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Assessment of neighborhood sustainability in terms of urban mobility: A case study in Dhaka City, Bangladesh

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Abstract

For achieving sustainable cities, sustainable mobility is one of the key elements. Policymakers around the world are taking different strategies to ensure sustainable urban mobility at the local level. However, sustainable urban mobility assessment at neighborhoods of a developing country received a significant research gap. This study attempts to close this research gap by deriving and comparing neighborhood sustainability based on three indicators: modal share, travel time, and travel cost, in Dhaka city, Bangladesh. Using a two-step cluster model, neighborhoods were grouped into three clusters. Study results classified 41 (44.6%) neighborhoods as sustainable, 30 (32.6%) as potentially sustainable, and 21 (22.8%) as unsustainable neighborhoods due to less positive outcomes of sustainable mobility policies. Later, median income and jobs-housing ratio value for different neighborhood types validated the classification result. Findings from this study reveal insights for transport planners, development agencies, policymakers to identify areas where mobility of the residents needs to be improved on a priority basis; advocate further research on comprehensive sustainability assessment at the neighborhood level.

Keywords

Transport Sustainability,
Neighborhood Sustainability,
Modal share,
Cluster Analysis,
Dhaka

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Highlights for public administration, management and planning:

- There is a significant difference in modal share, travel time, and travel cost in neighborhoods.
- A traditional neighborhood of the city is comparatively more sustainable than newly developed ones.
- Neighborhoods with similar sustainability status tend to be clustered on the city scale.
- Median income and jobs-housing ratio can effectively capture the difference in sustainability level in terms of urban mobility.
- Sustainable urban mobility assessment can contribute city planning and development process.

1 Introduction

1.1 Background of the study

Transportation is widely recognized as a significant component of sustainability (Asadi-Shekari et al. 2013; Litman 2007; Shen et al. 2011). Urban transportation drives cities' social and economic development and ensures access to basic urban services (Gudmundsson 2004). However, the transport sector is a major source of fossil fuel-based air pollution and emissions (Colvile et al. 2001). Urban transport-based mobility influences the environment through energy consumption, land use provision for transport infrastructure, noise-air-water pollution, and climate change (Gudmundsson et al. 2016). The economic impacts of inefficient urban transportation systems, i.e., traffic congestion that consumes a significant working hour, hamper the economic growth (Chandran & Tang 2013). Also, the transport sector impacts social life

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through safety, inequity, and social exclusion (Litman & Brenman 2012). Achieving sustainability goals through transportation systems has become an essential objective of policymakers and public initiatives (Castillo & Pitfield 2010; Haque et al. 2013). There is a broad consensus that the issues related to transport sustainability should be incorporated in the decision-making process to ensure a significant policy effect on the transportation system. However, planners, policymakers, researchers face several difficulties quantifying the existing sustainability levels of urban areas with measurable attributes and performance indicators. Thus, it is critical to develop methods for the evolution of the sustainability of transport, specifically under the lens of mobility dimension, to ensure sustainable urban development.

1.2 Dimensions of Sustainable Transport

Current transport sustainability studies suggest that sustainability's environmental, social, and economic dimensions should be included while quantifying sustainable urban mobility (Zheng et al. 2013). A transport system must have a low level of CO_2 emissions, air pollution, and noise pollution, focusing on optimizing resource use in terms of fuel and land consumption to ensure environmental sustainability (Campos et al. 2009). Non-motorized and public transit has the potential to lower vehicle miles traveled (VMT) and vehicle hour traveled (VHT) per person, which leads to environmental sustainability (De Freitas Miranda & da Silva 2012). Economic sustainability emphasizes maximizing economic efficiency and affordability and encouraging economic development; these criteria can be obtained by reducing travel time and cost (De Freitas Miranda & da Silva 2012). In contrast, the objective of social sustainability is to maximize equity and improve public health. To maximize equity, transportation facilities should be distributed regarding residents' needs and demands, and improved public health can be ensured by minimizing emission and pollution exposure levels (Jeon et al. 2013; Reisi et al. 2014).

1.3 Sustainable Urban Mobility

Although there have been various notions of sustainable mobility with different concepts, there is no unanimous global definition (Marsden et al. 2010; Gudmundsson et al. 2016). Sustainable urban mobility possesses key characteristics, which are: (1) provides access to essential services with a reasonable level of safety at a time maintains consistency with human and ecological health; (2) promotes promoting intra and inter-generational equality; (3) ensures affordability with different mode choice options to varieties of economic groups; (4) limits emissions and residues level to earth ability to absorb them and uses non-renewable resources at or below the rates of development of renewable substitute (Gudmundsson 2004; OECD 2000).
Sustainable travel behavior lies in more sustainable transport mode use or modal shift, actions to reduce trip numbers, and greater efficiency in the transport system (Banister 2008). Mobility aspects like trip length, travel time, mode, and choice can be used as proxy measures of emergency consumption and transport emissions (Black 2010). Different transport modes have a disparate outcome in terms of sustainability. Public transport has less per capita emission than private cars (Andong & Sajor 2017). With efficient public transportation, people can move faster with less amount of cost. Whereas increasing dependency on private vehicles negatively impacts environments in both developed and developing countries (Cervero 2013). Private vehicles or automobiles disproportionately occupy road space contributing to traffic congestion in most developing cities where roads are narrow (Cervero 2013). The adverse effect of traffic congestion indirectly hampering work productivity and job satisfaction (Ma & Ye 2019). Hence, sustainable urban mobility plans worldwide advocate for walking and cycling based on active mode use (Newman & Kenworthy 2001). It has been found that active transport can reduce construction and maintenance costs, reduced the amount of traffic accidents, fuel efficiency, and fewer pollutant emissions (Keall et al. 2018). Also, active mode use is linked with improved public health as it contributes to physical activity and reduces overweight and obesity issues (Buehler et al. 2016; Antipova 2018).

1.4 Previous Research on Sustainable Urban Mobility

Sustainable Urban Mobility Planning (SUMP) is a strategic concept applied by OECD and later complemented by European Commission. Indicators used for sustainability assessment varied with context, policy relevance, analytical validity and simplicity, and cost-effectiveness (Yigitcanlar et al. 2015). Previous literature of Sustainable Urban Mobility (SUM) focused on evaluating SUM plans' effectiveness (Pisoni et al. 2019), tools for measuring SUM Plans effectiveness (Zope et al. 2019), advancement in formulation and implementation of SUM Plans (Kiba–Janiak & Witkowski

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2019), importance of citizen participation in SUM Plans (Lindenau & Böhler–Baedeker 2014), comparison among SUM projects (Mozos–Blanco et al. 2018), shared viewpoints of stakeholders in sustainable mobility concept (Foltýnová et al. 2020). Also, there were studies where composite index has been formulated to evaluate the sustainability of urban transportation through comprehensive indicators (Campos et al. 2009; Zito & Salvo 2011; Gudmundsson & Regmi 2017; Zope et al. 2019). De Freitas Miranda and da Silva (2012) used eighty-seven indicators under nine domains in Curitiba, Brazil, to develop index of Sustainable Urban Mobility. Gudmundsson and Regmi (2017) developed sustainable urban transport index (SUTI) through broadly ten criteria relevant for Asian cities based on SDG targets and sustainable mobility strategies. Zope et al. (2019) developed Composite Sustainable Transport Index (CSTI) to compare, and rank selected Indian cities using broadly eight indicators. Lopez–Carreiro and Monzon (2018) proposed a quantitative methodology for accessing the smartness of urban transportation systems through Smart Mobility Index (SMI) derivation in the context of six Spanish cities.

1.5 Need for Research

Although there has been enormous research on sustainable mobility in past two decades, this research would contribute to several crucial research gaps identified in sustainable urban mobility literature, considering different geographic scale. First, majority of the research on sustainable urban mobility took place on regional or city or metropolitan scale. However, urban mobility shaped by the travel patterns of individuals, it is important to evaluate sustainable mobility at lower geographic unit i.e., neighborhood or Traffic Analysis Zone (TAZ) level. Popular Neighborhood Sustainability Assessment (NSA) framework, i.e., Leadership in Environmental and Energy Designs-Neighborhood (LEED-ND) (Garde 2009); Building Research Establishment Environmental Assessment (BREEAM) (BRE 2011); Comprehensive Assessment System for Built Environment Efficiency (CASBEE-UD) (Sharifi & Murayama 2014), all have urban mobility as a key indicator of performance measurement of neighborhood sustainability. Second, there is little research on SUM on developing country context, especially in cities of global south. In developing countries, planners are often dependent upon the empirical observations of developed countries to develop their plans and policies (Rahman et al. 2022a). Literature suggests that the urban system varies significantly between contexts and priorities, leading to a valid question on that dependency (Li et al. 2008; Oginni et al. 2009; Kamble & Bahadure 2020). The current research aims to contribute to the sustainability assessment knowledge gap by investigating urban mobility outcomes of neighborhoods of an exemplar developing country, i.e., Bangladesh. This way, this paper contributes to the sustainable urban mobility assessment literature in a neglected geographic lacuna.

Third, availability of transport related statistical data is often unavailable in country context like Bangladesh. Moreover, mobility is a context-dependent concept for which different country sets different priorities. Data used for this research is from a comprehensive Transport survey conducted in Dhaka city which adds value to reveal mobility scenarios at local geographic units of a developing country. Fourth, unlike previous research that used a large set of variables with a complex process of scoring for sustainable mobility assessment, the method provided a much simpler analytical and graphical approach (i.e., spatial mapping) to compare the existing sustainability level of neighborhoods in terms of sustainable urban areas mobility frames. The proposed method in this study would be benchmarking for local governments of developing countries to link higher-level policy objectives for sustainability and lower-order actions.

Against the backdrop, this paper aims to: (a) evaluate and compare the sustainability level of neighborhoods based on urban mobility characteristics – modal share, travel time, and travel cost analysis, by operating a two-step cluster analysis technique; (b) provide reasoning behind variation in neighborhoods sustainability levels through socioeconomic and built environment characters (median income and job-housing balance); (c) introduce policy measure to improve sustainable urban mobility in the study context.

This section gives the background of this study with relevant literature and needs for research; Section 2 introduces data sources, study area, and detailed analytical methods; Section 3 presents the results of sustainability assessment and discussion on the local context for such result. Lastly, section 4 section summarizes the whole work.

2 Materials and methods

2.1 Study Area

Dhaka is a representative case study from a developing country context as it is the capital city

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of Bangladesh, one of the first growing megacities with high population densities and increased rural-urban migration. Due to inefficient housing policies and ineffective transportation systems, the residents of Dhaka's mode choice behaviour are very different from developed countries' cities. Here, around 55% of the daily 21 million trips are non-motorized trips, including rickshaw (37%), bicycling (less than 2%), and walking (17%) though very few facilities are available for these modes (Dhaka Transport Coordination Authority (DTCA) 2015; Gallagher 2017; Government of Bangladesh 2016). Besides, the modal share of the poor public transportation system is around 37% (Government of Bangladesh 2016). The rest of the trips are made by motorized modes, including motorcycle, private car, para-transit modes, and so on (Dhaka Transport Coordination Authority (DTCA) 2015). With the sheer amount of transportation challenges like traffic jams, increased automobile dependency, and traffic accidents, it is important to explore the city's current situation.

2.2 Data

The Revised Strategic Transport Plan (2016–2035) of the Bangladesh government was for building the capacity of the transportation system of Dhaka city. This study analysed the Household Interview Survey (HIS) of the Revised Strategic Transport Plan (RSTP) to derive modal share, average travel time, and average travel cost. HIS data covers trip characteristics (i.e., including the trip origin and destination, trip purpose, travel mode, transfers, departure, and arrival times). The study used 134,362 trips made by 67,397 members from 16,925 households within 92 TAZs. Data related to median income, jobs and housing information was collected from Bangladesh Bureau of Statistics (BBS).

The spatial unit of the survey mentioned in the RSTP 2015 was the Traffic Analysis Zone (TAZ). The average size of TAZs is around 371 acres. TAZs of the RSTP followed the ward or neighborhood boundary (which is the lowest administrative unit in the case of Dhaka, also the lowest unit for statistical purposes) of two city corporations-Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC). A neighborhood or TAZs demarcated in the Revised Strategic Transport Plan-2015 (RSTP) of Dhaka city were selected as a spatial unit for measuring the sustainability in terms of urban mobility of the residents (Fig. 1). Hence, in this study, we interchangeably used different terms, including a TAZ, a Ward, or a neighborhood, in different parts of the manuscript. Also, public transportation, public transport, and transit are used interchangeably as well.

Table 1 Indicators, rules, and sustainability dimensions of urban mobility

Indicators		Rules	Impact on Sustainability
Modal Share	Active	Walking, cycling, rickshaw, and other NMT mode use would reduce transport-related CO2 emissions; induce less traffic congestion; improve neighborhood air quality; ensure affordability of residence	Environmental, Social, and Economic Sustainability
	Private	Private mode use would negatively affect neighborhood environmental condition; increase the amount of pollution, fuel consumption; deteriorate traffic safety; negate the health benefit of active travel	Environmental, Social, andSustainability
	Transit	Public bus, Leguna, and other public modes would make the~area more compact, would reduce private vehicle-related externalities, affordability consideration	Environmental, Social, and Economic Sustainability
	Para-transit	CNG, Leguna would provide local level access to people with low to middle income	Equity and Environmental Sustainability
Travel Time		Increased travel time would impact total travel distance (VMT), increase people's expenditure for travel, increase pollution from motor-vehicle, working hour reduction	Economic Sustainability
Travel Cost		Inadequate transport options for neighborhood people would increase per capita fuel cost	Economic Sustainability

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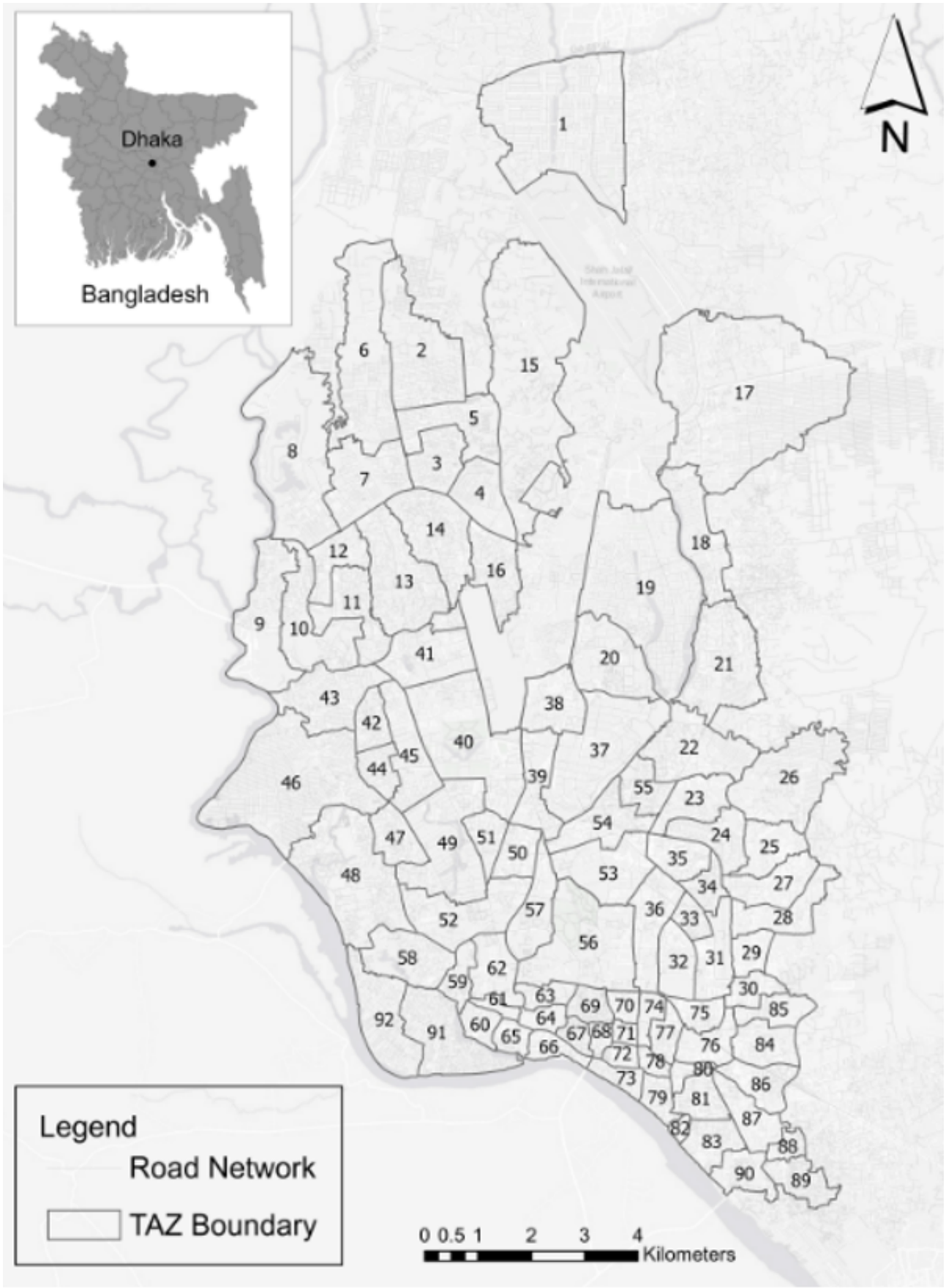


Fig. 1 Study area showing different wards (TAZs) or neighborhoods

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2.3 Indicators of Assessment

For assessing the sustainability level in existing travel characteristics of the residents, indicators were selected based on their relation with different sustainability dimensions. Table 1 provides an overview of selected indicators and their linkage with different sustainability dimensions.

2.4 Model Reclassification

Mode reclassification (Table 2) was necessary to maintain relevance to the analysis of this study. The scope was limited only to land transport, omitting the water transport modes. The categories were as follows.

Table 2 Mode classification for the study

Modes	Reclassified Name
Walking, Cycling, Rickshaw, Van	Active
CNG, Mishuk, Leguna, Maxi, and Auto	Para-Transit
Motor Cycle, Car, Taxi and~Microbus	Private
Bus, Train, Truck	Transit

2.5 Modal Share

The study utilized the inter-zonal and intra-zonal trips of the residents incurred by active, private, para-transit, and transit. The modal share of each mode was calculated by taking the percentage of total trips generated by different modes.

2.6 Travel Time

For each trip, travel time for moving from one traffic analysis zone to another was considered for the only first transfer. Then average travel time for each TAZ was aggregated by taking the average travel time for all trips.

2.7 Travel Cost

RSTP categorized trips into different trip types, i.e., work, school, shopping, business, etc. Like travel time analysis, travel cost was calculated irrespective of trip types for the first transfer of a trip maker.

2.8 Spatial Modelling

For mapping the location local clusters and local spatial outliers, a local indicator of spatial association (LISA) was carried out on GeoDa software through local Moran statistics suggested by Anselin (1995). Global Moran's I formula is as follows (Cliff & Ord 1972):

$$I = \frac{N\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - x)(x_j - x)}{(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij})(x_i - \bar{x})^2}, \quad (1)$$

Here, N = number of neighborhoods; x_i = neighborhood type in unit i, x_j = neighborhood type in j, x = average different sustainability level, and w_{ij} = relative weights between neighborhoods i and j. Local Moran's I for each spatial unit and evaluation of the statistical significance for each Ii was done in ArcGIS following the equation proposed by Anselin (1995). It produced a bivariate LISA cluster map examining the relationship among different neighborhood types.

2.9 Classification of Neighborhoods

Neighborhoods were clustered using the "Two Step Cluster" analysis technique, popularly used in TOD-ness study (Kamruzzaman et al. 2014, 2018; Zemp et al. 2011; Rahman et al. 2022b) - here, six indicators were used to cluster the neighborhoods. The Two-Step Cluster method identifies natural groupings of the neighborhoods based on their sustainable urban mobility indicators. Cluster analysis is a sensitive approach; during cluster formation, 5% highest and lowest scores were set equal to the 95th and fifth percentile point respectively, for lessening outlier's effect as suggested by many of the studies (Kamruzzaman et al. 2014; de Vos et al. 2012).

Table 3 Descriptive statistics of key variables

Measures	Min	Max	M	Median	STD	Kurtosis	Skewness
Active	28.70	91.00	62.42	63.00	14.41	-0.57	-0.24
Transit	3.20	44.60	23.45	23.60	9.70	-0.47	0.04
Private	0.40	24.90	7.82	6.00	5.54	1.43	1.32
Para-transit	1.10	14.60	6.30	5.75	2.69	0.28	0.59
Travel Time	16.50	49.42	33.98	32.82	6.42	0.12	0.35
Travel Cost	10.50	47.64	22.06	20.59	10.61	0.03	0.65

note: N=92

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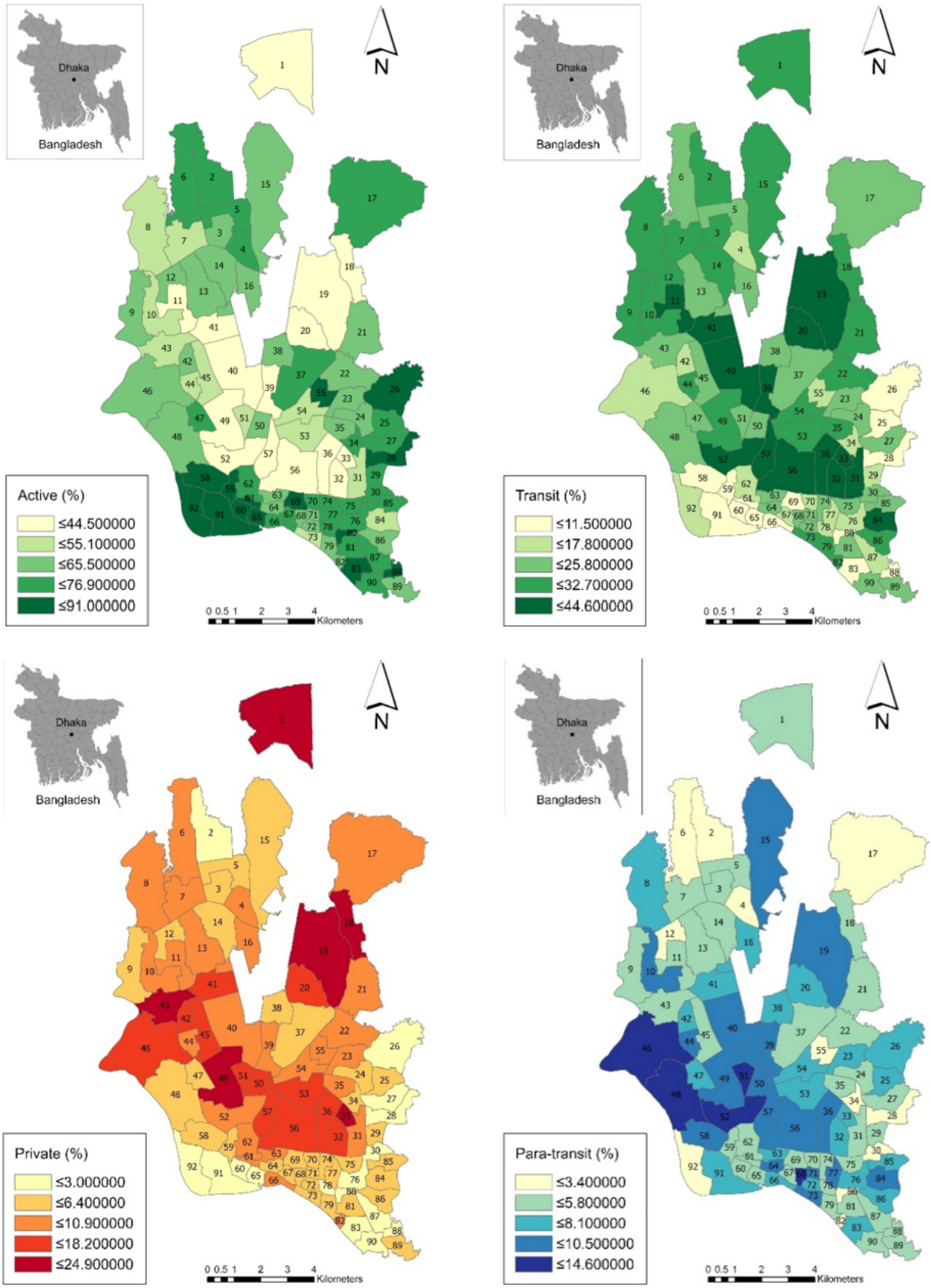


Fig. 2 Modal share of studied neighborhoods

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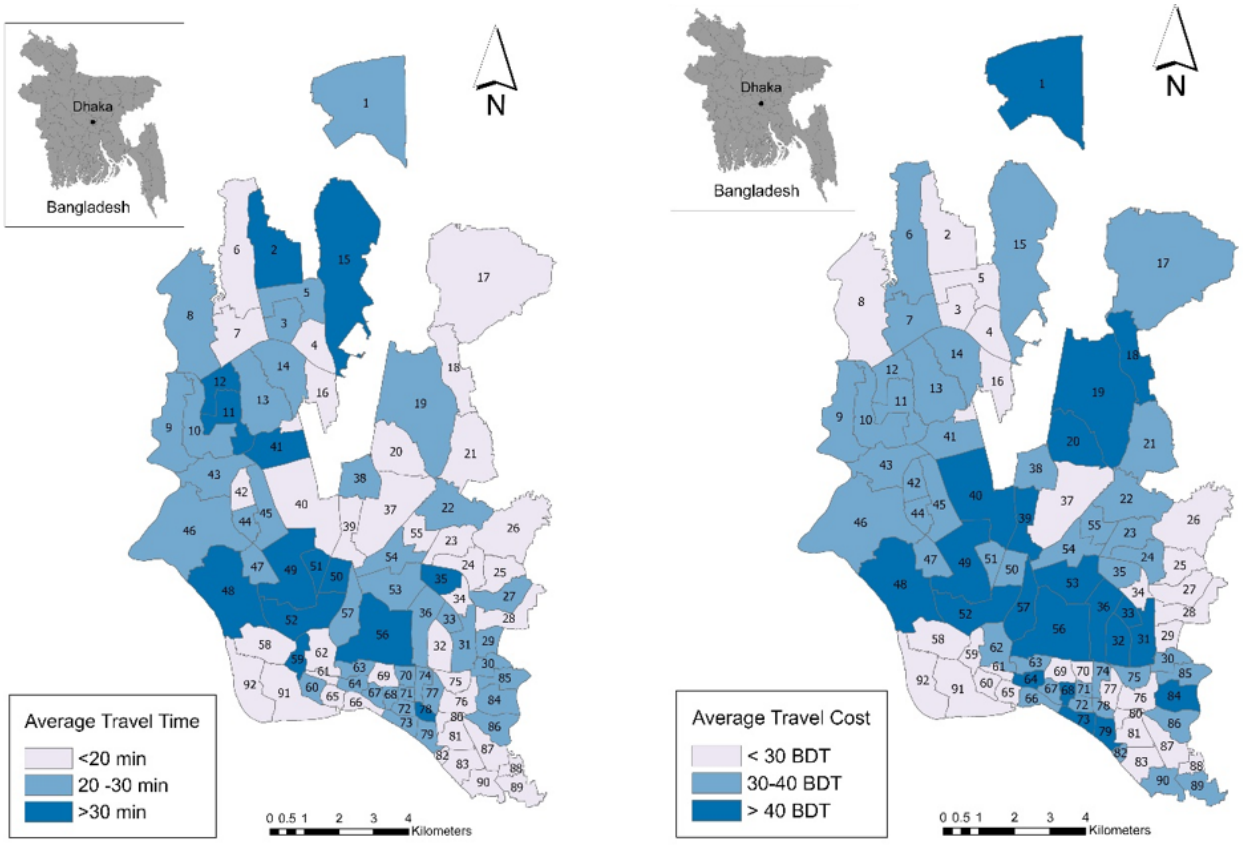


Fig. 3 Average travel time and travel cost of the residents

3 Results and discussion

Urban travel characteristics of the residents were aggregated at the TAZ level. The following Table 3 shows the descriptive statistics of the measured indicators of neighborhood sustainability study.

Modal share data shows that active modes have the highest share (62.42%), followed by transit (23.45%), private (7.82%), and para-transit (6.3%) being the lowest share (Table 3). The higher standard deviation value of active mode and travel cost variable indicate heterogeneity among the neighborhoods in terms of these two variables. Fig. 2 shows the modal share distribution at the TAZ level from which a spatial direction on how modal share contributes to the overall sustainability performance of the TAZs. For active mode, the old portion in the southwest of the city shows a higher percentage than the newer portion (mainly northern part) (Fig. 2). A reason behind this scenario might be a good job-housing balance in these neighborhoods, which makes people having short trips by walking for different purposes. A very contrasting situation is seen in the percentage of transit as more provision of active mode can often be caused by the absence of transit routes in an area (Fig. Fig. 2). Affordability to private mode is a major determinant of modal share. Percentage of private mode was found higher in the neighborhoods with high-income social groups and around CBDs (Fig. 2). On the other hand, para-transit is higher in the city's peripheral area, where transit is in low percentage, and people cannot afford private vehicles (Fig. 2). Besides, people residing there may not generally take a long-distance trip for which para-transit seems the most suitable mode. Meanwhile, travel time data shows that people, on average, need half an hour to reach different destinations inside the city and incur an average of 22 BDT ($ 0.25) (Table 3). Fig. 3 show the distribution of travel time and travel cost value over the city neighborhoods. Being capital city of Bangladesh, core city area is prone to severe traffic congestion during peak hours which also impacted the average travel time of the residence. Here, average travel cost is higher in the TAZs with higher income area

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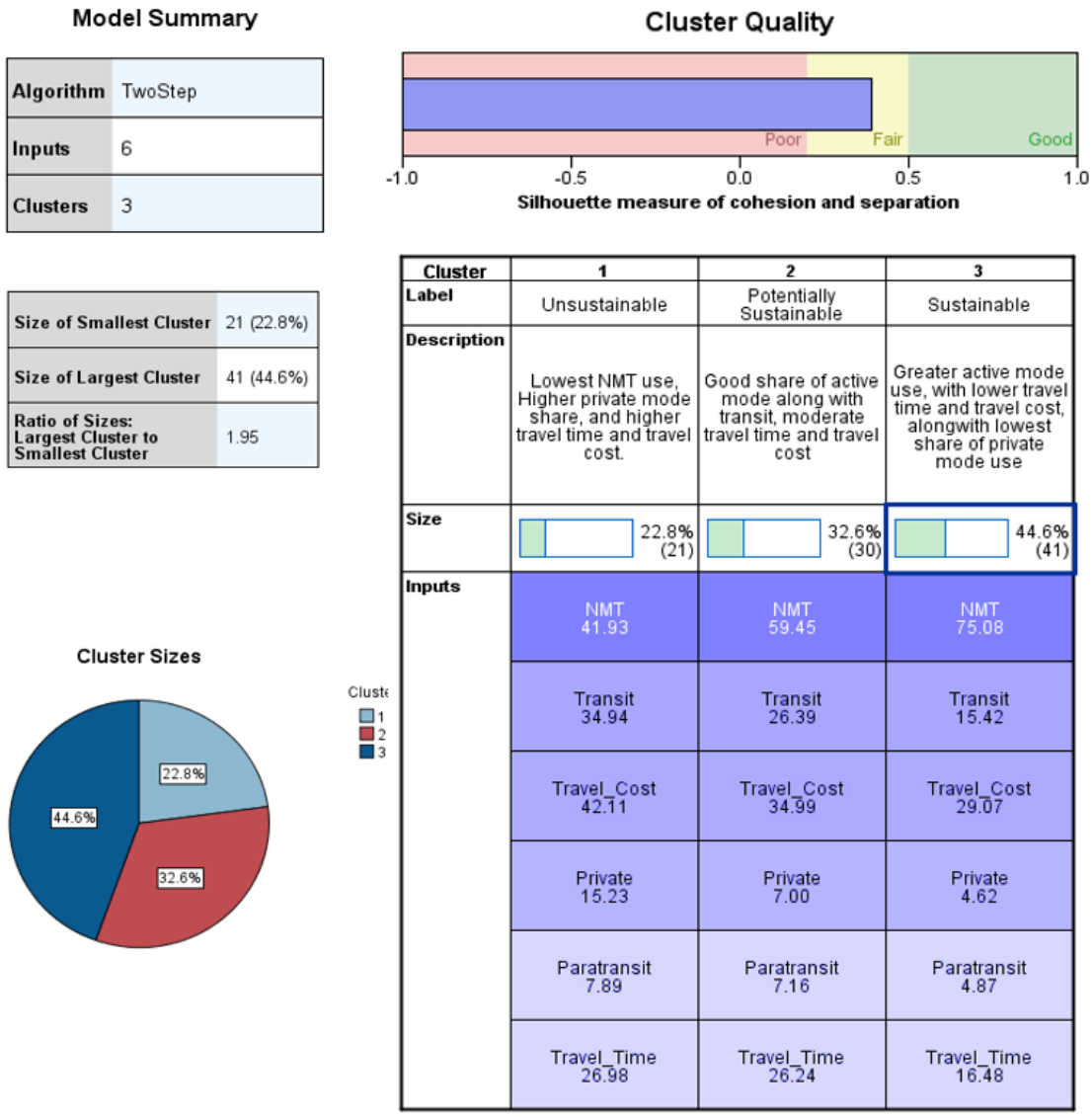


Fig. 4 Two-step cluster analysis result

and around the CBD areas because of the dominance of private modes.

3.1 Clustering of Neighborhood

Neighborhoods were clustered through a two-step cluster analysis method based on six indicators under three pillars of sustainability. Fig. 4 shows that the cluster analysis resulted in a 'Fair' quality model, and three unique clusters have been created, namely – Unsustainable, Potentially Sustainable, and Sustainable. Fig. 4 also presents the cluster-wise descriptions and mean values of the mentioned indicators to interpret and differentiate the clusters' components easily. Moreover, the order of the six sustainability indicators indicates how each variable relatively influenced the clustering method. In this model, active modes appeared to have the most substantial influence in creating the clusters. The relative comparison between the three clusters has been discussed in the following section.

3.1.1 Cluster 1 – Unsustainable Neighborhoods:

About 23% (21 out of 92) of the neighborhoods of Dhaka City are classified as having the characteristics of an unsustainable neighborhood (Fig. 4). All of the sustainability indicators of this cluster have a mean value far less than the other two clusters. Moreover, these neighborhoods showed the lowest

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use of active modes, higher travel costs, and private mode share. These values are highly deviated from the median of Dhaka city and pulled these neighborhoods into the unsustainable cluster.

3.1.2 Cluster 2 – Potentially Sustainable Neighborhoods:

Around 33% (30 out of 92) of the neighborhoods may have the potential to be developed as sustainable (Fig. 4). In terms of active mode use, travel cost, and share of private modes, these neighborhoods are very close to the median value of Dhaka. Thus, they are termed as 'Potentially Sustainable.' Slight deviation towards unsustainability from the median value of Dhaka was seen in transit locations, paratransit locations, and travel time, which restrained this cluster from being a sustainable one.

3.1.3 Cluster 3 – Sustainable Neighborhoods:

41 out of 92 neighborhoods (about 45%) were pointed out as sustainable (Fig. 4). The mean value of NMT or Active mode use in this cluster (75.08) is far above the other two clusters. All six of the sustainability indicators that can positively impact the sustainability performance of an area are highest in the cluster and favourably inclined to the margin of sustainability than the median value for Dhaka city.

Overall, the study result showed that sustainable neighborhoods have the lowest average travel time (16 minutes) and average trip costs (29 BDT) per trip. Also, in sustainable neighborhoods, the majority of the trips are taken with active modes (75%) with lower private mode share (4.62%). Whereas unsustainable neighborhood clusters have higher private mode use (15.23%) and also have a more significant average travel time (27 minutes) and travel cost (42 BDT) per trip for different trip purposes.

Fig. 5 shows the clustering result of the two-step clustering algorithm. For validating the statistical significance of the clustering of the neighborhoods with different sustainability level, Cluster and Outlier Analysis (Anselin Local Moran's I) was performed in ArcGIS Pro 2.4 platform (Fig. 5). While running the Cluster and Outlier Analysis Geoprocessing tool, inverse distance squared was selected to conceptualize the spatial relationship as it assumes that the closer two features are in space, the more likely they are to interact with or influence each other.

The cluster/outlier type field distinguishes between a statistically significant cluster of sustainable neighborhoods (HH), cluster of potentially or unsustainable neighborhoods (LL), an outlier in which sustainable neighborhoods are surrounded primarily by unsustainable ones (HL), and an outlier in which unsustainable neighborhoods are surrounded primarily by sustainable neighborhoods (LH) (Anselin 1995). The spatial location of neighborhoods suggests that most unsustainable neighborhoods are clustered around central parts of the city (Fig. 5). In contrast, sustainable neighborhoods are clustered in the southern part of the city, part of Old Dhaka. Potentially sustainable communities are located western part of the town, clustering in the peripheral areas. The reasons behind this spatial distribution neighborhood with different sustainability levels can be validated through city characteristics in terms of the built environment and sociodemographic characteristics of the residents.

3.2 Reasoning behind sustainability characters of the identified neighborhood clusters

This study examined the sustainability of urban mobility character of the studied neighborhood by examining resident's median income and job-housing balance data.

3.2.1 Median Income

Socio-economic condition significantly impacts the travel behavior of the resident (Delbosc & Currie 2011). Joshi et al. (2017), found that socioeconomic characteristics were influential factors for findings neighborhoods contributing more to travel-related GHG emissions. In the case of Dhaka, a lack of affordable housing is one of the underlying reasons for which low to middle-income people have to choose their residing place in peripheral areas, distant from the workplace (Ashik et al. 2020; Rahman & Ashik 2020). Here, low to middle-income people use active modes, i.e., walking and rickshaw for their daily travel, whereas high-income groups residing in central areas have greater private vehicle use. Moreover, an increased amount of private mode use would result in premature traffic congestion, which would increase trip travel time and travel cost (Ewing & Cervero 2010). Hence, vehicular emissions would be more acute in central areas than peripheral areas affecting neighborhoods' environment, health, and economic sustainability.

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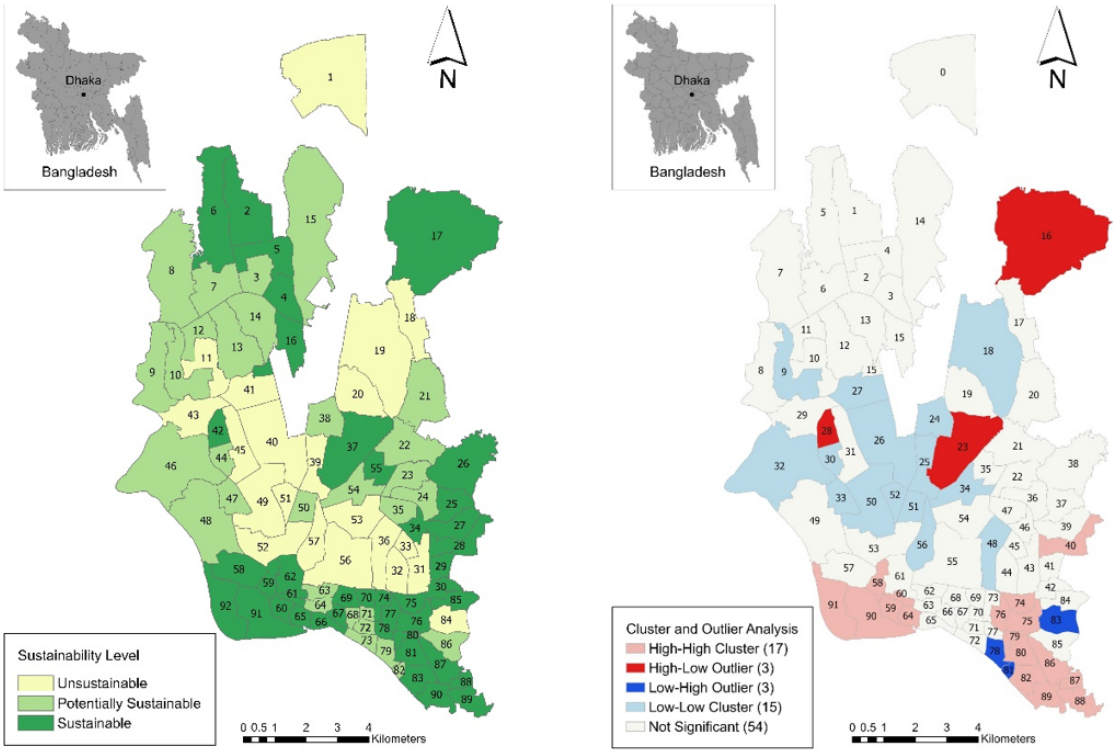


Fig. 5 Map showing the geographical location of identified clusters of neighborhoods with different sustainability levels.

Table 4 Difference in median income of people living in different types of neighborhoods

Neighborhood Types	Difference in Median Income in Thousands BDT (Significance Level)
Sustainable vs. Unsustainable	-5.98 (p = .002*)
Sustainable vs. Potentially Sustainable	-0.08 (p = .998)
Potentially Sustainable vs. Unsustainable	6.05 (p = .004*)
Overall	F (2,89) = 7.050 (p = .001*)

*note: the mean difference is significant at the 0.05 level

A one-way analysis of variance has been conducted to evaluate whether there is any significant difference in the median income among the neighborhood types with different sustainability levels. The post-hoc analysis evaluated pairwise differences in median income. Table 4 confirms that, overall, there is a significant difference in the neighborhood's median income. Residents living in sustainable neighborhoods have slightly higher median income than potentially sustainable neighborhoods, which is not statistically significant. But, unsustainable neighborhoods have higher median income than sustainable or potentially sustainable neighborhoods, and the difference is statistically significant. This result indicates that, with greater affordability, residents of identified unsustainable neighborhoods have a greater chance of using the private mode, less transit, and less active mode use, which largely impacts sustainability level.

3.2.2 Job-housing Balance

The spatial location of jobs and housing shape the travel pattern of the residents (Giuliano 1991; O'Kelly & Lee 2005). Balanced neighborhoods in terms of jobs-housing ratio would reduce commuters' travel time and travel distance, as there would be short trips to reach destinations, i.e., jobs. Cervero (2013), Ewing and Cervero (2010), Frank & Pivo (1994) recommend jobs-housing ratio value for city-scale where the values range from 0.8 to 1.8 for balanced neighborhoods. Rahman and Ashik (2020) also classified Dhaka city Neighborhoods as balanced ones where the job-housing ratio ranges from 0.80 to 1.80, ratio value less than .80 are identified as Housing-rich areas where

there is an insufficient supply of jobs for local residents. Besides, Rahman and Ashik (2020) argued that the job-housing ratio displays a diminishing return with commuting time and distance and suggested that the job housing ratio closer to 1 is more effective in reducing commuting time and distance. At 1.4, a one-unit change of job household ratio affects a 1.71 km reduction in the commuting distance, while at point 1.6, commuting distance reduces 1.62 km due to one-unit change.

Table 5 Difference in job-housing balance in different types of neighborhoods

Neighborhood Types	Mean (jobs-housing ratio)	Standard Deviation
Sustainable	1.42	1.66
Potentially Sustainable	1.82	2.01
Unsustainable	1.57	1.72
Overall	F (2, 89) = .429 (p = .001*)	

*note: the mean difference is significant at the 0.05 level

Table 5 outlines differences in the job-housing ratio between different neighborhood types and confirms that the job-household ratio of sustainable neighborhoods is more effective in reducing travel time and distance as its value is closer to a 1, more balanced job-housing ratio. Above all, it can be deduced that a balanced jobs-housing ratio is associated with sustainable mobility at the city neighborhood scale. However, the question of whether and to what degree the job-housing ratio contributes to the improvement of sustainable mobility outcomes can't be captured here.

Employment efficiency and labour efficiency are both get affected by job-housing balance. When workers reside locally, it contributes to employment efficiency, whereas sharing residents who work locally facilitates labour efficiency. These would affect travel patterns, which involves mode choice, commuting time, and travel cost. In the case of Dhaka city, neighborhoods located in old parts (southern part) of the city have more balance in terms of local employment and housing options (Rahman & Ashik 2020). That is, people can avail themselves of their employment options within proximity of the residence.

4 Conclusions

Sustainable urban mobility has become a central concern for sustainable cities and the environment. This study provided a comparative assessment of neighborhoods of Dhaka city in terms of transport sustainability in environmental, social, and economic aspects. Sustainability indicators relevant to urban transport were selected by assessing and reviewing past research and based on available data for Dhaka city. Following the two-step cluster algorithm, neighborhoods were classified into three clusters-sustainable, potentially sustainable, and unsustainable. The study result showed that sustainable neighborhoods have the lowest average travel time and trip costs per trip, with higher active mode use (75%) and lowest private mode share (4.62%). Whereas unsustainable neighborhood clusters have higher private mode use (15.23%) and also have a more significant average travel time (27 minutes) and travel cost (42 BDT) per trip for different trip purposes. Other clusters identified through this study would be beneficial to policymakers and planners to make strategic decisions. For example, policymakers need to take location-specific measures to ensure sustainability for the overall city. Here, unsustainable neighborhoods need to be accommodated with more efficient public transit options to improve mobility and accessibility from city centers.

Moreover, potentially sustainable and unsustainable areas should include a compaction policy so that balance between jobs and housing options can be made. Policies related to reducing private car ownership should be emphasized to make those neighborhoods more sustainable. Here, the built environment and Travel Demand Management (TDM) can play a vital role in reducing car ownership (Ding et al. 2018). Besides, our study suggests emphasizing the localization of jobs and housing more effectively.

Though this study includes the main determinants of transport sustainability, indicators like accessibility, traffic intensities, emissions, PT infrastructure and quality of services, pedestrian and cycling infrastructure availability, level of institutional, financial, or technical barriers, should be used to measure sustainability comprehensively. The findings from this research can be regarded as an initiation; further studies should be conducted as a follow-up, especially for cities of developing countries like Dhaka that require huge infrastructural investment and plan to improve transit and active service system.

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