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ASSESSMENT OF VEHICULAR EMISSIONS AND ITS IMPACT ON CLIMATE CHANGE IN URBAN AREAS OF KATHMANDU VALLEY, NEPAL

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ABSTRACT

Cities are key hubs of the transportation sector. With rapid growing economies and population, there is an increasing trend of expansion of urban sprawl and auto-mobilization. This has a direct effect on the level of transport demand, travel patterns and its impact on the environment. This research is focused on studying vehicular emissions in context of urban areas of Kathmandu Valley, Nepal. The cities within the valley are in the stage of rapid urbanization and with it, there has been a sharp increase in travel demand and vehicle number, with growing population and high level of economic activities. This has resulted in a situation of unsustainable mobility, due to excessive vehicular emissions and is causing severe negative impact on urban climate. In this research, urban transport model (4 step) is used, to predict travel pattern of the city and resulting emissions. The results show that urban transport sector is having a significant share in the total emissions and the major cause of it is due to excessive use of vehicles, especially private. Thus, it highlights the need to cut down excessive emissions by promoting sustainable urban transport planning strategies.

INTRODUCTION

Sustainable development strategies are becoming increasing concern for decision makers, planners and the public as a threat of global warming, climate change, energy consumption and high levels of pollution become evident. Urban Transport is one of the major sector for energy consumption and Greenhouse gas (GHG) emission. As the level of GHG increases, it will have severe impact on urban climate. GHG vary according to types of transportation systems, geographic location, scale, and time period. The transport sector is responsible for about 23% of world energy-related greenhouse gas emissions (Kahn-Ribeiro, et al.,2007). So it is very crucial to promote sustainable transport development strategies, to minimize the climate change impacts, resulting from the transport sector.

A practical application of transport sustainability would seek to balance the negative effects of the transport system, such as energy use, pollution, delays in travel on congested roads and emissions, with the positive aspects, such as a high level of accessibility for individuals and organizations (Bertolini 2005). Adaptation to climate change means minimizing the potential impacts on the transportation system from climatic changes such as rising average temperatures, increased intensity of storms, rising sea levels, and increases in overall climatic variability. Mitigation, in the context of urban transport, implies reduction in GHG emissions resulting from movement of goods, services, and people in cities (Mehrotra, et al. 2011). The aim of mitigation strategies should be to reduce the transport carbon footprint of the city by promoting sustainable urban transport solutions.

STUDY AREA: THE KATHMANDU VALLEY (KV)

Nepal is in the state of rapid urbanization. Urban population is increasing, mainly due to migration from rural to urban for better opportunities and livelihood. Most urbanized areas are in Kathmandu Valley. The valley comprises of three districts, Kathmandu, the capital city of Nepal, along with Lalitpur and Bhaktapur with population of over 2.5 million (CBS 2011).

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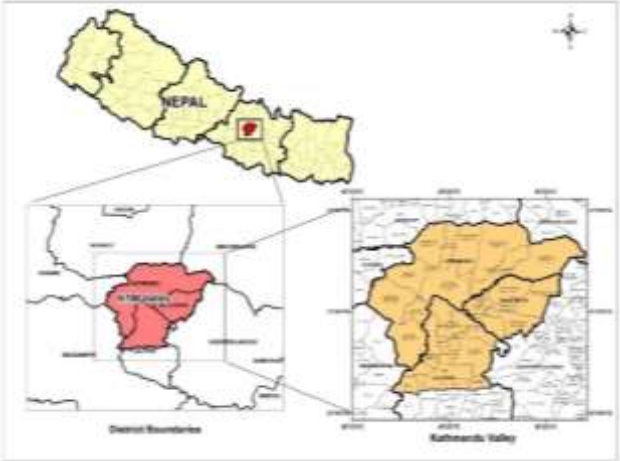

Figure 1: Location Map

Population of its cities and level of economic activates are in the sharp rise. This has resulted in increment in travel demand and increase in travel demand has led to more commuters, more vehicles and more emission. With population growth, the city sprawl is increasing without adequate infrastructure and planning measures. This is causing degradation in city landscape and inefficient mobility.

In terms of mobility, the narrow roads, increasing use of private vehicles (Motorcycles and cars), Low occupancy public vehicles (Micro bus and Tempos) and insignificant use of non-motorized modes (Bicycles) are responsible for inefficient urban mobility. As a result, the roads are all the time congested, resulting in delays due to increased travel time, along with air pollution due to excessive emissions.

Number of vehicles have increased drastically in the past few years. And more alarmingly, ownership of private vehicles is pacing up rapidly as shown in Table 1.

Table 1: Vehicle Registration data for Bagmati Zone (1989/90 - 2013/14)

Year	Bus	Mini Bus	Car/Jeep/Van	Micro Bus	Tempo	Motorcycle	Others	Total
1989/90	797	1,028	9,868	-	507	18,594	3,812	**34,606**
2013/14	8,298	7,023	93,847	1,720	2,518	601,951	40,189	**755,546**
Total	**9,095**	**8,051**	**103,715**	**1,720**	**3,025**	**620,545**	**44,001**	**790,152**

Source: (DoTM 2014)

METHODOLOGY FOR ESTIMATING VEHICULAR EMISSIONS

The first part of the methodology consists of data collection using household questionnaire survey, from various parts of the study area, to study travel behavior of commuters at household level. It was aimed to know the characteristics of mainly daily trips i.e. work and educational trips and frequency of other trips. The sample size for the survey, was 2000, collected from various parts of the study area, using stratified random sampling technique to have uniform coverage over the study area. The data from household survey was used for transport model. Roadside interviews were also carried out with the drivers to know fuel efficiency and route identification of public vehicles. Urban Transport Model System (4-step transport modelling) which consists of Trip Generation, Trip Distribution, Modal Split and Route Assignment, was used to predict travel pattern within the study. The traffic volume assignment obtained from the model was used for the estimation of annual vehicular emissions. Emissions consisted of Green House Gases (GHG), mainly, carbon dioxide (CO_2) which accounts for about 95%. Emissions of other GHG gases, like CO, CH_4, N_2O and HFCs were taken as 5% of CO_2 taking into consideration, global warming potential of each greenhouse gases. Contribution of all GHG were calculated as equivalent amount of carbondioxide [CO_2e]. It is to be noted that there are limitations in the model developed as it involves approximation and assumptions in its stages. Thus, the results represent only approximate figures.

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RESULTS AND DISCUSSIONS

Basis for emission calculation is the vehicular distance for one-way daily trip, given by the final step ie Route Assignment of the model. The steps for calculation of emissions are shown in

Table **2** and

Table **3**. Total annual CO_2e is found to be 207527 tons.

Table 2: Calculation of Daily Emissions (Daily One-way)

Travel Mode	Vehicular Distance (m)		Total Distance (KM)	CO_2 gm/km[1]	Total CO_2 (gm)	Total CO_2 (ton)
	Edu. Trips	Work Trips				
Car	15641974.3	626516864.8	642158.8	234.8	150759511.0	150.8
Motorcycle	517399570.5	671271240.6	1188670.8	75.7	90020653.1	90.0
Bicycle	7421171.6	19773752.1	27194.9			
Bus	48619471.2	16670746.9	65290.2	768.0	50142887.5	50.1
Micro	17450664.7	25397274.8	42847.9	358.6	15363972.9	15.4
Tempo	5973143.8	6035351.0	12008.5			
Total Emission						**306.3**

Table 3: Annual Emissions

SN	Particulars	Notation	CO_2 Emissions in tons	Calculation	Remarks
1	Total (One–way)	E1	306.3		From Table **2**
2	Total (+Return Home)	E2	612.6	$E1 \times 2$	Assuming that commuters travel same way in returning home as going from home to work place or to school
3	Total Annual Emissions (Daily Trips)	E3	171520.7	$E2 \times 280$	Out of 365 days, 52 days (Saturdays) and 83 days (Public Holidays)[1] are deducted to get net working days.
4	Total Annual CO_2 Emissions (All trips)	E4	197150.3	$\frac{E3}{87} \times 100$	As per Household Survey, 87% accounts for daily trips and 13 % for other trip purpose. It is assumed that emissions for each trip purpose is proportionate to its share. So 13% emissions resulting from other trip purposes are accounted with the emissions of 87

[1] Emission rates are based on fuel efficiency of vehicles (obtained from interviews with drivers) and conversion of fuel to emissions (EPA 2014)

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SN	Particulars	Notation	CO_2 Emissions in tons	Calculation	Remarks
					% for daily trips to get total emission.
5	Total Annual Emissions [CO_2e]	E5	207526.6	$\frac{E4}{95} \times 100$	Total emissions in terms of equivalent CO_2, taking into account, other GHG emissions (5%).

[1]For Public Holidays, Calendar of year 2016 AD was referred. It is assumed that same is the number for all other years.

In the above calculation, only person trips are considered and share of freight transportation is not included as it was not within the scope of this research. Therefore, the actual figure of total emission from transport sector could be slightly higher than those presented.

SHARE OF URBAN TRANSPORTATION SECTOR IN KV TOTAL EMISSIONS

Total estimated CO_2 emission from urban transportation is 197150.3 tons, which is about 20% of total Kathmandu valley (KV) emission. The share could be even higher if freight transport were also to be included. Total valley emission is estimated from the fuel consumption data which is obtained by the share of Kathmandu valley out of National Sales. The Kathmandu valley has dominant share of overall national fuel consumption as cities within the valley have high population density and high level of economic activities. As revealed in

Table **4**, vehicular emissions are contributing significantly, in adding up GHG and it will have profound effect in the climate of Kathmandu valley.

Table 4: Total Estimated Emission in KTM Valley

S.N	Fuel Type	National Sales (KL/MT) [1]	Share of KTM Valley [2]	Consumption within KV	Annual Emission (CO_2) in Tons
1	Petrol	283,567 KL	45.0%	127605.2 KL	299578.4
2	Diesel	901,393 KL	15.5%	139715.9 KL	375734.2
3	Kerosene	18,628 KL	37.6%	7004.1 KL	18455.9
4	LPG	258,299 MT	60.0%	154979.4 MT	418444.4
Total KV Emission					1112212.8
Total CO_2 emissions from Urban Transportation (Table 3)					197150.3

Source: [1] (NOC 2016), [2] (NRB 2012)

As urban population, number of vehicles and traffic congestion within the valley continues to grow; vehicular emissions are expected to rise, sharply. So it is very essential that the transport system within the valley is prepared to manage the escalating travel demand with the solutions that provides better solutions to prevent to its

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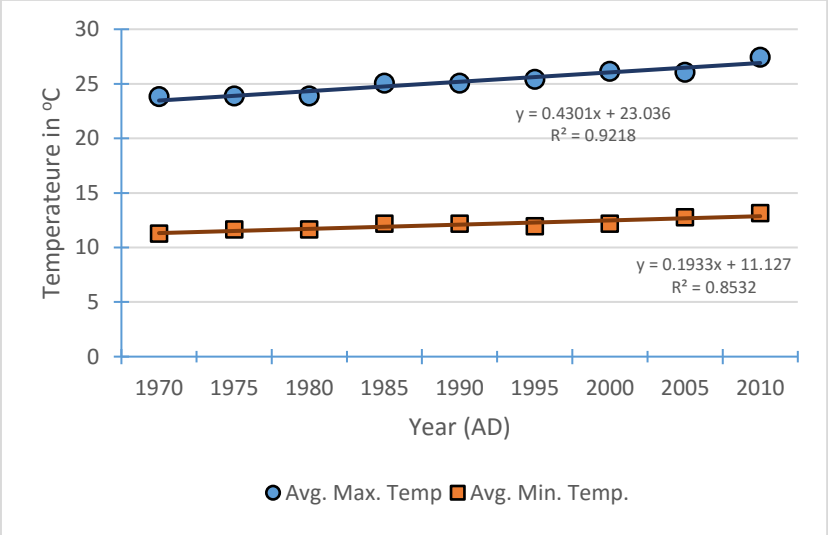
environment. The attempts to reduce GHG will be beneficial to minimize climate change effect, while at the same time, minimizes fuel consumption, which will help to uplift national economy.

One of the main indicator for climate change in the rise in temperature. The graph below (
Figure **2**) shows the pattern of temperature (Average Annual Maximum and Average Annual Minimum) over the course of last 4 decades. The trend line has upward slope that is clearly indicating the temperature, rising with time.

Figure 2: Rising Temperature in KV



Source: (DHM 2010), Station: KTM Airport

The rate of rising temperature is 0.09°C / year for annual maximum and 0.04°C / year for annual minimum temperature. The main factor behind this trend is increasing emission as shown by sharp increment in the consumption of fuel and GHG emissions in the recent years. Therefore, from climate change perspective, it is very essential to cut down emissions. Temperature rise is creating a warming effect and there is more of urban heat island effect with increasing built-up areas. It can disturb city ecosystem and in future, there could be more of problems, which city dwellers have to face. Apart from temperature rise, there air pollution is also affecting air quality and health of the people.

If we have to project annual GHG emission for future, it is expected to rise rapidly with growing population and travel demand. In just a matter of 15 years from 2015 to 2030, the rise is expected to be twice ie from approximately 200,000 to 400,000 ton (
Figure ***3***). It is assumed that trip rate per household, average trip distance and modal share remains same overtime in the projection. However, there is likely that modal share of private vehicle will increase and trip distance could also increase with increasing urban sprawl. In that case, the curve is expected to be even steeper.

Figure 3: Trend Analysis of Annual Emissions from Vehicular Trips (Person Trips)

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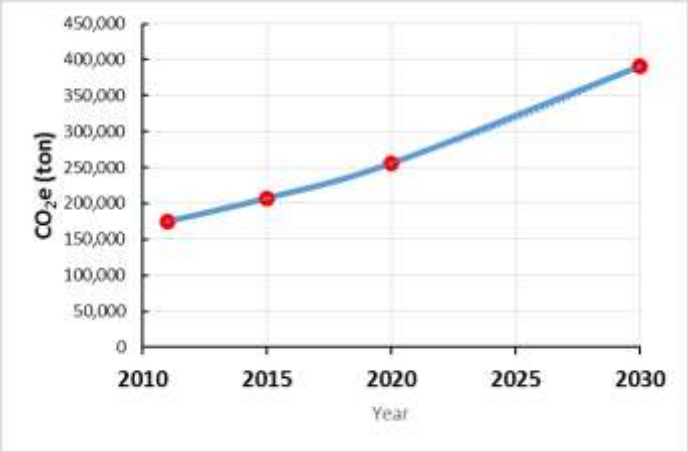

CONCLUSION AND RECOMMENDATION

Kathmandu valley is experiencing rapid economic growth and urbanization and with it, the urban transport sector faces enormous challenges and opportunities in addressing the overall objectives of climate change, social and economic sustainable developments. With growing economy and population, travel demand is on a steep rise. The vehicle number is increasing rapidly and more alarmingly, the private vehicles. Excessive accumulation of GHGs is causing the temperature to the Kathmandu Valley, to rise slowly as shown by the trend line of temperature data of past 4 decades. Reducing CO_2 emissions is a growing challenge for the transport sector. To cut down emissions from urban transport sector, it is very essential to promote sustainable urban transport solutions. Development of mass transit oriented transport system plays an important role in minimizing vehicular emissions, if there could be significant shift towards it from private modes. For that, there has to be comfortable and high quality public transport system to attract more commuters towards it. Further, more encouragement towards non-motorized modes, improving vehicle emission standard, proper traffic management and road condition and use of alternative energy sources like renewable energy, electric vehicles, so as to minimize the use of fossil fuel, all should be incorporated to achieve the goal of minimizing the impact of urban transport on climate change. This research presents the preliminary picture of the cause and effect of climate change and the role of urban transport in it. Further, more research is required to address all the issues in broad perspective, if effect of climate change from transport sector is to be minimized.

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