Urban Sustainability Index of Guwahati City

Bhaskar Borah [1], Chayanika Borah [2]

[1]*PhD Research Scholar, Department of Economics, Gauhati University*
[2]*PhD Research Scholar, Department of Humanities and Social Sciences,*
IIT Guwahati

ABSTRACT

In the past century the process of urbanisation over the globe reaches at its peak. Urbanisation brings changes to the fabric of socio economic structures of cities. Cities are the main hubs of economic activities and are being urbanized rapidly. But the question arises here to what extent urban growth pattern in a certain city is sustainable.

The idea of 'sustainable development' of cities was addressed in Agenda 21 of Earth Summit which aims at providing city planning strategies to achieve sustainability in development pattern. In 1986 Indian Prime Minister Rajiv Gandhi constituted the National Commission on Urbanisation which was followed by passage of 74th Constitution Amendment Act (CAA) in 1992.

Guwahati is one of the fastest growing city of North East Region of India. Guwahati is experiencing steep rise in population in the past few decades. It also possess potentials of connecting the Southeast and South Asian Nations which brings into notice the importance of its development which must be sustainable in nature for the decades to come.

The main aim of this study is to develop Urban Sustainability Index (USI) of Guwahati city. Through USI we will check the state of sustainability in urban growth pattern of the city .USI is measured in quantitative unit taking the relevant information on three indicators viz. economic, environmental and social .Comparing the information with best and poor threshold values of most and poor sustainable regions of the world (London and Shanghai respectively) we will get the relative indicators. Finally a composite indicator will give us the value of USI. The value of USI will be lying between the range of 0 to 1 indicating 1 is best and 0 is worse sustainable condition.

Key words: urbanisation , Guwahati , sustainability index.

1. INTRODUCTION

In 1800 total urban world population was only 2% but in 1900 it was 14%. In the current period more than half of world population live in urban areas and cities are producing means of sustenance for the other half. Cities are the hub of entrepreneurship and innovations. In 1960, the urban population of India was over 80 million, in 2013 it is 400 million. The urban population has doubled every twenty-five years. Now new regions are being urbanized at an accelerating pace.

Urbanisation is the process of improving standard of living of people with extensive use of natural resource without considering the effect of developmental activities on ecosystem. According to Anon urbanisation (2000) is the main cause behind major global and local changes in economic, environmental and social sectors.

But the question arises here about the sustainability component lying in the urbanisation pattern. Agenda 21 of the Earth Summit addresses the idea of 'sustainable development' of cities which aims at providing city planning strategies to achieve sustainability in development pattern. The 'concrete 'plans proposed in Agenda 21 include equity, entrepreneurship, technology transfer, access to land, security of land tenure, tenants' rights, liberalized credit policies and low-cost building material programs to 'sustainable' urban living for the homeless and for the urban poor (Chakraborty , 2017). Sustainable development is a guideline that improves the lives of the people without exhausting the environment or other resources. Sustainable assessment is needed to evaluate sustainability performance of urban development programmes. Assessment helps in revising the actions to bring necessary changes towards sustainable urban development.

Selection of indicators in assessing urban sustainability is crucial and differ in different context. Proper selection of indicators can possibly direct policy guidelines of cities. The main criteria for the selection of indicators are: (i) easily understood by stakeholders; (ii) measurable using the available data at city and national levels; and (iii) related to policy goals and capable of being changed. To be useful, indicators should be user-driven and depend on factors and the purpose for which they are used (Reddy et al., 2013). In this paper three basic indicators viz. economic, environmental and social are considered and relevant information of them are collected. The analysis is conducted against some benchmark indicators of cities like London and Shanghai. The evaluation reflects the gap in those indicators against the benchmark values to achieve sustainability in urbanisation pattern.

This paper draws a quantitative evaluation of urban sustainability of Guwahati city. This evaluation of urban sustainability index is based on the following notion of sustainable city –

Sustainable city

The idea of sustainability emerged in the 70's as the environmental impacts of developmental activities gained significant remedial attention. According to Holdren

Daily and Ehrilich (1995) sustainable process or condition is that which can be maintained indefinitely without progressive diminution of valued qualities inside or outside the system in which processes operates or the condition prevails. A number of communities have taken initiatives to develop sustainability indicators that will help them to design and implement comprehensive plans (Alberti et al., 1996). But there is no universal consensus on how to define sustainability. No single definition equally applies in all communities (Alberti 1996). Notion of sustainability depends upon socio economic fabric and geographic aspects of cities. Hence a particular model prepared for assessment of sustainability hardly can be applied in all cases.

In this paper the idea of sustainability include three basic dimension: economic, social and environmental. Cities showing better performance on several sub issues under these three categories can be termed as sustainable city.

The Index measures a city's performance against the following aspects which can be believed to be critical to sustainable development:

Environmental and social

- Access to safe water.
- Sufficient living space, healthcare.
- Education.
- Efficient use of water and energy and effective waste recycling.
- Lessening exposure to harmful pollutants.

Social and political

- Increased efficiency of communities comes with equitable access to public transportation, as well as dense and efficient buildings.

Economic

- More staff and financial resources reflecting how city governments are meeting their commitments to implement national and local policies and standards.

2. LITERATURE REVIEW

There has been immense researches and analysis that defines Sustainable city. But there is no universal consensus on the definition of sustainable urban city. It differs on different contexts of different cities. To assess urban sustainability, perfect selection of indicators is important. Indicators are generally user driven and related to policy goal. A wide range of indicators is therefore in use across the diversity of different cities and regions, which vary according to particular needs and goals (Verbruggen et al.,1995). Inadequate selection of indicators can provide undesired results.(Briassoulis, 2001 et al., 2004). In the paper by Mega and Pedersen (1998), they tried to define sustainability city

as 'one which succeeds in balancing economic, environmental and socio-culture progress through process of active citizen participation.'

In India an important study is given by B. Sudhakar Reddy and P. Balachandra(2013). This study tries to measure sustainability index of Bangalore and Mumbai City against some benchmark indicators of world class cities like London, Singapore and Shanghai.

In this paper the methodology from the above mentioned study is adopted to evaluate sustainability of Guwahati. The study is entirely based on the data available for the time period 2010-2013.

3. METHODOLOGY

In this work, the sustainability of a city is viewed through three indicator viz. economic, environmental and social. For composite indicator it is essential to transform the indicator into standard form. Thus as mentioned in the analysis of S Reddy a relative indicator is estimated using the actual and sustainability threshold values. For each indicator a minimum and maximum threshold value is taken from the above paper. The relative indicator is developed using a scaling technique where the minimum value is taken to 0 and maximum is taken to 1. The equation used for this is –

Relative indicator   =

$$\frac{\text{Actual value} - \text{Minimum threshold value}}{\text{Maximum threshold value} - \text{Minimum threshold value}}$$

Then we have to calculate a composite indicator of each dimension. The composite dimension index is computed as the root mean square of the relative indicator variables belonging to that particular dimension.

The equation used is as follows:

$$d_j = \left[\frac{(\Sigma_{i=1}^{I} V_{ij}^2 \quad)}{I} \right]^{0.5}$$

Where,

d_j= Dimension of type "j"

V_{ij} = Variables "i" belonging to dimension "j", i = 1, 2, …., I

I = Number of variables in a dimension

Finally a composite urban sustainability index needs to be calculated using all the dimensions. We can calculate it by the following way

$$USI = \left[\frac{\left(\Sigma_{j=1}^{J} dj2 \right)}{J} \right]^{0.5}$$

where,

USI = Urban sustainability index

dj = Dimension "j", j = 1, 2, …., J

J = Number of dimensions

The passage from thematic indicators to an index of sustainability policy performance for cities is a complex task as indicators have to be weighted by contribution to sustainability levels and all the previous levels of aggregation have to be taken into account (Reddy and Balachandra, 2013).

Guwahati City Profile

Guwahati is one of the most rapidly growing cities in India located in the state of Assam; during the past few decades it has experienced expansion and also a steep rise in population. In the survey of UK media outlet, it is revealed that Guwahati is among the 100 fastest growing cities of the world. Guwahati is situated at the southern bank of the Brhmaputar River.

The Guwahati Municipal Corporation, the city's local government, administers an area of 219 km², while the Guwahati Metropolitan Development Authority, the planning and development administers an area of 340 km². GMC, The Corporation has four revenue zones and twenty three public works zones for administration along with 31 municipal wards. GMC is responsible for governing, developing and managing the city. The Guwahati Metropolitan Development Authority (GGMDA) is currently responsible for planning and development including grant of building permissions, provision and maintenance of urban infrastructure & services of the greater Guwahati Metropolitan Area, which is currently revising the Guwahati Master Plan 2025.

The city has a well-developed public transportation system. The Assam State Transportation Corporation (ASTC) along with private units give bus service at a regular basis.

Guwahati city gets water supply from Assam Urban Water Supply and Sewerage Board (AUWSSB), Guwahati Municipal Corporation (GMC), Public Health, Engineering, Railway, Refinery and other govt. agencies. Main source of water is the river

Demography data

Table :1

Description	
Population *	1.05 million
Population decadal growth rate *	17.81%
Average literacy**	91.47
Area **	219.6 sq km
Population density / km^2 **	2695.43 sq km
Land use**	
Residential, business , industry	31.9%
Forest	25.5%

*Source: Interim report on Delineation of New Guwahati Metropolitan Region, GMDA, February 2013 and analysis based on data

of   Census of India, 2011

** Census of India, 2011

Total population of Guwahati is 1 million. Guwahati shows decadal population growth rate 17.81% from 2001 to 2011. Population density of Guwahati city is 2695.43 persons per square km. Migration from and other parts of the state as well as the influx problem from the neighbouring nations due to its educational and occupational centric opportunities has led to rapid population growth over some decades. As per 2011 data sex ratio of the city is 936 females per 1000 males (Indian avg. is 940). The literacy is 91.47. GMC has identified 217 slum pockets of population 1.39 lakh. In the slums sanitary and garbage management system is very poor. Work participation rate of Guwahati city is 31.75%.

Data collection

For the present work data on indicators were collected from secondary sources of information viz. various governmental published reports, project reports, research papers , articles websites related concerned departments and variety of databases from internet (census data 2011, India Smart City Profile – Guwahati ,District Census Handbook , Statistical Hand Book of Assam 2011, Assam HDR 2014 ,Centre for Urban Equity (CUE) working paper 2014, Emission data of PBL Netherlands(28) for India for 2010, Guwahati Solar City Master plan 2012, Smart City proposal 2015, Climate Proofing Guwahati Assam City Resilient Strategy and Mainstreaming Plan Synthesis Report 2013 Smart City proposal 2015 MMR Report Assam ,2009 ,Guwahati TMICC and NUTH

Operations Document(2016) etc.). Data is collected for 14 economic indicators, for 22 Social indicators and 12 environmental indicators .Total data gathered is for 48 indicators.

Assessing data for economic dimension

We have presented the collected data for economic dimension in table 2. Economic dimension is classified into five group viz. income, growth /development, consumption, infrastructure and transportation.

Table:2 Quantifying indicators of Urban sustainability :Economic Dimension

Categories of sustainability	Indicators of urban sustainability	Guwahati
Income	Per capita income(US $/year)	1020
	City GDP(US $ billion PPP)	1.5
Growth	City product as a % of nation's GDP	0.082
	Unemployment rate(%)	4.32
Consumption	Per capita water consumption (litres)	90.6
	Per capita electricity consumption(kwh)	795.35
Infrastructure services and urban development	Bank branches /100,000 population	14.44
	Schools/1000 population	0.53
	Share of household with access to telephone (%)	78.88
Transportation	Cars per 1000 population	87
	Two wheelers per 1000 population	144
	Share of non-motorised transport including walking (%)	42
	Proportion of total motorised road PKM on public transport (%)	8
	Avg road network speed(kmph)	20

Assessing data for social dimension

Social dimension is divided into five sub group viz. demographics, education, health, equity, access to basic needs which are presented in table 3.

Table:3 Quantifying indicators of Urban sustainability :Social Dimension

Categories of Sustainability	Indicators of urban sustainability	Guwahati
Demographics	City population(million)	1.05
	Gender Ratio(Females/1000 males)	936
	Child sex ratio	908
	Literacy rate (%)	91.47
	Male literacy	94.08
	Female literacy	88.09
	Population density(persons/sq KM)	2695.43
	Slum population (% of total)	2.69
Education	Enrolment rate in Lower primary school	103.2
	Enrolment rate in upper primary school	101
	Literacy rate (%)	91.47
	School enrolment rate	94.7
Health	No. of hospitals beds/10,000	10
	Maternal mortality rate(per 1,00,000 population)	269
	Life expectancy at Birth years	62
	Birth rate(birth /1000 population)	16.2
	Death rate	4.5
	Infant mortality rate	22
	No. of physicians per 10,000 population	1.1

Equity	Household below poverty line (%)	31.1
Access to basic needs	HH with electricity connection (%)	92.94
	Population with access to sanitation (%)	85.04

Assessing data for environmental dimension

Environmental dimension is subdivided into 6 groups viz. air pollution, soil pollution , water pollution , energy consumption, water consumption and urban green space which are presented in the table 4.

Table:4 Quantifying indicators of Urban sustainability :Environmental Dimension

Categories of sustainability	Indicators of urban sustainability	Guwahati
Air pollution	SO2 emission($\mu g/m^3$)	6.92
	NO$_2$ emission($\mu g/m^3$)	14.91
Soil pollution	Per capita solid waste(kg/capita/year)	255.5
	% of solid waste that is recycled	20
Water pollution	Water system leakage(% of total)	40
	Share of waste water treated (%)	16.78
Energy consumption	Electricity consumption per capita(kwh)	795.35
	Diesel Consumption/capita (litre/year)	131.53
	Petrol consumption/capita (litre/year)	50
Land use pattern	Green spaces/person (m2)	33.46
Water consumption	Consumption of water (l/day/person)	90.66
	per cent of HH having piped water connection	35

Now we will take the benchmark indicators and further calculate the relative indicators. The benchmark indicators are presented in the table 5.

Table:5 Quantifying relative indicators and dimension index :comparing with threshold value

Dimension of sustainability	Categories of sustainability	Indicators of urban sustainability	Guwahati	Maximum	Minimum
Economic framework	Income	Per capita income(US $/year)	1020	45,578	5,004
		City GDP(US $ billion)	1.5	1479	24
	Growth	City product as a % of nation's GDP	0.082	35.73	1.00
		Unemployment rate(%)	4.32	50	4.2
	Consumption	Per capita water consumption (litres)	90.6	527	53.1
		Per capita electricity consumption (kwh)	795.35	17619	352
	Infrastructure services and urban development	Bank branches /100,000 population	14.44	95.87	3.14
		Schools/1000 population	0.53	0.955	0.05
		Share of household with access to telephone (%)	78.88	100	37.6
	Transportation	Cars per 1000 population	87	587.1	26.1
		Two wheelers per 1000 population	144	258	32
		Share of non motorised transport including walking (%)	42	65	8.1
		Proportion of total	8	72.2	2.9

		motorised road PKM on public transport (%)			
		Avg road network speed(kmph)	20	49.3	18.7
Social Framework	Demographics	City population(million)	1.05	32.45	4.796
		Gender Ratio(Females/1000 males)	936	1176	734
		Population density(persons/sq KM)	2695.43	43079	1700
	Education	Literacy rate(%)	91.47	100	22
		School enrolment rate	94.7	100	45
	Health	No. of hospitals beds/10,000	10	137	3
		Maternal mortality rate(per 1,00,000 population)	269	540	25
		Life expectancy at Birth years	62	83.75	48.69
		Birth rate(birth /1000 population)	16.2	50.06	6.85
		Death rate	4.5	17.23	1.56
		Infant mortality rate	22	61.27	2.65
	Equity	Household below poverty line (%)	31.1	70	3.8

	Access to basic needs	HH with electricity connection (%)	92.94	100	86.3
Environmental framework	Air pollution	SO2 emission($\mu g/m^3$)	6.92	90	11
		NO_2 emission($\mu g/m^3$)	14.91	130	23
	Soil pollution	Per capita solid waste(kg/capita/year)	255.5	995.6	146.8
		% of solid waste that is recycled	20	100	32.4
	Water pollution	Water system leakage (% of total)	40	50.2	3.1
		Share of waste water treated (%)	16.78	100	10
	Energy consumption	Electricity consumption per capita (kwh)	795.35	17619	352
		Diesel Consumption/capita (litre/year)	131.53	734.5	10.9
			50	1129.8	6.1
	Water consumption	Consumption of water (l/day/person)	90.66	527	53.1
		per cent of HH having piped water connection	35	100	26
	Urban green space	Green spaces/person (m2)	33.46	166.3	1.8

Calculation of relative index and dimension index

Comparing the indicators with threshold values we have calculated relative indicators for each indicators of economic, social and environmental performance .The calculated values of relative indicators have presented in the following table 6.

Table 6 Relative index :Normalized indicator values

Dimension of sustainability	Categories of sustainability	Indicators of urban sustainability	Guwahati
Economic framework	Income	Per capita income(US $/year)	-0.098
		City GDP(US $ billion)	-0.015
	Growth	City product as a % of nation's GDP	-0.026
		Unemployment rate(%)	0.002
	Consumption	Per capita water consumption (litres)	0.079
		Per capita electricity consumption(kwh)	0.025
	Infrastructure services and urban development	Bank branches /100,000 population	0.121
		Schools/1000 population	0.53
		Share of household with access to telephone (%)	0.661
	Transportation	Cars per 1000 population	0.10
		Two wheelers per 1000 population	0.49
		Share of non motorised transport including walking(%)	0.59
		Proportion of total motorised road PKM on	0.073

		public transport(%)	
		Avg road network speed(kmph)	0.04
	Demographics	City population(million)	-0.13
		Gender Ratio(Females/1000 males)	0.45
		Population density(persons/sq KM)	0.02
	Education	Literacy rate (%)	0.89
		School enrolment rate	0.90
	Health	No. of hospitals beds/10,000	0.05
		Maternal mortality rate(per 1,00,000 population)	0.47
		Life expectancy at Birth years	0.37
		Birth rate(birth /1000 population)	0.21
		Death rate	0.18
		Infant mortality rate	0.33
Social Framework	Equity	Household below poverty line (%)	0.41
		% of HH with access to sanitation	0.8
	Access to basic needs	HH with electricity connection (%)	0.48

Environmental framework	Air pollution	SO2 emission($\mu g/m^3$)	-0.48
		NO$_2$ emission($\mu g/m^3$)	-0.07
	Soil pollution	Per capita solid waste(kg/capita/year)	0.12
		% of solid waste that is recycled	-0.18
	Water pollution	Water system leakage (% of total	0.78
		Share of waste water treated (%)	0.07
	Energy consumption	Electricity consumption per capita (kwh)	0.02
		Diesel Consumption/capita (litre/year)	0.16
		Petrol Consumption/capita (litre/year)	0.03
	Water consumption	Consumption of water (l/day/person)	0.079
		per cent of HH having piped water connection	0.12
	Urban green space	Green spaces /person (m^2)	0.19

Now we will calculate the dimension index and then composite USI for three factors using root mean square and these are presented in the next table –

Dimension of sustainability	Categories of sustainability	Composite indicators values(categories)	Composite indicators values (Dimensions)
Economic framework	Income	0.07	0.35
	Growth/development	0.018	
	Consumption	0.058	

	Infrastructure ,services and urban equipment	0.49	
	Transportation	0.034	
Social framework	Demographic	0.27	0.60
	Education	0.89	
	Health	0.30	
	Equity	0.63	
	Access to basic needs	0.48	
Environmental Framework	Air pollution	0.34	0.359
	Soil pollution	0.15	
	Water pollution	0.55	
	Energy consumption	0.09	
	Water consumption	0.56	
	Urban green space	0.12	
Composite urban sustainability index			0.451

Economic sustainability

In the economic dimension the city remains far away from the highest economic sustainability index value i.e. 1 holding its own value as 0.35. All the categories of economic dimension show very poor performance. In case of income and growth scenario city scores very low rates despite of having a good employment prospects. The results of relative index of these three indicators indicate poor strength of the city to maintain a good standard of living. The per capita water consumption of the city is very low i.e. 90.6 litres per day which is lower than nation's average 135 per head/day. Despite of having a huge volume of water resources (major contribution of water supply is found from the river Brahmaputra) there is absence of adequate supply provision and most importantly transmission loss (up to 40%) makes the water supply system less sustainable in practise. Infrastructure and urban equipment shows a moderate score.

The city has a public transportation system covering 8% of the total transport system. 48% of the total vehicle is owned by private sector. A high percentage of use of private transport can be linked to higher vehicular emission and thus by causing higher pollution levels. On the other hand, the density of public transport network plays a very important role in the sustainable mobility of a city (Reddy and Balachandra 2013). In case of transportation system Guwahati is 34% sustainable and in infrastructure and urban equipment sustainability

is 40%. The composite indicator of economic dimension of the city shows that Guwahati is only 35% sustainable.

Social Sustainability

Social sustainability includes five components such as demography, education, health, equity, access to basic needs. On an average social index of Guwahati shows a good result. City's population density is moderate. Guwahati shows a good enrolment in education having two State universities, one technical institution, and numerous private universities, colleges along with private and public schools. It shows a good performance in literacy level i.e. 91.47%. The enrolment and literacy sustainability of the city are 89% and 90% respectively. The public health of the city though is improving over the time but fail to provide satisfactory health infrastructure facilities to general mass. Studies show that majority of city dwellers prefer private equipped health treatment than public health system. Health indicator shows a very lower index reflecting that public health is only 30% sustainable in the city.

Electricity accessibility of the population in the city is very high i.e. 92.94%. The total electricity consumed by household sector in the period 2009-10 was 274.77 MU which in commercial sector in the same period was 173.06 MU. The annual consumption of kerosene, petroleum and diesel for the period 2009-10 stood at 11654 KL, 50200 KL, and 133120 KL respectively. The equity and access to basic needs indicators are showing 63% and 48% sustainability. Guwahati performs a good index for sanitation accessibility i.e. 0.8. Access to clean drinking water facility shows an unsatisfactory results with 40% transmission loss at the supply level.

Social index map the extent of equitable distribution of the benefits of economic development to the people. Overall social index of the city is good i.e. the city is 60% sustainable in social dimension.

Environmental Sustainability

Environmental framework performs below average results indicating the wide gap of present urbanisation framework to sustain the environment along with economic growth. Rapid uneven urbanisation coupled with substantial economic activities over few decades leads to degradation of environmental quality in the city. Data on various pollutant including So_2, No_2 published by State Pollution Control Board (SPCB) reflects a rising pattern due to vehicular, industrial, household and economic activities. The SPCB monitors quality of air and water on regular basis. The GHG emission of Guwahati has been rising at CAGR of 5.77% from 2006 to 2009 (Guwahti Solar City Master Plan, 2012). In environmental dimension city is 35% sustainable.

4. DISCUSSION

The Urban Sustainability Index of Guwahati city is equal to 0.451. Current urbanisation pattern of Guwahati is 45% sustainable. The result is far from the target of 1 indicating need for adopting strategic policy to bridge this gap.

Share of municipality water connectivity to the city is only 35% implying 75% of the population needs to depend upon other sources of water with varying ranges of cost and quality. As per City Development Plan solid waste management is highly inadequate which is sole responsibility of GMC. Door to door waste collection has not reached 100% coverage yet. Moreover encroachment in hilly areas by different parties for residential and commercial purposes has resulted in rapid ecological degradation of those regions. Guwahati receives a good quantity of rain of 90 – 120 days during monsoon season. Water logging problem is aggravated by the small and narrow drain tunnels constructed in an unplanned manner which lack proper sustainable design. The authority does not maintain 45% of the residential drains (Phukan ,Baruah , Goswami 2016). During monsoon drains are frequently covered by mud i.e. carried by rain water from hills and this causes overflowing of water throughout some roads or human settlements. Some areas like Anil Nagar, Nabin Nagar are severely affected by artificial flood. The natural wetlands like Deepor bill etc. are the natural collectors of rain water flowing through the hilly areas. But rapid shrinking of these wetlands (using for commercial and other purposes) made the flood problem acute in the city during rainy season.

The green space along with air and soil pollution of the city shows 12%, 34% and 15% sustainability. The share of less urban green space lower the environmental sustainability of the city. The built up area increased from 23.9 to 115.1 km^2 in 2015 becoming the dominant land cover class accounting for 41.8% of the total geographical area. During this period natural and semi natural vegetated land were reduced by 88.9 $km^{2\ at}$ an annual rate of 2.2 km^2 (Pawe and Saikia 2017).

The city needs to target the indicators with low index to achieve the desired sustainability goals. Some of the aspects which can be improved to achieve the goals are given below-

- Emphasis must be put forwarded to energy efficiency along with increased renewable base.
- Foster Small business in informal sector.
- Conservation of wetlands and strict regulations must be initiated.
- Proper policy prescription and regulation for conservation of ecology of hilly areas handling the issue of encroachment without affecting settlements of the mass and not at the cost of leaving the question of quality of hill ecology at their hands.
- Accession of GMC's waste collection system must be ensured in hilly areas.
- Guwahati receives a good amount of solar radiation over the year. It has been observed that the daily horizontal solar radiation over the city is 4.69kwh/m2/day. It shows a good potential for solar energy generation capacity of the city which can be transformed into reality through proper planning.

Urbanisation brings irreversible changes in the social and ecological aspects of cities at global national and local level. USI calculates extent of sustainability in any urbanisation process quantitatively. The USI value of Guwahati being 0.451 shows a below average performance of its urbanisation policy in achieving sustainability. The city planning of Guwahati needs to foster the financial strength of the people to raise the standard of living along with improving the conditions of water supply, solid waste management system and renewable energy base to attain desired sustainability in its urbanisation process.

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