International Journal on Emerging Technologies **8**(1): 330-336(2017)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

The Water Sustainability Index (WSI_{OC}) for Office Complexes. Part 1: A Preliminary Framework

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(Received 28 December, 2016 accepted 18 January, 2017)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The availability of fresh water is crucial in India due to burgeoning urbanization. In this study, expert opinion based water management attributes in office complexes, and their relative importance is examined. Notably, the determination and pairwise comparison of the components are computed using Delphi approach and Analytical Hierarchal Process (AHP) is used to calculate the weights representing their relative importance. Finally, the water supply, consumption, and financial aspects are found as imperative components with 0.378, 0.422, and 0.20 relative weights respectively. The study offers a preliminary framework to develop water sustainability index for office buildings in Uttar Pradesh, India.

Keywords: Water; Office building; AHP; Delphi; Management; India.

I. INTRODUCTION

The demand of freshwater resources intake is intensifying worldwide; (Morrison *et al.* 2000). At present, as the complexity of urban water issues has increased, an extensive research has also performed to use the sustainability dimensions with these issues (Starkl & Brunner, 2004; Ashley *et al.,* 2004). The disproportionate use of finite resources is building stress for urban water systems. However, approximation of sustainability measures is critical to deal with chaotic natural resource problem i.e. water stress/scarcity (Loucks & Gladwell, 1999). The use of sustainability concepts ensures the responsible utilization of urban hydrological resources for human civilization. In this connection, Mays (2006) emphasized three prime realms i.e. scope, scale, and governance for Integrated Water Resource Management (IWRM). Additionally, Savenije & Van der Zaag (2002) interprets the importance of 'Dublin' statements on IWRM, stating that water is vital resource, which has to be used effectively. The rising population and complex urban systems have activated the water demand in the neighborhoods. Nowadays, the water sustainability is one of the important defining issues worldwide. Significantly, in last three decades groundwater scenario in the state of Uttar-Pradesh (referred as U.P. hereafter), India, has changed, which results into diverse array of environmental problems. Notably, major geographical area of the U.P. lies within the Gangetic river basin; therefore, this situation favors the presence of sufficient aquifers, but relentless human induced activities creating a negative pressure on these water reserves. Consequently, in the potential groundwater shallow dynamic zone a prominent disproportion between 'recharge' and 'discharge' has occurred, causing frequent depletion of aquifers richness and also deterioration in the water quality over the state. Particularly, in U.P. the increasing dependency on ground water resources can be easily estimated by the fact that the rate of ground water exploitation assessed as 54.31%, 69.00% to 72.16 % from the year 2000, 2004, to 2009 respectively. Similarly, there are 820 blocks in U.P. and in the year 2004, the total no. of stressed blocks were 138, out of which the no. of over- exploited, critical, semi-critical, and safe were 37, 13, 88, & 682 respectively.

Whereas, in the year 2011, the total no. of stressed blocks raised up to 261, with over- exploited 111, critical 68, semi-critical 82, and safe 559. Urban centers in U.P; ranging from metro cities to small satellite towns, prone to decrease in water resources and occurrence of disasters. The state of U.P. is facing the dual pressures of exceptionally inadequate water resource infrastructure and supply management. Exploring ways to improve urban water sustainability, which is a basic pillar of the present environmental scenario, and its complex extents in the provision of basic facilities, is the major step towards making urban center sustainable. Notably, the institutional and commercial buildings use a significant portion of the supplied drinking water. Presumably, it can be estimated that a single institutional building need hundreds of liters water including for drinking purpose or other uses. There is a noticeable difference in the water utilization pattern of the general household and in the large institutional building. The office buildings are not only one of the major contributors to resource exhaustion, they are also the most evident and enduring components of an organization's assurance to implement sustainability. Therefore, this study advocates the development and implementation of the concepts of urban water sustainability.

The sustainability is part of a prototype for decision making in urban water issues and multi criteria decision analysis (MCDM) is an exclusive technique used in water sustainability assessment (Lai, E. *et al.* 2008). Various researchers use MCDM methods to deal with water-related issues, for obtaining sustainable development schemes. Significantly, MCDM has been used as a foremost component of decision support systems (DSS) (Jaber and Mohsen, 2001; Hamalainen *et al.,* 2001; Qureshi and Harrison, 2001; Fassio *et al.,* 2005; Maia and Schumann, 2007; Makropoulos *et al.,* 2008). The MCDM has been used in diverse issues associated with aquatic resource management, including urban water issues (De Marchi *et al.,* 2000; Zarghami *et al.,* 2008), waste water treatment substitutions (Khalil *et al.,* 2005), irrigation development (Gupta *et al.,* 2000), river basin planning (Qin *et al.,* 2008), design of monitoring networks (Harmancioglu and Alpaslan, 1992), water allocation and reservoir operation (Srdjevic *et al.,* 2004), flood control, groundwater quality and management (Tkach and Simonovich, 1997; Pietersen, 2006;), and wetland management (Janssen *et al.,* 2005).

Notably, multitudinous research has been reviewed, which depicts that sustainable water management is possible through the application of indicator-based approach (Jakeman *et al;* 2005). Recent studies regarding development of Water Sustainability indices *e.g.,* Water Poverty Index (WPI) (Sullivan, 2002), Canadian Water Sustainability Index (CWSI) (Policy research initiative, 2007), Watershed Sustainability Index (WSI) and West Java Water Sustainability Index (WJWSI) (Juwana, 2012) put forward the very approach. Particularly, these indices are site-specific that limits their worldwide implementation. In this view, the present study offers a preliminary framework to develop water sustainability index for office buildings in the state of U.P.

II. METHODOLOGY

Due to the acuteness of water scarcity challenges in various regions of the country, as discussed above, there is a need to conserve this finite natural resource and to achieve water sustainability in buildings. Since, after the residential sector, the commercial (office complexes) are the second largest consumers of water, consuming at an average of approx. 20-25% water of the total consumption of a city (Chanan, *et al.* 2003; EPA Water Sense, 2009; Morton, 2011. Pieterse-Quirijns *et al.*, 2013), therefore assessing the efficient water consumption attributes in office complexes would be a significant step towards water sustainability. Notably, the previously mentioned attributes would be much suitable for a mid-level office complex where approximately 100 persons work, as these types of offices are large in numbers in this segment, and the application of the outcome of this research would be significant to produce major effects regarding communal water sustainability. In assessing the attributes there is a need to form consensus among the water experts opinions, therefore widely accepted Delphi technique has been used.

Using the existing indices, literature, and experts' opinion, a proposed framework (survey questionnaire) for the selection of the components, indicators, sub-indicators (decisive in the water consumption in office complexes) was prepared to make the consensus among the experts opinion. The questionnaire was circulated to the respondents in three rounds including their in depth interviews. The feedbacks in the form of suggestions & modifications received from the respondents after each round has been studied and analyzed. Where 67% (Two third opinions to form a consensus) of the respondents agreed or suggested corrections unanimously for the related parameters, modifications are incorporated in the framework accordingly.

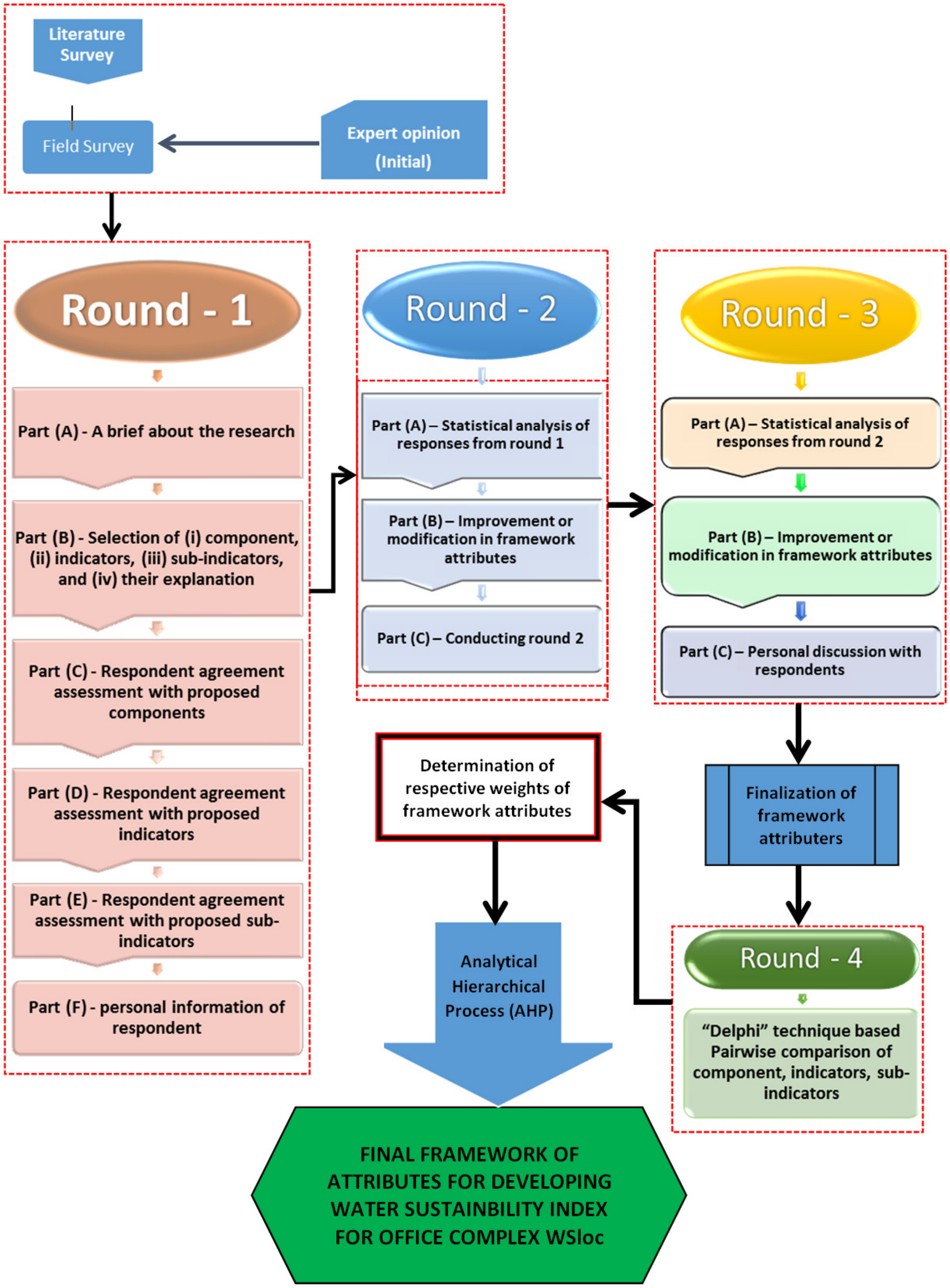

Fig.1. Showing the preliminary framework for selection of attributes.

After the execution of this round-3 the different attributes are finalized with a requirement to list their respective threshold values. To determine the same a survey questionnaire was prepared to collect the primary data from the office buildings of all the ‘A’ class cities of U.P. There are 13 cities divided in four zones (e.g., Awadh, Budelkhand, Eastern, and Western) of the state approximately covering entire U.P. state. Therefore, the primary data is collected from 26 office complexes (one Public and one Private each) of 13 cities of U.P. and the threshold values are determined based on it. These threshold values were inserted in the table of framework finalized in round-3 with their respective attributes to prepare the questionnaire for round-4. To assess the relative importance of the attributes, it is necessary to form a consensus among the opinions of the respondents regarding the pair wise comparison between the attributes. Hence, theround-4 was conducted and the feedbacks received were studied and analyzed by applying AHP technique as shown in Fig.1. The results obtained thus are the relative weights of the attributes, which represent the relative importance of each of them as mentioned in Table 1.

RESULT AND DISCUSSIONS

Based on literature, and expert opinions, adoption of Delphi technique to form a consensus among the opinions of the respondents to select the different attributes (components, indicators, sub-indicators) along with their pair wise comparisons, and therefore applying AHP technique, results for their respective mathematical values (Table 1), which can be considered as their weights.

Table 1: The final relative weights for the efficient water consumption attributes in office complexes.

Sl.	Components	Pair wise Comparison Weight (Principal Vector)Component WeightCW_i	Indicators (Sub components)	Sub- indicators	Pair wise Comparison Weight by (Principal Vector)Sub ind. Weight SIW_i	Threshold Unit	Threshold Max	Threshold Min	Data Availability
1.	Water Supply	0.378	External Source of water supply (Ground water through Bore well)	-----	0.112	%	100 [b]	40 [a]	Water supply norms./Data collected by surveys.
			Conservation	Adopting Water Savings Techniques	0.164	%	100 [a]	0.0 [b]	Water (rain + waste) qty. conversed is collected from surveys/case studies.
				Reuse	0.469	%	100[a]	0.0 [b]	
				Rainwater harvesting	0.255	%	100[a]	0.0 [b]	
2.	Water use (Consumption)	0.422	Water Demand	Toilets	0.061	Lt./cap/day	16.0 [b]	10.0[a]	Institutional standards/ norms and survey data from case studies.
				Pantry (Including Drinking)	0.040	Lt./cap/day	6.0[b]	4.0[a]	
				Air Cooling (Desert Coolers)	0.131	Lt./cap/day	25.0 [b]	10.0[a]	
				A.C. (Cooling towers)	0.243	Lt./ min./Ton	6.5	0.0	
				Maintenance (Floor Cleansing etc.	0.098	Lt./Sq.mt./day	0.40 [b]	0.20[a]	
				Landscape Irrigation	0.263	Lt./Sq. mt. area/day	10.0 [b]	2.4[a]	
				Water losses (leakages & Misuses)	0.164	%	13.0 [b]	8.0[a]	

Sl.	**Components**	**Pair wise Comparison Weight (Principal Vector)Component WeightCW_i**	**Indicators (Sub components)**	**Sub- indicators**	**Pair wise Comparison Weight by (Principal Vector)Sub ind. Weight SIW_i**	**Threshold**			**Data Availability**
						Unit	**Max**	**Min**	
3.	Financial Aspect	0.20	Annual budget for water consumption	Price to pay to municipality for supply water (metered Usage)	Not to be considered for Sub- Index value	Rs.	Yearly fixed charges from local body *		
				Electricity charges for pumping etc.	Not to be considered for Sub- Index value	Rs.	No separate record is found.*		
			Annual maint. for infrastructure	Motors supply pipelines& plumbing items.	0.430	Rs./Sqmt./year	250.0[b]	110.0[a]	Running cost occurred yearly as per off. Records. / Data collected from surveys.
				S.T.P./Waste water treatment plant	0.253	Rs./Year	1.0 lac	0.0	
			Action for awareness to the employees	Activities for promotion of awareness for water savings	0.317	Rs./Year	1.0[a] Lac	0.0[b] Lac	Cost occurred yearly as per off. records. / Data collected from surveys.

Note: [a]Preferable, [b]not preferable, [c]> 0 preferable, < 0 not preferable
*Since most of the sample buildings are using municipal water supply facility partially/ fully, therefore the management of the office pays a fixed amount to the municipal body every year. Presently, in U.P., there is no arrangement of having water meters in the premises, to record the water consumption per month/per year. Thus, the municipal body has fixed the per year water charges rate for the buildings as per their rules.

The activity wise threshold values, for water consumption in different activities in the office complexes is somewhat similar to the values recorded during the literature study, which indicates the significance of the field data values and collection methods adopted for primary data collection. The consumption of water in different activities in an office complex, a comparative analysis can be summarized as under:

Table 2: Comparative analysis of calculated weights and average water consumption in different activities in office building.

S.N.	**Sub- Indicator**	**Calculated weight**	**Weight in %**	**Average water consumption (%) in different activities**
1	Cooling	0.374	37.4	33.0
	(a) A.C. (cooling towers)	0.243		
	(b) Air cooling (Desert coolers)	0.131		
2	Landscape irrigation	0.263	26.3	26.0
3	Water losses (leakages and misuses)	0.164	16.4	18.0
4	Others	0.199	19.9	23.0
	Maintenance of the office complex	0.098		
	Toilets	0.061		
	Kitchen/Pantry	0.040		

Note: The average water consumption (%) in difference activities taken from Chanan, *et al.* 2003; Blint, 2009; EPA Water Sense, 2009.

In Table 2, the respective weights (calculated as in %) of the sub-indicators have been listed from Table1. The average water consumption (%) in different activities in office complexes, showed in Table 2 is taken from secondary data.

Comparing the cooling, landscape irrigation, water losses and others (maintenance of the office complex, toilets, kitchen / pantry) sub-indicators' weight (%) 37.4, 26.3, 16.4 and 19.9 respectively with their consumption values (%) of 33.0, 26.0, 18.0 and 23.0 respectively, it has been found that there is a marginal difference between both of their values. Notably, the approximation equivalence of both values (sub-indicator % weight and % average consumption of the activity) proves that the results of present study are significant and well acceptable to assess the consumption efficiency of water in an office complex. Notably, the frame work's component 'Water use' and its sub-indicator 'Cooling' [A.C. (Cooling Towers) including 'Air cooling' (Desert coolers)] are scoring maximum values 0.422 and 0.374 (Table 1) respectively among their groups, which indicates that they are having higher importance over other components / sub-indicators of the group.

Therefore, it is well inferred, that the higher weight of the attribute denotes the higher importance in comparison to others, as calculated on the basis of opinions presented by the experts. Additionally, the poor performance of the assessed attribute, which has gained a high importance in weighting process, would definitely produce adverse effects leading to water unsustainability in office complexes. Finally, the proposed framework can be implemented worldwide, if selective geographical properties are accounted for.

CONCLUSION

Implementing the water-efficient tools and practices that lessen consumption holds prodigious potential for users in office complexes. For achieving better water management results in office complexes, the following recommendations based on the research study should be adopted:

1. The major water consuming activities scoring higher weights i.e. cooling, landscape irrigation and water losses (leakages & misuses) should be dealt priority wise.
2. In office complexes, justified cooling loads and landscape irrigation systems should be designed intelligently, as these activities are of higher importance and consuming approx. 60% of water of the total consumption (Table 2).
3. Similarly, water losses (leakages & misuse) should be closely observed for achieving water efficiency.
4. Yearly water audit should be performed so as to monitor the efficient consumption of water in office complexes.

Reduction in energy would lower down the water demand for different energy related fields considerably. The attributes' weights obtained from the present study may have some uncertainty factors so far, as it is based on the knowledge and personal opinion of the regional experts. Moreover, the findings of this study would play a key role in achieving water sustainability, and underpinning a prototype for the development of indices. The present research reveals, as less consumption of water in office complexes would help in lowering down the energy consumption and production in the society.

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