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Evaluation of Sustainability index for Urban Water Management System

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***Abstract*— integrated sustainability assessment is the part of a new paradigm for urban water decision making. Multi criteria decision analysis is an integrative frame work used in urban water sustainability assessment [1]. The cities are facing range of dynamic pressure including rapid population growth, urban sprawl, and industrialization and climate change results into exploitation of available natural resources. Therefore ecological footprints of cities are growing rapidly in many developing countries. The sustainable urban water management is concerned with not only functional aspect of urban water management but also environmental, economic, social and engineering aspects of sustainable development. Therefore it is required to undertake holistic analysis of entire urban water cycle by setting up relatively simple model with reasonable accuracy. Today, municipalities are facing great challenge for managing urban water systems. Therefore, effort is put forward by making a simple model to find out loopholes in the water management system and to find the potential in the system where chances of improvement lies which makes system sustainable for future. The data were collected from Surat Municipal Corporation and sustainability index is found by developing simple additive weightage model.**

Keywords- Sustainability index, Urban water management

I. INTRODUCTION

The cities are facing a growing pressure for sustainable water services in a scenario, where water is becoming increasingly scarcer. Most urban systems were developed under criteria guided by hygiene and efficient performance goals that are necessarily encompassed with sustainability principle in present scenario. Are the UWS (Urban Water System) sustainable? Answering the question is strategic to plan viable cities in the future [2]

The conventional urban water cycle incorporates high quality drinking water for all domestic purpose like; large quantity of drinking water is used to transport human excreta, for washing roads and vehicles etc. There for this open cycle is further required to redesign. Urban water management involves water supply, urban drainage, storm water, water and waste water treatment and sludge handling. The past two decades have seen global transformation at an un-precedent rate. The population growth, globalization and urbanization all are having a significant role in reshaping of society.

The planning or reforming urban water sector is the urgent need for maximizing water beneficial use. The planning is to be driven based on key postulates of Dublin Environmental and economic principles. The sustainability and conservation of resources are the key drivers of such governance reforms in water management sector.

These sector reforms of service arrangement are based on performance criteria- equity efficiency and social, economic, ecological and environmental sustainability.

Water is key element to socio- economic development and quality of life. (Stockholm conference) Environmental, Economic, Social and Engineering sustainability is a concern objective for municipalities and organizations but is often vaguely defined and clear measurement procedure are lacking.

II. BACKGROUND

The principle of sustainable development is embedded first time in the 1972 Stockholm conference which was introduced by the international union for the conservation of the nature (IUCN). The IUCN is the first who has lay down the concrete base for economic, social and environmental sustainability (Adams 2001).

The year 1981, launched as first decade of action, focussing on safe water and sanitation for everyone.

In 1987, Brundtland Commission report stated the definition for sustainable development [3].

In 1992, UN Conference on Environment and Development, Rio de Janerio: Established the Agenda 21, a guide for sustainable development in to the 21st century. This Agenda mentions the importance of an integrated water management approach [4].

In 1992, International conference on water and environment, held at Dublin. They issued four guiding principles regarding water, (1) its importance as a finite and vulnerable resource, essential to sustain life, development and the environment, (2) the management should be based on participatory approach, (3) the importance of woman's role, (4) water is an economic good, in all its competing uses [5].

In 2000, Millennium development goals stated eight major goals for the year 2015.

In the year 2002, World summit on sustainable development, Johannesburg added a target to the MDG for halving the number of people without safe access to drinking water and included a commitment for the development of integrated water management [6].

The year 2005 was launched as water for life decade to promote the efforts in the field of water targeting the horizon 2015.

The year 2006, fourth world water forum, Mexico published a guideline regarding water issue and target is to achieve environmental sustainability and protection [7].

As a result at the beginning of year 2007, many water related success and failure stories are available.

PAST STUDIES:

For Integrated assessment UNEP describes selected tools which are Stake holder analysis and mapping, Expert panel, Focus groups, household survey, Sustainable framework indicator, casual chain analysis, Root cause analysis, trend analysis, scenario-building , Multi criteria decision analysis [10]. The comparative study of sustainability index was carried out by for South African cities by Triple bottom line perspective and MCA was used by Carden et al [8]. Sahely et al used mathematical model for quantifying Environmental and economic sustainability indicator [11]. Shovini Dasgupta et al has categorized Mendatory screening indicator and judgement indicator and multi layer approach is used to incorporating these indicators. A normalization procedure has been adapted to work within the framework to help compare alternative across a range of indicator and different orders of data magnitude [12]. E Lai et al has reviewed numbers of method for Integrated Sustainable urban water system. The four dominant approaches applied are cost benefit analysis, triple bootom line, integrated assessment and multi criteria analysis [13]. Vairavamoorthy et al has done risk assessment for sustainable urban water management using fuzzy logic [14]. Stefan Hajkowicz et al has review the method of MCA which includes fuzzy set analysis, comparative programming, analytical hierarchy process ELECTRE, PROMETHEE,MAUT, MCQA, EXPROM, MACBETH, SAW, TOPSIS etc [15].

III. METHODOLOGY

- **System boundary** is decided based on systematic consideration of the various dimension of water. Domain of system boundary consists of water supply system, waste water, storm water, rain water recharging/harvesting & its sub criteria. Sustainability is related to prolonged time perspectives hence it should be selected accordingly.
- **Criteria selection** involved the selection of appropriate criteria for the field of research given their relevance to current issues, their appropriateness to the area in question, their scientific and analytical basis plus their ability to effectively represent the issues they are designed for. Theoretical framework building provides the underlying basis for criteria selection and supported the overall index structure. The four dimensional view on sustainability was employed, and these four dimensions constituted the basic components of the index.
- **Data collection** is very important aspect as incorrect data set results in to misleading sustainability Index. Imputation of missing data involves assessing step wise procedure for creating data sets, and when data are missing, determining how to address the issue. The non availability of data is largest constraint hence indicator with incomplete data, either substitution or exclusion of criteria is adopted.
- **For Analysis** the indicator chosen were both quantitative and qualitative over wide range. **Normalization** involved the conversion of these criteria and sub criteria to a comparable form which ensures commensurability of data. The criteria are compared with standard norms established by WHO guide lines and based on their unit of measurement**.**
- The **Weighting** entailed the aggregation of criteria and sub-criteria. A ranking approach was adopted, in which criteria and sub-criteria were ranked within their category and then assigned corresponding weight based on expert's opinion.
- To establish an initial base situation weightage for each criteria and sub-criteria was assign. **The aggregation** refers to grouping of criteria and sub-criteria. A composite index approach was employed to calculate the overall sustainability index score. The normalized value for each criterion X_{ij}, was multiplied by the aggregate weight of criteria and sub-criteria Wj. The score for each sub-criteria was added to get final Sustainability Index value.

The scores were normalized (converted) by the following formulas

$$x_{ij} = \frac{aij}{ajmax} \quad \text{---------- (1)}$$

$$x_{ij} = \frac{aj\ min}{aij} \quad \text{---------- (2)}$$

Where, aij = reference value for the sub-criteria

a_{jmax}, a_{jmin} = threshold value for sub-criteria

When criteria are maximized, formula (1) is to be used, and formula (2) is to be used when criteria are minimized. For normalization reference value/ threshold value is taken as a standard value.

Sustainability Index (S.I) = $\sum_{j=1}^{n} Xijwj \;\; j = 1, \ldots n$

Where, n = number of criteria,

wj = weight of the criterion, and

xij = normalized score for the criterion.

IV APPLICATION OF SUSTAINABILITY INDEX FOR SURAT CITY

The city of Surat is situated at latitude 21°12'N and longitude 72°52'E on the bank of river Tapi having coastline of Arabian Sea on its West. It is 13 m above the mean sea level. The topography is controlled by the river and is flat in general and the gentle slope is from north-east to south-west. The summers are quite hot with temperatures ranging from 37^0 C to 44^0 C. The winters are not very cold but the temperatures in January range from 10^0 C to 25^0 C. The maximum humidity is at 80%. The south west monsoon is usually four months with an average rainfall of 1200 mm**.**

Surat city has perennial river Tapi, which is main source of water supply. The tragedy is local government can extract

only 700 MLD of water daily from river Tapi according to riparian right, which is not sufficient to fulfill the demand of citizen and high growth rate of population. Surat Local government demanding more water extraction capacity from river Tapi, with state government since long time but these all are political issues and not yet resolved. The City limit is increased in last few years from 112 Sq.

TABLE.1 CRITERIA AND SUB-CRITERIA FOR SUSTAINABLE URBAN WATER MANAGEMENT SYSTEM

Sustaina-bility Index	CRITERIA	VARIABLE USED
	Social (0.24)	• Access to water supply (0.20) • Access to sanitation (0.15) • Water availability/capita/day (0.14) • Supply hours (0.13) • Service complaints (0.17) • Flood prone area (0.21)
	Economic (0.24)	• Capital investment (0.29) • Cost recovery & Operation and maintenance cost (0.50) • Research and development investment (0.21)
	Environmental (0.28)	• Water withdrawal (0.14) • Energy consumption (0.12) • Pollution load on environment (0.12) • Waste water treatment performance (0.12) • Water reuse (0.10) • Recycling of nutrients and sludge reuse (0.09) • Storm water-area covered under pipe network (0.10) • Rain water harvesting/recharging (0.10) • Salinity ingress (0.11)
	Engineering (0.24)	• Metered connection (0.40) • Service interruption & Water losses (0.60)

Km to 334 Sq.Km area and corporation is not in position to cope up their demand at faster rate. Due to construction of weir cum cause way on river Tapi reservoir is formed on upstream side of river, which led to stagnation of flowing river water. Stagnation of water give rise to growth of algal and weed, hence raw water quality get degraded which will cause problem in intake well as well as in subsequent treatment process. It also reduces the yield of water. To improve the raw water quality, frequently release of water from nearby (Ukai) dam is required. Moreover, a sewage discharge from Chaprabhatha, Kosad, Amreli, Motta Varraccha, and Kathor has created terrible impact on river water quality on upstream of river. Sewage discharge enhances the growth of algae, weed and other vegetation. Recently, it was decided to lay down pipelines from Ukai to Surat to resolve the issues regarding quality and quantity of water supply demand as a suggestion in revised city development plan. Will this decision economically viable or sustainable?

In the downstream of weir in river Tapi, due to tidal influences river water become brackish. Owing to these problems the bore water of adjacent area like Rander, Athwa, and Old walled city area becomes salty and not fit for drinking.Over withdrawal of ground water for industrial and irrigation purpose has depleted the ground water table and degraded the quality of ground water also. Only 56% of the total population (45 lakhs) gets easy access to water supply. Only 33% of area is covered with sewage network and 81% of population of 33% area is covered.

Municipal Corporation received approximately 400-450 complaints related to water supply every year. Approximately 200-250 flood prone areas are there in Surat city which needs storm water pipe network. Water meter are installed only 0.41% total area of city. Water losses are not measured but approximately 30% (as per officers of S.M.C.)

TABLE.2 SUSTAINABILITY INDEX VALUE FOR CRITERIA AND OVER ALL SUSTAINABILITY INDEX

Criteria	Individual index	Average weightage	Aggregate Index value
Social criteria	0.453	0.24	0.1087
Economic criteria	0.65915	0.24	0.158196
Environment criteria	0.435	0.28	0.1218
Engineering criteria	0.03164	0.24	0.0075936
SUSTANABILITY INDEX			**0.396289**

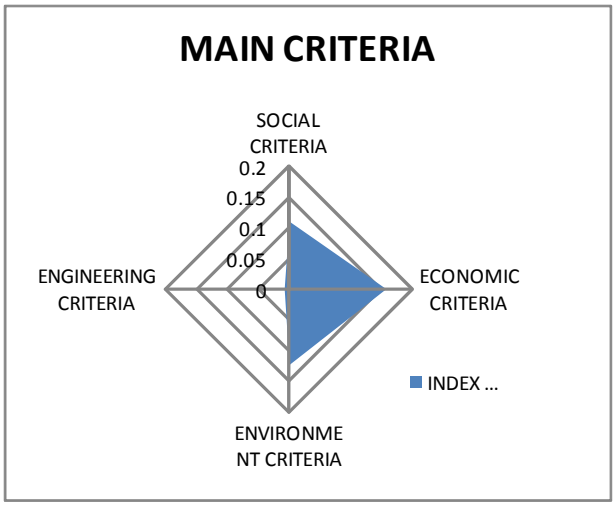

Fig.1 Graphical presentation of aggregate Index

V. RESULTS AND DISCUSSION

The result shows that Surat city standing in the sustainability continuum is moderate with composite index scoring of social, economical, environmental, & engineering criteria are 0.1087, 0.158196, 0.1218 and 0.0075936 respectively. Individual Index for above criteria are 0.453, 0.659, 0.4351, and 0.031 respectively. Sustainability index for urban water management system found is 0.396.

The result shows that Surat city standing in the sustainability continuum is moderate with over all scoring of social, economical, environmental, & engineering indexes are 0.453, 0.659, 0.4351, and 0.031 respectively.

Engineering index is very less and it has high potential for improvement. According to the collected data metered connection is only in the area of 0.41% of Surat city which brings down engineering index. Water losses can also be minimized by installing efficient devices and conducting water audit.

Environmental index can be raised by implementing water reusing system. The energy consumption contributes 66% of total water management cost so, it can be reduced to some extent by implementing energy efficient technique or renewable energy sources should be used.

There is huge variation between area covered under pipe network & percentage population covered before & after extension of city limit. This is because of transition stage of extension of city limit. It takes time for establish infrastructure facilities which represents a drop in population & area coverage. Apart from that important issue is riparian right for water withdrawal capacity hence it is urgent need for sustainability of system to develop rainwater recharging and harvesting system, Reuse of water and waste water and water meter should be implemented to minimize water losses.

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