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SAW MODEL FOR QUANTIFYING SUSTAINABILITY IN URBAN WATER SECTOR

Reena Popawala and N.C. Shah*

Department of Civil Engineering, C.K.Pithawalla College of Engg. & Tech., Surat
*CED & Section Head (TEP), SVNIT, Surat, India
Corresponding author: reenackpced@yahoo.com

ABSTRACT

Integrated sustainability assessment is part of a new paradigm for performance evaluation of urban water sector. Multi criteria decision aid is used as integrative framework in urban water sustainability assessment. In this paper, for evaluation of performance of water sector Simple Additive Weightage model (SAW) is used and sustainability index is calculated. For research purpose sustainability was extrapolated from the perspective of "Triple bottom line" which highlights social, environmental and economic dimensions. The case study of Surat city in Gujarat, India is taken for quantification of urban water sector. The result provides useful information to water managers and decision makers for framing development program and future policy for sustainable urban water management.

Key words: *urban water management, sustainability index and sustainability assessment*

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 urban water systems sustainable? Answering the question is strategic to plan viable cities in the future (Guio, 2006). The conventional urban water cycle incorporates high quality drinking water for all purpose 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. Therefore, 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. 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.

BACKGROUND

The past two decades have seen global transformation at an unprecedented rate. Population growth, globalization and urbanization are all having a significant role in reshaping of society. The world population has risen from 1.7 billion at the beginning of the 20th century to its current figure of over 6 billion. The population projection indicates that it will reach 9 billion by 2050 (PRB 1999). A majority of the world's population lives under extreme poverty and as a consequence the gap between rich and poor has widened restricting progress in many developing countries (Weisbrot, 2002). It is expected that by 2015, nearly 3 billion inhabitants, mainly from the developing countries, are expected to face water stress (UN 2005) By 2030, population in developing countries is 84.7% of world's population, mainly in Asian regions and more than a half population in urban areas (UNPP 2004). The growth of urban sprawl coupled with a high level of water consumption per head has placed a great demand on urban water systems and the problem is compounded by declining growth in total water storage. The water is key to socio-economic development (Stockholm, 2003). The United Nations Environmental Program (UNEP) has stressed the importance of utilizing sound scientific knowledge; viz, better information cannot guarantee improved decision, but it is prerequisite for sound decision making. Decision making thus requires sound sustainability assessment to provide key and timely information (Millennium Ecosystem Assessment 2003). The principal of sustainable development, which are embedded in sustainability assessment, was first appeared in the 1972 Stockholm conference introduced by the international union for the conservation of nation (IUCN). The notion was formerly published in the world conservation strategy by same institution in 1980. It was the IUCN who first laid the foundation of well known three pillars for sustainability economy, environment and society. These principles were further promoted through international consensus by the world commission on Environment and Development (WCED) Brundtland Commission's report our common future in 1987, the 1992 Rio summit conducted by the United Nations Conference on Environment and Development and again at the world summits on sustainable development in 2002 and 2005.

The concept of sustainability is extended to urban water management as dictated in Agenda 21, with a clearly defined objective. To clarify our understanding of sustainable urban water services, we begin by defining the urban water system as one that includes collection, treatment and distribution of water; wastewater and storm water. It has been long recognized that there is an absence of a truly integrated sustainability assessment. The task of conducting sustainability assessment becomes difficult because the definition is vague and contains multiple dimensions. The common quantitative approach to measure sustainability has many limitations, both theoretically and practically due to the complexity and inherent fuzziness in the concept (Munda *et al.* 2005).

STATE OF KNOWLEDGE:

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. Shovini Dasgupta and Edwin, (2005) have categorized mandatory screening indicator and judgment indicator. Multi layer approach was used to incorporating these indicators. A normalization procedure has been adapted to work within the framework and to compare alternative across a range of indicator and different orders of data magnitude. Lai *et al.* (2008) have reviewed numbers of method for integrated sustainable urban water system. The four dominant approaches applied were cost benefit analysis, triple bottom line, integrated assessment and multi criteria analysis.

PROBLEM STATEMENT:

In the Surat City, due to population explosion & urbanization the stress on urban water sector is increasing. Water supply, sanitation provision and drainage – are vital in the quest to promote economic, environmental and social healthy development. The scientific approach to facilitate decision making in equity, efficiency and sustainability criteria is the main goal for performance evaluation of urban water sector. For efficient management of urban water sector Sustainability Index was found which indicates performance of urban water sector in different dimensions. 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.Km to 334 Sq.Km areas and corporation is not in position to cope up demand of city 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 some of the area 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 suggested in city development plan to lay down pipelines from Ukai dam to Surat (100 Km) to resolve the issues regarding quality and quantity of water supply? 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 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. 100% population is not covered with access to water supply and sewerage system (UNU-INWEH. 2005. Integrated assessment, 2009 and Halla *et al.,* 2007).

METHODOLOGY:

System boundary for urban water management system: System boundary is decided based on systematic consideration of the various dimension of water sector. 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.

Selection of indicator and criteria: Criteria selection involved the selection of appropriate criteria for the field of research, 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 structure of urban water management. The four dimensional view on sustainability was employed, and these four dimensions constituted the basic components for measure of sustainability of system.

Framework of questionnaire: Fig. 1 Format of selected criteria and indicator

DATA COLLECTION:

The data were collected related to the criteria and indicators which were selected for the study. This includes data related to social, economic, environmental and engineering factors and its sub factor like population served by water supply and waste water system, storm water, capital investment, economic expenditure and maintenance, water supply per capita per day, waste water generation per capita per day, area covered under pipe network, energy consumption, cost recovery, revenue collection from water supply, sewerage system, flood prone area etc. from Surat municipal corporation (SMC). The non-availability of data is one of the largest constraints to the success of most assessment study; where there were instance of indicators with incomplete data, either substitution or exclusion of variables was adopted.

ANALYSIS METHOD:

For Analysis the Simple additive weightage method is used. 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. The Normalization involved the conversion of these criteria and sub criteria to a comparable form which ensures commensurability of data. The criteria are compared with target value based on their unit of measurement.

The scores were normalized (converted) by the following formulas

$$X_{ij} = \frac{a_{ij}}{a_{jmax}} \text{---------------- (1)}$$

$$X_{ij} = \frac{a_{j\,min}}{a_{ij}} \text{---------------- (2)}$$

Where, aij = actual existing value for the sub-criteria

a_{jmax}, a_{jmin} = target 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 target value/ threshold value is taken as a standard value. The Weighting entailed the aggregation of criteria and sub-criteria. 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-criterion was added to get final Sustainability Index value (Table 1 and Fig 2-6).

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

Where, n = number of criteria,

wj = weight of the criterion, and xij = normalized score for the criterion.

RESULT:

The composite sustainability index is 0.396 and social, economical, environmental, & engineering indexes are 0.453, 0.659, 0.4351, and 0.031 respectively. The study reveals that, there is large gap between threshold value and existing situation in social criteria. The whole area of city is not covered with water supply and drainage network so it is essential to complete the network. At the same time per capita water consumption is higher than the basic need which represents that due to lack of infrastructure facility people are not getting water supply in some of the area. This happened due to extension of city limit in year 2003. 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 establishing infrastructure facilities which represents a drop in population & area coverage. The consumer with intermittent water supply tend to use more water than those with continuous supply because consumer store water, which they then throw away to replace with fresh supply each day. The Engineering criteria reveals that unaccounted for water results both from leakage and illegal connections, therefore to improve UWM system it is essential requirement to install metered connection in whole city area.. Along with that SMC has to think in the direction of asset management and for modeling of pipe failure or leakage prediction. This will minimize the water losses and that water can be utilized to serve more people. The environmental criteria shows that system can be improved by reusing water, recycling of nutrients, recharging and harvesting of rain water, installing storm water line in whole city area. 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. In economical criteria percentage recovery is almost 99% so it is also one of the factors which affect the economical index due to which economical index goes on increasing. In year of 2005-06 there is a sudden drop of 58.4 % of cost recovery due to tariff changes.

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REFERENCES:

De Crvalho, K J Carden and NP Armitage " Application of sustainability index for integrated urban water management in Southern African cities: Case study comparision – Maputo and Hermanus" Water SA. 35 (2): 12-19.

De Long BJ. 2001. The world's income distribution: turning the corner? http://econ161.berkeley.edu /TotW/World income_dist_html.

Guio, D.M. 2006. Torres "Sustainability indicators for assessment of urban water systems: The need for common ground", First SWITCH scientific meeting at university of Birmingham, U.K, 9 – 10 Jan 2006

Halla R. Sahely and Christopher A. Kennedy. 2007. "Water used model for environmental and economic sustainability indicators" *Journal of water resources planning and management*, ASCE/Dec/Pp. 550-559

Integrated assessment, 2009. Mainstreaming sustainability into policymaking UNEP A guidance manual, August 2009.

Lai, E. Lundie S and N.J.Ashbilt. 2008. "Review of multi- criteria decision aid for integrated sustainability assessment of urban water system" *Urban water journal*, 5 (4): 315-327.

Larson. K., 2001 Opening address of the 10th Stockholm Water Symposium. *Water Science Technology,* 43 (3), 11-12

Millennium Ecosystem Assessment. 2003. Ecosystem and human well-being: A framework for assessment. Island Press. Washington DC.

Munda G, 2005. Measuring sustainability: A multi-criterion framework. *Environment, Development and Sustainability,* 7,117-134.

Population reference Bureau (PRB). 1999. World population: More than just numbers. http://www.prb.org.

Shovini Dasgupta and Edwin K.L.Tam. 2005. "Indicators and framework for assessing sustainable infrastructure" *Canadian Journal of Civil engineering*, 32:30-44.

Stockholm. 2003. Urgent Action needed for water security. *Water science and technology*, 47(6): 5-7.

UN. 2005. The Millennium development goal report 2005. New York, United Nations 34.

UNU-INWEH. 2005. The four pillars approach to water sustainability. Available on website http:// www.inweh.unu.edu/inweh/4pillars.html

Weisbrot M, 2002. Economists in denial. Washington post http://www.commondreams.org /views02/0805-02.htm.

Fig. 1 Format of selected criteria and indicator

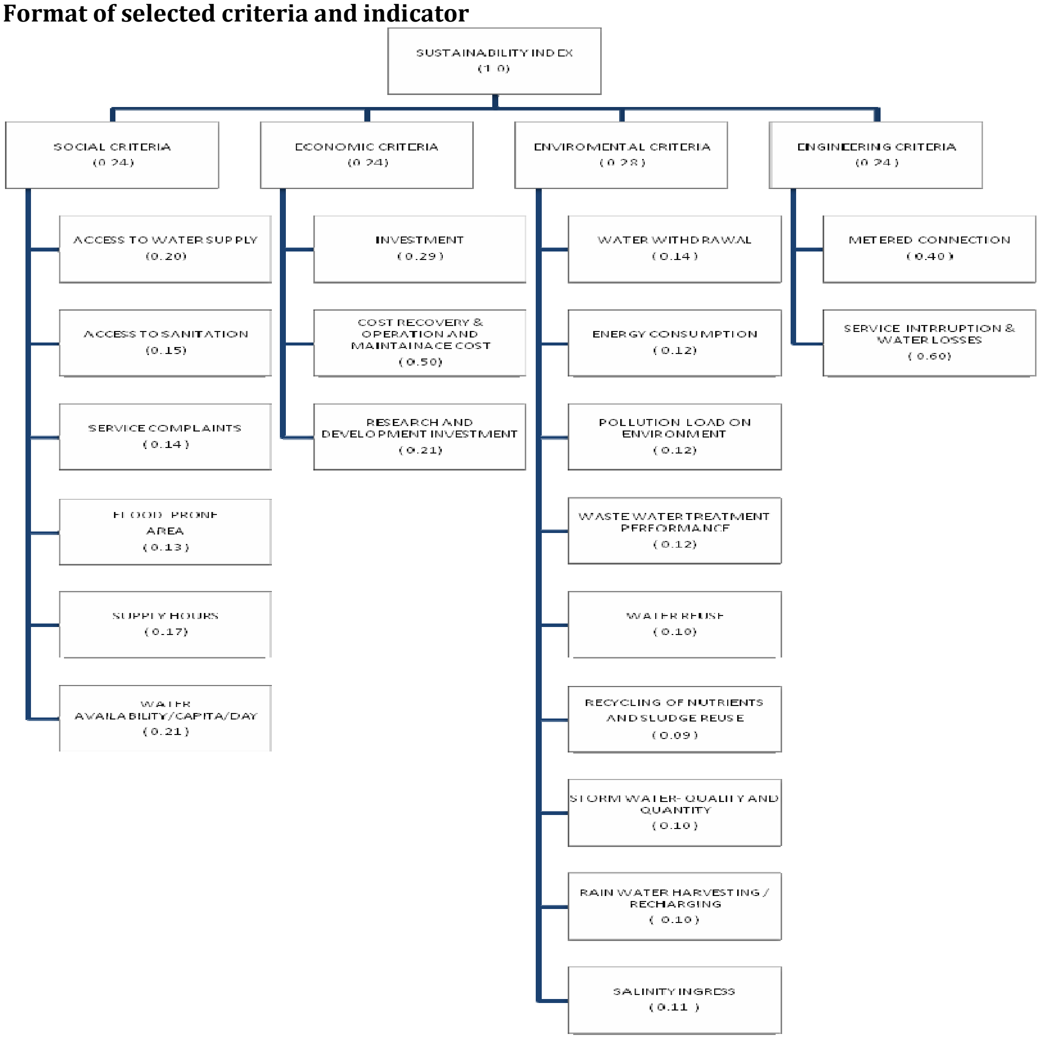

Fig.2 Index value for individual social criteria

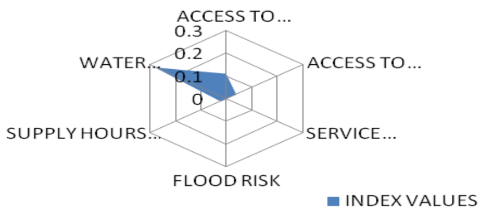

Fig.3 Index value for individual engineering criteria

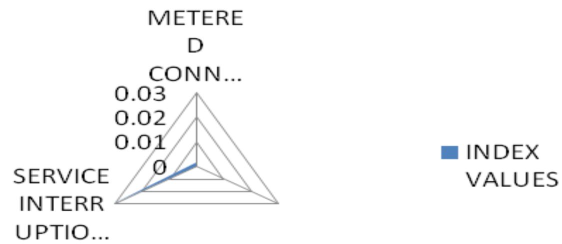

Fig. 4 Index value for individual economic criteria

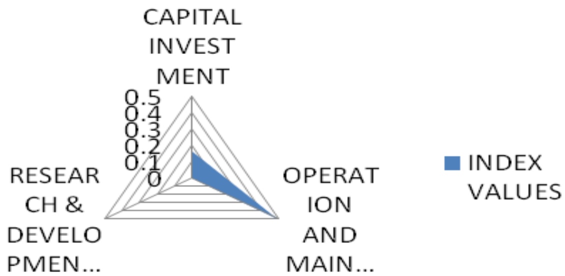

Fig. 5 Index value for individual environmental criteria

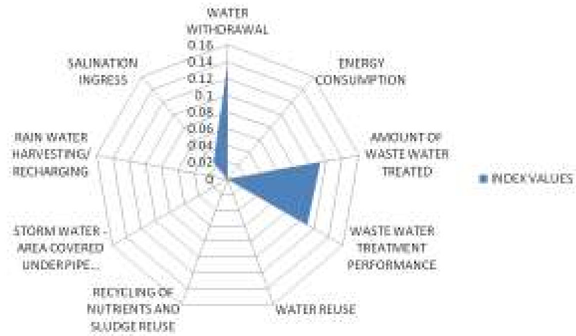

Fig. 6 Sustainability Index value for main criteria

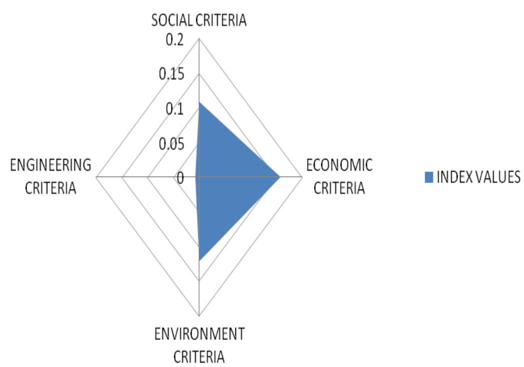

Table.1 representation of individual and combined index

CRITERIA	Individual Index	Weight age	Composite Index
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**

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