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ORIGINAL PAPER

Spatial distribution of strategic service infrastructures that favour quality of life (QOL) in the Greater Dhaka Region (GDR), Bangladesh

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Abstract
This paper illustrates the spatial distribution pattern of the basic services infrastructures in the Greater Dhaka Region (GDR), Bangladesh that favour a quality life to live. The study employed the modified Human Development Index (here we termed as Service Infrastructure Index) to assess the spatial inequalities of service infrastructures at the sub-district level. Total 13 indicators from three major dimensions, such as housing and related services, education and health were used to estimate the service infrastructure index. Spatial autocorrelation based on the Global Moran's *I* was used to assess the statistical significance of the observed distribution pattern and Local Moran's *I* (cluster and outlier analysis) was employed to map the locations of infrastructure concentrations. The study found that the basic service infrastructures are unevenly distributed across the sub-districts. The index score ranges from 0.12 in Daulatpur of Manikganj district to 0.80 in Dhaka Metropolitan Area (DMA) while the regional mean is 0.29. The core city (DMA) and the areas near the core city (especially the Gazipur district) with a higher level of urbanisation and inter-regional connectivity enjoy better services. This study identified where the infrastructures are clustered and which type of infrastructure lack in different areas. Thus, it is expected that demand-based infrastructure development should get priority in the development agenda of the region.

Keywords Spatial distribution · Service infrastructure · Quality of life · Inequality · Dhaka

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Introduction

Many developing countries have been experiencing rapid growth, especially in their economic domain in recent decades. Some of them also achieving significant improvement in human development domains (UNDP 2012). However, the economic development and improvement in human development indicators at the national level do not necessarily mean that the respective countries are achieving a spatially even development. It has been argued that large urban agglomerations especially metropolitan capitals are the engines of growth of the respective countries (Campbell, n.d.; European Union 2011; Fan and Scott 2003; Vliet 2002; World Bank 2009) because they enjoy better services infrastructure (Haque 2016; Heshmati and Rashidghalam 2020; Xiao et al. 2018). Thus, it can be assumed that the standard of the living environment which build the foundation of quality of life is better in these regions.

In contemporary development literature, intra-regional inequalities gain importance along with inter-regional inequalities (Diwakar 2009; Gu et al. 2019; Majumder et al. 1995; Yin et al. 2018). The general perception is that within a region there might be an uneven distribution of some of the resources or service infrastructures, especially those which are economically important or the specialized services. It can be expected that the basic service infrastructures that support a decent living must evenly be distributed and remain accessible for all within the region. However, there is hardly any city or region, which shows an inclusive development. For instance, in most of the South Asian megacities, there is a significant disparity exists in accessing housing, healthcare facilities, even in access to education (Nambissan 2021; Sultana and Nazem 2020; Thapa et al. 2021). The accessibility differs due to both socio-economic differentiation and proximity to the services (Gu et al. 2019; Nahar Lata 2021). Even in the case of developed economies, Haffner and Hulse (2021) found that fast-growing suburbs in large cities often struggle to provide the necessary infrastructure to achieve social inclusions, health and well-being. Sharifi et al. (2021) argued that high-income groups have better access to a healthy environment, green spaces. Moreover, they also found that low-income group have to move from a healthy environment to less livable areas due to their limited affordability. There is also high disparities in accessing education facilities in the cities (Touitou et al. 2020). The high-income neighbourhood enjoys better education infrastructure and comparatively greater education achievements (Owens and Candipan 2019). There are many other similar studies (Gu et al. 2019; Rogerson and Nel 2016; Wang et al. 2018; X. Wei et al. 2018; Yin et al. 2018; Zimbalist 2017) found the existence of spatial disparities of infrastructure provisions and their accessibility.

There are several methods to measure and compare spatial inequalities. Indices such as Gini Inequality Index (GNI) (Dadashpoor et al. 2016; Wei et al. 2017; Yitzhaki 1983), Theil Index (Yin et al. 2018; Zhang and Deng 2016), Human Development Index (HDI) (Anand and Sen 1994), Inequality-adjusted HDI (Hicks 1997) are commonly used in assessing the spatial inequality and disparity. Global Moran's *I*, Geary's *C*, Local Indicators of Spatial Association (LISA) are some techniques that are used to relate indicators with space that helps in ascertaining spatial inequalities (Yin et al. 2018).

This study has been designed based on the argument mentioned above and aimed to assess and provide an aggregated pattern of the spatial distribution of basic services infrastructures that favour quality of life in an economically important region in Bangladesh. Like many developing nations, Bangladesh has also been experiencing spatial disparity in the distribution of basic infrastructure services within and between regions (Islam et al. 2018). Cities are the prime areas where such unevenness is comparatively extreme (Rana 2011). The Greater Dhaka Region (GDR) has been selected as a case to study the spatial distribution pattern of service infrastructures across its sub-regions. There are three reasons to select the GDR as a case study. Firstly, the economic landscape of the area is undergoing rapid changes in recent years, and it is the most economically competitive region in the country (Choe et al. 2011; Choe and Roberts 2011; Hossain and Huggins 2021). Secondly, this region accommodates one of the world's fastest-growing megacity, Dhaka (BBS 2014; Roy et al. 2019). In most of the national and international studies, Dhaka mega city represents the country. This study has attempted to understand the pattern of distributions of service infrastructures around a megacity and to identify whether the city is growing inclusively with its surrounding areas. Thirdly, there is a general perception that the political, socio-economic and service infrastructure primacy of Dhaka result in rapid urbanisation through migration towards Dhaka city. Thus, the study also focuses on exploring the level of infrastructure primacy of Dhaka and inequalities in the sub-regions (*Upazila*) of the GDR regarding service infrastructures.

This study has progressed making a hypothesis. We have set the null hypothesis (H_0) of the study as—*there is no significant difference in the distribution of basic service infrastructures across the sub-regions of the study area*. To assess the hypothesis, preliminarily, the study adopted a customized version of the human development index (HDI) to measure the coefficient of service infrastructure index. Then, the spatial distribution has been analysed using a spatial autocorrelation method to assess the statistical significance of the distribution pattern (discussed in detail in 'The study area, empirical approach and data'). Finally, we have tried to explain the observed distribution pattern by some proximity and urbanisation variables.

Effects of basic services infrastructure on quality of life

The quality of life (QOL) is an elusive concept, usually denotes a life that is considered as well lived with satisfaction (Rojas 2014). It also refers to a living condition that an individual or society achieves and enjoys (Diener and Suh 1997). However, there are no universally accepted standards for life quality (Costanza et al. 2008; Das 2008; Felce and Perry 1995). A wide range of literature shows that QOL is a context-dependent on multidimensional factors such as an individual's philosophy of life, socio-political freedom to live a life with dignity, the presence of affordable amenities of life, and strategic infrastructures that favour better livable environments (Felce and Perry 1995; Landesman 1986).

There has been a long debate on measuring the quality of life (Costanza et al. 2008; Das 2008; Diener and Suh 1997; Narvaez et al. 2008; Rojas 2014). Three approaches are explicitly applied for understanding quality of life, subjective, objective and normative (Ballas and Dorling 2013; Marans and Stimson 2011). The subjective approach focuses on the individual's perception (Douglas et al. 2018) and the objective approach concentrates on the evaluation of physical, social and environmental indicators (Apparicio et al. 2008), while the normative approach highlights the philosophical aspects of a decent life (Marans and Stimson 2011). However, scholars converge on the point that living conditions would always be the focal point of measuring the quality of life as they are the precondition of providing satisfaction with life (Das 2008; Rogerson et al. 1989; Shin et al. 2003). It is factual that the level of satisfaction on available life conditions may vary among individuals (Narvaez et al. 2008), however, the presence of adequate, such services with good access by the people of all strata may increase their level of satisfaction.

Numerous studies (Das 2008; Diener and Suh 1997; McCrea et al. 2006; Narvaez et al. 2008; Rojas 2014) investigated the relationship between services infrastructures, living conditions and quality of life and found a significant positive association. Streimikiene (2015) and Kowaltowski et al. (2006) considered housing, education, and health infrastructures as the essential components of living conditions that favour a quality life because they usually form the foundation of other life issues (Trainor et al. 1999). A satisfactory accommodation with essential services such as water, sanitation and electricity facilities offer security, privacy and personal space as well as good health and childhood development (Myers et al. 1996; Streimikiene 2015). Proper and adequate housing is such an essential element that, it is also noted as the critical factor in achieving and maintaining healthy and quality life (Streimikiene 2015; Trainor et al. 1999). The European Quality of Life Survey (2012) found that economically stable people (employed or have sufficient income for a living) are highly satisfied than the unemployed, underemployed and economically inactive populations (Eurofound 2012). People with a higher level of education enjoy a higher quality of life, and educated individuals have a significant impact on economic affordability and satisfaction (Glaeser et al. 1995; Glaeser and Shapiro 2003; Simon 1998, 2004; Simon and Nardinelli 2002). Higher access to health facilities also offers higher satisfaction in the health domain of quality of life (Eurofound 2012; Li and Wei 2010).

The study area, empirical approach and data

The study area

The Greater Dhaka Region (GDR) consists of six administrative districts: Dhaka, Narayanganj, Gazipur, Narsingdi, Manikganj and Munshiganj (Fig. 1) covering an area of 7942 square kilometres. A substantial part of the area is fully urbanised, while some pocket areas are semi-urban, and some are still rural. According to the Population and Housing Census 2011 (BBS 2014), there were about 23.5 million people in the GDR in 2001 and the population density was 3131 persons per square

Fig. 1 Greater Dhaka Region (GDR). Source: Prepared by authors based on (BBS 2012f; Islam and Hossain 2013; RAJUK 2015)

kilometres. Within GDR, the level of urbanisation is 67.28% (about 15.8 million people living in the officially designated urban areas), the highest in the country if we consider it as a region. It comprises over 35% of the national urban population (BBS 2014). The GDR is growing at a rate of 4.1% per year—way above the national population growth rate (1.4% per year) (BBS 2012f). If similar growth trends continue, it is estimated that by 2021, there will be more than 36 million people will be in the area (authors' estimate using geometric growth formula).

Table 1 shows that within the region there is an unequal distribution of population and the growth rate also vary significantly. Dhaka district contains a significant portion of the Dhaka megacity, comprises more than half of the GDR's population, although in terms of the geographical area it is about one-fifth of the GDR. In Dhaka district, the population density is more than two and half times the average of the region. In the DMA, the city core of the megacity region the population density is about 41,000 per square kilometre (Bird et al. 2018). The table also shows that the level of urbanisation is equal to or less than 20% in three among the six districts, while the average level of urbanisation is more than 67%. In terms of population growth rate, Dhaka district shows a relatively lower rate than the regional average because the area is dense, and the growth is now transmitting to its surrounding districts. The population growth rate is found higher in Gazipur and Narayanganj districts because the megacity Dhaka and major production activities are expanding towards these districts (Hossain and Huggins 2021).

Dhaka megacity, one of the largest cities in the world is in the GDR. Figure 1 shows the geographical extent of the megacity (more or less equivalent to the Dhaka Metropolitan Development Plan, DMDP area) in hatched line. It covers an

Table 1 Area, population, density, level of urbanisation, growth rate in GDR

District	Area (in sq.km)	Population	Urban population	Population density (per sq.km)	Level of urbanization (%)	Population growth rate (% per year)	Population in 2021 (estimated by authors)
Dhaka	1463.3	12,043,977	10,828,905	8229	89.9	3.3	16,663,765
Gazipur	1806.4	3,403,912	2,200,360	1884	64.6	9.0	8,058,298
Manikganj	1383.7	1,392,867	129,223	1007	9.3	3.1	1,890,150
Munshiganj	1004.3	1,445,660	219,584	1439	15.2	4.0	2,139,930
Narayanganj	684.4	2,948,217	1,956,601	4308	66.4	4.8	4,711,642
Narsingdi	1150.1	2,224,944	449,487	1934	20.2	2.5	2,848,116
GDR	7492.4	23,459,577	15,784,160	3131	67.3	**4.1**	36,311,901

Source BBS (2012a, b, c, d, e, f) and authors' estimate based on the Census data area of 1530 square kilometres and accommodating more than 18 million population (RAJUK 2015). There is no regional level GDP or economic data available in Bangladesh, however, several studies estimated that Dhaka city (1530 square kilometres) generates more than 20% of the national GDP (Bird et al. 2018). The city comprises more than 31% of the country's manufacturing employment, 44% of all formal employment and 80% of export-oriented garment factories (Bird et al. 2018).

Empirical approach

The service infrastructure index

The study adopted the United Nation's composite indices (Stanton 2007) to assess the aggregated service infrastructure quality. It is a globally accepted and justified method to assess spatial disparities. The empirical analysis estimates the strategic infrastructure function using cross-sectional regional service infrastructure data from three major dimensions (or categories) in the Greater Dhaka Region at the sub-district (*Upazila*) level, as shown in Eq. 1:

$$SI_{\mathrm{r}} = f\left(HOU_{\mathrm{r}}, EDU_{\mathrm{r}}, HEA_{\mathrm{r}}\right) \tag{1}$$

In Eq. 1, $\mathrm{SI_r}$ is the aggregated score of strategic infrastructures in sub-district 'r' which is determined by the quality of housing (HOU_{r}), quality of education (EDU_{r}), and quality of health (HEA_{r}) infrastructures in 'r' sub-district. Each dimension (housing, education and health) function was estimated using cross-sectional data at the same sub-district level. The procedure followed to assess the aggregated service infrastructure quality index is described below.

(a) Index for the individual indicator was calculated using the following formula (Eq. 2). This process is also known as the normalisation of values as they come from a different population or on a different scale. The index values range from 0 to 1.

$$I_{r,i} = \frac{X_{r,i} - X_{\mathrm{min},i}}{X_{\mathrm{max},i} - X_{\mathrm{min},i}} \tag{2}$$

Here, $I_{\mathrm{r},i}$ is the index or normalized value of indicator '*i*' in sub-district 'r', $X_{\mathrm{r},i}$ is the actual value of indicator '*i*' in sub-district 'r', $X_{\mathrm{min},i}$ is the minimum value of indicator '*i*' in the distribution (over the GDR region), and $X_{\mathrm{max},i}$ is the maximum value of indicator '*i*' in the distribution.

(b) Dimension index is the arithmetic mean of the index of the indicator within the dimension. The following formula (Eq. 3) was used to calculate the dimension index.

$$D_{\mathrm{r},i} = \sum_{i=0}^{n} I_{\mathrm{r},i} W_{\mathrm{r},i} \tag{3}$$

Here, $D_{\mathrm{r},i}$ is the dimension 'i' index in sub-district 'r', $I_{\mathrm{r},i}$ is the indicator's (from dimension 'i') index in sub-district 'r', and $W_{\mathrm{r},i}$ is the weight of the indicator within the dimension 'i'. In this study, the indicator's weight was considered equal within the dimension, and thus the formula stands as the following (Eq. 4).

$$D_{\mathrm{r},i} = \sum_{i=0}^{n} I_{\mathrm{r},i} \tag{4}$$

(c) Finally, the aggregated score was the geometric mean of dimension indexes for each sub-district. The following formula (Eq. 5) is used to calculate the geometric mean.

$$\mathrm{SII}_{\mathrm{r}} = \left(\prod_{i=o}^{n} D_{\mathrm{r},i} \right)^{\frac{1}{n}} \tag{5}$$

Here, $\mathrm{SII}_{\mathrm{r},i}$ is the aggregated service infrastructure index of sub-district 'r' and $D_{\mathrm{r},i}$ is the score of dimension 'i' in sub-district 'r'.

Assessing and mapping the significance of the observed distribution pattern

To assess the distribution pattern of the services infrastructure and statistical significance of the observed pattern, we employed spatial autocorrelation based on Global Moran's *I* and used the Moran's cluster and outlier analysis (Anselin 1995) to identify and map the significant concentration of the service infrastructures. This is a very popular technique to assess spatial distribution or spatial inequality (Gezici and Hewings 2007). In this method, global statistics provide the overall distribution pattern and local statistics provide the location of significant concentrations. The following formula was used to calculate the Moran's *I*.

$$I = \frac{n}{W} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{\sum_{i=1}^{n} \left(x_i - \overline{x}\right)^2} \tag{6}$$

where W_{ij} is the weight between observation i and j, and W is the sum of all W_{ij}. Values of x will be positively correlated if the observed value of I is significantly greater than the expected values (I_o), whereas if I is less than I_o indicates negative autocorrelation. Local Moran's I identify spatial clusters of features with high or low values. High values indicate that the given area is in the proximity of the other areas with similarly high levels of clustering. As a result, maps of the I-statistics provide a summary of the regional distribution of clustering as well as important localised clusters in neighbour areas.

Explaining the observed distribution pattern

Several studies show that uneven spatial distribution and accessibility of service infrastructures are influenced by geographical characteristics of the place, urbanization, population density, transportation and connectivity, resource allocation and investment (CBS 2011; Gu et al. 2019; Ma et al. 2017; Yin et al. 2018). In this study, we used locational phenomena to explain the spatial disparities of service infrastructure in the GDR. Literature suggests that the quality of service infrastructures is better in urban agglomerations (Jones et al. 2014; Rana et al. 2017). Besides, location theories also argue that the service infrastructure tends to grow in such a place that is more accessible at the intra-regional or inter-regional level. In such a context, in this study, we use three variables related to location advantages to explain the regional disparities of infrastructures. They are (a) level of urbanization to explain the urban agglomeration, (b) proximity to the nearest national highway to explain the access the inter-regional connectivity, and (c) proximity to the capital city Dhaka, as the capital city has a significant impact on the spatial development of the surrounding regions. We perform Pearson's correlation test to assess the associations between the observed infrastructure index and the variables. The Pearson correlation test is used to measure the linear correlation between two variables (Ott and Longnecker 2015). The coefficient value of the test is a normalised measurement of the covariance and thus the coefficient values are between -1 and 1. The coefficient value of -1 or $+1$ indicates a perfect linear correlation between the two variables, though the direction is opposite. The coefficient value 0 indicates no correlation between the variables. Thus, values close to $+1$ or -1 indicates a higher correlation and the significance of the correlation is determined by p values (normally $p<0.05$).

Data description and sources

In this study, 13 indicators from three major dimensions were used to assess the quality of service infrastructures. Table 2 shows the major dimensions, indicators in each dimension, the scale of measurements and their relationship with quality of living conditions and quality of life.

Data on various service infrastructures for 2011 was collected from the District Statistics Report (BBS 2013a, b, c, d, e). The data on the level of urbanisation was collected from the Community Report (BBS 2012a, b, c, d, e, 2016) of the Population and Housing Census 2011 published by the Bangladesh Bureau of Statistics (BBS). National highway data were extracted from the Open Street Map (www.openstreetmap.org) as GIS shape. Historical information on the national highway was collected from the Department of Roads and Highway to correct the OSM dataset for 2011. The sub-district level GIS shape and municipal shape for 2011 were collected from the BBS. All spatial datasets were geo-referenced using Transverse Mercator (WGS_1984_UTM_Zone_46N) projection system. The distance (Euclidian distance in metres) were measured from the geographically weighted centre of each sub-district to the nearest municipal boundary, nearest highway and Dhaka city

Table 2 Dimensions and Indicators of service infrastructures related to QOL with the scale of measurements

Dimension	Indicators	Scale of measurements	Relationship with QOL
Housing	Type of dwelling structures	% of people lived in the improved or permanent structure	People living in good quality houses enjoy better living conditions. Besides, this is also representing the affordability of the housing
	Tenure	% of people lives in owned houses	Tenure is strongly related to housing security. Numerous studies found that people who own houses feel secured and satisfied with their livable environments than the tenant or illegal dwellers
	Use of safe water	% of households use safe sources of water	Access to safe water and sanitation directly linked to health risks. It also determines the quality of livable environments
	Sanitation	% of households use sanitary toilets	
	Availability of electricity	% of households have electricity connection to their houses	Access to electricity increase the use of modern amenities and information technology. Several studies found that the availability of modern amenities and technology increases the level of satisfaction of life
Education	Availability of schools	No. of schools per 100,000 population	A higher number of per capita schools and colleges indicates that better availability of education infrastructures
	Availability of colleges and higher education institutions	No. of colleges per 100,000 population	
	Physical Accessibility to schools	Density of schools (per square kilometre)	The higher density of schools or colleges indicates that the educational institutions are located very close, and physical access to the education services become higher
	Physical accessibility to higher education institutions	Density of colleges (per square kilometre)	
	Literacy rate	Literacy rate in 7 + populations in %	The literacy rate is the outcome of the presence of education infrastructure services. Quality of life in a more educated society found better than a low educated society

Table 2 (continued)

Dimension	Indicators	Scale of measurements	Relationship with QOL
Health	Availability of hospital services	No. of hospital bed per 100,000 population	A higher number of hospital beds indicates higher access to quality health facilities
	Availability of doctors	No. of doctors in public and private hospitals per 100,000 population	A higher number of doctors indicates higher access to quality health facilities, and they do not need to move to other areas for their health issues
	Availability of diagnostic centres	No. of diagnostic centres per 100,000 population	In the context of Bangladesh, diagnostic centres work not only providing health examination facilities but also; they have facilities to provide doctor's consultancy. Thus, the availability of such centres increases the access to health facilities

boundary. Table 3 shows the summary statistics of the indicators, measures of service infrastructures and explanatory variables.

Findings

Spatial distribution of services infrastructure

Housing and household services infrastructure

The sub-district level data shows that the quality of housing structure (in terms of durability and material used) is better in the Dhaka Metropolitan Area (DMA) and its surrounding areas. More than 80% of the households of DMA and Savar *Upazila* live in better-quality houses followed by 60–80% in Keraniganj, Narayanganj Sadar and Gazipur Sadar *Upazila* (Fig. 2A). In terms of tenure condition, the periphery areas (especially the rural dominant sub-districts) found to be better as more than 80% of people of those sub-districts are living in owned houses (Fig. 2B). In the DMA, less than 10% of the households live in owned houses.

Access to safe drinking water is very good in the region. More than 95% of households have access to safe drinking water and the spatial variation is very low (Fig. 2C). The sanitation condition in the GDR (about 85%) is better than the national average (63.5%) (BBS 2012f). Figure 2D shows that the central part of the region (Dhaka mega city) has better access to sanitation services. About 95% of

Table 3 Summary statistics of the indicators and explanatory variables

Indicators/variables	Scale	Range	Min	Max	Mean	SD
Indicators						
Households live in improved dwelling structure	%	83.50	5.10	88.60	32.21	22.52
Households live in owned houses (tenure security)	%	88.13	8.97	97.10	77.12	23.51
Households have access to safe drinking water	%	6.00	93.20	99.20	97.12	1.25
Households have access to sanitary toilets	%	48.60	45.90	94.50	74.57	13.31
Households have access to electricity connections	%	65.70	32.90	98.60	77.42	18.80
No. of schools per 100,000 population	No	170.79	28.10	198.89	80.82	37.59
No. of colleges per 100,000 population	No	3.67	0.64	4.31	1.84	0.99
School density (per square kilometre)	No	12.42	0.44	12.86	1.65	2.08
College density (per square kilometre)	No	0.63	0.01	0.64	0.05	0.11
Literacy rate in the 7 + population	%	39.70	34.90	74.60	54.68	7.41
No. of hospital beds per 100,000 population	No	275.28	13.44	288.72	56.27	56.62
No. of doctors per 100,000 population	No	106.02	6.39	112.41	21.33	18.35
No. of diagnostic centres per 100,000 population	No	13.93	0.00	13.93	3.08	3.00
Explanatory variables						
Level of urbanization	%	100.00	0.00	100.00	18.62	20.74
Av. distance from Dhaka City	Meters	55,358	1405	56,763	26,905	14,146
Av. distance from the nearest highway	Meters	10,367	942	11,309	3193	2161

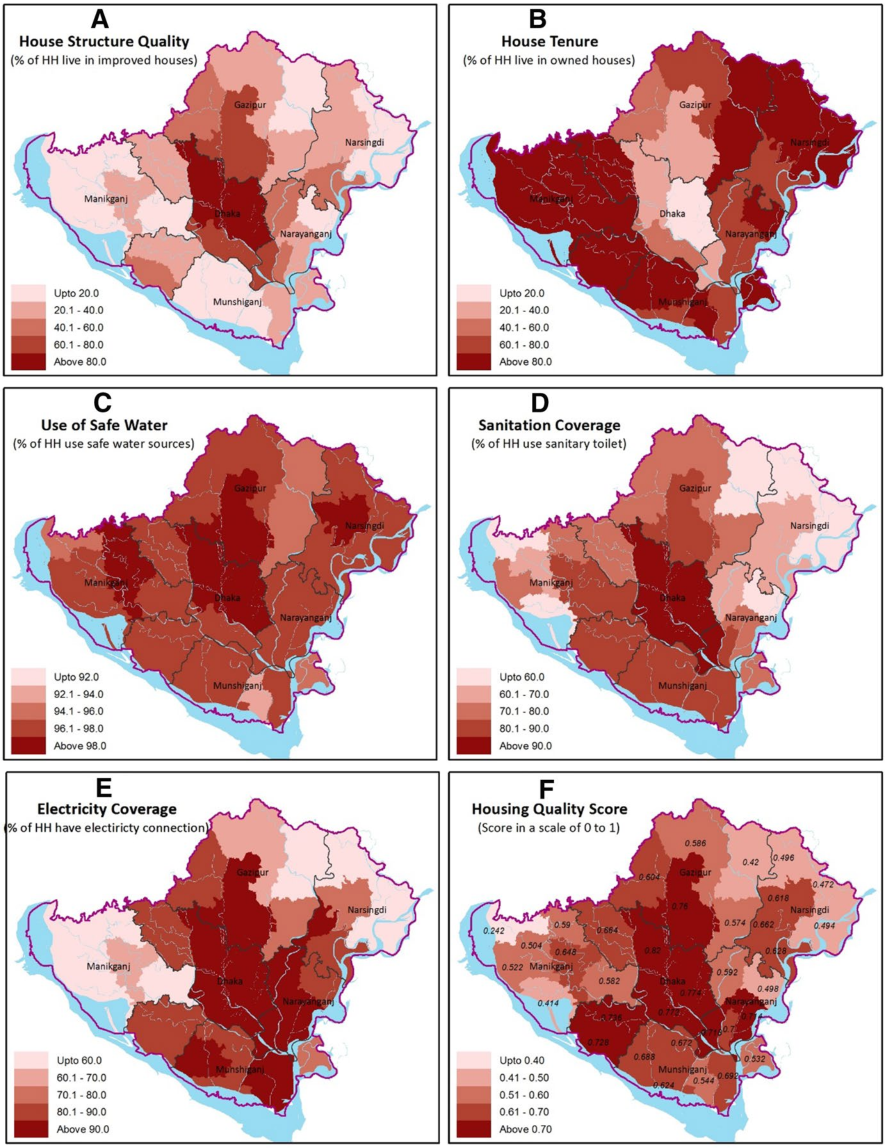

Fig. 2 Housing Quality Indicators and Housing Quality Index

the households use sanitary toilets in that area followed by 80–90% in the *Upazials* adjacent to Dhaka Metropolitan Area in the north and south. A significant portion of the Narsingdi district lacks sanitation facilities where about 40% of households do not have access to this facility.

Electricity is possibly the most critical factor contributing to a better living environment. Access to electricity is relatively good all over the region, however, there is an acute shortage of electricity supply, and most areas experience frequent blackouts. In the central part of GDR, especially in Dhaka district, about 97% of households have access to electricity (Fig. 2E). Significant portions of Manikganj and Narsingdi districts lack access to electricity. Only about 52% of the households of Manikganj and 72% of households of Narsingdi districts have electricity connections.

Education infrastructures

Gazipur district found to be better than the other five districts regarding both the per capita schools and colleges (Fig. 3A and 3B). This result contradicts the general perception that DMA has higher concentrations of education institutions in the region. Although DMA accommodates the highest number of institutions, such pattern of low per capita institutions in DMA has been found due to higher concentration (or density) of the population. Moreover, the size of the institutions in DMA in terms of student capacity is very large.

However, the density of institutions is very high in DMA (Fig. 3C and D). There are more than 12 schools in the DMA in a square kilometre, while other regions except for Gazipur Sadar and Narayanganj Sadar have less than two schools in a square kilometre. Although in terms of the number of institutions per capita DMA found to be worst in GDR, in terms of accessibility it is found far better than other areas.

The literacy rate is not a service but an outcome of education services. This study assumes that the region with a high level of literacy rate enjoys better access to education services. At the district level, the literacy rate in Dhaka is found to be 70.5%, followed by Gazipur (62.6%) and Narayanganj (57.1%). At the sub-district level, urban agglomerations, (i.e.) DMA, Savar, Gazipur Sadar and Narayanganj Sadar have a higher proportion of the literate population than other areas (Fig. 3E).

Health infrastructures

In terms of the number of the hospital bed per capita, the DMA and Manikganj Sadar are found to be better where more than 160 hospital beds are available for 100,000 population (Fig. 4A). The rural dominant *Upazilas* have poor hospital facilities and only up to 40 hospital beds are available for every 100,000 population. According to the availability of doctors in the hospital, a similar pattern has been found in the GDR (Fig. 4B). The DMA has a higher quantity of doctors both in public and private hospitals. Except some *Upazilas* in Gazipur and Narsingdi, the number of doctors per capita is found very few in other areas. The number of diagnostic centres is found to be higher in the DMA, and Sreepur and Kaliakair *Upazila* of Gazipur district (Fig. 4C).

The strategic infrastructure indices

The housing quality and service infrastructure index shows that there is a robust spatial disparity in the GDR where the highest score accounted as 0.82 and the lowest

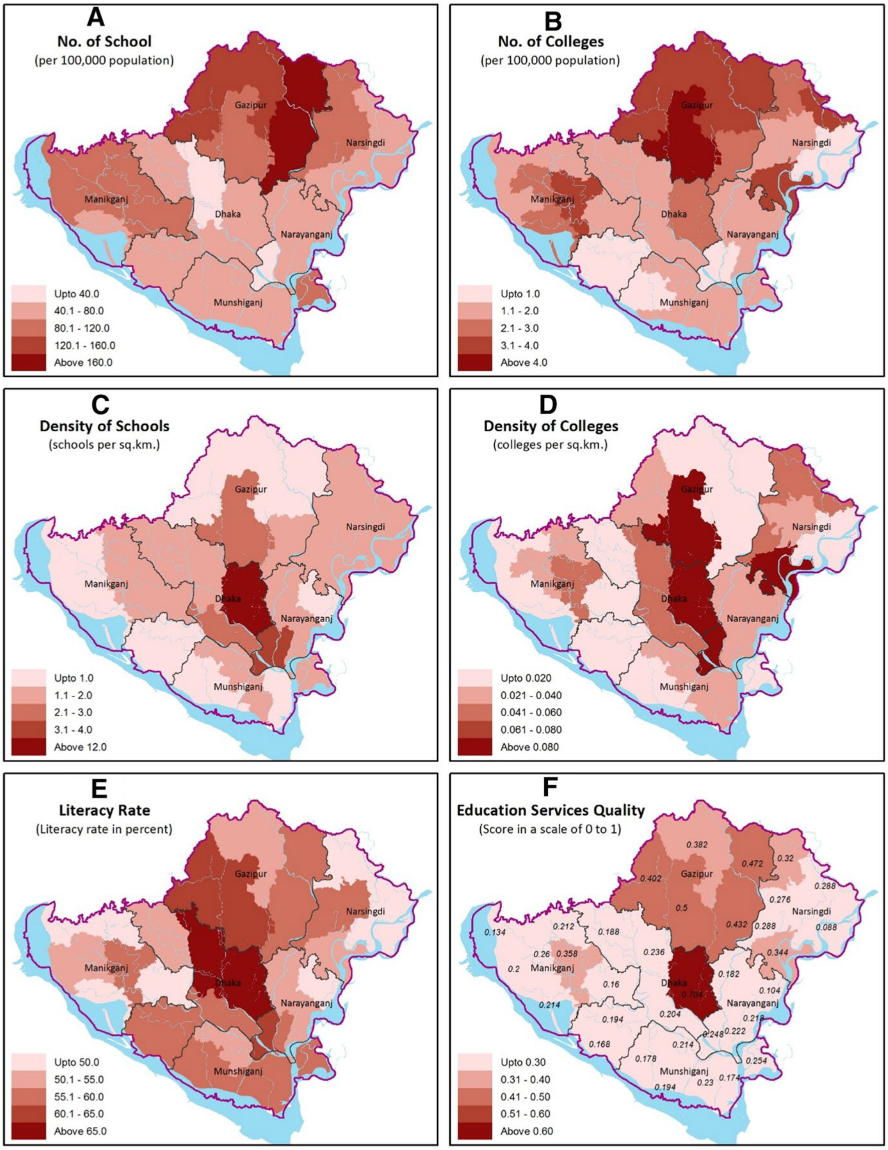

Fig. 3 Education Infrastructure Indicators and Quality of Education Services Index

score as 0.24 (Table 4 and Fig. 2F). The mean of the sub-district level index is 0.61 with a standard deviation of 0.12. The people living in the Dhaka district enjoy a far better-quality of housing and household services than the other regions. The Savar *Upazila* ranks top with a score of 0.82 followed by DMA (0.774), Keraniganj (0.772), Gazipur Sadar (0.76). In the other districts, the housing quality is found to be better in the urban dominant sub-districts. Moran's index of spatial distribution

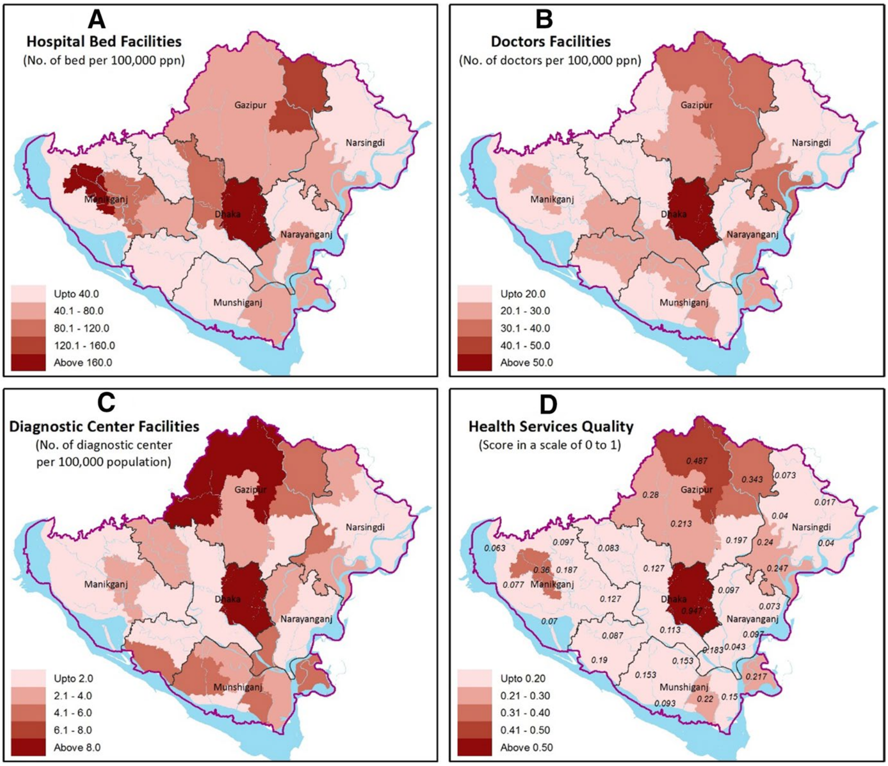

Fig. 4 Health Infrastructure Indicators and Quality of Health Services Index

Table 4 Descriptive statistics of service infrastructure index by domains

Measures of service infrastructures	Scale	Range	Min	Max	Mean	SD
Housing infrastructure index (SII_HOU)	1.00	0.58	0.24	0.82	0.61	0.12
Education infrastructure index (SII_EDU)	1.00	0.62	0.09	0.70	0.26	0.12
Health infrastructure index (SII_HEA)	1.00	0.93	0.02	0.95	0.18	0.17
Aggregated SII	1.00	0.65	0.12	0.77	0.29	0.11

(Table 5) shows the housing quality and services infrastructure are significantly concentrated in the GDR. The observed Moran's index found to be 0.338775 with a p-value of 0.000224.

The mean of the sub-district level education infrastructure index is 0.26 with a standard deviation of 0.12. Figure 3F shows the Dhaka Metropolitan Area (DMA) enjoys far better-quality education infrastructure than the other areas of the GDR. The index score of DMA is found to be 0.704 followed by only 0.500 in Gazipur Sadar. The education infrastructures are very poor in the surrounding areas of DMA (although they are parts of the Dhaka district). In the Gazipur district, the education

Table 5 Moran's Index and related statistics by indicator domains

Infrastructure domains	Index	Expected	Variance	*Z* value	*P*-value
SII_Agg	0.240099	− 0.029412	0.008248	2.967521	0.003002
SII_HOU	0.338775	− 0.029412	0.009957	3.689787	0.000224
SII_EDU	0.278211	− 0.029412	0.009236	3.200952	0.00137
SII_HEA	− 0.005241	− 0.029412	0.006653	0.296332	0.766976

services are almost equally distributed throughout its sub-districts. The Moran's Index for the education infrastructure is found to be 0.278211 ($p = 0.001370$), which indicates the infrastructures are significantly concentrated.

The mean of the sub-district level health infrastructure index is 0.18 with a standard deviation of 0.17. The mean and standard deviation indicate that there are very few sub-districts where the concentration of health infrastructure is very high. The aggregate health infrastructure index shows that DMA enjoys far better health services than the other regions of GDR. The health infrastructure index score of DMA is found to be 0.947 while most of the *Upazilas'* index score was less than 0.3. The statistical significance test shows that the observed Moran's Index is − 0.005241 ($p = 0.766976$). This result indicates that the distribution of health infrastructures are random in the GDR. If we look at the variable level, in terms of the number of hospital beds and number of doctors, DMA shows a higher concentration. However, small clinic and diagnostic centres are highly concentrated in a large portion of the periphery areas. These two opposite patterns combinedly reduce the health infrastructure inequalities between the sub-regions.

Figure 5 shows the index of aggregate strategic infrastructures at the sub-district level in the GDR. The aggregated index score of the DMA is the highest, 0.766. Except for Munshiganj, the district headquarter regions enjoy better services than other areas. The inequality of services infrastructure is highly significant not only in the GDR but also within the districts. For example, in the Dhaka district, the score difference between the better one (DMR 0.766) and the worst one (Dhamrai 0.238) is 0.528. However, the results show that all *Upazilas* of the Gazipur district enjoy similar service infrastructures as they are distributed uniformly across the sub-districts. The difference between the highest score (0.452) and the lowest score (0.404) is found to be only 0.048 in the Gazipur district. The Moran's Index for the aggregated strategic infrastructure is 0.240099 ($p = 0.003002$) indicates that the distribution pattern is significantly clustered in the GDR.

Mapping significant concentrations of infrastructures

The earlier 'The strategic infrastructure indices' illustrated the infrastructures are unevenly spatially distributed in GDR. In this section, we identify and map the locations of significant concentrations of infrastructures. To map the significant concentration of infrastructures, we employed Moran's cluster and outlier analysis and plotted only statistically significant concentrations ($p < 0.05$; z_i is < -1.96 or $> +1.96$)

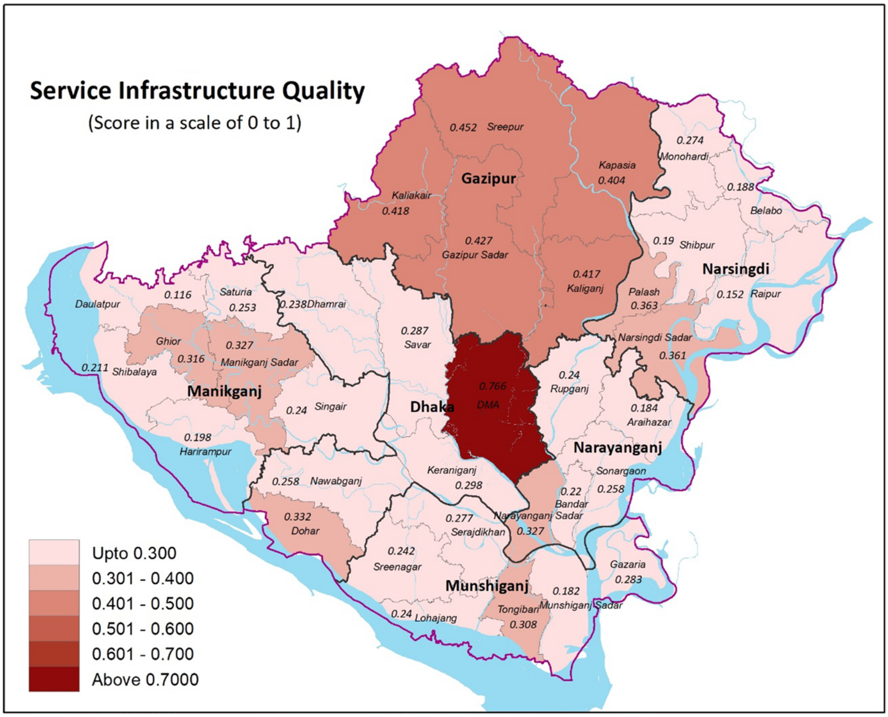

Fig. 5 Aggregate Services Infrastructure Index

in the map. This technique identifies four types of clustering, (a) high–high cluster represents a high value surrounded by high values, (b) high–low clustering, a high value surrounded by low values, (c) low–high clustering, a low value surrounded by high values and (d) low–low clustering, a low value surrounded by low values. In our analysis, we considered the first two types of clustering, High-High and High-Low. Figure 6 shows the significant concentrations of infrastructures by the major domains. The map shows that the better-quality housing and housing service infrastructures are significantly concentrated in DMA and adjacent west and south sub-districts (Savar, Keraniganj and Narayanganj Sadar *Upazila*, respectively), while the education infrastructures are concentrated in DMA and the adjacent northern sub-districts. The health infrastructure is mainly concentrated in DMA and the northern-most subdistrict of the Gazipur district. Comparing Figs. 5 and 6, it can be argued that although DMA and its adjacent northern and southern sub-districts shows the high aggregated score, however, the locations of concentrations are not the same by the infrastructure domains.

Effects of urbanisation and proximity factors on the distribution pattern

The study identifies that the basic infrastructures that support the quality of life are unevenly distributed in GDR. In most cases, the urban dominant sub-districts

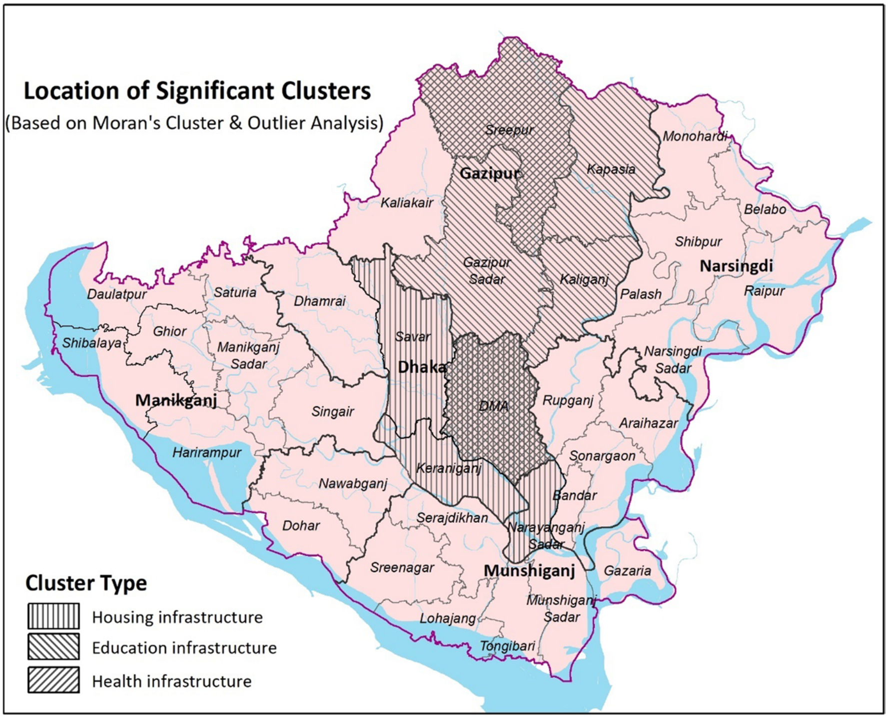

Fig. 6 Locations of significant concentration of infrastructures

enjoy better infrastructures than the other sub-districts. DMA, the major urban agglomeration of the country enjoys far better infrastructure followed by its surrounding sub-districts. We also found that the sub-districts that contain large municipalities also enjoy better services than the other sub-districts of the respective district. The correlation of the level of urbanisation with aggregated service infrastructure is 0.670**. By domains, the highest association has been found with the health infrastructure (0.636**) followed by education infrastructure (0.593**), and housing infrastructure (0.444**) (Table 6).

In regional growth literature, it is argued that when the core city area becomes overconcentrated, infrastructure and growth take place in the adjacent areas. However, we have found that infrastructure is better only in those adjacent areas which have better access to inter-regional connectivity. The correlation between access to regional connectivity and aggregated service infrastructure is highly significant (– 0.515**). The assessment result shows that education and housing infrastructures are found to better in those areas where the inter-regional connectivity is better.

The association between proximity to Dhaka City and aggregated service infrastructure is found – 0.550**. It shows housing infrastructure has the strongest association (– 0.689**) with capital city followed by health infrastructure and education infrastructure.

Table 6 Correlation between measures of service infrastructures and explanatory variables

Variables	SII	SII_HOU	SII_EDU	SII_HEA
Level of urbanisation (UR)				
r	0.670**	0.444**	0.593**	0.636**
Sig.	0.000	0.008	0.000	0.000
Distance from Dhaka City (in log scale) DD_log				
r	− 0.550**	− 0.689**	− 0.374*	− 0.497**
Sig.	0.001	0.000	0.027	0.002
Minimum distance from inter-regional transport networks (DN_log)				
r	− 0.515**	− 0.518**	− 0.532**	− 0.406*
Sig.	0.002	0.001	0.001	0.016

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Discussion and conclusions

Before making any conclusion, first, we need to address the methodological issue and justify how significantly the variables are representative to assess the quality of life. There is no study or data on the quality of life in Bangladesh at a regional level. Thus, we use a human development index as the proxy variable to assess the appropriateness of the used indicators. However, there are also limitations as the regional level human development index is not available. To overcome this, we estimated the human development index at the district level using the available human development indicators' dataset. Then we test the association between the district level infrastructure index and district level human development index. The association result shows that our observed service infrastructure index is highly correlated ($r = 0.615$) with the human development index and the correlation is significant ($p = 0.097$). From this finding, we can argue that the indicators we selected to measure the quality of life infrastructures are very representative.

The study findings confirm that there is high spatial inequality in the provision of basic services infrastructures within the Greater Dhaka Region. The DMA, which is the core of the region, enjoys better infrastructures compare to other sub-districts in all studied service domains (housing, education and health). This situation can be explained by what Henderson (2002) argued regarding the growth and development of developing country cities. He argued that due to limited resources and capital, many of the developing countries development can be characterised as primate city favouritism, as there is already a comparatively better infrastructure and a lower investment in the region can return higher growth. However, the DMA is also suffering from excessive concentration of people and activities (Bird et al. 2018; Hossain and Huggins 2021), such as lack of affordable housing, traffic congestions, higher informality. RAJUK (2015) estimates that the housing backlog is about 0.46 million in Dhaka city. Thus, like other South Asian cities, many people live in slums, a poor-quality housing type in terms of size and services (Sultana and Nazem 2020).

In the DMA, more than one-third of the city population lives in slums (Islam et al. 2006). Moreover, excessive congestions-induced traffic congestions to slow down the movement of people. In Dhaka, the driving speed has declined from 21 km to only 7 km per hour in the last 10 years and on average people are spending about 2.4 h daily on the road (Bird et al. 2018).

On the other hand, adjacent to the DMA, some of the areas enjoy better infrastructures. These are mainly the new growth areas in the north, south and west. This pattern of growth in the adjacent areas can be explained by the 'wave of dispersion' effects in growth-pole theory (Perroux 1950), 'spread effects' in Myrdal's growth theory (Myrdal 1957). Perroux argued that while the wave of polarisation creates the growth of the pole, the wave of dispersion is responsible for the transmission of development to their zone of influence. The possible development receiving zones are those, which are close to the core and have a better connection to the core. In such a context, the Gazipur (the northern adjacent area), Narayanganj (the southern adjacent area) and Savar (the western adjacent area) have the most efficient transport connection through the national highways to the core. Previous studies in different cities of Pakistan, China, Africa found that distance from primary cities, urban agglomeration and road network negatively affects infrastructure development (Fadahunsi et al. 2017; Rana et al. 2017; Wei et al. 2018).

However, there are also many areas, located close to the city centre, where the service infrastructures are very poor, even less than the far rural areas. This pattern can be labelled similar to what Rogerson and Nel (2016) argued as deprived zones of city region or disparity between the city centre and newly developed sub-centres (Li and Wei 2014). These deprived areas could not participate in the growth process due to a lack of better transport connectivity to the core city (Hossain and Huggins 2021; Nazem and Hossain 2019). In the other areas of the GDR, the services infrastructures are very poor, however, in the district headquarter areas the infrastructure are comparatively better. This is because the public-funded infrastructures are concentrated near the district headquarters. Although basic service infrastructures are relatively better in the new growth areas compared to other regions, the quality of the services is still poor. A study conducted by Hossain and Huggins (2021) in the newly formed suburban areas found that health and education infrastructures have increased significantly, however, the service quality is very poor. Most of the health and education institutions are not registered, thus, not maintaining the quality of the services.

Bangladesh has been observing remarkable progress in Sustainable Development Goal (SDG) indicators, however, we do not know how evenly the progress is happening. This study found that the GDR, the most promising region of the country has severe spatial inequality in the access to basic services like housing and related services, education and health that foster a better-quality of life. The study found that within the megacity boundary there are also some cold spots where the service infrastructures are very poor. The metropolitan area of this region has been extending towards its periphery and each year more than 400 thousand people are adding up to the city (IGS 2012). Due to the growth process, it has been expected that these people will live in the periphery areas (Hossain and Huggins 2021; Nazem and Hossain 2019). Thus, the demand and supply gap will be enhanced in future in the absence of immediate and appropriate initiatives. This study identified where the infrastructures are clustered and which type of infrastructure lack in different areas. Thus, it is expected that in the first phase, demand-based infrastructure development should get priority in the development agenda of the region.

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Author contributions All authors contributed to conceptualizing and designing the study. MAH conceptualised the initial idea, developed the methodology, analyse and interpret the data and prepared the first draft of the manuscript. SS collected the data, conducted the literature review and assist in the preparation of the first draft of the manuscript. NIN interprets the findings, review the draft and finalized the paper. All authors read and approved the final manuscript.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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