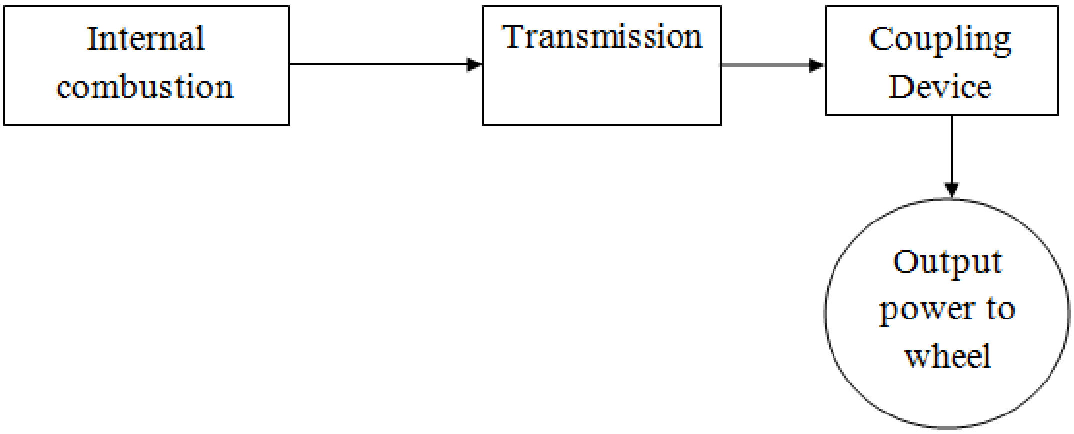

Figure 2.8: Block diagram of power flow in a gasoline vehicle

2.10 Trend of three wheeler vehicles

The figure 2.9 and 2.10 below shows how the three wheeler vehicles number is being increased in all fuels of Nepal. The fuel may be of any types i.e. gasoline, diesel and electric.

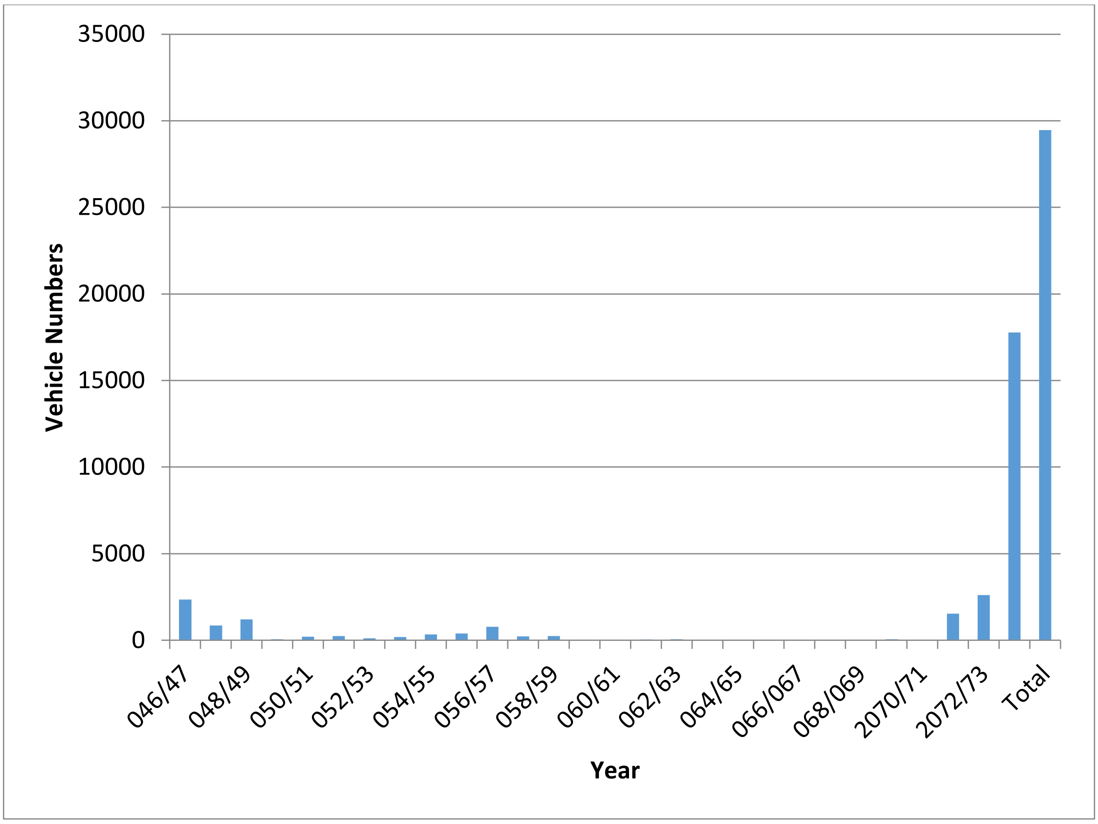

Figure 2.9: Year wise increment of Number of tempos in Nepal (DOTM, 2017)

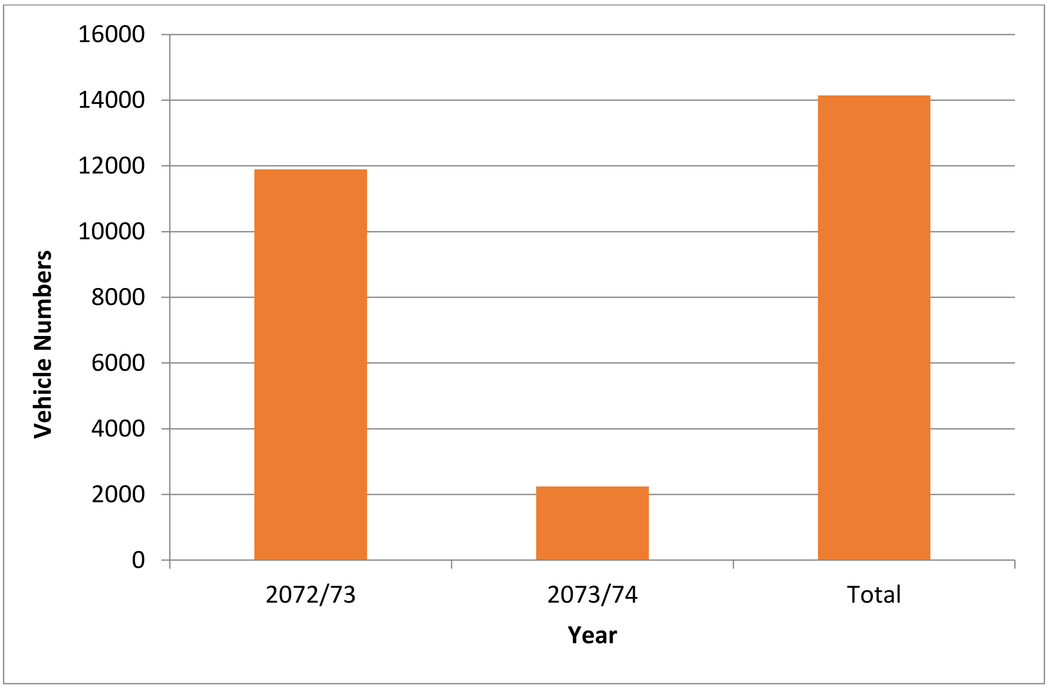

Figure 2.10: Year wise number of electric vehicles in Nepal (DOTM, 2017)

2.11 Gap identification

As the above figure of the three wheeler shows that day by day different three wheeler vehicle has been introduced in Nepal. Whether it may be of gasoline, electric and diesel. The increment of the three wheeler is being high as this can be noticed by above figure. Its good if three wheeler vehicle is replace i.e. gasoline and diesel being replace by electric vehicle. As our country is producing more domestic electricity. This lead to save our money that being paid to third country for importing high amount of oil products. As well as it helps in less GHG emission product. A case in Hetauda is done here because there was lager number of electric vehicles registered in F/Y 2072/73 i.e. 7,686. Hoping this may be increased more in next F/Y as compare to other vehicles in Narayani zone. Hetauda is Plain and Teria area so that tempo is most feasible in this area.

2.12 Case area

In short, through this case study, we can thereby understand the development pattern of EV in the context of Nepal and think how the development of EV can be done with policy interventions more successfully in upcoming days in Nepal.

Geographical information

The city is situated in a unique geographical structure called Doon, giving it a valley-like geography. It is surrounded by mountains, with the Mahabharata Range to the north and the Sivalik Hills to the south. The rivers Rapti, Samari, and Karra run through the city and flow southwest to meet the Narayani, one of the bigger rivers of Nepal.It is properly situated at the central of the Makwanpur district. It lies in the 27°25' N latitude and 85°02' E longitude and is situated at a level of 300-390m above the sea level. The total area of the city is 261 km^2 where around 254 km^2. (97%) is land and the remaining 7 km^2 (3%) consists of water. Boundary: East: Chhatiwan V.D.C West: Manahari, Haandikhola and Sarikhet V.D.C North: Naamtaar, Bhainse and Makwanpurgadhi V.D.C South: Bara and Parsa District, the city is surrounded by three rivers; Rapti river to the west, Samari river to the north, and Karra river to the south and is part of an important industrial regions. The settlement developed because of its location along the Tribhuvan Highway, and was later linked to another major national thoroughfare: the Mahendra Highway, also known as the East-West Highway.

Demographic information

According to 2018 census, Hetauda has the total population of 84,775. It was awarded as the cleanest city of Nepal in the year 2016 and 2017.

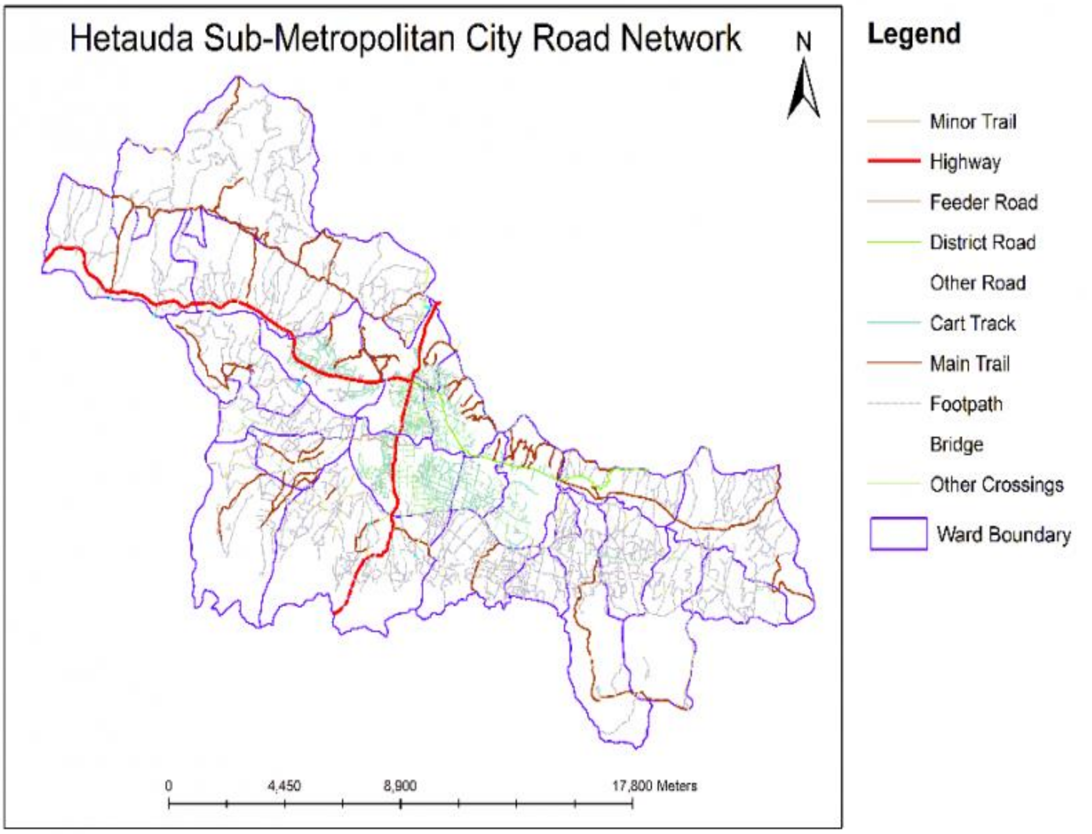

Figure 2.11: Hetauda Sub-Metropolitan City road network (DOTM, 2017)

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CHAPTER THREE: RESEARCH METHODOLOGY

3.1 General

The main sources of data i.e. primary and secondary data are collected from the Department of Customs and Transport Management Office through field visit and the various reports available. The secondary data related to energy consumption in the transportation sector is collected from relevant authentic government sources, both published and unpublished. These data are used to realize current situation of total number of electric vehicles and total number of gasoline vehicles. The main sources are (i) Statistical Yearbook of Nepal - CBS, (ii) National Living Standard Survey-CBS, (iii)Economic Survey – Ministry of Finance, (iv) Energy Sector Synopsis Report – WECS, (v) Annual Report – Nepal Electricity Authority, (vi) Annual Report of Department of Transportation Management, (VI) Nepal Oil Corporation, etc. These data will be analyzed in the Microsoft Excel Software and then will be brought into the Long-Range Energy Alternative Planning Software (LEAP). A number of scenarios will be created in the LEAP model.

The methodology adopted in this study is as follows:

1) Literature review
2) Data collection (Primary and secondary)
3) Data analysis
4) Model develops
    - Microsoft worksheet or spread sheet
    - Data flow in LEAP model
5) Results and discussions
6) Thesis report writing, submission and final presentation

The methodology for estimation of energy demand in future year varies widely. Traditional methods such as time series, regression, econometric, ARIMA as well as soft computing techniques such as fuzzy logic, genetic algorithm and neural networks are being extensively used for demand side management (Suganthi& Samuel, 2012).

3.2 Literature review

The study was carried for existing related data and other review of three wheeler vehicle of Nepal as well as of the Hetauda.

3.3 Data collection

The field survey or data collection was conducted for collection of primary and secondary data. Secondary data consists of total number of registered/operating vehicles in Hetauda. Secondary data were collected from several government offices, associated partners of electric vehicle as well as private research organizations. The collected data is in high number so its sample size is taken as it is. The various survey procedure applied for the collection of data are listed here.

The Survey Questionnaire is made which is presented in Annex.

3.4 Data analysis

The total data is collected then what is activity can be performed and other related what result can be drawn out etc. were analyzed. So, the following method was used to calculate carryout. The sampling unit is the driver of the public transportation vehicle. The sample size was determined by stratified sample technique. The certification was done on the basis of homogenous group.

Table 3.1: Sample collection data for the F/Y 73/74

S. N	Type	Ns	z^2pq	z^2pq/e^2	e^2Ns	z^2pq (Ns)	$e^2Ns+pqz^2$	z^2pq (Ns)/e^2Ns+pq z^2=(ni)	n0	Final sample size n=n0/ (1 +no/N)
1	Electric	989	0.96	384.2	9.89	949.44	10.85	96.96	52.52	34
2	Gasoline	837	0.96	384.2	8.37	803.52	9.33	96.96	44.44	30

In the table, z (1.96) is the desired degree of precision taken under the area of normal curve, p (0.5) and q (0.5) are the probability of successes and failure (if there is no past information available) and e (0.1) is the maximum risk admitted (acceptable error). The smaller this value is the more uniform.

3.5 Spread sheet

By using the spread sheet different calculation such as vehicle kilo meter, passenger per trip, passengers per kilometer, average maintenance cost total consumption per year and many other required is carried out.

3.6 Leap

TheLong Range Energy Alternative Planning Software (LEAP) is a widely used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute at Boston. It is a bottom up type accounting framework which allows user to define input at various levels. It requires data to be first assembled in hierarchical format following four levels viz. sector, subsector, end use and device.

The data of the vehicles were taken from DOTM and field survey and categorized according to our requirement. The classification used in DOTM is very broad; hence the gaps between the required data and available data were fulfilled using various published literatures. The operation factor has been used to account for the share of vehicle that is registered but not in operation (Dhakal, 2006).

The past trends and regression analysis are exogenous to the LEAP model. For the analysis 2017 was chosen as a base year with a horizon up to 2035.For future forecasting the necessary input required for LEAP model should be studied. A number of scenarios will be created in the LEAP model with the possible intervention of electric transportation system.

Overview to LEAP

The Long-range Energy Alternatives Planning system (LEAP) is a widely-used software tool for energy policy analysis and climate change mitigation assessment developed at the Stockholm Environment Institute (SEI). It has been adopted by hundreds of organizations in more than 150 countries worldwide. Its users include government agencies, academics, non-governmental organizations, consulting companies, and energy utilities, and it has been used at scales ranging from cities and states to national, regional and global applications). Some of the important features of LEAP defined by SEI in LEAP user guide (2011) are given below: (SEI & INSTITUTE, 2011)

Integrated planning

LEAP is an integrated modeling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy. It can be used to account for both energy sector and non-energy sector greenhouse gas (GHG) emission sources and sinks. In addition to tracking GHGs, LEAP can also be used to analyze emissions of local and regional air pollutants, making it well-suited to studies of the climate co-benefits of local air pollution reduction.

Flexibility and ease-of use

LEAP has developed a reputation among its users for presenting complex energy analysis concepts in a transparent and intuitive way. At the same time, LEAP is flexible enough for users with a wide range of expertise: from leading global experts who wish to design policies and demonstrate their benefits to decision makers to trainers who want to build capacity among young analysts who are embarking on the challenge of understanding the complexity of energy systems.

Modeling methodologies

LEAP is not a model of a particular energy system, but rather a tool that can be used to create models of different energy systems, where each requires its own unique data structures. LEAP supports a wide range of different modeling methodologies: on the demand side these range from bottom-up, end-use accounting techniques to top-down macroeconomic modeling. LEAP also includes a range of optional specialized methodologies including stock-turnover modeling for areas such as transport planning. On the supply side, LEAP provides a range of accounting and simulation methodologies that are powerful enough for modeling electric sector generation and capacity expansion planning, but which are also sufficiently flexible and transparent to allow LEAP to easily incorporate data and results from other more specialized models.

LEAP's modeling capabilities operate at two basic conceptual levels. At one level, Leap's built-in calculations handle all of the "non-controversial" energy, emissions and cost benefit accounting calculations. At the second level, users enter spreadsheet like expressions that can be used to specify time-varying data or to create a wide variety of sophisticated multi-variable models, thus enabling econometric and simulation approaches to be embedded within LEAP's overall accounting framework. The new version of LEAP (LEAP 2011) also supports optimization modeling.

Time frames

LEAP is intended as a medium to long-term modeling tool. Most of its calculations occur on an annual time-step, and the time horizon can extend for an unlimited number of years. Studies typically include both a historical period known as the *Current Accounts*, in which the model is run to test its ability to replicate known statistical data, as well as multiple forward-looking scenarios. Typically, most studies use a forecast period of between 20 and 50 years. Some results are calculated with a finer level of temporal detail. For example, for electric sector calculations the year can be split into different user-defined "time slices" to represent seasons, types of days or even representative times of the day. These slices can be used to examine how loads vary within the year and how electric power plants are dispatched differently in different seasons.

Scenario analysis

LEAP is designed around the concept of long-range scenario analysis. Scenarios are self-consistent story lines of how an energy system might evolve over time. Using LEAP, policy analysts can create and then evaluate alternative scenarios by comparing their energy requirements, their social costs and benefits and their environmental impacts. The LEAP Scenario Manager, shown right, can be used to describe individual policy measures which can then be combined in different combinations and permutations into alternative integrated scenarios. This approach allows policy makers to assess the marginal impact of an individual policy as well as the interactions that occur when multiple policies and measures are combined. For example, the benefits of appliance efficiency standards combined with a renewable portfolio standard might be less than the sum of the benefits of the two measures considered separately. In the screen shown right, individual measures are combined into an overall GHG Mitigation scenario containing various measures for reducing greenhouse gas emissions.

Low initial data requirements

A key benefit of LEAP is its low initial data requirements. Modeling tools that rely on optimization tend to have high initial data requirements because they require that all technologies are fully defined both in terms of both their operating characteristics and their costs. They also require that the market penetration rates of those technologies have been reasonably constrained to prevent implausible knife-edge solutions. Developing the data for such models is a time-consuming task, requiring relatively high levels of expertise. By contrast, because LEAP relies on simpler accounting principles, and because many aspects of LEAP are optional, its initial data requirements are thus relatively low. Energy and environmental forecasts can be prepared before any cost data have been entered. Moreover, Leap's adaptable and transparent data structures are well suited to an iterative analytical approach: one in which the user starts by rapidly creating an initial analysis that is as simple as possible.

By using LEAP different scenario is created for the calculated value of the spread sheet. Such scenario created as BAU, ETRM 100, ETRM 75, and GHG emission etc. is carried out.

Result and discussion

After using LEAP different result can be shown as economic, environmental etc. This result is discussed as its good result with the current period and after ERTM 100, ETRM 75 also.

Thesis report writing, submission and final presentation

After the completion of the all above mention topic the final way to complete the report is by report writing, submission to the college and final presentation of the thesis.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Survey analysis

By the Survey analysis it was found that total number of the three wheeler vehicles was 4,086. The composition of the different vehicles, i.e. gasoline and electric were 1,874 and 2,212 respectively. Different brand name of three wheeler vehicles running in Hetauda are as follows:

Electric three wheeler vehicles are:

1. Terra company
2. Mayuri Company
3. Dafiya Company
4. Pathivera Company
5. Spiggo Company

Gasoline three wheeler vehicle is:

1. TVS Company
2. Baja Company
3. Autol company
4. Piggo Company

4.2 Calculation on spread sheet

4.2.1 Travel demand estimation

The term ‘passenger-km’ is used to express the travel demand of any route or place. Passenger kilometer is the total passenger transported by a vehicle during the total trips in a year multiplied by the length of the trip (Pradhan, 2004).In this report, travel demand is estimated using both the electric and gasoline tempo.

Passenger-kilometer/day= (trips/day ***** kilometer/trip ***** passenger/ trip)

Passenger-kilometer/year= passenger-kilometer/day *360

Vehicle kilometers

Vehicle kilometer is the activity of the vehicle during each year. Usually it is defined as the distance travelled by each vehicle during the year and the unit for the same is v-km (Pradhan, 2004). The following equations are used to estimate vehicle kilometers:

$$\text{Veh-km /day} = \frac{\text{Pass-km/day}}{\text{Pass/trip}}$$

$$\text{Veh} - \text{km/year} = \text{Veh} - \text{km/day} * 365 \text{ days}$$

Table 4.1: Details calculation of Spread sheet for the LEAP model

Parameters	Gasoline	Electric
V-km	41,523.2	38,312.59
P-km	412,416,727	542,383,747.1
km/Year	77,814,476.8	84,747,460.48
km/Liter	12.8	10.3(km/kW)
Total liter consumption per year	6,079,256	8,227,908.78(kWh)
Tera Joule	201.58	29.62
Giga Joule per person	0.000488789	5.46117E-05

4.3 Calculation on LEAP

4.3.1 Data flow in LEAP model

The LEAP version 2011 is used for the scenario analysis in this project. The social discount rate and social inflation are used as 10% and 5% respectively. The energy demand module and emission module as utilized in LEAP are given below in Table 4.2 and 4.3 respectively.

Table 4.2: Energy demand module in LEAP

Sector	Subsector	Device	Final energy Intensity	Final energy demand
Travel demand (passenger kilometers)	Road transport (100%)	Reverse of occupancy for each modal split (vehicle space per unit passenger)	Fuel economy of each vehicle type (GJ/v-km and kWh/Veh-km)	Total energy demand in the scenario (GJ)

As shown in Table 4.2, in LEAP the total energy demand was calculated using the following expression:

$$\text{Total Energy} = \sum (\text{Veh} - \text{km} * \text{FE})\ i$$

Where, 'TE' is the total energy demand in the respective scenario, Veh-km is the total activity of the vehicle type 'i' and 'FE' is the fuel economy of the vehicle type i.

As shown in Table 4.3.1 b, in LEAP, the total emission was calculated using the following expression:

$TEm = \sum (Veh - km * FE * EF)\ i$

Where, 'TEm' is the total emission in respective scenario, 'Veh-km' is the total activity of the vehicle type 'i', 'FE' is the fuel economy of each vehicle type and EF is the emission factor for the fuel for each vehicle type 'i'.

Table 4.3: Emission module in LEAP

Sector	**Sub-sector**	**End use**	**Device**	**Final energy demand**	**Emission factors**	**Emission**
Travel demand (passenger kilometers)	Road transport (100%)	Modal split (Share of passenger demand by each vehicle type)	Type of fuel used Gasoline and Electricity)	Total Energy demand in each type (GJ)	Various emission factors for each fuel(g/MJ)	Total emission in the scenario (Metric tons)

4.4 Scenario description and relevancy

Three scenarios are developed in LEAP framework in order to assess the possible implications due to the introduction of the electric microbuses in the current scenario. Their description and the relevant purpose are given in Table 4.4.

Table 4.4: Description of the scenario developed in LEAP and their relevancy

S. N	Scenario	Description	Purpose
1	BAU Scenario	This is the Business as usual (baseline) scenario, which is the extension of the current activity.	To set the baseline projection of the current demand, cost and emission when no alternatives are implemented.
2	100% replacement scenario (EMB100)	The electric tempo will be introduced in 2018 and its share will gradually go on increasing and will reach to 100% in 2035.	To find out the implications of 100% replacement in cost, emission and energy demand up To 2035. The scenario gives an idea if the government policy intervened in future to replace entire petrol tempo fleet with the Electric tempo up to 2035.
3	75% replacement scenario (EMB75)	The electric tempo will be introduced in 2018 and its share will gradually go on increasing and will reaches to 75% in 2035.	To know the consequences if the decision is made only for 75 % Replacement.

4.5 Technical aspect

The technical parameters are aimed at checking the safety of the electric tempo in operation, as well as understanding the manufacturing cycle of the battery rickshaws. The technical study also tried to assess the efficiency of electric tempos. This would help in suggesting the recommendations for the manufacturing policies that can be adopted by the state government.

4.6 System description

The electric tempo is not built or designed within the country. Instead the most of the tempo are imported into the country from countries like China, in SKD (Semi Knocked Down) form, after paying a high amount of import duty. These tempos are then assembled here, and the various components are put together to form the final product. The duty and the assembling put a markup on the initial cost price higher than even 125%.

There is no strict manufacturing or assembling rules for the electric tempo, but the production of electric tempo is allowed only to manufacturers.

The parameters for the study have been selected to address these issues related to the functioning and the manufacturing of the electric tempo. These have been further segregated into vehicle parameters, operational parameters and life-cycle parameters.

Table 4.5: Parameter for the technical study

General objective	**Parameter**	**Variables**
Technical characteristics of the electric tempo	Vehicle Parameter	• Motor Power • Battery -voltage • Capacity • Weight • Seating capacity
	Operational Parameter	• Travel speed • Cost • Charging time • Distance covered on one charge
	Life Cycle Parameter	• Battery recycling time • Durability • Safe Ratings-certification

The study and analysis of the technical data provides a fair amount of information on the operation of the electric tempo in Hetauda.

Table 4.6: Technical Parameter

Technical Parameter	**Mean Value**
Motor power	1500 W
Battery voltage (system value)	60 V
Battery capacity (Peak)	85 Ah
Maximum load capacity	380 kilograms (5 people)

Vehicle weight (approximate figure large variations)	215 kilograms (with batteries)
Charging time	6-8 hours
Distance covered (1 charge)	10 kilometers
Battery recycling time period	3 years guarantee and 1-year warranty

The study showed that the mean value of the motor power is 1500W, which was put forward in 2014. It was found that none of the manufacturers had any safety setup or safety ratings in place. The design was adapted from China, and thus a virtual testing was also not possible for the rickshaws. In the survey of the e-rickshaw drivers, it was found that 7% of the drivers had experienced a situation where their vehicle was prone to toppling, and thus creating a dangerous situation for the passengers. Moreover, the batteries of the rickshaws had a life - cycle of 7.5 months and the disposal of the batteries was not done in an environment friendly or efficient manner. The regularization of the e-rickshaws can result in framing of rules for the manufacturing. This would result in a safer design and a safer mode of transport for the city. (Singh, 2014)

Fitness ratings and registration of the rickshaws can help in city planning, structuring and government revenue. The life cycle of the e-rickshaws can be made more environment-friendly and the disposing off of the batteries can be turned efficient. The regulations may be framed so as to help the manufacturing sector of India with the help of subsidies or infrastructural support rather than direct SKD import from China.

4.6.1 Based on the technical study

A manufacturing policy framework should be setup by the government to regulate the manufacturing sector of the vehicles.

b. Certificate of Fitness

- The Certificate of Fitness should be issued to every driver after registration of the vehicles.
- -The Certificate should be renewed after a specified period of time.

c. Submission of a prototype for testing

A prototype of the vehicle should be submitted to the Transport Department of Nepal, and one of the automotive research organizations for clearance.

d. Safety Standards

-Safety rating for the vehicles should be in place, according to certain parameters which should be updated after a specified period of time.

2. To help in city planning, and to increase the efficiency of the transport system.

a. Area of Route

-The Area of Route should be specified by the specified authority to regulate the functioning of the vehicles.

- Special zones should be made to regulate the number of vehicles within a specified area.

b. Parking Places and Halting Stations

-In order to avoid the traffic problems and obstruction of the path, special parking places and halting stations should be designated for these battery rickshaws.

c. Rate of Fare and hire of a Battery-Operated Rickshaw

-The rates should be specified according to the distance, location and the zoning of the e - rickshaws.

4.6.2 Based on the socio-economic study

a. Financing and Credit/Asset-based lending options should be available for the battery rickshaw drivers to finance their vehicles. The Government of Nepal can announce Scheme that would have provisions to make it easier to own and operate a rickshaw.

b. Insurance options should be introduced for the rickshaws, and the vehicles should be recognized as motor vehicles. This would help the commuters in claiming insurance in case of mishap or a motor accident

4.7 Fuel consumption

Fuel consumption in transport sector is dependent upon vehicle activity, type of vehicle, specific fuel consumption and other driving parameters like speed, vehicle ages etc. (Pradhan, 2004). While in this study, parameters like specific fuel consumption, type of vehicle and the vehicle activity are taken into account for determining the fuel consumption.

The trend of fuel consumption for different scenarios is determined. Specific fuel consumption for the electric tempo is determined from primary survey interviewing drivers/operators of Electric tempo. The specific fuel consumption for gasoline tempo is found to be 0.0781 l/km (Malla, 2014) .The specific fuel consumption for electric tempo is taken as 0.0970 kWh/km by survey. The following figure shows the fuel properties for each type of fuel.

Table 4.7: Fuel properties for each type of fuel

Fuel type	Physical unit	Net energy content GJ (GJ/ton)	Density (kg/l)
Gasoline	1 Liter	0.35392(44.8)	0.76
Electricity	1 kWh	0.0036 (NA)	NA

4.7.1 Fuel consumption scenarios

BAU scenario

In this scenario, the total fuel consumption, during 2018 to 2035, is increased by 1.4 times as shown in figure 4.1. The share of is about 50 % throughout this scenario. The total energy consumption is increased from 230.4 TJ in 2018 to 333.5 TJ in 2035. The total energy consumption is by electric and gasoline is 29.7 TJ and 200.7 TJ respectively for the 2018.Similarly for the 2035 its energy composition is 43 TJ and 290.5 TJ respectively for electric and gasoline.

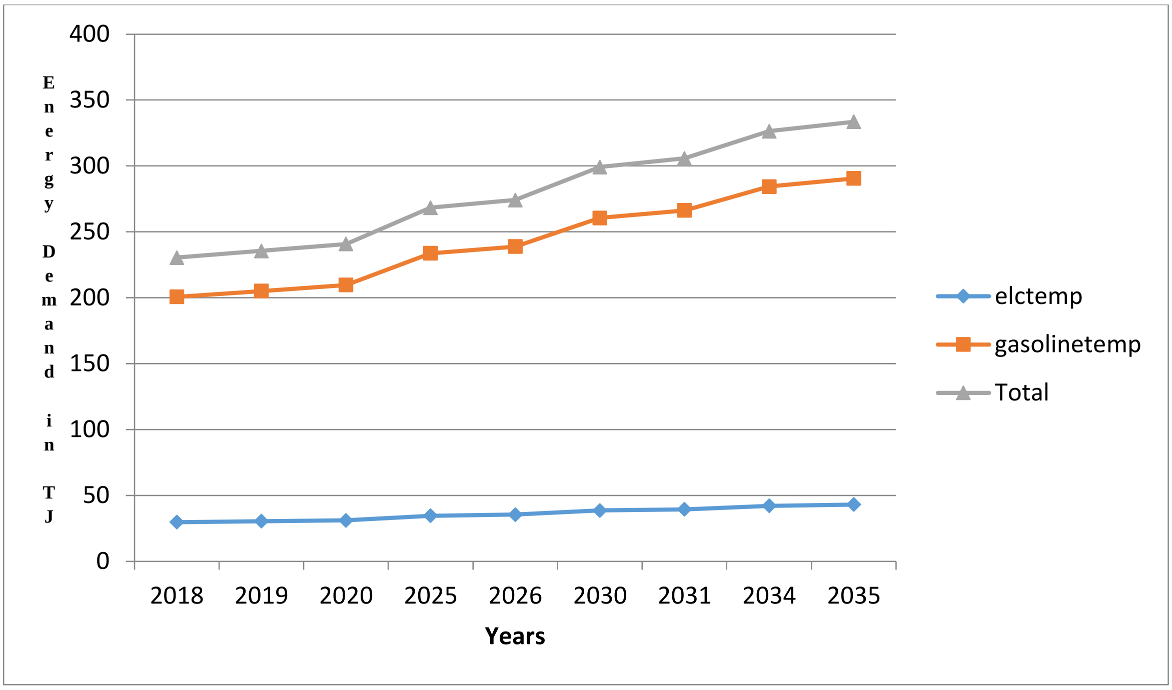

Figure 4.1: Share of fuel consumption by vehicle split in BAU scenario

Alternative scenarios

ETRM 100 scenario

In this scenario, the total energy consumption is decreased from 230.4 GJ to 75.5 TJ by the year 2018 to 2035.The gasoline consumption is reduced from 100% in 2018 to 0 % in 2035. The electricity consumption is increased from 25% in 2018 to 100% in 2035. Here in this scenario by we can save 258.1 TJ energy to save the fuel.

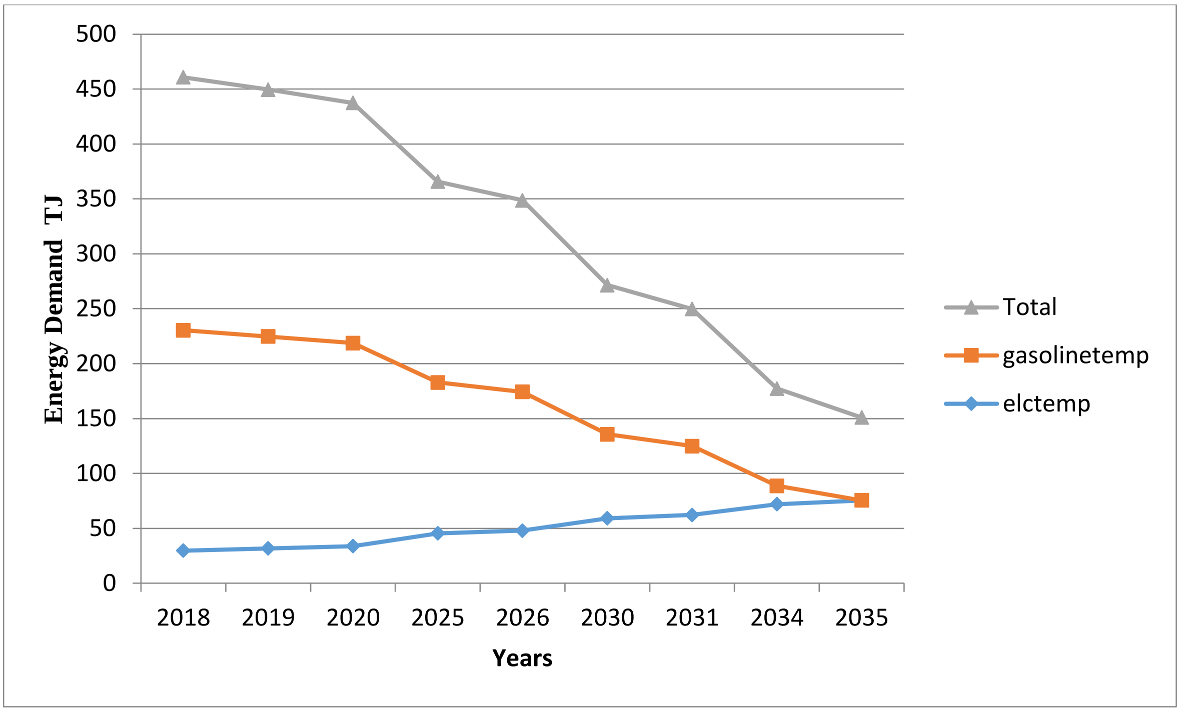

Figure 4.2: Share of fuel consumption by vehicle split in ETM100 scenario

ETRM 75 scenario

The total energy consumption is increased from 230.4 TJ to 225.5 TJ by the year 2018 to 2035. The energy composition of the electric and gasoline in this scenario is 56.6 TJ and 168.9 TJ respectively for 2035. Here in this scenario by we can save 108 TJ energy to save the fuel.

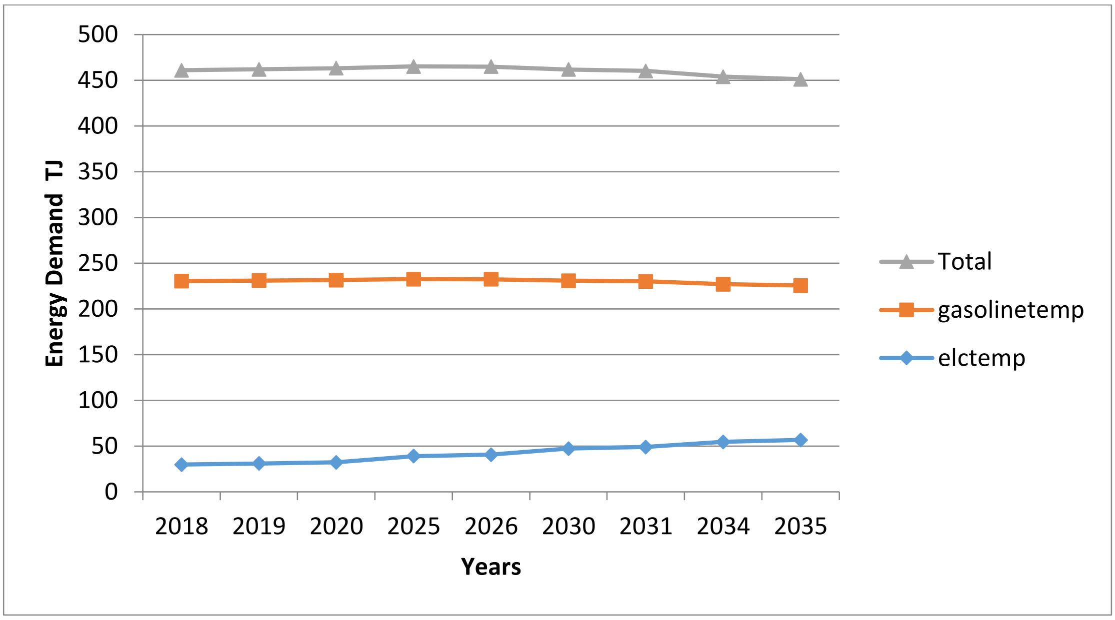

Figure 4.3: Share of fuel consumption by vehicle split in ETRM 75 scenario

The fuel consumption in the alternative scenarios shows that the avoided fuel consumption in ETRM100 scenario is highest.

4.7.2 Cost saved from saved energy

The cumulative cost saved from avoided energy is 1.1 million Nepali Rupee in ETRM 75 scenario at constant price of 2018 in comparison to BAU scenario. Similarly, it is 2.5million Nepali Rupee in ETRM 100. The cumulative cost saved from energy saved in ETRM 75 and ETRM 100 scenarios by type of fuel is given in Figure 4.4 and 5.5 in graphical form.

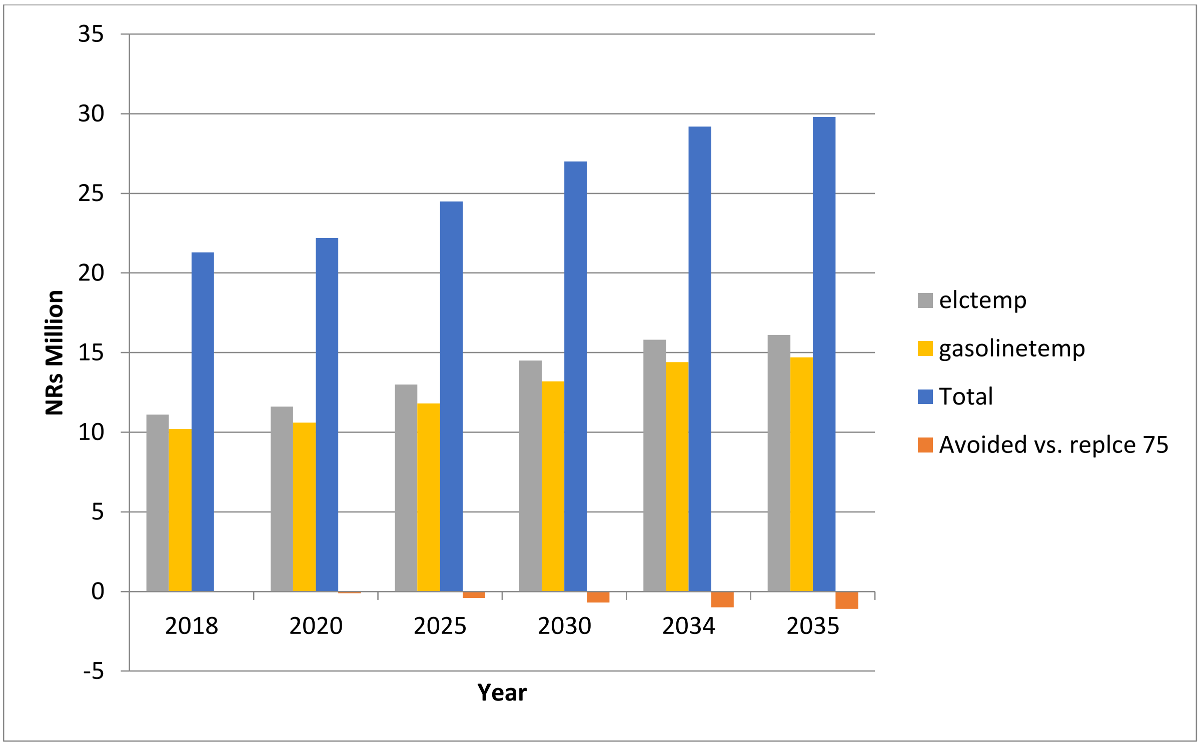

Figure 4.4: Cumulative cost saved from saved energy in ETRM 75 scenario

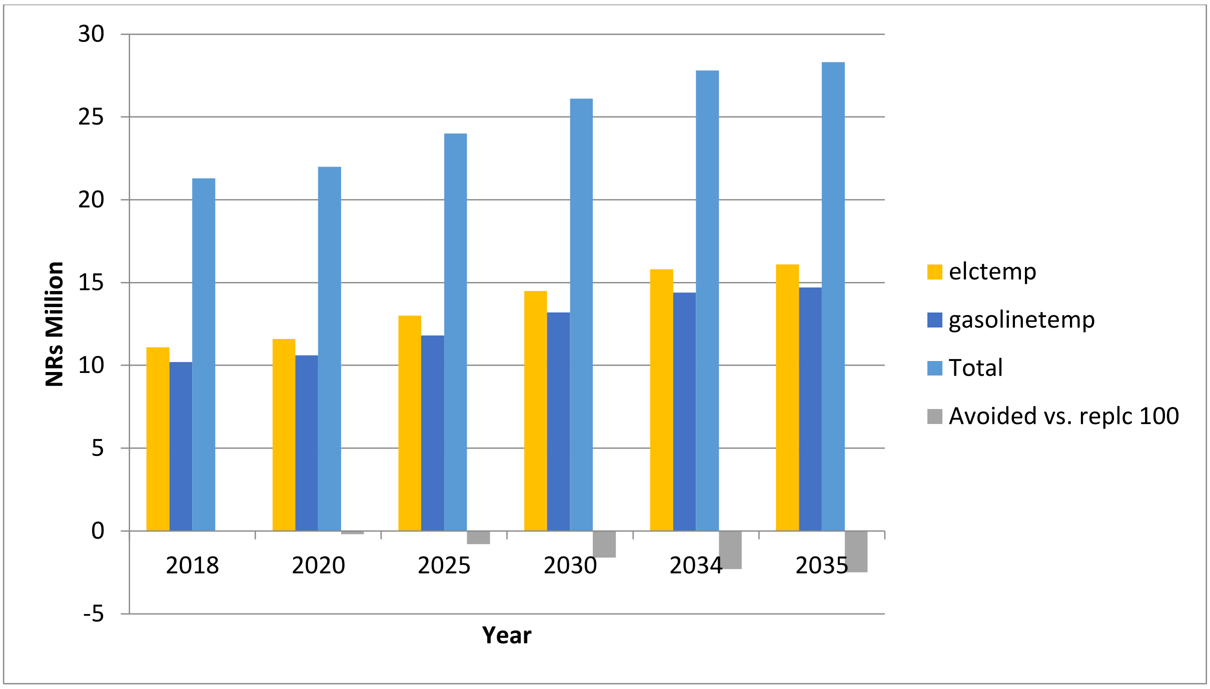

Figure 4.5: Cumulative cost saved from saved energy in ETRM 100 scenario

4.7.3 Fuel Consumption

In the below figure shows the different fuel consumption i.e. gasoline and electric in different scenarios with year wise. The maximum electricity is being used in ETRM100. Similarly, the use of gasoline will be zero in ETRM 100 for the year 2035.

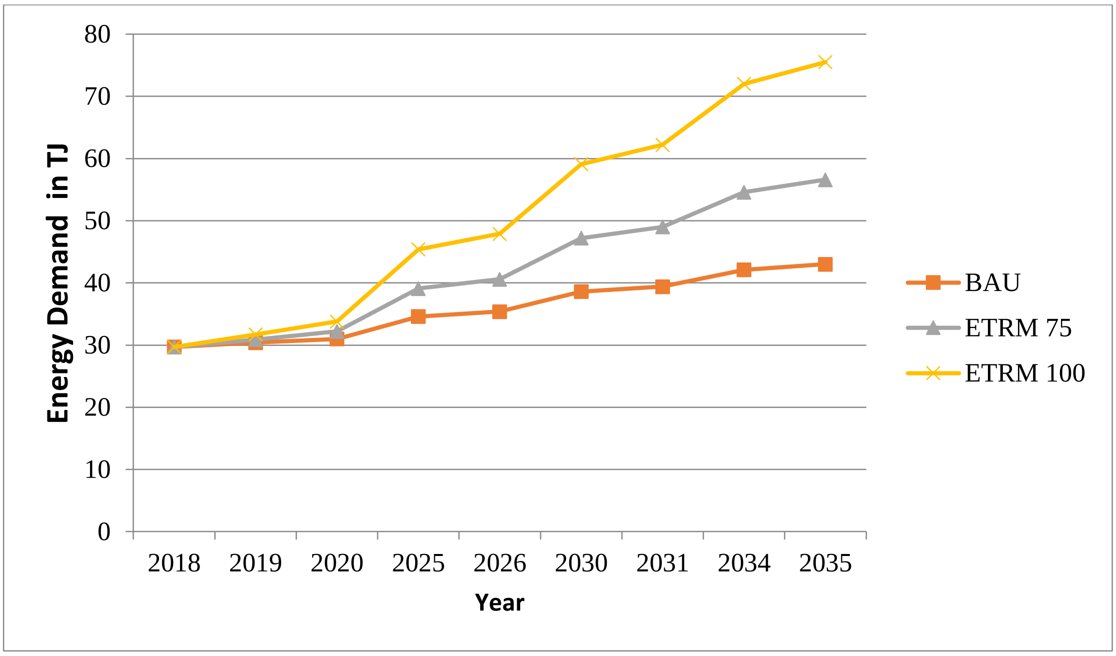

Figure 4.6: Cumulative energy demand scenarios for electricity in year wise

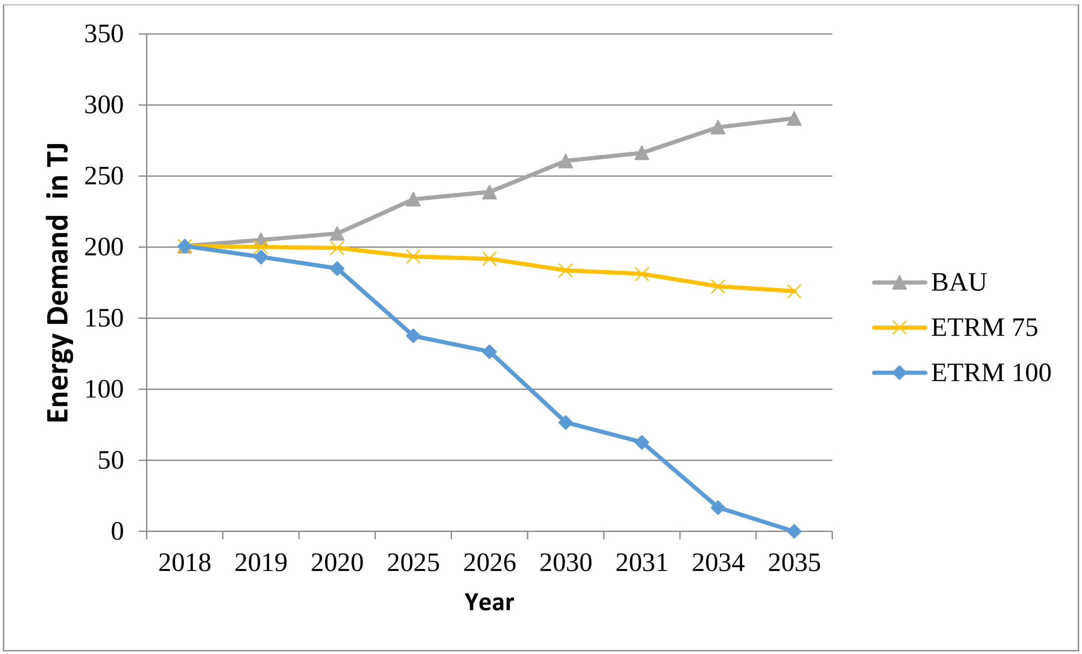

Figure 4.7: Cumulative energy demand scenarios for gasoline in year wise

4.8 Environmental aspect

4.8.1 Local and GHG emission

The local air pollutants considered in this study are CO, NO_2, SO_2 and PM_{10} only. The Green houses gases taken into account in this study include CO_2 and NO_2 only. The one-hundred-year Global Warming Potential is considered in this study. The Global Warming Potentials (GWPs) of CO_2 and NO_2 are taken 1 and 310 t CO_2 equivalent for this analysis based on LEAP-IPCC Assessment Report (1995) integrated in LEAP (2011). GWPs show their relative strength to have effect in Global Warming Potential. The direct GWP of NO_2, for example, is defined as the cumulative direct effect on the atmosphere's energy budget resulting from one kilogram release of NO_2, relative to the direct effect of a one kilogram release of CO_2. (J., K, M., & P., 2013).

Other greenhouse gases like methane and non-methane volatile organic compounds (e.g. olefins, ketons, aldehydes) which are the product of incomplete combustion. They are volatile under ambient air conditions.

The science and empirical formulas for the calculation of CO2 was developed in the 1970s and it was initially based on UN fuel consumption data (Marland, 1984) (Rotty, 1973) . There are many studies conducted on the GHG emission reduction and its public health benefits like (Facts, 2005)& (Wilkinson, Adair, Armstrong, Barrett,, & Oreszczyn, 2009). Wilkinson et al., 2009 have modeled the health benefits of emissions reduction.

Dalkmann and Brannigan (2007) listed primary ways to reduce GHG emissions from transport. Avoiding the use of transportation where possible. e.g. through improved spatial planning or teleworking (Dalkmann & C., 2007).

1) Shifting to more environmentally friendly modes such as public transport, cycling and walking.

2) Improving vehicle and fuel technology to improve the environmental efficiency of each kilometer travelled.

In transport sector, various majors are taken to reduce air pollutant emissions from conventional internal combustion engines. The Vehicle Emission Standard 2000 can be seen in response to the country's adoption of more stringent emissions standards. However, improved engine combustion and exhaust gas treatment will have virtually no effect on energy efficiency or GHG emissions unless and until it gains fuel economy. Further it may increase the fuel consumption due to the additional accessories like air pumps in order to meet the emission standard. Such use may even increase the GHG emission per passenger travel (Pradhan, 2004).

Following emission factors for different pollutants are used in this study as suggested by (Bhatta & & Joshi, 2004).

Table 4.8: Emission factors used for different pollutants

S. N.	**Pollutants**	**Emission (g/km)**
1	NO_2	0.496
2	SO_2	0.049
3	CO	1.904
4	CO_2	365.6
5	NMVOC	0.360

4.8.2 Local emission scenarios

The local emission s in different scenarios for the year 2018 -2035 in the metric tons is listed in the table.

Table 4.9: Local air pollutant emissions in the different scenarios (in metric tons)

Pollutants	Scenarios	2018	2020	2025	2030	2034	2035	Ratio 2018/2035
CO	BAU	1,605.40	1,676.90	1,869.60	2,084.50	2,274.10	2,324.10	0.69
	ETRM 75	1,605.40	1,594.30	1,547.30	1,468.60	1,378.10	1,351.20	1.19
	ETRM 100	1,605.40	1,479.60	1,099.80	613.1	133.8	0	0.00
NO_2	BAU	120.4	125.8	140.2	156.3	170.6	174.3	0.69
	ETRM 75	120.4	119.6	116.1	110.1	103.4	101.3	1.19
	ETRM 100	120.4	111	82.5	46	10	0	0.00
NMVOC	BAU	301.00	314.40	350.60	390.80	426.40	435.80	0.69
	ETRM 75	301	298.9	290.1	275.4	258.4	253.4	1.19
	ETRM 100	301	277.4	206.2	115	25.1	0	0.00
SO_2	BAU	3.6	3.7	4.2	4.6	5.1	5.2	0.69
	ETRM 75	3.6	3.6	3.5	3.3	3.1	3	1.20
	ETRM 100	3.6	3.3	2.5	1.4	0.3	0	0.00
CO_2	BAU	13.8	14.4	16	17.9	19.5	19.9	0.69
	ETRM 75	13.8	13.7	13.3	12.6	11.8	11.6	1.19
	ETRM 100	13.8	12.7	9.4	5.3	1.1	0	0.00

4.9 GHG emission

Carbon dioxide

Here in this figure shows the different scenarios of CO_2. In BAU CO_2 has increased from 13.8 thousand metric tons to 19.9 thousand metric tons in year 2018 to 2035.This increment is by 44.20 %. In ETRM 75 the content of CO_2 starts to decrease from 13.8 thousand metric tons to 11.6 thousand metric tons for year 2018 to 2035.Similarly, in ETRM 100 it decreases to 0. This decrease is only possible by the replace of gasoline by electric three wheelers.

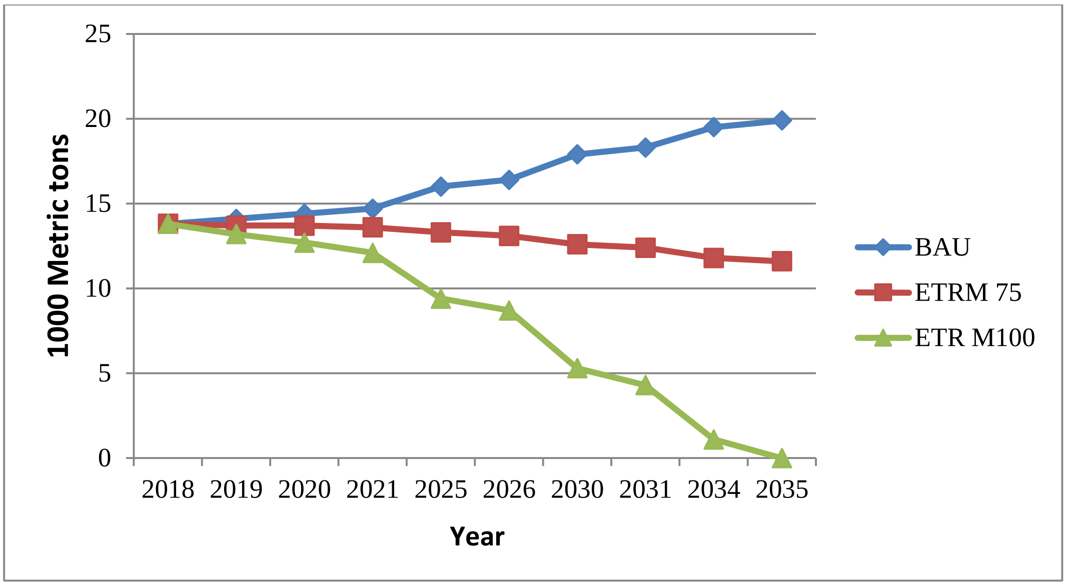

Figure 4.8:Year wise scenarios of GHG emissions carbon dioxide

Methane

The figure shows the different scenarios of methane. In BAU methane is increased from 4 metric tons to 5.8 metric tons in year 2018 to 2035.This increment is by 45 %. In ETRM 75 the content of methane starts to decrease from 4 metric tons to 3.4 metric tons for year 2018 to 2035.Similarly, in ETRM 100 it decreases to 0. This decrease is only possible by the replace of gasoline by electric three wheelers.

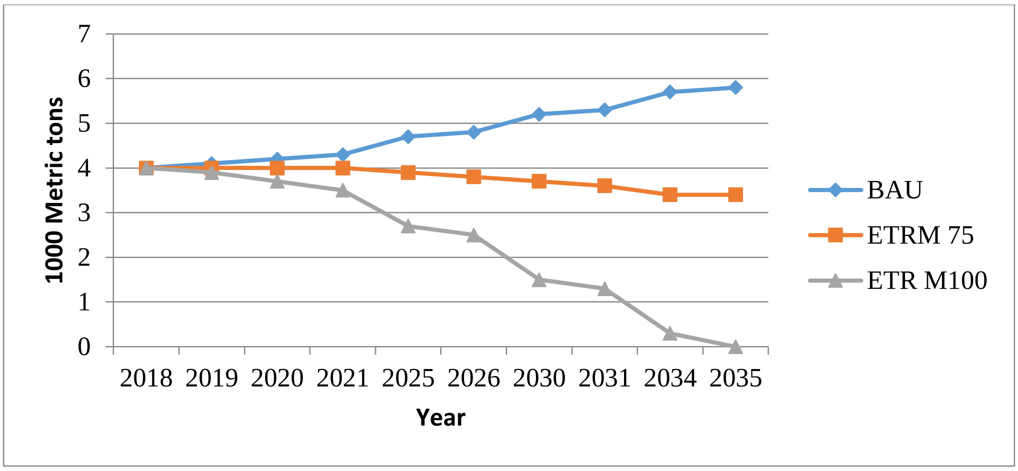

Figure 4.9: Year wise scenarios of GHG emissions methane

Nitrous oxide

The figure shows the different scenarios of nitrous oxide. In BAU nitrous oxide is increased from 0.1 metric tons to0.2 metric tons in year 2018 to 2035.By the year 2030 values of nitrous oxide will be 0.2 metric tons. In ETRM 75 the content of nitrous oxide starts to remain constant throughout year 2018 to 2035 as 0.1metric tons. Similarly, in ETRM 100 it decreases to 0 in 2030.This decrease is only possible by the replace of gasoline by electric three wheelers.

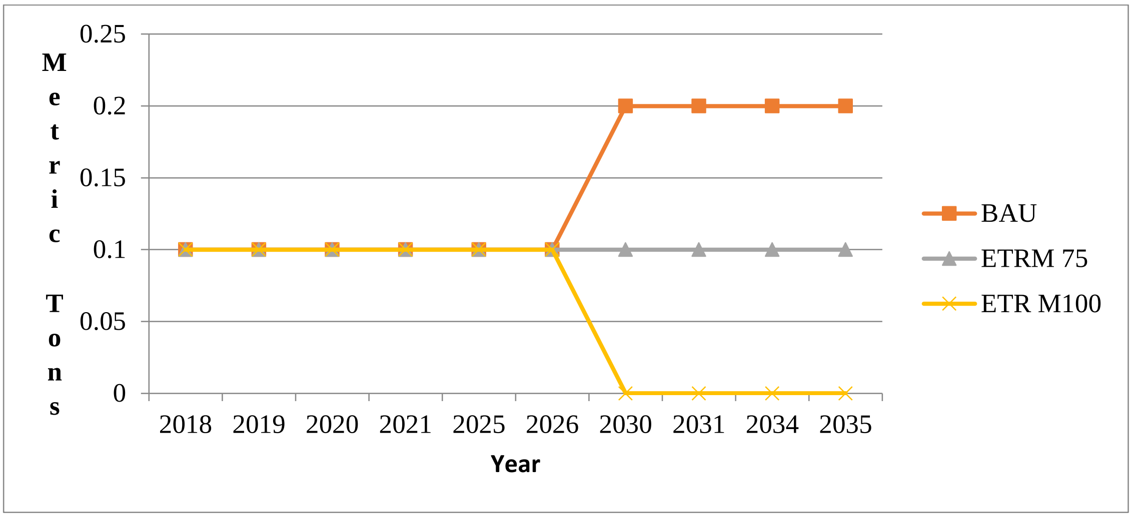

Figure 4.10: Year wise scenario of GHG emissions nitrous oxide

4.10 Financial aspect

4.10.1 Total system cost with different scenarios

BAU

In this scenario the system cost of the electric and gasoline is NRs.163.8 million and NRs.659.8 million in Nepali Rupee respectively. And the increment is shown in 2035 i.e. NRs.237.1 million and NRs.955.2 million for electric and gasoline respectively.

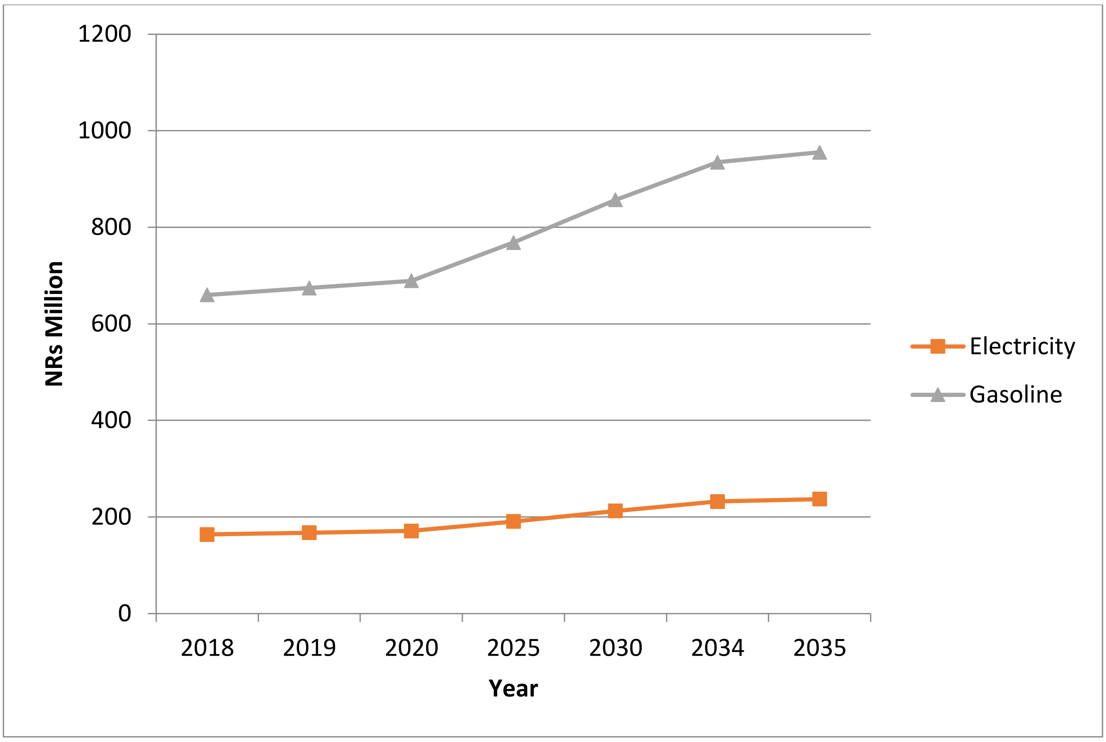

Figure 4.11: Year wise system cost of BAU scenario

ETRM 75

In this scenario the system cost is shown for ERTM 75 so the electric and gasoline system cost areNRs.163.8 million and NRs659.8 million respectively for 2018. And the increment is shown in 2035 i.e. NRs 311.9 million and NRs 555.3 million in for electric and gasoline respectively

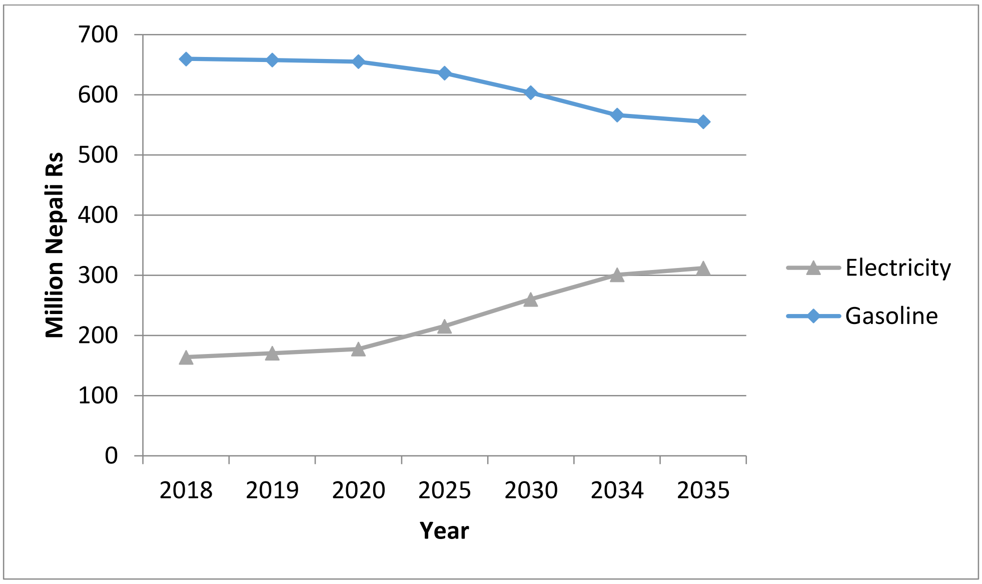

Figure 4.12: Year wise system cost of ETRM 75 scenario

ETRM 100

In this scenario the system cost is shown for ERTM 100.as the system cost of the electric is increased to NRs 415.9 million and for the gasoline its system cost decrease to 0 for the 2035.

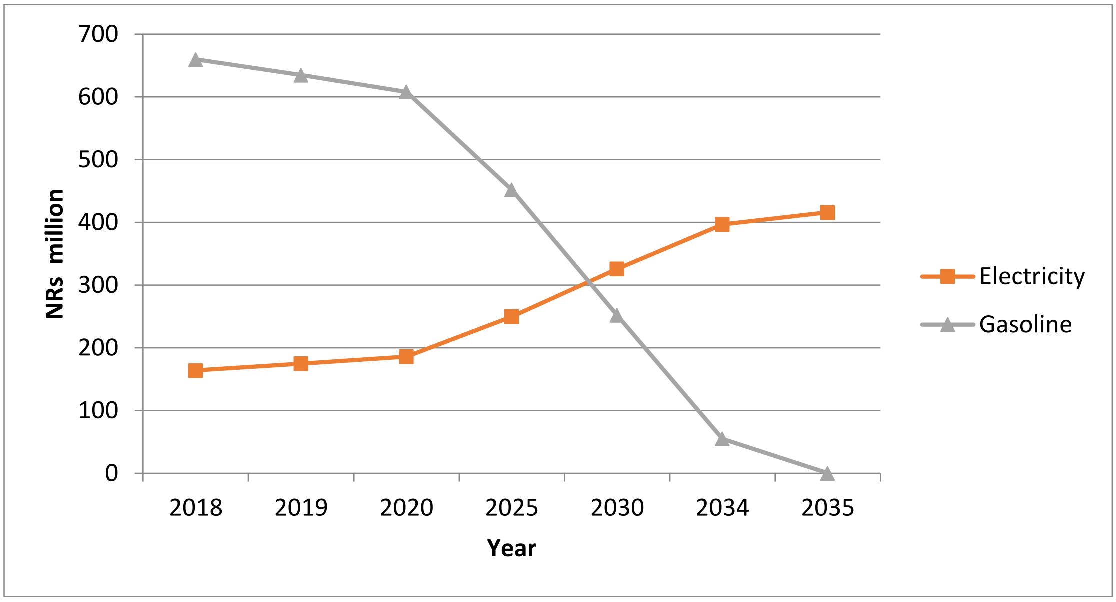

Figure 4.13: Year wise system cost of ETRM100scenario

4.11 Net fuel import cost with different scenarios

Here in this figure year wised different scenarios of the fuel import cost are shown. The cost of the fuel at BAU is NRs 659.8 million in 2018 and it will increase NRs955.2 million in 2035.In ERTM 75 scenarios there will slightly decrease in cost of the fuel i.e. NRs555.3 million in 2035.Smilarly in ETRM 100 scenarios there is highly fall in fuel cost that is NRs55 million in 2034 but in 2035 it goes to be 0 fuel cost.

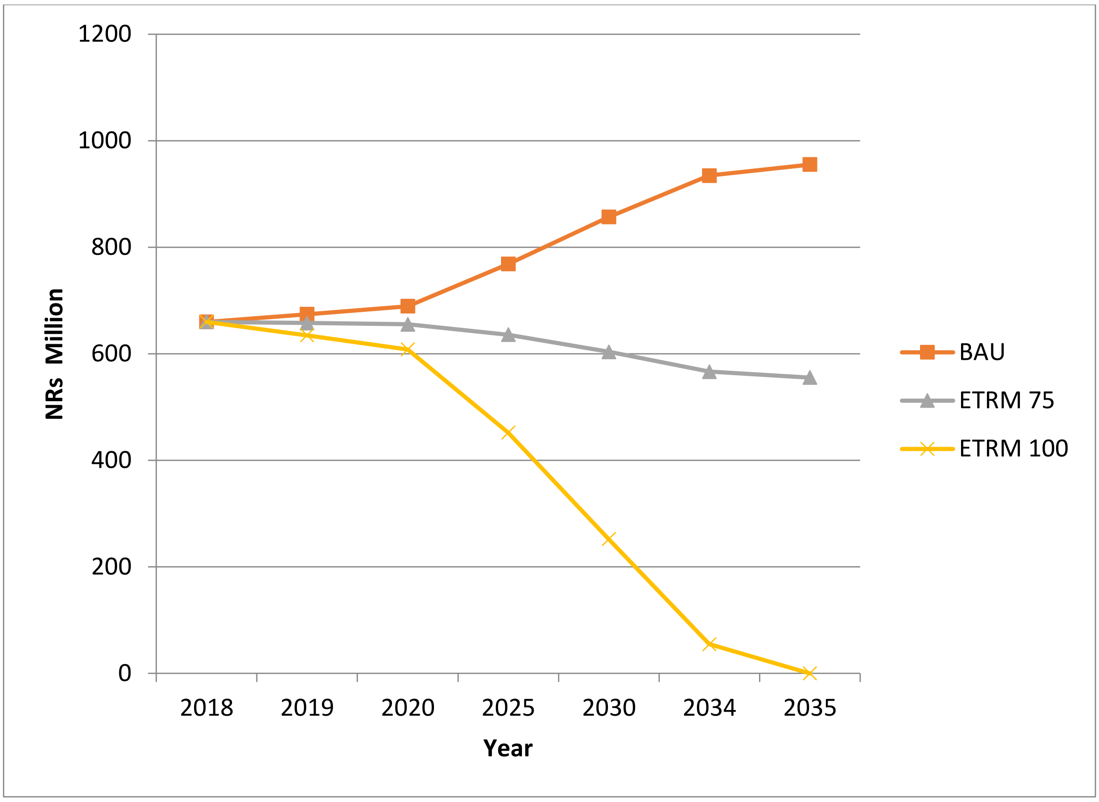

Figure 4.14: Year wise net fuel import cost with different scenarios

Here in this figure year wise different scenarios of the electricity cost are shown. The cost of the electricity at BAU isNRs163.8 million in 2018 and it will increase NRs237.1 million in 2035**.**In ERTM 75 scenarios there will slightly increase in cost of the electricity i.e. NRs311.9 million in 2035.Smilarly in ETRM 100 scenarios there is highly increase in electricity cost that is NRs415.9 million in 2035.

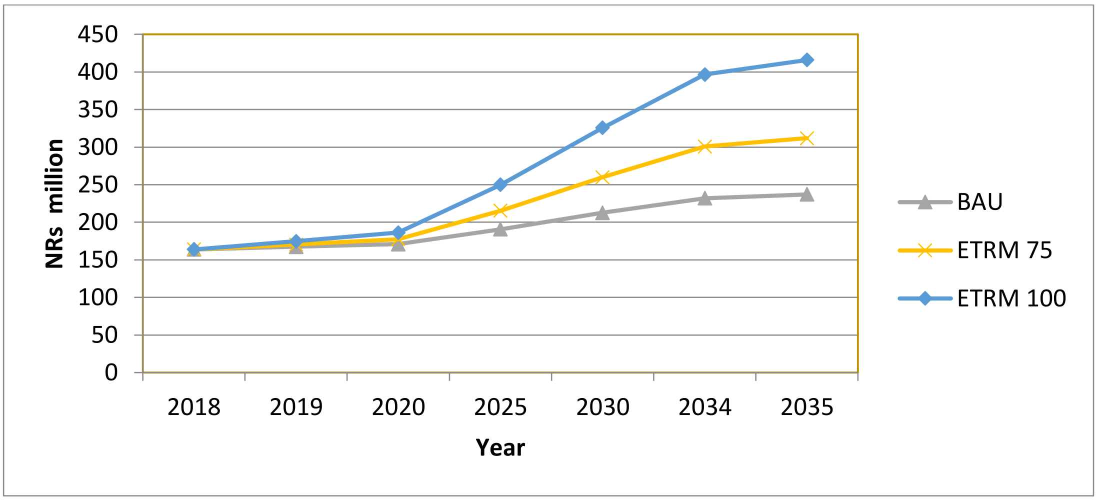

Figure 4.15: Year wise net electricity cost with different scenarios

4.12 Net fuel cost to consumer with different scenarios

Here in this figure year wise different scenarios of the fuel cost to consumer (vehicles owners) is shown. The fuel cost to consumer at BAU is NRs823.6 million in 2018 and it will increase NRs1192.3 million in 2035.In ERTM 75 scenarios there will slightly decrease in fuel cost to consumer i.e. NRs867.2 million in 2035.Smilarly in ETRM 100 scenarios there is highly rise in fuel cost to consumer that is NRs415.9 million in 2035.

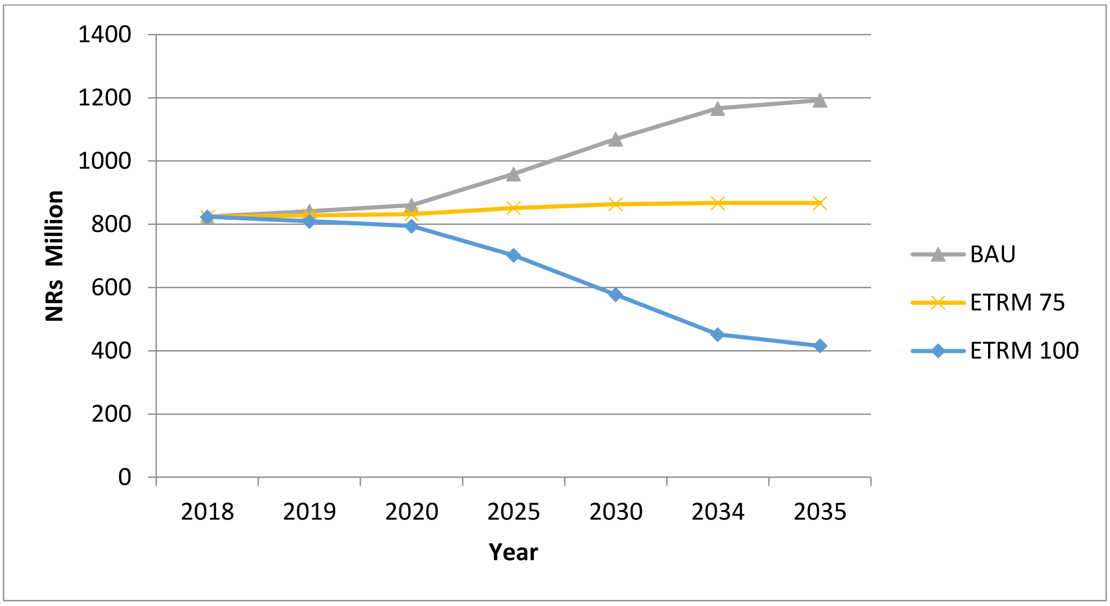

Figure 4.16: Year wise net fuel cost to consumer with different scenarios

4.13 Marginal abatement cost (MAC)

Nowadays marginal abatement cost (MAC) curves have frequently been used to illustrate the economics of climate change mitigation and help in reducing carbon emissions in a cost-efficient way. Marginal abatement signifies the cost to reduce or offset a unit of pollution, usually one ton of GHG emissions. A Marginal Abatement Cost (MAC) curve is a graphical way to show options for a low carbon development pathway, and its costs and impacts of the alternatives available. A MAC presents the extra (marginal) costs and carbon reduction (Abatement) potential of these options relative to a baseline. Typical options in a MAC include switching to clean energy, improving energy efficiency, avoiding deforestation, improving agricultural practices and avoiding gas flaring (Tilburg & R., 2010).

MAC curves generally show the cost, in $ per ton CO2-e, associated with the emissions reductions achievable by different energy efficiency options at a given point in time. Mathematically,

$$\text{MAC}=\frac{\text{additional investment cost (supply and demand technology}}{\text{Emission abated}}$$

However, there are some weaknesses associated with the concept of MAC curves, (Kesicki, 2011) which are:

i. Abatement costs are shown only for a specific point in time, generally for one particular year.

ii. The shape of the MAC curve depends on the cumulative emission reduction, which means actions in earlier and later time periods have an influence. Thus, the MAC curve is subject to inter-temporal dynamics.

iii. MAC curves usually include direct costs, i.e. the cost reduction of ancillary benefits is not considered in the abatement cost.

iv. MAC curves generally do not give any indication of the uncertainties involved in carbon dioxide emission reduction.

Marginal abatement cost (MAC) depicts investment required to reduce the emission from that of business as usual level and is generally expressed in cost per kg of CO2 equivalent. Figure 4.15shows the MAC for GHG emission reduction for two policy scenarios. ETRM 100 scenario shows a gradual decreasing trend of MAC. MAC in an early stage at around NRs. 0.1 per kg of CO_2-e abated. This is due to high investment as these are cost intensive in terms of capital cost. The higher capital cost for power plant increases MAC by highest factor. But once the generation technology and end-use devices is there, MAC reduces gradually to about NRs minus point one four five (0.145) in the year 2035 when electric technologies will be takeover other non-electric technologies. Thus, we can see that, electrification is most appropriate practical energy scenario. Moreover, having a hydro power plant and diversification in the generation system, it gives the assurance of reliability and energy security and other risks.

Meanwhile, ETRM 75 scenarios show a lesser value as compare with ETRM 100, which indicates net economic benefit. This implies a cost saving with the implication of this scenario. This seems to be the most favorable scenarios in terms of environmental and economic aspect. However, there have been many arguments regarding the negative-cost or lesser value of abatement opportunities as stated by (Ackerman & & Bueno, 2011) in their working paper. If a net economic benefit can be achieved with energy saving, why hasn't it been implemented? The possible reasons for this efficiency gap as put upon by (Brown, 2011.) are discouragement in investment due to market failures and barriers. (DeCanio, 1998.) Terms it as "efficiency paradox" and argues consumer behavior and organizational factors could be cause for such deviations.

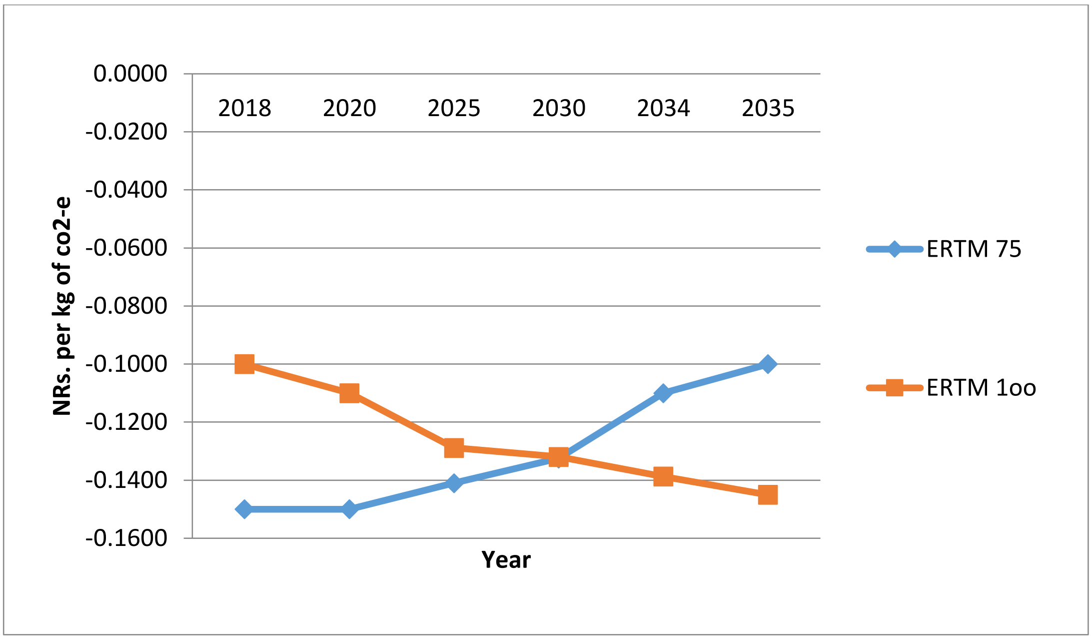

Figure 4.17: Marginal abatement cost

4.14 Preliminary cost-benefit analysis

Cost-benefits analysis technique was adopted for the economic evaluation of the various scenarios in this study. In this study, the cost of the system is expressed in terms of Present Value (PV) of cost of transformation (investment and operation and maintenance cost) as well as resources (fuel cost) over the period of the study discounted at 6 % to the base year. Table 4.6 presents the results of the cost-benefit analysis provided by the LEAP model.

The demand costs in ETRM 75 and ETRM 100 scenarios are low compared to the BAU scenario. However, in ETRM 75 and ETRM 100 scenarios, the imports cost is lower compared to the BAU scenario, because of fuel switching from fossil fuel to renewable energy. Further, notwithstanding its relatively small contribution to global GHG emissions, Nepal as a country still has the moral and legal obligation to work out and declare emission peak year and strive to mitigate emission output to conform to the climate commitments at home and abroad as mention in the table, Scenario analysis has shown GHG emission is least in ETRM 100 scenario which not only fulfil its commitment to emission but also shifting to cleaner fuel will enhance energy security, reduce the trade deficit with India and promote investment in the real sector.

Table 4.10: Cumulative costs & benefits

Cumulative Costs & Benefits:2018-2035	**At 6% discounted Rate (In Million Rupees)**		
	BAU (2018)	**ETRM 75 (2035)**	**ETRM 100 (2035)**
Demand	278	273	267.8
Imports	10,747.60	9451	7650.1
Present Value	11,025.60	9724.7	7917.9
GHG Emissions (Mill Tones CO_2e)	0.3	0.2	0.1

The most important part of cost-benefit analysis is the present value (PV), which is one of the criteria to select the scenario. The NPV in ETRM 75 and ETRM 100 scenarios are lower than BAU, which means that, both of the scenarios are economically viable. In ETRM 75 and ETRM 100 scenario GHG saving is achieved. Form PV value, as compare to ETRM 75, it is found that the ETRM 100 scenario is most economically viable with PV value NRs. 7917.9 million. With co-benefit (like: higher economic growth, reduced trade deficit, reduction of GHG emission etc.) in

ETRM 100 scenario. Therefore, the ETRM 100 scenario stands out best amongst all scenarios.

Comparison

As comparing with other outcomes the result was similar with others literature such as with of Estimation amount of co2 reduction by safa Tempo (electric three wheelers) in Kathmandu valley by Vijay Dev Bhatt. Similarly with Sunil Malla Assessment of mobility and its impact on energy use and air pollution in Nepal

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- The survey conducted for estimating maintenance/repair cost was for the electric is NRs53, 788and for the gasoline is NRs.50,960. The vehicle kilometre is 41523.2 Vkm and 383112.6 Vkm for gasoline and electric respectively.
- The total energy consumption is increased from 230.4 TJ in 2018 to 333.5 TJ in 2035. The total energy consumption is by electric and gasoline is 29.7 TJ and 200.7 TJ respectively for the 2018. Similarly, for the 2035 its energy composition is 43 TJ and 290.5 TJ respectively for electric and gasoline. The total energy consumption was increased by 44.78 %
- The total energy consumption is decreased from 230.4 TJ to 225.5 TJ by the year 2018 to 2035. The energy composition of the electric and gasoline in this scenario is 56.6 TJ and 168.9 TJ respectively for 2035.The total energy consumption was decreased by 2.16 %
- In this scenario, the total energy consumption is decreased from 230.4 GJ to 75.5 TJ by the year 2018 to 2035.The gasoline consumption is reduced from 100% in 2018 to 0% in 2035. The electricity consumption is increased from 25% in 2018 to 100% in 2035.The total energy consumption was decreased by 67.23 %
- In BAU CO_2 is increased from 13.8 thousand metric tons to 19.9 thousand metric tons in year 2018 to 2035.This increment is by 44.20 %. In ETRM 75 the content of CO_2 starts to decrease from13.8 tons thousand metric tons to 11.6 thousand metric tons for year 2018 to 2035.Similarly, in ETRM 100 it decreases to 0. This decrease is only possible by the replace of gasoline by electric three wheelers.
- In BAU methane is increased from 4 metric tons to 5.8 metric tons in year 2018 to 2035.This increment is by 45 %. In ETRM 75 the content of methane starts to decrease from 4 metric tons to 3.4 metric tons for year 2018 to 2035.Similarly, in ETRM 100 it decreases to 0.This decrease is only possible by the replace of gasoline by electric three wheelers

- In BAU nitrous oxide is increased from 0.1 metric tons to 0.2 metric tons in year 2018 to 2035.By the year 2030 values of nitrous oxide will be 0.2 metric tons. In ETRM 75 the content of nitrous oxide starts to remain constant throughout year 2018 to 2035 as 0.1metric tons. Similarly, in ETRM 100 it decreases to 0 in 2030.This decrease is only possible by the replace of gasoline by electric three wheelers.
- From MAC, ETRM 75 scenarios show a lesser value as compare with ETRM 100, which indicates net economic benefit. This implies a cost saving with the implication of this scenario. This seems to be the most favorable scenarios in terms of environmental and economic aspect.
- Form present value, of preliminary cost-Benefit Analysis compare to ETRM 75, it is found that the ETRM 100 scenario is most economically viable with PV value NRs. 7917.9 million. With co-benefit (like: higher economic growth, reduced trade deficit, reduction of GHG emission etc.) in ETRM 100 scenario. Therefore, the ETRM 100 scenario stands out best amongst all scenarios.

5.2 Policy recommendations

- As maximizing social welfare is the main concern for the government, it should make favorable policy to promote EVs where social benefits of EVs outweigh the social costs of ICEVs.
- Since other vehicles like private cars and two wheelers constitute major transportation fleet in Hetauda, government should make plan to encourage the introduction of electric cars and two wheelers.
- Based on this study, the government should support and encourage the entrepreneurs for the introduction of large electric vehicle in Hetauda

5.3 Recommendations for further study

- Since this project only deals with economic analysis of replacing gasoline tempo by electric tempo, further research can be carried out for financial benefit-cost analysis.
- The detail study can be carried out to reduce the impact and control of lead discharge in environment from EV batteries.

- Further research could be done for replacing fossil fuel vehicle and other means of transport like bus and minibus by electric vehicles.
- Research related to introduction of vehicles running from other types of energy like fuel cells, ethanol and bio-diesel could be done in future.

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Name of Authors: Sabina Uprety, Prof. Ram Chandra Sapkota

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APPENDICES

Appendix: A

Three wheeler vehicles (electric and gasoline) Survey Questionnaires

PART A: Introduction

Driver's Personal Information

1. Driver's name:
2. Address :

Information about vehicle

1. Model
2. Manufactured year
3. Plate number
4. Passenger capacity

PART B: Survey

1. Trip Origin
2. Average no. of trips per day
3. Distance travelled per day
4. Mileage
5. Repair and maintenance cost / month
6. Average waiting time in stop
7. Passenger occupancy
8. Start and end time
9. How reliable is this transportation for daily travel?

Appendix: B

Average passengers per trip of three wheeler (electric and gasoline) running in Hetauda

For Electric tempo						
Sample no	**6-7 am**	**9-10am**	**12-1pm**	**4-5pm**	**6-7pm**	**Average**
1	8	7	6	8	7	7.2
2	8	8	7	8	6	7
3	8	8	6	8	6	7
4	8	7	5	8	7	7
5	8	6	6	8	6	7
6	8	8	7	8	8	8
7	8	7	6	8	5	7
8	8	7	8	8	4	7
9	8	6	5	8	5	6
10	8	7	4	8	6	7
11	8	6	5	8	5	6
12	8	7	6	8	6	7
13	8	8	6	8	6	7
14	8	6	5	8	5	6
15	8	7	7	8	7	7
16	8	6	6	8	6	7
17	8	7	4	8	4	6
18	8	8	6	8	6	7
19	8	7	5	8	5	7
20	8	8	7	8	7	8
21	8	6	4	8	4	6
22	8	7	6	8	6	7
23	8	5	4	8	4	6
24	8	7	6	8	6	7
25	8	8	6	8	6	7
26	8	6	5	8	5	6

27	8	7	6	8	6	7
28	8	6	8	8	8	8
29	8	7	6	8	6	7
30	8	8	7	8	7	8
31	8	6	5	8	5	6
32	8	7	7	8	7	7
33	8	5	4	8	4	6
34	8	7	6	8	6	7
Total Average	8	8	4	8	4	6.40

For Gasoline tempo						
Sample no	**6-7 am**	**9-10am**	**12-1pm**	**4-5pm**	**6-7pm**	**Average**
1	8	6	6	8	6	7
2	8	8	7	8	8	8
3	8	7	6	8	5	7
4	8	7	8	8	4	7
5	8	6	5	8	5	6
6	8	7	4	8	6	7
7	8	6	5	8	5	6
8	8	7	6	8	6	7
9	8	8	6	8	6	7
10	8	6	5	8	5	6
11	8	7	7	8	7	7
12	8	6	6	8	6	7
13	7	5	4	7	5	6
14	7	7	5	7	5	6
15	8	6	6	8	6	7
16	8	7	4	8	4	6
17	8	8	6	8	6	7
18	8	7	5	8	5	7
19	8	8	7	8	7	8
20	8	6	4	8	4	6

21	8	7	6	8	6	7
22	8	8	6	8	6	7
23	8	6	5	8	5	6
24	8	7	6	8	6	7
25	8	6	8	8	8	8
26	8	7	6	8	6	7
27	8	8	7	8	7	8
28	8	6	5	8	5	6
29	8	7	7	8	7	7
30	7	6	5	6	4	6
Total Average	8	7	6	8	6	5.23

Appendix: C

Average distance travelled with Trips per day of three wheeler (electric and gasoline) running in Hetauda

For electric tempo		
Sample no	**Distance travelled(km)**	**Trips/day**
1	20	5
2	25	4
3	30	3
4	15	2
5	21	4
6	24	3
7	25	5
8	36	4
9	28	3
10	18	7
11	21	5
12	26	3
13	23	4
14	19	5
15	17	7
16	18	5
17	25	3
18	35	3
19	22	4
20	28	6
21	29	3
22	16	8
23	32	4
24	40	1
25	31	2
26	35	5
27	24	6
28	37	3

29	40	1
30	30	3
31	21	4
32	38	3
33	23	4
34	26	5
TotalAverage	26.41	4.03

Gasoline tempo		
Sample no	**Distance travelled(km)**	**Trips/day**
1	32	4
2	27	5
3	31	6
4	35	3
5	24	4
6	37	2
7	40	2
8	30	3
9	21	5
10	38	2
11	23	3
12	26	4
13	40	2
14	41	1
15	20	3
16	25	3
17	30	4
18	15	8
19	21	4
20	24	5
21	25	6
22	36	4
23	28	3

24	18	7
25	21	4
26	26	5
27	23	5
28	19	6
29	17	8
30	18	7
Total Average	27.03	4.27

Appendix: D

Maintenance Cost of three wheeler (electric and gasoline) running in Hetauda

Electric tempo				
Sample No	**Maintenance Cost (NRs/month)**	**Maintenance Cost (NRs/ Year)**	**Mileage (km/kWh)**	**Sfc(kWh/km)**
1	1000	12000	13	0.08
2	900	10800	14	0.07
3	2000	24000	12	0.08
4	4000	48000	13	0.08
5	10,000	120000	9	0.11
6	2500	30000	14	0.07
7	1900	22800	13	0.08
8	2800	33600	14	0.07
9	3000	36000	14	0.07
10	5000	60000	10	0.10
11	3500	42000	13	0.08
12	2700	32400	14	0.07
13	4200	50400	10	0.10
14	7500	90000	11	0.09
15	3700	44400	13	0.08
16	2800	33600	14	0.07
17	6500	78000	11	0.09
18	5500	66000	10	0.10
19	1000	12000	13	0.08
20	4300	51600	12	0.08
21	7200	86400	11	0.09
22	3700	44400	13	0.08
23	6000	72000	11	0.09
24	1800	21600	14	0.07
25	4500	54000	10	0.10
26	8000	96000	11	0.09
27	12000	144000	9	0.11
28	7800	93600	11	0.09
29	5700	68400	10	0.10
30	3900	46800	13	0.08
31	2100	25200	14	0.07
32	8600	103200	11	0.09
33	2000	24000	14	0.07
34	4300	51600	10	0.10
Total	152400	53788.24	10.03	0.09

Gasoline tempo				
Sample No	**Maintenance Cost (NRs/month)**	**Maintenance Cost (NRs/Year)**	**Mileage (km/liter)**	**Sfc (liter/km)**
1	5000	60000	11	0.09
2	3500	42000	13	0.08
3	2700	32400	14	0.07
4	4200	50400	11	0.09
5	7500	90000	10	0.10
6	3700	44400	14	0.07
7	2800	33600	12	0.08
8	1000	12000	11	0.09
9	900	10800	13	0.08
10	2000	24000	11	0.09
11	4000	48000	15	0.07
12	10000	120000	10	0.10
13	2500	30000	13	0.08
14	1900	22800	15	0.07
15	2800	33600	12	0.08
16	3000	36000	13	0.08
17	12000	144000	10	0.10
18	7800	93600	14	0.07
19	5700	68400	15	0.07
20	3900	46800	14	0.07
21	2100	25200	14	0.07
22	8600	103200	10	0.10
23	2000	24000	13	0.08
24	4300	51600	11	0.09
25	1800	21600	10	0.10
26	5500	66000	11	0.09
27	1000	12000	10	0.10
28	4300	51600	13	0.08
29	7200	86400	14	0.07
30	3700	44400	11	0.09
Total	127400	50960	12.3	0.08