Assessing Vehicular Emission Reduction Potential for Home-based Work-trips for Kathmandu Valley, Nepal

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Abstract

Kathmandu valley is known to be the prime center economic activities and employment opportunities and it has become a major concern to manage work trips to cut down emissions from the urban transport sector. This paper analyses home-based work trips and estimates total vehicular emission, resulting from it. The trip data was collected through a household survey, conducted on different parts of the study area, using stratified random sampling, to study how people travelled from their homes to their work places. One of the major factors behind excessive vehicular emission is the high modal share of private vehicles for work trips. Furthermore, the study area is disaggregated into two parts. The first part is the area inside ring road, that covers the central part of the valley and second part includes the settlements on the outskirts, situated outside the ring road. The estimates reveal that trips originating outside the ring road comparatively contributes more to the emissions than those within the ring road, primarily due to increased travel distance for peripheral settlements. Consequently, the paper explores possible methods to minimize emissions from work trips, including conventional approaches and new emerging trends, along with the associated challenges.

Keywords: *Urban Transport, Work Trips, Vehicular Emission, Kathmandu Valley*

Introduction

Transport is one of the sectors targeted for effective public interventions to reduce CO_2 emissions and implement adaptation measures to reduce vulnerability to climatic changes. Currently, CO_2 emissions in the transport sector account for approximately 30% in developed countries and about 23% of total man-made CO_2 emissions worldwide (UNECE, 2023). An important challenge in reducing CO_2 emissions from transportation and promoting the development of environmentally-friendly cities is the necessity to gain a deeper comprehension of the factors that influence travel behavior and the consequent carbon emissions (Ma, Liu, & Chai, 2015). Addressing the issue of reducing CO_2 emissions has become an increasingly formidable task for the transportation sector. Approximately 23 percent of global CO_2 emissions from fuel combustion are attributed to transportation. What is more concerning is that transportation is currently the fastest-growing consumer of fossil fuels and the leading contributor to CO_2 emissions. The rapid urbanization in developing nations has further exacerbated the problem, as it has led to a substantial rise in energy consumption and CO_2 emissions resulting from urban transportation (The World Bank, 2023). The combustion of fossil fuels such as gasoline and diesel releases carbon dioxide, a type of greenhouse gas, into the atmosphere. The accumulation of carbon dioxide (CO_2) and other greenhouse gases like methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs) is leading to the warming of the Earth's atmosphere. This warming is causing observable changes in our climate, which are becoming increasingly evident (EPA, 2023). The rising awareness of global warming, climate change, excessive energy consumption, and high pollution levels has made sustainable development strategies a growing priority for decision-makers, planners, and the general public. One key aspect of sustainability efforts lies in addressing land use and transport planning. Taking positive actions in this area can have a significant impact on promoting sustainable development (Banister, 1997).

An effective implementation of transport sustainability would aim to seek a balance between the adverse impacts of the transportation system, such as energy consumption, pollution, traffic congestion, and emissions, and the positive aspects, such as providing convenient accessibility for individuals and organizations (Bertolini, le Clercq, & Kapoen, 2005). Additionally, a comprehensive approach to transport sustainability would involve the integration of transport and land use planning policies. This integration aims to minimize the necessity for extensive travel by implementing measures such as developing mixed-use areas near public transportation hubs. Furthermore, it would focus on enhancing the urban environment to promote and facilitate walking and cycling as alternative modes of transportation (Banister, 1997). The design and structure of a city have a significant influence on people's travel patterns. By reducing the frequency and distance of travel and facilitating a transition from private vehicles to more sustainable modes of transportation, urban planning can effectively contribute to the reduction of greenhouse gas emissions. The fundamental principle that underlies the connection between land use and transportation is accessibility (Hanson, 1995). In order to achieve this, there needs to be a shift in focus from solely prioritizing personal mobility to placing a greater emphasis on accessibility (Whitelegg, 1997). The significant increase in the widespread use of motorized vehicles by the public in developing countries can be attributed to their flexibility, versatility, and relatively low initial cost, making them suitable for various travel purposes (Gireesh Kumar, Lekhana, Tejaswi, & Chandrakala, 2021).

Air pollution is a significant issue in our society, and there are various factors that contribute to its deterioration. One of these factors is vehicular emissions. When traffic congestion occurs, it leads to increased emissions from vehicles, resulting in a decline in the overall quality of the air we breathe. Recent research has highlighted the negative health impacts, including higher rates of illness and mortality, for drivers, commuters, and individuals residing close to major roadways (Zhang & Batterman, 2013). The role of employment is widely acknowledged as a crucial element in shaping travel behaviors, as people's travel patterns are primarily influenced by where they work, their work schedules, and their daily commute between their residence and workplace (Cerqueira, Baumvol, Chevallier, & Bonin, 2020). Besides the impact on commuting and business-related travel, alterations in workplaces also have a notable influence on non-work trips. The geographical positioning and schedules of workplaces play a vital role in organizing daily activities, thereby affecting other categories of trips such as shopping, recreational outings, and healthcare-related visits. The spatial arrangement and timing of work can shape the patterns and motivations behind the diverse trips, individuals undertake outside of work-related travel (Aguiléra, Massot, & Proulhac, 2009).

Therefore, it is important to recognize that work-related travel significantly impacts individuals' overall travel behavior, even extending to non-work trips. Other activities and trips are often planned and organized around the primary purpose of work travel, emphasizing its central role in shaping travel patterns and influencing the timing and purpose of various trips (Westelius, 1973). A significant portion of non-work trips are centered around three key locations: the workplace, the home, and the journey between the two. (Aguiléra, Massot, & Proulhac, 2009).

The advancement of Information and Communication Technology (ICT) has brought about significant changes in the traditional notion of the workplace. As a result, there has been a notable rise in the number of individuals who now have the choice to work from home, either on a full-time basis or for a few days each week. This modern work arrangement, often referred to as telework or telecommuting, has gained widespread popularity and is viewed as a promising solution for addressing various challenges such as reducing travel demand, alleviating congestion, and mitigating greenhouse gas (GHG) emissions. By allowing employees to work remotely, telework offers the potential to decrease the need for daily commuting and replace it with virtual collaboration and communication technologies. This shift has the potential to bring about positive environmental impacts by reducing the reliance on traditional modes of transportation and their associated emissions (de Abreu e Silva & Melo, 2018).

Study Area and Research Problem

The study area is the Kathmandu valley. that constitutes 18 municipalities and has population of around 3 million (NSO, 2021). Due to the expansion of economic activities and the availability of employment opportunities, work trips have become the primary component of overall travel patterns. Consequently, there has been a substantial surge in travel demand for work-related trips, leading to an increased number of vehicular trips and a subsequent rise in emissions associated with these trips. According to CEN/CANN (2012), work trip constitutes 39 % of total trips generated within the valley, which is the highest, compared to other trip purposes. Educational trips follow closely behind, accounting for 34% of the total, while other trips, including personal, recreational, and shopping trips, make up 27% of the share.

Economic activities occur mainly concentrated around Central Business District (CBD), that lies around central region of the valley (Figure 1), The CBD offers commercial, financial, and administrative services, creating job opportunities in various sectors, both formal and informal. As a result, the majority of the workforce is attracted to the CBD.

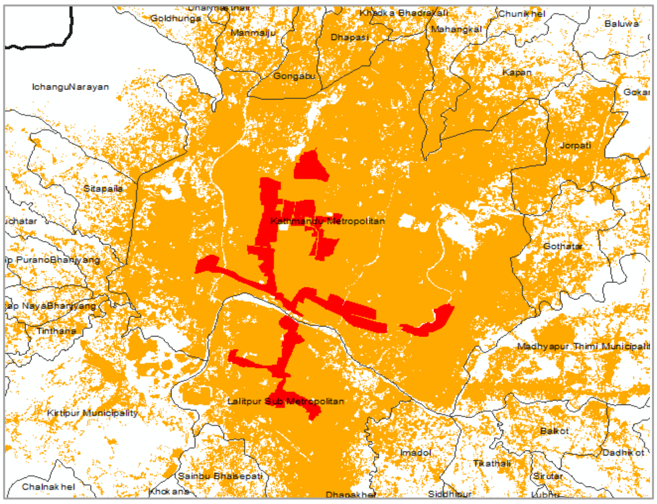

Figure 1: CBD in KV (Source: KVDA (2014))

The population of Kathmandu Valley is primarily concentrated within the boundaries of the ring road, as seen in the land use map (Figure 2). However, due to the continuous growth of the population, settlements are rapidly expanding towards the peripheral areas. This urban sprawl has resulted in an uneven distribution of services and facilities, with most of them concentrated in the central area. As a consequence, residents living on the outskirts of the valley experience longer travel distances for accessing essential services. As urbanization continues to rise, the demand for fossil fuels is also escalating. Figure 3 illustrates the increasing consumption of fuel at national scale. On average, over the past 10 years, the yearly increment rate for petrol consumption has been around 50,000 KL, while for diesel, it has been approximately 100,000 KL. This upward trend reflects the growing reliance on these fuels for transportation and other energy needs in the country.

The excessive consumption of fuel has a direct correlation with greenhouse gas (GHG) emissions, which in turn has severe impacts on the urban climate. In Nepal, transportation ranks as the third most energy-consuming sector, having consumed 56.6 PJ of energy, accounting for 10.3% of the national total. Among all sectors, transportation is the highest energy-consuming sector in terms of petroleum product energy (WECS, 2022). Populated urban areas, such as those in Kathmandu Valley, consume a significant share of the national energy and resources. Therefore, it is imperative to promote sustainable transport development strategies as part of the urban development process, aiming to minimize climate change impacts stemming from the transportation sector.

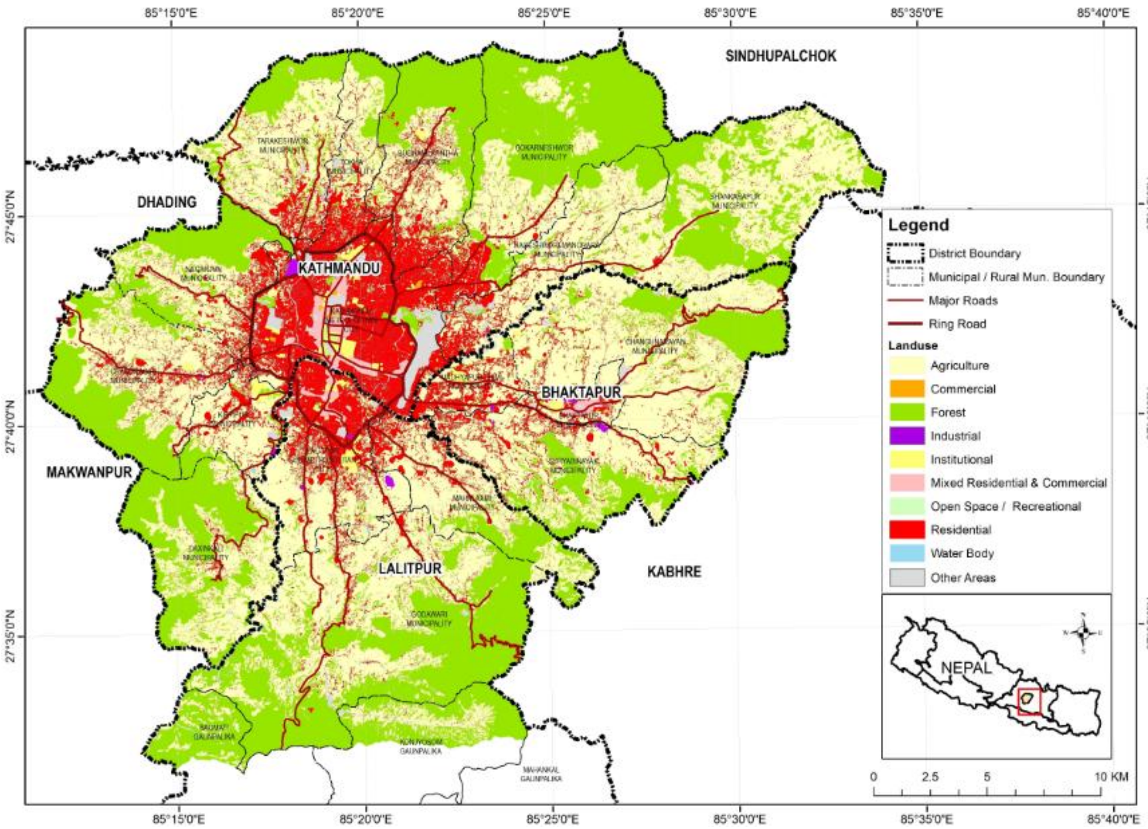

Figure 2: Landuse map with Road Networks and Ring Road (Source: KVDA (2014))

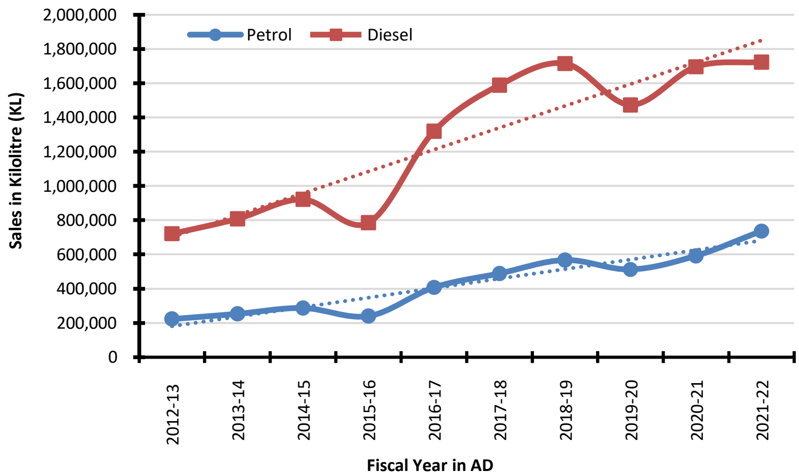

Figure 3: Sales of Petroleum Products (Source: NOC (2023))

Objectives

The primary objective of this paper is to analyze vehicular emissions specifically generated by home-based work trips within the Kathmandu Valley. Further, the paper explores the potentials for minimizing the resulting emissions from perspectives of modal shift, landuse and tele-working. Home-based work trips include those trips that originates from a place of residence and ends at work place. While there have been several studies conducted on vehicular emissions in Nepal, there is a notable lack of research examining the effects based on trip purpose. By analyzing vehicular emissions according to trip purpose, this research aims to establish a connection between travel behavior and trip patterns, with a specific focus on work trips. Through this analysis, valuable insights can be gained into the environmental impact of work-related travel, facilitating a better understanding of the relationship between travel behavior and emissions in the context of the Kathmandu Valley. This analysis is particularly crucial since the valley serves as the primary hub for employment opportunities nationwide, leading to a growing number of work trips across the region. The takeaways from this research provides useful insights for further planning of cities, serving as employment centers.

Methodology

This section explains the methods adopted for data collection and steps followed in the estimation of emission from work trips.

Data Collection

The basis for data collection in this study was a household survey aimed at gathering trip data for work trips made by household members who are workers. A total of 2300 households were surveyed, which were divided across 59 traffic analysis zones (TAZ) as shown in Figure 4. This approach ensured that the survey collected representative data from the population and allowed for accurate analysis and generalization of the findings. The survey utilized stratified random sampling, proportional to the number of households in each zone. The sample size was determined to achieve a 95% confidence interval with a 2% margin of error, assuming a response distribution of 0.5. To focus the study on urban areas, the research excluded regions along the outskirts of the Kathmandu Valley that primarily consisted of forest and agricultural land. In total, the survey includes 3602 work trips. During the survey, relevant data such as mode choice, trip distance, and other travel parameters were recorded for each trip.

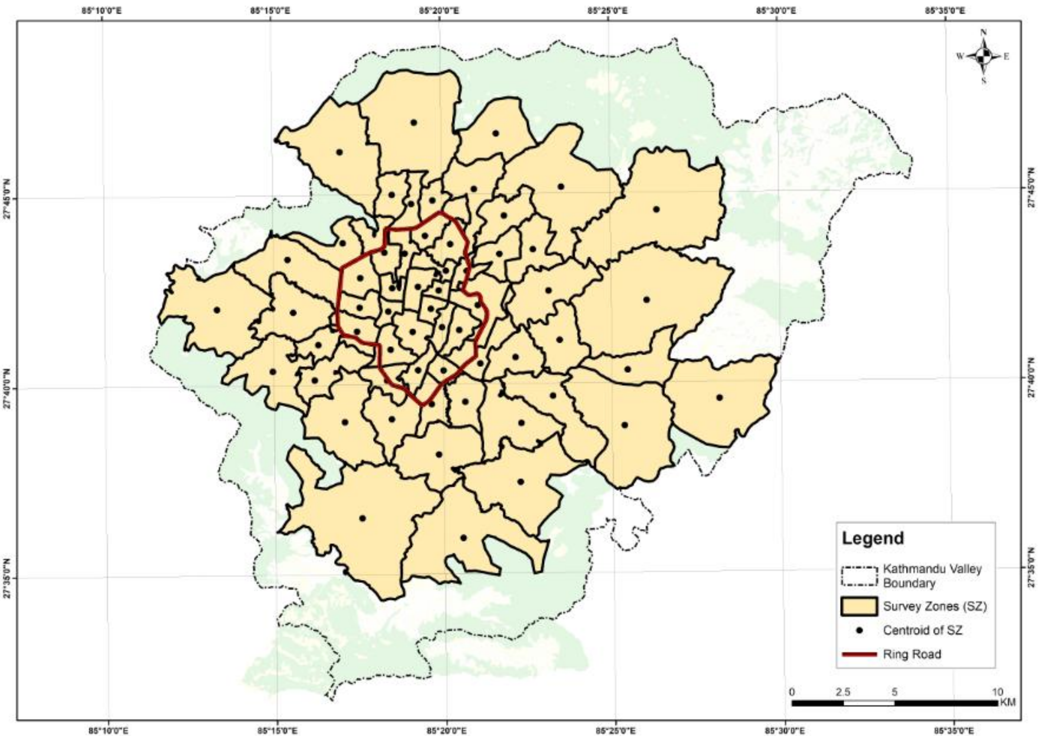

Figure 4: Survey Zones

Estimation of total work trips

This paper employs a relatively simple method known as Category Analysis to estimate the total number of work trips. The estimation is based on the trip rate per household. For each Traffic Analysis Zone (TAZ), the total number of work trips is obtained by.

$$\mathbf{TT_{w} = HH_{T} \times TR} \quad \textbf{(1)}$$

TT_w : Total number of work trips originating from a zone
HH_T : Total number of households in a zone
TR_w : Trip rate per household for the work trips

Estimation of Vehicular Distance for work trips

Distance travelled by each travel mode for work trips is obtained from is modal share, average trip length and average vehicular occupancy, as given by Equation 2.

$$TVD_j = TT_w \times AVO_j \times MS_j \times ATL_j \qquad (2)$$

TVD_j : Total vehicular distance for mode 'j' in km
MSj : Modal share of mode 'j'
ATLj : Average trip length for mode 'j'
AVOj : Average vehicle occupancy for mode 'j'

For public vehicles, the estimation of vehicular distance is approximate because it assumes that the entire vehicle is dedicated solely to work trips, without accounting for other trip purposes. This assumption particularly applies to peak hours, such as the morning trip from home to the workplace and the late-afternoon return-home trips when the majority of passengers are workers. During these times, the majority of individuals traveling are assumed to be commuting for work trips.

Estimation of Vehicular Emission

In order to determine the total vehicular emissions, Table 1 was referred. This table serves as a basis for calculating the total equivalent amount of carbon dioxide (CO2e) by following the standards prescribed by the EPA (2014), using Equation 3. According to this method, it is assumed that, on average, greenhouse gases (GHG) other than CO2 (such as CO, CH4, N2O, and HFCs) contribute approximately 5-6% of the total GHG emissions from a vehicle, while CO2 accounts for 94-95% of the emissions. This estimation takes into consideration the global warming potential of each greenhouse gas. To include the effects of these other greenhouse gases as an equivalent amount of carbon dioxide, the CO2 estimate is multiplied by 100/95.

It's important to note that the estimate provided by this research does not include lifecycle emissions, which include emissions associated with production, maintenance, and other stages of a vehicle's lifecycle. The focus of this estimation is specifically on the emissions resulting from work trips, only during its operational phase.

$$DE_w = \sum_{j=1}^{n} TVD_j \times GHG/km_j \times 2 \qquad (3)$$

DE_w : Total Daily Emission (CO_2e) for work trips
GHG/km : Greenhouse gas emission per km for mode 'j'
TVD_j : Total vehicular distance for mode 'j'

It is assumed that a trip behavior is same for both going from home to workplace and returning to home from work place. Thus, it is multiplied by 2.

Table 1: Vehicular Emission by Mode

Mode	Fuel Economy (Km/lit) [1]	Average Journey Speed (km/hr.) [1]	Occupancy [1]	CO_2-gm/Lit [2]	$C0_2$-gm/km	$C0_2$e-gm/km
Motorcycle	31	20	1.5	2347.7	75.7	79.7
Car	10	15	1.8	2347.7	234.7	247.1
Microbus (Public vehicle)	7.5	13	15	2689.3	358.6	377.5
Bus	3.5	12	35	2689.3	768.4	808.8
Safa Tempo (Electric Vehicle)		13	8			

Source: [1] Household Survey Data, [2] EPA (2014)

Finally, daily emissions are converted to annual emissions, using average number of working days

$$AE_w = DE_w \times AWD \quad (4)$$

AE_w : Annual GHG Emission, resulting from work trips
AWD : Average number of working days in a year (taken as 280)

Results and Discussions

Table 2 presents the estimated total emissions resulting from work trips in Kathmandu Valley. Annually, work trips contribute approximately 186,000 tons of greenhouse gas (GHG) emissions. Non-motorized modes, such as walking and cycling, do not generate any emissions and are therefore excluded from the calculation. Safa Tempo, an electric, low-occupancy public vehicle, also does not contribute to GHG emissions during its operational phase.

Among the motorized modes, which are responsible for emissions, private modes (cars and motorcycles) and public modes (buses and microbuses) are considered. Motorcycles have the highest GHG emissions, accounting for about 48% of the total, followed by cars with a 44% share (Figure 5). Trips from private modes that includes both cars and motorcycles, collectively contribute to over 90% of the total emissions. Public vehicles have comparatively lower emissions, with buses accounting for 6% and microbuses for 2% of the total emissions.

The main factor influencing these emissions is the modal share. As shown in Table 2, motorcycles have the highest modal share in work trips, accounting for nearly half of the total trips, which is nearly 50%. Cars have a share of around 18%. Public transport is not a preferred option for most commuters, with only a marginal portion (around 19%) opting for buses, microbuses, and tempos for work trips. Non-motorized transport, including bicycles and walking, has an aggregate share of approximately 13%. Among these options, bicycles are the least preferred, with a share of less than 1%.

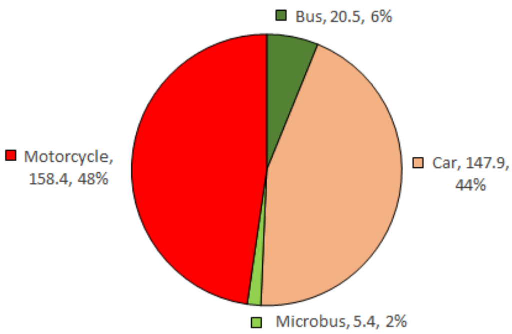

Figure 5: GHG % by Travel Mode (CO_2e)

Table 2: Total Emission for Work Trips

Trip Mode	Person Trips	Modal Share	P-km *	V-km	CO_2e/km	CO_2e-gm	CO_2e-ton	Remarks
Bicycle	8066	0.7%	26960.3					
Bus	157479	13.7%	888735.9	25392.5	808.8	20537416.4	20.5	
Car	210090	18.2%	1077191.1	598439.5	247.1	147874399.3	147.9	
Microbus	49979	4.3%	213182.5	14212.2	377.5	5365093.2	5.4	
Motorcycle	567460	49.2%	2980645.4	1987096.9	79.7	158371624.1	158.4	
Safa Tempo	12740	1.1%	42563.9	5320.5				
Walking	146439	12.7%	144442.4					
	1152252						332.1	Total for one-way trip (T)

	664.3	Total Daily Emission, including return home trips ($DE_w = T \times 2$)
	186003.2	Annual Emission ($AE_w = DE_w \times 280$)

*** P-km**: Passenger km, **V-km:** Vehicular Distance in km

Further, emission per trip is obtained using Equation 5.

$$\textbf{Emission per Trip} = \frac{\text{Total Emissions \_VF}}{\text{Total Persons Trips \_VF}} = \frac{332148533.1\ gm}{985008} = 337.2 \text{ gm / trip} \qquad (5)$$

where,

Total Emission_VF is the emission in aggregate, from the travel modes that use fossil fuel. It includes Bus, Car, Microbus and Motorcycles.

Total Person Trips_VF is the total person trips for the given travel mode.

In average, each trip using motorized travel modes (Bus, Car, Microbus, Motorcycle) contributes about 337 gm of CO_2, as per the estimate. Since NMT and electric vehicles do not contribute to emission, their emission/trip is not calculated.

For further analysis, the total trips are divided into two categories based on their place of origin: trips originating within the ring road (RR) and trips originating outside the ring road. The calculations of GHG emissions for both categories are presented in Table 3 and Table 4, respectively.

Table 3: Emissions inside RR

Trip Mode	Person Trips	Modal Share	P-km *	V-km	Average Trip Distance (km)	CO_2e / km	CO_2e-gm	CO_2e-ton	Remarks
Bicycle	2920	0.8%	10211.7	0.0	3.5				
Bus	17509	4.9%	71814.6	2051.8	4.1	808.8	1659533.0	1.7	
Car	82742	23.3%	358246.8	199026.0	4.3	247.1	49179319.3	49.2	
Microbus	16527	4.7%	54332.2	3622.1	3.3	377.5	1367361.4	1.4	
Motorcycle	180069	50.8%	648410.5	432273.7	3.6	79.7	34452213.1	34.5	
Tempo	10926	3.1%	30479.3	3809.9	2.8				
Walking	44091	12.4%	33061.0	0.0	0.7				
	354784						86658426.8	86.7	Total for one-way trip (T)
								173.3	Total Daily Emission, including return home trips ($DE_w = T \times 2$)
								48528.7	Annual Emission ($AE_w = DE_w \times 280$)

*** P-km**: Passenger km, **V-km**: Vehicular Distance in km

$$\textbf{Emission per Trip} = \frac{\text{Total Emissions \_VF}}{\text{Total Persons Trips \_VF}} = \frac{86658426.8\ gm}{296847} = 291.9 \text{ gm / trip} \qquad (6)$$

Table 4: Emissions outside RR

Trip Mode	Person Trips	Modal Share	P-km	V-km	Average Trip Distance (km)	CO_2e / km	CO_2e -gm	CO_2e - ton	Remarks
Bicycle	5146	0.6%	16748.6	0.0	3.3				
Bus	139969	17.6%	816921.3	23340.6	5.8	808.8	18877883.4	18.9	
Car	127348	16.0%	718944.3	399413.5	5.6	247.1	98695080.0	98.7	

Microbus	33453	4.2%	158850.3	10590.0	4.7	377.5	3997731.9	4.0	
Motorcycle	387391	48.6%	2332234.8	1554823.2	6.0	79.7	123919411.0	123.9	
Tempo	1814	0.2%	12084.5	1510.6	6.7				
Walking	102347	12.8%	111381.4	0.0	1.1				
	797468						245490106.3	245.5	Total for one-way trip (T)
								491.0	Total Daily Emission, including return home trips ($DE_w = T \times 2$)
								137474.5	Annual Emission ($AE_w = DE_w \times 280$)

*** P-km**: Passenger km, **V-km**: Vehicular Distance in km

$$\textbf{Emission per Trip} = \frac{\text{Total Emissions \_VF}}{\text{Total Persons Trips \_VF}} = \frac{245490106.3\ gm}{688161} = 356.7 \text{ gm / trip} \qquad (7)$$

The total annual emissions for trips outside the RR are almost three times higher compared to those inside the RR. This difference can be attributed to a higher number of trips originating outside the RR, as well as the comparatively longer trip distances involved. Consequently, the average GHG emissions per trip for outside the RR are approximately 20% higher than those for inside the RR, with respective values of 356 g/ trip and 291 g/ trip (as shown above in Equations 6 and 7).

These figures highlight a problem associated with increasing urban sprawl and its resulting emissions. With a concentration of employment opportunities in the central region of the valley, workers residing outside the RR face longer trip distances, leading to higher emissions.

GHG Reduction Potentials

After estimating the vehicular emissions, it is important is to explore possible strategies towards its minimization. However, this task is not as straightforward as it may seem and addressing vehicular emissions requires a comprehensive approach that combines policy-level initiatives, changes in individual behavior, and overcoming implementation challenges. This paper discusses some of the potential approaches for reducing vehicular emissions, particularly for home-based work trips.

Modal shift to efficient modes

More than 65% of work trips currently rely on private modes of transportation. To reduce this dependency, a shift towards public transport is necessary. However, the lack of reliable and high-quality public transport services hinders this shift. Therefore, improvements are required in the public transport system to meet commuters' expectations, particularly in terms of timely service and comfort.

Recent developments have shown notable improvements in the quality of service provided by several public bus operators in the region. These advancements include the introduction of electric buses equipped with GPS tracking facilities and comfortable interiors for passengers. Such innovations not only enhance the overall travel experience but also contribute to reducing emissions associated with traditional fossil fuel-powered vehicles. With the increasing availability of these services and a growing awareness among the public about the environmental benefits of using public transport, there is a promising potential for a significant shift towards this mode of transportation. Additionally, services like the Safa Tempo, a three-wheeler public vehicle, along with microbuses, have expanded public transport options by servicing both main routes and feeder routes. This increased accessibility is crucial in encouraging commuters to opt for public transport over private vehicles, thus further aiding efforts to minimize vehicular emissions. In addition to enhancing the quality of public transport services, it is essential for individuals to have self-awareness and motivation to utilize public transport for their work trips whenever possible. This dual approach encourages greater use of public transit and contributes to more sustainable commuting practices.

Furthermore, the popularity of electric vehicles is gradually increasing, with more people starting to use electric cars and scooters. However, their current market share remains insignificant. The transport sector's energy demand in Nepal is primarily met by petroleum products, with electricity accounting for less than 1% of the overall share (WECS, 2022). Electric vehicles do not have any emissions, during its operational phase. However, more of the research is required with additional surveys to identify the share of electric vehicles and to analyze the emissions associated with other phases such as such as manufacturing, battery production, and electricity generation. While electric private vehicles seem to contribute to reduced emissions, they also present a significant drawback in the form of increased traffic congestion. The sheer number of these vehicles on the road can lead to heavy traffic, offsetting some of the environmental benefits they offer. Therefore, while electric cars and scooters may prove beneficial to the environment in the short run, it is important to consider their long-term sustainability from a broader perspective. Mass transit modes, such as public transportation, continue to be a more viable and sustainable solution.

Mixed Landuse and Compact Settlement

From a transportation perspective, the benefits of mixed landuse primarily stem from bringing diverse origins and destinations closer together. This proximity facilitates shifts towards nonmotorized modes of transportation and/or reduces travel distances ((Song, Merlin, & Rodriguez, 2013). However, in the context of Kathmandu Valley, the uneven distribution of residential and workplace locations results in longer trip distances for journeys outside the ring road (RR) compared to those within the RR. The region's increasing urban sprawl and concentration of centralized employment zones exacerbate this issue, leading to longer trip distances and ultimately higher emissions for trips originating from peripheral areas.

Minimizing trip distance through close proximity between homes and workplaces, achieved through mixed land use, can encourage the shift towards non-motorized modes of transportation. The concept of seeking job-housing balance holds many theoretical benefits. However, in practice, achieving this balance can be quite challenging. In some areas of Kathmandu, compact settlements have been established with residences and employment areas in close proximity. Nevertheless, finding a suitable match between nearby homes and workplaces is often difficult, as the available job opportunities may not align with the preferences or requirements of the residents. Consequently, there are cases where people still have to travel longer distances in search of suitable employment. While compact settlements with close proximity between homes and workplaces have not been entirely successful in the context of the Kathmandu Valley, they still possess the potential to minimize the need for longer commutes. Therefore, careful integration of such settlements in the planning process is crucial, rather than simply placing them together.

On the other hand, from a sustainable transport perspective, compact settlements with close proximity are generally preferred. However, it is important to consider other aspects as well. It has been observed that overly compact areas, such as many densely populated core settlements within the Kathmandu Valley, is creating an unhealthy living environment. The excessive compactness is leading to very dense settlements, resulting in a lack of open spaces, inadequate light and ventilation in dwelling units, and even unsafe areas from a disaster perspective. Therefore, it is important to find an optimal level of compactness that strikes a balance between mobility and a high-quality living environment.

When it comes to the use of non-motorized modes of transportation, compact settlements with shorter trip distances are often considered the preferable choice, as suggested by numerous studies. However, in the case of the Kathmandu Valley, this is not the reality, as the utilization of non-motorized is found to have no relation with the compactness. There is no significant relation between NMT share and population density as shown from correlation analysis in Figure 6. Bicycles are the least preferred option as shown by its share of less than 1 % for work trips. The lack of awareness regarding non-motorized transportation options, as well as concerns about road safety and poor road conditions, contribute to their unpopularity.

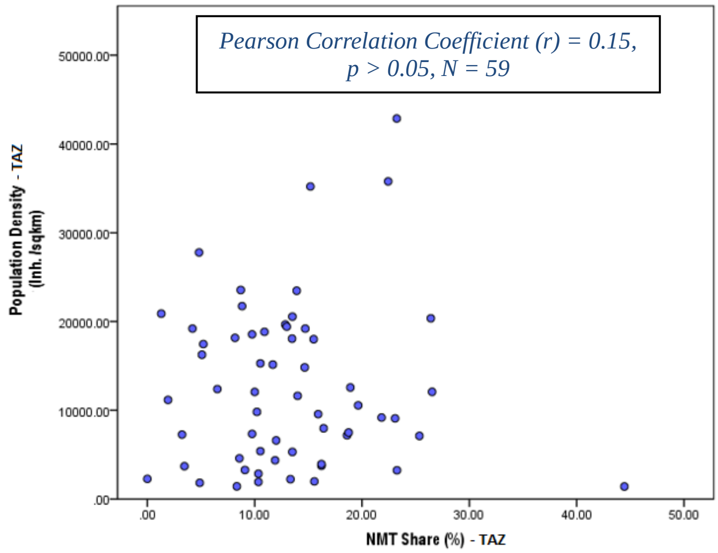

Figure 6: Scatter Plot - Population Density and NMT Share

Work from home trend: Tele-working

With the advancements in communication technology, working from home is becoming increasingly common. This trend provides an opportunity to eliminate work trips altogether, thereby avoiding associated emissions. According to estimates, work trips contribute approximately 664 tons of GHG emissions per day (Table 2). The adoption of remote work, even for one or two days a week, can make a significant contribution to reducing GHG emissions resulting from work-related travel. This is quite possible as one of the major lessons learned during the COVID-19 pandemic is the work-from-home trend. With the technology now familiar to most people, companies can take the initiative to develop work schedules that allow employees to work from home, as applicable. Promoting this trend will undoubtedly help minimize vehicular emissions by reducing the need for work-related travel. Working from home can minimize the need to travel. However, an extended period of remote work can lead to feelings of isolation and have negative psychological effects. Therefore, it is important to seek a balance between working remotely and working at the office. This combination allows for the advantages of online work while also providing the benefits of in-person collaboration and social interaction.

Conclusion

This paper analyzes the contribution of work trips to GHG emissions in Kathmandu Valley. The role of work trips in the transport sector has become a major concern due to the region's growing economic activities and urbanization. Balancing climate change and economic development poses a significant challenge for the urban transport sector.

The increasing number of vehicles, especially private vehicles, is the emerging problem for the transport system. Attracting commuters to public transport is a significant challenge, yet it is crucial for minimizing emissions, as the share of public transport for work trips remains significantly lower compared to private modes. Additionally, increasing the use of electric vehicles can provide environmental benefits, although there are some reservations regarding their overall impact.

Urban sprawl is a significant concern, as services and facilities are predominantly concentrated in the central region of the Kathmandu Valley. Trips originating from outside the ring road contribute more GHG emissions compared to those within the ring road. The primary factor responsible for the difference in trip distances is the longer travel distances associated with trips originating from the outskirt regions. These areas often require residents to travel further to access essential services and amenities compared to more central urban locations. Thus, achieving an optimal land use mix and compactness, as well as a job-housing balance within a given area, is crucial for minimizing the need for longer trips. This strategy encourages residents to live closer to their workplaces, thereby reducing travel distances and enhancing overall quality of life. In addition to reducing trip distance and promoting modal shift, the trend of working from home can play a significant role in emission reduction by reducing the need for travel. However, the implementation of a work-from-home system is still in progress, and the country lags behind in this regard.

While the research method used in this paper provides approximate estimates, it offers insights into the current scenario of GHG emissions resulting from work trips and explores potential solutions. To obtain more accurate results, advanced transport models could be employed to precisely map the mobility patterns. This study focuses solely on work trips, and future studies could include other trip purposes such as education, shopping, recreation, and freight to comprehensively analyze the transport sector as a whole. This paper discusses some of the measures that have the potential to minimize vehicular emissions. However, it is important to note that even within these measures, numerous challenges exist, making the task of reducing vehicular emissions complex. It is crucial to consider the solution from a transportation perspective, but also to examine its potential impact from different angles. Taking a holistic approach will help address the complexities associated with reducing vehicular emissions.

To conclude, this paper presents only a portion of the overall picture, highlighting the need for further research to comprehensively address the issue. It is important to acknowledge that reducing vehicular emissions is not a straightforward task. Ultimately, a successful approach requires a combination of top-down and bottom-up strategies. Collaborative efforts at the policy level are crucial, but equally important are the changes in individual behaviors that can lead towards reducing vehicular emissions.

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References

Aguiléra, A., Massot, M.-H., & Proulhac, L. (2009). Exploring the Relationship Between Work and Travel Behavior on Weekdays Analysis of Paris Region Travel Survey over 20 Years. Transportation Research Record: *Journal of the Transportation Research Board*, 2135, 69-77. doi:10.3141/2135-09

Banister, D. (1997). Reducing the Need to Travel. *Environment and Planning B: Planning and Design* 24(3): 437-449.

Bertolini, L., le Clercq, F., & Kapoen, L. (2005). Sustainable accessibility: a conceptual framework to integrate transport and land use plan-making. Two test-applications in the Netherlands and a reflection on the way forward. Transport Policy, 12(3), 207-220. doi:https://doi.org/10.1016/j.tranpol.2005.01.006

NSO (2021). *National Population and Housing Census 2021*, National Statistics Office, Government of Nepal.

CEN/CANN (2012). *Public Transport Quality Survey.* Clean Air Network Nepal (CANN) and Clean Energy Nepal (CEN).

Cerqueira, E. V., Baumvol, B. M., Chevallier, L. B., & Bonin, O. (2020). Does working from home reduce CO2 emissions? An analysis of travel patterns as dictated by workplaces. Transportation Research Part D: *Transport and Environment*. doi:ff10.1016/j.trd.2020.102338

de Abreu e Silva, J., & Melo, P. C. (2018). Does home-based telework reduce household total travel? A path analysis using single and two worker British households. *Journal of Transport Geography*, 73, 148-162. doi:https://doi.org/10.1016/j.jtrangeo.2018.10.009

EPA. (2014). *Emission Facts*. Environmental Protection Agency.

EPA. (2023). *Carbon Pollution from Transportation.* Environmental Protection Agency

Gireesh Kumar, P., Lekhana, P., Tejaswi, M., & Chandrakala, S. (2021). Effects of vehicular emissions on the urban environment- a state of the art. *Materials Today: Proceedings*, 45, 6314-6320. doi:https://doi.org/10.1016/j.matpr.2020.10.739

Hanson, S. (1995). The Geography of Urban Transportation: Second Edition.

KVDA (2014). Twenty Years Strategic Development Master Plan (2015 – 2035) for Kathmandu Valley, Kathmandu Valley Development Authority, Anamnagar, Kathmandu.

Ma, J., Liu, Z., & Chai, Y. (2015). The impact of urban form on CO2 emission from work and non-work trips: The case of Beijing, China. *Habitat International*, 47, 1-10. doi:https://doi.org/10.1016/j.habitatint.2014.12.007

NOC. (2023). *Import of Petroleum Products*. Nepal Oil Corporation

Song, Y., Merlin, L., & Rodriguez, D. (2013). Comparing measures of urban land use mix. *Computers, Environment and Urban Systems, 42*, 1-13. doi:https://doi.org/10.1016/j.compenvurbsys.2013.08.001

The World Bank. (2023). Urban Transport and Climate Change. Retrieved from https://www.worldbank.org/en/news/feature/2006/05/03/urban-transport-and-climate-change

UNECE. (2023). Climate Change and Sustainable Transport. Retrieved from https://unece.org/transport/climate-change-and-sustainable-transport

WECS. (2022). *Energy Sector Synopsis Report 2021/2022*. Water and Energy Commission Secretariat, Singha Durbar, Kathmandu, Nepal

Westelius, O. (1973). *The individual's way of choosing between alternative outlets.* National Swedish Institute for Building Research Document D 17, Sevensk Byggtjanst, Stockholm.

Whitelegg, J. (1997). Critical Mass: Transport, Environment and Society in the Twenty-first Century, Pluto Press, London.

Zhang, K., & Batterman, S. (2013). Air pollution and health risks due to vehicle traffic. Sci Total Environ, 450-451, 307-316. doi:10.1016/j.scitotenv.2013.01.074