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Estimating Emission Loads from Road Transportation in Kathmandu Valley

by

Pratima Neupane

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Estimating Emission Loads from Road Transportation in Kathmandu Valley**" submitted by Pratima Neupane in partial fulfillment of the requirements for the degree of Master of Science in Climate Change and Development.

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ABSTRACT

Kathmandu Valley which was previously known as city of temples have now transformed into a city of pollution. Dust resuspension due to motor vehicles is the major source of air pollution. The department of environment, in 2017, find out that the transport sector contributed to 28% of pollutants in Kathmandu valley. Emission loads can result in serious health issues like heart diseases, COPD, respiratory syndromes etc. The study looked at the increasing tendency in the evolution of various vehicle types, their energy use and associated environmental pollutants in the Kathmandu valley. The number of vehicles registered each year in the Kathmandu valley were collected from the Department of Transport Management situated at Ekantakuna in Lalitpur district and Department of Transport Management situated at Gurjudhara in Kathmandu district. The majority of vehicles registered in the valley were motorbikes which comprised about 78.28 % of total vehicles registered in Kathmandu valley followed by 13.97 % composed by car/jeep/van type of vehicles. Microbus were seen to be registered lowest, comprising only 0.35% of total number of vehicles registered in Kathmandu valley. Since the annual vehicle scrap data was lacking, the concept of vehicle survival was used to simulate the evolution of actual vehicles on the road. The vehicle's life cycle profile was mixed with the Weibull distribution function for this. The estimated vehicle energy demand and emissions were calculated using these predicted vehicle numbers. The total emission load in 2020 was 2.7 million tons/year for CO_2, 101 thousand tons/year for CO, 12 thousand tons/year for NO_x, 20 thousand tons/year for HC and 5 thousand tons/year for PM_{10} approximately. The study has predicted the CO_2 emission in the valley for 2025 and 2030 years as 4.5 million tons and 6.4 million tons, respectively. The study shows that people preferred private vehicles in comparison to public vehicles ultimately increasing the fuel requirement for travelling the same distance.

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LIST OF ABBREVIATIONS

CO_2	Carbon dioxide
CO	Carbon monoxide
HC	Hydro Carbon
NO_x	Nitrous oxide
PM	Particulate Matter
COPD	Chronic Obstructive Pulmonary Disease
HDV	Heavy Duty Vehicles
LDV	Light Duty Vehicles
CDES	Central Department of Environmental Science
IHME	Institute for Health Matrix and Evaluation
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
EPA	Environmental Protection Agency
VOCs	Volatile Organic Compounds
LEAPS	Long-range Energy Alternative Planning System
WHO	World Health Organization
TSPs	Total Suspended Particulates
VKT	Vehicle Kilometer Travelled
NDCs	Nationally Determined Contributions
EVs	Electric Vehicles

CHAPTER ONE: INTRODUCTION

1.1 Background

The Kathmandu, Bhaktapur and Lalitpur districts make up the Kathmandu valley, which spans 220 square miles (570 km^2). The Shivapuri hills, Phulchowki, Nagarjun and Chandragiri hills surround the Kathmandu valley. The Bagmati river is the main river that runs through the Kathmandu valley. It is a bowl-shaped valley. It is the country's central hub in every aspect including politics, business, demographics, occupation, study and many others. Kathmandu valley is the most populated and also the most polluted area in Nepal. The Kathmandu Valley is one of the world's most polluted cities, with air pollution being one of the valley's significant issues (Rahman, 2020).

Development activities have resulted in certain unfavorable changes in the physical environment, especially in metropolitan areas, where air quality has deteriorated. Unplanned urbanization, pollution-prone industry, an increase in the number of uncontrolled polluting vehicles, poor road quality, a lack of solid environmental regulation and so on are some of the major underlying causes of the degradation. The chief sources of air pollution are dust resuspension from motor vehicles and construction, smoky vehicles and the production of particulate matter (PM) by small-scale enterprises like brick kilns (Dhakal, 2006).

Pollutants emitted from vehicular emissions contains Carbon dioxide which is one of the major GHGs and air pollutants. Pollution generated by automobiles is a result of the reaction of fuel with other gases and the surrounding environment (Asif Faiz, 1996). Vehicle emissions are the result of the interdependence of vehicle technology, fuel quality, and the state of use of the vehicle (D. Borys, 2001). Vehicle emissions rise considerably as the fleet size grows, as do the differences in vehicle travel characteristics (K. S. Nesamani, 2007). Since 2010, the quality of gasoline and diesel in Nepal has met the Euro III standard and it is imported in refined form from India and other countries for direct use (B. Das, 2019).

It has been studied that the major cause of air pollution in Kathmandu valley is the increase in the number of vehicular fleets (Shrestha R. M., 1996).

The valley's rapidly expanding road traffic fleet is a significant source of air pollution, especially given the valley's congested traffic conditions and high elevation. Transportation accounted for 24 percent of worldwide CO_2 emissions from combustion in 2018. Passenger and freight transportation by automobile, truck, bus or two-wheeler was by far the most significant source of emissions, accounting for over three quarters of total emissions (IEA, 2020).

1.2 Problem Statement

The topography of Kathmandu Valley is bowl-like which restricts the continuous air movements across the valley. The road network's compliance with the steep topography also promotes the vehicular emissions due to increased road gradients. The length of dry seasons with short rainy seasons is another supporting factor for increasing air pollution in the Kathmandu valley.

The increase in emission of greenhouse gases from anthropogenic activities is one of the major and growing problems of the globe. Emissions from the transportation sector is one of the major additions in global GHGs emission. So, it is very necessary to find the estimate of how much emission load is represented by transportation. Finding the measure of the amount of GHGs emissions in a particular place will also provide the tentative figures of total GHGs emission occurring throughout the country. So, the concerned authority will be able to find out the possible solutions for the management of the transportation sector and subsequently reduce emissions of GHGs. It is equally important to predict the future scenario in the transportation sector and the emissions rising from the sector so that immediate and long-term actions can be planned and executed.

In Nepal, the petroleum demand is about 1.8 million tons per annum which will increase by 20% in 2019 and it constitutes about 11% of total energy consumed in Nepal (Economic survey 2019/20, 2020).The consumption of total petrol in Kathmandu valley alone is 40% and diesel is 16% of total consumption in entire Nepal (Annual Report-Fiscal Year 2011/12, 2011). The consumption of fossil fuel at such higher rates is very much dissatisfying, realizing the fact that Nepal has a huge potential of Hydroelectric energy generation. On one hand, a huge sum of national assets is being sent to countries abroad for trade in fossil fuels. On the other hand, the electric power is not being used wisely for powering the transportation sector which has negative consequences of both weakening the national economy and emission of more GHGs. In Kathmandu valley, the major source of PM_{10} emission is vehicular emission which accounts for 38% of total emissions compared to 18% from agriculture sector and 11% from the brick kilns. Vehicles and road dust account for about 63 percent of total PM_{10} emissions, while resuspended dust accounts for 25% of PM_{10} emissions in the Kathmandu valley (UN HABITAT, 2013).

The poor air quality in urban places such as the Kathmandu valley has a significant influence on people's health and welfare as well as the environment (D. Mage, 1996). The number of people suffering from Chronic Obstructive Pulmonary Disease (COPD) rises dramatically during the winter months when pollution levels are at their highest (CEN, 2003). COPD is the second most common cause of mortality in Nepal, according to the Institute for Health Matrix and Evaluation (IHME, 2018).

According to a study, Nepal is estimated to have 24,000 premature deaths per year due to outdoor air pollution by 2030 (D. Shindell, 2012).

1.3 Objectives

The general objective of the study is to estimate the different type of emission loads from the road transport sector in the Kathmandu valley.

The specific objective of the study is as follows:

- To analyze the trend of vehicular registrations and its impact on emission of CO_2 in the Kathmandu valley.
- To find the trend of emission loads from road transportation in the Kathmandu valley.
- To estimate the CO_2 emission in the near future based on the past trend.

1.4 Rationale of Study

Time and again the pollution at Kathmandu Valley tops the world's cities and ranks itself above the list. One of the major causes for such an increase in pollution level is emissions from the transportation sector among others like brick kilns industries. It's a subject of concern that different types of harmful gases and other pollutants are increasing from the transportation sector despite the fact that Nepal is a rich country in terms of hydroelectric power which can severely change the pattern of our transportation modality, with transition from fossil fuel-based energy to clean energy.

So, it is essential to determine with greater accuracy the emission loads from transportation so as to demote the use of fossil fuels and increase the use of cleaner energy sources like hydroelectricity. Furthermore, the health risks of emission loads are very hazardous which needs immediate response from the top-level authorities as it can result in serious health issues like heart diseases, COPD, respiratory syndromes etc.

So, the estimation of emission loads from the transportation sector and prediction of future emission rates should be able to draw attention from the government and concerned authorities and promote the use of clean energy sources. The government should make favorable policy changes and mitigation strategies for replacing fossil fuels with clean energy sources in the transportation sector in Kathmandu valley and all over Nepal.

1.5 Research Questions

What are the emission trends of various emission loads from the road transport sector in Kathmandu valley?
What will be the emission trends of CO_2 in the near future?

1.6 Scope and Limitation of the Study

This study would calculate the amount of emission loads from the road transport sector and would calculate the trends of emission of CO_2 from the road transport sector of Kathmandu valley. This study would provide the information about the air pollution in Kathmandu valley from the transport sector and would also provide measures to minimize the air pollution in Kathmandu valley. Some outcomes of the study are as follows:

- Emission loads from road transport sector in Kathmandu valley
- Trend analysis of various emission loads
- Trend analysis of energy demand of each vehicle type
- Trend analysis of CO_2 gas emission
- Estimation of CO_2 emission in the near future

The research work being discussed could be very successful, if its success rate strikes the accuracy as we desire. The limitations are mentioned as below:

1. Availability of transport sector data in detailed form
2. Availability of data and standards related to emission
3. Vehicles condemning to national standards and laws
4. Study has not considered the company of each vehicle type

CHAPTER TWO: LITERATURE REVIEW

2.1 Green House Gases

Green House Gases (GHGs) are those gases in the atmosphere which are found naturally and produced from anthropogenic processes. These gases absorb and emit radiation mostly in the *infrared spectrum* from the Earth's surface, atmosphere and clouds (B. Metz, 2007). As the world population is increasing rapidly, anthropogenic activities are also increasing which are responsible for the production of GHGs and ultimately increase the overall surface temperature of the Earth. Mostly after the advent of industrial era and urbanization, the natural process got assisted by the anthropogenic emission of GHG for increasing the temperature. The concentration of GHGs in the atmosphere has been concentrated regularly which is the major cause for global warming and the climate change (J.T. Houghton, 2001).

Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydroflurocarbons (HFCs), etc. are major Greenhouse gases which account for the climate change the world is facing. Among these GHGs, Carbon dioxide accounts for 77% of global CO_2 equivalent for global warming (B. Metz, 2007).

2.2 GHG Emission

Different human activities like fossil fuel (coal, oil, gas) usage for energy, deforestation, livestock farming, industrial processes, fertilizers usage that contain mostly Nitrogen etc. are responsible for the production and emission of GHGs. Studies found that the amount of CO_2 emission has increased from about 280 in 1750/1800 to 367 ppm in 1999 (J.T. Houghton, 2001) and 379 ppm in 2005 (Anderson, 2010). The CO_2 levels have crossed 400 ppm in 2016 and forward. Various human activities like biomass burning, fossil fuel production, manure use, paddy farming, livestock fermentation process, waste management have led to an increase in the amount of Methane (CH_4). It is estimated that 50% of global CH_4 emission is accounted for by these human activities (Eggleston, 2006). The concentration of methane is increasing regularly as its concentration in 1998 was about 1745 ppb (Anderson, 2010) and 1775 ppb in 2005 (Zachariadis T, 2001). Similarly, Nitrous Oxide (N_2O) emission is a result of activities like Sewage treatment, animal manure, fertilizers treatment, fossil fuels and microbial activities (Eggleston, 2006).

2.3 Road Transport

Road transport is a classic method for freight and passenger carriage. It is a very versatile option today and well-suits with many human needs. Its flexibility for door-to-door service and easy availability and speed for short and medium distance are the major reasons for its adoption all over the world. It is a dependable option for peoples travel and goods transfer from different locations.

Road transport in this study can be grouped as

1. **Transportation of Goods:** Transportation for supply and delivery of fundamental and all types of goods are done in Kathmandu valley through road transport.
2. **Transportation of People:** People use road transportation for travelling from one place to another for their regular and business activities.

2.4 GHG Emission from Road Transport

Road transport has been dependent upon fossil fuels for a long time and transport in Nepal has very much relied upon fossil fuels. The use of fossil fuels in any form leads to the emission of GHGs. Road transport systems have led to emission of different GHGs and pollutants like CO_2, CO, NO_x, HC, Particulate Matters etc.

2.4.1. CO_2 emissions from Road Transport

Carbon Dioxide is one of the GHGs emitted from the transportation sector. The carbon (C) produced from the complete combustion of fossil fuel mixed with Oxygen(O_2) in the atmosphere produces CO_2. According to the EPA, CO_2 emissions from a gallon of gasoline is 8,887 grams CO_2/ gallon and CO_2 emissions from a gallon of diesel is 10,180 grams CO_2/ gallon. Increasing the amount of CO_2 in the atmosphere is a boost to global warming.

2.4.2. CO emissions from Road Transport

When the amount of air required for the air-fuel mixture, for combustion, is lower or limited, then the burning of fossil fuel in such conditions causes the production of Carbon Monoxide. Carbon monoxide is a very harmful gas for human health as it directly affects the blood circulation by the formulation of carboxyhemoglobin which is one of the major causes for heart diseases.

2.4.3. NO_x emissions from Road Transport

Nitric oxides (NO) and Nitrogen dioxides (NO_2) are major nitrogen byproducts which are produced when nitrogen and free oxygen react inside the combustion chamber in engines. These nitrogen oxides are the major contributors for the formation of smog and acid rains.

2.4.4. Hydrocarbons (HC) emissions from Road Transport

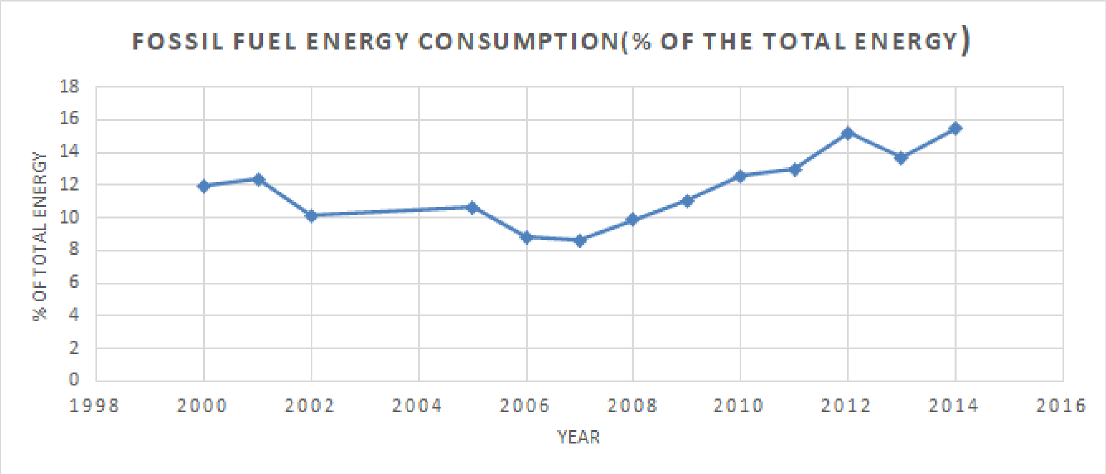
Hydrocarbons are produced as a byproduct from the incomplete combustion of fossil fuels in the combustion chamber and are released from the tailpipe of the vehicles. They are also referred to as the Volatile Organic Compounds (VOCs). These VOCs react in presence of sunlight and Nitrogen compounds to form smog and ground level ozone also.

2.4.5. Particulate Matters emissions from Road Transport

Particulate matters are the results of unburned fossil fuels and lubricating oils that are left unburnt in the engine system. These are suspended in the air environment causing pollution and health hazards.

2.5 Fossil Fuel Consumption Scenario in Transport Sector in Nepal

Figure 1 shows the trend of the fossil fuel consumption in the transport sector. The fossil fuel consumption is found to be increasing in each year.



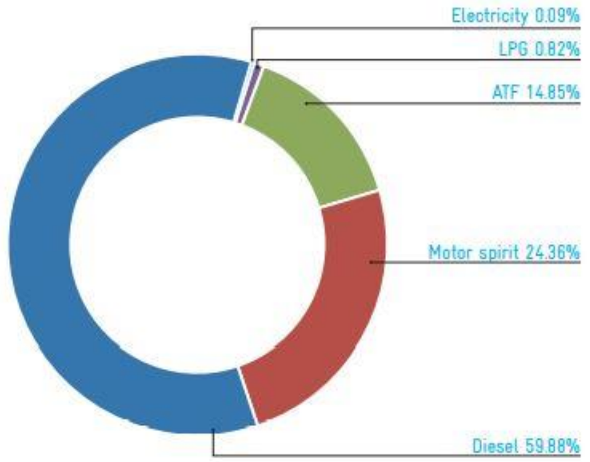
Source: World bank data sets

Figure 1: Fossil fuel consumption scenario

Energy Consumption in Transport Sector ('000 GJ)

Transport Type	Fuel						
	Diesel	Motor spirit	ATF	LPG	Electricity	Grand Total	Percent
Bus	4,272.73					4,272.73	15.97%
Minibus_microbus	1,988.17					1,988.17	7.43%
Car_jeep_van_pickup	2,305.38	4,373.63				6,679.01	24.97%
Truck_tanker_lorry	6,671.03					6,671.03	24.94%
Three wheeler	222.69			219.79		442.47	1.65%
Tractor_others	463.00					463.00	1.73%
Two wheeler		2,143.48				2,143.48	8.01%
Rails	97.73					97.73	0.37%
Cable car					23.36	23.36	0.09%
Domestic flight			973.27			973.27	3.64%
International flight			2,998.49			2,998.49	11.21%
Grand Total	16,020.72	6,517.11	3,971.76	219.79	23.36	26,752.73	100%
Percent	59.88%	24.36%	14.85%	0.82%	0.09%	100%	

ENERGY CONSUMPTION IN THE TRANSPORT SECTOR BY FUEL TYPE



Source: ENERGY DATA SHEET, NOC and WECS report 2014

Figure 2: Energy consumption in Transport sector

From the figure 2, we can clearly see that the energy consumption rate of vehicle of type Car/ Jeep/ Van is found to be high which shares 24.97 % of total energy consumed in transport sector by all vehicles. The second type of vehicle that have the highest share is Truck/ Tanker which shares 24.94 % of total energy consumed in transport sector. The energy consumption of cable car is very less which is only 0.09 % of total energy consumption. From the figure, we can also see that the diesel is consumed in higher percent than other type of fuels. About 59.88% of energy is consumed by the diesel and 24.36 % of energy is consumed by the motor sprint which use gasoline fuel.

2.6 Vehicle Survivability and Travel Mileage

To accurately analyze the impact of car fuel efficiency and safety regulations, survivability and vehicle mileage by age schedules are required. The survivability timeline can be used to estimate when new safety equipment will be installed in the fleet of vehicles (Bhattarai, 2016).

The actual vehicle fleet on the road must be determined in order to predict the energy demand and pollutants produced by automobiles. The vehicle data provided by the Department of Transport Management is simply the total number of vehicles since their first registration and do not represent the actual vehicle fleet on the road. A considerable number of vehicles scrapped each year due to their age. If the annual scrapping rate is known, the actual vehicle fleet on the road may be calculated by subtracting scrapped vehicles from the number of vehicles registered annually (Asif Faiz, 1996).

2.7 Past Research and Research Gap

A number of researches have been carried out for estimating and predicting the emission loads from the road transportation sector. Since the traditional and present-day transport system in Nepal has been, moreover, dependent upon fossil fuels. So, the transportation sector is a major source of GHGs emission. Road transportation is considered as one of the major sources of urban pollution in developing countries (Jha P.K., 2003). The estimation of emission loads is very important research that could lead the policy makers and authorized bodies to make action and plans for the reduction in emission loads.

A study conducted by Jha and Lekhak (2003) showed that the number of vehicles in the Kathmandu valley has increased by 14 % in 2003. The dust particles in the air were 10 times more than the World Health Organizations standard values. The presence of air pollutants like SO_2 and NO_x was at maximum level. Despite the efforts of many governmental, non-governmental and international non-government organizations, the state of air quality in Kathmandu valley did not improve. Also, despite the government's rules and regulations to avoid the air pollution in Kathmandu which was implemented in 1997, the pollution did not improve in the valley (Jha P.K., 2003).

Baidya and Borken-Kleefeld (2009) analyzed the emission of GHGs from the vehicles operated in the Kathmandu Valley. For calculating the emissions, first the vehicles were categorized into three categories. The vehicles were categorized as gasoline vehicles, diesel vehicles and natural gas vehicles. Again, the categorized vehicles were divided into four groups based on their age and technology. The vehicles that were out of service was deducted for determining the net GHGs emissions. The study also showed that the number of two-wheeler vehicles nearly doubled during 1995 to 2005 which ultimately doubled the GHGs emission in the valley. A sensitivity analysis conducted by the author showed that the CO_2 emissions ranged from -51% to + 68%. The study showed that the trucks consumed the maximum amount of fuel and also emitted the maximum amount of CO_2 emissions as compared to buses and other vehicles. According to the findings, the number of motorized two-wheelers increased dramatically in 2005 when compared to 1995 figures. The rise in the number of motorized two-wheelers contributed significantly to the growth in traffic congestion. In comparison to big vehicles or huge public buses, the powered two-wheelers and light vehicles consume more unit fuel per passenger (Baidya, 2009).

Kishor , Pramen and Geeta Shrestha concluded that the total number of vehicles in the Kathmandu valley have increased from 45,871 in 1990/1991 to 570,145 in 2010/2011. They have determined the amount of carbon dioxide emitted by the vehicles. The total number of vehicles registered were collected from the Department of Motor Vehicles, Kathmandu. Vehicle manufacturers were contacted for the emission rates of each type of vehicle. The Kathmandu valley had the greatest amount of pollution in Nepal, according to the report. The carbon dioxide emissions from each vehicle type were also determined. The transportation sector is the most polluting source in the valley. The study has recommended for improving the air quality of the valley (Shrestha P. P., 2017).

Shrestha and Malla (1996) have studied the air pollution in the Kathmandu valley from various type of energy use. Because of its bowl-like topology, which inhibits wind movement and traps pollutants in the atmosphere during thermal inversions, the valley is particularly prone to air pollution. Total suspended particulate (TSP) concentrations in major urban areas have consistently exceeded World Health Organization (WHO) standards. From 115 days in 1970 to only about 20 days in 1993, the number of days with a visibility of more than 8,000 m (at 11:45 hr local time) during the months of November to February, the months with the lowest visibility, has declined. Air quality is projected to deteriorate more as a result of fast expanding fuel use as a result of increased urbanization and industrialization if no effort is taken to alleviate the situation (Shrestha R. M., 1996).

A study conducted by Shrestha and Rajbhandari (2010) analyzed the energy consumption in the Kathmandu valley from different sectors as well as the CO_2 emission. The study showed that there was a three-fold increase of passengers between 2003 and 2025 and also the fuel consumption and greenhouse gas emission went up to 240 % and 300% respectively. The transportation sector contributed about 34% of CO_2 emission and the residential sector contributed about 33% in 2005 (Shrestha R. M., 2010).

A study conducted by Byungil Kim (2012) quantified the GHGs emitted by the construction equipment in South Korea. The principal GHGs, carbon dioxide, methane and nitrous oxide were calculated based on the equipment fuel use. The fuel usage was computed based on the construction equipment's direct operating hours. To begin, the total working hours of the specific equipment were determined using the equipment's productivity and the amount of work to be completed. To calculate the total fuel consumption, multiply the total number of hours of operation of a vehicle by the fuel consumption of the cars per unit hour. So, the total amount of GHGs emission was calculated by multiplying:

- The amount of fuel
- The oil conversion factor
- Specific gas emission factors
- The ratio of molecular weight of gas to the element such as the molecular weight of carbon dioxide gas to the molecular weight of carbon

The findings revealed that earthwork excavation accounted for 90% for total GHG emissions. In addition, the study identified eight operations at construction sites that release that greatest GHGs: topsoil, weathered rock, rock transportation, subgrade and roadbed embankment. Dump trucks, bulldozers and loaders were the equipment that emitted the most GHGs (Byungil Kim, 2012).

A study conducted by Shobhakar (2003) studied the implications of transportation policies on energy and environment in the Kathmandu valley. From 1988 to 2000, the author determined the past and future trends in transportation as well as the energy demand. The findings revealed a 13 percent increase in car registrations in the Kathmandu valley in 2000 as well as an increase in the number of two-wheelers vehicles from 51% to 69%. The desire for travel increased rapidly after 1998 according to the historical statistics. Finally, the study found that private light-duty and two-wheeler vehicles operating on gasoline contributed more than 70% of total carbon dioxide emissions in the Kathmandu valley (Dhakal, 2003).

Bajracharya and Bhattarai (2016) concluded that if the vehicle fleets are left unrestrained in the Kathmandu valley in the next fifteen years then there will be huge increase of vehicle fleets, particularly small vehicles such as motorcycles and light commercial vehicles. Small vehicles were found to be the most significant users of cumulative fuel consumption, accounting for 58 percent of total CO_2 emission, 84 percent of total CO, 92 percent of total HC, 32 percent of total NO_x and 65 percent of total PM_{10} emissions in the valley. This research has revealed various alternate approaches to manage the vehicle fuel demand, particularly for urban transportation in Nepal's Kathmandu valley. For the period 2016-2030 AD, the modeling tool Long-range Energy Alternative Planning System (LEAPS) was used to construct a bottom-up model to estimate the energy demand and environmental emissions in the Kathmandu valley. Four alternative scenarios (Public Bus Penetration, Improved Fuel Economy, Electric Motorbike and Hybrid Electric Car) have been produced in addition to the References scenario. Within the analysis period, the total energy demand in the Reference scenario will reach 142,092 thousand GJ. Motorcycles and the light duty vehicles account for about 65 percent of total demand. Within the research period, if all of the alternative scenarios are implemented combined, around 38% of energy demand and 54 % of CO_2 emissions can be avoided compared to the reference scenario. If all four choices are used combined, a total of 1641 million US dollars can be saved over the course of the analysis period (Bhattarai, 2016).

Bajracharya, Manandhar, et.al. (2020) studied the vehicular emission load of Bhaktapur Municipality which were found to be 3,310 tons/year including CO_2, CO, NO_x, HC, and PM_{10} of which CO_2 accounts for 94.36% of total emissions followed by CO (4.39%), HC (0.72%), NO_x (0.35%), and PM_{10} (0.18%), respectively. Significant positive correlation was found (r =0.92, p = 0.002) between CO_2 and PM_{10} (r = 0.87, p = 0.009), between CO_2 and NO_x (r = 0.90, p = 0.004), between CO and HC (r = 0.74, p = 0.05), and between NO_x and PM_{10}, respectively. Vehicle emissions have played a key role in the deterioration of air quality in many metropolitan areas of Nepal, resulting in negative health effects on commuters and pedestrians due to severe respiratory ailments. After obtaining primary data such as the number of vehicles (N) using two-hour peak (8 am to 10 am) and two-hour non peak (1pm to 3pm) counts, the average annual vehicle kilometer (VKT) and fuel economy (F) required for emission load estimation were obtained from vehicle surveys using the simple random sampling method, with sampling size taken statistically under a 5 % margin of error. Emission factors and derived equations from a published paper were used as secondary data in this study (Prasidha R. Neupane, 2020).

The Kathmandu valley sees the annual average growth rate of 14.3 % in total registered vehicles from 1990-2011 of which the motorbikes alone share 17% increase. Motorcycle comprises 73.2% and car/jeep comprises 18.5% of the transportation means which shows that the transportation is getting more private (Clean Air Network Nepal, 2013).

The GHG (CO_2) emission from Bus/ Minibus is high among the vehicle studied (Parth Sarathi Mahapatra, 2019). The lack of high resolution and updated emission inventories caused the underestimation of pollution load in Kathmandu valley (Sadavarte, 2019).

Energy consumption increased by factor of 1.6 in 2016 compare to the consumption in 2001 and at the same time the emissions increased by a factor of 1.2 - 2.4. Overloaded vehicles in the city forced the drivers to adjust the injection pump for allowing more fuel to the engine for increasing the power. As a result, fuel consumption increased by 10% or more while the power increased only by 2% (GGGI, 2018).

When compared to the other sectors, the transportation sector contributes the most to the total emissions of the energy-using sector. After 2007, there was a significant increase in transportation sector emissions. Passenger vehicles have been a major source of pollution in Kathmandu’s transportation sector (Zachariadis T, 2001).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Research Design

Research begins with the selection of a topic. To achieve the research objectives, the basic framework of research design is formulated as shown in the chart Figure.

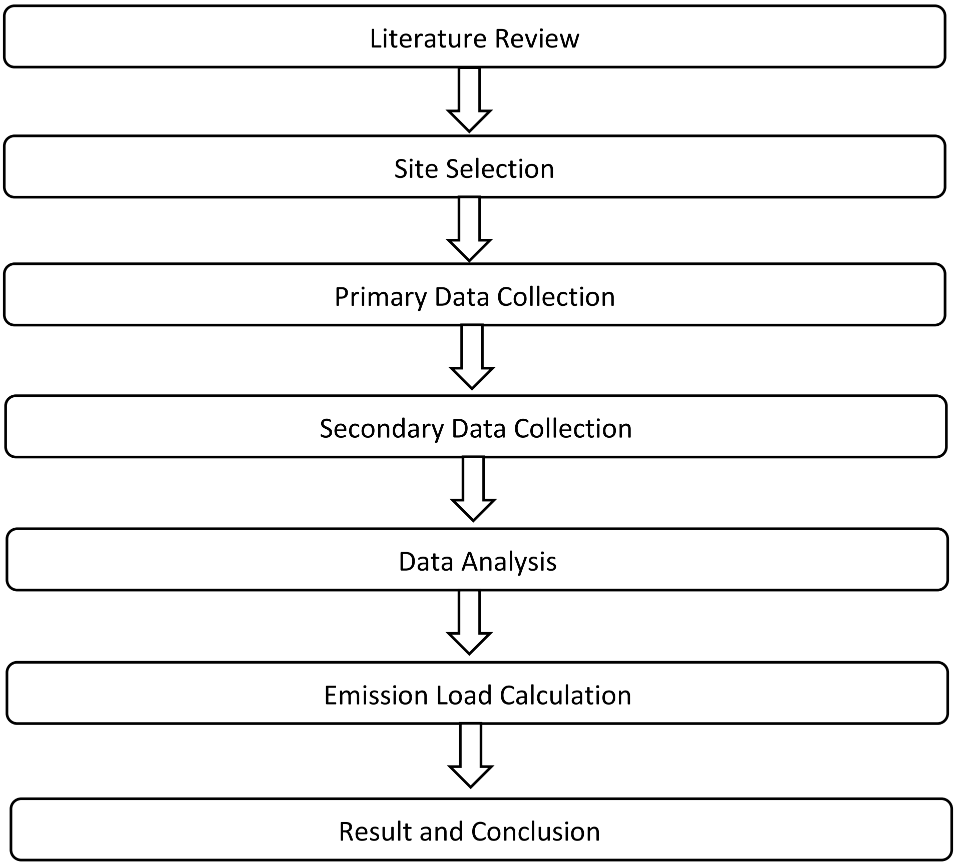


Figure 3: Framework of Research Design

The research design starts with the research of various literatures. Different types of papers related to the emission from transportation were reviewed thoroughly. The papers from other countries like China, India, etc. were also considered during the literature review period. After selecting the topic and doing several research regarding the selected topic, the research location was selected. Kathmandu valley is the most polluted city of Nepal and large number of vehicles runs throughout the city area. Due to these reasons, the research location was selected as the Kathmandu valley which comprises the three districts as Kathmandu, Bhaktapur and Lalitpur. After finalizing the research site, the important step of the research was done that was to collect the primary data. Primary data collection includes the collection of vehicles data that were registered in each year from 2000 to 2020. Since, due to the time limitation, the annual vehicle kilometer travelled data was taken as the secondary data and was taken from the latest literature in which the author had done manual survey for calculating the VKT of each vehicle type. Secondary data collection includes the fuel consumption rate, VKT, emission factors for each vehicle type and different parameters for calculating the survival probability of the vehicles in each year.

After the collection of both primary and secondary data collection, these data were analyzed using various methods. First step in the data analysis process is to estimate the existing vehicle stock in each year. The next step is to estimate the energy demand in each year of each type of vehicle using the existing vehicle number, VKT and the average annual fuel consumption of each vehicle type. The final step is to estimate the emission loads of each type of vehicle in each year from 2000 to 2020 using the energy demand that was estimated before and the emission factors for each vehicle type. After the final calculation is done, the research ends with writing the results and conclusion of the research that was done.

3.2 Research Methodology

3.2.1 Scope for accounting emission

Transportation is vital to human society because it allows people to move about and supports industry and trade. However, transportation is not simply advantageous. There are several environmental consequences, including habitat fragmentation, climate change, noise, and air, soil, and water pollution, to name a few. It is one of the main sectors that contributes to the emission of Greenhouse gases. The decay of buried carbon-based organisms that died millions of years ago produces fossil fuels. They produce carbon-rich deposits, which are mined and burned for energy. They are non-renewable and currently provide roughly 80% of global energy. When the fossil fuels are burned, they release large amounts of greenhouse gases. Transportation is the major sector of consuming fossil fuel. The transport sector generates the largest share of greenhouse gas emissions. The combustion of fossil fuels in our automobiles, trucks, ships, trains and planes is the primary source of greenhouse gas emissions from transportation.

3.2.2 Identification of the type of emission

Carbon Dioxide is one of the GHGs emitted from the transportation sector. The carbon (C) produced from the complete combustion of fossil fuel mixed with Oxygen(O_2) in the atmosphere produces CO_2. Nitric oxides (NO) and Nitrogen oxides (NO_2) are major nitrogen byproducts which are produced when nitrogen and free oxygen react inside the combustion chamber in engines. Hydrocarbons are produced as a byproduct from the incomplete combustion of fossil fuels in the combustion chamber and are released from the tailpipe of the vehicles. Particulate matters are the results of unburned fossil fuels and lubricating oils that are left unburnt in the engine system. These are suspended in the air environment causing pollution and health hazards. The vehicular emissions is determined by the amount of fuel consumed and the type of fuel used.

3.2.3 Data analysis of each vehicle type

There are different types of vehicles that are registered each year in the Kathmandu valley. The vehicles have been classified as Bus, Mini Bus, Car/Jeep/Van, Pickup, Micro Bus, Truck/Mini Truck, Motorbikes, Heavy Duty Vehicles (HDV) and Light Duty Vehicles (LDV). Dozer, Loader, Roller, Skavater and Tipper are classified as HDV. Ambulance and C.D/U.N are classified as LDV. The data analysis of each vehicle type was done in the following ways:

1. Analyze the existing vehicle stock
2. Analyze the Average Vehicle Kilometer Travelled of each vehicle type
3. Analyze the fuel consumption of each vehicle type
4. Analyze the energy demand of each vehicle type

3.2.4 Analysis of Emissions of each vehicle type

Vehicles exhaust various types of emission such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_2), hydrocarbons (HCs) and suspended particulate matters. Emission factors of each type of vehicle should be considered in order to estimate the emission that comes from vehicles. Each type of vehicle has their own emission factors and the type of emission is also different for each vehicle. The different emission types can be analyzed using the energy demand and the emission factors.

3.2.5 Interpretation of emission

The emission load of each vehicle is different because of the type of fuel they use and the energy demand. Some vehicles are large in numbers and their emission load is also high in number. The amount of emission load of the vehicle is dependent on the type of fuel that the vehicle consumes.

3.3 Data Collection

Data was collected from the Transport Management Office, Ekantakuna, Lalitpur and Yatayat Office Motorcycle, Gurjudhara. The four-wheeler and three-wheeler vehicles data were collected from the Transport Management Office and Motorcycle data was collected from Yatayat Office Motorcycle. The data taken was from the year 2000 to 2020 AD. The total number of vehicle types before 2000 AD were also considered and included in the data of 2000. The vehicles have been classified as Bus, Mini Bus, Car/Jeep/Van, Pickup, Micro Bus, Truck/Mini Truck, Motorbikes, HDV and LDV.

3.4 Data Analysis

After the collection of data, the next step is to analyze those collected data in order to estimate the emission loads of each vehicle type in each year.

3.4.1 Existing Vehicle Stock

Due to the age of vehicles, a large number of vehicles scrapped in each year. The actual number of vehicles that are plying on the road can be calculated if we know the annual scrapping rate of vehicles by subtracting the number of scrapped vehicles from the total number of vehicles registered annually. But in Nepal, such type of data does not exist. So, in order to calculate the energy demand of each vehicle first step is to calculate the existing vehicle stocks on the road. The existing vehicle stock in each year can be estimated by using the following equation (1)

$$N_{i,t} = 0.5 * D_{i,t} + \sum_{x=2000}^{t-1} D_{i,t} * \emptyset_i(\text{t-x}) \quad (1)$$

Where, $D_{i,t}$is the number of vehicles of type i registered in year t$\emptyset_i$(t-x) is the survival probability of a vehicle of type I of age (t-x) (Baidya, 2009). The vehicle data registered since 2000 to 2020 have been taken into account in order to estimate the vehicle stock. The survival probability of vehicle can be estimated by using the following Weibull function (2)

$$\emptyset_i(k) = e^{-[(\frac{k+b_i}{T_i})^{b_i}]} \quad (2)$$

Where, $\emptyset_i$(k) is the survival probability of vehicle of type i having age k, k is the age of vehicles expressed in years, b_i is the failure steepness for vehicles of type i and T_i is the service life of vehicle of type I (Zachariadis T, 2001). The value of these parameters b and T are required to estimate the existing vehicle stock by doing the iterative process by matching with the actual data provided with the annual vehicle scrap data available. The values of b and T were taken from the literature (Bhattarai, 2016). Table 1 presents the values of the parameters b and T.

Table 1: Parameters used for survival probability of vehicles

Para-meters	**Vehicle Type**								
	Bus	**Minibus**	**Pickup**	**Car/Van**	**Microbus**	**Motorbikes**	**Truck**	**HDV**	**LDV**
b	2.29	2.29	2.03	2.03	2.03	1.99	2.29	2.29	2.03
T(years)	14	12	10	12	18	8	12	12	12

3.4.2 Average Vehicle Kilometer Travelled

The average annual VKT have taken the reference from the published article (Bhattarai, 2016). The authors of this article have conducted vehicle surveys in the Kathmandu valley in 2013 and estimated the average annual vehicle kilometer travelled for different types of vehicles. Table 2 shows the estimated average annual vehicle kilometer travelled for different types of vehicles.

Table 2: Average annual vehicle kilometer travelled

Vehicle Type	**Average Annual Vehicle Kilometer Travelled (VKT)**
Bus	44,105
Minibus	43,307
Pickup	37,415
Car/Van	12,310
Microbus	38,520
Motorbikes	8952
HDV	37,800
LDV	25,356

3.4.3 Average Fuel Consumption

Average fuel consumption is the average fuel consumed per kilometer distance travelled by a vehicle. Average fuel consumption is required to estimate the energy demand of each type of vehicle. Each vehicle type has their own fuel consumption rate. Since, this study has categorized similar type of vehicles in a group, the fuel consumption of the vehicles of those group were considered as the same. The average fuel consumption data were taken from the article (Prasidha R. Neupane, 2020). Table 3 shows the average fuel consumption by different type of vehicles during the valley drive in the Kathmandu valley (Prasidha R. Neupane, 2020).

Table 3: Average fuel consumption by different vehicle types

Vehicle Types	**Fuel Types**	**Fuel economy (*l*/km)**
Bus	Diesel	0.28
Mini Bus	Diesel	0.25
Car/Van	Gasoline	0.07
Truck/Mini Truck	Diesel	0.25
Motorbikes	Gasoline	0.02
Pickup	Diesel	0.15
HDV	Diesel	0.25
LDV	Diesel	0.16

3.4.4 Estimation of Energy Demand

The total annual energy demand in liters by each vehicle type i in year t ($ED_{i,t}$) can be estimated if the total number of existing vehicles in year t ($N_{i,t}$), their average annual mileage in kilometer ($VKT_{i,t}$) and average fuel economy in liters per kilometer (F_i) are known. Basically, energy demand shows the amount of fuel consumed by certain number of vehicles by travelling certain distance in each year.

The annual energy demand by each vehicle type can be estimated by using the following equation (3)

$$ED_{i,t} = N_{i,t} * VKT_{i,t} * F_i \quad (3)$$

3.4.5 Estimation of Emission

Emission from a vehicle is a function of energy consumed by it. So, the total amount of emissions of emission type j emitted by the vehicle of type i in year t ($E_{j,i,t}$) can be estimated by multiplying the total energy demand by vehicle of type in in year t ($ED_{i,t}$) and the emission factor of type j expressed in gram per liter of vehicle of type i in year t ($EF_{j,i,t}$). The five types of emission factors for each type of vehicle were considered. Each vehicle type has their own emission factor value for each type of emission factor. The emission made by each vehicle type can be estimated by the following equation (4)

$$E_{j,i,t} = ED_{i,t} * EF_{j,i,t} \quad (4)$$

The data for emission factors of type j of vehicle of type i were taken from the literature (Prasidha R. Neupane, 2020). Table 4 presents the average emission factors by vehicle type.

Table 4: Emission factors by vehicle type

Vehicle Type	Fuel Type	CO_2	CO	NO_x	HC	PM_{10}
Bus	Diesel	3440	24	35.61	11.11	11.7
Mini Bus	Diesel	3440	24.8	11.2	10.4	8.1
Car/Van	Gasoline	3985	261.9	29.6	87.9	2.27
Truck/Mini Truck	Diesel	3440	24.8	11.2	10.4	8.12
Motorbikes	Gasoline	3766	726.3	11.3	69.9	4.3
Pickup	Diesel	3440	24.8	11.2	10.4	7.2
Micro Bus	Diesel	3440	24.8	11.2	10.4	7.2
HDV	Diesel	3440	24.8	11.2	10.4	7.2
LDV	Diesel	3440	24.8	11.2	10.4	7.2

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Number and Types of Vehicles

The number of vehicles registered each year in the Kathmandu valley were collected from the Department of Transport Management situated at Ekantakuna in Lalitpur district and Department of Transport Management situated at Gurjudhara in Kathmandu district. Table 5 shows the number and types of vehicles registered in each year since 2000 AD. The vehicles registered before 2000 AD were taken all at once which summed up to 2187 and included in the year 2000 AD. The numbers of vehicles registered thereafter are taken as it is in their individual years of registration. The numbers of vehicles saw rapid increment after 2007 AD which marked the beginning of the Federal Democratic Republic of Nepal brought by huge people's movement. Later during the coronavirus pandemic days in December 2019, the first wave of pandemic brought strict lockdown into force which resulted in lower number of new vehicles registered in the year 2019/20. The majority of vehicles registered in the valley were motorbikes which comprised about 78.28 % of total vehicles registered in Kathmandu valley followed by 13.97 % composed by car/jeep/van type of vehicles. Microbus were seen to be registered lowest, comprising only 0.35% of total number of vehicles registered in Kathmandu valley.

Table 5: Number of vehicles registered in each year

Nepali Year	English Year	Bus	Mini Bus	Car/Jeep/Van	Pickup	Micro Bus	Truck/ Mini Truck	Motor Bike	HDV	LDV
057/58	2000/01	2187	2264	41451	411	617	5685	112809	81	7997
058/59	2001/02	114	368	2173	451	104	751	22,535	31	149
059/60	2002/03	236	232	2260	559	292	744	19,322	67	180
060/61	2003/04	285	116	6285	495	675	540	18,289	17	34
061/62	2004/05	198	445	12146		670	440	18,986	72	181
062/63	2005/06	806	242	3369	17		1007	21,001	63	234
063/64	2006/07	420	380	3624	492	68	509	32,503	121	119
064/65	2007/08	531	504	5671	865	30	948	36,394	289	86
065/66	2008/09	674	490	5184	672	43	1230	42,054	661	170
066/67	2009/10	495	268	8309	979	149	1488	70,527	604	183
067/68	2010/11	389	279	7013	1028	69	801	55,092	442	28
068/69	2011/12	392	139	5561	1378	60	447	39003	219	33
069/70	2012/13	611	185	6334	2561	105	520	59589	405	43
070/71	2013/14	763	194	8397	3003	115	731	56497	698	52
071/72	2014/15	897	336	10528	2397	138	1310	61838	1140	41
072/73	2015/16	1183	367	21647	2047	136	1889	73265	2483	36
073/74	2016/17	1405	357	14542	3027	222	1173	98344	4443	36
074/75	2017/18	833	262	14452	3177	1457	1228	104869	3548	156
075/76	2018/19	921	565	16577	4628	371	1525	80831	3252	254
076/77	2019/20	667	252	10675	2870	122	536	74180	933	236
077/78	2020/21	334	474	8466	4791	0	600	104440	474	159

4.2 Trends of Vehicle Types

The data collected showed that the total number of vehicles registered have been increasing every year except in the year of political movements and pandemics. The number of motorbikes in 2020/21 was 104440 which is a higher number than the other types of vehicles. We can see that the number of Car/Jeep/Van has also increased considerably in the valley. The vehicles other than motorbikes and Car/Jeep/Van have been increasing at the same pace.

Figure 4 shows the trend in the evolution of vehicles fleets in the Kathmandu valley from the year 2000 to 2020.

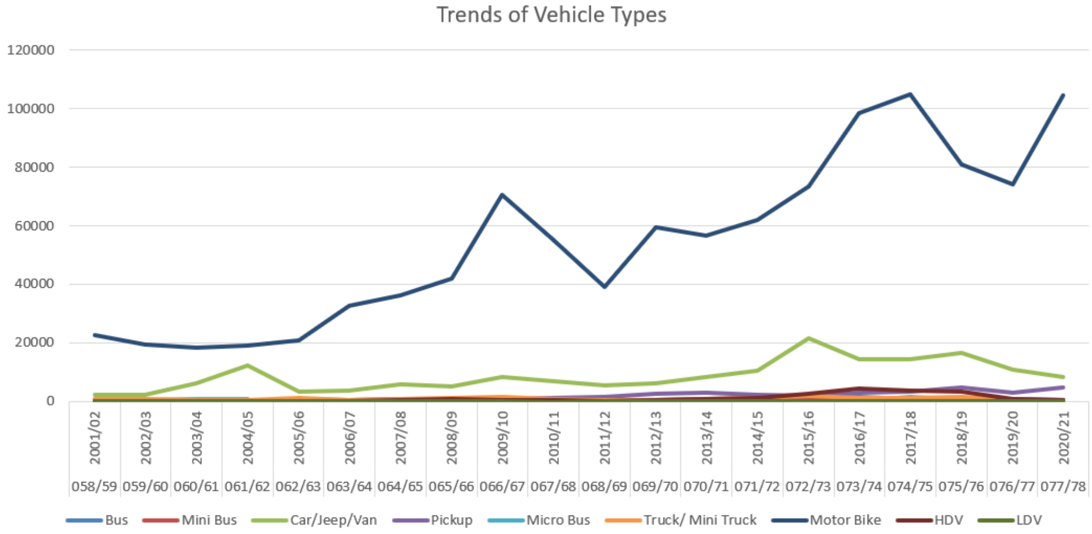


Figure 4: Trends of Vehicle Type

4.3 Trends of Energy Demand

The number of vehicles and energy demand are intertwined. With the increasing number of vehicles, the transportation sector's energy demand is also increasing. Though Nepal is a richer country in terms of hydroelectric potential, this opportunity is not still capitalized. It means Nepalese transport modality depends hugely upon fossil fuels. The trends of Energy demand reveal that the fuel demand is in increasing trend from 2000 to 2020 AD except some years that had well-defined reasons. Figure 5 depicts the trend of energy demand which shows that the year 2018-2019 had the highest demand of fossil fuel measuring 7402000139.94 liters.

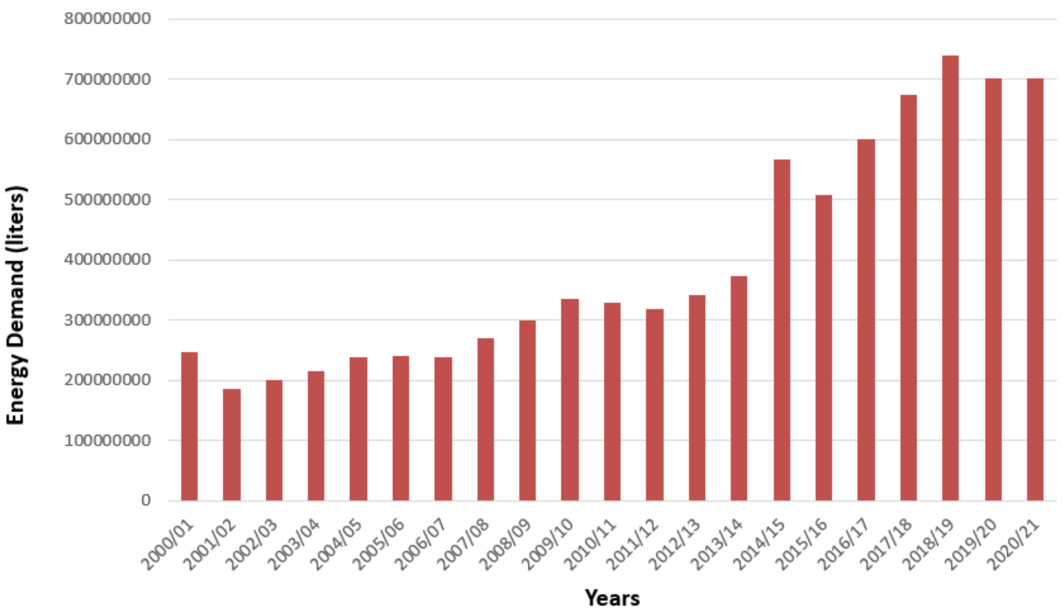


Figure 5: Trend of Energy demand

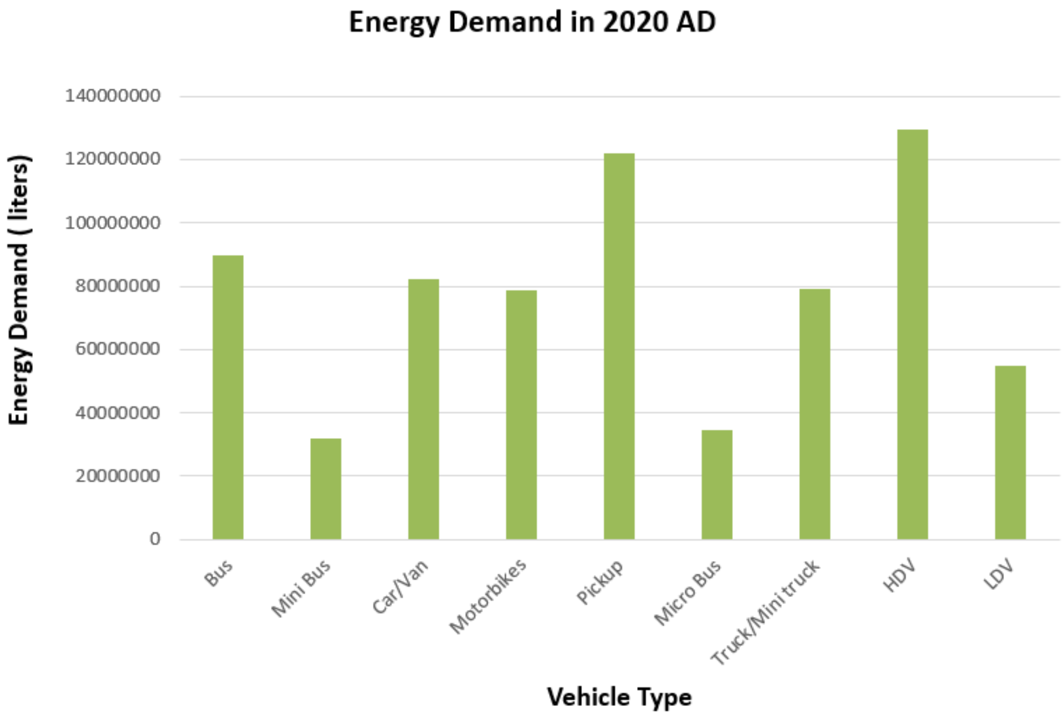


Figure 6: Energy demand in 2020 AD

From figure 5, the energy demand in 2020 is seen as 702700706.98 liters consisting of a combined measure of petrol and diesel individual requirement. Since this year is hit by a pandemic so hard that the actual demand could be a bit different from theoretical procedures.

Figure 6 shows how the type of vehicles has an effect upon the consumption of petroleum fuel. Here bus, minibus, pickup, microbus, truck / mini truck, HDV, LDV are diesel dependent and car/van, motorbikes are petrol dependent. So, among diesel engine vehicles, HDV are found to have more demand of diesels which summed to 129279743 liters of diesel and minibus consumed 31749176 liters of diesel. Similarly, car and van types of vehicles are seen to consume more petrol (82412258 liters) than motorcycles (78888406 liters).

4.4 Estimation of Emission load from Road Transport Sector

Fossil fuels used for energy supply are the main cause for emission of GHGs. Transport sector is that sector which almost completely depends upon fossil fuel. So, it is obvious that the transportation sector is one of the major contributors of GHGs emissions.

Table 6 shows how the emission load varied among each other during various years between 2000 to 2020. CO_2 topped among all emissions every year. PM_{10} emission was found to be less than all other emission loads.

The figure 5(energy demand) and figure 7 show greater resemblance which shows that the trend in energy demand is so similar to trends in total emission loads.

The total emission load was estimated for both gasoline and diesel vehicles as shown in figure 7. The total emission load in 2020 was 2.7 million tons/year for CO_2, 101 thousand tons/year for CO, 12 thousand tons/year for NO_x, 20 thousand tons/year for HC and 5 thousand tons/year for PM_{10} respectively.

Table 6: Estimation of emission load in each year.

Years	CO2	CO	NOx	HC	PM10
2000/01	976388.2147	41530.82563	5156.876542	9067.655644	1898.816357
2001/02	732434.9244	30552.60895	3733.849223	6508.888337	1438.852472
2002/03	786415.2257	31130.2088	3974.208024	6681.331764	1567.825961
2003/04	848575.7834	32621.17754	4320.463558	7233.876727	1678.939083
2004/05	938496.4261	36743.76954	4873.497192	8667.793206	1776.567463
2005/06	941082.0428	32170.79589	4857.098197	7182.478786	1973.110102
2006/07	931556.5206	34109.14628	4828.572182	7328.030805	1932.632266
2007/08	1056708.473	37928.63243	5429.18377	8239.627631	2188.34687
2008/09	1169218.232	40925.2063	5934.012628	8733.872147	2453.329629
2009/10	1313426.336	50883.27003	6556.462052	10369.75542	2682.474815
2010/11	1288847.83	52063.40932	6458.112863	10362.8198	2614.38059
2011/12	1245564.748	50359.8629	6291.045814	9994.012778	2530.559775
2012/13	1339121.786	55265.26759	6723.941486	10721.33808	2712.814663
2013/14	1460246.919	58643.88359	7329.82746	11557.34209	2955.757513
2014/15	2242085.629	106481.0555	10926.3775	20581.33779	4177.681296
2015/16	1989404.412	75347.38813	9978.362665	15901.07318	3959.396283
2016/17	2347752.997	85006.9737	11450.55526	17553.9661	4731.496054
2017/18	2631693.796	94254.66073	12448.69763	19311.92306	5263.202026
2018/19	2885033.013	98139.10518	13530.33747	20717.22255	5775.330008
2019/20	2738613.194	96401.70137	12972.55654	20044.7143	5468.627617
2020/21	2742464.584	101671.9604	12772.76529	20339.59805	5432.698733

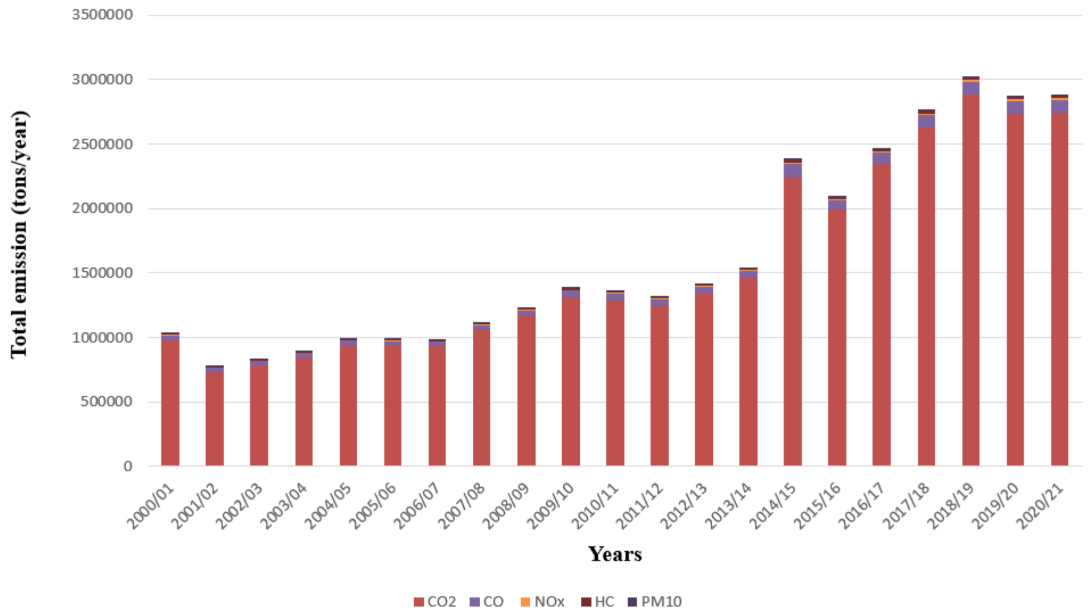


Figure 7: Trend of total emission load

4.5 Estimation of CO_2 Emission in Transport Sector

We know that carbon dioxide is the primary greenhouse gas emitted from the transport sector. The total emission of CO_2 was calculated for diesel and gasoline vehicles as shown in table 7. The total CO_2 emission in 2020 was about 2.74 million tons. The study results showed that the CO_2 emission is increasing rapidly every year, which is having a significant impact on the environment of the valley.

Table 7: Estimation of CO_2 emission in each year.

Years	Total existing vehicles	CO2 Emissions
2000	230539	976388.2147
2001	171976	732434.9244
2002	175078	786415.2257
2003	180704	848575.7834
2004	196586	938496.4261
2005	178061	941082.0428
2006	192213	931556.5206
2007	213198	1056708.473
2008	232702	1169218.232
2009	294860	1313426.336
2010	304794	1288847.83
2011	295684	1245564.748
2012	328329	1339121.786
2013	347461	1460246.919
2014	631132	2242085.629
2015	435295	1989404.412
2016	499226	2347752.997
2017	556165	2631693.796
2018	574414	2885033.013
2019	566908	2738613.194
2020	607002	2742464.584

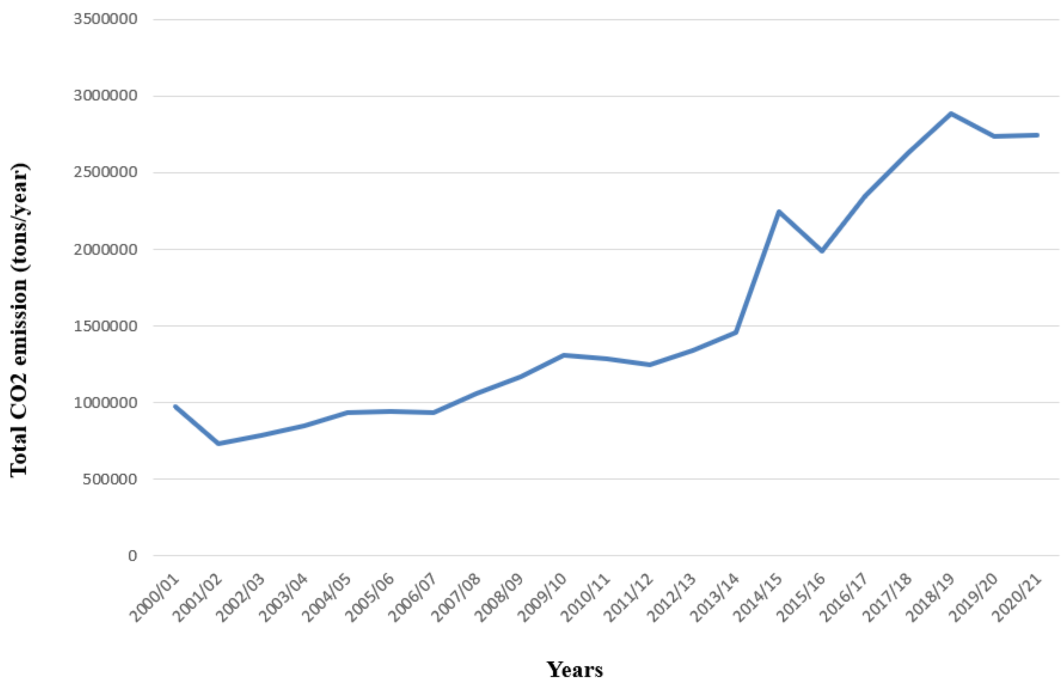


Figure 8: Trend of total CO_2 emission

Figure 8 shows the trend of CO_2 emission between the year 2000 to 2020. The CO_2 emission was found to be high during 2014 and 2018 year due to the increased number of vehicle registration during those years. In the year 2015, the emission was found to be reduced due to the blocked situation after the earthquake in Nepal during that year.

4.6 Road Transport Sector in the Business-as-usual Scenarios

4.6.1 Projection of CO_2 Emission

According to vehicle registration data, the number of vehicles registered in the Kathmandu valley is increasing at a rate of about 15 % per year. Furthermore, CO_2 emissions are increasing at an alarming rate. The number of vehicles on the road grows every year and emissions are proportional to the number of vehicles on the road.

A regression analysis was used to forecast a CO_2 emission trend based on the past trend of emission. The prediction model's R-square value was very high, around 93 percent. The regression model that was used for the prediction of CO_2 emission is given in Equation 5.

$$Y = 3E\text{-}56e^{0.0707x} \quad (5)$$

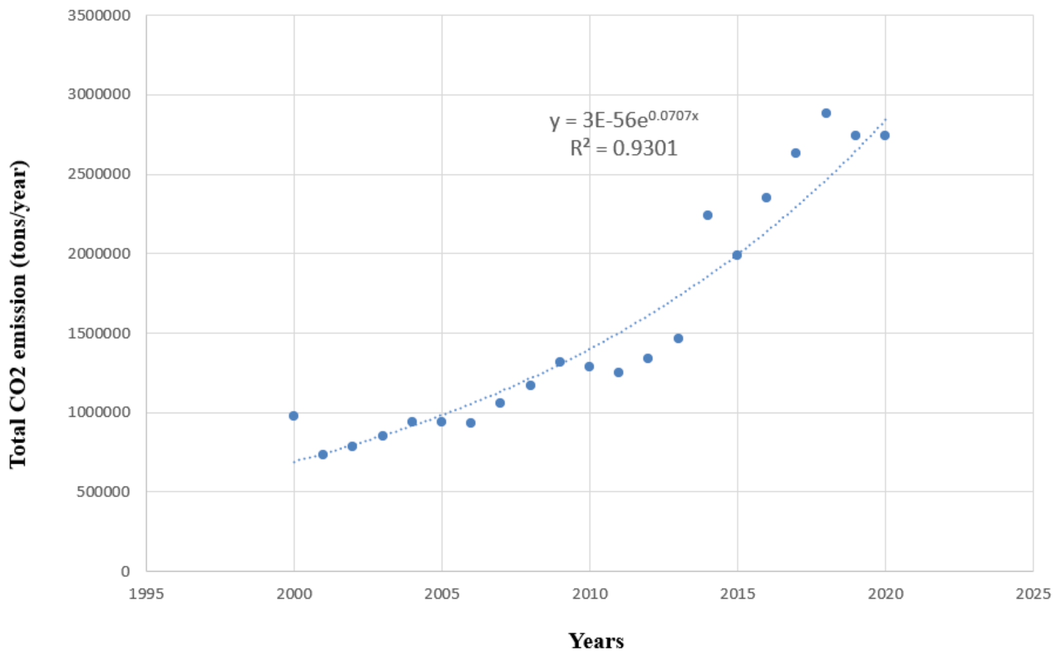


Figure 9: Projection of CO_2 emission

4.6.2 Prediction of CO_2 emission in the coming years

Using the above regression model, the carbon dioxide emissions of each year till 2030 AD have been estimated. From the table below, we can see that the CO_2 emission in the valley for 2025 and 2030 years are estimated to be 4.5 million tons and 6.4 million tons, respectively. The table below shows that the CO_2 emission will go on increasing in each year if the trend of vehicle registration follows the past trend. The CO_2 emission will increase at a quicker rate if aggressive and long-term mitigation initiatives are not enacted.

Table 8: Prediction of CO_2 emission

Year	CO2 Emissions
2021	3397488.639
2022	3646385.938
2023	3913517.254
2024	4200218.396
2025	4507923.035
2026	4838169.869
2027	5192610.322
2028	5573016.8
2029	5981291.551
2030	6419476.184

4.7 Comparison of findings with other literatures

The results found during this research were compared with previously published literatures and found similar results on different scenarios.

The study conducted by (S. R. Shrestha, 2013) estimated the total CO_2 emission of Kathmandu Valley in 2010 as 1,553,852 tonnes. They used composite emission factor, total vehicle kilometer travelled and the number of starts of each vehicle type for estimating the emission of CO_2 for the base year 2010. In the year 2010/11, this study estimated the value of CO_2 emission as 1,288,847.83 tonnes which shows the resemblance with the mentioned study.

The study conducted by (Pramen P. Shrestha, 2012) calculated the emission scenarios by multiplying the average fuel consumption with the typical average of daily distance travelled by different types of vehicles by using the US Environmental Protection Agency data. The total CO_2 emission in Kathmandu valley was found as 1.2 million tons per year in 2010 which is similar to the findings of the present research.

The study conducted by (Shrestha P. P., 2017) estimated the emission of CO_2 in the Kathmandu valley in the year 2010 as 1094 kilotons. This value is also similar to the result of this present research which is equal to 1288.847 kilotons of CO_2 in 2010. The result is slightly higher in number because the present research has considered the existing vehicles rather than just the cumulative number of vehicles.

4.8 Use of Electric vehicles

Electric vehicles are a dependable source for the reduction of emissions from the transportation sector. Since electric vehicles make use of clean energy and the fossil fuels are completely avoided in electrical vehicles, they show a promising behavior in reduction of emissions.

Although, it is not mentioned in the objectives additional attempt have been done in order to analyze how much CO_2 emission can be reduced by using electric vehicle instead of gasoline vehicles.

As found in the study, the total number of fossil fuel dependent motorbikes in 2020/21 is 440619 which is responsible for the production of 327489.69 tons of CO_2 emission. It corresponds to 0.674 tonnes of CO_2 emission per year in 2020/21 from a single motorbike. That means, 0.674 tonnes of CO_2 emission can be prevented by using a single electric motorbike. By replacing these fossil fuel-dependent motorbikes with electrical motorbikes, a huge amount of CO_2 emission can be prevented from being released to the atmosphere. If one electric motorbike is used instead of one gasoline motorbike then 0.74 tons of CO_2 emission will be reduced from the total CO_2 emission emitted in each year.

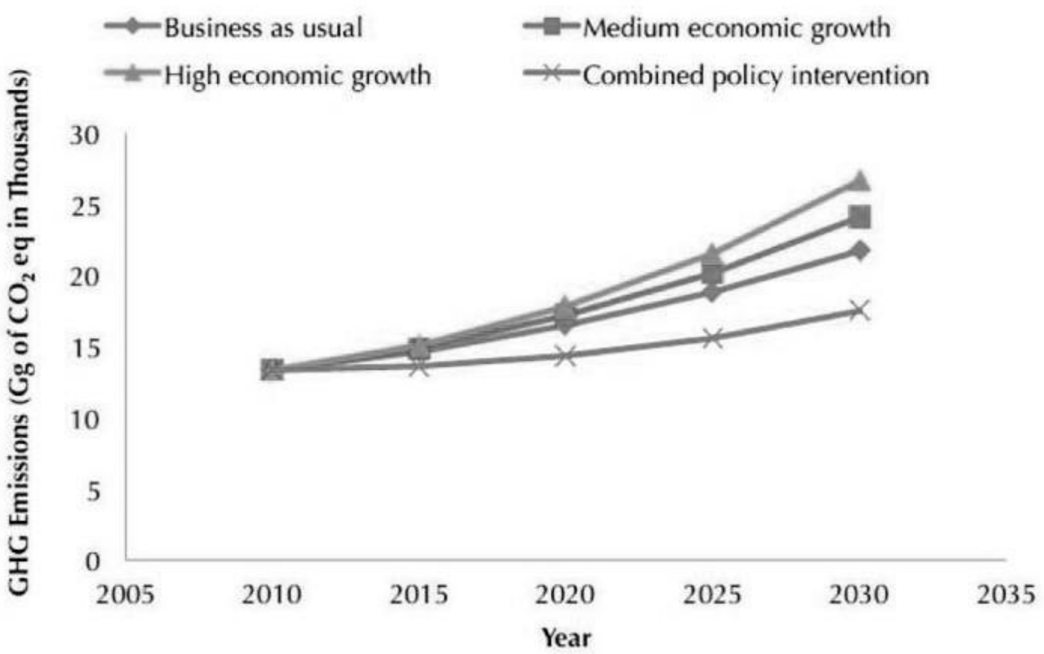
Similarly, 1 Car/jeep/van type of vehicle emit 3.78 tons of CO_2 emission per year. The total number of this type of vehicles registered in year 2020/21 is 95631 which contribute 362013.097 tons of CO_2 emission. If electric cars replaced the traditional fossil fueled vehicles, a huge amount of emission can be prohibited. Thus, use of electric vehicles should be more prioritized for the reduction of emissions from the transportation sector.

4.9 Electrification of the Road Transport Sector

Nepal imports all of its fossil fuel resources because the country lacks viable fossil fuel reserves. The transportation sector has the greatest nonrenewable energy demand of any sector. The residential sector utilizes the most energy, followed by transportation and manufacturing. However, because the residential sector uses mostly biomass, a renewable energy source, the transportation sector consumes the most fossil fuels.

It is widely acknowledged that greenhouse gas emissions, such as carbon dioxide, contribute to global warming. Energy systems must shift away from fossil fuels and toward renewable energy sources. Because it does not involve the use of petroleum fuels, electric mobility is a preferred option. It is possible to minimize petroleum fuel demand and environmental pollution by introducing and encouraging the usage of electric vehicles instead of conventional gasoline and diesel automobiles. Electric vehicles will cut final energy consumption, greenhouse gas and local pollutant emissions, and improve energy security as they become more widely adopted in the transportation sector.

CDES conducted a study in 2017 and published in their annual report, the GHG emission from different energy sectors under different scenarios as shown in figure 10. The policy intervention could be a dependable medium for reduction of GHG emissions as compared to other scenarios.



Source: CDES, 2017

Figure 10: GHG Emissions Scenarios

15th Five Year plan (2019/20 - 2023/24) has set the reduction in import of petroleum products as one of its major objectives. It aimed at fixing appropriate tariff rates for

EVs and setting up charging stations at different locations for promoting EVs. But the implication of this plan is set behind but due to inefficiency of planning authority for providing detailed plans and targets for EVs (MoFE, 2021).

National Climate Change Policy, 2019 includes industry, transport and physical infrastructure as one of its eight themes. Its policies are targeted for promoting electric vehicles and energy-efficient technologies. Yet, specific timelines and targets are not mentioned clearly in the policy itself.

The National Environment Policy, 2019 also sets its goal to control pollution and safeguarding every citizen right to clean environment. It also includes clean vehicles promotion as one of its 23 strategies.

Kathmandu Valley Air Quality Management Action Plan, 2020, also lists promoting EV as one of the measures to reduce pollution. It sets its target as establishing charging stations and terminal, converting old vehicles to EVs and only operate zero-emission vehicles in tourists and sensitive areas. Though the targets set by the plan are very much astonishing to listen but its implementation is unexpected in a serious note.

National Action Plan for Electric Mobility, 2018 suggested policies and financial activities for the promotion of e-mobility including the barriers. It suggested a total of 24 initiatives which are activities with limited scope and can address to identified barriers.

4.10 Barriers to Electric Mobility

4.10.1 Policy and Governance Barriers

Both the Environment Friendly Transport Policy and the National Sustainable Transportation Strategy included provisions and targets for electric vehicles, some of which were included in the Nationally Determined Contributions (NDCs). However, the government has taken no further action to establish directives, instructions, or processes for implementing these policies.

4.10.2 Infrastructure and Market Barriers

Nepal is currently investing very little on electric vehicle infrastructure and facilities. This is a key impediment to increased electric car adoption, as the availability of charging stations, in particular, is important for wider acceptance. To overcome market results that are not favorable to electric car adoption, the governance of electric vehicle distributors could be enhanced. Consumer electric automobiles, in particular, are extremely expensive, often out of reach of the ordinary car customer. Consumers must be able to expect wide energy supply stability in order to have market confidence in electric automobiles.

4.10.3 Financing and Resource Barriers

Currently, there is no government-backed funding for electric mobility. The government has reduced disincentives for electric vehicles by reforming the customs and value added tax regimes. This is a wonderful step forward. The government, on the other hand, does not yet give any proactive incentives for switching to electricity. An incentive like this, in the form of a subsidy, would be beneficial. In Nepal, there is a scarcity of educated engineers and technicians for electric vehicles.

4.10.4 Data and Monitoring Barriers

There is a scarcity of trustworthy and usable data. This makes monitoring much more difficult and undermines the evidence basis needed for good policy and decision-making. The data on emissions and air quality support increasing investment in electric mobility.

4.11 Air pollution in Kathmandu valley

Air pollution has been a dominating problem in the Kathmandu valley which caused the degradation of the environment quality in the last few decades. The major source of pollution in the valley is from the road transport sector which emit huge quantities of smoke in the ambient environment. Kathmandu valley is the largest consumer of gasoline and diesel throughout the country of which more than 50% of gasoline and 20% of diesel is consumed in the Kathmandu valley only.

The department of environment, in 2017, studied to find out that the transport sector contributed to 28% of pollutants in Kathmandu valley.

Road transport is responsible for almost 70% of all particulate matters at street levels making it one of the major sources for ambient air pollution. A 2017 survey by the Department of Environment states that PM_{10} from diesel vehicles alone contributed

34% of the air pollution. In 2017, 45.9 µg/m³ of $PM_{2.5}$ was recorded which rose up to 54.4 µg/m³ in 2018 showing a fairly large increase of $PM_{2.5}$ and thus a significant degradation of air quality from 2017 to 2018. Later in 2019, $PM_{2.5}$ reading was 48 µg/m³ which showed a little improvement compared to 2018. However, when compared to 2017's reading, it showed an overall decline in air quality.

In figure 11, the 2019 lines indicate the daily average value of $PM_{2.5}$ during April 2019 and the 2020 lines indicate the daily average value of $PM_{2.5}$ during April 2020. Since there was strict lockdown due to pandemic during April 2020 in Kathmandu valley, the level of $PM_{2.5}$ measured seems to decreased during that period.

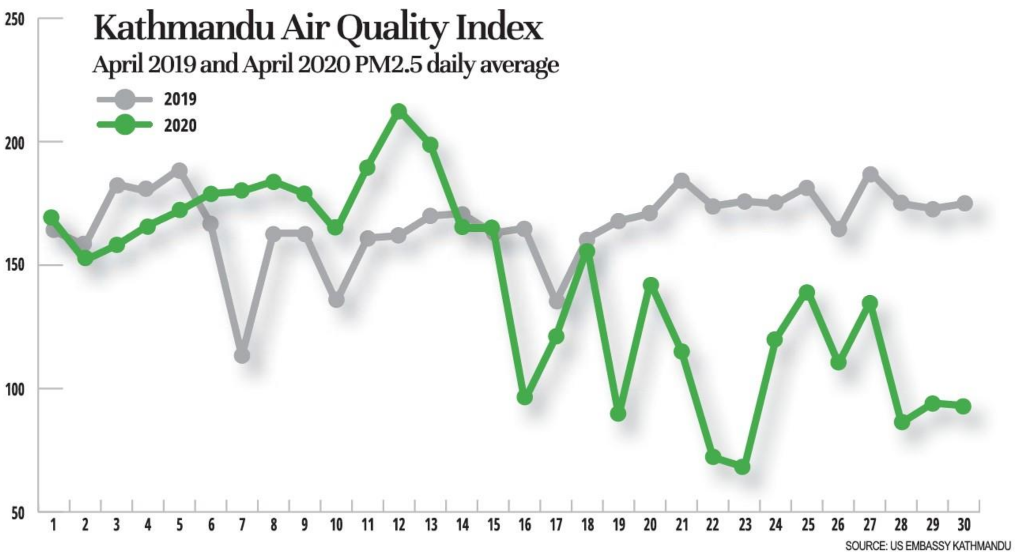


Figure 11: Kathmandu Air quality index of 2019 and 2020

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

In this paper, the total emission loads from the road transport sector in the Kathmandu valley was estimated. The study looked at the increasing tendency in the evolution of various vehicle types, their energy use, and associated environmental pollutants in the Kathmandu valley. The majority of vehicles registered in the valley were motorbikes which comprised about 78.28 % of total vehicles registered in Kathmandu valley followed by 13.97 % composed by car/jeep/van type of vehicles. Microbus were seen to be registered lowest, comprising only 0.35% of total number of vehicles registered in Kathmandu valley. The study shows that the number of private vehicles is increasing in higher quantity than the public vehicles. The trend of energy demand shows that the year 2018-2019 had the highest demand of fossil fuel measuring 7402000139.94 liters. The results indicated that the total emission load in 2020 was 2.7 million tons/year for CO_2, 101 thousand tons/year for CO, 12 thousand tons/year for NO_x, 20 thousand tons/year for HC and 5 thousand tons/year for PM_{10} respectively. The study also predicted the total CO_2 emission from the vehicles between the year 2021 to 2030. The study has predicted the CO_2 emission in the valley for 2025 and 2030 years as 4.5 million tons and 6.4 million tons, respectively.

5.2 Recommendations

1. The study could be further done for knowing the Chronic Obstructive Pulmonary Disease (COPD) patients due to the pollution caused by the transport sector.
2. The vehicles data used in this study is not the exact data of the Kathmandu valley. Assumption have been made that the data are from the Kathmandu valley. Deep analysis of data or the survey of vehicles can be done in order to calculate the accurate emission from the transportation sector of the valley.
3. The emission trend of transportation sector can be compared with the trend of air quality of the valley.

4. The study has not considered vehicle of each company type which may have altered the result. So, further study specifying the company of the vehicle and their related fuel consumption and vehicle travelled data can be used for more accurate estimation.
5. The similar types of vehicles are categorized in one or two categories for doing the estimation. For example, both motorcycles and scooters are categorized as Motor bikes in the study. So, instead of categorizing those vehicles in one category individual analysis can be done for better result.

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