Transport Sustainability of Dhaka: A Measure of Ecological Footprint and Means for Sustainable Transportation System

S. M. Labib[1]
Hossain Mohiuddin[1]
Shahadat Hossain Shakil[2]

Abstract

Sustainable city with sustainable transportation system in now become the heartiest demand for burgher, especially in a city like Dhaka; where ecological imbalance lead to unbearable livable condition with unsustainable growth in every sector resulting the degradation of life quality. Transportation sector in Dhaka is one of the major adherents behind ecological deterioration by emitting enormous CO_2 in atmosphere. Thus this study aimed at determining the transport footprint for vehicles travel in Dhaka. The study estimates the CO_2 emission from motorized vehicles using average emission factor method and then determines the average bio-capacity of Dhaka city to compare it with the footprint. The study finds out that only for vehicles CO_2 emission and physical transportation network; the transport footprint is seventy times larger than the bio-capacity. In transportation sector of Dhaka; ecological footprint credibly depicts the present condition, that is not at all sustainable from environmental friendly transport system context and it also an absolute indication for future concerning transport development pattern and their holes. At this point for developing sustainable transportation system considering ecological balance; Transport Demand Management (TDM), low carbon transport, transit oriented development (TOD), and creation of green corridors can be of some greatest tools for Dhaka.

Introduction

In the passage of time with the improvement of civilization the world faced hasty development, a rapid growth of urbanization which has created a negative impact on our environment by destructing the natural ecosystem. Fortunately, many countries become conscious about this problem and move forward for the model of sustainable development first articulated at Rio Earth Summit 1992. As defined by the United Nations World Commission on Environment and Development (WCED), "sustainable development requires that the economic and social needs of current generations be met without sacrificing the ability of future generations to achieve an acceptable quality of life." To design such a sustainable model Mathis Wackernagel and William Rees at the University of British Columbia proposed a method "Ecological Footprint". As explained by its creators, "ecological footprint analysis is an accounting tool that enables us to estimate the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area .Footprint comprises of many components, some of these are energy, transportation, water, waste, food etc" (Wackernagel and Rees 1996, p. 9).

Transport sector is an important sector to calculate the footprint of an urban area. In the urban area a large amount of vehicles moves per day. They use a large volume of fossil fuel. Burning these fuels in the chamber of these vehicles they produce a huge amount of CO_2 which they exhaust in the air daily. So, to reduce the effect of these extra CO_2 in the air we need to take some measure which can absorb this extra CO_2 from the air.

[1]Department of Urban and Regional Planning, BUET, Email: Labib.l.m@gmail.com / ovi_babu@yahoo.com
[2]Graduate Student, School of Environment, Education and Development (SEED), The University of Manchester, E-mail: shakil.shahadathossain@postgrad.manchester.ac.uk

Bangladesh was ranked 146th out of 187 countries in the 2011 Human Development Index, and Dhaka is consistently ranked one of the world's most unlivable cities in the Global Livability Report. Traffic congestion and air pollution play a major role in these poor rankings (Asian development bank, 2012). The transport conditions in Dhaka are characterized by chronic traffic congestion and delays, low quality of public transport service, lack of comfort and safety for pedestrians and growing air pollution (World Bank, 2009).

Here traffic congestion cost Tk 19,555 crore (nearly $3 billion) financial loss, wasted time on the streets accounts for nearly Tk 11,896 crore followed by environmental cost Tk 2,200 crore and business loss of passenger transport and freight industries Tk 2,000 crore each. Excess fuel (at the rate of CNG price) eats up Tk 575 crore and accidents Tk 50 crore. It also cost 3.2 million business hours are lost every day, which is about one hour per working people (The Daily star, 2010).

From the need of sustainable development the term sustainable transport has become a prime concern for this city. Sustainable transport deserves a system which does not or a few interrupt the existing ecology. So, the term ecological footprint is a tool to evaluate the transport system in the condition of sustainability.

Objectives

- To calculate the transport footprint of Dhaka city and make a comparative study between transport footprint and bio-capacity.
- To provide guidelines for transportation sustainability for Dhaka.

Methods and Materials

Study Design

To estimate the transportation footprint of Dhaka city's vehicles and road network, some sequential steps have been followed. At first the total number of vehicles travel in Dhaka city up to year 2009 has been collected from Bangladesh Road transport Authority (BRTA). For final computation of emission for Dhaka city's vehicles, data are collected from the research of Mr. Zia Wadud (Wadud, 2011) on CNG conversion on motor vehicles of Dhaka. Then for average emission factor method, CO_2 emission factors for various types of vehicles and various fuel types, has been collected. By multiplying the average emission factor with total number of vehicles and average vehicle activity for a typical day for that specific vehicle group the total emission for different vehicle groups has been estimated for a typical day on a year and finally by multiplying the total days of a year, the overall tons of CO_2 emission has been determined.

After determining the total CO_2 emission for a year, energy footprint of the roadway network on the basis of the area of forest land required to sequester carbon emissions produced by network travel during one year has been estimated. Here the carbon sequestration factor has been obtained from Climate Leaders – EPA, USA. From this process the energy footprint for vehicles and vehicle activity in Dhaka has been obtained. While for Road pavement footprint, the percentage of area under road network has been obtained from Detail Area Plan (DAP, 2004). From this percentage of land cover for Dhaka city dedicated for road network has been calculated. Finally the energy footprint for vehicle data and activity in combining with the road network footprint, the total transport footprint for Dhaka has been calculated.

The bio-capacity of Dhaka has been estimated form land use percentages for open spaces of Dhaka city. Here several criteria, such as; agricultural land, parks, garden, lakes, playgrounds, ponds, swamps, urban forest has been used. By determining the bio-capacity for Dhaka, the result is used for dividing the transport footprint to obtain the number of times the transport footprint exceed the bio-capacity. Based on these results some tools for sustainable transport sector for Dhaka has been determined on the basis of environmentally sustainable transport. Here major focus was given of emission reduction, alternative fuel, travel demand management etc.

Study area

Dhaka, the capital of Bangladesh and one of the major megacities in the world is the study area for this study. It is the 9th largest city in the world (World Bank, 2010). The geographic coordinate of the study area is 23°42′0″N 90°22′30″E with an area of 360km^2. According to 2008 data base of Bangladesh Bureau of Statistics (BBS) the total population is 7 million with a density of 23,029/km^2.

According to Detail area plan (DAP, 2004), Dhaka city has only 8% of land dedicated for the transport network. The city road network is characterized by chronic traffic congestion and delays, low quality of public transport service, lack of comfort and safety for pedestrians and growing air pollution (World Bank, 2009).

Motor Vehicle increase and composition in Dhaka

From BRTA the data of total registered vehicles up to 2009 have been collected. There are several categories of vehicles that have been registered up to 2009. The overall composition of all the vehicles types depicts a mixed characteristic. The increase in vehicle number form year 1995 to 2009 has remarkable with the increase of motor car and motor cycle (Figure 1).
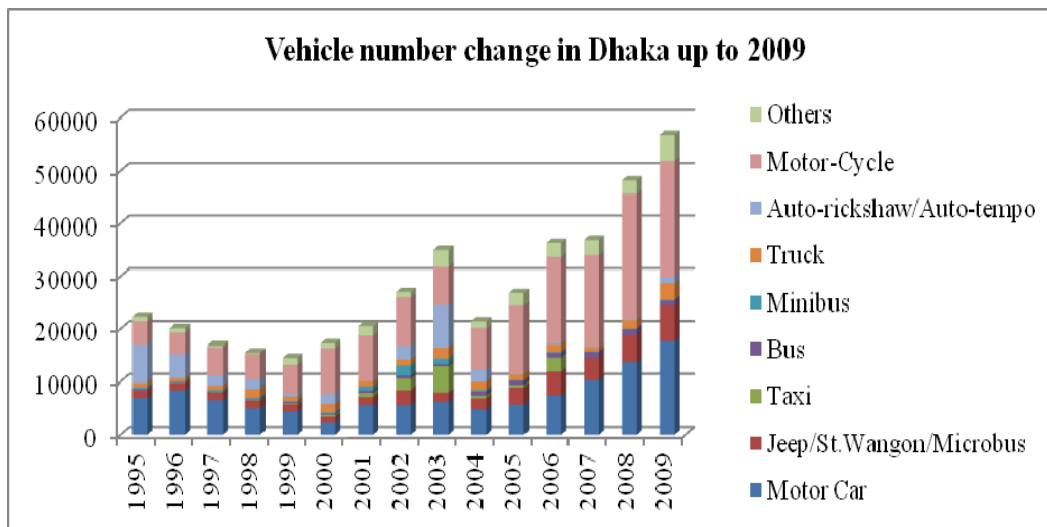

Figure 1: Number of vehicle change in Dhaka, up to 2009 (BRTA, 2010); Source: BRTA, 2011

For vehicle composition the study estimated the percentages of different vehicle categories (Figure 2).
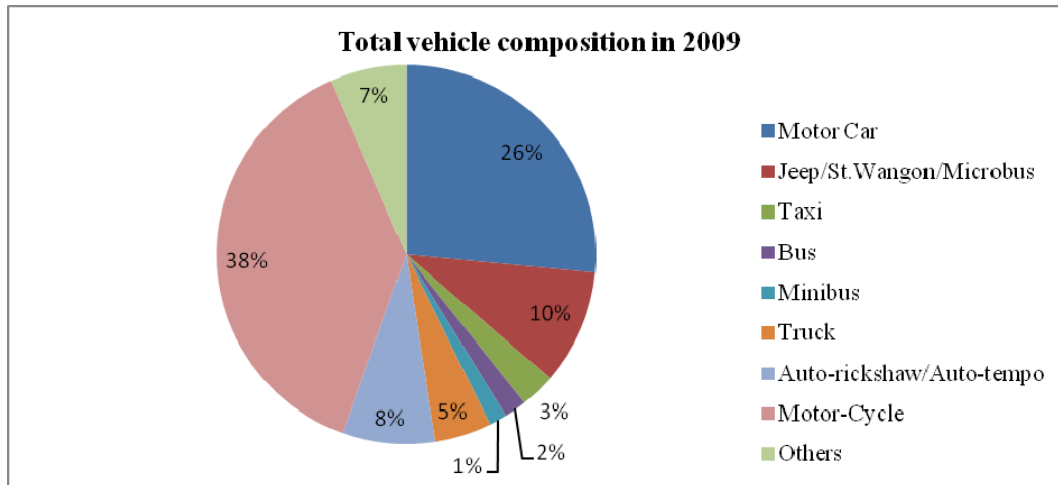
Figure 2: Vehicle composition in 2009; Source: BRTA, 2011

Fuel consumption pattern

The major fossil fuels consumed by vehicles in Dhaka are; compressed natural gas (CNG), Petrol, Diesel and Octane. The demand for petroleum products in the transport sector was 1.56 million MT in 1999-2000, which has increased to 2.03 million MT by the year 2005-06. Though the country has initiated a major drive to switch to compressed natural gas (CNG), cars driven by CNG has increased from 4.59% per year in the period 1999-2003 to only 4.62% per year in the period 2003-2006 (BPC, 2008). For the transport sector of Dhaka City, the daily consumption petroleum products has been reported as diesel 526.04 thousands liter, octane 175.97 thousands liter and petrol 23.12 thousands liter (Table 1). For CNG driven cars, the demand of petroleum products is very high. (M. Shafi q-Ur, 2009) nearly 70 million cubic feet of gas per day (mmcfd) is consumed by CNG stations in the capital (BPC, 2008).

Table1: Fuel Consumption in 2008 by Transport sector in Dhaka

Fuel type	Total consumption in year 2008
CNG	25,550,000,000 cubic feet (cft)
Diesel	192,004,600 liters
Octane	64,229,050 liters
Petrol	8,438,800 liters

Source: Bangladesh Petroleum Corporation (BPC), 2008.

Road network

Dhaka has less than 8% of its area devoted to circulation and it does not have an efficient public transport such as Mass Rapid Transit (MRT). More critically, only 250 km of the existing around 3000 km road network is wide enough and suitable for large size bus operation (Figure 3). The road network of Dhaka is very complex due to its unplanned development pattern. There are a lot of roads that are not in a condition of well operation for the vehicles. Considering the total 8% of

land devoted to transport sector the total area of 28.8sq km of land for transport network is
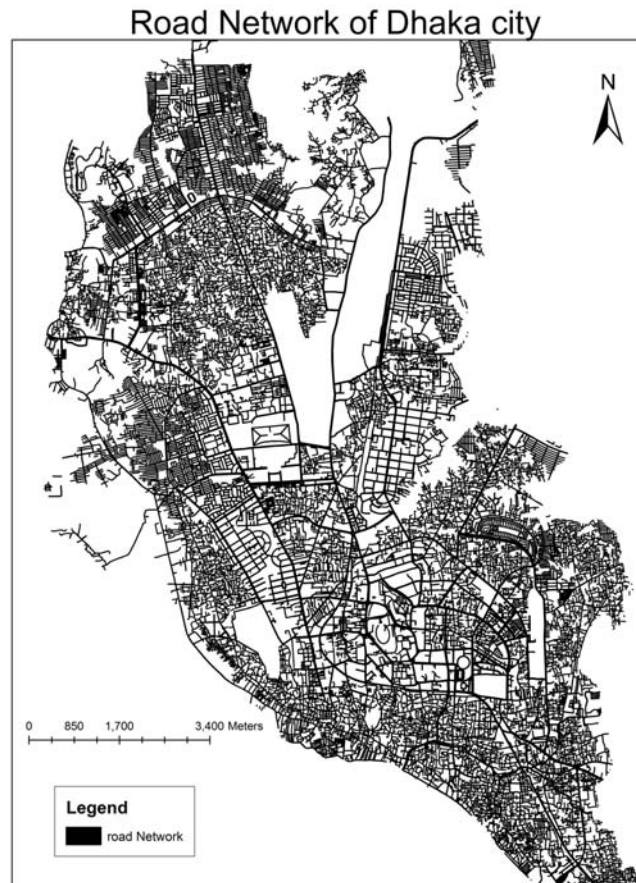calculated from the total area of Dhaka.

Figure 3: Map of road network in Dhaka; Source: DAP, 2004

Modal share

Majority of the trips, more than 55% of the total, in Dhaka City are pedestrian and Non Motorized
trips (Rahman, 2009). Data from a sample survey of STP conducted in 2004 reveals about 44%
trips are on bus or minibus and 34% on rickshaw whilst the remaining are walking and other
motor car trips respectively 14% and 8%(STP, 2005).

Theories and Calculation

Ecological Footprint

A measure of how much biologically productive land and water an individual, population or
activity requires to produce all the resources it consumes and to absorb the carbon dioxide

emissions it generates using prevailing technology and resource management practices (Rees & Wackernagel, 1996). Unit of measurement for ecological footprint is Global Hectare (gha).

Transport footprint

The transportation footprint quantifies two attributes of roadway networks. First, the total land area physically occupied by roadway paving is estimated and it is called "physical" or Road network footprint, this is easily derived with information about the number of lane kilometers roads and as well as the amount of land devoted for transportation network in a city. Second, it assess the amount of land that is required to remediate the energy waste produced through vehicular operation in a roadway network, the term is "energy" footprint (Guangqing Chi1 and Brian Stone Jr, 2005).

Emission Factor model

A single emission factor is used to represent a particular type of vehicle and general type of driving. Emission is estimated using the equation:

E (p, k, m, t) = y (p, k, m, t) * v (p, k, m, t) * VKT (k, m, t)

Where,

E = emissions of pollutant (p), for vehicle class (k) and fuel type (m) during time interval (t)

y = emission factor for pollutant (p), for vehicle class (k) and fuel type (m) during time interval (t)

v = volume of vehicle class (k) differentiated by fuel type (m) at specific time interval (t), and

VKT = Vehicle kilometer travel by vehicle class (k) for fuel type (m) at time interval (t).

Estimating energy footprint

For estimation of energy footprint, the amount of CO_2 emitted in Dhaka from transport activity has been calculated using the emission factor model. The number of vehicles is determined based on the percentage of CNG and other fuel types for each vehicle class (Tanim, 2011). These percentages are used on the base data of BRTA vehicle numbers. Here for other types of vehicles 50 -50 between petrol and diesel were assumed (Wadud, 2011).

For the emission factors for different vehicle groups based on fuel type has been obtained from Urbanemissions (2009) and also from Wadud (2011). These emission factors are primarily focused on vehicles travel on Dhaka's road network. The emission factors expressed emission from different vehicle types in gm/kilometer unit.

The vehicle activity data for specific vehicle groups on an average day is obtained from Khaliquzzaman (2006). These vehicle activity data express the average travel distance for specific vehicle groups in km/day unit.

The overall emission form vehicles travel in Dhaka is given in Table 2.

Table 2: Vehicle CO_2 emission in 2009 for Dhaka

Vehicle types	Vehicle type percentages[1]	Fuel Types	Number of Vehicles[2]	Vehicle activity (KM/Day)[3]	CO2 Emission factor(gm/km)[4]	Emission (Ton/day)
Motor cars	13.80%	Petrol	15219	40	258	157.06
Motor cars	86.20%	CNG	95066	40	237	901.22
SUV/station wagons	24.70%	Petrol	10046	40	331	133.00
SUV/station wagons	57.80%	CNG	23508	40	304	512.00

SUV/station wagons	17.50%	Diesel	7117	60	332.5	141.99
Taxis	100%	CNG	12291	130	237	378.68
Buses	24.20%	Diesel	3448	130	887	397.61
Buses	75.80%	CNG	10801	130	968	1359.16
Trucks	82.60%	Diesel	16718	60	887	889.74
Trucks	17.40%	CNG	3522	60	450	95.08
Autorickshaws	100%	CNG	32890	130	75	320.67
Motor cycle	100%	Petrol	157965	30	40	189.55
Others	50%	Petrol	13586	40	331	179.87
Others	50%	Diesel	13586	60	332.5	271.03
Total (ton/day)			415,763			5926.72
Year Average: 365*5926.72 = 2,163,255 ton per year						

Sources: ([1] Tanim, 2011); ([2] BRTA, 2011); ([3] Khaliquzzaman, 2006); ([4] Wadud, 2011).

Now to determine the total biologically productive hectares of area needed for consuming this emission a CO_2 Sequestration Factor is used for. It is 1.6175 for per acre of land then it is converted to local hectare by multiplying the resulting value by 0.4047 (Table, 3).

Table 3: Total area needed for absorbing the CO2 for fuel

Total tons of CO_2	Sequestration (tons CO_2/acre/year)	×	Hectares
2,163,255	1.6175[1]	×	0.4047[2]
Total area needed (in hectares)			541248.3

Sources: ([1] Ewing, Moore, Goldfinger, Oursler, Reed, & Wackernagel, 2010); ([2] U.S. Department of Energy and Information Administration, 2011).

Estimating Physical footprint:

Then total physical footprint or road network determined by calculating the total road area of Dhaka city. It is 28.8 sq.km (2880 hectares).DAP report indicates that 8% of total land of Dhaka city is dedicated for road network (DAP, 2004).So the total physical footprint is 2880 hectares.

Total Transport footprint

The total transport footprint is just the function of the total energy footprint and the physical footprint of the road network system. It is the sum of these two factors. By summing them the transport footprint is 544128.3 hectares (Table 4).

Table 4: Total Transport footprint

Total energy footprint	541248.3 hectares
Total physical footprint	2880 hectares
Total transport footprint	544128.3 hectares

Sources: Aughor.

Bio-capacity of Dhaka city

The total Dhaka city is about 360 square km. It is estimated that about 21.57 %of the Dhaka city area is dedicated to open space which is about 7765 hectares of land. Among this open space agricultural land is 12.12%, garden 0.9%, graveyard 0.036%, lake 0.15%, vacant space 5%, park 0.9%, playground 0.39%, pond 0.25%, swamp 1.82%, urban forest 0.02% etc. (Uddin M.N, 2006).

Results and Discussion

Transportation footprint and bio-capacity comparison

From the total ecological footprint it is evident that Dhaka city must have 544128.3 hectares of biologically productive area to absorb the CO_2 produced from the transport sector of Dhaka city. But bio-capacity in Dhaka city available in Dhaka city is 7765 hectares land only. So we can say that ecological footprint exceed ecological capacity by 70 times. So it is clearly evident that the Dhaka city is unable to absorb the produced CO_2 from the transport sector. Per-capita transport footprint is 0.077 hectares (For 7 million people, BBS 2008); while the national average of per-capita carbon emission is 0.34 metric ton (World Bank, 2009).

Therefore this pollution is scattered in Dhaka city and its surrounding areas and creating disruption in the environment. The ecological footprint is an important fact in the transport sector. It is found that the open spaces in Dhaka city is degrading in an alarming rate due to rapid urbanization and unplanned growth. Destruction of the parks, water bodies are increasing. New initiative of creating open space, parks, water bodies and planting trees become stagnant. So the overall open space in Dhaka city is decreasing. Also in the other hand in the transport sector of Dhaka; construction of new road ways and elevated express ways encourage the use of private automobile. This large amount of automobiles are consuming large amount of fuels which are also increasing the amount of CO_2 in rapid rate. Also the initiative of creating compact mixed used community, pedestrian friendly design has vanished from the town planning practice of Dhaka city. Which lead the people to become more dependent on the transport rather walk to small distance. These will lead the city people to become more and more dependent on transport. So if this trend continues the gap between per capita ecological footprint and bio capacity will rise further and create an unbearable effect on the Dhaka cities and its surrounding environment.

Unsustainable transport development and land use planning

The ecological footprint from transport sector and available bio capacity is showing the lack of sustainability concept in the transport sector. This is huge percentage in respect to the whole countries perspective. A higher concentration CO_2 emission is occurred from a small area only from transport sector. But this CO_2 needs a huge amount of open space to absorb to reduce its effect on the city and its surrounding environment. This indicates the lack of ecological concern in the transport planning.

The transport planning without considering any feasibility analysis lead to construction of more paved elevated road in the form of flyover, elevated expressway which will increase the footprint. In past 12 years 90% wetlands and low lands of Dhaka filled up. In surrounding areas of Dhaka 12 years ago there was 70% to 80% open spaces. But now it is also decreasing for change in land use. As the bio-capacity is decreasing and emission from transport sector is increasing; the overall scenario will be more devastating for ecology of Dhaka and surrounding areas.

Ecological footprint is now a day's used as a key issue in transport and urban planning context. The initiatives for reducing ecological footprint are taking as objectives in transportation planning. From the viewpoint of sustainable transport system it is necessary to ensure the individual demand

for transportation with maintaining the ecology, economy and the regional development. In context of Dhaka Sustainable transportation policy should be taken giving consideration on ecology and environmental condition of the city. The following aspects and policies should be incorporated in the urban and transportation planning of a city.

Transport Demand Management

Transport demand management (TDM) is a well-designed system for achieving sustainable transport system in a city. In Dhaka, to reduce the carbon footprint it can be a very efficient tool. Under TDM the following strategies could be utilized in context of Dhaka.

Pedestrian network improvement

As it is discussed before a considerable amount trips in Dhaka are made by pedestrian. Hence improving pedestrian facilities and integrate it to form well-articulated multimodal network can be a lucrative solution to reduce the carbon emission in Dhaka.

Improved non-motorized transportation

Non-motorized vehicles (i.e. Rickshaw) represent the image of Dhaka city. Non-motorized transport is fuel free transport and they do not produce any carbon emission; along with these they also carry the lion share of the trips in Dhaka. Hence improving non-motorized transportation system and making an efficient integration of them with vehicular transport can be another appealing solution for sustainable transportation system in Dhaka.

Innovation and utilization of low carbon transport

Pedestrian and non-motorized vehicles are two major components of low carbon transport system. Besides them energy efficient public transport and use of non-fossil energy source for vehicles and hybrid use of fossil fuel with non-fossil sources are another two important aspects of low carbon transport system. In Dhaka majority of the people use public transport for movement. But public transport system in Dhaka is not so improved to meet the demand; here we need the management issue along with the improvement in accessibility and service level and decreased generalized cost to attract all classes of people to use public transport. This will lower the use of private transport specially cars which emits a huge amount of CO_2 in the atmosphere. So fuel efficiency can be by using public transport.

Carpool or Car share

Carpool or Car share for office and school going trips can be arranged in Dhaka. A lot of office and school trips are usually made in Dhaka by motor car. For those trips the arrangement of car pool facility can be highly effective and efficient. This also could reduce the emission from individual motor car as well as could be convenient for the trip makers, usually do not like to travel in public transport.

Pay as you drive

To decrease the extensive use of private care, Pay as you drive; could be an efficient and effective option. This includes charge on mileage travel for private cars. This would discourage the car users to travel more and encourage them to shift form car to other modes.

Besides these under TDM fuel taxing for carbon content could be introduced in transport system of Dhaka. Along with TDM some other initiatives could be taken by the policy maker to improve the ecological condition and to ensure sustainability in transportation sector. Some of them are discussed below;

Non fossil energy source for vehicles and hybrid use of fossil fuel with non-fossil sources

Electronic vehicles (EV) could be largely used in Dhaka. There are some Battery Operated Auto-rickshaws in the city, but their use is not highly marked. These Battery Operated Auto-rickshaws could be a very well example for non-fossil energy driven vehicles. In other vehicles the conversion from fossil energy to electronic energy can be used also. Hybrid and Electric Vehicles could be section for innovation for Dhaka. Essentially a hybrid is a vehicle that combines electric power from an on board battery with a standard internal combustion engine (ICE) running on petrol, diesel or biofuels. In many vehicles of Dhaka we might utilize this system to reduce the emission of carbon.

Use of biofuels can be another section for further innovation in the transportation system of Dhaka. Biofuels are liquid fuels derived from many different biological sources which at present include sugar, wheat, corn, rapeseed, soy and palm oils. Using these new technologies to reduce the emission of carbon and dependency on fossil fuel can be better solution to improve ecological condition of Dhaka.

Mixed land use

Mixed land use necessary for a countries economic efficiency. It also lead to low dependency on transportation as work place and home become close enough to access by walking. So these lead to low emission of CO_2. Urban planning policy should be that discourage sprawl and encourage mixed land use.

Transit oriented development (TOD)

Transit oriented development is also significant policy to reduce dependency on motorized private vehicle and more dependent on transit facilities which will reduce the emission of CO_2. These are some policy recommendations for sustainable transportation system development in Dhaka city from the ecological, economic and environmental perspectives.

Conclusions

Environmental concern in the transportation sector is influencing the transportation planning process now a day's in all around the world. Ecological footprint in transport gives the policy makers a view of the transport pollution parameter and its scope for planning environment friendly transportation system. Dhaka city per capita transport footprint is not high compared to the development country. But in the context of the overall land use composition and available forestry it is unbearable for the city. So sustainable and efficient transportation system with improved non-motorized transport and low carbon transport policy can add a innovative dimension in the transport policy. Thus implementing the policies and taking the environmental concern on the Dhaka cities transportation planning a sustainable environment friendly transportation system can be achieved.

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