Proceedings of IOE Graduate Conference, 2019-Summer
Peer Reviewed
Year: 2019 Month: May Volume: 6
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Sustainable Urban Development Index for Kathmandu Metropolitan City

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Abstract
Sustainable urban development index is a burning issue around the whole world as it is one of the effective measures to measure sustainability to know how the cities are being developed and if the development is sustainable. Kathmandu Metropolitan city has experienced rapid population growth with the annual rate of 4.5 percent in 2011, putting massive pressure on basic infrastructure and services. The objective of this study is to develop a sustainable urban development indicator and a composite index which is tailor-made to assess the cities similar to Kathmandu. The research uses mixed method being in pragmatism paradigm. This paper examines urban sustainability in an integrated manner with its five dimensions of economic, social, environmental, governance/ institutional and cultural using indicator based approach. The research is based on study of the earlier developed indicators all over the world and has chosen indicators which are relevant to similar context and whose data is available in our context. Using the theme based framework, it is possible to obtain a composite index for Urban Sustainability Indicator whose model can be applied to cities with similar background with contextual changes. The scores obtained from the model helps in bench-marking the cities and identifying gaps so that it can inform local government policy and planning about the situation in the city.

Keywords
Sustainable development, Sustainable Indicator, Sustainable index

1. Introduction

Urbanization in Nepal has boomed in the rapid rate and Kathmandu valley being administrative center, is not an exception. Kathmandu Valley is the most populated urban region and one of the fastest-growing urban agglomerations in South Asia[1]. The rapid march towards urbanization makes the urban planning a priority at all levels of government. Sustainable development - to meet the needs of the present generation without compromising those of future generations - has become a fundamental objective of development planning that requires dealing with economic, social and environmental policies in a mutually reinforcing way[2]. As the concept of sustainable development is becoming important, monitoring cities in terms of sustainability has increased, resulting in a need to formulate sustainable development index. In September, 2015, the United Nations approved 17 sustainable development goals, of which goal No. 11 was to "make cities and human settlements inclusive, safe, resilient and sustainable", targeting urban development.

Measuring the sustainability in urban areas - which are crucial engines of local socio-economic development, but at the same time present concentration points of environmental decay - is a major challenge for environmental managers and decision-makers [3]. Indicator is defined as, statistics, statistical series, and all other forms of evidence, that enable us to assess where we stand and are going with respect to our values and goal[4]. Application of sustainable urban development indicators is one of the most important strategies to achieve the sustainable development. Thus, development and utilization of indicators as the assessment tool is a must for every city in developing countries like Nepal.

As the indicators need to be locally relevant and locally accessed, establishing the indicators in terms of locally relevant dimensions and assessing performance of case city in terms of urban sustainability will be the scope of the research. The research has focused on Kathmandu Metropolitan city

as KMC is one of the densely populated urban center and politically as well as administratively important city. The research will make a sincere attempt to establish an indicator in municipal level and formulating the urban sustainability index which indeed will help to find ways to improvise the condition as there are huge plans of future urbanization that need effective indicators to guide the practice of their sustainable urbanization plans.

2. Research Objective

The main objective of the research is the assessment of politically and administratively important Kathmandu Metropolitan city to determine the state of sustainability and the ways to improve it. The specific objective are as follows:

- To identify and establish indicators for the sustainable urban development of KMC.
- To formulate sustainable development index for the case.
- To formulate recommendations to improve the current situation to ensure healthy future growth and sustainable development.

3. Study Area - Kathmandu Metropolitan City

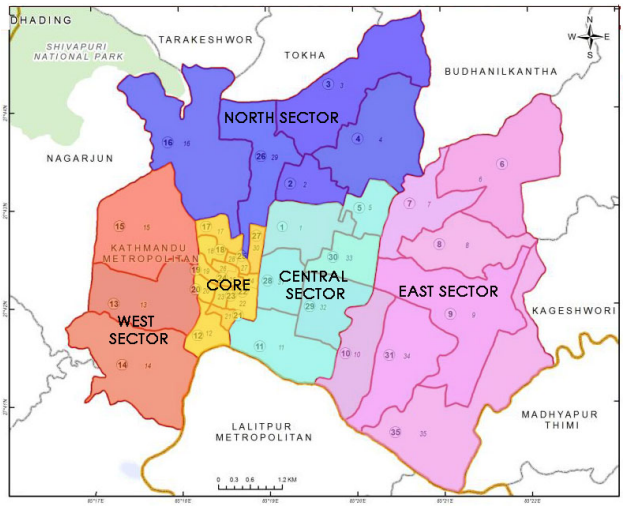

Figure 1: Sectors of KMC - study area

Kathmandu, the capital of Nepal, has long history of development almost 2000 yrs. old and exhibits a typical city surrounded by complex mountain terrains in the Himalayan region. History has witnessed its development as a strategic center of power, politics, culture and commerce[5]. Being the eldest metropolitan in country, KMC is one of the largest urban agglomeration city and hence it need to be sustainable in order to maintain and acquire the development as well as to provide the better living in the city.

4. Methodology

The ontological position of the research is to assess the sustainability of KMC by indices where the profit driven haphazard urbanization has been using all the natural, environmental prospects and turning Kathmandu into a concrete jungle. The research is based on pragmatism paradigm and uses mixed method research strategy i.e. combining both quantitative and qualitative research strategy. Qualitative research strategy is used to identify the indicators , reviewing the literature and cases around the world. Quantitative research strategy is used to formulate the indices of KMC. The study is categorized into two parts, first part comprises of literature review, selection of indicators and data collection which is followed by normalizing the values , developing composite dimension index(CDI) and then finally estimating urban sustainability index(USI).

4.1 Design of Indicator based Approach

The first step in this approach is to compile then prioritize the relevant indicators. An in-depth literature studies have been carried out to enable us in selecting the final indicators belonging to five dimensions used in the study – economic, environmental, social, governance/institutional and cultural. Next, the indicators will be quantified by analyzing extensively the data collected, mostly from secondary sources. The threshold indicator database for the best and worst sustainability indicator values across standards set by nation or other standards, would enable the development of the benchmark sustainable urban indicator template for comparison and evaluation.

4.2 Normalising Values

Different indicator values have different measurement units (income in rupees, Electricity in kWh, etc.). For developing composite indicators, it is essential to normalize the values of all these indicators into some

standard form. Thus, for each of the indicators included in the analysis, a relative indicator is estimated using the actual and the sustainability threshold values. For each indicator, a minimum and maximum threshold values will be determined. The relative indicator is developed by using a scaling technique where the minimum value is set to 0 and the maximum to 1. The equation used is as follows [6]:

$$\frac{\text{Actual Value(x)} - \text{Min Threshold(MNT)}}{\text{Max Threshold(MXT)} - \text{Min Threshold(MNT)}} \quad (1)$$

4.3 Developing composite dimension index (CDI)

The next step is to derive the composite indicator dimensions from appropriate indicators belonging to that particular dimension. In this research, each dimension is given the equal weightage assigned to them. 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 [6]:

$$CDI_j = \left(\frac{\sum_{i=1}^{n} v_{ij}^2}{N_j} \right)^{0.5} \quad (2)$$

Where CDI_j = Dimension of type "j", where j = 1,2,3,.....,N (N = Number of dimension)

vij= variables "i" belongs to dimension "j" where i = 1,2,3,.....,N

N = number of variables considered in jth dimension.

4.4 Developing composite Urban Sustainability Indicator (USI)

Further, we develop the composite urban sustainability index(USI), from these dimensions that are assumed to contribute to the issue of urban sustainability. Where weights of dimensions are available from the survey, then these could be used to derive the USI, and where unavailable, the following modified equation could be used[7]:

$$USI = \left(\frac{\sum_{j=1}^{M} d_j^2}{M} \right)^{0.5} \quad (3)$$

Where USI = Urban sustainability index
d_j =Dimension "j" , where j = 1,2,3,4,5, ..., M
M = Number of Dimensions considered

5. Limitation of the study

The research is limited to Kathmandu Metropolitan city only. The valid secondary data taken from different sources like CBS 2011 and metropolitan and government office will be used and primary surveys will not be done hence, data which are not available could be lacking. Availability of data from government official can be a challenge as there may not be existence and availability of all records. Some data of district will be used as it is for some indicators.

6. Dimensions of Sustainability

The organizing principle of sustainable development is translated into practice using frameworks like the three pillars of sustainable development i.e. Economic, Environment and Social[8]. Kathmandu Metropolitan city is administratively and politically strong city so governance/institution is taken as the fourth pillar of sustainability and the city is known for its cultural heritage since ages so, this research has included the culture as the fifth pillar to address the culture sustainability in the city. Thus, the present study has used five pillars of sustainability to assess the sustainability of city. Each dimension is broken down into specific themes. Each theme is then populated by relevant indicators.

6.1 Framework for urban sustainability indicators

The sustainability dimensions represent different aspects of a city and a significant number of indicator variables are necessary to measure their extent. In other words, these dimensions constitute large number of representative indicators belonging to different groups of indicators[7]. The five dimensions are again classified into categories based on the literature studies. Following the initial classification, 26 commonly used categories were formed in order to better structure the indicators within each dimension. The research attempted to remain as faithful as possible to the classifications and categories suggested by most of the studies. The prioritization of categories of urban sustainability indicators has been made with the support of literature. The frequency of use of each indicator was then calculated for each category in sustainable indicator development studies of areas like Valmiera, Mumbai, Malaysia, USA and some of the global indexing system namely ISO37120, China USI, UNHabitat 2009 and SDG

Nepal. It is easily apparent that the environmental component is characterized by a large variety of indicators-hence a lesser consensus-whereas the social, economic and institutional components comprise indicators that are more consensual and therefore more frequently used (Refer Table 2). This process facilitated shortlisting of 26 categories of indicators under five dimensions of sustainability.

Table 1: Five Dimensions and Categories of Sustainability

Dimension	Categories
Economic	Income Employment Industry/establishment Infrastructure Communication Transportation
Environmental	Air pollution Water Pollution Solid Waste Drinking Water Sanitation Energy Open Spaces
Social	Demographics Housing Education Health Poverty Safety and well being
Governance/ Institutional	Voting Metropolitan Finance Institutional Capacity
Cultural	Cultural events Protected areas including Forest Ethnicity Cultural Tourist

The research initially compiled studies that apply indicators related to sustainable development to one or more cities or urban centers. The goal was to cover a broad array of indicators from cities relevant to the case study area as possible. The study has subsequently decided to limit the analysis to studies specifically covering urban indicators of sustainable development. Of the initial studies, three were specific to the field of three pillars of sustainability. From the literature examined, the study compiled 122 common and relevant indicators. From the studies, it

Table 2: Frequency of indicators in each dimension in 10 studies

Dimension	Frequency of indicator
Economic	154
Environmental	183
Social	255
Governance/Institutional	32
Cultural	28

can be seen that the social dimension has been used more frequent in the sustainable development indicators then environment categories have more weightage. It can be seen that the cultural dimension lacks in most of the studies. The three pillars of sustainable dimensions are only mainly focused in most of the studies. Even the governance/ institutional dimension is lacking. In this study, all dimension have given equal weightage.

7. Sustanability Indicators for KMC

7.1 Selection of Final Indicators

The indicators should be based on the specific system that is supposed to be analyzed, like geographic, biophysical and socioeconomic characteristics[9], related to the specific problems regarding sustainable development issues [10] and measurable and comprehensible[11]. The indicators in this study were chosen on the basis that they were, as far as possible, measurable and comprehensible. According to matrix developed by UN[12] shown in Figure 2,the indicators are classified into four categories of data availability: fully available; potentially available; related data available; and not available. The first category is the preferred. The second one, indicators with potentially available data, contains those cases where data could be made available within a reasonable time frame and costs. The third category contains those indicators where important data are missing, but there are data that could be used to compute related indicators. Relevance is the second dimension of the matrix. Again, the introduction of four different categories indicators are placed: relevant; related indicator relevant; relevant but missing; irrelevant. The indicators fulfilling the data availability and relevant are taken as the final indicators.

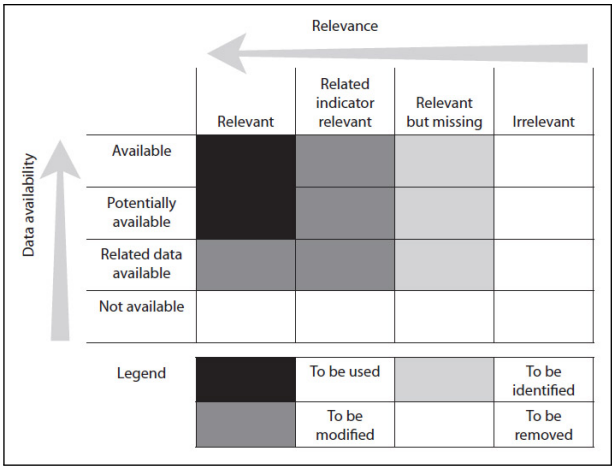

Figure 2: Matrix for adapting CSD Indicators of Sustainable Development[12]

7.1.1 Economic indicators

Economic dimension has 12 final selected indicators from the compiled list of 36 indicators. Economic dimension also included city infrastructure and transportation related indicators. In addition to traditional service accessibility, the number of Wi-Fi places and e-governance indicators are also suggested in communication field. Some of them are important and should be measured for sustainability like parking area and time travel, hence though there is the data unavailability, these indicators are highly recommended.

Indicators	Code
Per capita income (US$ PPP/year)	EC1
Number of establishment per 100,000 population	EC2
Unemployment rate	EC3
Ratio of women to men engaged in establishments (%)	EC4
Road density (km/sq. km)	EC5
Number of commercial bank branches per 100,000 population	EC6
Proportion of adults with active mobile banking service(%)	EC7
Share of households with access to mobile phones (%)	EC8
Share of households with access to internet (%)	EC9
E-governance; accessibility of e-services (Number)	EC10
Percentage of Automobile ownership	EC11
Accessibility of public transportation infrastructure (%)	EC12

Figure 3: Final Economic Indicator

7.1.2 Environmental indicators

Environmental dimension contains 11 final selected indicators, selected from 24 compiled indicators. Environmental dimension emphasizes availability of green space, reduction of emissions, and the availability of clean drinking water as well as provision of improved sanitation.

Indicator	Code
PM10 concentration (µg/m³)	EN1
PM2.5 concentration(µg/m³)	EN2
Level of Turbidity	EN3
Level of BOD	EN4
Level of DO	EN5
Waste Collection efficiency (%)	EN6
Population with access to improved sanitation (%)	EN7
Percentage of city population with Piped water connection	EN8
Percentage of household with electricity connection	EN9
Household using clean fuels as primary source for cooking (%)	EN10
Percentage of open spaces to urban area	EN11

Figure 4: Final Environmental Indicator

7.1.3 Social indicators

Social dimension included 18 final selected indicators. Growing importance of life quality and well-being means have been addressed. Social indicators provide information on the categories like demographics, housing, education, health, equity as well as safety and well-being of citizens. This indicator provides the database on situation of basic needs in the city as well as the empowerment and equity in the city. Several indicators of local security, Number of Crimes per Type and Road Traffic Accidents are also included indicators.

Indicator	Code
Percentage of young cohort(AGE 15-40 YRS)	SO1
Percentage of household/ tangible assets in women's name (in total)	SO2
Households living in safe houses (%)	SO3
Household units roofed with RCC (%)	SO4
Literacy rate (%)	SO5
Female literacy (%)	SO6
Educational attainment SLC/SEE and above (%)	SO7
Number of hospital beds per 100,000 population in government hospitals	SO8
Life expectancy at birth (years)	SO9
Percent of institutional delivery	SO10
Maternal mortality ratio per 100,000 live births	SO11
Slum household (% of total)	SO12
Poverty Rate(%)	SO13
Crime related women and children rate per 100,000 population	SO14
Suicide rate per 100000 population	SO15
Number of murders per 100,000 population	SO16
Transportation accidents per 100,000 population	SO17
Missing persons and persons affected by disaster per 100,000 (number)	SO18

Figure 5: Final Social Indicator

7.1.4 Governance/institutional indicators

Governance/Institutional dimension has 4 final selected indicators, selected from 13 compiled indicators. These indicators provide information on the categories like metropolitan finance, institutional capacity and participation in elections. This indicator provides the database on situation of metropolitan budget as well as its institutional capacity in the city.

Indicators	Code
Voter's turnout in election(%)	GI1
Primary government expenditures as a proportion of original approved budget, by sector	GI2
Proportion of internal budget funded by domestic taxes	GI3
% of women elected officials in metropolitan	GI4

Figure 6: Final Governance Indicator

7.1.5 Cultural indicators

Cultural dimension included 5 final selected indicators. Cultural indicators provide information on the categories like cultural activities, protected area, forest, ethnicity and cultural tourist.

Indicators	Code
Number of annual cultural events	CU1
Budget allocated for the protection of natural and cultural heritage (%)	CU2
Protected area (including religious forest, in % of total land area)	CU3
Ratio of largest ethnic population to second largest	CU4
Percentage of international tourists visiting heritage sites	CU5

Figure 7: Final Cultural Indicator

8. Data Analysis

8.1 Data Collection

The baseline of the data is from 2011 to 2018/2019. Most of the data for the city has been obtained from the relevant wards and metropolitan, CBS and relevant departments. The data available in the government portal are accessed from the web like portal of NRB, DRR etc. Other sources of data are Government reports like District Statistical Handbook, District Information system for education, Annual Health Survey, etc. Some of the values of indicators are taken that of district like Life expectancy, Per capita, Mortality rate etc.

8.2 Determination of Threshold

Thresholds are important to normalize the values of indicators. In this study, most of the thresholds are taken from the standards set by SDG Nepal and national standards. Some of them are referred from international standards. The remaining which cannot be found in standards are set by authors.

8.3 Normalizing Value

Normalised value for each indicator in every dimension is then calculated using the formula described in section 4 equation 1. Normalised values of indicators are shown in Figures 8,9,10,11,12.

Code	MXT	MNT	x	Score	Data Source
EC1	3500	1000	2764	0.71	HDI Report,2014
EC2	3000	9000	8161.03	0.14	CBS,2018
EC3	0	10	2.324	0.77	CBS 2011
EC4	40	0	58.69	1	CBS,2018
EC5	15	1	20.95	1	GIS analysis
EC6	36	20	46.337	1	NRB,2019
EC7	99	34	125.7	1	NRB,2019
EC8	100	75	91.9	0.68	CBS,2011
EC9	90	20	23.7	0.05	CBS,2011
EC10	30	0	18	0.6	KMC,2018
EC11	20	80	49.4	0.51	CBS,2011

Figure 8: Economic Index

Code	MXT	MNT	x	Score	Data Source
EN1	50	120	1021.2	0	MoPE report,2017
EN2	20	40	167.83	0	
EN3	20	50	272.4	0	HPCIDBC, 2018
EN4	0	30	168.4	0	
EN5	7	5	2.74	0	
EN6	100	80	86.9	0.345	ADB,2013
EN7	100	80	92.1	0.605	CBS,2011
EN8	100	50	64.2	0.284	
EN9	100	80	98.3	0.915	
EN10	100	80	94.2	0.71	
EN11	35	5	5.99	0.033	KVDA,2015

Figure 9: Environmental Index

Code	MXT	MNT	x	Score	Data Source
SO1	80	50	53.86	0.13	CBS,2011
SO2	40	0	6.36	0.16	
SO3	100	50	41.9	0	
SO4	100	45	80.6	0.65	
SO5	100	80	89	0.45	
SO6	100	50	83	0.66	
SO7	100	50	44	0	
SO8	500	300	319.23	0.10	DoHS,2017
SO9	80	50	75.4	0.85	HDI Report, 2014
SO10	100	0	81	0.81	DoHS,2017
SO11	0	70	30.9	0.56	DoHS,2017
SO12	0	5	0.80	0.84	NUDS,2017
SO13	0	5	0.9	0.82	District profile,2018
SO14	0	20	29.52	0	Metropolitan Police
SO15	0	16	35.778	0	
SO16	0	20	20.8	0	KTM,2018
SO17	0	20	11.58	0.42	
SO18	0	50	9.64	0.81	MOHA,2019

Figure 10: Social Index

Code	MXT	MNT	x	Score	Data Source
GI1	80	60	70.05	0.50	Election commison
GI2	90	40	39.89	0	,2018
GI3	80	40	40.71	0.02	KMC,2019
GI4	42	33	41.212	0.91	

Figure 11: Governance Index

Code	MXT	MNT	x	Score	Data Source
CU1	12	2	10	0.80	Guthi Sansthan
CU2	5	2	4.4446	0.81	KMC,2019
CU3	20	0	2.53	0.13	UNESCO
CU4	100	50	101.065	1.00	CBS,2011
CU5	30	10	20	0.50	Related offices

Figure 12: Cultural Index

8.4 Formulating CDI and USI

After normalisation of values, composite dimension indices(CDI) are calculated using the equation 2 given in section 4. If actual value $\geq$ maximum threshold, then its score is 1 and if actual value $<$ minimum threshold then its score is 0. In case of PM10, PM 2.5, BOD, DO and turbidity, if actual value $\leq$ maximum threshold then its score is 1 and if actual value $\geq$ minimum threshold then its score is 0.

Table 3: Composite Dimension Indices

Composite Dimension Index (CDI)	Score
Gross Economic Index	0.75
Gross Environmental Index	0.42
Gross Social Index	0.52
Gross Governance / Institutional Index	0.52
Gross Cultural Index	0.71

Using CDIs in Table 3, Urban Sustainability Index (USI) of KMC is estimated using the equation 3 given in section 4. Here, USI is as an equally weighted average of five dimensions – economy, environment, social, governance/institutional and cultural. The estimated USI of KMC is 0.59. The maximum is 1 and the minimum is 0. It is important to remember that these are relative index values and not the absolute one.

9. Discussion

Urban Sustainability Index of KMC in five dimensions is estimated as 0.59. This is the average score between the best rank 1 and worst ranking 0. The good performance of USI of KMC is contribution of the economic dimension with 0.75 and cultural dimension with 0.71 score. The environmental dimension has score 0.42 score, which means air and water pollution is high in KMC. The governance and social dimension stands in average level with 0.52 score. The social security and well-being is not good in KMC as suicide rate and crime rates are high. Poverty is less in KMC and the percentage of young cohort is less in KMC. Less score of governance is due to the proportion of expenditure of budget in metropolitan. In overall, KMC has secured average score in spite of some least scores in environmental indicators and social indicator.

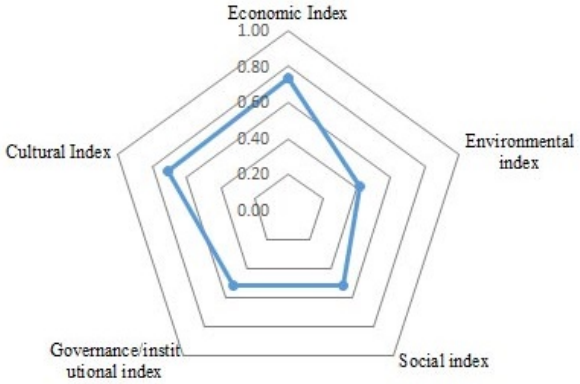

Figure 13: Urban Sustainability Index for KMC

10. Conclusion

Measuring the sustainability of urban area is a challenges. Different urban area needs different set of indicators according to its background and characteristics. The use of indicators for assessing urban sustainability performance is an important tool and is being adopted widely in recent times in many countries. A short list of indicators is recommended and indicators can be added or eliminated depending on emerging needs. There is an urgent need to harmonize indicator development initiatives at all levels — local, provincial and national.

Kathmandu Metropolitan city scoring 0.59 USI, shows that KMC is economically and culturally in better situation than that of other dimensions. The environmental dimension of KMC, in terms of pollution has worst situation and has to take actions to reduce pollution in KMC. The social safety and well being is satisfactory only as the crime rate and suicide rate are higher in KMC. The governance dimension value shows that the metropolitan finance is not being

used hence it has least score. In summary, KMC has scored average when compared to the benchmark value of 1.

Recommendation

- With respect to economic dimension with the score of 0.75, KMC can still focus on practice of decreasing establishments in many areas of the city to increase the aesthetics and protect cultural identity of city. Mass transit should be encouraged and automobile ownership should be discouraged to manage the traffic congestion. Likewise, the transportation infrastructure like parking areas etc. should be made available.

- With the index value of 0.42, environment dimension holds lower position. Air pollution and water pollution has worst figure, which suggest that strict policies and actions are needed to reduce the pollution in KMC. Emissions from vehicles, industries and even residential areas should be in control. Wastewater treatment plant should be made in different places of the city. Recycling, reducing and reusing of solid wastes should be strictly implemented from the local levels and efficient waste collection should be maintained. Open spaces in the city should be encouraged and protected from encroachments.

- Social dimension in KMC holds an average position with the index value of 0.52. Health, education categories have good score and the lower score is due to safety and well-being, demographics and housing. The value suggest that KMC can improve their social sustainability index values by focusing on issues related safety of citizens.

- With the index value of 0.52, the governance/institutional dimension has average score. Institutional capacity has scored 0.91 which suggests that participation of woman elected in metropolitan is high in KMC. The lower index value is contributed by the metropolitan finance which suggest that KMC should use more of its finance in the sustainable development of city.

- Cultural dimension has a good position in KMC with the score of 0.71. This performance of KMC is because of cultural activities and ethnicity, which are still holding the good place. It can be seen that the cultural tourism need to be organized and the infrastructure for tourists need to be fulfilled in order to be sustainable.

Sustainability issues are interconnected, and any approach that needs implementation requires the administration to consider across various sectors, through policy and legislative framework and act collaboratively to construct feasible sustainability plans. At the municipality level, effective coordination and institutional alignment is important at wards and also needs the active participation of communities in planning, policy development and implementation. This should be supported by allowing metropolitan to exercise budget allocations. Finally, to achieve sustainability a common commitment and effort to cooperate on initiatives must be adopted. This commitment must include monitoring and acting on these issues to ensure a common minimal standard of urban sustainability.

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