Land use change in Dhaka City Corporation Area and its impact on transportation: A way forward towards integration into national policies

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ABSTRACT

Land use and transport integration has been highlighted as one of the most important policy objectives considering the interrelationship between the two concepts and can be used as a means of planning through intervention. From the standpoint of revealing the interplay, the study's objective is to assess the land use change of Dhaka City Corporation Area and determine its impact on transportation to assist the national policymaking and achieve Sustainable Development Goals (SDGs). The methodology directed the determination of the land use change from 2010 to 2018, and then the consequent change in traffic flow while the necessary data in this regard were collected from secondary sources. The study shows that mixed-use development generates fewer trips. This is the study's finding in regard to integration among the national policies regarding land use and transport planning. This study is a methodological approach to analyse the impact of land use change on transportation and can be a role model for solving complex urban problems, e.g., traffic congestion by integrating the Land Use-Transport interaction. The study provides a background of the policymakers in their policymaking process, and an integrated policy will enable the nation to fulfil its Sustainable Development Goals.

KEYWORDS Integrated national policies; land use change; methodological approach; mixed use development; transportation
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1. Introduction

The rapid pace of urbanisation in developing countries is leading to drastic changes in land use and a significant impact on transport and road energy (Poumanyvong et al., 2012). With the rapid urbanisation and growing population of cities, the implications of changing lifestyles related to sustainable development problems and how these are addressed could be considered among the most pressing subjects of the urban planning profession. The complex nature of cities and politics force urban planners to scrutinise cities' contemporary sustainable development problems more comprehensively in order to produce more effective policy recommendations. It is evident that it is not easy to delineate sustainable development policies without an evaluation framework. Therefore, the demarcation of the problems associated with urbanisation patterns according to their effects on urban sustainability is a good starting point.

While urban sustainability encompasses a wide range of urban planning interests such as sustainable urban economy, infrastructure and services, integration of communities, green attitudes, public participation, and governance (Deakin and Lombardi, 2005; Finco and Nijkamp, 2001), most of the urban sustainability issues are discussed by focusing on spatial considerations, particularly on the urban form and its effects on mobility patterns (Kenworthy and Laube, 1996; Yigitcanlar et al., 2008). Identifying this interdependence between the urban form and travel pattern of individuals/households makes it possible to address the causes and intervention options for the pressing sustainable development problems. In fact, the emergence of the land use and transport correlation approach is a direct consequence of the contemporary planning practice dealing with the problems mentioned earlier from a comprehensive perspective (Krizek and Levinson, 2005).

Bangladesh, a developing country, aims to celebrate the golden jubilee of the nation in 2021 by taking its place amongst middle-income nations of the world from a low-income economy (General Economics Division, BD, 2012; Sarker, 2018). Declaring the Second Perspective Plan – "Vision 2041" as a guideline to reach Upper Middle-Income Country (UMIC) status by eliminating extreme poverty by 2030 and High-Income Country (HIC) status with poverty becoming non-existent by around 2041, Bangladesh is targeting to build sustainable cities, enforce efficient transport and reduce air pollution through low carbon strategies (BSS, 2019a; BSS, 2019b). Bangladesh has not only become among the top five fastest-growing economies in the world with a 7.3% GDP (Gross Domestic Product) growth rate but also has experienced faster urbanisation than South Asia as a whole (UNB, 2019; Das et al., 2019). United Nations projections show that by 2040, Bangladesh's urban population will likely have increased by 50% from the present 28% (Jones et al., 2016). Rapid GDP growth and urbanisation have resulted in considerable loss of arable lands and exerted tremendous pressure on limited resources, predominantly cultivated areas and forest cover (Dewan et al., 2012; Uddin et al., 2023). With a higher population density, the forest coverage of the country has been progressively depleted by agricultural expansion (Chandra and Shrestha, 1996). To attain substantial GDP growth and maintain the quality of the environment, a balance must be established between urbanisation and environmental pollution.

The full implementation of 13 out of 33 Millennium Development Goals (MDGs) has given Bangladesh the confidence to achieve the SDGs (Sustainable Development Goals) (BSS, 2016). Achieving the goals with limited resources, Bangladesh has to face some considerable challenges and may be putting too much pressure on energy consumption and the environment (Alam, 2019). A global report on the SDG index of 149 countries by the Sustainable Development Solution Network ranked Bangladesh last among the BIMSTEC (Bay of Bengal Initiative for Multi-Sectoral, Technical and Economic Cooperation) countries and second last among the SAARC (South Asian Association for Regional Cooperation) countries (Sachs et al., 2018). Estimates show that global investments of US$5 trillion to US$7 trillion per year (up to 2030) will be additionally required in order to achieve the SDGs in all countries (Department of Economic and Social Affairs, UN, 2014). Though Bangladesh will need a considerable investment in basic infrastructure, rural development, climate change mitigation and adaptation, etc., recent trends in investment in these sectors are not up to the desired level. However, the lack of integration of SDGs into the national planning process has been identified as a major constraint in achieving the goals (Das et al., 2021).

Under these circumstances, the research initiative aims to assess the relationship between land use and transportation, the key elements of economic development, with inherent coordination of environmental interaction, to show a way forward to achieve a balance between urbanisation and economic growth as well as the integration of co-beneficiary approaches to the national policies for efficient and effective allocation of resources to resolve multiple environmental problems.

Keeping pace with the urbanisation of the country, the capital city Dhaka, geographical position at 23°43′0″ North latitude and 90°24′0″ East longitude, is changing its land use (Ahmed et al., 2014). A study in Dhaka City Corporation Area with the above research objective can represent the whole country's Land Use-Transport dependency and fulfil the aim. Again, different reports on extreme traffic jams in Dhaka City draw attention to Dhaka. At the same time, other literature on land use change and transport studies has supported choosing Dhaka City Corporation Area as the study area. In this context, both Dhaka North City Corporation and Dhaka South City Corporation have been considered. Dhaka City Corporation (DCC) had 92 wards in 2011, and was divided into two self-governing corporations of Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC), having 36 wards (1-23, 37-47, 54 and 55) and 56 wards (24-36, 48-53 and 56-92) respectively (Tusher, 2011). Bangladesh's biggest urban agglomeration, Dhaka, is the largest city in Eastern South Asia and among the Bay of Bengal countries (Jones et al., 2016). It has grown mostly without adequate planning interventions, and has been substantially organic in nature since its establishment (Islam, 2005). The urbanisation of Bangladesh and the intense development of Dhaka City are inextricably interlinked as when the national population growth was 2.2%, its urban population was growing at an estimated 4% each year since independence (RAJUK, 2015). Dhaka is now the 11th largest city and is predicted to be the sixth largest megacity in the world in 2030. Therefore, the study assessed the land use change of Dhaka City Corporation Area from 2010 to 2018 to determine its impact on transportation to assist national policymaking and achieve the SDGs.

2. Literature review

Kodukula (2018) focused on the importance of integrating urban mobility and land use and the positive benefits of such integration. In his study, the aspects of compactness through policies on land use and connectivity were explored through this integration. His study also shows that some of the urban problems that the cities are facing in the urban mobility sector can be addressed through better land-use planning and appropriate integration with sustainable urban mobility modes.

Ahmed et al. (2014) analysed the transformation of the urban morphology of Dhaka city from 1947 to 2007. In their study, space syntax was used to examine the transformation of urban settlement patterns. The study shows that the combination, connectivity and comprehensibility measures of Dhaka City are found to be high, medium and low for the indigenous, mixed and planned settlement types, respectively. Islam et al. (General Economics Division, BD, 2012) evaluated the present condition of Wetlands compared to the past condition of wetlands in Dhaka city. The pre and present conditions of these wetlands were analysed using a map from 1960, a satellite image prepared by the GIS (Geographic Information System) and remote sensing. The study revealed that 49% of wetland areas in Dhaka city have been lost during the period of 1960 to 2008 due to unplanned urbanisation. These studies assessed the land use change of Dhaka City.

To understand the methods, some of the literature has been reviewed. Zsuzsannaa and Mariana (2012) evaluated the development of an enterprise active in this domain in Romania. According to their analysis, three performance indicators, namely the self-financing capacity, the return on equity and the degree of the technical endowment, are significant predictors for the dependent variable, namely the profit size. The correlation between personnel costs per employee and investment per person employed (0.977) is strong. Other important co-relations are self-financing capacity and investment per person employed (0.718) and self-financing capacity and personnel cost per employee (0.692). Their study helped to interpret the regression model.

Bharatkar and Patel (2013) performed supervised and unsupervised techniques on remote sensing data regarding land use/cover classification and evaluated the accuracy of both classification techniques. Their study revealed that the maximum likelihood classifier is a more desirable classifier for effective LULC mapping.

Sathya and Deepa (2017) conducted a comparative study on the accuracy of different supervised classification algorithms and techniques. Through the classification of satellite imagery, information such as cadastral information, land cover type, vegetation type, and soil properties could be obtained. The study applied supervised image classification using ArcGIS following the study.

Bharatkar and Patel (2013) discussed the accuracy of assessments determining the quality of the information derived from remotely sensed data. Evaluation of classification performance is an essential step in the classification process. Different approaches ranging from a qualitative evaluation based on expert knowledge to a quantitative accuracy assessment based on sampling strategies may be employed to evaluate classification performance. Six criteria are important for evaluating classification performance. They are accuracy, reproducibility, robustness, ability to fully use the information content of the data, uniform applicability, and objectiveness. In the study, classification accuracy assessment was performed to evaluate an efficient classification method for deriving the land use land cover map of the Ralegaon Sidhi watershed. According to observations, the classification accuracy of shrubs was found to be better for all classifiers except box classifiers, which indicates that the likelihood classifier is better for effective LULC mapping. LULC map and quantitative assessment could be utilised for better planning of wasteland management and agriculture development schemes. The study also checked the accuracy of image classification.

Fung (2006) examined and compared the effectiveness of different models for estimating missing values in time series data models. In this study, both deterministic and stochastic approaches were examined for time series with missing values. To compare their performance, simulated datasets for AR and MA techniques were used in each method, and MAD values were calculated. This research revealed that for most of the ARIMA time series models, ARIMA interpolation is the most suitable method for estimating a missing value with enough data to obtain a reliable ARIMA model. This study helped the estimation of missing values.

Moreover, from the perspective of Bangladesh, the General Economics Division and Planning Commission (2012) introduced transport as a vital element in fostering economic growth and development. The main vision of the perspective plan concerning transportation is to develop an efficient, sustainable, safe and regionally balanced transportation system. Some of the policy objectives are meeting the transport demand, introducing modern technology, re-orientating the development strategy, improving resource mobilisation, provision of required incentive packages and preparing a transport development strategy framework. Some road network strategies are being upgraded with existing roads maintained, along with routine and periodic maintenance programmes, an adequate number of east-west connections, and the pursuit of the road development policy. Reduction of the dependency on private automobiles, taxi cabs, and baby taxies, increasing the number of large-sized buses, and the introduction of Rapid Bus Transit will help develop urban transport. Some sustainable strategies are utilising the available land, arresting and reversing the land degradation process, protecting and enhancing biodiversity, managing and improving sanitation, increasing surface water sources, and designing policies on crop diversification. The literature review reflects that land use changes impact transportation, and no study has assessed this impact on the whole Dhaka City Corporation Area. To fill this research gap, the objective of the current has been formulated to identify the land use change and its impact on transportation in the case of Dhaka.

3. Methodology

A rigorous literature review has been conducted throughout the study, starting from the problem identification to the report writing. The literature review has helped to summarise the previous studies regarding these problems and assist with the methods and interpretation of the analysis. All data used for the study have been collected from secondary sources. Two types of satellite imagery were used to detect the land cover change through image classification. To analyse the land cover change, the supervised classification of remote sensing data has been adopted for the study.

Remote sensing data can be managed through a process called image classification to produce Land Use and Land Cover maps. Classification in remote sensing involves clustering the pixels of an image to a (relatively small) set of classes, such that pixels in the same class have similar properties (Mohd Hasmadi et al., 2009). Image classification is defined as the process of categorising all pixels in an image, or raw remotely sensed satellite data to obtain a given set of labels or land cover themes. For classification, the Supervised Classification method has been used, applying Maximum Likelihood Classification based on statistical analysis (Al-doski et al., 2013). In supervised classification, the analyst supervises the categorisation through a set of specific classes by providing training statistics that identify each category. The selection of appropriate training areas is based on the actual surface cover types present in the image (Lusch, 2015). Maximum likelihood classification calculates the probability of a given pixel belonging to each class. It then allocates the pixel to a particular class with the highest probability by calculating the mean and covariance matrix for the training sets whilst assuming a normal distribution (Sathya and Deepa, 2017). Supervised classification steps follow the following flow chart.

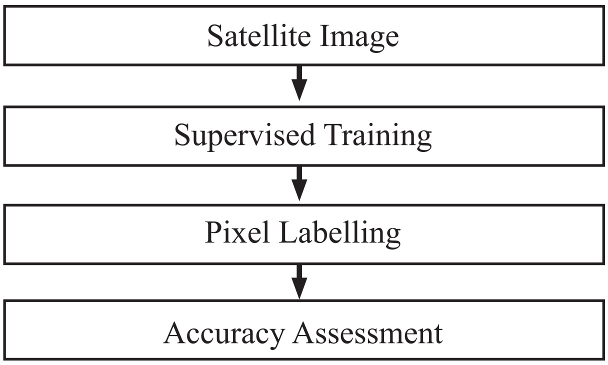


Figure 1. Steps of supervised classification (Al-doski et al., 2013).

Comparison to existing land cover maps from different literature reveals that supervised classification yields "cleaner" images than unsupervised classification (Tinio, n.d.). Following the flow chart and mentioned method, data classification was conducted with ArcGIS and the land cover change is presented on maps.

For 2010, Landsat 4-5 imagery and for the year 2018, Sentel-2 image was downloaded from the United States Geological Survey (USGS) website. Floor area data were extracted from the database of Detail Area Plans, i.e., DAP-2010 and DAP-2018. RAJUK (Rajdhani Unnayan Kartripakkha) set the structural use of buildings according to the maximum used floor (i.e., if most of the floor is residential, the building is declared a residential building). Transport data were collected from the BRTA (Bangladesh Road Transport Authority) and DTCA (Dhaka Transport Coordination Authority). The number of registered vehicles, number of vehicles with RFID (Radio Frequency Identification) tags, categories of vehicles providing RFID tags and most importantly, traffic count data of 24 arch points were collected from the BRTA. Survey data of RSTP (Revised Strategic Transport Plan) and DHUTS (Dhaka Urban Transport Study) were collected from DTCA. Then necessary data were extracted and analysed to achieve the study's objective.

The collected satellite imagery from 2010 and 2018 was classified with Supervised Classification following the Maximum Likelihood Method. The image classification was checked for accuracy to ensure the reliability and satisfactory accuracy of image classification allowed further analysis with this classification output. The total overall accuracy and kappa coefficient were determined from different types of accuracy assessment methods, as these are used in most studies which perform accuracy assessment (Adefioye, 2014). Total accuracy is computed by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels (n.d-b). A Kappa coefficient of 90% may be interpreted as 90% better classification than would be expected by the random assignment of classes. The general range for Kappa values is that $K < 0.4$ is a poor kappa value, while $0.4 < K < 0.75$ is a good kappa value and $K > 0.75$ is an excellent kappa value. The assessment of accuracy ensures the reliability of the classification method. The whole Dhaka City Corporation structures were extracted according to the ward for analysis separately. The different floor use of every structure was categorised in an organised way for further analysis. The raw or ungrouped data are generally in an unorganised form, which need to be presented in a meaningful and readily comprehensible form to proceed with further statistical analysis (n.d-a). The study assumes six types of uses and categorises data accordingly. No study or secondary data source gives the AADT (Annual Average Daily Traffic) of Dhaka City for the years of the study time period.

The yearly traffic count of the 24 Arch Point of Dhaka was converted to the AADT for the study area. As Dhaka City's traffic has not yet adopted the DNP (Digital Number Plate) and the Arch only counts the traffic with DNP, an error factor must be estimated, and the AADT was calculated with consideration of that error factor. To convert the AADT count to PCUs (Passenger Car Units), the average PCU (0.91) was calculated accordingly. As the BRTA provides RFID tags according to vehicle type, it was difficult to calculate the actual PCU value. However, average PCU values of each category were calculated. A weighted average PCU was found from the percentage of vehicles having RFID tags for each category of vehicle. Some missing data needed interpolation to undertake further analysis. In this context, the linear regression line was used for interpolating missing data. The DHUTS data provided the traffic scenario of 2014 and that predicted for 2025. To present the scenario in 2018, traffic generation from the TAZ (Traffic Analysis Zone) was interpolated.

Data analysis led to the ultimate output of the study. The land cover classification analysis depicts the land cover change from 2010 to 2018. The analysis with ward-wise different categories of floor area use presents the change from 2010 to 2018 and indicates the vertical expansion influence on different land uses. Scrutinising analysis of the increase in residential floors was also included in the study. Multivariate regression model analysis also explains the influence of the change of the variables on the dependent variable and thus explains the relationships between land use and transport. Correlation analysis is also a major indicator of the relation between transport and the environment. Trend line analysis shows the change with time. Thus, further quantitative analysis gradually enabled the study to fulfil the objective.

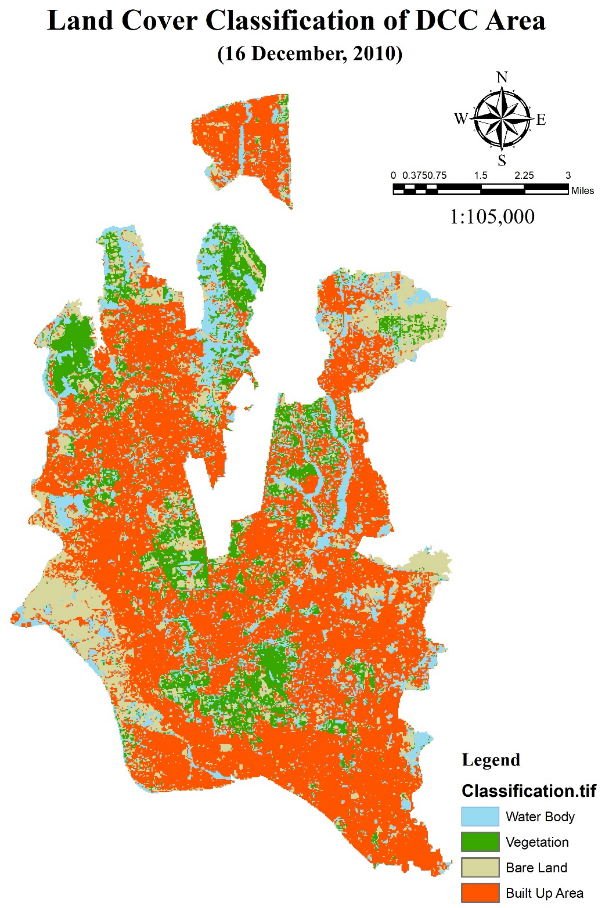


Figure 2. Land cover classification of DCC Area in 2010.

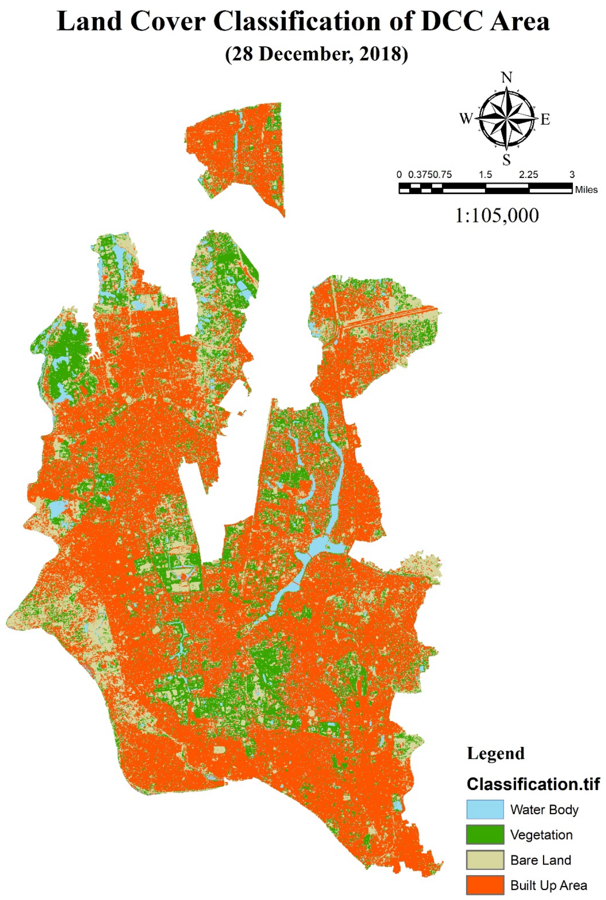


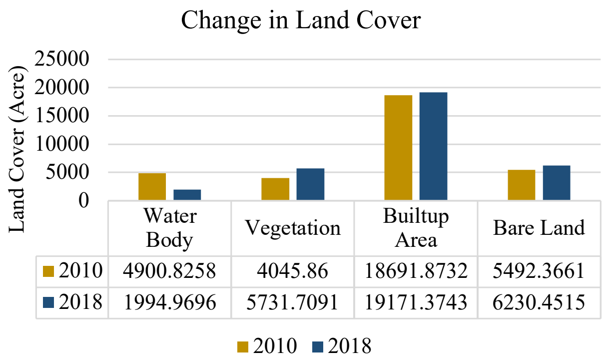
Figure 3. Land cover classification of DCC Area in 2018.

4. Change in land cover from 2010 to 2018

The Landsat satellite imagery of 30 m resolution of Dhaka City Corporation Area of 2010 was classified with ArcGIS in the four classes (vegetation, water body, built up area and bare land). The classification exhibits an accuracy of 90.5% and a Kappa Coefficient value of 0.87, which is a good level for acceptance. The classification output shows that the land's major category is the built-up area. In 2010, there were 18,691.87 acres of built-up area, 5,492.37 acres of bare land, 4,900.83 acres of water body and vegetation of 4,045.86 acres. The high proportion of built-up area is an expected output because the literature shows Dhaka City Corporation Area to have a high density of buildings.

On the other hand, the classification of sentinel images of 10 m resolution in the year 2018 followed the same method. The Supervised Maximum Likelihood Classification method has an accuracy of 96.1%, and the Kappa Coefficient value is 0.95, which supports the accepted classification. In 2018, Dhaka City Corporation had 19,171.37 acres of built-up area, 6,230.45 acres of bare land, 5,731.71 acres of vegetation and 1,994.97 acres of water body. The built-up area accounts for more than the natural land (sum of water body, vegetation, and bare land). These results show a high building density in Dhaka City Corporation (both north and south). The sum of the total area remains unchanged from 2010 as Dhaka City Corporation has not expanded horizontally (ignoring the little difference that happened due to the difference in resolution of images in 2010 and 2018).

Comparing these two land cover classifications for the years 2010 and 2018 of Dhaka City Corporation Area demonstrates the change in land cover during the last eight years. The following bar chart illustrates the difference in land cover.



	Water Body	Vegetation	Builtup Area	Bare Land
2010	4900.8258	4045.86	18691.8732	5492.3661
2018	1994.9696	5731.7091	19171.3743	6230.4515

Figure 4. Change in Land Cover.

The comparison shows that the water body decreased in 2018, and the other land cover classes increased. Different studies also show a decrease in water body in Dhaka City (Sultana et al., 2009). Landfilling and encroachment are two leading causes of decreased water bodies (Islam et al., 2010). Due to landfilling, the water bodies are being converted to other land uses. However, the chart shows that the greatest increase of land cover is vegetation, but most of the water bodies have been converted into built-up area. The increased number of buildings from 2010 to 2018 evidences this conversion. But along with the increase in buildings, rooftop gardening has increased in recent times. Government policies have also encouraged rooftop gardening in Dhaka City Corporation Area. Sayeed Khokon, Mayor of DSCC, declared a 10% tax rebate if house owners do gardening on the rooftop, balcony or the compound (The Daily Star, 2016). Other literature also shows a mentionable percentage of rooftop gardening in different places of Dhaka City, notably Lalmatia (59.2%), Dhanmondi (39.1%), Mohakhali Defense Officers Housing Society (DOHS) (36.6%), Uttara (22.2%), Mirpur, Mohammadpur, etc. (Islam et al., 2019; Nira, 2004; Rahman, 2014). The satellite image does not consider these buildings as built-up areas but as vegetation cover. The conversion of natural land (water body) to built-up area has resulted in a more congested Dhaka City.

5. Change in floor area use from 2010 to 2018

The land cover change assessment indicates that within these eight years (2010 to 2018), the study area has not expanded horizontally, but there has been an increase in built-up area. Analysing the floor area use will also show the change in floor area used in the built-up area. The assessment of floor area use is based on the database of DAP (the first one for 2010 and the second for 2018). Residential floor area dominated every ward of DCC in the year 2010. The other uses are of a low percentage compared to the residential uses. DCC (all together with the 92 wards) has 3,175,485,678.63 m2 of residential floor use, which is 99.21% of the total floor area use.

Due to the restriction of urban service boundaries, Dhaka City expanded vertically more than horizontally between 2010 and 2018. This vertical change has had a great impact on the floor area use too. The analysis reflects that residential floor use represents the top category of uses in every ward. In 2018, DCC (considering the DNCC and DSCC as DCC area and analysing it as a whole) had 91,065,455.15 m^2 of residential floor, 12,329,677.75 m^2 of commercial floor, 9,890,793.73 m^2 of institutional floor, 26,770,107.08 m^2 of mixed-use floor, 2,554,390.10 m^2 of industrial floor, and other uses accounted for 6,230,595.21 m2 of floor area. DCC (both north and south) has the greatest floor area for residential use, but the other uses have increased in percentage terms. It is indicated that there has been a change in the percentage of different floor area uses in DCC from 2010 to 2018.

Further analysis of the floor area shows that residential floor area decreased and institutional and mixed-use floor area increased. Residential use decreased (the percentage of residential floor area use decreased from 99.21% to 59.93% from 2010 to 2018) because the core residential buildings have decreased in number and been converted to mixed-use buildings. As the study cannot analyse the floors individually, floor use has been considered as use for the building and for all the floors of that building. This indicates that mixed-use buildings also have residential floor uses, which have not been considered separately. A decrease in residential use does not indicate fewer residents in Dhaka City Corporation Area in 2018 than in 2010. The increase in institutional buildings indicates an increase in education, health, service or other community facilities and at the same time, an increase in government and non-government offices and institutions. This is an indication that Dhaka City Corporation's facilities are expanding as well. There has also been an increase in the utilisation of mixed floor space. Growth in commercial applications indicates that Dhaka is becoming a bustling metropolis. Though industrial use has increased, the portion is not much compared to the increase in institutional or mixed-use floor areas. Other types of land use are considered in a category, and their percentage also has increased compared to 2010.

The summary of the comparison of different types of floor area uses in the wards is in relation to land uses in 2010 and 2018 in DCC. The core residential uses decreased from 99.21% to 59.93% with conversion to other floor area uses. The comparison of floor area uses (other than residential use) is shown below by the height of the bar chart.

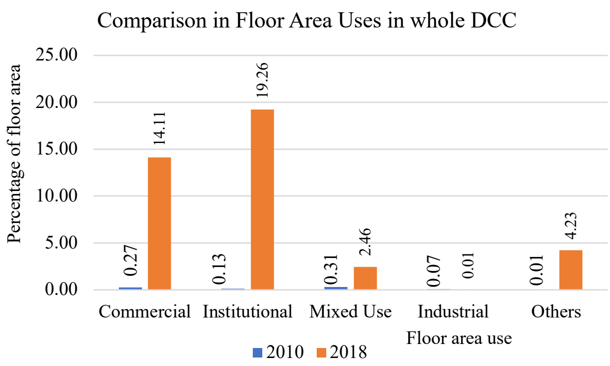


Figure 5. Comparison of floor area uses.

The change in percentage overall in DCC is shown in the bar chart that illustrates more clearly the increase and decrease in different land uses in 2018. The rightwards moving bars indicate the increase, and the leftwards moving bar indicates the decrease in land use. The bar length shows the extent of land use change. The graph explains that only residential use has decreased, and institutional use has increased the most overall in DCC. The next land use that has increased in DCC is commercial land use and other uses. Changes in floor use areas differ from ward to ward. Considering the greatest changes in a specific floor use, 12 wards experienced a major increase in residential use. Similarly, six wards saw an increase in commercial use, 10 wards in institutional, 41 wards in mixed-use and 23 more in terms of other types of land use where no ward saw increase in industrial use to a major extent. Though the whole of DCC witnessed an increase in institutional land use considering the floor area, most of the wards experienced a percentage increase in mixed use.

The land cover assessment shows that there had been an increase in built-up areas and a remarkable decrease in wetlands by 2018 from 2010. The land use assessment shows a decrease in core residential land uses and the greatest increase in institutional land use in the DCC area. Ward-wise analysis shows that most wards experienced the highest increase in mixed land uses. Residential floor areas have increased with the increasing number of buildings as well as the number of floors in each building in the wards.

6. Dependency of AADT on Built-up Area, Total Traffic and Per Capita Income

A multivariate model with the variables AADT, Built-up Area, Total Traffic, and Per Capita Income can express the dependency of traffic on land use and the associated variables. Multiple linear regression analysis is considered to present the relationship among the significant driving factors of AADT to avoid multiple dimensional complexities (Permana and Aziz, 2016). Annual Average Daily Traffic (AADT) is the dependent variable. More built-up area indicates more residents in the city who may contribute to generating more traffic. This means that there is a relation between the built-up area and the generated traffic, i.e., AADT. Again, more traffic will contribute to the increase in AADT. If the per capita income of people increases, it is expected that people will travel more, and the number of trips will increase. So the increased number of trips will result in increased AADT. These all indicate that the AADT depends on the amount of built-up area, the amount of total traffic in the city and the per capita income of the people.

Permana and Aziz (2016), in their book *Land Use, Urban Mobility & Environment Nexus: Evidence from a Developing City* explained land use and traffic dependency using a multivariate model where Traffic Volume (PCU) is the dependent variable with Natural landuse to built-up environment change (ha), Car ownership (per thousand population), Length of urban road (km), and Per capita income (USD) as independent variables. This also defines the dependency of AADT on Built-up Area, Total Traffic and Per Capita Income.

The relation can be expressed as the following function:

$$\text{AADT} = f(\text{Built-up Area, Total Traffic, Per Capita Income}). \quad (1)$$

Here the built-up area is in acres as this is the unit used for ground measurement, and per capita income is in BDT (considering an average of 1 US$ = 84 BDT). Per capita income for the whole of Bangladesh is used as the per capita income of Dhaka City Corporation.

The Pearson's correlation values are significant as the significance values are less than 0.05. Again, it is shown that the independent variables are very strongly correlated with the dependent variable.

Multiple regression is a statistical technique that can be used to analyse the relationship between a single dependent variable and several independent variables. The objective of multiple regression analysis is to use the independent variables whose values are known to predict the value of the single dependent value. Each predictor value is weighed, with the weights denoting their relative contribution to the overall prediction.

$$Y = a + b_1X_1 + b_2X_2 + \cdots + b_nX_n. \quad (2)$$

Here Y is the dependent variable, and $X_1,\ldots,X_n$ are the n independent variables. In calculating the weights, a, $b_1,\ldots,b_n$, regression analysis ensures maximal prediction of the dependent variable from the set of independent variables. This is usually done by least squares estimation.

Though the multivariate linear regression demands the independent are not highly correlated with each other, there is also a robust correlation. Then proceeding to the multilinear regression analysis with the variables using the SPSS (Statistical Package for the Social Sciences) software, the following equation has been formulated.

$$Y = -487963.652 + 28.588\,X_1 + .003\,X_2 + .494\,X_3. \quad (3)$$

Here,

$$Y = \text{AADT (PCU)},\ X_1 = \text{Built-up area (Acre)},$$
$$X_2 = \text{Total volume of traffic in Dhaka City}, \quad (4)$$
$$X_3 = \text{Per Capita Income (BDT)}.$$

The regression statistics summary is shown below.

Table 1. Regression model summary.

Model summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995[a]	.990	.976	2035.1628

a. Predictors: (Constant), income, built-up area, car number
b. Dependent variable: AADT

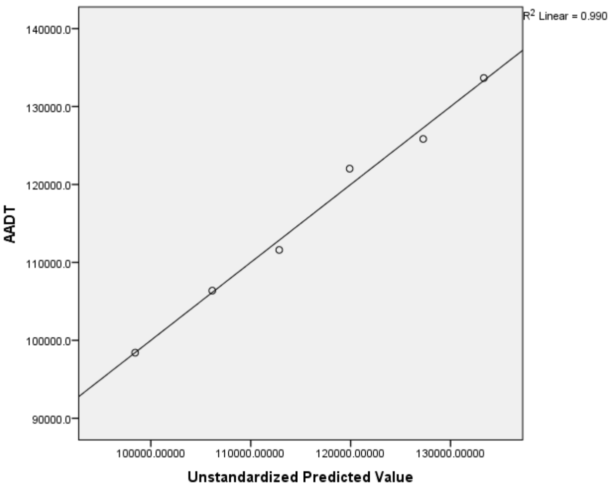


Figure 6. Regression line of AADT with other independent variables.

With a 95% confidence level and a standard error of 2035.16, the regression coefficient r is 0.995, and r^2 is 0.990. The intercept in the equation appears because of a few reasons such as not considering the other influencing factors in relation to AADT and the very strong correlation among the independent variables. The equation explains how AADT will be changed with a change of specific variables in a unit. The equation shows that if other variables remain unchanged, a unit change in built-up area will increase by 28.59 times. Similarly, 0.003 and 0.494 values denote the slope of AADT increase with the total volume of traffic in the city and per capita income. The regression model shows that for an increase by one unit of the dependent variable, built-up area makes a 98.29% contribution to the increase in AADT. The total traffic in the city contributes 0.01% and the per capita income contributes 1.70%. This indicates that an increase in built-up area contributes the most to the AADT. An increase in per capita income does not mean an increase in private cars as the increase is not accelerated due to inflation. However, an increase in built-up areas accelerated the increase of AADT the most.

7. Relation between household income and trip purpose

The previous multivariate model indicates a positive relationship between per capita income and AADT. This leads to an analysis of the relationship between trip purpose and household income. The DHUTS conducted a survey in 2014 to determine the trip purpose of households. They considered some Traffic Analysis Zones (TAZs) to conduct the survey where the TAZ Zone 1 to 90 where a combination of the Ward 1 to 36 of DNCC and ward 1 to 54 of DSCC, and the TAZ 97 area was considered as the DSCC ward 55 and 56.

To compare the trips in different income groups, the following bar chart helps.

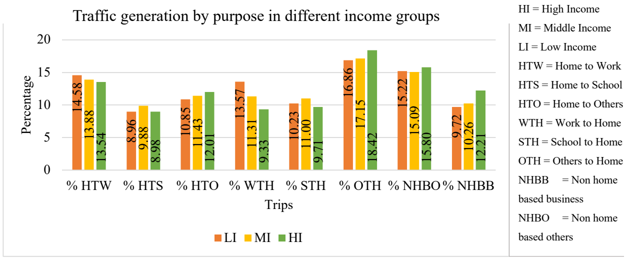


Figure 7. Traffic generation by purpose.

The comparison shows that high-income households make more trips other than for work or school, whereas middle- and low-income people mainly travel for work or school. So, the increase in income results in a greater number of trips, which the previous regression analysis also supports.

8. Modelling trip generation and floor area use

The study formulated a multivariate model to analyse the relation between trip generation and different types of floor area use. Different land uses impact the trip generation where the land uses are independent and not correlated with each other. As representing the dependency of trip generation on different floor area uses has been the main concern, multiple linear regression analysis is a measure for presenting the relationship. Therefore, significant analogous variables were selected, and other externalities were negotiated to avoid complexities and stay focused on the relationship between trip generation and floor area uses. The trip generations of wards were collected from the DHUTS survey data and interpolated for 2018. The two-tailed Pearson's correlation analysis with a 95% confidence level shows a moderate correlation of different floor area uses with trip generation. The multivariate regression line was formulated after the multiple regression analysis with the data set.

$$Y = 50652.562 + .014\,X_1 + .192\,X_2 + .076\,X_3 - .040\,X_4 - .267\,X_5 + .389\,X_6, \quad (5)$$

where Y = Trip Generation (vehicle count), X_1 = Residential Floor Area Use (m^2), X_2 = Commercial Floor Area Use (m^2), X_3 = Institutional Floor Area Use (m^2), X_4 = Mixed Floor Area Use (m^2), X_5 = Industrial Floor Area Use (m^2), X_6 = Others Floor Area Use (m^2).

Table 2. Regression model summary.

Model summary.				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.728a	.530	.497	70385.873

a. Predictors: (Constant), other floor use, industrial floor, institutional floor, mixed-use floor, commercial floor, residential floor

b. Dependent variable: trip generation

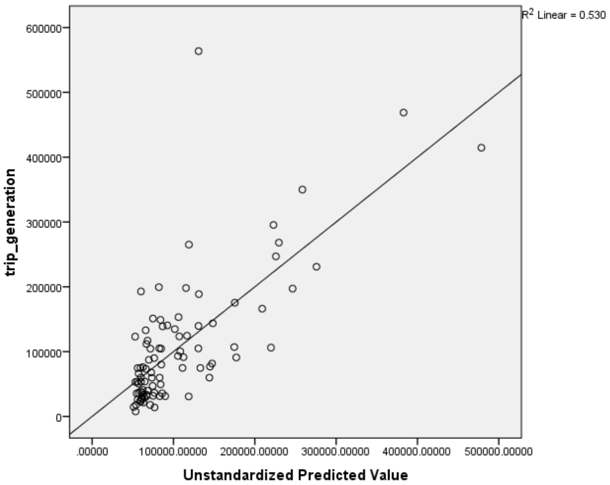


Figure 8. Regression line of trip generation and other independent variables.

With a 95% confidence level and a standard error of 70385.873, the regression coefficient r is 0.728 and r^2 is 0.530. The intercept in the equation appears because of not considering the other influencing factors in relation to trip generation like road condition, traffic availability, etc. The equation explains how the trip generation will change with the change in different types of land use. It shows that the trip generation will increase if the residential and commercial floor area use increase. Residential area is the origin and destination of every journey, and that is why more residential areas increase trip generation.

Similarly, the increase in commercial floor area means that the city is becoming busier, and it is usual for this to increase trip generation. Again, an increase in institutional floor use also attracts people to travel to that area to enjoy the facilities. However, there is a negative relation between trip generation and mixed and industrial use. Industrial uses are not inviting for people to choose to live there. As few people want to live in an industrial area, fewer trips will be generated. Again, in the case of increased mixed use areas, people buy their necessities within the area and need to move with the traffic. This results in less trip generation. The regression model also explains that for a unit change of the dependent variable, the industrial area will contribute 27.3%, commercial area 19.63%, institutional area 7.77%, mixed use area 4.09%, residential area 1.43%, and the other percentage will be contributed by other uses.

It can be concluded that the built-up area greatly impacts AADT, and also, AADT relates positively to total traffic and income. Along with the variation in income, travel purpose changes impact trip generation. Again trip generation increases with residential, commercial or institutional land use and decreases with industrial or mixed use area increase. This means that a change in land use type can impact transportation with a change in trip generation and the AADT. The models also explain the extent of this impact.

9. Major findings and outcome of the study

Analysis of the land use of Dhaka City Corporation Area shows that land use has undergone a change in direction over the last eight years. In the last eight years, Dhaka city's water body decreased by 2,905.856 acres and was converted to other uses. Though the image classification shows a great increase in vegetation, this vegetation is mainly due to rooftop gardening, and the increase also happened in built-up areas. The increase in built-up areas led the study to analyse the vertical change and assess the land use change in built-up areas. The land use assessment in conjunction with the floor area use shows that whereas in 2010, most floor was used for residential purposes, in 2018 other land use increased in proportion. Among 92 wards, only 12 wards saw increases in core residential land use, and the other wards experienced conversion of residential land use to other uses. Most wards (45%) have faced a major increase in mixed-use floor area. The whole of Dhaka City Corporation (both north and south) lost 39.28% residential area with a major increase in institutional area (19.13%). More scrutinising analysis of those wards that underwent increases in residential floor area use shows that along with the number of buildings, the number of floors of residential buildings has also increased. This increase in residential use may impact transportation as the household’s area is the origin and destination of every journey. Analysis of the dependency of AADT on Built-up Area, Total Traffic and Per Capita Income shows that the built-up area contributes 98.29% to a unit change of Annual Average Daily Traffic (AADT). The multivariate model shows that if other variables remain unchanged, a unit change in built-up area will increase the AADT by 28.59 times, and the AADT also has a positive relationship with the total traffic (.003 times) and per capita income (.494 times). Trip purpose varies with household income, and a high-income household has a greater percentage of trips other than for work or school. Trip from the house to other purpose indicates an increase in trip number resulting in an increase in trip generation. Trip generation is positively proportional to residential floor use (.014 times), commercial floor area use (.192 times) and institutional floor area use (.076). Trip generation decreases with an increase in industrial floor area use (.040 times) and mixed-use floor area (.267 times). This trip generation dependency on different land uses and the industrial floor area use contributes the most (27.3%) in total the total raise of the transportation demand. This multivariate model indicates that an increase in mixed land use can decrease trip generation, and this land use impacts trip generation by 4.09%. Urbanisation influences the way people travel, and in turn, the traffic flow of the urban area is influenced. Numerous studies have shown that people living in a compact neighbourhood with a higher level of public transport accessibility do not use cars frequently. They are more likely to use public transport, hence reducing AADT and pollution (Li, 2011). To reduce the transport/land use impacts, policy interventions can be classified into push and pull measures. Push measures encourage higher taxes to discourage the use of private vehicles, and pull measures encourage improving the attractiveness of public transport services by lowering fares (Cools et al., 2009; Kamruzzaman et al., 2013). However, it can be concluded that with the development of highly accessible public transport, a balance between employment and housing land use by reducing the disparity between inter or intra-region promotion of mixed-used development must be incorporated with land use policies to inspire travel on foot or use of bicycles and public transport (Parvez and Das, 2021).

Moreover, Bangladesh is not well prepared for electric vehicles as most electricity is generated from fossil fuels (coal and natural gas). Renewable and nuclear energy have not yet contributed much to the power sector (Roy and Parvez, 2019). Again, discouraging people from using cars by imposing fuel and parking taxes, congestion fees, and electronic road pricing must be added to transportation policies along with emission and noise control rules.

10. Conclusion

The study finds that a less built-up area contributes to less traffic (AADT). Again the land use type also impacts the trip generation and AADT. Mixed floor area use decreases the trip generation where the residential area increases. Development of mixed-use areas, rather than zoning, will generate less traffic and AADT. The study recommends limiting the increase of built-up area and encouraging mixed-use development to reduce the AADT. Encouraging mixed-use development in the national land use policies and master plans and integration of transport planning can result in environmental protection as the co-benefits and reduce the cost of environmental protection measures. This integration of national policies will guide the city's future development during its urbanisation. This study will work as a background study of the policymakers in their national policymaking process.

Notes on Contributors

Ms Sumita Roy is practising as an Urban Planner in Bangladesh after graduating from the Department of Urban & Regional Planning, Rajshahi University of Engineering & Technology (RUET). To contribute more to her professional field, she is also very dedicated to research. She has a number of publications on different domains of urban planning. Her research interest is focused on, but not limited to, land use planning, transport planning, environmental planning, regional planning, and participatory planning. She aims to work towards the nation's development with her knowledge and experience of urban planning and also contributes to protecting the global environment.

Mr Mohammad Shahriyar Parvez is an Urban Planner who wishes to contribute to the substantial research activity regarding climate change, environment, and sustainable development happening throughout the globe. Mr Parvez is a graduate in Urban Planning from Rajshahi University of Engineering & Technology (RUET). He is a member of the Bangladesh Institute of Planners (BIP). He has a genuine interest in the social development sector of Bangladesh to collaborate on broader sustainability agenda. His research interest resonates around adaptation strategies for combating climate change, including community-based adaptation to enrich community resilience as well as ensuring participatory planning and facilitation of environmental sustainability with proper natural resource management. He has an excellent and practical understanding of the socio-political and economic contexts around the globe. As a budding student from Bangladesh, he is always keen to build an advanced knowledge base, with the efficiency and capabilities to make a significant positive difference to the world's welfare.

Mr Anutosh Das is an Urban Planner by Passion and Profession who wishes to comprehend the interplay between haphazard urban growth and the environmental sustainability of cities from a global, inclusive standpoint. Mr Das has been a Faculty Member in the Department of Urban & Regional Planning at Rajshahi University of Engineering & Technology (RUET), Bangladesh since 2016. He is a graduate in Urban Planning from Bangladesh University of Engineering and Technology (BUET) and currently pursuing an M.Sc. in Urban Planning at The University of Hong Kong (HKU) as a ADB-JSP Fellow. He is an affiliated Member of the Royal Town Planning Institute (RTPI) as well as an Associate Member of the Bangladesh Institute of Planners (BIP). As a professional, he is predominantly interested in effecting positive change in cities and urban environments globally. His research interests are diverse but all revolve around Environmental Planning and Natural Resource Management with a focus on Climate Change Adaptation and Natural Resource Economics, Natural Hazard and Disaster Risk Management, Green Infrastructure Planning, Regional Econometric Analysis, Spatial Planning and Urban Land Use - Transportation Interaction Analysis. His profound academic and professional background focuses on the sound assimilation of the global economic and socio-political context in mainstreaming governance issues as an adaptive measure of global climate change.

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