



## EXPLORING IMPACTS OF URBAN DENSITY ON TRAVEL BEHAVIOR IN KHULNA CITY, BANGLADESH USING SPATIAL ANALYSIS

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KUS: 21/41: 29112021

Manuscript submitted: November 29, 2021

Accepted: July 24, 2022

### Abstract

Urban density not only represents the intensity of travel demand, but also serves as a useful tool for quantifying the elements that influence travel behavior and demand. In this study, Khulna City of Bangladesh has been selected as a case study to explore the impacts of urban density on travel behavior in a city of a developing country. The average characteristics of urban density, as well as their impacts on travel behavior and demand, have been studied using geospatial analysis techniques. Urban densities have been categorized into Single Density (Population Density, Employment Density, and Building Density) and Composite Density (Household to Work trip Density, Household to School trip Density and Household to Shop trip Density) based on characteristics of travel behavior and demand. Descriptive statistics have been used to explore the impacts of urban densities on the various trip characteristics such as trip production, trip distance, trip cost, trip time, and trip mode. Diversity of trips and overall trip attraction areas have been identified using the Shannon diversity index and other spatial analyses. Trip production, trip distance, trip time, trip cost, and mode choice all show a positive linear relationship with urban single-density, according to this study. The everyday activities of residents are closely related to urban composite densities, and trip production increase in tandem with composite densities. It has been concluded that different urban densities have significant impacts on travel demand and travel behavior.

**Keywords:** Urban density, travel behavior, mode choice, spatial analysis, trip variation

### Introduction

Transportation is one of the most important sectors among all sectors that the urban planner has to plan because the economic and social condition of a city largely depends on the transportation systems. Urban transportation systems spatially connect various activities occurring in an urban area (Meyer & Miller, 1984; Sun et al., 2017). The urbanization of developing countries is dynamic; large cities in these countries are under constant strain as a result of massive migration from rural regions and the rapid rise of private transportation services in addition to the public transportation (Domencich & McFadden, 1975). Travel behavior depends on dynamic factors of transportation where people's characteristic and the geographic location plays an important role. People use transportation for different purpose but the variation of travel behavior highly depends on the geographic location. Travel behavior in urban area is different from other sub-urban and rural area (Ewers, 1995; Kockelman, 1997). People's activities cannot be performed without traveling; hence transportation plays the most crucial part in their day-to-day activities. The trip of people is closely related to their social demographic characteristics such as gender, age, marital status, occupation, education level, vehicle ownership, and family activities. Working activities, educational activities, shopping, leisure activities, and so on are all included in the activities (Maduwanthi & Marasinghe, 2015). One of the most important factors in determining travel demand and behavior is urban density. It not only reflects the magnitude of travel demand, but also provides a useful technique for quantifying the elements that influence travel demand and behavior (Cervero & Kockelman, 1997). The significant proportion of data collected and analyzed in many disciplines of urban planning and development, such as various statistics and observation data, is regional. As a result, it is a useful tool for identifying, quantifying, and describing urban development and changes based on urban densities (Peng & Lu, 2007).

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DOI: <https://doi.org/10.53808/KUS.2022.19.02.2141-se>

Bangladesh is a developing country and its third largest metropolitan city is Khulna. With the passage of time, modern science and technology adhere the changes required for the human civilization. The earth has become the primary concern to prioritize the changes in terms of land use and transportation. In this era urban density is increasing day by day (Bhadra & Sazid, 2015). With the growth of population, the demand will change with socio-economic pattern of the community. The urban transportation system has been aggravated by population growth, which has resulted in it exceeding its capacity (Sharmeen, 2014). Khulna city is also facing increased population growth and rapid growth of urban built up area day by day. Defining the Khulna city's transportation sector, it has peculiarities and has great dependence on non-motorized slow-moving vehicle (Bhadra & Sazid, 2015).

Individual and household socioeconomic variables have been proven to have a significant impact on mode choice decisions in previous study. Income, gender, car ownership, and employment status are the most important variables in determining the mode of transportation, and approximately 50 to 60 percent of trips are completed for work, school, or shopping (Lin & Yang, 2009; Miller et al., 2005). According to a series of researches, sociodemographic factors have a significant impact on travel preferences (Hanaoka et al., 2014; Hsieh et al., 1992). Gender, household income, household composition, car ownership, and age, among other variables, have a larger impact in socio-demographic aspects (Curtis & Perkins, 2006). Many researches have investigated into the connections between work patterns, time management, and travel behavior (Aguilera, 2008). The majority of human trips are done for work, school, and shopping purpose that's why these three purposes of trip is used in this research. This study aims to identify the patterns of travel behavior in Khulna City, investigate the relationship between urban density and travel behavior, and determine the most diversely attractive travel destination in the city.

### **Materials and Methods**

This research has applied spatial analysis to explore the impact of urban density on travel behavior in Khulna, Bangladesh. The impact of urban densities on travel behavior has been studied for various landforms and activities based on this analysis. The main purpose of this research is to observe the spatial relationship between urban density and travel behavior. The selected study area for this research is Khulna City Corporation area. Khulna is one of the largest metropolitan cities in Bangladesh. Geographically, Khulna lies at 22°49' north latitude and 89°34' east longitudes. Khulna is a linear-shaped city. There are mainly two reasons behind the selection of the study- i) Urban density is increasing day by day in this city and the purpose of this research is to explore the impact of urban densities on travel behavior. ii) The census data, Detailed Area Plan and Master Plan of Khulna city is available which can be a great help for data collection.

### ***Necessary Data and Sample Size***

For this research both primary and secondary data have been used. Secondary data has been collected from BBS population and housing census 2011, Detail area plan and other related information. Necessary secondary GIS database is collected from KDA and Urban and Rural Planning discipline of Khulna University. BBS statistics were forecasted for 2019 in order to be used in this study. To get travel behavior data systematic random sampling technique have been used to determine the sample size. Each ward has been considered as traffic zone and major road is the main target to collect sample data in this sampling process. Primary data collection has been done through questionnaire survey at household level in 2019. The Household interview survey has been conducted to know the socio-economic status of the trip maker, travel characteristics for different modes, trip purpose, travel distance, travel time, travel cost etc. For estimating the sample size, Yamane's Simplified Formula for Proportions method is used. Total 400 household survey has been done for this research where the acceptable sampling significance was 5%.

### ***Urban Density and Travel Behavior***

In this research, Single density and composite-density are two forms of measurable urban density indicators that have been used. Population density, employment density, and building density are all included in a single density. Home to work trip density, home to school trip density, and home to shopping trip density are all included in the composite density. Trip production, mode choice, trip distance, trip cost, and trip time, on the other hand, have all been considered into travel demand. In this work, the single density and composite density are calculated using the spatial analysis approach. GRID has been created for all data in the GIS environment to identify the relationship between urban densities and travel behavior. Basically, (400m\*400m) 0.16 sq km GRIDs are prepared to increase

the accuracy of the trip destination data and then using a spatial analysis method, mathematical calculations were made among the GRID data in the context of urban density and travel behavior.

According to method suggested by (Hanaoka et al., 2014), purpose wise trip origin-destination and trip number composite density is generated. Where trip flow from origin to destination and trip number is used to measure composite density in Khulna city. Line density is measured through ArcGIS where each trip flow represents the length of the portion of each line that falls within the circle radius. The corresponding population field values are total number of weekly trips in a household for each trip purpose.

$$\text{Composite Density} = ((L1 * V1) + (L2 * V2)) / (\text{area of circle})$$

The length of the portion of each line that falls within the circle is represented by lines L1 and L2. V1 and V2 are the corresponding population field values.

It has been hypothesized that people's travel behavior will vary because of the variation of urban density. In order to meet the objectives formulated before the study, various analytical procedures e.g. cross-tabulation, and multiple response analysis have been performed. This analysis was done using SPSS and MS Excel. These procedures have given us information on trip generation, the pattern of trip variation with variation in housing condition, land use, family-size income group modal choices in the study area. The conceptualization of this research is shown in **Figure 1**.

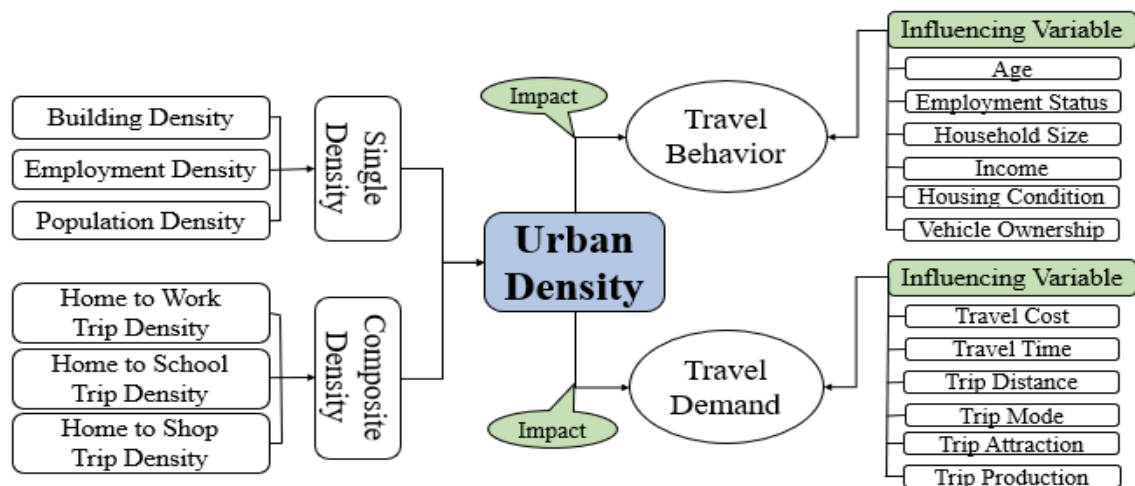


Figure 1. Conceptual flow chart of this study

## Result & Discussion

### *Travel Behavior in Khulna City*

The study of what people do in space and how they use transportation is known as travel behavior. It is critical to understand the behavior of a large number of people while examining travel behavior. Individuals' decision to choose one option among the others in the choice set, as well as their assessment and consideration of the various alternatives, must be based on various of factors, including their need, task, socioeconomic, environmental, and the level of service provided by the various alternatives. In the following part analysis has been done for household and individual attributes including housing type and mode choice, mode choice by income group, mode choice and trip purpose, and using travel distance by trip purpose for different modes.

The analysis result (Figure 2a) shows that use of various kind of modes varies significantly with the change of housing type of the trip makers. Lower income group basically lives in Katcha house, and they like to walk prior to use any kind of motorized mode for producing trip. That's why people from Katcha housing likes to walk and produce 48% of total walking trip. Easy Bike has been found as the most dominated mode in Khulna City. The 'private car' mode is used only by the people from 'Pucca' house type, as they earn more. The high-income group people in Khulna city prefer to use mainly motor cycle, rickshaw or private car.

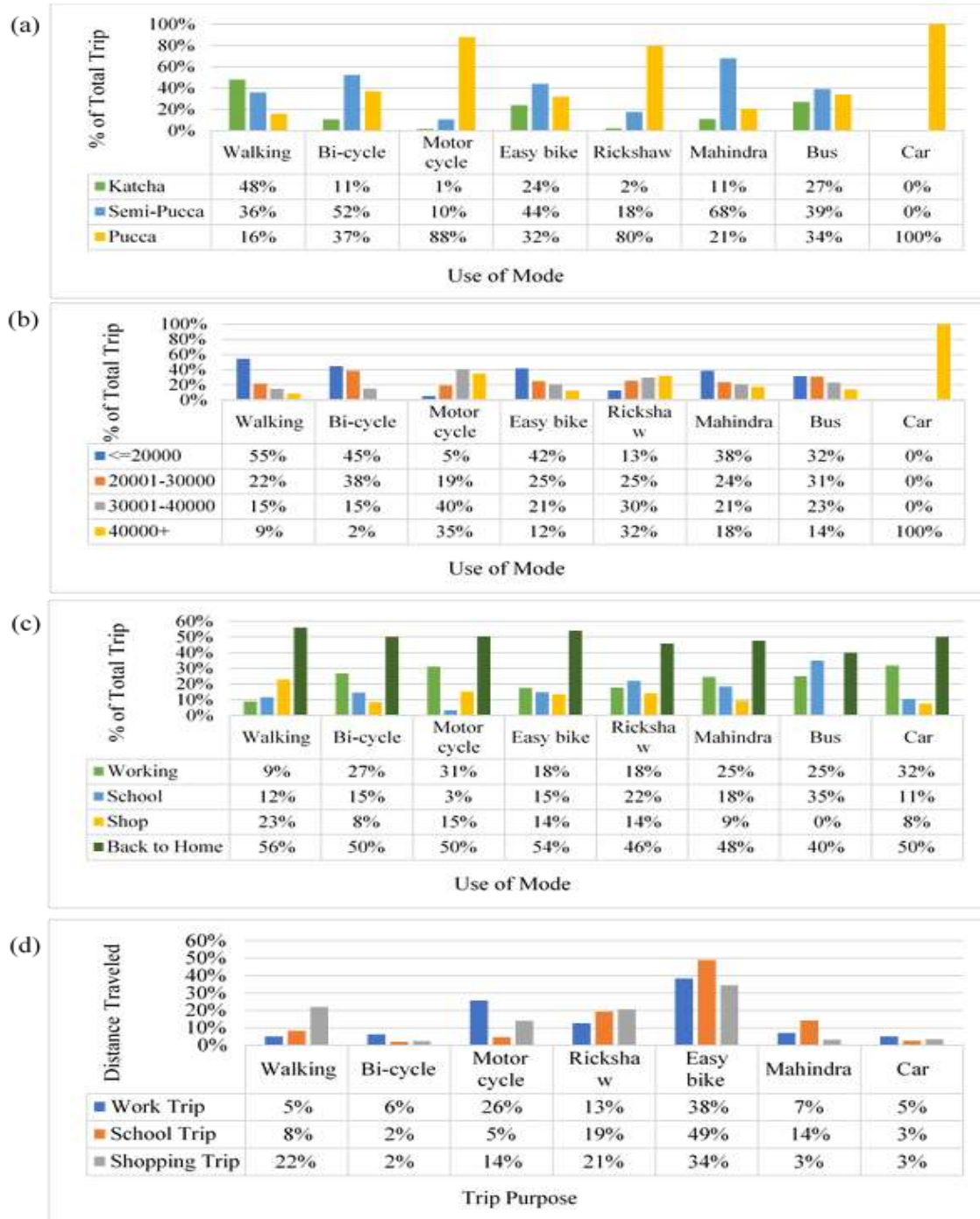


Figure 2. Travel Behavior in Khulna City use of different Mode by a) Housing Type  
 b) Income Group c) Trip Purpose d) Travel Distance

Use of mode changes when the income group changes (Figure 2b). People who have a lower income usually likes to walk where person with a handsome income tends to choose motorized mode e.g. motorcycle, rickshaw, personal

car or others. Figure 2b shows the monthly household income in Khulna city, broadly categorized into four major groups. Use of personal vehicles e.g. motorbike or personal car is pretty low in the study area and so does the use of public transport as there is no effective public transport system in Khulna city. Privately owned vehicle and rickshaw is mainly used by the comparatively high-income group. Use of travel mode changes with the change of purpose of any trips.

The cluster bar chart (Figure 2c) shows that people like to walk for shorter trips no matter what the purpose is. But in case of women or child use of rickshaw and easy bike is common for making any trip regardless of travel distance. It is also seen that people use different modes in different times of the day.

In recent decades, trends in travel behavior have been characterized by increase of trip distances and a modal shift towards the private vehicle. But in the selected area the scenario is different, here most of trips are made by a particular paratransit called ‘easy bike’. From the clustered bar chart (Figure 2d) it is clear that for all purposes of trip maximum distance is travelled by easy bike- such as for work trip 38%, school trip 49% and shopping trip 34% distance of the journey is travelled by easy bike. In the case of shopping trip maximum distance is travelled by rickshaw compared to other two trip purposes.

### **Mode Choice of the Home-Based and Home-End Trip**

Mode choice is the most important determinant of the travel behavior of the people. Travel mode choice indicate the social and economic condition of the people in developing countries. The mode also indicates the transportation supply in the city.

Work trip is the most important purpose for all trip makers. For leading human life work trip is mandatory for all. Work trip is the main factor which produces most of the trips. The result (Table 1a) shows that Easy bike is the most dominant mode for work trip. It also shows the differences between Home-Based Trip and Home-End Trip mode choice. Here for the work trip purpose Home-End rickshaw choice is lower than Home-Based trips but Home-End walking & Easy Bike choice is higher than Home-Based trips.

Table 1: Mode Choice of Home-Based & Home-End Trip for a) Work b) School c) Shopping

Purpose	(a) For Work		(b) For School		(c) For Shopping	
	Home-Based Trip	Home-End Trip	Home-Based Trip	Home-End Trip	Home-Based Trip	Home-End Trip
Walking	13%	15%	17%	24%	37%	31%
Bi-cycle	7%	7%	5%	5%	3%	3%
Motor cycle	18%	18%	2%	2%	11%	11%
Rickshaw	17%	10%	27%	18%	16%	24%
Easy bike	34%	40%	42%	44%	31%	29%
Mahindra	3%	3%	3%	2%	2%	2%
Car	4%	4%	2%	2%	1%	1%
Bus	3%	3%	2%	2%	---	---

School trip also another major purpose for all educated family. According to Bangladesh Government, now a day’s primary education is mandatory for all level of people. Here for the school trip purpose Home-End rickshaw choice is lower than Home-Based trips but Home-End walking & Easy Bike choice is higher than Home-Based trips (Table 1b). Easy bike is the most dominant mode for school trips as well. Shopping trip is also another major trip purpose; to meet basic need shopping trip is a must for any household. Shopping trip distance and trip number per week is low compared to other two purposes of trip. It also shows the differences between Home-Based Trip and Home-End Trip mode choice (Table 1c). Here, for the shopping trip purpose Home-End walking and Easy Bike choice is lower than Home-Based trips, but Home-End rickshaw choice is higher than Home-Based trips.

### ***Urban Density and Travel Demand in Khulna City***

The number of people who live in a given urbanized area is referred to as urban density in urban planning and design. As a result, it differs from other population density measurements. When it comes to understanding how things operate, urban density is a critical factor to consider. The intensity of human activities within the confines of city space, as well as the intensity of urban land use development, are both reflected in urban density. Due to the close relationship between urban density and mixed land use, its analysis can produce a lot of information about urban travel demand. Considering all issue, two types of density have been considered in this research- **A.** single density and **B.** composite density.

#### **A. Single Density:**

In this research under the single density category three types of density have been considered-population density, employment density and building density. Population density and Employment density maps have been prepared using BBS 2011 community series data where the density map shows per acre population density and employment density respectively. And building density is prepared using the KDA DAP data, where per acre floor density is measured. Figure 3a shows the population density in KCC area where per acre density is measured. Ward no 19, 20, 27, 26, 25, 10, 11 and 12 shows high population density where per acre population density is 151 or close to 151. Figure 3b shows the employment density in KCC area where per acre density is measured. Here, ward no 7, 11, 19, 20, 21, 22, 26 and 27 shows high employment density where per acre employment density is 9 or close to 9. This result shows high variation of employment density among the wards. Figure 3c shows the building floor density in KCC area where per acre building floor density is measured. Minimum per acre building floor density is 3 and maximum building floor density is 23.65 per acre in KCC area.

#### **B. Composite Density:**

In this study three types of composite density are measured through origin to destination trip flow. According to three purposes of trip three types of composite density are measured using spatial analysis- Household to Work trip density, Household to School trip density and Household to Shop trip density. Figure 4a shows the Household to Work trip density. From the spatial analysis it is clear that trip concentration is higher in the ward no 19, 20, 21, 22 and 23. Highest household to work trip density indicates the TAZ where maximum work trips are attracted. Basically, this is the CBD area in Khulna city.

Figure 4b shows the school trip density, and it is clear that trip concentration is higher in the ward number 6, 9, 14, 24 and 27 where maximum school trips are attracted. Most of the bigger educational institutes are situated in these wards. It is also clear that most of the household to school trip density is observed at the middle of the southern and northern part of the KCC area. Figure 4c shows the shopping trip flow from household. Trip density is higher in ward no 5, 6, 10, 14, 16, 17, 19, 20, 21 and 24. Higher household to shopping trip density is visible near the residential areas of KCC area. This indicates the fact that most residential areas are served by a market in proximity. To meet the local demand most of the wards in KCC area have small or medium sized grocery market in proximity to the residential areas.

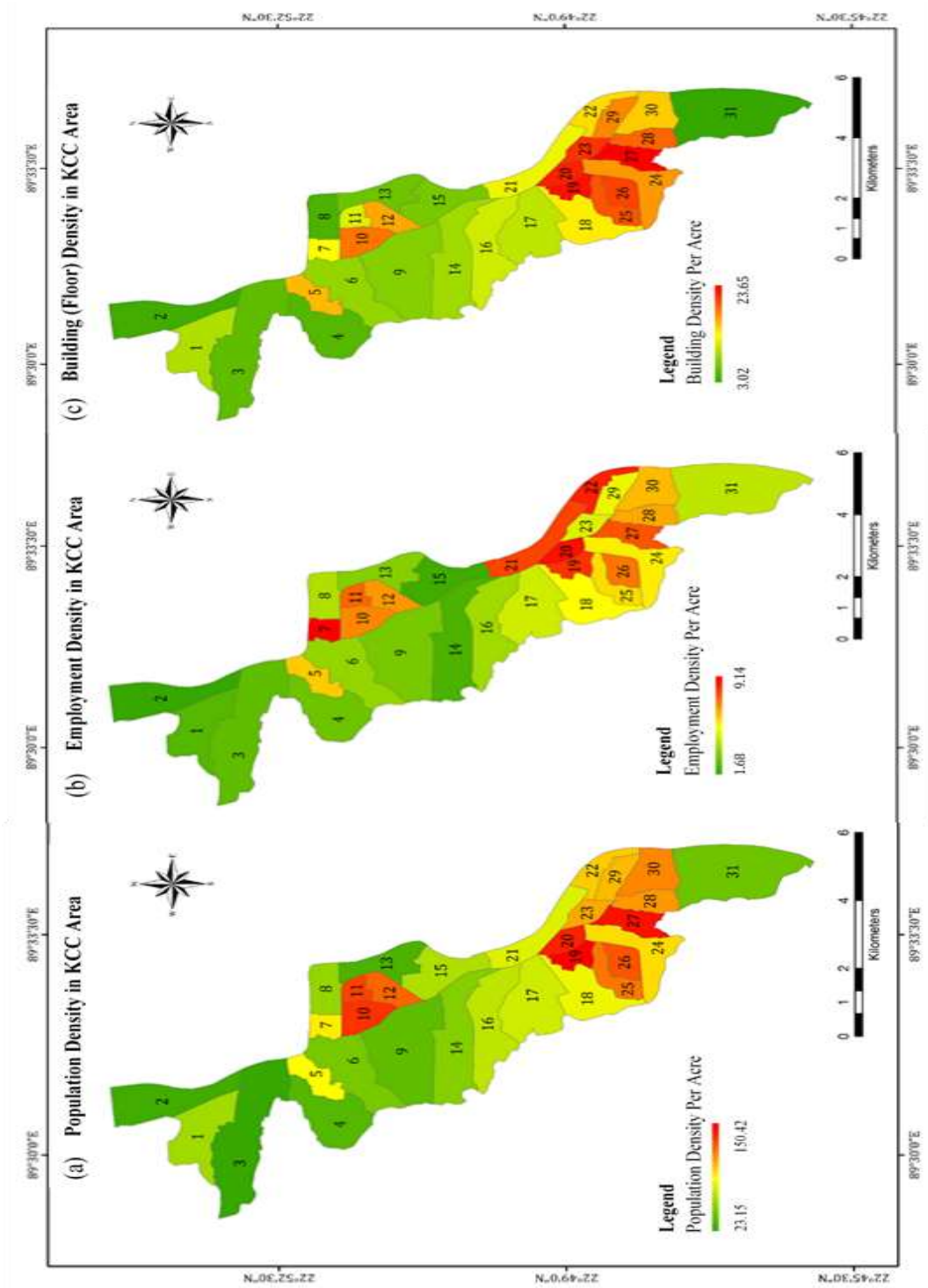


Figure 3. Map of Single Density in KCC a) Population Density b) Employment Density c) Building Density

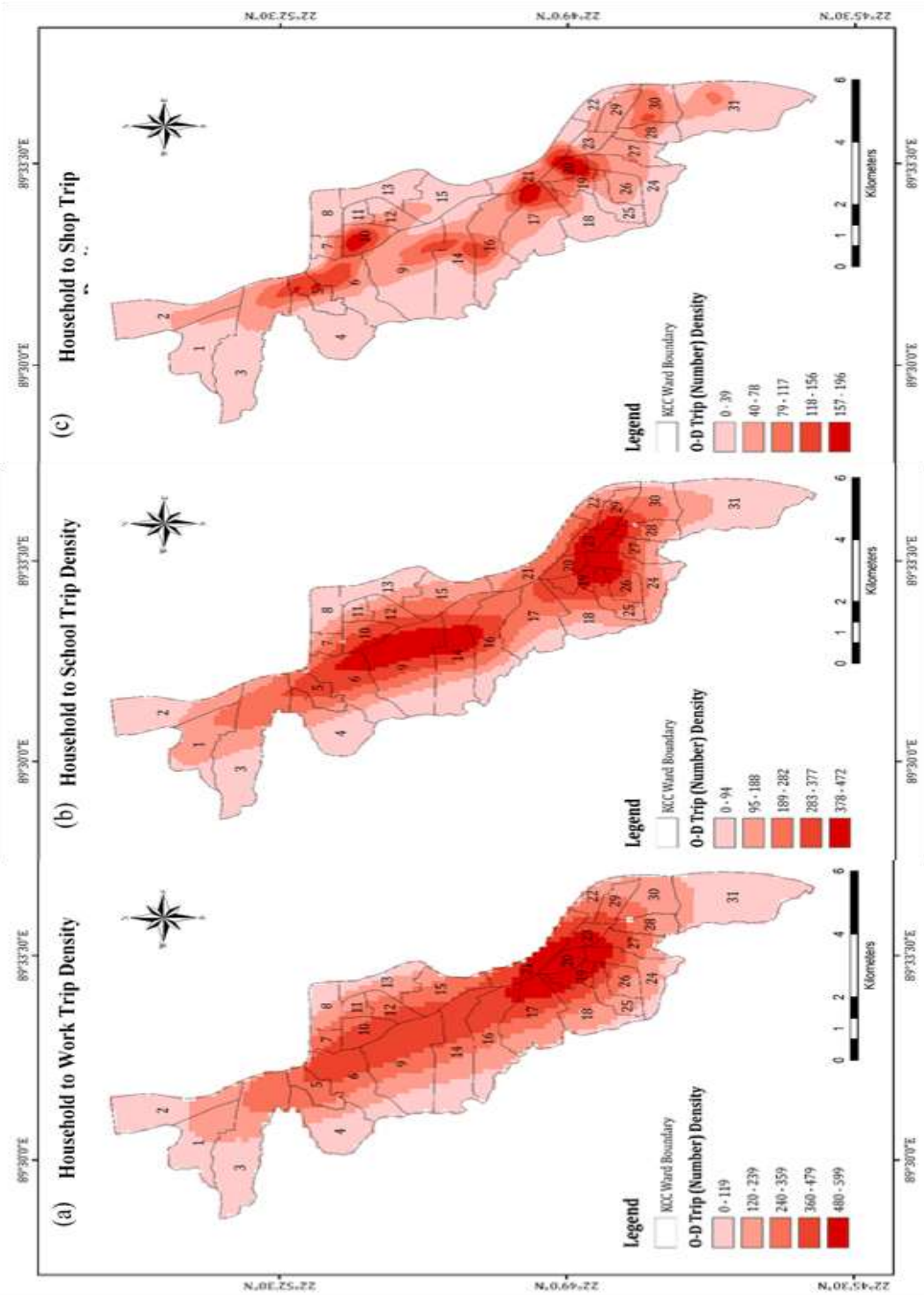


Figure 4. Map of Composite Density in KCC a) HH to Work Trip b) HH to School Trip c) HH to Shop Trip

### **a) Population Density and Trip Parameters**

For the purposes of urban transportation analysis, population density is a critical factor. Spatial analysis has been used to study the relationship between urban densities and travel behavior since the introduction of GIS in transportation research. The relationships among population density, trip production, trip distance, trip time, and trip cost were investigated using spatial analysis in this study. Here, population density is considered as five categories of density (<38=Very Low, 38-57= Low, 57-102= Medium, 102-124= High and 124+= Very High). All the density is provided as per acre population density.

In Khulna City, the box plot (Figure 5a) illustrates a monotonically increasing relationship between population density and trip production. As the population density is higher, the number of trips produced is also higher. Where population density is low or medium, the number of trips produced (weekly) is low compared to higher density area. Ward no 17 and 24 are exceptional considering their density category and high trip production. Trip distance also shows similar relationship with population density. The trip distance (in km) decreased as the population density increased in Khulna City (Figure 5b). Trip distance variability is high for very low and low population density area compare to other density area. Trip distance variability is low for very high-density area. That means travel distances of the people of high-density area is low compared to low density area's people. Population density and trip time box plot (Figure 5c) shows that with the increase of the population density, the trip time (in minute) is decreased in Khulna City. Trip time variability is high for low and medium population density compared to other density area. Population density and trip cost box plot (Figure 5d) indicates that with the increase of population density trip cost (weekly) is decreased in Khulna City. Trip cost variability is high for very low, low and very high density compared to other density area. Low population density area's people spend more money for making trips compared to very high population density area's people.

### **b) Employment Density and Trip Parameters**

The method for determining employment density is similar to that used to determine population density. Employment density, trip production, trip distance, trip time, and trip cost are all related in the same way that population density and trip parameters are. Here, employment density is considered as five categories of density (<2=Very Low, 2-3.4= Low, 3.4-4.8= Medium, 4.8-7.22= High and 7.22+= Very High). All the density is provided as per acre employment density.

In Khulna City, the analysis reveals a monotonously increasing relationship between employment density and trip production (Figure 5e). When employment density is low and very low, the trip production (weekly) variability is low compared to other density category area. That means where employment density is high, the probability of trip production is also high. Figure 5f, Figure 5g and Figure 5h shows a generic trend where if employment density is increased, people's trip distance (in km), trip time and trip cost is decreased. Trip distance variability is high for very low and low employment density area compared to other density areas. That means high density area's people usually make shorter trips compared to low density area's people. Trip time variability is low for high and medium density area. That means people of very high-density area's travel time is low compared to low density area's people. Accordingly, trip cost variability is high for low, very low and very high density compared to other density areas. That means trip cost of high-density area's people is lower compared to low and very low-density area's people.

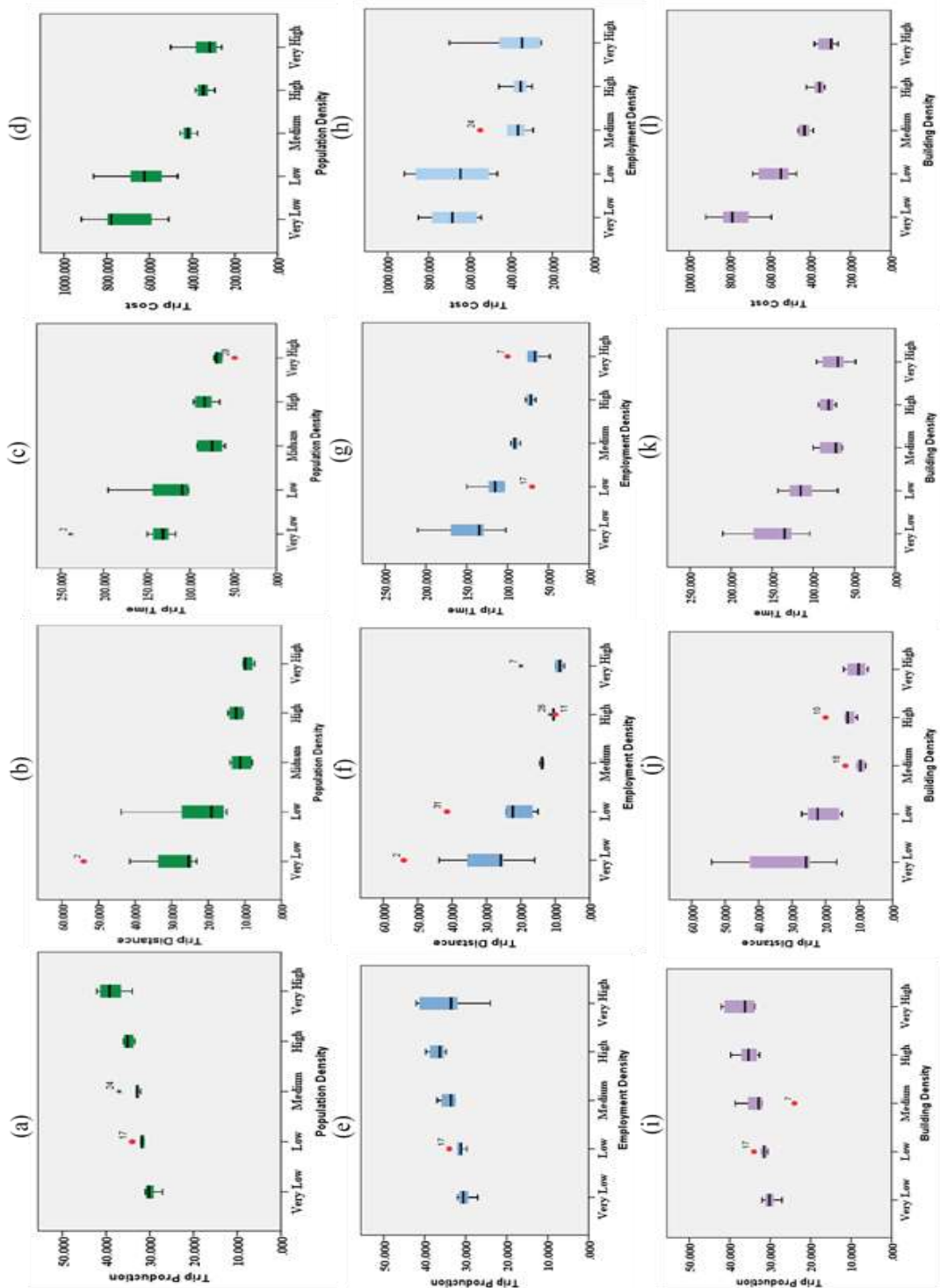


Figure 5. Single Density and Variation of Trip Parameter

**c) Building Density and Trip Parameters**

The density of buildings is an important factor to consider when analyzing urban transportation. Where building density is high, people’s residence and activity will also be high. At the same time those places produce or attract more trips compared to low density area. The relationships among building density, trip production, trip distance, trip time, and trip cost have been analyzed using spatial analysis and spatial statistics. Here, building density is considered as five categories of density (<6=Very Low, 6-9= Low, 9-14= Medium, 14-19= High and 19+= Very High). All the density is provided as per acre building density.

There is (Figure 5i) a positive linear relationship between building density and amount of traffic in Khulna City. When building density is low and very low, the trip production (weekly) is also low compared to other density area. Figure 5j, Figure 5k and Figure 5l also shows the trend similar to employment density. When the area’s building density is increased, trip distance, trip time and trip cost are also decreased. Trip distance is higher for very low and low building density compared to other density areas. It is also seen that high building-density area’s people make shorter trips compared to low density area’s people. Trip time is higher for very low and low building density compared to other density area. Accordingly, trip cost is higher for very low, low density compared to other density area. Low building density area’s people spend more money for making trips compared to very high building density area’s people.

**Trip Attraction**

The map (Figure 6a) shows the trip attraction pattern. Total number of destination trip points is analyzed through hot spot analysis where spatial clustering tendency has been found significant. Using the hot spot Z score value, IDW interpolation has been done to get the predicted trip-attraction surface, where high Z value indicates the areas with higher trip attraction. Here, ward no 14, 17, 21, 20 and 23 attracts more trips compared to other wards. In fact, ward no 17, 21, 20 and 23 are the CBD area in KCC.

**Spatial Autocorrelation for Destination**

From the Global Moran’s I analysis (Table 2), the autocorrelation value of Z=5.78 indicates a strong significance that trip points are spatially clustered, not random. The near zero (0) p value rejects the null hypothesis and indicates that total number of trip points distribution are more spatially clustered than random with high confidence level. Positive Moran’s index also suggests spatial clustering of the trip points.

Table 2. Global Moran’s I statistics

Global Moran’s I Summary	
Moran's Index:	0.250894
Expected Index:	-0.003559
Variance:	0.001935
z-score:	5.784607
p-value:	0.000000

From the spatial analysis it is identified that in KCC area trips are spatially clustered. In reality, CBD area attract more trips compared to other area or wards.

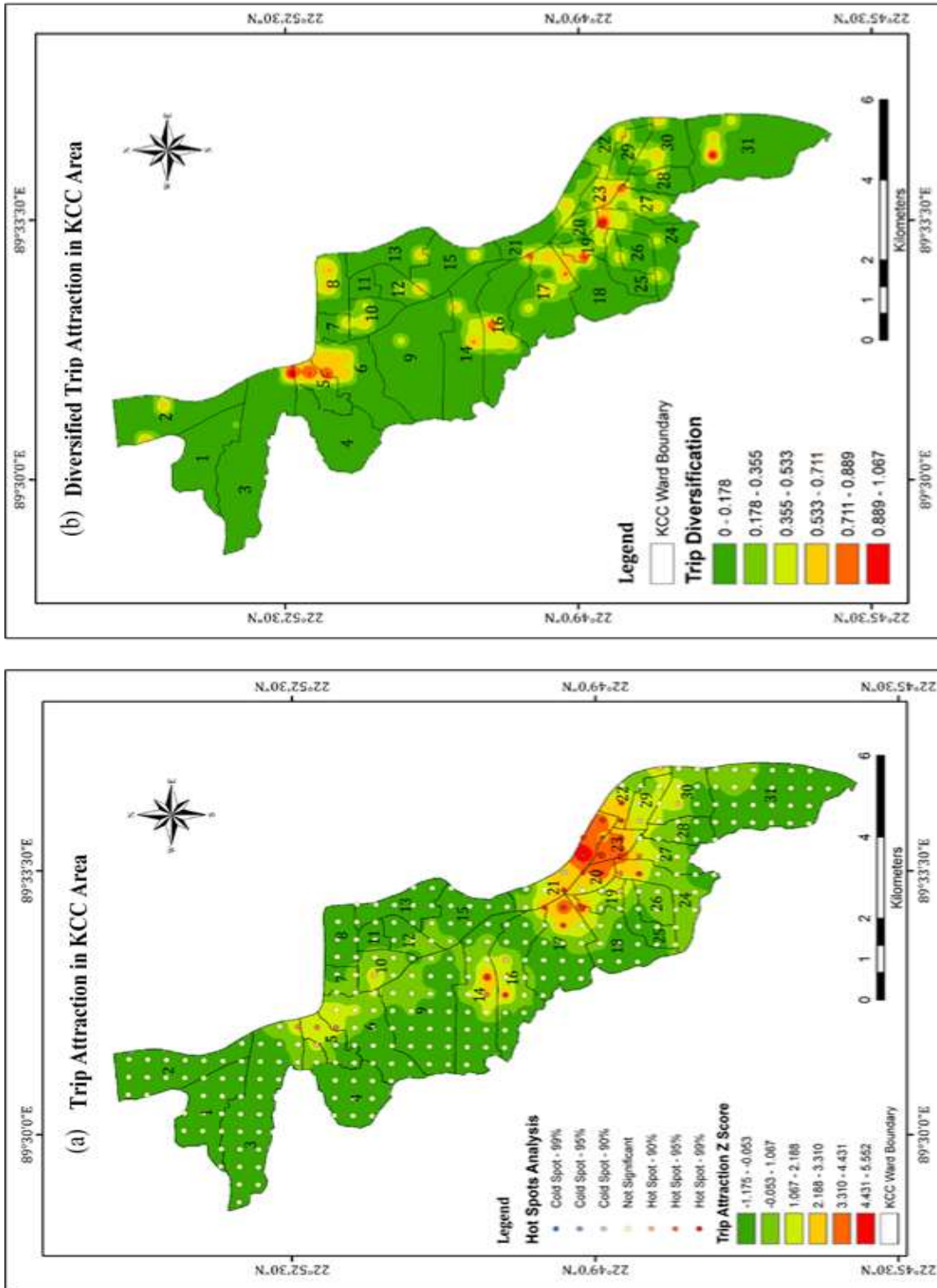


Figure 6. Map of Trip Attraction in KCC Area a) Trip Attraction Hot Spot b) Diversified Trip Attraction

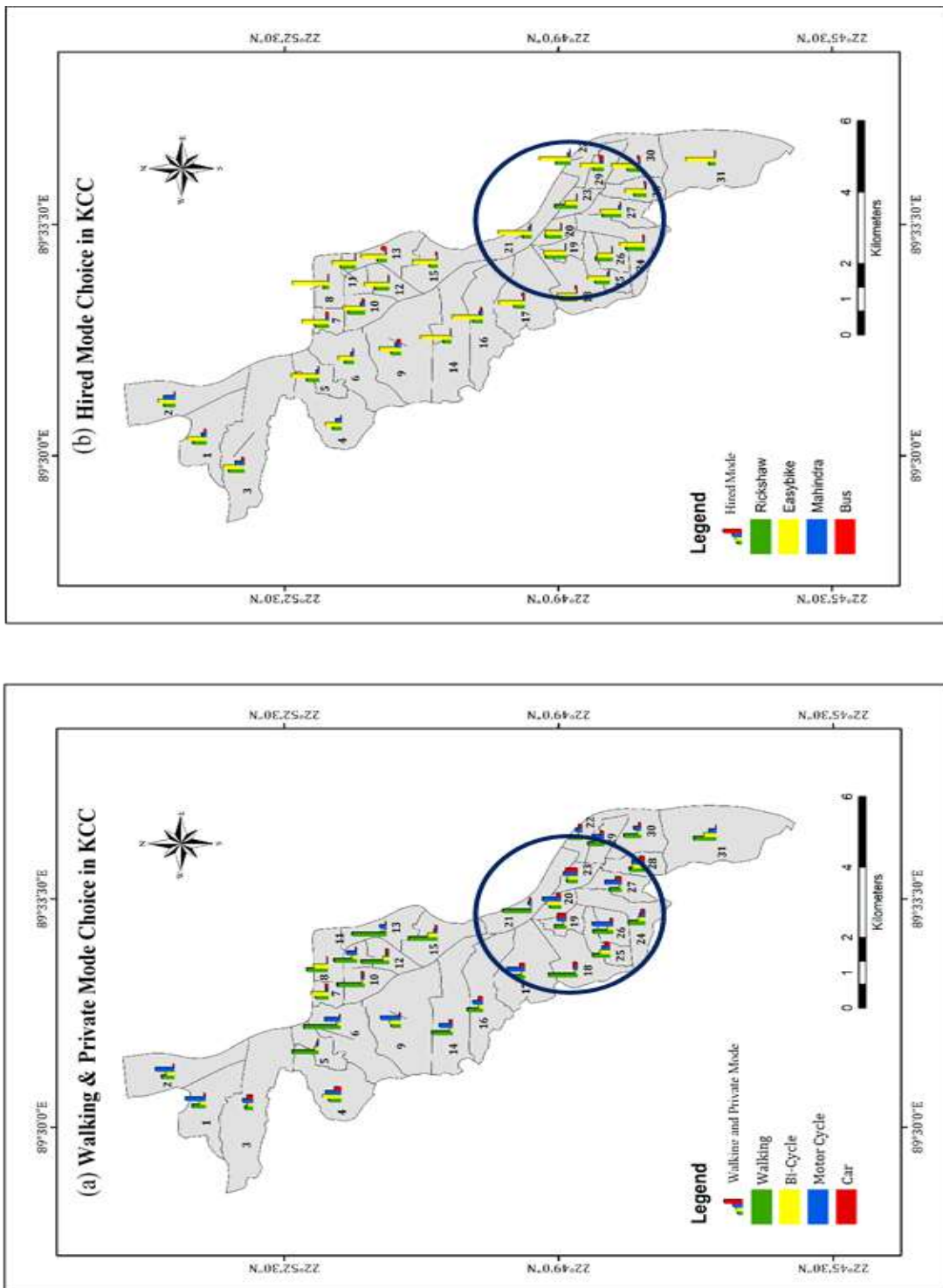


Figure 7. Map of Spatial Variation of Mode Choice a) Walking & Private Mode Choice b) Hired Mode Choice

### ***Diversified Trip Attraction Area in KCC***

**Figure 6b** shows diversification of trip attraction in KCC area. To measure diversity of trip attraction, Shannon diversity index has been used. Here, three purposes of trip have been considered here to measure trip diversity. For Khulna City Corporation area 1.06 is the maximum value for diversified trip attraction which is indicated by red color. These red colored areas indicate that these areas attract all three purposes of trip (work trip, school trip and shopping trip). Highest value of Shannon diversity index indicates existing maximum trip diversity. On the other hand, close to zero or zero value indicate there is no trip diversity. No trip diversity means there is only one type of trip attraction, high value indicates that this area attracts all types of trips. In contrast, the green color indicates that the area attracts only one type of trips from work trip, school trip or shopping trip.

### ***Spatial Variation of Mode Choice***

In this part of the study eight modes of travel have been chosen to describe the spatial variation of mode choice. Here, these modes are categorized into two groups. The first one is walking and private mode (Bi-Cycle, Motor Cycle and Car) and second one is hired mode (Rickshaw, Easybike, Mahindra and Bus). Figure 7a and Figure 7b shows the percentages of total mode share for the wards in KCC. From the previous spatial analysis of urban density, areas of high density have been identified. Both single and composite density areas are identified for ward number 18 to 29. Figure 7a shows the percentages of Walking, Bi-Cycle, Motor Cycle and Car choice of total trips in the respective wards. Here, the blue circle area represents highly dense areas and the diversity of chosen mode is also higher in those areas compared to outside areas of the circle. In reality, this area is the CBD area in KCC and people in this area like to use more private mode compared to low density area. Areas outside the circle are mainly low-density areas. Figure 7b shows the percentages of Rickshaw, Easybike, Mahindra and Bus choice of total trips in the respective wards. Here also, the blue circle area shows high density areas and the diversity of chosen mode is also higher in these areas compared to outside areas of the circle. Highly dense area's people like to use more Rickshaw and Easybike. Share of Rickshaw is higher in areas within the blue circle or high-density areas. Overall, in Khulna the most dominating mode is Easybike. Easybike takes the highest share in all wards. People of high-density areas like to use Rickshaw more than low density areas.

### **Conclusion**

One of the most important factors that reflects travel behavior and demand is urban density. Travel behavior and demand are affected differently by different densities. The average density, on the other hand, does not reflect the diversity in the same traffic area. In this study, spatial analysis was used to show that it is possible to overcome the drawbacks of using average density and investigate how urban density influences travel behavior and demand. The scientific and reasonable parameters of the urban space configuration for job or work, school, and shop can be obtained after the analyses on the relationship between urban densities, travel behavior, and travel demand.

In this study, both single density and composite urban density were used. Where the result shows interesting findings for the Khulna City. Interestingly, Home-Based and Home-End Trip mode choice has differences. For work trip and School Trip rickshaw choice is comparatively lower while returning home, but for shopping trip the share is comparatively higher. On the other hand, for Work and school trips share of Walking and Easy Bike is comparatively higher while returning home, but for shopping trips the share is comparatively lower. In Khulna city, urban single-density has a monotonously positive relationship with trip production, distance, time, cost, and mode choice. The daily activities of residents are closely related to urban composite densities (Household to Work trip density, Household to School trip density, Household to shopping trip density). It has been discovered that as composite density rises, trip production rises as well. Diversified Trip and Overall Trip Attraction area have some dissimilarities. CBD area does not attract diversified trip but has attraction of overall trip. Diversified trip attraction is spread out on the geographic space but overall trip attraction is more spatially clustered. The percentage of Rickshaws choice in high-density areas is higher than in low-density areas. In dense areas, the preference for private mode choice is also higher compare to low density area.

### **Acknowledgement**

This study would not have been possible without the assistance and support of Professor Dr. Md. Ahsanul Kabir and Assistant Professor Mahmud Uz Zaman sir. We acknowledge all of the anonymous reviewers' insightful and

helpful criticism of the paper. The authors are appreciative of their constructive criticism and valuable suggestions for making the manuscript better.

### Conflict of Interests

The authors declare no conflict of interest.

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