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Energy Saving and Environmental Implication of Net Zero Target in Land Transport of Bagmati Province

by

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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 " **Energy saving and Environmental implication of Net Zero target in land transport of Bagmati province"** submitted by Pratik Adhikari (078MSESPM007) in partial fulfillment of the requirements for the degree of Master of Science in Energy System planning and Management.

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ABSTRACT

Global warming is seen to be raising concern on the global level, so the Paris agreement has been made by most of the nations setting the target of gaining net zero to reduce the global temperature rise and all nations have been developing their policies to achieve the common goal. The GON has also set different NetZero targets, which can impact the national energy demand. In the case of Nepal being a developing country, the transportation sector is seen to be mainly based on petroleum products. So, the impact of the target on the fuel mix of the Nation needs to be studied. Taking Bagmati province as the study area, the passenger and freight transport demand of Nepal is calculated from the years 2022-2050. The vehicle registered and the Weibull survival equation are used to determine the total number of vehicles in operation in Bagmati province which along with the loading factor were taken from to determine the present passenger-km and tonne-km demand. Using the Leap model, the different scenarios including GON targets are developed and the fuel mix and emission comparison is performed in this study. On the Long-term analysis of the year 2050, it is observed that the WAM scenario has a Fuel saving of 26% and an emission reduction of 44.7%. The fuel switching to cleaner electric vehicles shows the trade-off that the nation has to increase its Power plant capacity to fulfill the demand in order to reduce emissions. This helps to reduce the fuel import ratio and improve the energy security of a nation like Nepal with surplus energy from hydropower. The study shows that emissions can be reduced by the targets but cannot fully remain Net Zero in the case of the transportation sector.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

MW	Megawatt
PJ	Petajoule
TJ	Terajoule
TWh	Terawatt-hour
VKT	Annual Vehicle Km
OF	Occupancy Factor
VN	Vehicle Stock in that year
$TFD_{(t)}$	Total freight demand
$TPD_{(t)}$	Total Passenger demand
LF	Load factor for freight
TPED	Total passenger vehicle energy demand
TFED	Total Freight vehicle energy demand
Mf	Mileage factor
Ef	Emission factor
α1i	Elasticity coefficient population (Passenger)
α2i	Elasticity coefficient GDP (Passenger)
αi	Elasticity coefficient GDP (Freight)
$Ø_i(K)$	Vehicle Survivability factor
Ti	The service life of the vehicle
bi	Failure factor for vehicle
PKM	Passenger Km
TKM	Tonne Km

LIST OF ABBREVIATIONS

NEA	Nepal Electricity Authority
WECS	Water and Energy Commission Secretariat
EV	Electric Vehicle
GHG	Green House gases
GON	Government of Nepal
NDC	Nationally Determined Contribution
UNFCCC	United Nations Framework Convention on Climate Change
GDP	Gross Domestic Product
WAM	With Additional Measures
WEM	With Existing Measures
WTW	Well to wheel
ICEV	Internal Combustion Engine Vehicle
UNO	United Nations Organization
LEAP	Low Emissions Analysis Platform
NOC	Nepal Oil Corporation
NZE	Net Zero Emission
SDG	Sustainable Development Goals
MT	Metric tonnes
MOFE	Ministry of Forest and Environment
CBS	Central Bureau of Statistics
CJV	Car, Jeep, and Van
TCO	Total cost of Ownership

NMVOC	Non-Methane Volatile Organic Compounds
NHTSA	National Highway Traffic Safety Administration
NPC	National Planning commission

CHAPTER ONE: INTRODUCTION

1.1 Background

It is observed that the overall energy consumption in the case of Nepal is highly dependent on biomass and commercial energy. The shift to commercial energy in the case of Nepal is observed to be evident as renewable sources are being explored in the case of Nepal. Electric consumption has also seen picking up its pace in recent years. Out of the major six energy-intensive economic sectors transportation sector is also one of them. As of the year 2022 February, the total installed capacity of hydropower in Nepal is 2023 MW with 53.4 MW thermal power plants and 49.74 MW grid-connected solar power plants with a total installed capacity of 2,205 MW (WECS, 2022). It is observed that the peak energy demand in Nepal is 1864 MW and the national demand is 1564 MW. Nepal has been exporting electricity to neighboring nations at the time of the wet season. So, the electricity can be used to easily fuel vehicles as there is more under construction hydropower in Nepal as Nepal is seen to have a potential of about 42,000 MW of economically feasible hydroelectricity. (NEA, 2008)

In Nepal, the transportation sector is mainly dominated by the means of road transportation which comprises about 90% of all trips made throughout the nation (Acharya, 2015). Even though Nepal is in the earliest stages of motorization when compared with other nations, the growth of vehicle registration in Nepal growth rate has exceeded the rate of 16% per annum in the past decade. The petroleum vehicle in the world is the leading source of emission of GHG and the main area of consumption of petroleum products that leads to the depletion in the amount of fossil fuels throughout the world. Electric vehicles are taken as the means that can solve the problem of GHG emissions and depletion of fossil fuel resources. The EV runs using the energy from the battery cells that are used as the driving source to drive the motor which in turn drives the vehicle. As electricity in Nepal is reported to be mostly from clean hydropower, it can be said that most of the electric source is hydropower in Nepal. So, the use of the electric vehicle in the case of Nepal reduces the dependency on petroleum and reduces the GHG emission in Nepal to a great extent.

As observed in the case of Nepal out of 174TWh (626PJ) annual energy consumption electricity comprises 4.2% of the total energy of the country and petroleum products about 14.3% (WECS, 2022). Among all the energy Nepal is highly dependent on the import of petroleum products and the energy balance of Nepal is highly impacted by the import of petroleum. So, to maintain energy security in a country like Nepal it is much more practical to go with the electrification of the sources that consume high amounts of petroleum products. Petroleum products mainly diesel and petrol comprise about 96% of the total energy consumption of the transportation sector.

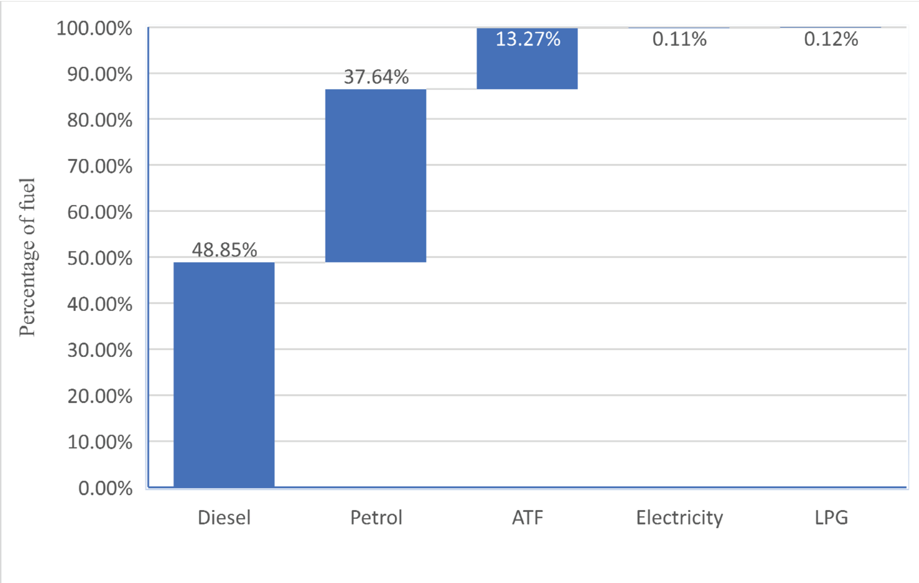

Figure 1.1 Transport sector mix of Nepal 2021

(Source; (WECS, 2022))

According to the data from the Department of Customs, Nepal, the import of about Rs. 155.43 billion of diesel and petrol was carried out for the 2018/2019 fiscal year which was about 30 billion rupees more than the previous fiscal year. (Lama, 2019). At present condition, the petroleum product price hike is predicted to increase the imported petroleum cost to about double the 2018/2019 fiscal year which is also now growing to a large sum with the recent price hike seen in the year 2022/2023. The carbon emission in Nepal has increased drastically by about 32 times in one and half decades from 2000-to 2015 making Kathmandu one of the most polluted cities in the world (Joshi, 2003). The subsequent increase in the vehicle's number in the valley is regarded as the main reason for the increase in pollution, especially in private vehicles (Zhang & Batterman, 2013). Thus, the search for a clean alternative vehicle in the case of Nepal is a necessity at the present date. In Nepal, more than 99% of the road vehicles that are in operation are petroleum-powered which induces pollution by increasing carbon emissions. (MOFE, 2021).

Nepal government had also set emission control goals via NDC to the UNFCCC secretariat. It is seen in the first NDC that Nepal had made the commitment to increase the EV shares by 20% by the year 2020 and the nation is planning to decrease the fossil fuel dependency in the transportation sector by 50% by 2050 as per the second NDC submitted. As Nepal was unable to attain the target of 2020 it is focusing on increasing the EV sale share by 25% in the case of private vehicles along with two-wheelers and 20% for four-wheeler public vehicles by 2025 (GON, 2020). GON has set ambiguous goals on EV adoption and emission control. There has not been any evaluation on the status of completion of the target as a feedback loop hence the EV penetration in the transportation sector is seen to be very small with a large deviation of status from the goals.

1.2 Statement of Problem/ Research Questions

Nepal is considered to be one of the most vulnerable countries to the impacts of climate change due to the nation's fragile topography. So, Nepal is seen to be more committed to getting along with the Paris Agreement even though the nation has negligible emissions compared to other emitter nations. Nepal is investing a large portion of its GDP in the import of fossil fuels and in the future when these resources get depleted, for Nepal to gain energy security it is required to search for an alternative that replaces the petroleum in Nepal which is indigenous hydropower produced. This alternative not only improves energy security but also helps in maintaining the energy balance in Nepal. Even as per the GON second NDC and Long-term strategy for net-zero emissions, Nepal is planning to develop a 200-Kilometer electric rail network along with 20-25% penetration in different public and private EVs in the transportation sectors in the case of Nepal by 2030. (GON, 2021)

Despite the government plans, there are different obstacles in the way of full EV adoption to the general public due to lack of awareness, lack of properly planned charging stations, non-reliable supply of electricity, and acceptance of new technology by the general public. EV technology is not in its matured stage it is in the continuous development phase for a country like Nepal it is observed that the EV demand in Nepal is mostly dependent on imports from India and China and other electric vehicle manufacturers. Electric mobility is highly dependent on the plans and national-level policies and EV production.

As Nepal is trying to switch to electric vehicle mobility, the most developed province of Nepal, Bagmati province is considered the pioneer in each of the plan implementations, but the benefits of fuel switching in transportation in Bagmati province are yet to be seen. How is GHG emission impacted by switching following the present scenario and for the future as stated in the second NDC published by Nepal? What will be the energy savings if these policies are implemented? What will be the peak power requirement that creates the need for power generation increment in the future due to a change in fuel mix? These are the questions that motivated in carrying out the search for the appropriate research topic in the field of transport sector electrification in a developing country like Nepal.

For the adoption of Electric Vehicle in Nepal there are seen a large number of barriers. It observed that the main areas that need to be considered are the lack of charging stations and the high initial capital cost of purchase of the vehicle are the main obstacles in the case of EV along with its limited distance on one charge (Adhikari et al., 2020). After studying different past literature on EV, it is observed that the research had been centered on the Kathmandu valley, where the emission analysis was performed for road passenger transport (Prajapati et al., 2023), and research on the analysis of the Kathmandu valley emission and fuel consumption (Bajracharya & Bhattarai, 2016). The research taking the Paris Agreement into consideration was not found which included the detailed analysis on the province level. Topics taking the Bagmati province and its data on different transportation factors were found to be researched less. Being the most developed province, here the GDP/ Capita is the highest among all the provinces and is the province where the general public can easily invest in the environmental-related policy even though the method is comparatively more costly like NZE goals. The aspect of how the following NDC and other government policies affect energy consumption and emissions has piqued the research interest. Hence, the research gap of the comprehensive case study of the impact of electrification of the transport sector in the case of Bagmati province considering the Net zero target along with the power generation requirement of fuel switching is taken as the topic of the research.

1.3 Research Objective

The main objective of this study is to analyze energy saving and environmental implications of the net zero targets in land transport of Bagmati province. The specific objectives are;

- To determine the current transportation demand of Bagmati province and its future growth under both passenger and freight modes of road transportation
- To analyze the vehicle stock of Bagmati province and study the different scenarios of electrification in transportation sectors and see how these will affect the emission of Bagmati Province
- To develop the LEAP model and analyze the emission on the provincial level due to the transportation sector and analyze the baseline scenario and net zero target scenario (WEM and WAM and make comparisons among them)
- To determine the additional power generation required under different scenarios if the WEM and WAM scenarios are implemented

1.4 Limitations of study

The research is carried out on the basis of secondary data in the case of vehicles from the DOTM and fuel consumption data from the study (WECS, 2022). Road transport is only taken into study and analyzed in the case of the Bagmati province of Nepal. The vehicle scrap data is not available, so the Weibull equation was used for the analysis of the current running vehicle on the basis of the survivability data from the Indian sub-context. The scenarios formulated for the study are the same NZE targets that are set nationwide like Long term strategy of Nepal (GON, 2021), SDG (NPC, 2016), and NDC (GON, 2020) rather than the province-level policies. Also, the Occupancy factor is taken from the research paper like (Singh, 2006),(Narsullah et al., 2013), (JICA, 2017), and (Dhakal, 2003) rather than performing the actual calculation by taking a certain sample size and determining the actual occupancy factor.

CHAPTER TWO: LITERATURE REVIEW

The target of having 25% of the private vehicular sales in two-wheelers and 20% of the four-wheelers is set by GON (MOFE, 2021). Along with the reduction in tax, the vehicular modification exemption for a 33-year period to modify the old petroleum-based vehicle to environment-friendly EV is also being promoted. The phasing out of the old petroleum-based vehicles can be obtained using the conversion method for the already available petrol and diesel cars into EV is being seen as the option to develop an environment-friendly vehicle. The EV was observed to be more efficient than the IC engine vehicle.

The well-to-wheel efficiency of the EV is high on the EV generated from the energy source and lowest on the gas power plant-based energy with the WTW efficiency ranging from 11-72%(Albatayneh et al., 2020). The electricity grid of Nepal is best for EV operation. The research focused on Italy showed that the energy transition even though there are co-provision to induce the transition the change in socio organizational change was observed to be patchy because if there is no greater monetary benefit the change is not generally welcomed by the masses (Carrosio & Scotti, 2019). As observed in the research EV has helped in the reduction of CO_2 emission and petroleum product dependence of any nation. Under different scenarios of the production of electricity, the societal impact of EV use was observed and the emission was largely reduced in smaller nations, and the countries using low-emission fuel are bound to gain millions of euros per year in the avoidance of external costs in case of countries in the EU (Buekers et al., 2014). The increase in income level in the nation is positive with energy transition whereas the increase in population increases demand and negatively affects the energy transition in lower middle-income group nations (Taghizadeh-Hesary & Rasoulinezhad, 2020). As seen in the study of India the comparative analysis of a nation highly dependent on thermal power the direct and indirect emissions in the case of ICEV and EV there seems to be a decrease in CO_2 and CO emissions in the case of EV but there is the increase in indirect increase in the SO_2 and NO_X production (Nimesh et al., 2020). The impact of the energy use assessment helps in the designing of a nation's better policies even on the macro level hence the econometric model with different variables (Pokharel, 2007). The study of both indirect as well as direct benefits of emission reduction from the year 2005 to 2100 in countries with clean electricity like

Nepal showed that the effect on supply mix, pollutant emission, cost of energy systems, and the energy security of the nation was analyzed using a model in the MARKAL framework. It shows an increment in employment opportunities and improvements in energy security in the case of Nepal if the low-carbon development is taken into consideration research (Shrestha & Shakya, 2012). The 3E mainly environmental, energy equity and energy security benefits of net-zero emission strategy case study of Nepal showed that the in condition of WAM the nation's air pollution was seen to be reduced by 70% and 85% for organic and black carbon and the improvement in our nation's energy security parameters as well as the energy equity(Shakya et al., 2023). The long-term impact on the electric grid due to electric vehicle showed that by the year 2040 EVs is bound to gain 11-28% of the global share of road transport which in turn increase electricity consumption by 11-20% (Kapustin & Grushevenko, 2020). The demand side management has to be induced to address the peak EV charging demand. The more sensitive and environment-friendly technology is being considered as one of the pathways to tackle the problem of fossil fuel dependency and increasing carbon emissions. The EV's different steps in the lifecycle of the EV and their impact on the environment showed the ambitious policy of switching all light-duty vehicles to EVs by the Indian government. It was observed that the overall emission is reduced even in the case of India where renewable energy in the form of electricity is low in the energy mix. The human behavior changes and switching and their relationship with the incentives provided by them are also observed in the study which shows EV penetration in India is a necessity. As per the article on the industries developed to fulfill of need for electric vehicles also the cause of environmental pollution so in the case of India to reduce emissions not only switching to EVs but also the energy mix has to improve with increment in renewable energy sources (Vidhi & Shrivastava, 2018).

EV has a high initial cost and low per km cost hence the model with total cost of ownership and EV and that of ICEV were compared in the case of India. For vehicles with usage above 110km per day only electric 3-wheelers EV TCO per km is found lower than the ICEV and in the case of the e-bus TCO per km of the e-bus is higher if the bus does not cover more than 264 km per day than that of ICE counterpart (Kumar & Chakrabarty, 2020). The study of India shows different scenarios showing TCO per km high in the case of lower-consuming vehicles in the research taken into consideration for the comparison of TCO calculated with that of the US, UK, and Japan

(Palmer et al., 2018). In the case of Nepal, it is observed that the two-wheelers in the case of Nepal are more economical than that of four-wheelers considering the present government policies of Nepal. The current policy has caused the TCO/ Km to rise by 20-30% in the case of Nepal which was cheaper before the 2021 finance act. With annual kilometer travel of 7760 Km for SUVs seen in Nepal. So switching to a better efficient and cost-effective option is a beast for Nepal. (Pathak & Subedi, 2021)

In the study in Thailand where the share of transport is 38% of the total energy consumption, it was observed that the reduction in fuel consumption can be obtained by using Natural gas, hybrid, and improved fuel efficiency vehicles which will reduce the fuel consumption as well as the emission of the nation on future when compared to business as usual scenario (Pongthanaisawan et al., 2007). Also, The demand analysis of the transportation sector can be estimated by two variables GDP and population, number of vehicles, and gas stations in the case of Thailand (Tansawat et al., 2012). In the case of Nepal, a different analysis is carried out in passenger transport using the GDP and population as independent variables with elasticities and for freight using only GDP as the independent variable (Shrestha & Rajbhandari, 2010).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Study Area

State 3 later named as Bagmati province of Nepal is situated at the latitude of 26^0 55' to 28^0 23' N and 83^0 55' to 86^0 34' Longitude. As the capital city of Nepal lies in this province, it is the most developed and pioneer province in energy consumption as well as GDP generation (MOF, 2022). Here the GDP/ Capita is the highest among all the provinces and is the province where the general public can easily invest in the environmental-related policy even though the method is comparatively more costly. Hence the province is taken as the area of study as shown in Figure3.1 below;

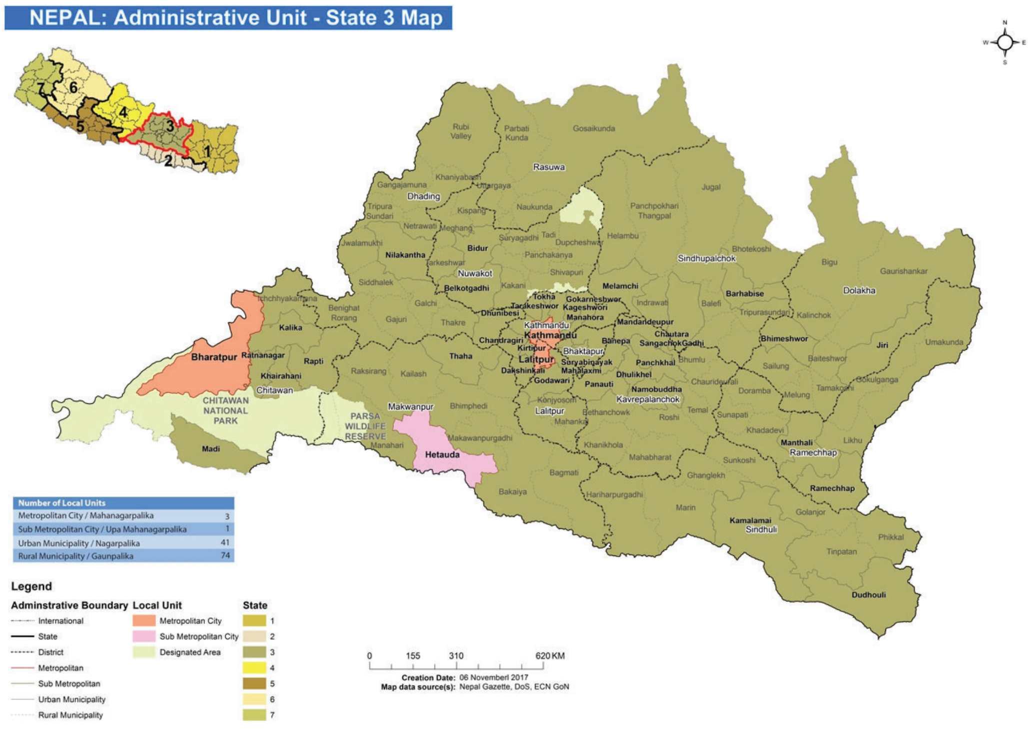

Figure 3.1 Bagmati Province map

Source: UNO Nepal (Nepal: Administrative Unit - Bagmati Province Map, n.d.)

On the basis of the energy consumption pattern of Bagmati province, It can observed that the transportation sector has 15.23% of the total energy consumption which accounts for 12,726 TJ of energy while road transport consumes 87% of the total energy in the transportation sector. The motorcycle has the highest energy consumption of 23.9% and the truck with 17.17%. Analyzing the pattern, it is observed that diesel consumption is highest and electricity is very low in the consumption pattern in Bagmati province.

3.2 Data collection

The secondary source data for the research is obtained from the Department of Transport with the number of vehicles registered. WECS report provided per year petroleum product consumption data and its share in the total transport energy mix on the data as the input for the research. The emission scenario of Nepal at present is carried out from different national and international journals (Shakya et al., 2023) and (IEA, 2022). The data on the population and GDP is taken from CBS and NHPC whereas the energy mix and the data on annual vehicle km as well as the mileage in the transportation sector is taken from the report published by WECS(WECS, 2022). The vehicle and their efficiency on the basis of fuel type are taken from (Sanguesa et al., 2021), and occupancy factor from (Singh, 2006),(Narsullah et al., 2013), (JICA, 2017), and from (Dhakal, 2003). Whereas for the freight transport loading factor, some of the different used models of pickup, tractor, and trucks and their capacity are taken and the average is taken.

3.3 Research Framework

A systematic research framework is required to carry out the research such that the objectives of the research are easily met. The modeling software used for the analysis of the policies and their scenario to make the comparison of emission LEAP is used by developing a bottom-up model for the road transportation system. The research framework listed below shows the key concept of carrying out the research project. The transportation sector is disaggregated into passenger and freight.

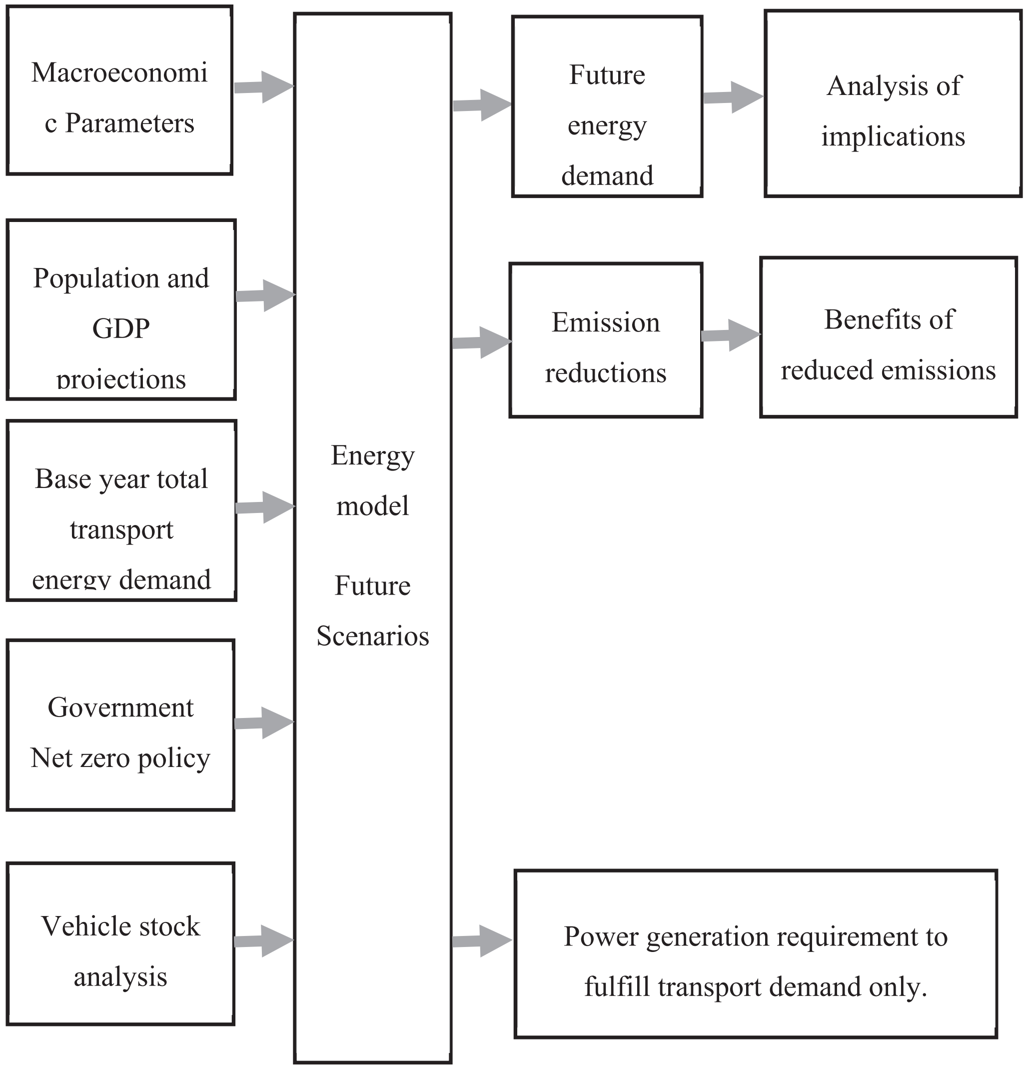

Figure 3.2 Research Methodology

The data of the energy consumption for the bae year, its macro-economic factors like GDP and population, and their elasticity are fed onto the system to develop the baseline scenario where the demand of the passenger and freight vehicles are calculated. Considering the fuel mix and transportation share of each vehicle type to be constant the calculation for the baseline demand for the year 2022-2050 is carried out. Net zero targets set up by the Government of Nepal mainly Second NDC and SDG goals separately along with goals introduced by and (GON, 2021) and other policies combined and developed (Shakya et al., 2023) introduced in the model in the form of WEM and WAM.

3.3.1 Classification of Vehicle

In the model, the road transportation sector is divided into freight and passenger vehicles. The different branches of each type are then sub-divided based on fuel used as shown in Figure 3.3 below;

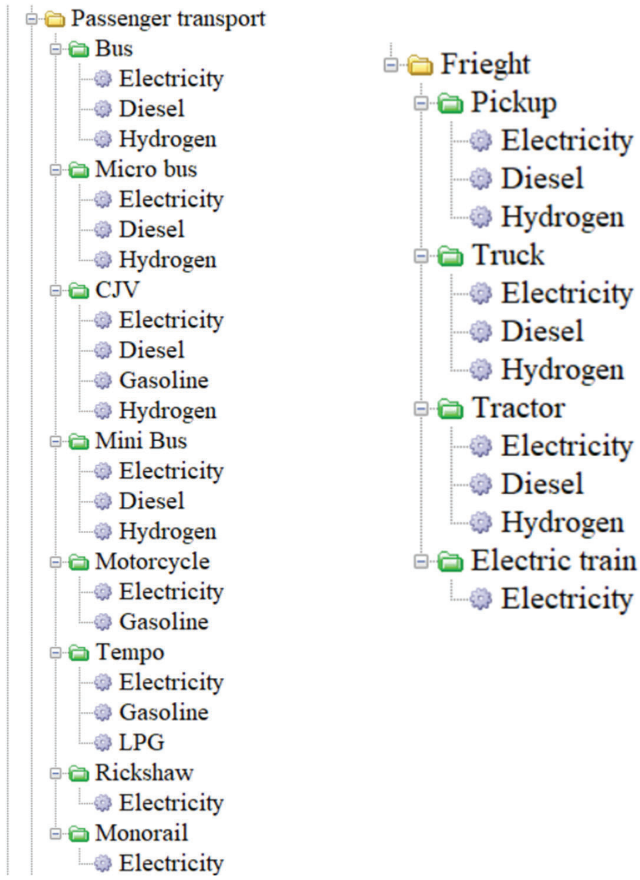

Figure 3.3 Division of transportation sector in LEAP

3.3.2 Calculation of passenger vehicle and freight vehicle demand

For different categories of vehicles, each of their analysis is carried out in different units. Tonne km for freight and passenger km for passenger vehicles. The driving factors considered in the demand estimation are energy intensity, transportation intensity as well and the GDP/ Capita of the Bagmati province.

The VKT (Annual vehicle KM), as well as the LF (Load factor) of the vehicles, is considered to be constant over the period of time.

For the calculation of the total demand of the passenger vehicle in passenger-km, the relation used in equation 1;

$$TPD_{(t)} = \sum_{k=0}^{n} (VKT * OF * VN) \quad 1$$

Here,

VKT = Annual vehicle KM

OF = Occupancy factor of passenger transport.

VN = vehicle stock on that year.

For the calculation of the total demand for the freight transport in tonne-km, the relation used in equation 2 below;

$$TFD_{(t)} = \sum_{k=0}^{n} (VKT * LF * VN) \quad 2$$

Here,

VKT = Annual vehicle KM

LF = Load factor of Freight transport in tonnes.

VN = vehicle stock on that year.

3.3.3 Emission and Energy Demand Estimation

The estimation of the annual energy demand of the passenger vehicle can be determined by the relation shown in equation 3,

$$TPED_{(t)} = \sum_{k=0}^{n} (VKT * VN * Mf) \quad 3$$

Similarly for freight vehicles equation 4 gives the relation,

$$TFED_{(t)} = \sum_{k=0}^{n} (VKT * VN * Mf) \quad 4$$

For total transport energy demand equation 5 is used;

$$TED_{(t)} = TPED_{(t)} + TFED_{(t)} \quad 5$$

Here;

Mf = Mileage of fuel

$TED_{(t)}$ = Annual total transport energy demand

Similarly, the emission of each of the transportation sectors is given by equation 6;

$$E_{(t)} = \sum_{k=0}^{n} (VKT * VN * Mf * EF) \quad 6$$

EF = Fuel emission factor

The emission factors are taken on the basis of national and international journal articles on the basis of the IPPC standards for the Indian sub-context. Energy demand and emission are calculated using leap software where emission factor and efficiency are input into the Leap system.

3.3.4 End-use energy calculation

While carrying out the analysis it is considered that the yearly demand for transportation on both passenger as well as freight is dependent on population growth as well as GDP growth as shown in equations 7 and 8 below.

$$TPED_{t} = TPED_{0} \times (POP_{,t}/POP_{0})^{\alpha 1i} \times (GDP_{r,t}/GDP_{r,0})^{\alpha 2i} \quad 7$$

$$TFED_{t} = TFED_{0} \times (GDP_{r,t}/GDP_{r,0})^{\alpha i} \quad 8$$

Here;

$TPED_{t}$ = Total Passenger energy demand type at year t;

$TPED_{0}$ = Total Passenger energy demand type at base year.

$TFED_{t}$ = Total Freight energy demand type at year t;

$TFED_{0}$ = Total Freight energy demand type at base year.

$POP_{,t}$ = Population of a given region in year t

POP_0 = Population of base year

α1i = Elasticity of population on Passenger transport demand

α2i = Elasticity of GDP on Passenger transport demand

αi = Elasticity of GDP on Freight transport demand

Table 3.1 Elasticity factors

Parameters	Value
α1i	1.44
α2i	0.41
αi	0.6

Source: (Shrestha & Rajbhandari, 2010)

3.3.5 Vehicle stock analysis

The Weibull equation is used to determine the stock of the vehicle stock remaining for that year. It is then multiplied with that year's registered vehicle data to determine the surviving stock of that year and the new year registration is added on each year to determine the Vehicle number that is operating on that year. The Weibull function is given as per (NHTSA, 2006) on equation 9 below;

$$\varnothing_i(K) = e^{-[\left(\frac{K+bi}{Ti}\right)^{\wedge}bi]} \quad 9$$

Here,

$\varnothing_i(K)$ = Vehicle survivability probability,

K = Age of vehicle in the year

bi = Failure steepness of that vehicle and Ti = service life of the vehicle

3.3.5 Development of Scenario in LEAP

The base year of 2022 is taken and the projection in LEAP is used to forecast the emission up to the year 2050. On the basis of the data on GDP and population growth, and the elasticity factor via which the baseline scenario is created. For the baseline scenario vehicle share is considered to be constant. The other scenarios for the analysis are the NDC (GON, 2020), and SDG scenario(NPC, 2016) separately along with WEM and WAM scenarios that are developed from the Long-term strategy (GON, 2021) and other policies combined and analyzed by (Shakya et al., 2023).

1. Baseline scenario considerations:

- The population growth rate is taken as 0.97% *(Source: Population Census* (CBS, 2021)*)* and the GDP growth rate of 6.74% *(Source: Economic survey report* (MOF, 2022)*).*
- The vehicle share and their fuel mix are considered to be the same throughout the period of analysis.
- The passenger transport demand is calculated taking GDP and population into consideration taking elasticity and freight transport demand is interpolated taking GDP and its elasticity into consideration.
- Year-on-year improvement of fuel intensity is taken to be the same for all with the rate of 1.2% per annum.

2. SDG scenario considerations:

- In this scenario, the electric vehicle in the public transportation sector is considered to be 35% by 2025 and 50% by 2030.
- Other transport demands not mentioned in SDG goals are taken the same as the baseline scenario. Whereas remaining fuel mix on the transportation ratio is taken to be 65% of the baseline mix and 50% of the baseline mix in 2025 and 2030 respectively for the public transport.

3. NDC scenario Considerations:

- In this scenario, vehicle sales are considered to be 25% and 20% in case of the Private and public vehicles in the year 2025 also it will increase by 90% and 60% in the case of private and public vehicles by 2030.

4. NZE with existing measures considerations (WEM):

It is based on the combination of policies from (GON, 2021) and (GON, 2020) (MOFE, 2021) in terms of low carbon technology penetration targets which are based on analysis from (Shakya et al., 2023).

- Since the Bagmati province is in the urban areas where most of the population are on the urban area. So, Intracity transport is more prominent in Bagmati province hence the target of intracity transport is taken into model.
- The electrification of passenger transport will be 33% on microbuses, 20% on cars/jeeps/vans, 5% on motorcycles, and 25% on public minibuses and buses by the year 2050. Also, 2% of the passenger demand will be reduced by monorail by 2050.
- The freight demand is 30% reduced by the electric train by 2050.

5. NZE with additional Scenario considerations (WAM):

To reduce the emissions further and meet the Net-zero emissions target additional scenario is created on the basis of all the technology present in the time period in the case of the transportation sectors. These are;

- The electrification is now bumped up in the case of buses to 48% and in the case of motorcycles to 10% whereas the ratio for the car/jeep/van is the same as 20% in WEM by 2050. 10% of the fuel mix of petroleum products will be replaced by electric fuel cells cars and buses by 2050.
- Similar to WEM the passenger demand of 2% is reduced by the introduction of monorail by 2050.
- In case of the freight transport, 40% of the freight demand will be reduced due to the introduction of electric trains by 2050. The remaining 30% will be fulfilled by electric and fuel-cell vehicles by the year 2050.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1 Vehicle survival analysis

The Weibull equation is used for all the passenger and freight vehicles to determine the actual vehicle running on the road as the DOTM does not have any data regarding the vehicles currently running on the roads but has the data of the registered number of vehicles. On the basis of the Weibull equation, the survivability factor of each type of vehicle with the year is calculated which is shown in Figure 4.1 below;

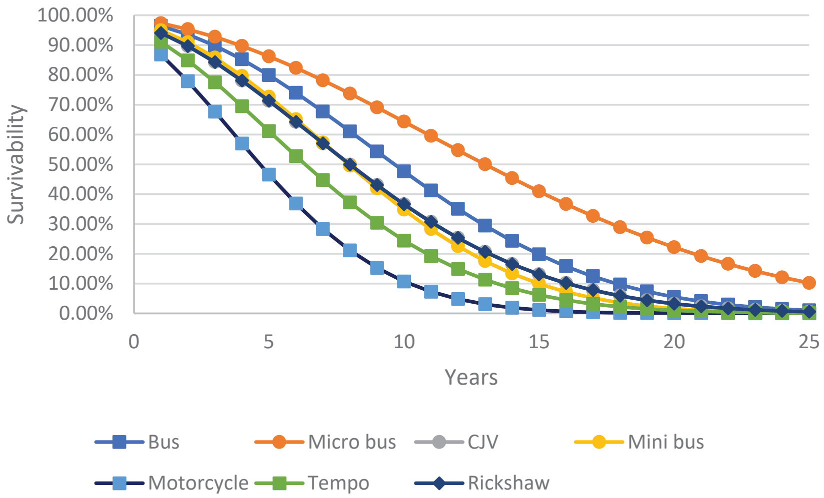

Figure 4.1 Passenger transport survivability factor

From the above analysis, it is observed that the scrappage of the motorcycle is highest and that of the microbus is lowest in the case of passenger vehicles. On the basis of the scrappage factor, the number of vehicles in operation at the base year is calculated.

Similarly, in case of the freight transport, the survivability factor is presented in figure 4.2 below;

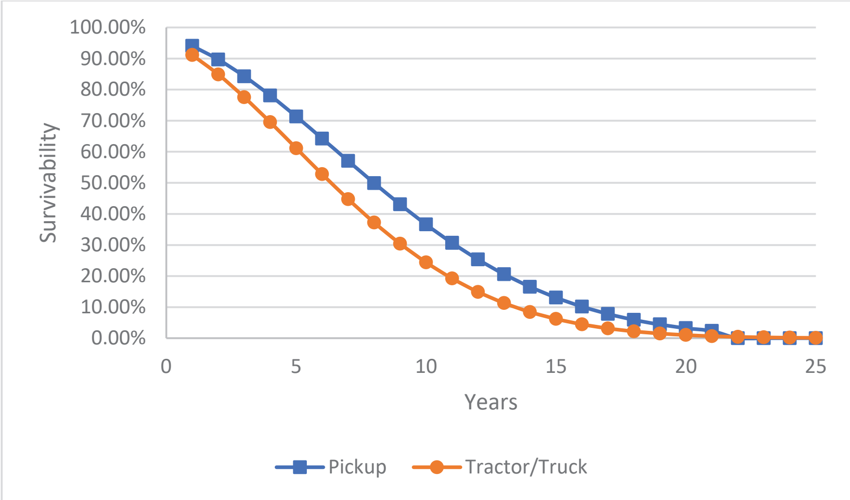

Figure 4.2 Freight transport survivability factor

On the basis of the survivability factor, it is observed that the tractor/truck scrappage factor is higher compared to that of pickup trucks.

From the above relation of the survivability factor, it is observed that each year's total number of vehicles registered and the vehicle in operation from the year 1990-2022 is shown in Figure 4.3 below;

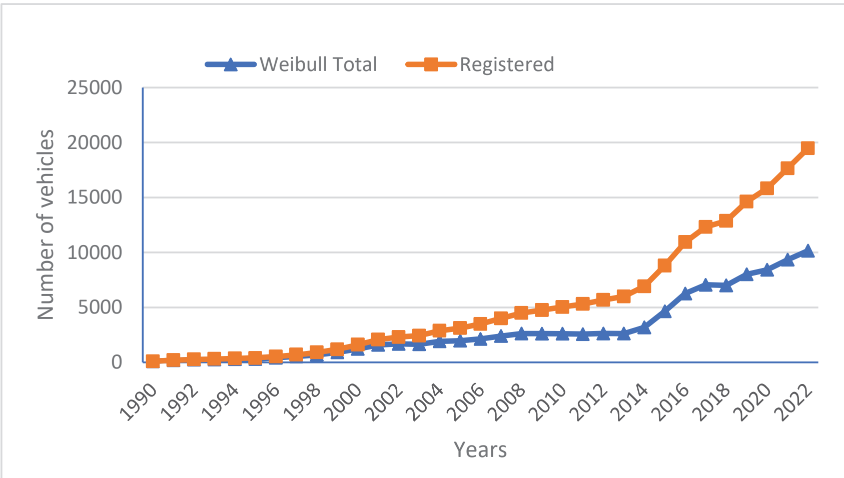

Figure 4.3 Vehicle survival analysis of Minibus

Figure 4.3 above shows how the minibus registered is getting scrapped along with the time using the Weibull equation with the relation of average life t and b of the minibus based on data from (NHTSA, 2006). The operating vehicle is found to be 52.18%

registered in the year 2022. The increase in the rate of vehicle registration is the main factor that caused the difference in the curve of Weibull total and registered vehicles to have small differences from the year 2012-2016.

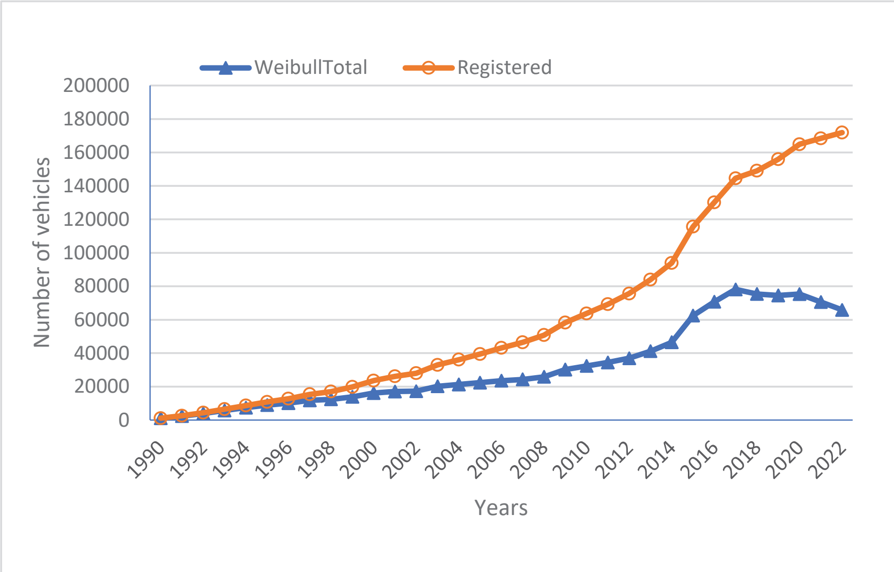

Figure 4.4 Vehicle survival analysis Car, Jeep, and Van

Figure 4.4 above shows how the Car jeep and van actually registered are getting scrapped along with the time using the Weibull equation. It is seen that 38.32% of cars, jeeps, and vans are only operating. As the scrappage value of the vehicle gets reduced with the year the growth rate of vehicles registered as vehicles is low after 2016 causing more diversification of the two curves.

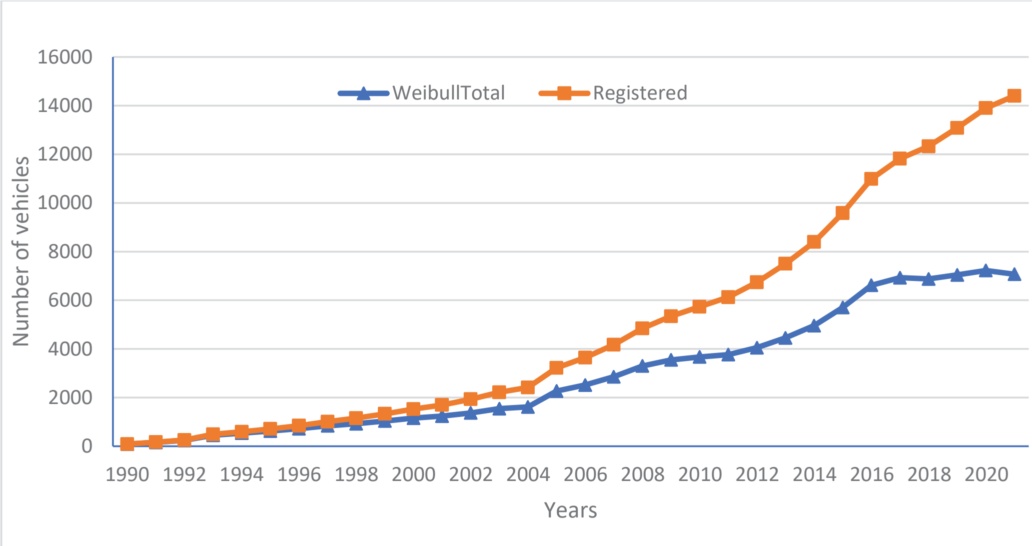

Figure 4.5 Vehicle survival analysis Bus

Figure 4.5 above shows how the bus actually registered is getting scrapped along with the time using the Weibull equation. It is seen that 46.31% of the buses are only operating. Similarly, on buses, it is observed that the difference between registered and operating vehicles is increasing after 2016 as the increase in vehicle registration is not substantially higher compared to its scrappage factor.

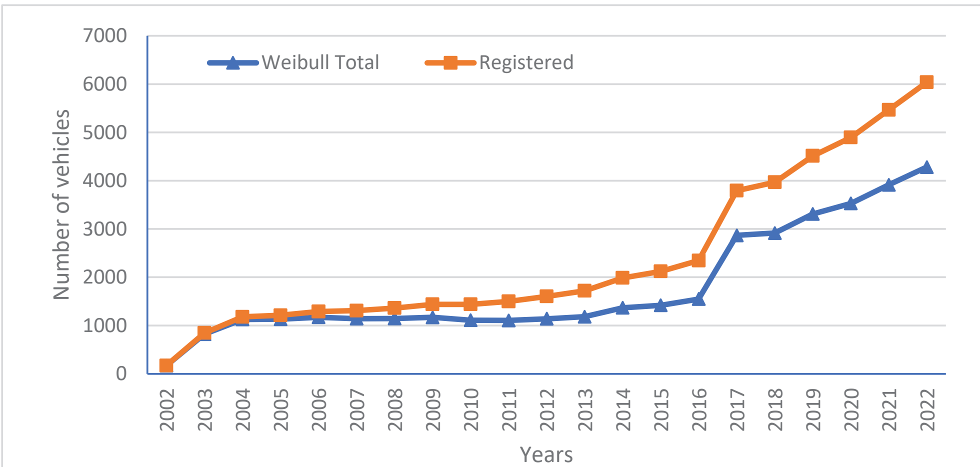

Figure 4.6 Vehicle survival analysis microbus

Figure 4.6 above shows how the microbus registered is getting scrapped along with the time using the Weibull equation. It is seen that the operating factor of the microbus is

70.90%. In the case of microbus, the scrappage factor is low compared to others and there was seen large increase in registration by the year 2016-2017 causing the difference in running and registered vehicles to be low compared to other passenger transport. Also, the microbus was introduced late so its scrappage is low compared to early introduced modes of passenger transport.

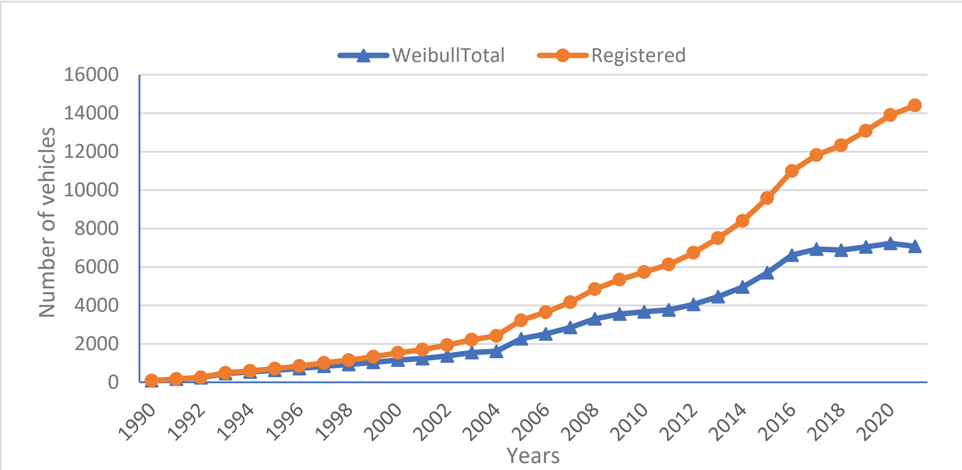

Figure 4.7 Vehicle survival analysis Motorcycle

Figure 4.7 above shows how the motorcycle actually registered is getting scrapped along with the time using the Weibull equation. It is seen that the operating factor of the motorcycle is 30.95%. The vehicle registration of motorcycles started in 1990 and the reduction in vehicle registration growth rate after 2016 is seen to be causing the reduction in the operating number of motorcycles. As the scrappage value of motorcycles is highest compared to others its operating factor is lowest in the case of passenger transports.

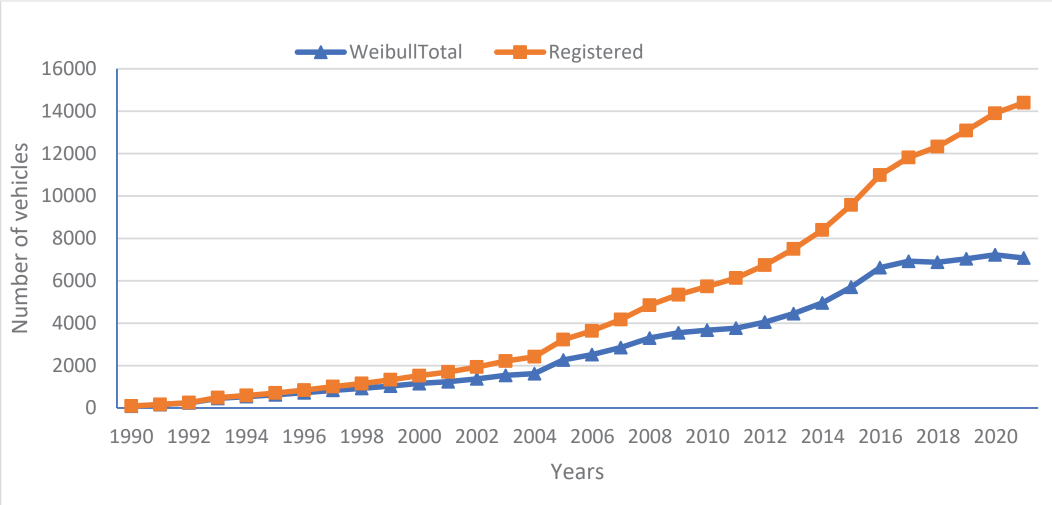

Figure 4.8 Vehicle survival analysis tempo

Figure 4.8 above shows how the tempo is getting scrapped along with the time using the Weibull equation. It is seen that the operating factor of the tempo is 68.20%. Even though tempo was introduced early the number of registrations was lower in the early period thus the operating factor of the tempo is high compared to other modes.

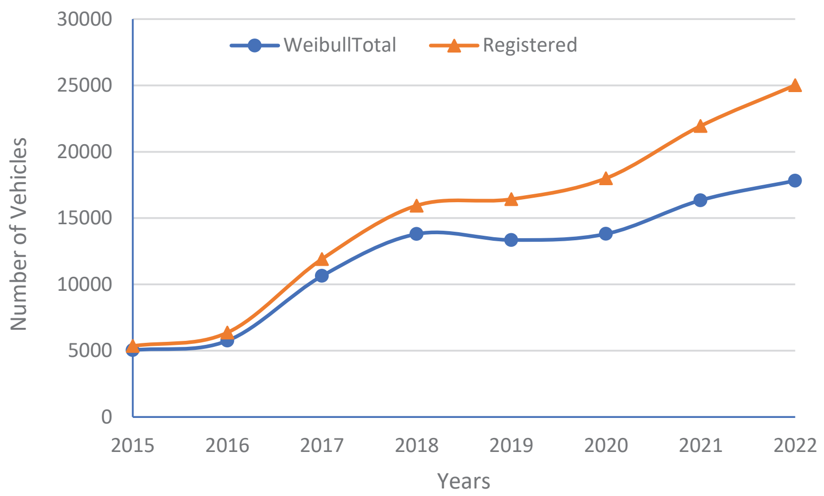

Figure 4.9 Vehicle survival analysis e-rickshaw

Figure 4.9 above shows how the e-rickshaw actually registered is getting scrapped along with the time using the Weibull equation. It is seen that the operating factor of the e-rickshaw is 71.23%. The e-rickshaw was introduced late in 2015 in Nepal thus they have a higher operating factor compared to other modes as the scrappage value is lower in the initial years compared to its year-on-year registration growth.

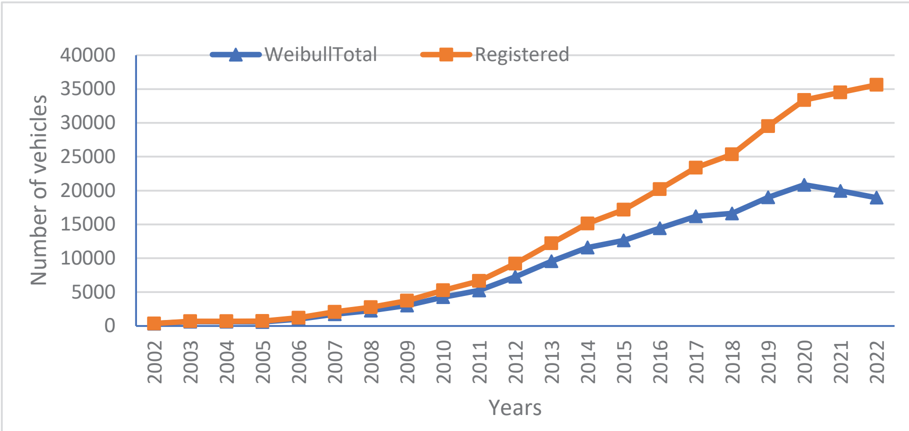

Figure 4.10 Vehicle survival analysis pickup

Figure 4.10 above shows how the pickup is getting scrapped along with the time using the Weibull equation. It is seen that the operating factor of the pickup is 53.24%. Even though the pickup was introduced late in Nepal the annual growth rate of the vehicle registration compared to the previous year reduced on year 2017 onwards causing the operation factor to fall highly reaching to measly 53.34% value though its scrappage value is lower than that of truck and tractor.

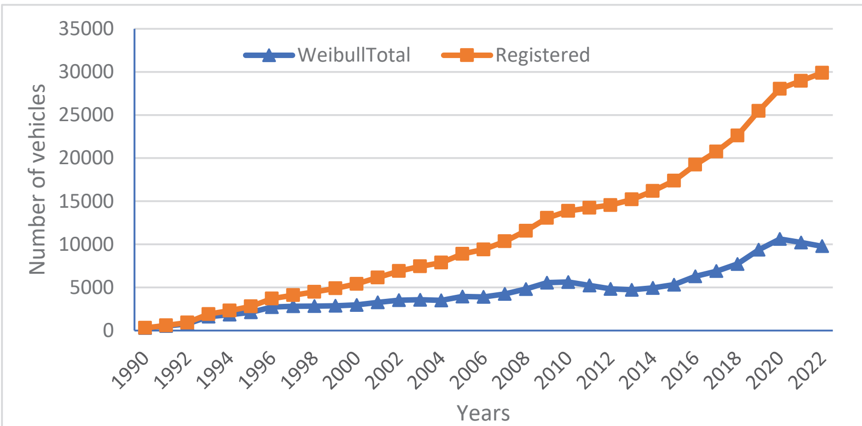

Figure 4.11 Vehicle survival analysis truck

Figure 4.11 above shows how the truck actually registered is getting scrapped along with the time using the Weibull equation. It is seen that the operating factor of the truck is 32.73%. The scrappage value of the truck is higher compared to that pickup and the early introduction of trucks in Nepal caused the operational factor to fall substantially.

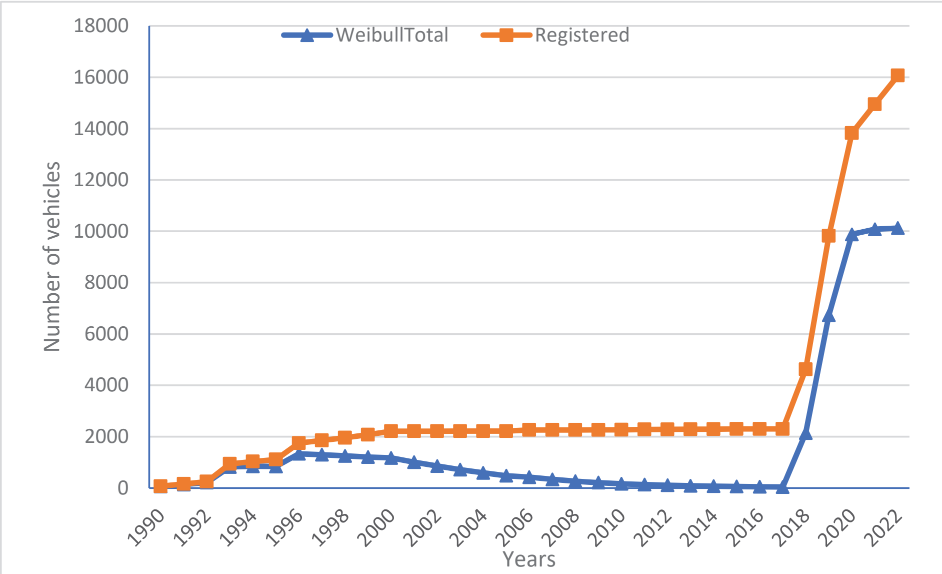

Figure 4.12 Vehicle survival analysis tractor

Figure 4.12 above shows how the tractor registered is scrapped along with the time using the Weibull equation. It is seen that the operating factor of the tractor is 62.99%. The operating vehicle ratio is higher in the case of the tractor is higher than in the pickup even though it has a higher scrappage value as there was a sudden peak in registration after the year 2016 causing the effect of scrappage to be minimal as the ratio of the year-on-year registration growth is high.

4.2 Total Road transport passenger travel demand and freight transport demand

On the basis of the population growth rate and GDP growth rate the population of the Bagmati province is calculated for the future and the passenger travel demand and freight transport demand that is forecasted for the Bagmati province is listed in Table 4.1 below;

Table 4.1 passenger and freight transport demand

Year	2022	2025	2030	2035	2040	2045	2050
Freight demand in billion tonne-km	4.26	4.79	5.83	7.09	8.62	10.5	12.8
Passenger demand in billion passenger-km	21.2	23.96	29.36	35.97	44.07	54.01	66.18

The future freight demand has been calculated by taking an elasticity of 0.6 on the basis of GDP. The year-on-year growth on the freight demand tonne km demand is observed to be 3.99% whereas that of the passenger-km demand is 4.15% as the GDP, as well as population elasticity, is taken in calculating the passenger demand.

4.3 Total Road transportation energy mix under different scenarios

The different scenarios and their energy mix are compared in this section. As observed from the Leap model the baseline energy mix is observed to be higher compared to that of the SDG, NDC, WAM, and WEM energy mix. The deviation of the baseline scenario from that of the 4 scenarios is analyzed in terms of energy consumption and emission separately.

4.3.1 Baseline Scenario: S1

Energy consumption by different types of transportation

On the baseline scenario the population growth rate and GDP have impacted the year-on-year growth of the transportation demand and as the modes of transportation share is considered constant on the baseline scenario the baseline energy consumption on passenger and freight transport in terms of TJ are shown on the figure 4.13 below;

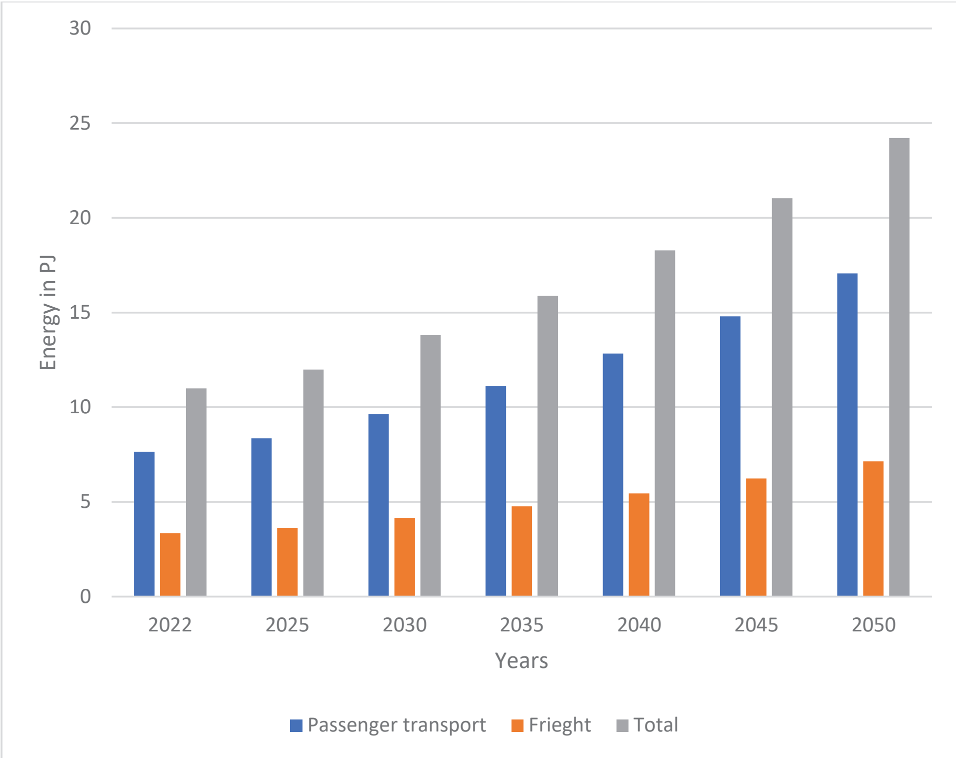

Figure 4.13 Energy consumption by the transport sector in the baseline scenario

The final energy consumption of the road-type passenger transport on the base year is 7.6 PJ and that of the freight transport is 3.3 PJ respectively. The total energy demand for transport is expected to rise by 2.86% per year on the baseline scenario causing the final transportation demand in the year 2050 to increase to 17.1 PJ for the passenger transport sector and 7.1 PJ for the freight transport sector which is equivalent to total transport sector fuel consumption of 24.2 PJ.

Types of transport and their share

The energy of the transportation sector on the basis of the vehicle types on the baseline scenario is presented in Figure 4.14 below;

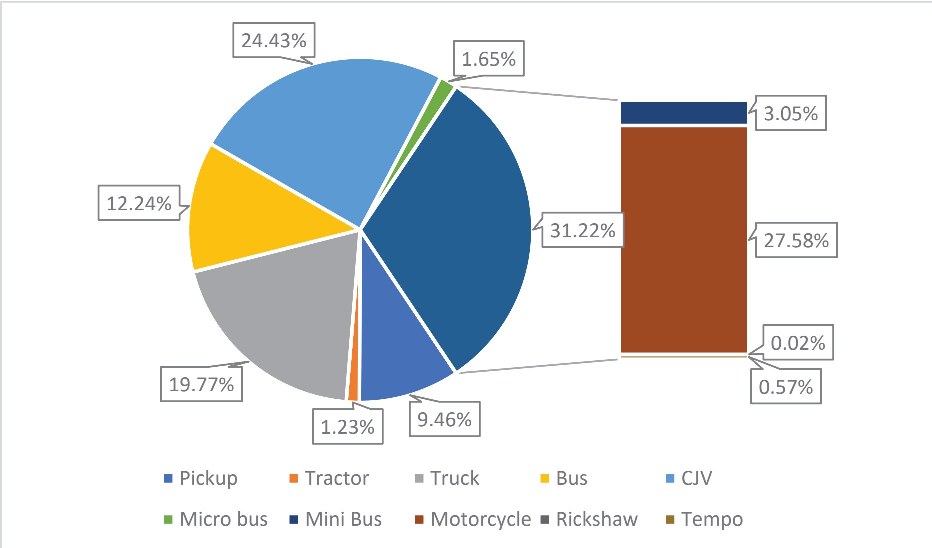

Figure 4.14 Share of each land vehicle type in the baseline scenario in the base year.

The share of fuel consumption is observed to be highest in the case of motorcycles that is 27.58% of total fuel consumption and that of cars, jeeps, and vans 24.43% is highest in the case of 4-wheeler passenger transport. This shows the private mode of transport has a share of 52.01% of the total land transport mix. The highest share of fuel consumption in the case of freight transport is by truck i.e., 19.77%. These shares of energy consumption are similar in 2050 when compared with the base year. There is a slight increase in % of passenger transport and the % of freight transport has a slight decrease due to differences in per annum increment of demand for these two types of transport as shown in Figure 4.15 below;

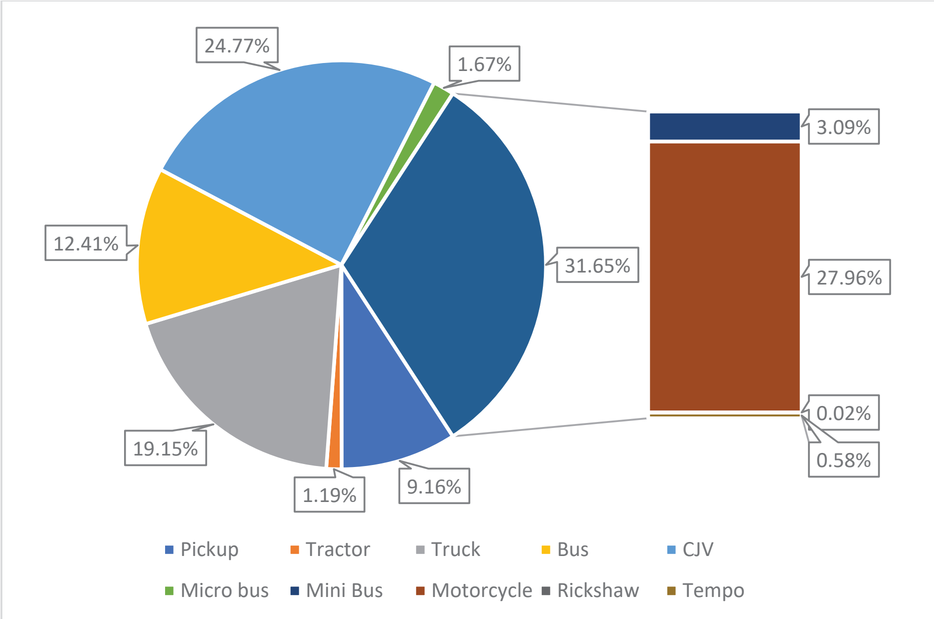

Figure 4.15 Share of each land vehicle type in the baseline scenario at the end year.

On the basis of the fuel types the transportation fuel mix of the baseline scenario is shown in Figure 4.16 below;

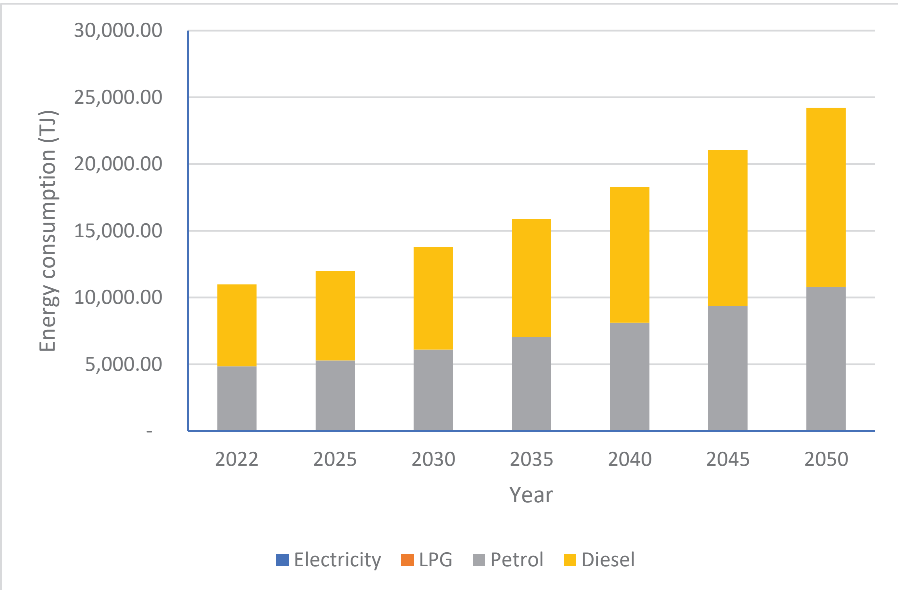

Figure 4.16 Fuel mix of the baseline scenario

The share of petroleum-based fuel is prominent as they comprise 99.93% of the total fuel mix. Where the share of electricity is a measly 0.07% of the fuel mix and LPG with only 0.14% of the fuel mix. The highest share is of diesel i.e. 55.97% in the year 2022 and it changes to 55.35% in the year 2050 as the gasoline share changes from 43.82% to 44.43% from the year 2022 to the year 2050 under the baseline scenario as shown in Table 4.2 below;

Table 4.2 Fuel demand on TJ in Baseline scenario

Year	2022	2025	2030	2035	2040	2045	2050
Electricity	8.06	8.81	10.16	11.73	13.53	15.60	18.00
LPG	15.17	16.58	19.13	22.07	25.46	29.36	33.8
Petrol	4,817.0	5,267.3	6,076.1	7,009.2	8,085.5	9,327.2	10,759
Diesel	6,151.9	6,695.7	7,692.5	8,838	10,153	11,665	13,403
Total	10,992	11,988	13,798	15,881	18,278	21,037	24,214

Emissions from the transport sector

The environmental emission in the case of the baseline scenario as well as the GHG emission of the transportation sector is calculated using the LEAP model and their variation with the mode of vehicle is presented in Table 4.3 below;

Table 4.3 Environmental emissions in baseline scenario in 000's MT of CO_2 equivalent

Year	2022	2025	2030	2035	2040	2045	2050
Pickup	76.54	83.01	95.04	108.8	124.6	142.6	163.3
Tractor	9.9335	10.77	12.33	14.12	16.17	18.51	21.19
Truck	159.9	173.4	198.6	227.3	260.3	298	341.1
Freight Total	**246.37**	**267.2**	**305.9**	**350.3**	**401**	**459.1**	**525.6**
Passenger Total	**541.09**	**591.6**	**682.4**	**787.2**	**908.1**	**1048**	**1208**
Bus	99.013	108.2	124.9	144	166.2	191.7	221.1

CJV	190.14	207.9	239.8	276.7	319.1	368.1	424.7
Micro bus	13.362	14.61	16.85	19.44	22.42	25.87	29.84
Mini Bus	24.666	26.97	31.11	35.88	41.39	47.75	55.08
Motorcycle	210.15	229.7	265	305.7	352.7	406.8	469.3
Tempo	3.7603	4.111	4.742	5.47	6.31	7.279	8.397
Total	**787.47**	**858.8**	**988.3**	**1137**	**1309**	**1507**	**1734**

In the case of passenger vehicles, the highest CO_2 equivalent emission is observed in the case of motorcycles which account for 26.7% of the total emission from the transport sector, and car/jeep/van with 24.1% emission. In the case of freight transport, the highest emission is observed from the truck which accounts for 20.3% of total emissions from the transportation sector in the year 2022. The emission share is observed to be increased in the case of passenger transport as its share of emission has increased from 68.7% in 2022 to 69.7% in the year 2050. In the year 2050, the emission ratio of motorcycles increased to 27.1% and that of trucks decreased to 19.7%.

From the emission data, the highest share of emissions is observed to be from CO_2 emission i.e. 92.6% followed by CO 5.3%, NMVOC 1%, and NO_x 0.9% emission in the case of emission from the transportation sector. Those data including the environmental effects from the transportation sector including other emissions are listed in Table 4.4 below;

Table 4.4 Emission in Physical units 000's MT

Year	2022	2025	2030	2035	2040	2045	2050
CO_2	781.9	852.7	981.3	1129	1300	1496	1721.7
CO	44.69	48.84	56.31	64.92	74.85	86.3	99.493
CH_4	0.128	0.14	0.161	0.185	0.214	0.246	0.2839
NMVOC	8.456	9.24	10.65	12.28	14.16	16.32	18.82
NO_X	7.821	8.527	9.811	11.29	12.99	14.95	17.198
N_2O	0.007	0.007	0.008	0.01	0.011	0.013	0.0145
SO_2	1.221	1.329	1.527	1.755	2.017	2.318	2.664
Total	**844.2**	**920.8**	**1060**	**1220**	**1404**	**1616**	**1860.1**

The data on the GHG emission of the 100-year-GWP from the transport sector is listed in table 4.5 below;

Table 4.5 GHG emissions in 000's metric ton CO_2 equivalent

Year	2022	2025	2030	2035	2040	2045	2050
Carbon Dioxide	781.9	852.7	981.3	1129	1300	1496	1722
Methane	3.836	4.19	4.828	5.564	6.413	7.39	8.517
Nitrous Oxide	1.744	1.903	2.19	2.52	2.901	3.339	3.843
Total	**787.5**	**858.8**	**988.3**	**1137**	**1309**	**1507**	**1734**

The share of GHG emissions consists of 0.782 million MT of CO_2 out of a total of 0.787 million MT of all GHG in CO_2 equivalent. In the year 2050, the total share of the emission is 2.2 times that of the base year.

4.3.2 SDG Scenario: S2

Energy consumption by different types of transportation

On the SDG scenario the SDG goals have impacted the year-on-year growth of the transportation demand and as the modes of transportation share compared to that on the baseline scenario the SDG scenario consumption on passenger and freight transport in terms of TJ are shown in Figure 4.17 below;

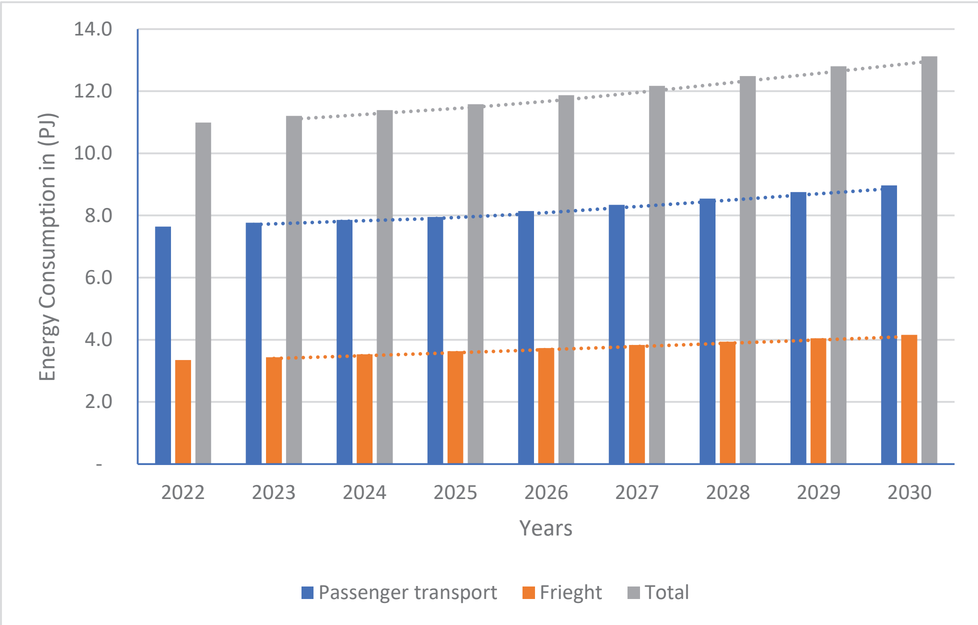

Figure 4.17 Energy consumption by the transport sector in the SDG scenario

The final energy consumption of the road-type passenger transport on the base year is 7.64 PJ and that of the freight transport is 3.35 PJ respectively. The total energy demand for freight transport is expected to rise by 2.2% per year from 2022 to 30 and The passenger transport has a gradual increase in the passenger transport demand after the year 2025 where growth averaging 2.4% per annum in that period with the initial growth rate being 1.6% in the initial year. Due to this, the year-on-year growth rate on total consumption from the transport sector under the SDG scenario has an initial increment of 1.9% which gradually increases to the value of 2.5% in the year 2030. The freight demand has a constant increment as that of the baseline scenario.

Types of transport and their share

The energy of the transportation sector on the basis of the vehicle types in the SDG scenario is presented in figure 4.18 below;

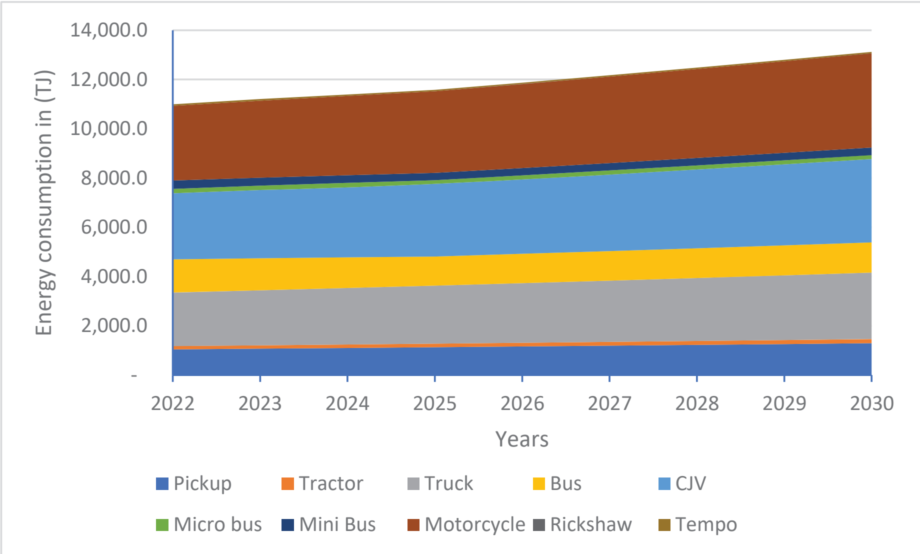

Figure 4.18 Transport share in fuel consumption SDG scenario

The share of fuel consumption is observed to be highest in the case of motorcycles that is 27.58% of total fuel consumption and that of cars/jeeps/vans 24.43% is highest in the case of 4-wheeler passenger transport and the highest share of fuel consumption is by truck i.e. 19.77% in case of freight transport. These shares of energy in the case of private means like motorcycle fuel demand increased to 25.81% by 2030 and car/jeep/van increased to 25.81%. The public mode consumption rate went down substantially, and the bus fuel consumption share fell from 12.24% to 9.33% in 2030.

On the basis of the fuel types the transportation fuel mix of the SDG scenario is shown in Figure 4.19 below;

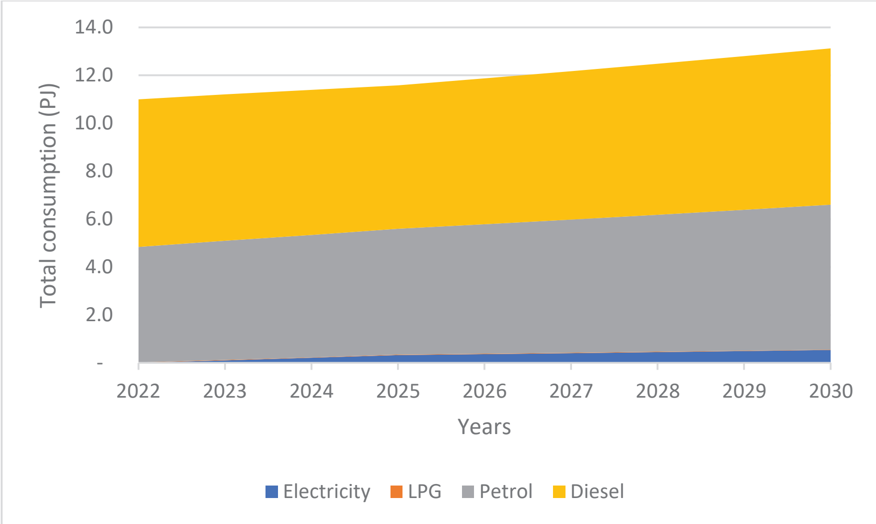

Figure 4.19 Fuel mix of the SDG scenario

The share of petroleum-based fuel is prominent as they comprise 99.93% of the total fuel mix. Where the share of electricity is a measly 0.07% of the fuel mix and LPG with only 0.14% of the fuel mix. The highest share is of diesel i.e., 55.97% in the year 2022 and it changes to 49.67% in the year 2030 whereas the petrol share changes from 43.82% to 46.10% from the year 2022 to the year 2030 under the SDG scenario. The electricity on the fuel mix will rise from 0.74% to 4.11% by 2030.

Emissions from the transport sector

The environmental emission in the case of the SDG scenario as well as the GHG emission of the transportation sector is calculated using the LEAP model and their variation with the mode of vehicle is presented in Table 4.6 below;

Table 4.6 Environmental emissions in SDG scenario in 000's MT of CO_2 equivalent

Branch	2022	2025	2030
Pickup	76.54	83.01	95.04
Tractor	9.93	10.77	12.33
Truck	159.90	173.42	198.55
Freight Total	**246.37**	**267.21**	**305.93**
Passenger Total	**541.09**	**538.11**	**593.99**
Bus	99.01	70.36	62.43

CJV	190.14	207.90	239.82
Micro bus	13.36	9.49	8.43
Mini Bus	24.67	17.53	15.55
Motorcycle	210.15	229.74	265.02
Tempo	3.76	3.09	2.74
Total	**787.47**	**805.32**	**899.92**

In the case of passenger vehicles, the highest CO_2 equivalent emission is observed in the case of motorcycles which account for 26.7% of the total emission from the transport sector, and car/jeep/van with 24.1% emission. In the case of freight transport, the highest emission is observed from the truck which accounts for 20.3% of total emissions from the transportation sector in the year 2022.

The emission share is observed to be decreased in the case of passenger transport as its share of emission has fallen from 68.71% in 2022 to 66.01% in year 2030 due to SDG goals that reduced the emission from public transportation. In the year 2030, the emission ratio of motorcycles increased to 29.45% and that of trucks increased to 22.06%. All the other environmental effects from the transportation sector including other emissions are listed in Table 4.7 below;

Table 4.7 Emission in Physical Units 000's MT

Year	2022	2025	2030
CO_2	781.89	799.46	893.29
CO	44.694	48.001	54.923
CH_4	0.1279	0.1358	0.1544
NMVOC	8.456	9.0738	10.378
NO_X	7.8209	7.9482	8.8541
N_2O	0.0066	0.0067	0.0075
SO_2	1.2206	1.1972	1.3102
Total	844.21	865.82	968.92

From the emission data the highest share of emissions is from CO_2 emission is observed to be 92.6% followed by CO 5.3%, NMVOC 1%, and NO_x 0.9% emission in the case of emission from the transportation sector. Due to the implications of SDG CO_2 emission decreased to 92.2% share followed by CO whose share increased to 5.7%, NMVOC bumped up to 1.1% in the year 2030.

The data of the GHG emission of the 100-year-GWP from the transport sector for the SDG scenario is listed in Table 4.8 below;

Table 4.8 GHG emissions in 000's metric ton CO_2 equivalent

GHG	2022	2025	2030
Carbon Dioxide	781.9	799.5	893.3
Methane	3.836	4.075	4.6
Nitrous Oxide	1.744	1.787	2.0
Total	787.5	805.3	899.9

4.3.3 NDC Scenario: S3

Energy consumption by different types of transportation

On the NDC scenario the NDC goals have impacted the year-on-year growth of the transportation demand and as the modes of transportation share compared to that on the baseline scenario the NDC scenario consumption on passenger and freight transport in terms of TJ are shown in figure 4.20 below;

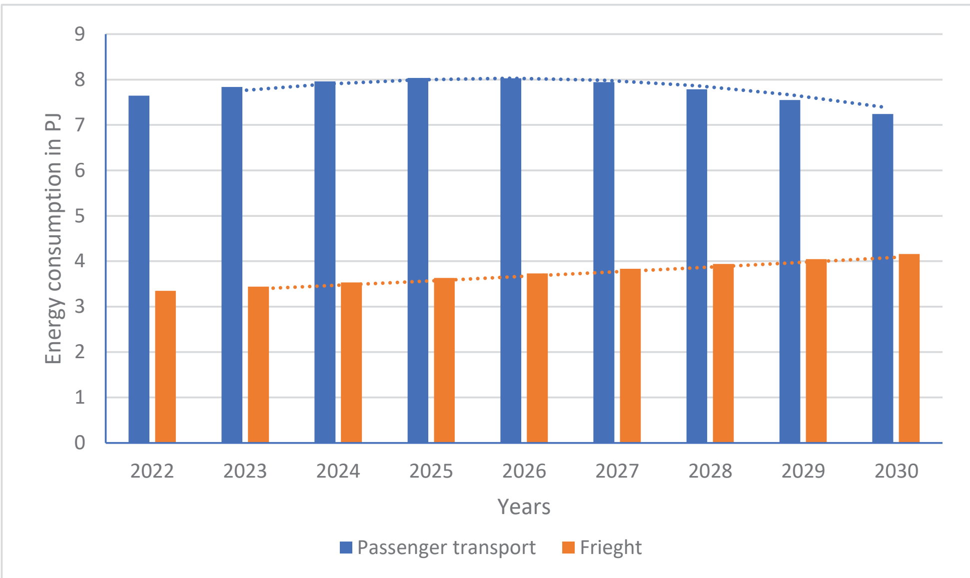

Figure 4.20 Energy consumption by the transport sector in the NDC scenario

The final energy consumption of the road-type passenger transport on the base year is 7.64 PJ and that of the freight transport is 3.35 PJ respectively. The total energy demand for freight transport is expected to rise by 2.7% per year from 2022-30 and passenger transport has a gradual decrease in the passenger transport demand after the year 2025. Due to this, the year-on-year growth rate on total consumption from the transport sector under the NDC scenario has an initial increment of 2.6% which gradually decreased to the value of -1.7% in the year 2030 in the case of passenger transport as high efficient electric vehicle share is gradually increasing. Since the goals are only on passenger transport the consumption of freight transport remains unchanged in this scenario compared to the baseline scenario.

Types of transport and their share

The energy of the transportation sector on the basis of the vehicle types in the NDC scenario is presented in Figure 4.21 below;

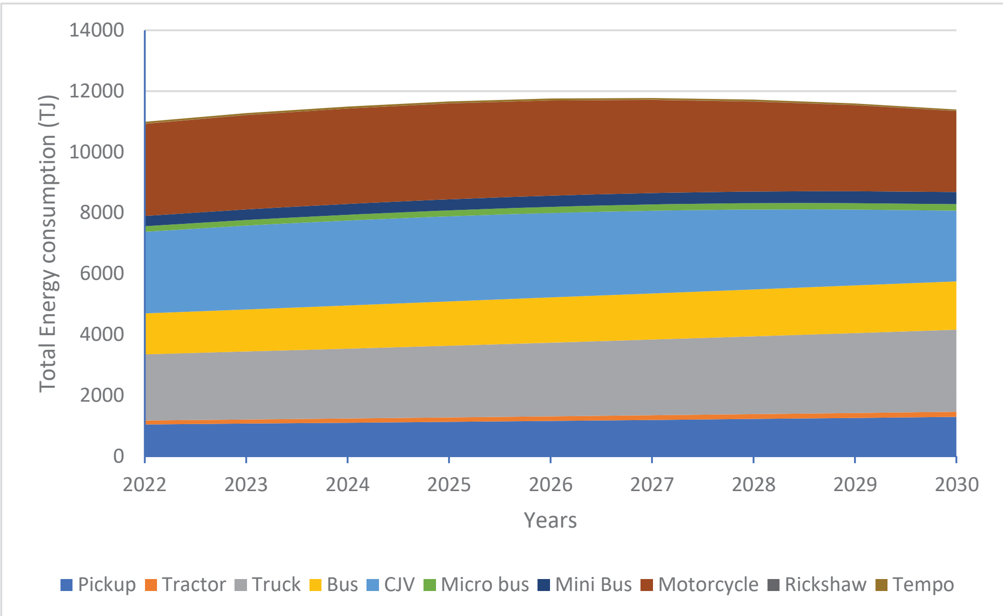

Figure 4.21 Transport share in fuel consumption NDC scenario

The share of fuel consumption is observed to be highest in the case of motorcycles that is 27.58% of total fuel consumption and that of cars/jeeps/vans 24.43% is highest in the case of 4-wheeler passenger transport and the highest share of fuel consumption is by truck i.e., 19.77% in case of freight transport. These shares of energy in the case of the motorcycle fuel demand decreased to 23.38% by 2030 and car/jeep/van decreased to 20.39%. The public mode consumption rate went down substantially, and the bus consumption share increased from 12.24% to 13.94% in 2030. The share of consumption of passenger transport in the mix fell from 69.54% on the base year to 63.53% and that of freight increased from 30.46% to 36.47% in the time frame of 2022-2030.

On the basis of the fuel types the transportation fuel mix of the NDC scenario is shown in figure 4.22 below;

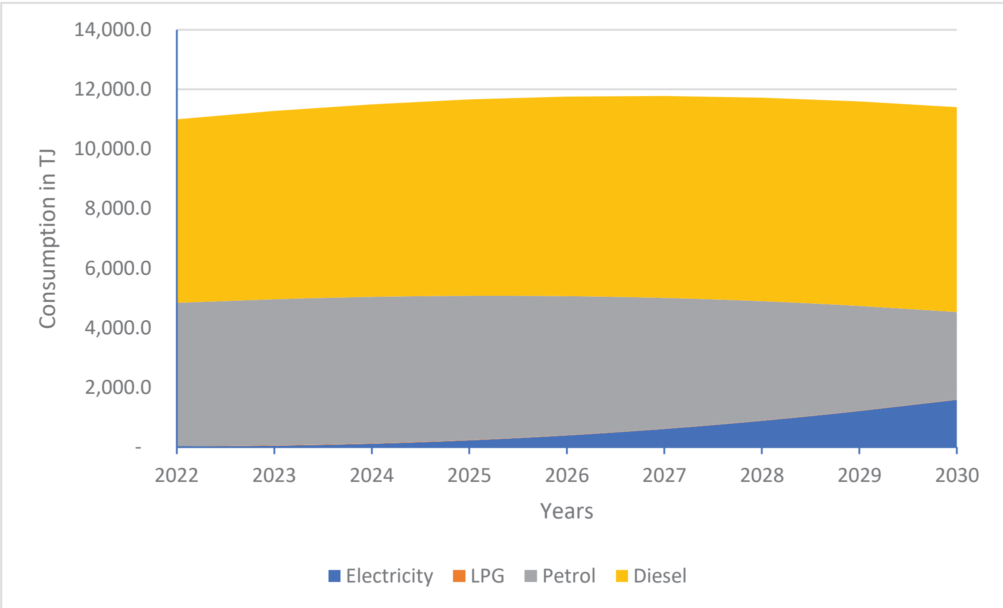

Figure 4.22 Fuel mix of the NDC scenario

The share of petroleum-based fuel is prominent as they comprise 99.93% of the total fuel mix. Where the share of electricity is a measly 0.07% of the fuel mix and LPG with only 0.14% of the fuel mix. The highest share is of diesel i.e. 55.97% in the year 2022 and it changes to 60.24% in the year 2030 as the petrol share changes from 43.82% to 25.74% from the year 2022 to the year 2030 under the NDC scenario. The electricity on the fuel mix will rise from 0.74% to 13.95% by 2030.

Emissions from the transport sector

The environmental emission in the case of the NDC scenario as well as the GHG emission of the transportation sector is calculated using the LEAP model and their variation with the mode of vehicle is presented in Table 4.9 below;

Table 4.9 Environmental emissions in NDC scenario in 000's MT of CO_2 equivalent

Year	2022	2025	2030
Pickup	76.54	83.01	95.04
Tractor	9.93	10.77	12.33
Truck	159.90	173.42	198.55
Freight Total	246.37	267.21	305.93
Passenger Total	541.09	553.67	403.39
Year	2022	2025	2030
Bus	99.01	106.21	110.61
CJV	190.14	193.48	127.30
Micro bus	13.36	14.33	14.87
Mini Bus	24.67	26.46	27.68
Motorcycle	210.15	209.47	121.00
Tempo	3.76	3.71	1.93
Total	787.47	820.88	709.32

In the case of passenger vehicles, the highest CO_2 equivalent emission is observed in the case of motorcycles which account for 26.7% of the total emission from the transport sector, and car/jeep/van with 24.15% emission. In the case of freight transport, the highest emission is observed from the truck which accounts for 20.31% of total emissions from the transportation sector in the year 2022. The emission share is observed to be decreased in the case of passenger transport as its share of emission has fallen from 68.71% in 2022 to 56.87% in year 2030 due to NDC goals that reduced the emission from public transportation. In the year 2030, the emission ratio of motorcycles decreased to 17.06% and that of trucks increased to 27.99%.

All the other environmental effects from the transportation sector including other emissions are listed in Table 4.10 below;

Table 4.10 Emission in Physical Units 000's MT

Year	2022	2025	2030
CO_2	781.89	815.15	704.96
CO	44.694	45.297	30.351
CH_4	0.1279	0.1304	0.0934
NMVOC	8.456	8.5746	5.7762
NO_X	7.8209	8.1809	7.2606
N_2O	0.0066	0.0069	0.0059
SO_2	1.2206	1.3011	1.3192
Total	**844.21**	**878.64**	**749.76**

From the emission data, the highest share of emissions is from CO_2 emission and is observed to be 92.6% followed by CO 5.3%, NMVOC 1%, and NO_x 0.9% emission in the case of emission from the transportation sector. Due to implications of NDC CO_2 emission increased to 94.02% share followed by CO which decreased to 4.05%, and NMVOC reduced to 0.77% in the year 2030. The emission is seen to be increasing from 2022-2025 and then decreasing in the remaining time frame of 2025-2030. The data of the GHG emission of the 100-year-GWP from the transport sector for the NDC scenario is listed in Table 4.11 below;

Table 4.11 GHG emissions in 000's metric ton CO_2 equivalent

Year	2022	2025	2030
Carbon Dioxide	781.9	815.2	705
Methane	3.836	3.913	2.803
Nitrous Oxide	1.744	1.817	1.559
Total	**787.5**	**820.9**	**709.3**

4.3.4 WEM Scenario: S4

Energy consumption by different types of transportation

On the WEM scenario, the policy of the Government of Nepal to gain Net zero emission is considered based on the Long-term strategy for net-zero and also considering low carbon technology penetration targets(Shakya et al., 2023)in terms of TJ are shown on the figure 4.23 below;

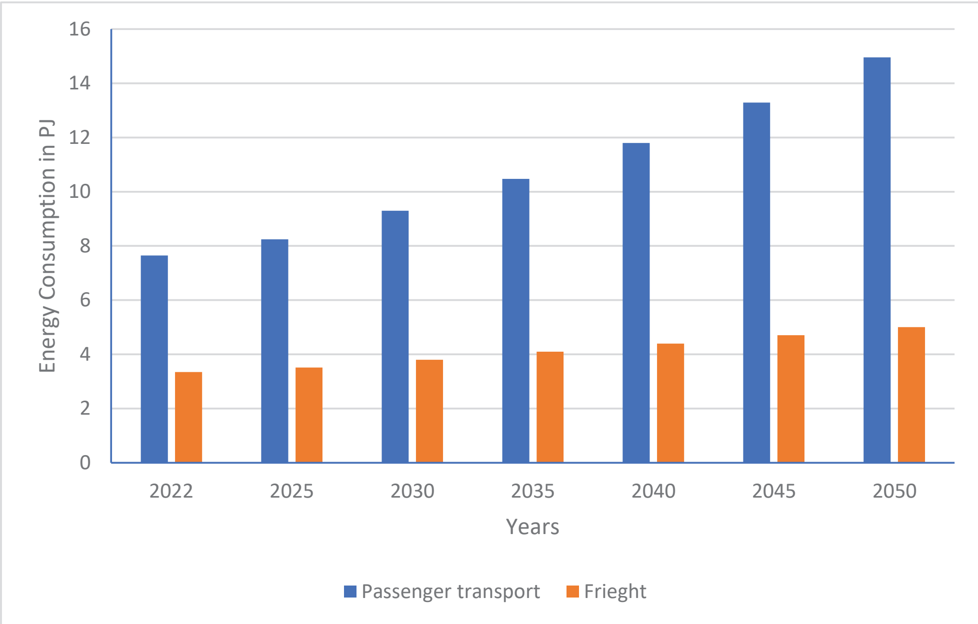

Figure 4.23 Energy consumption by the transport sector in the WEM scenario

The final energy consumption of the road-type passenger transport on the base year is 7.64 PJ and that of the freight transport is 3.35 PJ respectively. The total energy demand for transport is expected to rise by on average by 2.15% per year reaching 20PJ in the year 2050. Passenger transport and freight transport rose by an average growth rate of 2.43% and 1.45% per year respectively. Thus, the WEM scenario caused the passenger and freight transport sector to increase to 15 PJ and 5 PJ respectively in the year 2050. In the WEM scenario, the energy consumption of 2050 is 1.82 times that of 2022 energy consumption.

Types of transport and their share

The energy of the transportation sector on the basis of the vehicle types in the WEM scenario is presented in Figure 4.24 below;

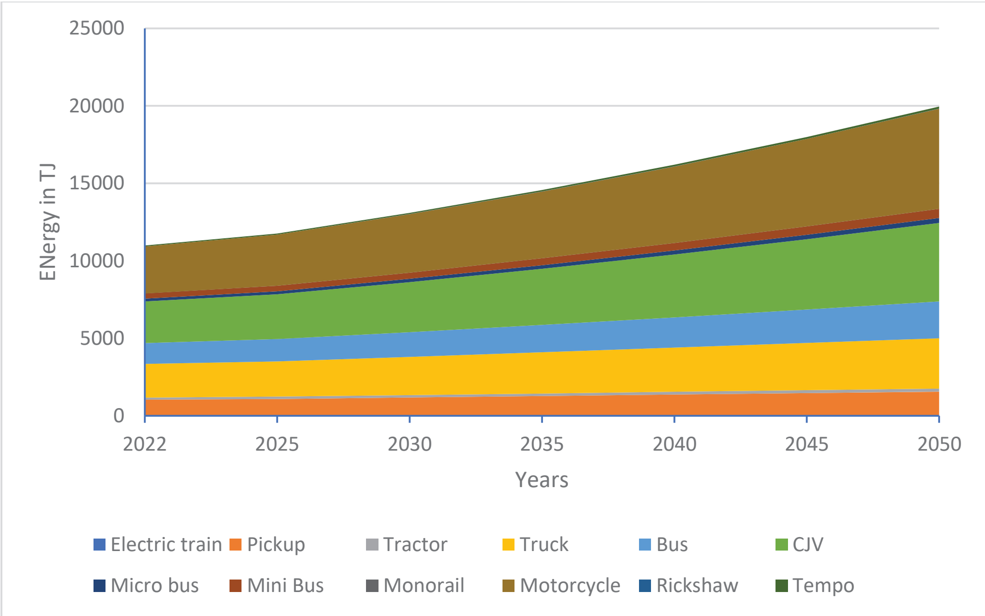

Figure 4.24 Energy consumption by vehicle type in the WEM scenario.

The share of fuel consumption is observed to be highest in the case of motorcycles that is 27.58% of total fuel consumption and that of cars, jeeps, and vans 24.43% is highest in the case of 4-wheeler passenger transport, and the highest share of the fuel consumption is by truck i.e., 19.77% in case of freight transport. These shares of energy consumption are expected to increase in the case of motorcycles to 32.35% in 2050 and that of trucks to fall to 16.26% of total consumption. The consumption of passenger transport on the mix increased from 69.54% in the base year to 74.93% in 2050 whereas the consumption of freight transport is seen to be increasing at a rate slower than that of passenger transport causing its share to fall from base year share 0f 30.46% to 25.07% in 2050.

On the basis of the fuel types the transportation fuel mix of the WEM scenario is shown in Figure 4.25 below;

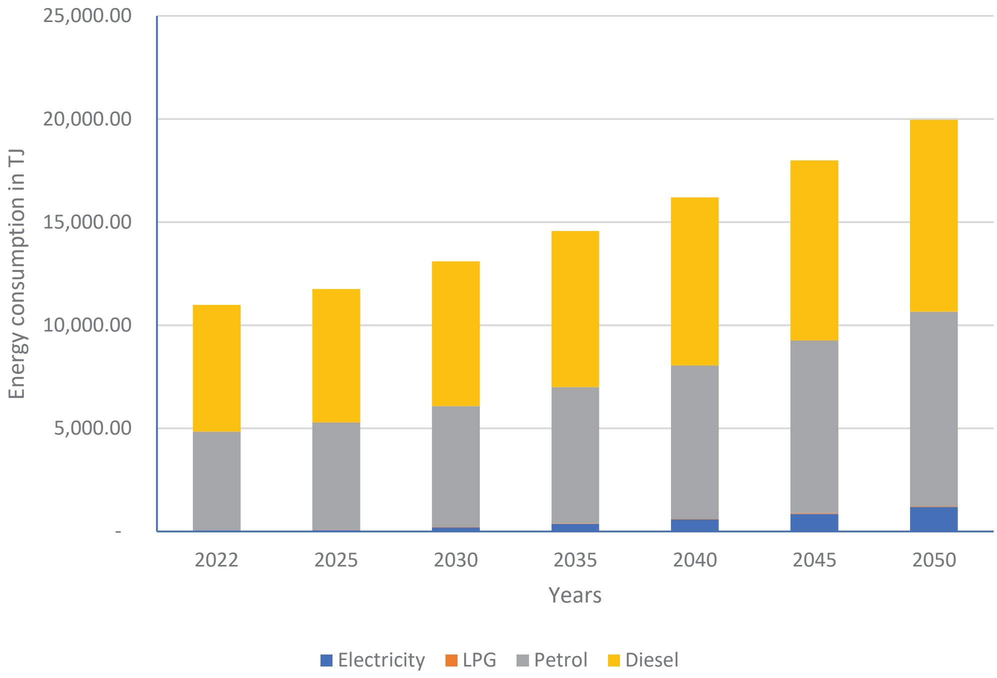

Figure 4.25 Fuel mix of the WEM scenario

The share of petroleum-based fuel is prominent as they comprise 99.93% of the total fuel mix. Where the share of electricity is a measly 0.07% of the fuel mix and LPG with only 0.14% of the fuel mix. The highest share is of diesel i.e., 55.97% in the year 2022, and it decreased to 46.61% being the second highest fuel consumed after petrol which has 47.30% fuel share in the year 2050. The share of electricity in the transportation sector will increase to 5.92% in 2050.

Table 4.12 Fuel demand on TJ in the WEM scenario

Year	2022	2025	2030	2035	2040	2045	2050
Electricity	8.06	71.02	200.82	367.78	580.08	847.53	1,181.87
LPG	15.17	16.55	19.03	21.88	25.15	28.91	33.24
Petrol	4,817.03	5,195.84	5,859.29	6,605.06	7,442.93	8,383.81	9,439.79
Diesel	6,151.92	6,475.31	7,016.72	7,577.41	8,151.34	8,730.30	9,303.38
Total	10,992.1	11,758.7	13,095.8	14,572.1	16,199.5	17,990.5	19,958.2

Emissions from the transport sector

The environmental emission in the case of the WEM scenario as well as the GHG emission of the transportation sector is calculated using the LEAP model and their variation with the mode of vehicle is presented in Table 4.13 below;

Table 4.13 Environmental emissions in WEM scenario in 000's MT of CO_2 equivalent

Year	2022	2025	2030	2035	2040	2045	2050
Pickup	76.54	80.363	86.948	93.755	100.71	107.71	114.62
Tractor	9.9335	10.424	11.269	12.139	13.024	13.912	14.783
Truck	159.9	167.85	181.54	195.67	210.08	224.56	238.83
Freight Total	**246.37**	**258.64**	**279.75**	**301.56**	**323.81**	**346.18**	**368.24**
Passenger Total	**541.09**	**578.96**	**643.82**	**715.13**	**793.38**	**879.04**	**972.61**

Year	2022	2025	2030	2035	2040	2045	2050
Bus	99.013	103.98	111.78	119.58	127.22	134.46	141.02
CJV	190.14	202.88	224.49	248.04	273.63	301.35	331.27
Micro bus	13.362	14.067	15.194	16.341	17.489	18.613	19.68
Mini Bus	24.666	25.897	27.83	29.763	31.652	33.442	35.061
Motorcycle	210.15	228.04	259.81	295.98	337.15	384.01	437.33
Tempo	3.7603	4.1026	4.7168	5.4228	6.2344	7.1674	8.24
Total	**787.47**	**837.6**	**923.57**	**1016.7**	**1117.2**	**1225.2**	**1340.8**

In the case of passenger vehicles, the highest CO_2 equivalent emission is observed in the case of motorcycles which account for 26.7% of the total emission from the transport sector, and car/jeep/van with 24.15% emission. In the case of freight transport, the highest emission is observed from the truck which accounts for 20.31% of total emissions from the transportation sector in the year 2022. The emission share is observed to be increased in the case of passenger transport as its share of emission has increased from 68.93% in 2022 to 72.50% in the year 2050. The emission ratio of motorcycles increased to 32.62% and that of trucks decreased to 17.81%.

From the emission data, the highest share of emissions is from CO_2 emission and is observed to be 92.6% followed by CO 5.3%, NMVOC 1%, and NO_x 0.9% emission in the case of emission from the transportation sector in the base year. Till 2050 the emission is found to be increasing by 1.94% per year under the WEM scenario. All the other environmental effects from the transportation sector including other emissions are listed in Table 4.14 below;

Table 4.14 Emission in Physical Units 000's MT

Year	2022	2025	2030	2035	2040	2045	2050
CO_2	781.89	831.63	916.93	1009.30	1108.98	1216.12	1330.75
CO	44.69	48.05	53.90	60.43	67.70	75.81	84.84
CH_4	0.13	0.14	0.15	0.17	0.19	0.21	0.24
NMVOC	8.46	9.09	10.19	11.42	12.79	14.32	16.02
NO_X	7.82	8.31	9.14	10.04	11.00	12.03	13.13
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SO_2	1.22	1.29	1.40	1.52	1.64	1.76	1.88
Total	**844.21**	**898.51**	**991.72**	**1092.88**	**1202.32**	**1320.27**	**1446.87**

The data on the GHG emission of the 100-year-GWP from the transport sector is listed in Table 4.15 below;

Table 4.15 GHG emissions in 000 metric ton CO_2 equivalent

Year	2022	2025	2030	2035	2040	2045	2050
Carbon Dioxide	781.9	831.6	916.9	1009.3	1109.0	1216.1	1330.8
Methane	3.8	4.1	4.6	5.1	5.7	6.4	7.1
Nitrous Oxide	1.7	1.9	2.0	2.3	2.5	2.7	3.0
Total	**787.5**	**837.6**	**923.6**	**1016.7**	**1117.2**	**1225.2**	**1340.8**

The increment in the GHG emission in terms of CO_2 equivalent is observed to be 1.92% per year where the value of the GHG emission is forecasted to be increasing from 0.78 million MT of CO_2 equivalent to 1.34 million MT of CO_2 equivalent.

4.3.5 WAM Scenario: S5

Energy consumption by different types of transportation

In the WAM scenario, the policy of the Government of Nepal to gain Net zero emission is considered based on low carbon technology penetration targets that are technologically feasible. The energy consumption in terms of TJ is shown in the figure 4.26 below;

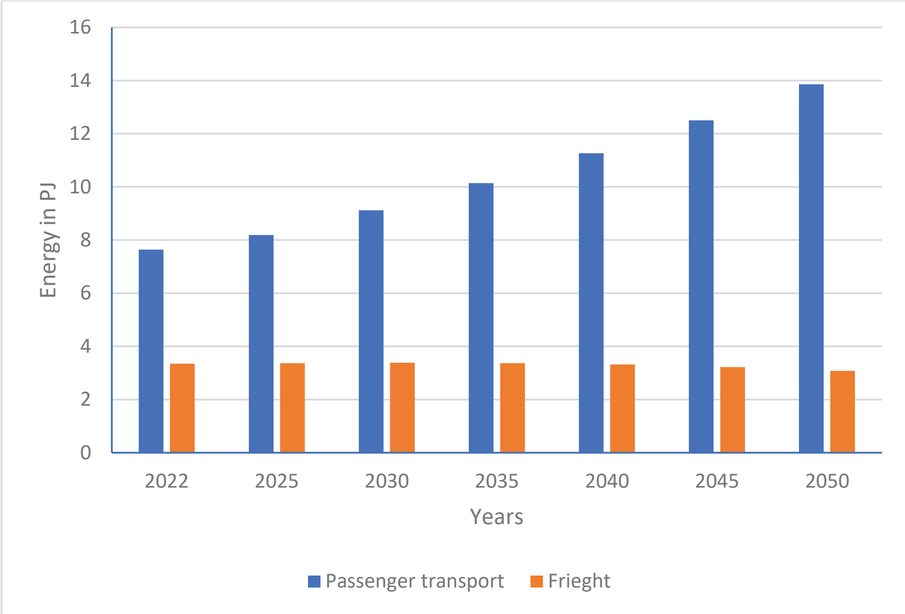

Figure 4.26 Energy consumption by the transport sector in the WAM scenario

The final energy consumption of the road-type passenger transport on the base year is 7.64 PJ and that of the freight transport is 3.35 PJ respectively. The total energy demand for transport is expected to rise on average by 1.56% per year reaching 16.9 PJ in the year 2050. Passenger transport and freight transport have an average growth rate of 2.15% and a reduction of 0.29% per year respectively. Thus, the WAM scenario caused the passenger and freight transport sector to increase to 13.9 PJ and decrease to 3.1 PJ respectively in the year 2050. In the WAM scenario, the energy consumption of 2050 is 1.54 times that of 2022 energy consumption. Up to the year 2030, there is seen an increment in the freight transport energy demand which then reduces each year from 2030-2050 and the passenger transport demand growth rate is also observed to be decreasing year on year. This is due to the introduction of a more energy-efficient fuel mix in different transport sectors.

Types of transport and their share

The energy of the transportation sector on the basis of the vehicle types on the WAM scenario is presented in Figure 4.27 below;

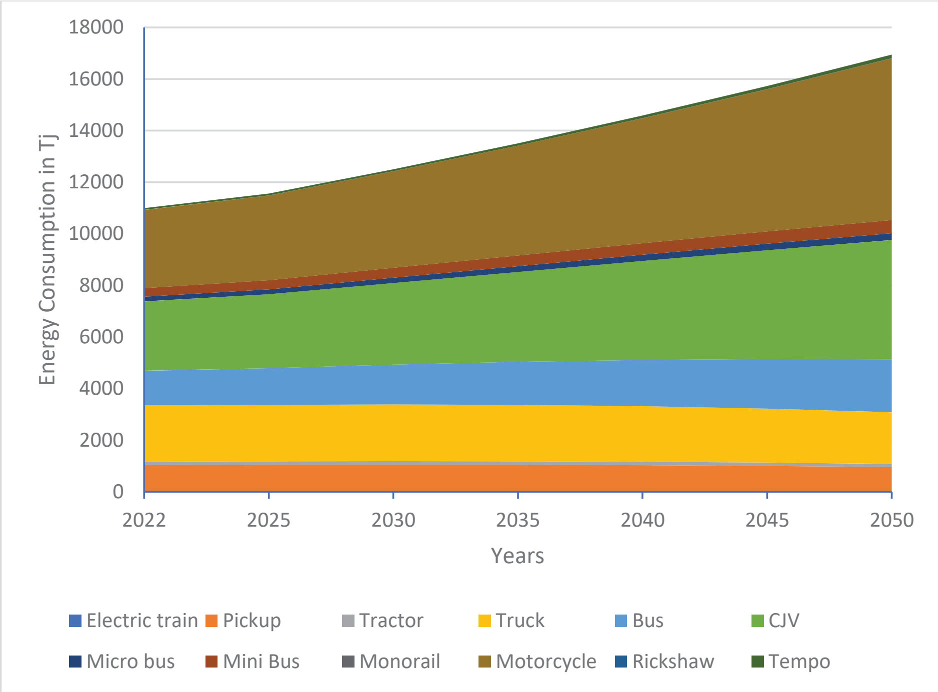

Figure 4.27 Energy consumption by vehicle types WAM scenario.

The share of fuel consumption is observed to be highest in the case of motorcycles that is 27.58% of total fuel consumption and that of cars, jeeps, and vans 24.43% is highest in the case of 4-wheeler passenger transport, and the highest share of the fuel consumption is by truck i.e., 19.77% in case of freight transport. These shares of energy consumption are expected to increase in the case of motorcycles to 37.01% in 2050 and that of trucks to fall to 11.80% of total consumption. The consumption of passenger transport on the mix increased from 69.54% in the base year to 81.80% in 2050 whereas the consumption of freight transport is seen to be increasing at a rate slower than that of passenger transport causing its share to fall from base year share of 30.46% to 18.20% in 2050.

On the basis of the fuel types the transportation fuel mix of the WAM scenario is shown in Figure 4.28 below;

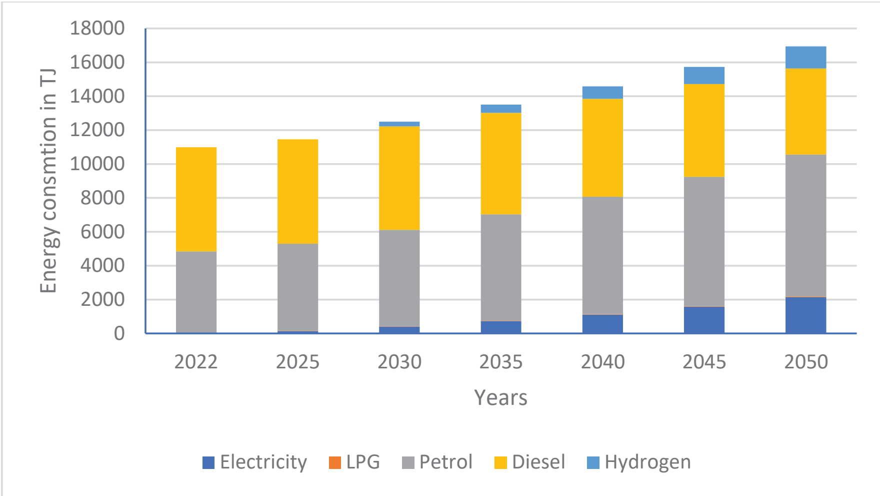

Figure 4.28 Fuel mix of the WAM scenario

The share of petroleum-based fuel is prominent as they comprise 99.93% of the total fuel mix. Where the share of electricity is a measly 0.07% of the fuel mix and LPG with only 0.14% of the fuel mix. The highest share is of diesel i.e., 55.97% in the year 2022, and it decreased to 29.92% being the second highest fuel consumed after petrol which has 49.54% fuel share in the year 2050. The share of electricity in the transportation sector will increase to 16.45% in 2050. Hydrogen will be introduced in the fuel mix and comprise a 6.40% share in the year 2050.

Table 4.16 Fuel demand on TJ in the WAM scenario

Year	2022	2025	2030	2035	2040	2045	2050
Electricity	8	141	404	725	1114	1581	2137
LPG	15	17	19	22	25	29	33
Petrol	4817	5140	5688	6285	6933	7636	8394
Diesel	6152	6162	6112	5987	5778	5475	5068
Hydrogen	0	0	280	492	734	1006	1310
Total	10992	11557	12502	13510	14584	15727	16942

Emissions from the transport sector

The environmental emission in the case of the WAM scenario as well as the GHG emission of the transportation sector is calculated using the LEAP model and their variation with the mode of vehicle is presented in Table 4.17 below;

Table 4.17 Environmental emissions in WAM scenario in 000's MT of CO_2 equivalent

Branch	2022	2025	2030	2035	2040	2045	2050
Pickup	76.54	74.36	69.79	63.98	56.93	48.67	39.3
Tractor	9.933	9.647	9.046	8.286	7.364	6.287	5.068
Truck	159.9	155.3	145.7	133.5	118.8	101.5	81.88
Freight Total	**246.4**	**239.3**	**224.5**	**205.8**	**183.1**	**156.4**	**126.3**
Passenger Total	**541.1**	**571.4**	**620.5**	**671.6**	**724.2**	**777.4**	**830.4**
Bus	99.01	101.3	103.6	104.3	102.9	98.81	91.12
CJV	190.1	200.2	216.4	232.9	249.5	265.9	281.8
Microbus	13.36	13.68	14	14.1	13.92	13.37	12.34
Minibus	24.67	25.23	25.8	25.97	25.61	24.57	22.65
Motorcycle	210.1	226.8	256	288.9	326	367.6	414.3
Tempo	3.76	4.103	4.717	5.423	6.234	7.167	8.24
Total	787.5	810.7	845.1	877.4	907.2	933.8	956.7

In the case of passenger vehicles, the highest CO_2 equivalent emission is observed in the case of motorcycles which account for 26.7% of the total emission from the transport sector, and car/jeep/van with 24.15% emission. In the case of freight transport, the highest emission is observed from the truck which accounts for 20.31% of total emissions from the transportation sector in the year 2022. The emission share is observed to be increased in the case of passenger transport as its share of emission has increased from 68.71% in 2022 to 86.80% in the year 2050. The emission ratio of motorcycles increased to 43.31% and that of trucks decreased to 8.56%. All the other environmental effects from the transportation sector including other emissions are listed in Table 4.18 below;

Table 4.18 Emission in Physical Units 000's MT

Year	2022	2025	2030	2035	2040	2045	2050
CO_2	787.3	838.54	928.66	1,024.4	1,125.2	1,230.5	1,339.3
CO	45.12	49.34	57.22	66.27	76.62	88.46	101.94
CH_4	0.13	0.14	0.16	0.18	0.21	0.24	0.28
NMVOC	8.54	9.33	10.81	12.51	14.46	16.67	19.20
NO_X	7.87	8.36	9.20	10.08	11.00	11.93	12.86
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SO_2	1.23	1.28	1.36	1.43	1.49	1.52	1.53
Total	**850.2**	**907.00**	**1,007.4**	**1,114.9**	**1,229.0**	**1,349.4**	**1,475.1**

From the emission data, the highest share of emissions is from CO_2 emission and is observed to be 92.6% followed by CO 5.3%, NMVOC 1%, and NO_x 0.9% emission in the case of emission from the transportation sector in the base year. Till 2050 the emission is found to be increasing by 0.76% per year under the WAM scenario in the initial years which is then decreased to the yearly growth rate of 0.53% when it reaches the year 2050.

The data on the GHG emission of the 100-year-GWP from the transport sector is listed in Table 4.5 below;

Table 4.19 GHG emissions in 000's metric ton CO_2 equivalent

Year	2022	2025	2030	2035	2040	2045	2050
Carbon Dioxide	781.9	804.9	838.8	870.8	900.1	926.3	948.7
Methane	3.836	4.033	4.358	4.702	5.064	5.446	5.846
Nitrous Oxide	1.744	1.797	1.877	1.952	2.022	2.085	2.141
Total	787.5	810.7	845.1	877.4	907.2	933.8	956.7

4.4 Scenario Comparison

4.4.1 Energy Comparison

The fuel consumption of the different scenarios is carried out in this section as the SDG and NDC has only adjustment written till 2030 in government policy. So, the comparison of all the scenarios from S1-S5 is carried out within the short-term range 2022-2030, and another long-term comparison is made between S1, S4, and S5.

Short-term energy comparison 2022-2030

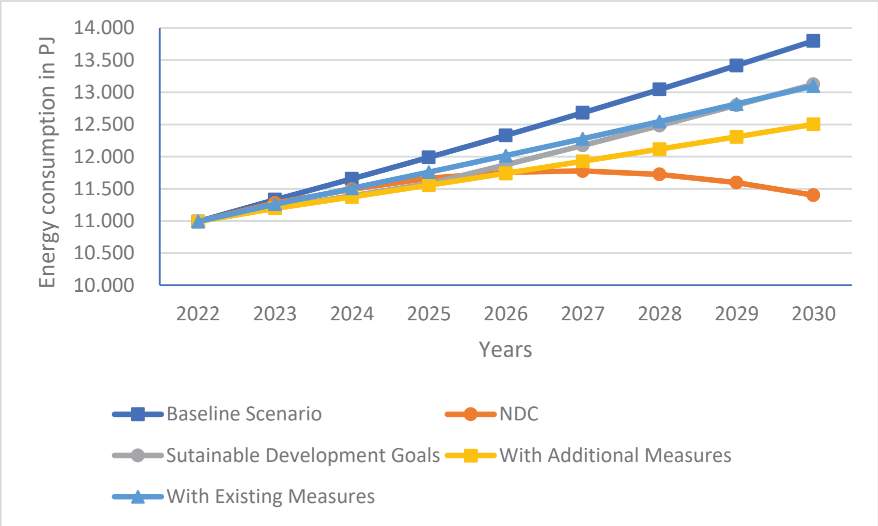

Figure 4.29 Scenarios impact on fuel consumption by the transport sector

As per Figure 4.29 above, out of all the scenarios developed for the study, the minimum fuel consumption is observed on the NDC. So, out of all the policies that are studied, NDC can help in substantial fuel consumption demand reduction in the transportation sector compared to that of other scenarios. The SDG scenario is observed to be less effective after the baseline scenario as it has less reduction in fuel consumption. The final energy demand in the year 2030 is seen to be 13.8 PJ under the baseline scenario which is very least reduced by the SDG Scenario to 13.12 PJ followed by WEM (S4) with 13.10 PJ. The lowest value of consumption can be attained by following NDC targets which is 11.4 PJ which reduced the consumption by 17.37% compared to the baseline scenario.

Long-term energy comparison 2022-2050

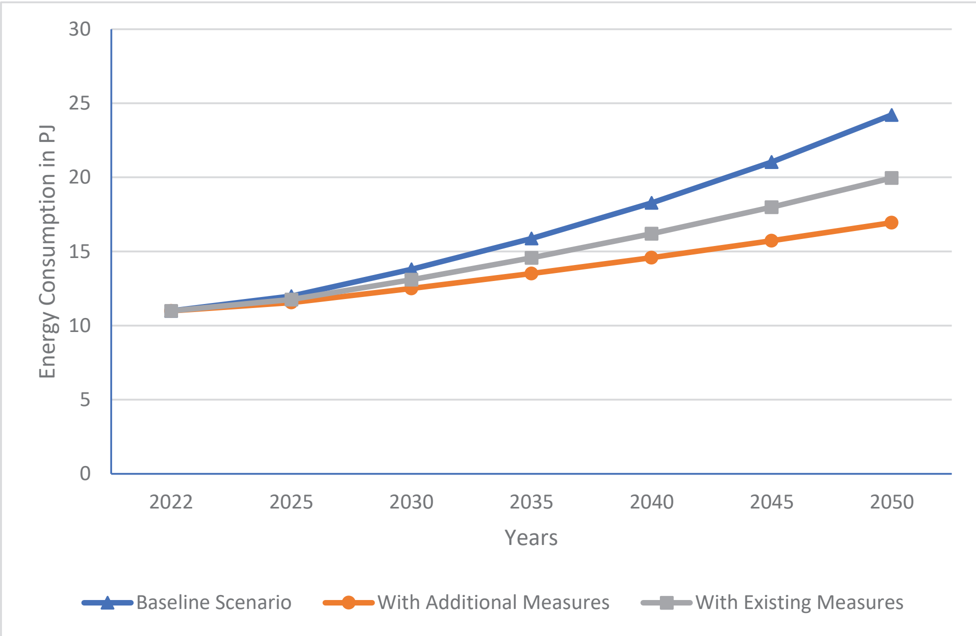

Figure 4.30 Scenarios comparison from 2022-2050 in case of fuel consumption

From above Figure 4.30, it is observed that the WAM (S5) scenario is able to fulfill the transportation demand of the Bagmati province with only 69.97% of the energy requirement on the baseline scenario where the WEM (S4) scenario takes 82.42% energy requirement of the baseline scenario in the year 2050.

4.4.2 Emission comparison

The implications of the different scenarios have their own environmental benefits, which can be analyzed on the basis of the 100-yr GWP emission of the GHG gases in different scenarios. Similar to the Fuel consumption analysis the comparison is carried out on short-term and long-term basis as stated below;

Short-term emission comparison 2022-2030

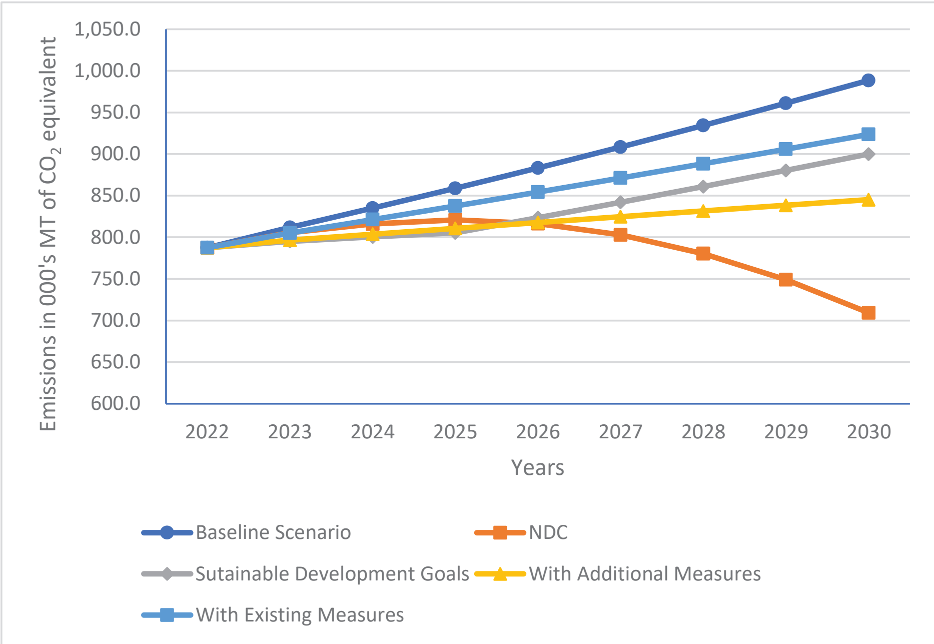

Figure 4.31 Scenarios impact on emission by the transport sector

From Figure 4.31 above, out of all the scenarios developed for the study the minimum emission is observed on the NDC. So, out of all the policies that are studied NDC can help in emission reduction and in attaining Net zero targets on the transportation sector compared to that of other scenarios. The WEM scenario is observed to be less effective as it has only a 6.55% emission reduction. The final emission in the year 2030 is seen to be 988.3 thousand Metric tonnes of CO_2 equivalent under the baseline scenario which is then reduced by SDG Scenario by 8.95% followed by WAM with a 14.5% reduction. The lowest value of emission can be attained by following NDC targets which is able to reduce the baseline emission by 28.23%.

Long-term emission comparison 2022-2050

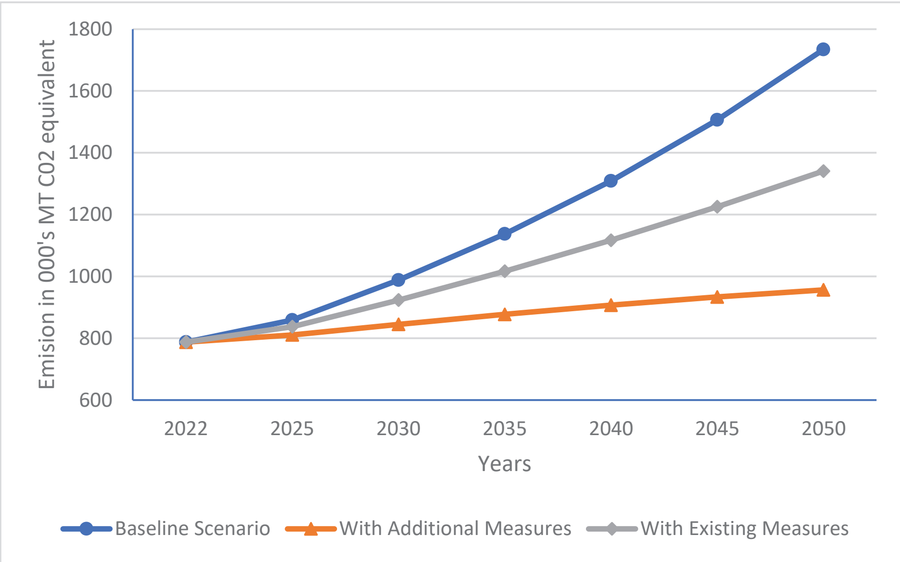

Figure 4.32 Scenarios comparison from 2022-2050 in case of emission

From the above figure 4.31, it is observed that the WAM scenario is able to reduce the increase of the emission of the Bagmati province compared to the baseline scenario with only a 21.49% increase in 2022 emissions over the period of 28 years. The WEM scenario on the other hand has a 77.33% increase in year 2022 emission of 792.94 thousand Metric tonne CO_2 equivalent over the period of 28 years.

4.5 Power plant capacity requirements

The electric capacity to fulfill the need for the electrification of the transportation sector in the case of the Bagmati province under scenarios S1-S5 is listed in Table 4.20 below;

Table 4.20 Electricity generation requirement

Scenario	2022	2025	2030	2035	2040	2045	2050
Baseline Scenario	0.31	0.34	0.39	0.45	0.52	0.6	0.69
NDC	0.31	8.63	61.1				
SDG	0.31	12.6	20.7				
WAM	0.31	5.42	15.5	27.8	42.8	60.7	82.1
WEM	0.31	2.73	7.71	14.1	22.3	32.5	45.4

The electricity generation demand on the base year is just 0.3 MW taking into consideration the share of electricity in the fuel mix. The rise in the baseline scenario in the year 2050 is 0.69 MW. Due to the electrical vehicle penetration following the net-zero strategy, the plant capacity is bound to increase to 82.1 MW in order to fulfil the demand need in the year 2050 under additional scenarios and that of the existing scenario will be 45.4 MW as shown in Figure 4.33 below,

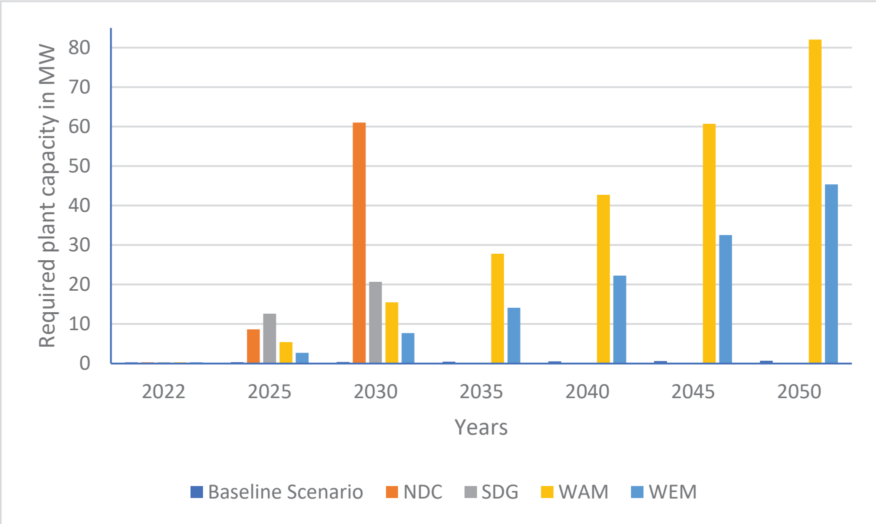

Figure 4.33 Plant capacity requirements

4.6 Validation and Comparison of Result

The data from the study and from different journal articles are validated in this section in order to check the deviation of the study from past literature.

4.6.1 Passenger Demand Validation

As per (Prajapati et al., 2023) data on the passenger demand in Kathmandu Valley in the year 2050 is observed to be 45 billion passenger-km which has been observed to be growing with the time frame upon close comparison is observed as follows in Table 4.21 below;

Table 4.21 Passenger Transport Demand Comparison

Year	(Prajapati et al., 2023)	Calculated	Share
2025	16	23.96	67%
2030	19	29.36	65%
2035	23	35.97	64%
2040	29	44.07	66%
2045	36	54.01	67%
2050	45	66.18	68%

Comparing the calculated data with the research paper, the share of demand of Kathmandu Valley has been ranging from a share of a minimum of 64% to a maximum of 68% where the average share is 69% throughout the time frame.

4.6.2 Energy Consumption Validation

The fuel consumption by land transport of the research and that of (WECS, 2022a) is 10,992.2 TJ on the base year and from our calculated value of 11,069.7 TJ. As per the projection of the transport energy consumption over the period, the growth rate of an average of 5.83% for the whole transport sector energy consumption is observed in (Bajracharya & Bhattarai, 2016) in reference scenario whereas under this study the rate of consumption growth is seen to be 4.1% in case of land transport without considering the fuel intensity improvement per year, whereas considering fuel intensity improvement the rate of increment of consumption in baseline scenario is 2.86%. In 2016, PGR was very high compared to that of the present time which has brought deviation in the growth rate.

4.6.3 Emission Validation

The increment of overall emission of Asian nation from 2010-2019 was 41% which translate to a 3.89% YOY increment (Regmi,2021). In the baseline scenario for Bagmati province in this research YOY increment is 2.86%. In the research (Regmi,2021) fuel intensity increment is not considered so the value on the Asian nation average is higher compared to this study.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study determined the operating factors of the different types of passenger and freight vehicles running in Bagmati province and also determined the passenger vehicle as well as the freight vehicle demand in Bagmati province. The demand for passenger transport is observed to be increasing by 4.15% and that of freight transport is increasing by 3.99% from the base value of 20.62 billion passenger-km and 4.26 billion tonne-km in the year 2022.

It is observed that the number of registered vehicles and vehicle number that denote operating vehicles is different for different types of vehicles as the scrappage factor differs for different types of vehicles. Due to the increase in the land transport demand the energy demand will increase from 10.992 PJ in 2022 to 24.214 PJ in the year 2050. Due to this, the emission will also increase from 0.788 million metric tonnes of CO_2 equivalent to 1.734 million metric tonnes of CO_2 equivalent in the time frame of 2022-2050.

On the basis of scenario analysis, the NDC scenario was able to reduce the emission by 28.23% in the year 2030 along with an energy consumption reduction of 17.37% which is followed by the WAM scenario that reduced 14.5% emission with 9.39% energy consumption reduction. The WEM has the least emission reduction of 6.53% in 2030 with an energy reduction of 5.09% whereas SDG has an emission reduction of 8.95% in 2030 and an energy consumption reduction of 4.89%. On the Long-term analysis of the year 2050, we observe that the WAM scenario has an energy reduction of 30.03% and an emission reduction of 44.83% and the WEM scenario has a reduction of emission by 22.67% and a fuel consumption reduction by 17.58%

Under the WAM scenario, the addition of power generation capacity to 82.1 MW is required to fulfill the demand of the year 2050 and 45.4 MW under the WEM scenario.

Thus, a better efficient fuel mix of electricity can help in drastically reducing energy consumption and emissions. The EV vehicles can help drastically reduce energy requirements as well as emissions, so they are to be encouraged by the government. The fuel mix in the transportation sector is observed to be very hard to completely change to electric fuel due to a lack of public motivation at present to switch to EV. The transport sector alone cannot be net-zero as there is emission in the creation of vehicles and it is hard to get a 100% electric fuel mix in the transportation sector. So, the emission of the transportation sector has to be cut off by other non-energy sectors with negative emissions.

5.2 Recommendation

The research has been focused on the analysis of the transportation demand of the Bagmati province along with the emission from the transportation sector under different scenarios as per government policies. Further study on other sectors and provinces of Nepal can be carried out. A Weibull equation has been used in this research to calculate the operating vehicle numbers for the year. The thorough analysis of the operating factor and fuel intensity of the vehicle types can be analyzed in further studies to increase the closeness of forecasted value with the real data. Some more scenarios can be introduced onto the demand forecast using year on year-on-year growth rate of GDP and population rather than using the average growth rate. Historical data on GDP and fuel price can be used in regression analysis to forecast the fuel consumption change pattern in future studies.

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ANNEX

From the Indian sub-context, the data is taken for the value of T and b for the vehicle (Baidya & Borken-Kleefeld, 2009) on the equation which is shown in (NHTSA, 2006),

Table A.1 Survivability equation parameters for passenger vehicle Bagmati province

Types (Passenger vehicle)	Average Life (T)	b
Bus	14	2.29
Car j and V	12	2.03
Minibus	12	2.03
Motorcycle	8.5	1.99
Microbus	12	2.03
Tempo	12	2.03
Rickshaw	12	2.03

and below shows the data of T and b for the freight vehicle, used in determining the scrappage and operation factor of the vehicle (NHTSA, 2006).

Table A.2 Survivability equation parameters for freight vehicle Bagmati province

Types (Freight vehicle)	Average Life (T)	b
Pickup	12	2.03
Truck	12	2.29
Tractor	12	2.03

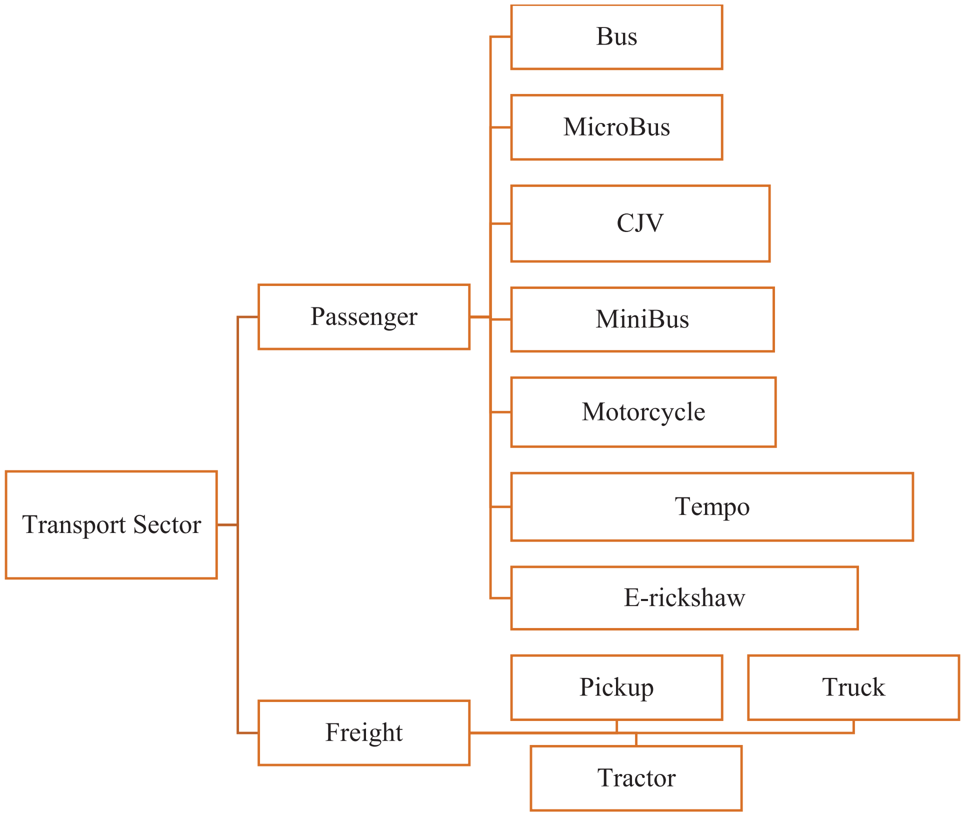

Figure A.1 Disaggregation of Land Transport

Table A.3 Fuel types and their operational efficiencies

Fuel	**Efficiency**
Electricity	70%
Diesel	31%
Gasoline	19%
LPG	38%
Monorail Electricity	85%
Hydrogen	50%

				Average factor	0.70	*calculated*
	Capacity (kW)	Annual Production (GWh)	kWh	Theoritical	Capacity Factor	
1 Khimti Khola	60,000	350	350000000	525,600,000	0.67	https://hpl.com.np/projects
2 Upper Bhotekoshi Khola	45,000	293.2	293200000	394,200,000	0.74	https://nwrmap.info/hydro
3 Indrawati III	7,500	50	50000000	65,700,000	0.76	https://nhpcl.com/indrawat
4 Chilime	22,100	150	150000000	193,596,000	0.77	https://www.chilime.com.n
5 Rairang Khola	500	3	3084580.731	4,380,000	0.70	
6 Sunkoshi Small	2,500	14.38	14380000	21,900,000	0.66	https://nwrmap.info/hydro
7 Chaku Khola	3,000	19	18507484.39	26,280,000	0.70	
8 Baramchi Khola	4,200	22	22000000	36,792,000	0.60	https://nwrmap.info/hydro
9 Sali Nadi	250	2	1542290.366	2,190,000	0.70	
10 Upper Hadi Khola	991	6	6113639.01	8,681,160	0.70	
11 Solar	680	1.46	1459416	5,956,800	0.25	
12 Sipring Khola	9,658	60	59581761.41	84,604,080	0.70	
13 Middle Chaku	1,800	11	11104490.63	15,768,000	0.70	
14 Tadi Khola (Thaprek)	5,000	31	30845807.31	43,800,000	0.70	
15 Ankhu Khola	8,400	52	51820956.29	73,584,000	0.70	
16 Charanawati Khola	3,520	20.529	20529000	30,835,200	0.67	https://nwrmap.info/hydro
17 Lower Chaku Khola	1,800	11	11104490.63	15,768,000	0.70	
18 Bhairab Kunda	3,000	19	18507484.39	26,280,000	0.70	
19 Mailung Khola	5,000	31	30845807.31	43,800,000	0.70	
20 Jiri Khola Small	2,200	14	13572155.22	19,272,000	0.70	
21 Belkhu	518	3	3195625.638	4,537,680	0.70	
22 Suspa Bukhari	998	6	6156823.14	8,742,480	0.70	
23 Jhyadi Khola	2,000	12	12338322.93	17,520,000	0.70	
24 Tungun-Thosne & Khani Khola	6,360	32.27	32270000	55,713,600	0.58	https://www.kkhpcl.com.np
26 Dhunge-Jiri	600	4	3701496.878	5,256,000	0.70	
27 Chake Khola	2,830	17	17458726.94	24,790,800	0.70	
28 Syauri Bhumey	23	0	141890.7136	201,480	0.70	
29 Bagmati Khola Small	22,000	136	135721552.2	192,720,000	0.70	
30 Hadi Khola, Sunkoshi A	997	7.8	7800000	8,733,720	0.89	https://nwrmap.info/hydro
31 Upper Chaku A	22,200	137	136955384.5	194,472,000	0.70	
32 Ghatte Khola	5,000	31	30845807.31	43,800,000	0.70	
33 Thoppal Khola	1,650	10	10179116.41	14,454,000	0.70	
	252,275	**1545**	*GWh*			
	252.28	*MW*				

Figure A.2 hydropower Availability

Table A.4 Survival profile calculation table

E-Rickshaw — Survival Profile for Bagmati

Year	Vehicle Age	New Registered Vehicle	New Balance	Total	Weibull	Total Prob. Survived Vehicle	Life Cycle Profile		2015	2016	2017	2018	2019	2020	2021	2022
2015	1	5352	0	5035	0.9407				5035							
2016	2	1011	5035	5750	0.8966				4799	951						
2017	3	5546	5750	10634	0.8427				4510	907	5217					
2018	4	4028	10634	13794	0.7809	2011			4179	852	4973	3789				
2019	5	481	13794	13345	0.7134	274			3818	790	4674	3612	452			
2020	6	1580	13345	13803	0.6425	1015			3439	721	4331	3395	431	1487		
2021	7	3945	13803	16338	0.5704	2814			3053	650	3957	3146	405	1417	3711	
2022	8	3069	16338	17817	0.4991	2396			2672	577	3563	2874	375	1332	3537	2887
Total		*25013*	**78698**													

Table A.5 CJV vehicle share calculation.

CJV			
	Petrol	Diesel	G/D
CF	34.00	35.00	0.971429
Energy	1,707.45	985.67	1.732268
Mileage	14.68	13.77	1.066086
Annual	16,411.43	17,671.09	0.928716
Other	0.961802882		
Share(G/D)	1.801063805	2.801063805	35.70%

Table A.6 Passenger KM calculation

Vehicle types	OF	VN	AAKM	VKT	Energy (TJ)	PKM	Share
BUS	33.5	6,900	29,416.62	202,971,939	1,350.18	6,799,559,965	32.06%
Micro	13.5	4,281	24,466.04	104,749,820	182.14	1,414,122,569	6.67%
CJV (G)	1.9	42,362	16,411.43	695,227,791	1,707.45	1,320,932,803	6.23%
CJV	1.9	23,520	17,671.09	415,624,635	985.67	789,686,807	3.72%
Mini	18.5	10,165	14,789.23	150,331,464	336.42	2,781,132,079	13.11%
Motorcycle	1.1	452,793	8,761.78	3,967,274,403	3,041.50	4,364,001,844	20.58%
Tempo	7.8	5,039	33,171.00	167,148,111	15.31	1,303,755,269	6.15%
Tempo (G)	7.8	8,632	23,132.07	199,667,123	42.09	1,557,403,560	7.34%
Tempo-E	7.8	1,466	33,171	48,620,228	6.13	379,237,782	1.79%
Rickshaw	2.8	17,817	10,004.02	178,237,096	2.55	499,063,869	2.35%
			Total	**6,129,852,612**	**7,669**	**21,208,896,547.16**	

Table A.7 Tonne Km calculation table

Vehicle types	LF	VN	AAKM	VKT	Energy(TJ)	TKM	Share
Pickup	0.75	18,956	21,843.88	414065212.3	1,042.63	310548909.2	7.28%
Tractor	2.4	10,122	14,967.11	151498306.1	135.14	363595934.6	8.53%
Truck	19.6	9,779	18,726.50	183126416	2,184.69	3589277754	84.19%
			Total	**748689934.4**	**3362.46**	**4263422598**	

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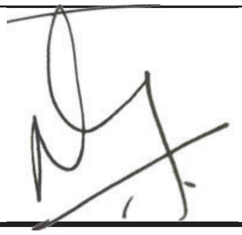

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