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Constructing a city liveability index and evaluating the spatial pattern of liveability of Guwahati city

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ABSTRACT

Introduction: Urbanization is a global phenomenon on the rise in recent decades. In this context, the concept of liveability has emerged as a fundamental instrument for assessing living standards in urban areas. Currently, cities are home to 55% of the world's population, and by 2050, that number is predicted to rise to 68%. The urbanization process has been more evident in developing countries of Asia, where a significant amount of the world's population growth is occurring. However, limited studies are exploring the liveability status of cities in developing countries and the spatial pattern of liveability across the city.

The purpose of the article: The study intends to construct a city liveability index incorporating residents' perspectives. The research also evaluates the liveability of different wards of the city and identifies the factors driving the spatial pattern of liveability across the city.

Research Methods: A weighted sum methodology was used to calculate the city liveability index and weights for each indicator were determined using Principal Component Analysis (PCA). The indicators are determined through residents' perspective and a primary survey was carried out to identify and rank the key indicators of liveability.

Main findings: In the current research, it can be observed that wards located at the undulating topography have been mostly identified as low-liveable or very low-liveable wards. City growth is hampered by undulating topography because of higher expenses and challenges in infrastructural development, restrictions on land use, difficulty in road construction and the risk of landslide or erosion. The land use, distribution of amenities and spatial structure of the city is also greatly influenced by the transportation network system, which determines the movement of people and goods in the metropolitan areas. In the current context, the location of Guwahati-Shillong Road connecting the core of the city with south eastern region has been vital to the development of this part of the area.

Scientific novelty and practical implication: The research for the first time attempts to construct a city liveability index incorporating indicators based on residents' definition of liveability in Guwahati city. The findings will assist the authorities and policymakers in formulating policies emphasizing the development of low-liveable wards. Moreover, the study recommends constructing strong road connectivity which contributes towards the growth of city facilities and services in least developed wards enhancing the overall liveability of the city.

Keywords: *City Liveability Index, Road Connectivity, Principal Component Analysis, Guwahati City, Spatial Pattern of Liveability.*

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Introduction: Currently, research and development on liveable cities has gained much attention due to the complexity and diversity of liveability standards. The construction of 'liveable cities' has become a growing policy aspiration for multiple levels of government worldwide and various international organizations such as the Sustainable Development Goals (SDGs) and the New Urban Agenda [1, 2]. This is mainly in response to the rapidly growing urbanization that poses many liveability challenges such as urban slums, poverty, exacerbating economic disparities, unsanitary conditions, poor urban infrastructure, inadequate city amenities, rising crimes and security issues [3]. The global urban population has reached 56.48 per cent in 2021 which is projected to rise to 68 per cent by 2050 [4]. As far as India is concerned population residing in urban areas is 35% in 2021 [5] and is projected to increase to 38.2% by 2036 [6]. The rapid process of urbanization has been most pronounced in developing countries of Asia which are going through the process of messy and hidden urbanization, without effective urban planning [7]. Moreover, the ongoing urban expansion and densification add additional pressure on limited space and resources lowering cities' ability to maintain an adequate standard of living [8]. Thus, the improvement of living conditions for citizens has emerged as a major goal in city planning and management in the contemporary environment of expanding urbanisation.

The enhancement of liveable conditions requires the development of indices that are capable of providing estimates of the present conditions and assist in implementing proper urban policies and strategies. Consequently, there are numerous wide-spread liveability evaluation indices proposed for assessing the liveability of cities at the global level such as The Global Liveability Index by Economist Intelligence Unit (EIU), Mercer's Quality of Living Index and

Better Life Index (BLI) by The Organization for Economic Co-operation and Development (OECD) [9,10,11].

In recent years, there have been handful of works focused on evaluating liveability by applying various indices. A study assess the performance of 14 SDGs for 56 Indian cities (separated into 6 regions) by analysing 77 variables from 2020 to 2021. Many techniques including Pearson's correlation, hierarchical clustering, data envelopment analysis and Theil index are employed to infer current status of liveability, interactions, inequality, efficiency and interrelationships between the cities [12].

Another study is conducted to analyse India's most liveable cities using the Global Liveability Index and its sociocultural, environmental, healthcare, educational and infrastructure criteria. For the survey, a mixed method approach is applied incorporating both qualitative and quantitative analyses with a targeted sample size of 100 people [13]. Patil & Sharma in 2022 also applied Principal Component Analysis (PCA) to create the Urban Quality of Life (UQoL) index using 29 indicators divided into seven components to measure the relative holistic urban development of 14 Indian cities [14]. Seven indices are produced from the seven components: 1) Index of basic amenities; 2) Index of economic development; 3) Index of safety and security; 4) Index of transportation access; 5) Index of infrastructure development; 6) Index of environmental impact and 7) Index of gender role. Thus, these studies has mainly focused on measuring relative liveability of Indian cities across different parameters. However, there are studies evaluating liveability across a city.

Saitluanga in 2014 conducted a study to identify patterns of inequality in livability in Aizawl, a rapidly expanding hill city in Northeastern India's Himalayan region [15]. The study uses the data reduction method to measure the objective and subjective dimensions of liveability at the neighbourhood level and finds that centrally located neighbourhoods are more liveable than their peripheral counterparts. However, the study only selected 6 Municipal Wards (32% of the total municipal wards) comprising of 27 local council (LC) units from central areas, middle areas and outer area. A study conducted on Madurai City, Tamil Nadu also attempt to identify spatial disparities in liveability using the Liveability Index, which was introduced by the Ministry of Urban Development, Government of India [16]. The study analyses 49 indicators divided into four pillars–institutional, social, economic, and physical. However, the study is based on only secondary data from multiple sources, including the Corporation of Madurai City.

Whereas, another study based on primary data aim at determining the subjective and objective liveability dimensions and indicators for Siliguri Municipal Corporation (SMC) [17]. The technique of stratified random sampling is used to gather the perceptions of the residents from core, semi-periphery and periphery areas, and statistical methods including Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) is applied. But the study lacks in developing a liveability index with the selected dimensions and indicators and evaluate liveability across the city.

In addition to indexing systems academic studies have also focused on a specific liveability feature through more in-depth analytical approaches which include studies that assess the effect of weather, air pollution, and environment on livability and sustainability or studies addressing the liveability needs of a specific demographic group as the older population [18, 19, 20, 21].

Following these, several significant research gaps are identified. First of all, despite the abundance of studies on index development at bigger scales (district, regional, and national) there are limited studies specifically focusing on constructing an index at ward level. Therefore, the current study attempts to construct an index that evaluate the spatial pattern of liveable conditions across the city at ward level and determine the factors driving the spatial pattern of liveability. Moreover, there are limited research that has developed a liveability index based on indicators that adhere to the residents' definition of liveability. Thus, the research also aims to develop a city liveability index based on indicators selected through residents' perception.

The current research on liveability is conducted in a medium-class city: Guwahati. Guwahati city, one of the busiest cities in North East India, the main urban centre in Assam and home to 963,429 people has the distinction of being the primate city and dominating the urban landscape of Assam [22,23]. Although, it is one of the fastest-growing cities in India, the city has scored very poorly (48.52 on a 100-point scale) and secured 46th rank out of 49 Indian cities in the Ease of Living Index 2020 [24]. The city has flared badly on the Municipal Performance Index, 2020 among Million+ municipalities with a 51 ranking and a very poor score of 18.14 (on a 100-point scale), indicating its poor liveable conditions [25]. Using Guwahati city as a case study (Fig.1), the research attempts to develop a City Liveability Index (LCI) based on residents' opinions with the integration of Principal component analysis and also evaluate the spatial pattern of liveable conditions of the city at ward level.

Materials and methods: This section highlights the selection of indicators, collection of data and statistical techniques used to construct a composite index:

Selection of the indicators: First of all, a thorough literature review is conducted to identify the key indicators of liveability. Then a set of indicators are identified as pulling indicators that attracts residents towards the city and pushing indicators of liveability that negatively impact the quality of life of residents and forces residents to move to a new place.

Primary Survey: In the next stage a primary survey is conducted using purposive random sampling. The five wards are selected purposively on the basis of their location in the city and the terrain these wards are situated on to create a sample population that includes residents from different part of the city living on different type of topography. Urban liveability is greatly influenced by the topography and its associated factors including elevation, slope and relief which affects infrastructural development, transport, accessibility, health of the environment and overall quality of life. Thus, topography was an important criteria in selecting the wards for primary survey along with their location. Then the residents for the survey from each wards are selected randomly. According to Cochran's formula, with a 95% confidence level and 7% marginal error, the minimum sample size required to represent each ward ranges from 192 to 195. Thus, a sample size of 200 residents from each ward is finalized for the primary survey (Table No. 1).

In the survey residents are asked to rank these push and pull indicators of liveability. Moreover, they are ask to identify whether pulling indicators or pushing indicators has a greater impact on the liveable conditions of the residents. According to the results, 83.50% of the sample population considers pulling indicators are more powerful in attracting residents than the repelling force of pushing indicators. Therefore, the constructed city liveability index includes only pulling indicators of liveability. Finally, based on the ranking of the residents during the primary survey and availability of secondary data to represent these indicators 17 pulling indicators of liveability under 6 factors are selected to construct the liveability index (Table No. 2).

Secondary sources: The secondary data representing each indicator selected in the primary survey at ward level are collected from different sources as: Census 2011, Guwahati Municipality Corporation, Sentinel-2A Image downloaded from USGS and Google Earth. The thematic maps of the indicators are prepared in the ArcGIS 10.2 software and Erdas Imagine (2015) software (Fig. 2, Fig. 3 and Fig. 4).

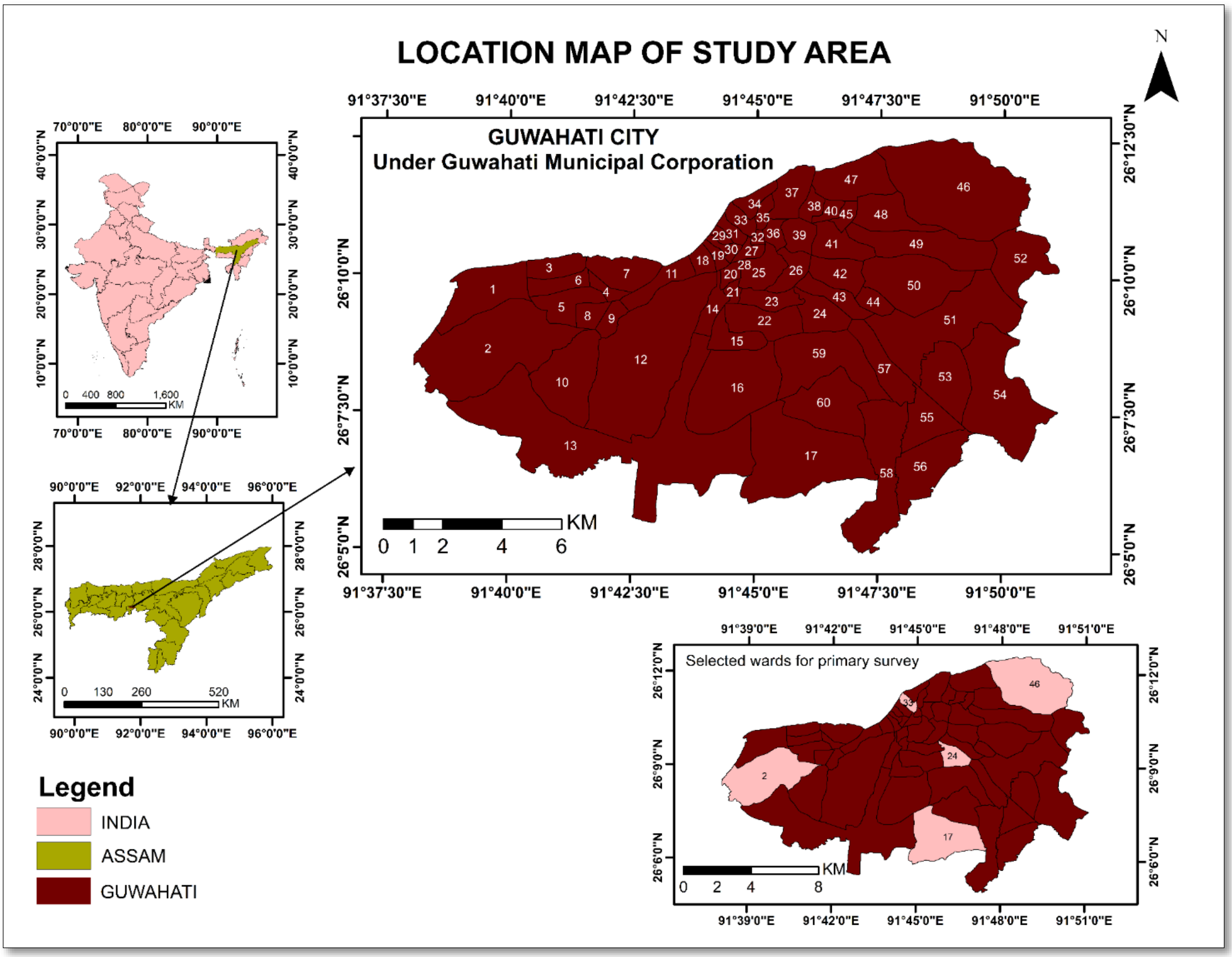

Fig. 1. Location map of the study area

Table 1

Sample population for Primary Survey

S.L No.	Ward	Total Population	Selection of wards based on location and topography	Required sample size (Based on Cochran's formula)	Sample size for primary survey
1	33	8368	Northern part of the city Plain topography	192	200
2	17	21292	Southern part of the city Plain topography	195	200
3	24	17830	Central part of the city Consist of both plain and hill topography	194	200
4	46	28309	Eastern part of the city Hill topography	195	200
5	2	16613	Western part of the city Plain topography	194	200
				Total sample size	1000

Table 2

Factors and Indicators of City Liveability Index with related literature

Factors	Pulling indicators of liveability selected by residents in primary survey	Indicators: (Secondary Data representing indicators selected by residents in primary survey)	References
Housing Conditions	Liveable Houses	Percentage of households with condition of Census House as Livable	(26, 27, 28, 29)
	Electricity	Percentage of households having electricity	
	Proper Water Quality	Percentage of households having access to treated tap water for drinking purpose	
	Easy Accessibility To Water	Percentage of households having access to main source of drinking water within premises	
	Cleanliness	Percentage of households having waste water outlet connected to drainage	
	Sanitation Facilities	Percentage of households having bathing facility within the premises	
	Sanitation Facilities	Percentage of households having latrine facility within the premises	
Educational Facilities	School	Schools per 1000 persons	(29, 30, 31)
	College	Colleges per 1000 persons	
	University	Universities per 1000 persons	
Healthcare Facilities	Medical Store	Medical Stores per 1000 persons	(15, 32, 33)
	Medical Centre	Healthcare Centres / Medical Centres per 1000 persons	
	Hospital	Hospitals per 1000 persons	
Transportation Facilities	Road Density	Road Density	(28, 29, 30, 34)
	Bus Stop	Bus Stops per 1000 persons	
	Railway Station	Railway Stations per 1000 persons	
Urban Security	Police Stations	Police Stations per 1000 persons	(27, 30, 35, 36)
	Police Outposts	Police Outposts per 1000 persons	
Physical Environment	Green Space [1]	Percentage of Green Space	(27,32,37,38,39)
	Blue Space	Percentage of Blue Space	

[1] Green Blue Space is extracted from land use land cover map prepared from Sentinel-2A Image (date: 07/03/2022 downloaded from USGS Earth Explorer) using Supervised classification in Erdas Imagine Software.

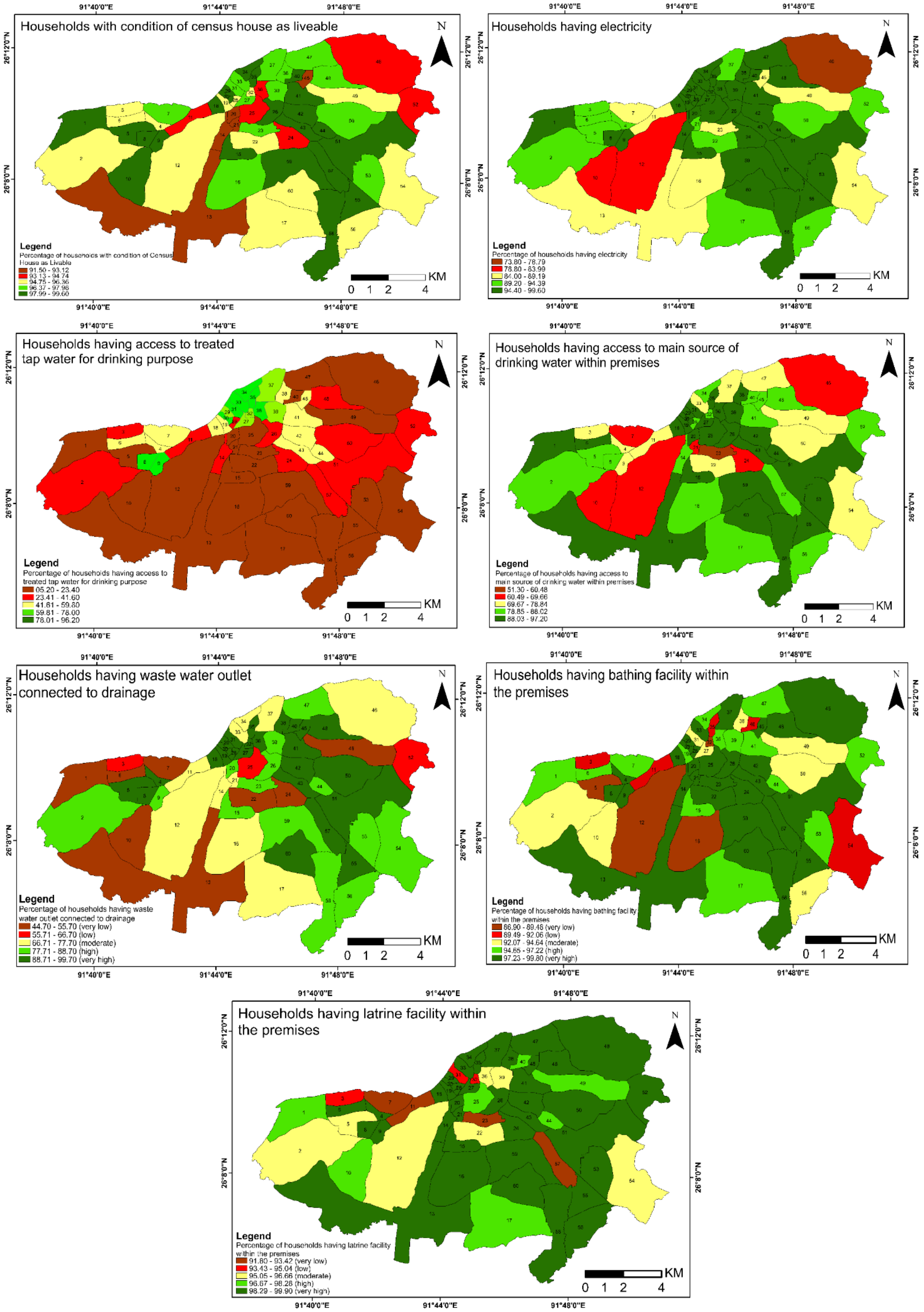

Fig. 2. Status of housing conditions of Guwahati City. *Source:* Census Data, 2011

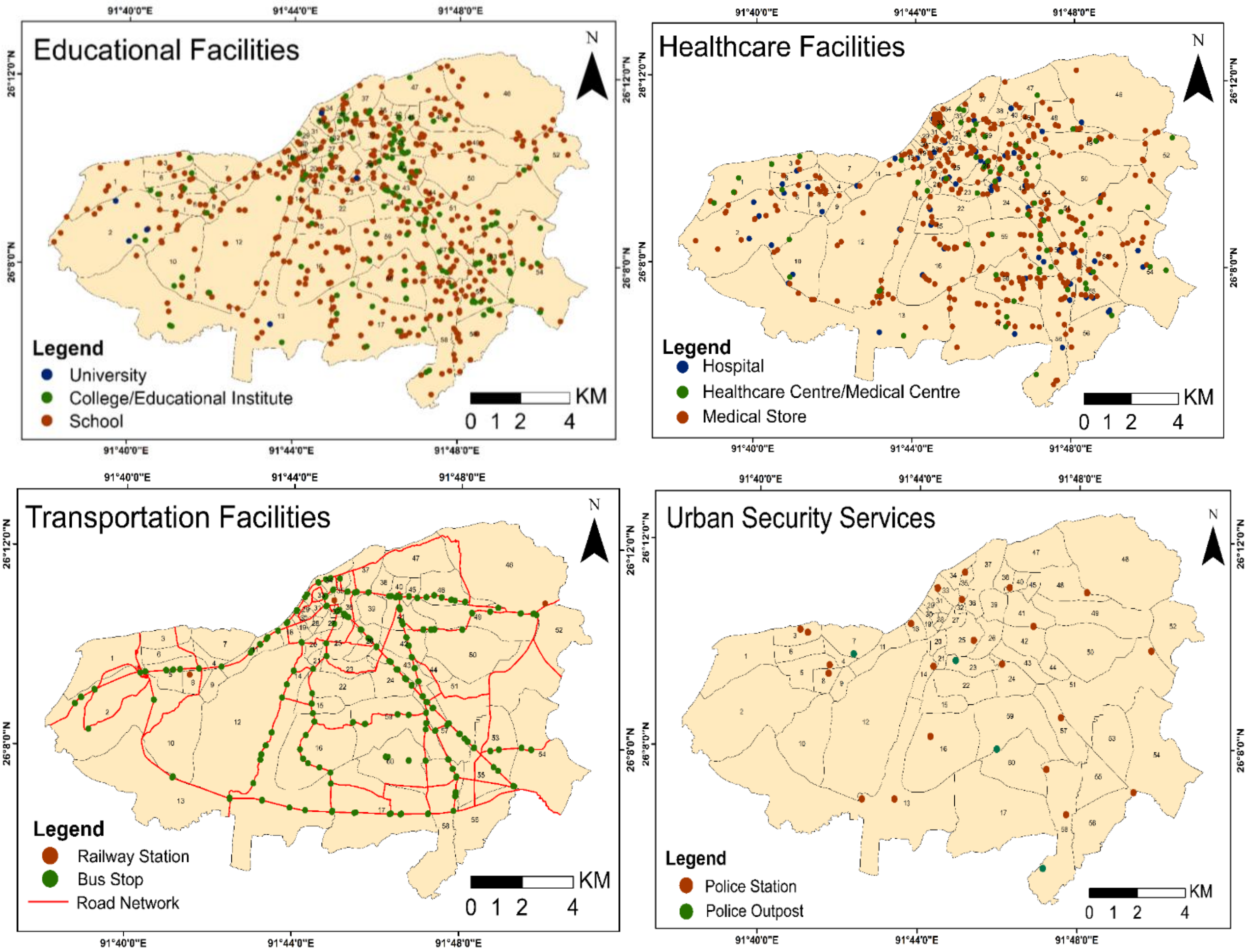

Fig. 3. Distribution of urban amenities in Guwahati City.
Source: Guwahati Municipality Corporation, 2022, Google Earth

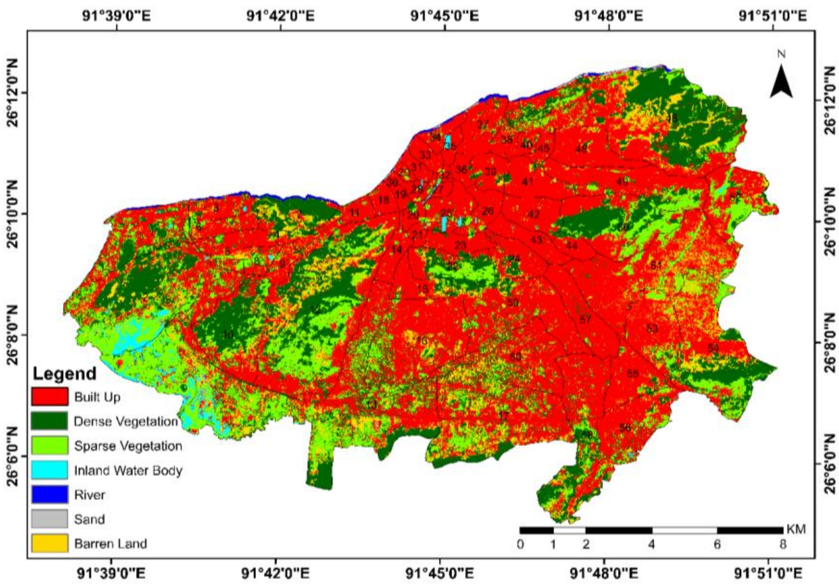

Fig. 4. Land use land cover map of Guwahati city.
Source: Sentinel-2A Image (date: 07/03/2022 downloaded from USGS Earth Explorer), Google Earth

Composite Index Construction. Principal Component Analysis (PCA) is the technique used to determine the weights of each indicator. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity were computed to ensure that the data were suitable to run principal component analysis (PCA). The data is considered suitable for PCA if the KMO statistic is equal to or higher than 0.50 [40]. In the present context, the value of KMO (0.622) is more than 0.5, therefore data is suitable for the application of PCA.

To run a principal component analysis, there must be correlations between the variables. As a result, a significant ($p < .001$) Bartlett's test of sphericity is required. In the present context, a value of approximate chi-square statistic is found to be 489.876 with 190 degrees of freedom, which is significant at the 0.000 level of significance. Thus, significant results of KMO and Bartlett's test show that the data is suitable for principal component analysis.

Identifying the Principal Components. To identify the number of principal components that can represent the variables the current study adopts the eigenvalue-one criterion [41]. According to the eigenvalue-one criterion, those principal components are selected which possess eigenvalues larger than 1. Thus, 7 components have been selected that possess an eigenvalue greater than 1.

For the first component, households with condition of census house as liveable, households having electricity, households having access to treated tap water for drinking purpose, households having access to main source of drinking water within premises and households having waste water outlet connected to drainage have strong positive factor loadings with 16.742% variance. This factor is a measure of housing conditions because all the five positive component loadings related to housing conditions load high on this factor.

The second component accounted for 15.915% of the variance and explains the variations in school, college, medical store, primary healthcare centre/ medical centre and hospital with strong positive loadings. This factor is a well representation of basic city amenities. The third component explains 9.917 % of the variance but the interpretation of this component is less straightforward. The indicators railway station and police station load high on this component and both the indicators are services that are minimum in number and they are spatially unevenly distributed. The fourth component represents the sanitation facilities of households and measures two important indicators of sanitation facilities which are households having bathing facility within the premises and households having latrine facility within the premises with high loading component of 0.794 and 0.808 respectively.

The fifth factor accounted for 7.984% of the variance and explains the variations in police outposts with strong positive loadings. The sixth component with 7.446% of variance represents the transport infrastructure and measures the indicators road density and bus stops with 0.440 and 0.605 component loading.

The seventh component explains 7.058 % variance, representing universities and urban blue space with component loadings 0.775 and 0.787. Both the variables are connected to one another since most of the universities are located towards the outskirt of the city in western part near to the riverine wetland Deepor Beel and they are explained by the seventh component.

Thus, the 7 principal component extracted cumulatively explain 73.566 % of variance Thus, 20 indicators of liveability are reduced to these 7 principal components that cumulatively explain 73.566 % of the variance (Table No. 3).

Construction of the City Liveability Index: The city liveability index was calculated using a weighted sum model [42, 43, 44]. The very first step in constructing the composite index includes the computation of component scores estimated using a regression method. A component score can be obtained as a linear combination of the standardized indicators that measure the position of a particular ward about the others concerning a particular component. However, the components do not carry the same weightage since they explain different percentage of variance. Thus, using these percentages as weights on the component scores, the city liveability index of each ward of Guwahati city based on principal component analysis was computed. Formula:

$$CL_i = \sum_{j=1}^{n} W_j * PCS_{ij}$$

where W_j is the contribution rate of *the jth* principal component (eigenvalue of *jth* principal component/sum of eigenvalues) and PCS_{ij} is the component score of *the ith* ward for the *jth* principal component. Finally, the computed scores of the city liveability index are scaled to a fixed range from 0 to 100 using Min-max Scaling.

Status of Liveability of Guwahati City. The liveability map of Guwahati city has been prepared with the composite scores calculated based on Principal Component Analysis (Fig. 5). The research findings distinctly highlight the influence of physical landscape on the city structure and its development. Urban studies scholars, urban planners and geographers have long attended to the influence of physical landscapes such as flat land, higher ground, steep valleys, water courses, sub-surface or surface conditions, gradients and slopes on the process of shaping the city to its present form [45]. Guwahati city sits on an undulating topography with narrow valleys and plain areas surrounded by a number of hills and wetlands (Fig. 6). These irregular features have largely influenced the current structure and development pattern of the city.

In the current research, it can be observed that wards located at the undulating topography have been mostly identified as low-liveable or very low-liveable wards (Fig. 5). The presence of Fatasil Hills

Table 3

Results of Principal Components Analysis

Indicators	Components						
	1	*2*	*3*	*4*	*5*	*6*	*7*
Percentage of households with the condition of Census House as Livable	0.560						
Percentage of households having electricity	0.670						
Percentage of households having access to treated tap water for drinking purposes	0.725						
Percentage of households having access to the main source of drinking water within the premises	0.865						
Percentage of households having waste water outlets connected to drainage	0.871						
Schools per 1000 persons		0.731					
Colleges per 1000 persons		0.665					
Medical Stores per 1000 persons		0.603					
Healthcare Centres / Medical Centres per 1000 persons		0.647					
Hospitals per 1000 persons		0.753					
Railway Stations per 1000 persons			0.756				
Police Stations per 1000 persons			0.768				
Percentage of households having bathing facilities within the premises				0.794			
Percentage of households having latrine facilities within the premises				0.808			
Police Outpost per 1000 persons					0.850		
Percentage of Green Space						-0.651	
Road Density						0.440	
Bus Stops per 1000 persons						0.605	
Percentage of Blue Space							0.787
Universities per 1000 persons							0.775
Eigen Value	3.348	3.183	1.983	1.701	1.597	1.489	1.412
Variance (%)	16.742	15.915	9.917	8.504	7.984	7.446	7.058
Cumulative Variance (%)	16.742	32.657	42.574	51.078	59.062	66.508	73.566
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. [a] a. Rotation converged in 14 iterations.							

in Dhirenpara and Tetelia locality minimizes the road density in the western part, consequently limiting the growth of this part of the city. Ward numbers 12 and 10 are located at the Fatasil Hills, mostly covering the locality of Dhirenpara, Fatasil Ambari, Tetelia and few areas of Maligaon are identified as very low liveable wards and low liveable wards respectively. The hilly topography of these localities which restricts proper road connectivity with other parts of the city has restrained urban development in this area. Urban development is a composite phenomenon where several interrelated factors work to improve the standard of living of the residents of towns and cities' health [23].

Similarly, ward number 23, 22 and 21 which represents the Birubari, Fatasil Ambari and Kahilipara neighbourhoods located at the Narakasur Hills with rugged terrain and lack of connectivity are visibly deficient in providing basic city amenities and services to the residents. Ward number 16 and ward number 13 situated on Kalapahar Hills and Sonaiguli Hills are also identified as areas with poor living conditions. The western part of Ward 13 is mostly occupied by Deepor Beel and the water body acts as a barrier to the expansion of the built environment in this ward. The presence of Nilachal hills in Ward 7 and Ward 4 acts as a hindrance to its development and restrains the wards from providing proper city servi-

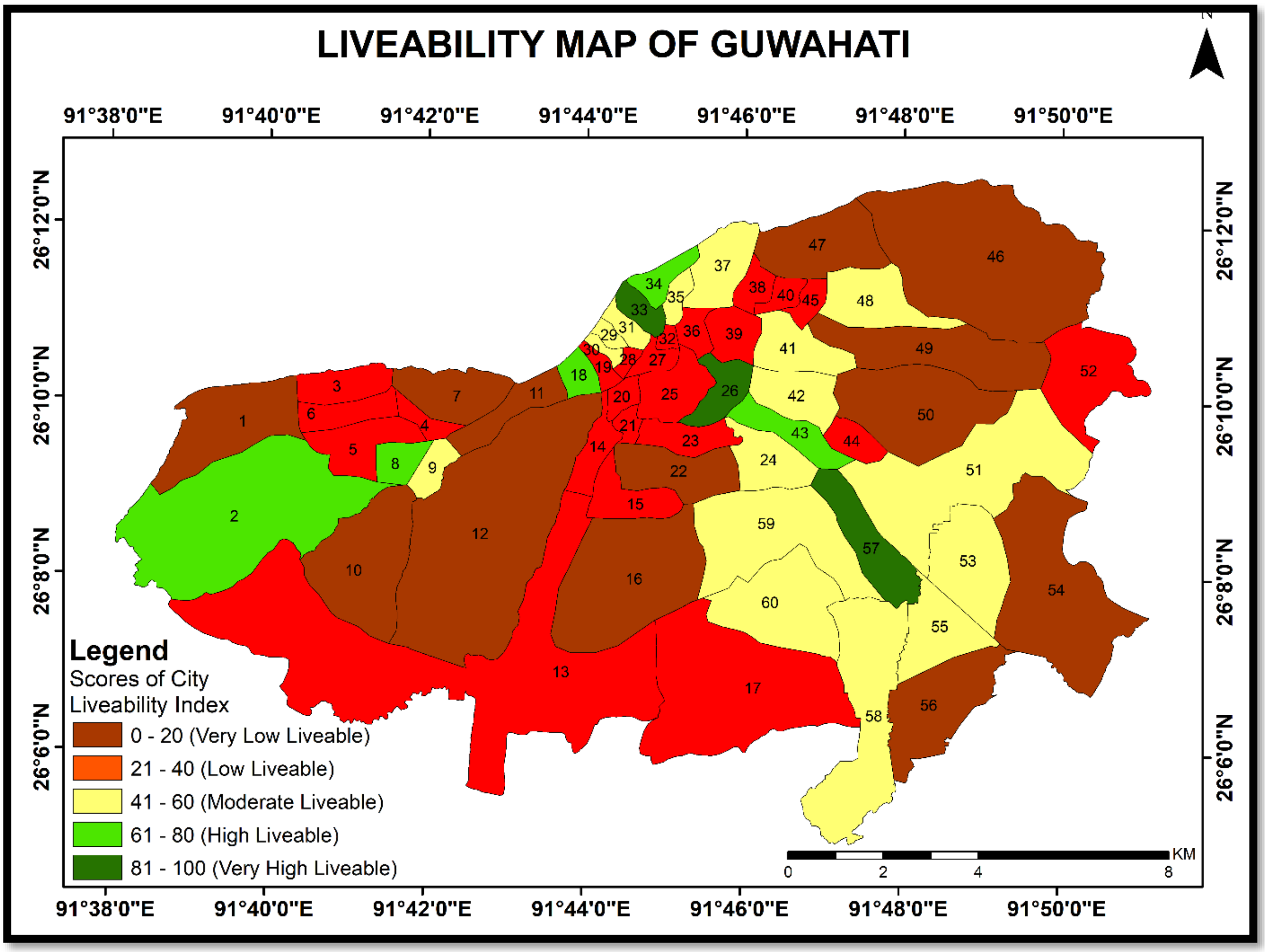

Fig. 5. Liveability map of Guwahati city based on City Liveability Index

ce to the residents.

In the eastern part of the city, wards number 46 and 52 expand over Noonmati, Kharguli Gaon, No. 2 Bonda Grant, Bonda, Kharguli NC locality and are located on the Chunsali Hills and Burha-gosain Hills along the eastern boundary of the city has scored low in the city liveability index. Similarly, Khanapara Hills and Koinadhara Hills covering Ward 54 and Ward 56 along the south-eastern boundary are identified as low-liveable wards. These wards being located on an irregular terrain and at the outskirts of the city poses a disadvantage in constructing an efficient transportation network, consequently limiting its overall development concerning city amenities, housing conditions and social functioning of the residents.

Furthermore, in the Northeastern part of the city ward numbers 49, 50, 44, 47, 38, 40 and 45 located on the Japorigog Hills and Kharguli Hills are identified as low-liveable areas. In certain wards such as ward number 46, 12 and 10 the dire situation of housing conditions is very much evident. Thus, the irregular topography of the city limits the various city services and amenities to the valley areas and plains, posing a disadvantage to the people living in surrounding hilly areas. These wards in addition to city services also fail to provide a liveable housing condition and essential services including access to treated tap water within premises, adequate electricity connection and proper drainage system.

The development of unplanned settlements leading to significant land rights conflicts has forced hill dwellers to experience a number of deprivations such as inadequate waste management services, limited accessibility, and a lack of water supply, sanitation, and drainage infrastructure. The establishment of the new capital at Dispur in 1972 sparked economic growth, and the influx of people from other parts of the state into the city dramatically increased the demand for housing and land within a few decades. Thus, the historically owned properties in and around the city for generations as shared property resources by the tribal community was traded to intermediaries informally. However, after selling their properties, the aboriginal people were forced by the land market and middlemen to relocate to the hills which are considered as ecologically sensitive areas. Although the hill settlements expanded and were encroached upon by migrants and landless tribal people over time but they still struggle with access to basic household amenities since these settlements are characterized by informal structures. Therefore, the state must take an inclusive approach and resolve the land rights issue

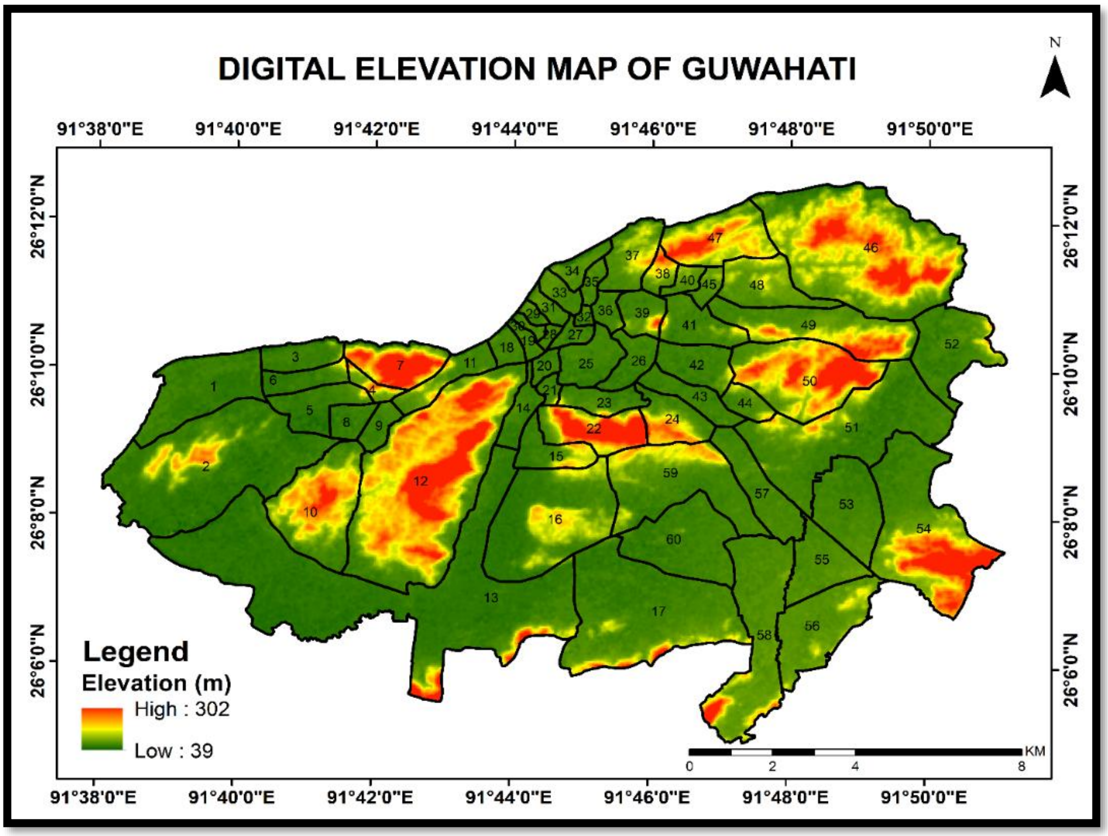

Fig. 6. Digital Elevation Map of Guwahati. *Source:* SRTM Data downloaded from USGS Earth Explorer

for the present inhabitants of hills by including them in the policy framework. However, better road connectivity and accessibility to public transportation might attract varied educational institutions, healthcare services, economic activities, and business establishments and improve liveability in these wards.

The authorities must pay attention to these low-liveable wards and strengthen their public transportation and road connectivity with other parts of the city. Additionally, the government policies must take steps to improve the housing amenities of wards that do not have adequate access to treated tap water, electricity and drainage connections. The absence of adequate urban amenities such as water supply, sanitation, sewerage, lightning, transport and affordable recreational facilities as well as efficient welfare services have been a few major challenges of the city [46].

Interestingly, most of these low-liveable wards sitting on uneven terrain offer a pleasing environment with more greenery compared to other wards. Despite being susceptible to landslides and inefficient in providing services and facilities, the wards offer benefits by enhancing the natural environment and consequently the human health of the residents.

Green infrastructure encourages physical activity by providing suitable space for walking, jogging, and running, delivers positive health impact, and offers mental and psychological relaxation, recreational activities, and oxygen for breathing and purifying air pollutants [47, 48, 49, 50, 51, 52]. They help residents socialise, foster social interactions and integrate with the community by acting as a natural gathering place and sparking cultural events [49]. Green spaces also have the power to preserve a sustainable environment in cities and well-managed urban green spaces are thought to be more important for providing ecosystem services (freshwater, food, and raw materials) [53]. The presence of urban green areas reduces the consequences of climate change and better biophysical characteristics of canopy vegetation in urban environments contribute towards the improvement of human health [54, 55].

Thus, the policymakers must formulate urban green policies in the city and develop these wards with huge green space by generating cultural services, recreational activities, spiritual and religious services, and ecotourism along with public needs, economic opportunities and practices. Green space can be a hub for local businesses, gardens parks or community events. Providing an attractive and accessible green environment encourages urbanites to live a less sedentary lifestyle and contributes towards providing better living conditions. Aesthetically pleasing green spaces might lessen anxiety and stimulate participation in health-promoting activities [56].

Contrarily, unmaintained green spaces that offer negative visual and auditory experiences may directly affect mental health by causing feelings of dread, mistrust, increased anxiety, and concern for one's safety, thus reducing the restorative potential of green spaces [57, 58]. Moreover, poor quality or neglected greenspaces such as abandoned buildings overtaken by grasses, covered by plants and trees with roots wrapped around them may serve as locations for criminal activity and drug use [59]. Vacant lots are one sort of poor quality greenspace which are not suitable for typical uses of a greenspace such as leisure, physical activity, or socialisation [60].

Thus, authorities should make efforts to implement urban green policies that focus on developing quality green space that can offer three general functions of green spaces: reducing harm (for example, reducing exposure to air pollution, heat, and noise), restoring capacities (for example, attention restoration and physiological stress recovery), and building capacities (for example, encouraging physical activity and facilitating social cohesion) [61].

Policymakers and urban planners should take into account the opinion of the general public when developing urban green policies and generate innovative solutions to strike a balance between various competing factors, including population density, over-urbanization, the presence of slums, land use for commercial purposes, and administrative costs. An inclusive and multifaceted multi-stakeholder engagement can be crucial in overcoming competing interests and unfavourable perceptions of UGS and assist in constructing a more comprehensive policy strategy [62].

Moreover, the local government should promote a positive perception of UGS conservation, provision and use in the policy-making process to better meet the different requirements and shifting demands of urban dwellers [63]. Positive perceptions among urbanites can be generated by prioritizing urban green infrastructure benefits such as urban risk resiliency measures and human well-being benefits in future urban development. The green space infrastructure when well networked with other blue spaces can increase the city's resilience and security in terms of energy, health, water, food, and biodiversity [64].

The urban transportation system has been one of the key engines driving urban space alteration via the changing accessibility of associated land parcels, which leads to changes in land value and land use structure [65]. An urban area's urban landscape, economic activity, and multipurpose mobility have all been transformed by a complex transport network [66]. Classic theories on urban land use such as sectoral theory [67], multiple nuclei theory [68] and bid rent theory [69] all stated the significance of transportation on urban land use development. The linkages between road infrastructure and urban growth have been highlighted by different recent studies [70, 71].

The booming infrastructural development, such as the expansion of the road network is one of the main drivers of the rapid rate of urban expansion in India. In the present context, the location of Guwahati-Shillong road towards the south-eastern part of Guwahati has played a crucial role in developing this part of the city. Guwahati-Shillong road is one of the prime commercial corridors of Guwahati that stretches from Paltan Bazar to Khanapara via Dispur (the capital of Assam) with several showrooms, brand stores, retail and wholesale developed along the main road and a densely built residential area in the inner parts in addition to being a posh address for major commercial and government buildings. Since the 2000s, Guwahati has seen an extraordinary commercial paradigm shift and G.S. Road has witnessed it all. The corridor has facilitated the expansion of Ganeshguri, a southern city sub-centre, and other southern residential areas including Hengrabari, Laxmi Nagar, Rajeeb Nagar, Dispur and Kalyani Nagar over the past few decades. GS Road further extends to connect key roads like RG Baruah Road, DR RP Road, VIP Road, Panjabari Road and Jayanagar Road.

The spatial growth of urban regions and their land use is largely influenced by the transport network system, which supports the movement of people and goods within urban areas [72]. Thus, it can be noted that wards number 26, 43 and 57 located along the GS road are highly liveable. Moreover, it can be observed that there are few wards surrounding these highly liveable areas that provide a moderate liveable condition. These wards (ward numbers: 39, 41, 42, 51, 53, 55, 58, 59, 60, 24 and 17) have well-developed road connectivity with GS road. A well-developed transit system has a significant impact on the spatial organisation, growth pattern, and economic development of a municipality area.

Thus, GS Road plays a crucial role in the overall development of the eastern part of the city. The relative accessibility, connectivity, and suitability of the transport system affect the demand for an urban area [73]. However, towards the outskirts and away from the corridor there are a few wards in the eastern part of the city as well, such as 46, 52, 54 and 56 that lack in providing suitable living conditions for the residents. Guwahati city in general has heavy traffic congestion with narrow roads, poorly managed traffic, inadequate road infrastructure and the absence of a reliable mass transit system that forces the people to rely on their vehicles. Das (2009) reported that residents are least satisfied with the traffic condition of the city among the variables associated with subjective quality of life [46].

At the extreme north few wards including wards number 33, 35, 18, 29, 30, 31, 34 and 37 with decent living conditions are the old places from where the city originated. The Guwahati city witnessed the growth of its urban settlement that started in the 8th

century with areas along the riverside [74]. Currently, these centrally located old areas like Fancy Bazar, Pan Bazar and Uzan Bazar along the Brahmaputra river still demonstrate high concentration of settlement [75]. Thus, these wards provide quality education facilities, excellent healthcare services, efficient economic services, and recreational and religious facilities with a strong transportation connectivity that connects the area with the rest of the city. These areas are crowded places with varied economic activities, administrative services, business establishments, transport and communication centres. Moreover, these wards have good housing conditions with a treated source of drinking water, proper drainage and sanitation facilities as well as better access to electricity. On the contrary, newly emerging areas including Narangi and Khanapara exhibit a dispersed settlement pattern [75] and lack efficient city services.

Ward numbers 2 and 8 located in the western part of the city are also reported as highly liveable with quality education, healthcare services, recreational facilities and a green environment. The premier educational institution Gauhati University is located in Ward 2, which aids in the development of infrastructure in that particular ward also brings revenue to the community and contributes towards the growth of housing amenities and city services. Whereas, the Northeast Frontier Railway, headquartered at Maligaon is located in Ward 8 and helps in the overall development of both the wards.

Thus, the government and policymakers must adopt urban decentralised policies to end the imbalances between wards concerning city amenities, housing conditions and transportation connectivity, to spread development evenly throughout the city. The policies must target the wards with undulating topography and improve their connectivity so that more people will be attracted to invest in those wards contribute towards the growth of amenities and uplift the economic condition of the people. Thus, improvement in economic conditions at the individual level will have a positive influence on their housing conditions.

Conclusion. The study developed a city liveability index by integrating rigorous primary surveys with statistical techniques and focus on a participatory approach where residents actively participate in selecting relevant indicators. The participatory approach will assist in comprehending liveability through the lens of the dwellers and formulate efficient policies that cater to the wants and needs of the residents, enhancing their quality of life. The proposed method for developing the index can be further applied in various study areas for evaluating liveability status. The study also aims at the spatial pattern of liveable conditions of the city at ward level and determine the factors driving the spatial pattern of liveability. The proposed index to determine ward-level liveability disparities is also useful for neighbourhood-level urban planning and development plans. Planners can identify neighbourhoods with poor liveability scores and prioritize interventions in these wards to achieve a more equitable and balanced liveability throughout the city. The creation of development plans and targeted policies that address the unique requirements and gaps in each neighbourhood can be also guided by the proposed index and use to track the effects of development plans over time and make the required modifications. Thus, a more nuanced understanding of specific needs and priorities within a city will provide more effective solutions and improve the general quality of life of the citizens.

The findings of the study report that road connectivity is the most important factor that determines the overall liveable condition. Wards with good road connectivity contribute towards the development of proper city amenities and services as well as enhance the citizens' overall quality of life. Moreover, wards with undulating terrain have a high percentage of green space but fail to provide a good transportation network and attract investments which in turn negatively affect their development with respect to city amenities and service. Moreover, due to the complicated legal status of informal settlements in the hills and their unresolved historical land tenure the hill dwellers had been found to suffer from a variety of deprivations including poor accessibility, insufficient waste management services, and a lack of infrastructure for drainage, sanitation, and water supply displaying social inequality through spatial patterns. Fear of eviction makes them hesitant while investing in construction of pucca houses and toilets negatively impacting their livelihood, education, healthcare and leading to housing insecurities. Therefore, the state must adopt a humane strategy to address the land rights issue for the current residents of hills by incorporating them into the policy framework. Moreover, the city planners must improve the overall road connectivity of the city and pay immediate attention to low-liveable wards. The city also requires formulation of an urban greening policy to develop quality green space in the low-liveable wards for their development. Thus, the model of the zonation map and the liveability index of Guwahati can be used by the city planners to enhance the overall liveability of the city.

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