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INTEGRATED EVALUATION FOR SUSTAINABILITY AND CLIMATE COMPATIBILITY OF WASTEWATER MANAGEMENT IN ECO-CITIES: CASE STUDY OF KIGAMBONI, TANZANIA

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ABSTRACT

The government of Tanzania developed a new master plan for the eco-city at Kigamboni area in Dar es Salaam. The new eco-city among other thing will provide an integrated wastewater system in line with climate change development initiatives. The master plan recommended the centralized Membrane Baffled Reactor (MBR) technology for the wastewater treatment in the city. However, sustainability issues of wastewater were not addressed in the master plan. Although the MBR technology is one of the best technology, its selection for the proposed city of Kigamboni city was made without prior evaluation for its sustainability. There is no detailed technical, social, environmental and economical analysis for the selected technology. The main objective of this study was to review the eco-city master plan with a view of assessing its sustainability and its capacity to integrate in the existing terrain. In order to evaluate the master plan, a set of criteria and indicators were developed based on social, economic and environmental dimensions. The set criteria were analyzed using the Analytical Hierarchy Process (AHP) to compare and rank different alternatives (decentralized or biological technology, Hybrid and centralized MBR) of wastewater technologies that are suitable for Kigamboni eco-city. Sustainability analysis based on AHP showed 38.87%, 36.28 and 24.86% for decentralized or biological technology, Hybrid and centralized MBR, respectively. MBR has scored low compare to other technologies such as Anaerobic Baffled Reactors (ABRs) and Constructed Wetlands (CWs). The study also found that public participation on selection of wastewater treatment technology was inadequate and the planning process involved few top political and influential leaders.

Keywords: Climate proofing; Green infrastructure; Integrated wastewater treatment technology; Wetland.

1. INTRODUCTION

African larger cities experience an increase of urbanizations because of population growth, rural–urban migration e.t.c., and the growth resulted into social, environmental and economic devastations. Tanzania like other African countries is experiencing urbanization problems, urbanization has risen from 5.7 million in 1967 to 29.1 million in 2012 with the annual urban population growth rate of 5.2% (NBS, 2012). The urban growth rate in Dar es Salaam city is higher than capacity of the responsible authorities to provide planned and serviced plots for shelter and urban development activities. An estimated 80% of Dar es Salaam's population lives in poor, unplanned settlements.

These areas are associated with inadequate basic service levels including lack of water and wastewater services, poor health and environmental conditions. To offset the urbanization problems for the Dar es Salaam city, the government is planning for more new satellite cities at Luguruni, Kawe and Tegeta. In 2010, the government of Tanzania developed a new master plan of the eco-city at Kigamboni area in Dar es Salaam region that will host about (500,000 peoples). Reasons for new city were many, the main one being to provide solutions that will mitigate urbanization problems of Dar es Salaam and its environment. The planned city is designed to qualify the modern and sustainable cities standards. The term "eco-city" is interchangeably expressed as "sustainable city," "low-carbon city," "eco-community," "green city" (van Dijk, 2011; Zhou, 2014). In recent years, eco–city as a sustainable urban model has gained increasing popularity and been discussed with researcher, policy makers, Politician's and other decision makers. Eco city concept have progressively translated into concrete projects, strategies, and policies, mainstreaming urban sustainability and being replicated across the world (Bardici, 2014). Dimensions of an eco-city based on urban environmental issues includes: Energy, Solid waste, transport, Pollution, Water and wastewater, Sanitation, Climate change, Housing, Sustainability and integrated approach (van Dijk, 2011; Wong & Yuen, 2011). Sustainability of wastewater treatment in the eco cities have been an important issue because of it is role in protecting human health and environment. The move toward sustainable wastewater management is supported by many researchers, governments, and International organizations such as the World Bank, UNHABITAT e.t.c. All these institutions, are promoting for sustainable solution to wastewater management in developing countries (Libralato *et al*. 2012). Various researchers, tried to question if combination of centralized and decentralized treatment can merge the advantages of both system (Muga and Mihelcic, 2008). Selection of an appropriate wastewater technology and infrastructure is a daunting challenge and continue to be a priority issues in developing countries. Impacts of selecting a non-sustainable technology extends beyond its immediate operational vicinity and affect also the future generation (Molinos-Senante *et al*. 2014).

To attain the climate compatible wastewater management, Membrane Baffled Reactor (MBR) and other mechanical centralized mechanical based WasteWater Treatment (WWT) technologies are not recommended. This is because; in some places many such WWT plants have been neglected due to failure to provide necessary operation and maintenance by the water and sanitations authorities. As an example, Flores *et al*. 2009 show that, in Mexico more than 90% of the centralized system were not functional and the cost for investment and operations for such system was higher. The new WWT plants were not compatible with local context and constrains, like affordability and funding, technical expertise and political commitment to run such plants e.t.c.

Thinking about appropriate wastewater treatment technologies for Kigamboni eco-city, is important aspect to ensure its sustainability. Its therefore selected management technology should not only provide the best performance at low cost, but it should also be sustainable in terms of meeting the local needs, socio-cultural acceptability, technological and institutional feasibility, economical affordability, and environmental acceptability (Singhirunnusorn, 2009).

This study aims to review the eco-city plan with a view of assessing the sustainability, climate change compatibility and integrated aspects of wastewater management in the proposed eco-city of Kigamboni, in Dar es Salaam, Tanzania. The motive behind was to analyze the performance of different wastewater treatment technologies such as centralized MBR, decentralized and integrated system with intention of finding out appropriate climate change compatible technology for this eco-city.

2. METHODOLOGY AND APPROACH

2.1. Documentary Reviews

Different documents related with wastewater management in Dar es Salaam and reports that were made during the planning of Kigamboni new city, were reviewed. Detailed review was done on the master plan of Kigamboni new city, Technical reports on wastewater design, feasibility report, funding strategies of the wastewater management in the new city, water reuse and water harvest.

2.2. Surveys and investigation

The sustainability assessment was based on comparing different indicators and criteria against the three models of waste water management. The three wastewater model evaluate include the, the decentralized system (Biological based WWT technologies), Centralized (Advanced MBR system proposed for Kigamboni) and hybrid or combined system. Seven criteria were used including the affordability, land requirement, reliability, simplicity, efficiency, Social or public acceptability, environmental impacts and sustainability (continuity) and from each criterion several indicators were developed.

The questionnaires with list of criteria and indicators were given to different experts in wastewater management. Respondents included academician, private companies, and local and central government officials. The design of questionnaire, were made in such that, AHP technique could be simply applied. AHP process was done by, comparing importance of different criteria and indicators against the different approach of wastewater management. The respondents has to rate the intensity of importance for each system. The rating was based on a scale of 1, 3,5,7 and 9 as developed by Saaty in 1977 (Mohammad, 2015).

2.3. Interviews and consultative meeting with stakeholders

In total 20 experts were interviewed, in fact, the number of interviewee was less than the planned number (35) this was because of few people who are conversant and experienced in wastewater management planning. Those who responded are the experts representing academicians, consultants and plant designers (private sector), and government officials, who have actively involved in wastewater management in Tanzania. Meanwhile, face-to-face interview were made

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with five ward leaders of Vijibweni, Mjimwema, Kigamboni, Somangira wards. These are leaders of current people living in Kigamboni. These are the leader of current estimated 100,000 people living in Kigamboni.

2.4. Theoretical data analysis and processing

2.4.1. AHP analysis: Indicator/Criteria's

The data analysis was done based on AHP approach. The weight of each pair-wise comparison between the three alternatives was calculated. To calculate relative weights of elements in each pair-wise comparison matrix, the Eigen value method was employed. To calculate Eigen vector, total of each column of the matrix was established, and then each element of the matrix was divided with the total of its column, after that it was normalized by the relative weight. To normalize Eigen vector, row elements was summed then divided by number of elements in the same row, in other words taking the average value. The Eigen vector explains relative weights among the objects that were compared. The Eigen value (λ_{max}) can be obtained by summing of products between each element of Eigen vector multiplied by totals of columns of the reciprocal matrix. Every Eigen value is scaled to total up to get priorities. The results were presented in the histogram for easy comparison. Figure 1 shows the procedure for AHP analysis for integrated wastewater management.

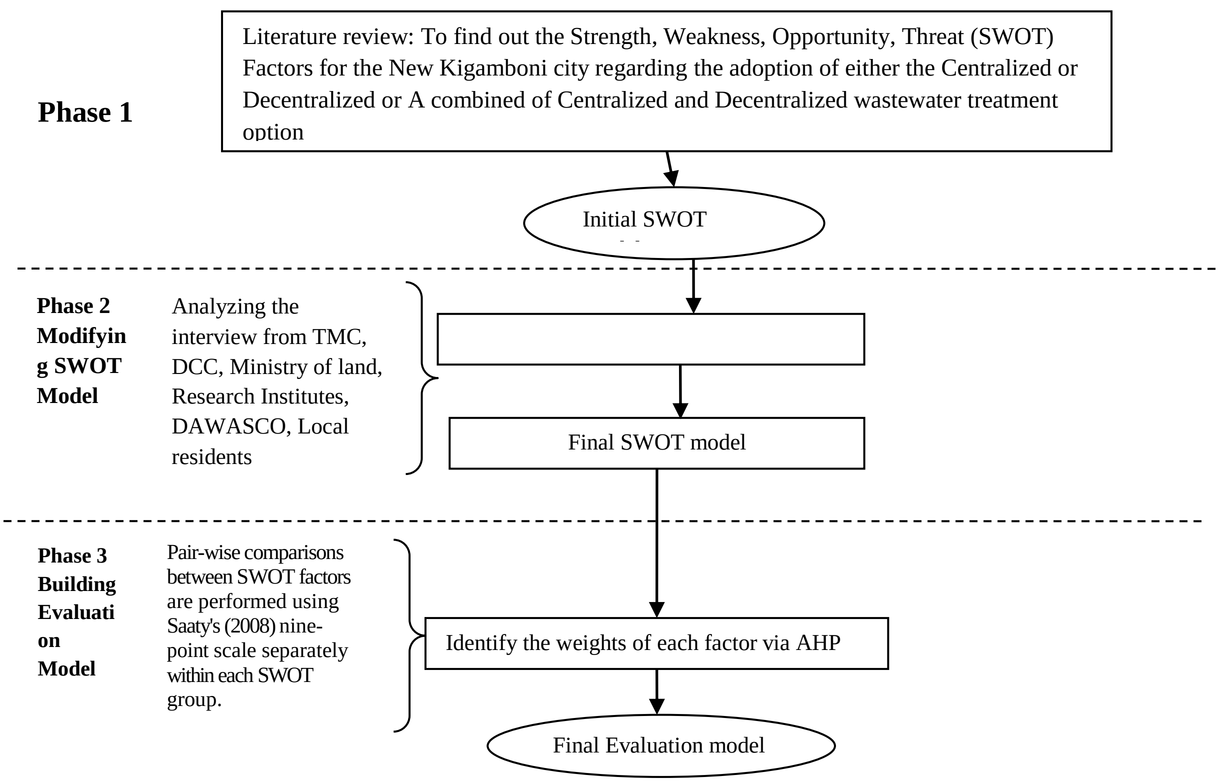

Figure 1: Phases for evaluating different strategies

2.4.2. SWOT & AHP analysis: SWOT factors

Having a good technology can be one thing, other thing is the having proper administrative strategy to manage the technology of your choice. For this reason, a SWOT analysis was done. The SWOT factors was also analysed though AHP process in the same way of the criteria analysed in the section 2.4.1. Figure 1 indicted the process used for combining SWOT and AHP process comparing different factors and strategies in wastewater technology selection.

3. RESULTS AND DISCUSSION

3.1. Sustainability of individual approach to MBR, Decentralized and integrated based on AHP analysis

3.1.1 Sustainability result related to centralized MBR Alternative

According to the master plan, the suggested technology for this eco-city is the Centralized MBR technology. Table 1 presents the results of ranking by the experts including academician, contractors, and government officials (grouped in eight categories). The survey shows that all criteria are more than strongly important for the sustainability of the MBR in this particular eco-city, the average score ranges between 6.4 to 8.4. This means that, any of the factors above will have large impact on the sustainability MBR technology, positive or negative. The analytical Hierarchy Process was done to find out, the extent of impact among criteria.

Table 1: Response of Experts on Sustainably of the Centralized MBR System

	Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Average
Economic	Affordability.	7	5	9	9	3	3	8	7	6.4
	Land Requirement	9	5	9	3	9	9	7	9	7.5
Environment	Sustainability (continuity)	9	5	9	3	9	5	9	9	7.3
	System reliability	9	5	9	9	9	9	8	9	8.4
	System	8	9	9	3	3	5	7	7	6.4

	Simplicity									
	System Efficiency	9	3	9	9	3	9	7	9	7.3
Social	Social or public acceptability	9	9	7	3	9	3	7	3	6.1

Table 2 shows that, ranked sustainability criteria of MBR technology in the new eco-city of Kigamboni. Although all criteria are strongly important, but they differ in their intensity and influence on decision making. The criteria in the table are arranged in the order of their importance

Table 2: Normalized, Weighted and Ranked Matrix of Pair-Wise Comparison among the Criteria

Criteria	Affordability	Land requirement	Sustainability	Reliability	Simplicity	Efficiency	Social acceptance	Percent (%)	Rank
Social/public acceptance	0.163	0.163	0.163	0.163	0.163	0.163	0.163	16.3	1st
Affordability	0.155	0.155	0.155	0.155	0.155	0.155	0.155	15.5	2nd
Simplicity	0.155	0.155	0.155	0.155	0.155	0.155	0.155	15.5	2nd
Efficiency	0.138	0.138	0.138	0.138	0.138	0.138	0.138	13.8	3rd
Sustainability/continuity	0.137	0.137	0.137	0.137	0.137	0.137	0.137	13.7	4th
Land requirement	0.133	0.133	0.133	0.133	0.133	0.133	0.133	13.3	5th
System Reliability	0.118	0.118	0.118	0.118	0.118	0.118	0.118	11.8	6th

Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	100

Public/ social acceptance: Sustainability of MBR in this new eco-city will mostly depend on how people accept or are against with the proposed system. According to the interview with five community leaders in Kigamboni area, MBR technology is positively recommended and accepted by most of the communities who are currently living in the Kigamboni area. This is because the MBR technology will be operating from underground. It expected that MBR will produce less odour and noise. The main problems which could rise from underground operation are the ground water pollution. The ground water is only dependable source of drinking water in the new Kigamboni city, precaution measures need to be taken to any activity that can affect the groundwater in this new city.

Affordability: Key issues related to economic sustainability includes, construction cost, land cost, operational cost, energy cost, maintenance cost, Personnel and other administration cost. Experts consulted through this study believed that, initial investment for the MBR technology is thought to be high but the technologies are of more benefit because it meets the effluent standard for an eco-city. Sustainability of MBR in this city is depending how the funding of the technology is planned. The reliability of the MBR technology is mainly depending on the consistent maintenance of its operating machineries. In Tanzania and other developing countries, the wastewater subsector is given low priority in terms of budgeting purposes, if this will be the case for this city, MBR performance will be ruined.

Simplicity MBR technology: In order for be sustainable, the MBR technology will need to be simplified interim of plant construction, system installation and start-up, Operation and maintenance requirement. The MBR is supposed to design in such a way that, only minimum level of expertise be required to opera it. How, in Tanzania this MBR Technology is very new, there no similar plant or technology like MBR. So, the construction activities will depend on the expertise from abroad. On the other hand, most of the materials for construction are not available in the country, so will also be imported. However, according to the wastewater planning report for this city; the MBR will need few people during its operation because of its parts will be automated.

Efficiency of MBR technology: The MBR as wastewater technology is one of the best technology for removal of the BOD, Suspended Solids, Total Nitrogen, Total Phosphorus, pathogens. However, the efficiency is much dependable on the performance of the other criteria mentioned above. Literature has shown a good performance of the MBR.

Continuity and environmental Sustainability aspects: The MBR technology will not be sustainable if does not provide room for resource recovery, reuse of by-product (biogas), reuse the treated wastewater, recycling of organic matter or fertilizer, appropriate sludge management e.t.c. Another key point for enhancing sustainability of this eco-city is that, MBR technology is supposed to provide some options to accommodate future modification in case of increased wastewater treatment demand due to population increase. About 50% of the people interviewed said that, it is possible to expand the MBR plant to accommodate additional space for treating extra waters; however, this adjustment is associated with cost aspects.

Land requirement: The sustainability of the MBR technology for this city is highly depending on the availability of land. However, based on the New city master plan reviewed, land reserved for MBR plant is 11.8ha. Based on (Singhirunnusorn, 2009) on MBR require more less land compared to the natural treatment technologies.

System reliability: Sustainability of MBR technology and its effectiveness for Kigamboni eco-city is highly depending on technical aspects of the treatment plant. The treatment plant will need to have minimum mechanical failure and breakdown. Since MBR, operate in centralized mode of wastewater management, any fault or mechanical failure of MBR will result into environmental problems for entire city. Wastewater will be untreated and released on environment; this will cause annoyance to the city dwellers, also can lead of health problems. Furthermore, experts commended that centralized MBR system will be effective removal of toxic contamination (pesticides, heavy metals e.t.c.); provided that plant is well managed, with minimum frequency of plant shutdowns because of hardware or process problems.

3.1.2 Sustainability result related to centralized decentralized wastewater management alternative

Decentralized waste management systems were also evaluated by using same criteria as indicated in Table 3. This section presents the results of ranking by the experts including academician, contractors, and government officials (grouped in eight categories).

Table 3: Response of Experts on Sustainably of DEWAT Alternative

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Average
Affordability	3	1	1	5	9	5	1	3	3.5
Land Requirement	5	3	1	7	9	7	1	3	4.3
Sustainability	5	9	1	3	3	7	1	3	4
System reliability	6	9	1	9	3	9	1	1	4.9
System Simplicity	7	5	1	3	9	9	1	1	4.6

System Efficiency	5	9	1	5	9	9	1	3	5.3
Social acceptance	5	3	1	9	3	9	1	9	4.9

The survey shows that all criteria in a range of 3.5 to 5.5, (moderate-strong Important) qualification. This means that the factors above will have relatively minimum impact (positive or negative) on the sustainability wastewater management in this eco-city when decentralized /biological approach is opted. The analytical Hierarchy Process was done to find out, extent of impact among criteria. A pair-wise matrix was formulated and the all criteria were analyzed in the matrix as shown in Table 4.

Table 4: Pair-Wise Comparison among the Criteria

	Criteria	Affordability	Land requirement	Sustainability	Reliability	Simplicity	Efficiency	Social
Economic	Affordability	1.000	1.250	1.143	1.393	1.321	1.500	1.393
	Land requirement	0.800	1.000	0.914	1.114	1.057	1.200	1.114
Environment	Sustainability	0.875	1.094	1.000	1.219	1.156	1.313	1.219
	Reliability	0.718	0.897	0.821	1.000	0.949	1.077	1.000
	Simplicity	0.757	0.946	0.865	1.054	1.000	1.135	1.054
	Efficiency	0.667	0.833	0.762	0.929	0.881	1.000	0.929
	Social	0.718	0.897	0.821	1.000	0.949	1.077	1.000
Social	Total	5.534	6.918	6.325	7.709	7.313	8.301	7.709

Table 4 shows the paired values from each criterion. However, according to Mohammad, 2015 the results of Table 4 cannot be used for rating and weighing of the criteria because the matrix is not normal and consistent. Therefore, the result of Table 4 was then normalized, weighed and ranked to allow easy comparison. Table 5 presents the normalized, weighted and ranked matrix of pair-wise comparison among the criteria and it shows ranked sustainability criteria of decentralized option of wastewater treatment system.

Table 5: Normalized, Weighted and Ranked Matrix of Pair-Wise Comparison among the Criteria

Criteria	Affordability	Land requirement	Sustainability	Reliability	Simplicity	Efficiency	Social acceptance	Percent (%)	Rank
System Reliability	0.181	0.181	0.181	0.181	0.181	0.181	0.181	18.1	1st
Social/public acceptance	0.158	0.158	0.158	0.158	0.158	0.158	0.158	15.8	2nd
Sustainability/continuity	0.145	0.145	0.145	0.145	0.145	0.145	0.145	14.5	3rd
Affordability	0.137	0.137	0.137	0.137	0.137	0.137	0.137	13.7	4th
Land requirement	0.130	0.130	0.130	0.130	0.130	0.130	0.130	13	5th
Efficiency	0.130	0.130	0.130	0.130	0.130	0.130	0.130	13	5th
Simplicity	0.120	0.120	0.120	0.120	0.120	0.120	0.120	12	6th
Total	1	1	1	1	1	1	1	100	

System reliability: For most of DEWATs systems the risks of mechanical failure during operation is minimum; most of these are not operate mechanically. The treatment approach in DEWATS system is naturally. The impacts can only be noted when there is an overflow, overflow be due to blockages of the system or the heavy rainfall. Since DEWATs are decentralized, in the case of overflow or blockage the problems will happens to few units.

Public/social acceptance: The main risks to the sustainability DEWAT system in this eco-city is the one related to odour from wastewater plant. Although, odour is common to all kind of wastewater treatment plants, the preferable wastewater treatment technology for eco-city is supposed to produce low level of door nuisance. The biological treatment plants such as Waste stabilization ponds, ABR, Constructed wetland will need close monitoring and control to maintain the accepted level of odour nuisance. Public may also reject the DEWAT system if it will attract most mosquitoes and other insects. According to the interview with five community leaders in Kigamboni area, DEWAST system be not positively recommended by most of the communities who are currently living in the Kigamboni area. This is because of the bad experience from exist similar treatment plant.

Continuity and environmental Sustainability aspects: Continuity and sustainability for this case are viewed into two angles for Kigamboni eco-city. One the DEWAT system is supposed to be flexible in term of expansion and upgrading when need arise. Based on the response from interviewed experts, the constructed wetland system, The Waste stabilization ponds and the ABR, are relatively easy to upgrade if there is available land for adding more series of pond. The second aspects of continuity of DEWATs in this eco-city are the provision of reuse opportunities. To make wastewater sustainable based on DEWATS, it is expected that, more resource recovery, reuse of by-product (biogas), reuse the treated wastewater, recycling of organic matter or fertilizer, appropriate sludge management will be better.

Affordability: This was ranked as the first issue of decentralized wastewater system for the Kigamboni eco-city. High cost was assumed for this option because of the amount of water needed for treated. The volumes of wastewater estimated to be generated in Kigamboni is 138,000m3/day (138 million litters per day). With decentralized wastewater treatment alternative, several wastewater treatment units will be needed to be constructed in different part of the city like from residential areas, industrial areas, public areas e.t.c. Given this consideration, it entails that, building and managing many small on-site treatment system is assumed to be expensive than one large central system. More cost will rise from construction, land, operational, maintenance, Personnel and other administration cost. According to the interviews with experts, the only advantage of the decentralized wastewater for this eco-city is that, different treatment units can be built phases and based on demand; this cannot be done with MBR. The new city will be built in phases from 2015 to 2030. Because of that, the need for instantaneous demand for investment can be reduced unlike in centralized option.

Land requirement: Sustainability of wastewater treatment for Kigamboni eco-city by using DEWAT is highly depends on availability of land. No common biological technologies fit for the 11.8ha located for wastewater treatment in this eco-city. The minimum land required is 33 ha in case the ABR is opted, the CWS is estimated to require 51.5ha and the maximum land required is 79.2ha in the case when WSP is opted. The sustainability of the MBR technology for this city is highly depending on the availability of land. However, based on the New city master plan reviewed, land reserved for MBR plant is 11.8ha. Based on (Singhirunnusorn, 2009*)* on MBR require less land compared to the natural treatment technologies.

Efficiency of DEWATs systems: The DEWATs systems have been proved in tropical countries to perform better for removal of the BOD, Suspended Solids, Total Nitrogen, Total Phosphorus, pathogens.

Simplicity of DEWAT technology: Most DEWATs systems are not complex facilities; they have minimum operational and maintenance requirement. However, for the sustainability of this eco-city, well-trained personnel form the city waste and wastewater management authority will be required to manage these plants.

3.1.3 Sustainability result related to centralized combined/hybrid option

The Hybrid system; this is the combined system in which two or more technologies or management systems are combined, e.g. centralized and decentralized or the Waste Stabilization Ponds (WSPs) and Constructed Wetlands (CWs) combined e.t.c. Hybrid waste management approach was also evaluated by using same criteria as indicated in Table 6.

Table 6: Response of Experts on Sustainably of the Centralized Hybrid System

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Average
1. Affordability.	5	7	1	7	5	7	1	5	4.6
2.Land Requirement	1	5	1	7	9	9	1	5	4.8
3. Sustainability (continuity)	1	7	1	3	7	7	1	7	4.4
4. System reliability	5	5	1	9	7	9	1	7	5.4
5. System Simplicity	7	7	1	3	5	9	1	5	4.8
6.System Efficiency	5	7	1	5	5	9	1	7	4.9
7.Social or public acceptability	7	5	1	5	5	9	1	7	4.9

The survey shows that all criteria in a range of 4.4 to 5.4 (moderate-strong Important) qualification. This means that the factors above will have relatively minimum impact (positive or negative) on the sustainability wastewater management in this eco-city in case hybrid system is opted. The analytical Hierarchy Process was done to find out, the extent of impact among the criteria. A pair-wise matrix was formulated and criteria were analyzed in the matrix as shown in Table 7. It shows the paired values from each criterion, however, according to Mohammad, 2015 the results of Table 7 cannot be used for rating and weight criteria because the matrix is not normal and consistent. Therefore, the result of Table 7 was then normalized, weighed and ranked to allow easy comparison. Table 8 presents the normalized, weighted and ranked matrix of pair-wise comparison among the criteria.

Table 7: Pair-Wise Comparison among the Criteria

	Criteria	Affordability	Land requirement	Sustainability	Reliability	Simplicity	Efficiency	Social
Economic	Affordability	1.000	1.054	0.946	1.162	1.027	1.054	1.054
	Land requirement	0.949	1.000	0.897	1.103	0.974	1.000	1.000
Environment	Sustainability	1.057	1.114	1.000	1.229	1.086	1.114	1.114
	Reliability	0.860	0.907	0.814	1.000	0.884	0.907	0.907
	Simplicity	0.974	1.026	0.921	1.132	1.000	1.026	1.026
	Efficiency	0.949	1.000	0.897	1.103	0.974	1.000	1.000
Social	Social	0.949	1.000	0.897	1.103	0.974	1.000	1.000
	Total	6.737	7.102	6.373	7.830	6.920	7.102	7.102

Table 8: Normalized, Weighted and Ranked Matrix of Pair-Wise Comparison among the Criteria

Criteria	Affordability	Land requirement	Sustainability	Reliability	Simplicity	Efficiency	Social acceptance	Percent (%)	Rank
Social/public acceptance	0.157	0.157	0.157	0.157	0.157	0.157	0.157	15.7	1st
System Reliability	0.148	0.148	0.148	0.148	0.148	0.148	0.148	14.8	2nd
Affordability	0.145	0.145	0.145	0.145	0.145	0.145	0.145	14.5	3rd
Sustainability/continuity	0.141	0.141	0.141	0.141	0.141	0.141	0.141	14.1	4th
Simplicity	0.141	0.141	0.141	0.141	0.141	0.141	0.141	14.1	4th

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Efficiency	0.141	0.141	0.141	0.141	0.141	0.141	0.141	14.1	4th
Land requirement	0.128	0.128	0.128	0.128	0.128	0.128	0.128	12.8	5th
Total	1	1	1	1	1	1	1	100	

Continuity and environmental Sustainability aspects: The sustainability of wastewater management can be highly affected (positively or negatively) based on performance of this criterion. The important indicator for success of hybrid system, that, the treatment system has to provide more opportunity for resource recovery, reuse of by-product (biogas), reuse the treated wastewater, recycling of organic matter or fertilizer. The hybrid system is also supposed provide appropriate solution for sludge management. Combined system can be more efficiency when centralized system treats some specific kind of wastewater. For example, Municipal wastewater from (Public facilities, commercial area, households) and the decentralized system treat the industrial wastewater e.t.c. Upgrading the hybrid system to accommodate future need might be of challenge, especially when two technologies are combined together in centralized model to improve treatment efficiency such as combining MBR and ABR, or WSP, ABR and CWs e.t.c. Since the combined system will be very specific to this particular situation further, medication might be difficult. On other hand, the cost of expansion and land requirement of hybrid system will be relatively high compared to independent system.

Affordability: Although the size of wastewater treatment plant could smaller in a combined system, the cost will depend on kinds of technologies involved in the treatment system. For example, if biological treatment technologies are combined such as WSP and CWS or ABR and CWS more cost will be for land and human resources. However, if the combination includes MBR and CWs or any other biological system, the cost might be high because of the construction cost of MBR and more land for the CWS.

Simplicity of hybrid technology: strong important issue for sustainability of the wastewater management through combined technologies. It is important that the hybrid system be simplified in term of plant construction, system installation and start-up, Operation and maintenance to allow the local technicians and engineers to run it without any problem. If the hybrid will not use local available resources including human resource manage it, then it will not be sustainable in this new eco-city.

Land requirement, Public/social acceptance and Efficiency of hybrid systems: Land issues is important when considering the hybrid system this is especially when the centralized system and decentralized are adopted to run together in this eco-city. As indicted in the previous section, most DEWAT system required huge land, for Kigamboni case the least amount of land required is 33ha. If the decision is made to combine two or more Biological based treatment system, more land will be required for that option. Given the scarcity of land in Kigamboni, only 11.8ha is reserved for the wastewater treatment, this call for technologies that will require less land without compromising the quality of treated effluent. On the other hand, the Hybrid system needs to be efficiency in term of removal of BOD, Suspended Solids, Total Nitrogen, Total Phosphorus, and pathogen. The treated effluent needs to comply with required standards. Furthermore, the Hybrid subsystem will need to be accepted by the residence of the eco-city, in this case the hybrid system is expected to cause minimal nuisance to people like noise, insects, door e.t.c. Otherwise, public might reject hybrid system if it will attract most mosquitoes and other insects and other nuisances.

System reliability: Reliability of hybrid system is a strong import factor as well sustainability of wastewater management in this eco-city. The risks of failure for hybrid system are minimized with a fact that, two or more technologies used for wastewater treatment in the city. In the case where the centralized MBR is used to other with biological based system, the risks associated with mechanical failure of the treatment plant is more possible for MBR plant more than biological systems. When one system is malfunction and does not treat wastewater to a required standard the other system in combination can do job properly. In case, the combination is among biological system, the risks of blockages and overflow is very minimal. The hybrid systems are expected to be effective in term of treating toxic contamination (pesticides, heavy metals e.t.c.) because of multiple technologies that could be used.

3.2 Integrated Analysis of Three Alternatives Options (Centralized, Decentralized and Combined/Hybrid) in the Proposed Kigamboni Eco-City Based on AHP Approach

3.2.1 Environmental Sustainability of the of the proposed wastewater treatment plant for Kigamboni city

About environmental sustainability, issues of sludge management, resource recovery and reuse of treated wastewater was analyzed. The planned eco-city lacks a sludge management plan. It is a requirement, an eco-city to have suitable sludge management plans and strategies to minimize the environmental impacts form sludge disposal. A new city master plan was reviewed to learn strategies set for the sludge management. However, it was found that, the new city has no set plans and strategies for sludge management for this eco-city. Wastewater issues was regarded as low priority issues in city planning, so planning was partially done, excluding some key aspects in the life cycle of wastewater management such as sludge management. Lack of sludge management strategies is an indication that, a business as usual option, to let sludge either be dumped in solid waste dumping site or somewhere else. The effect for this option is including that, increase of ground water pollution from dumped sludge, keeping in mind that, ground water is main source of water supply for this city. For best sludge management, it can be suggested that; government have to consider introducing recycling system for sludge with a target to extract organic matter and nutrient for agriculture and for soil conditioning. Other possible solution is to produce electricity energy from methane gas produced from sludge. This study made a comparison for easiness of sludge management between proposed MBR technologies operating as centralized WasteWater Management (WWM), other decentralized biological based technologies and hybrid based of WWM. The comparison was based on the response of the 20 experts of WWM; their response was analyzed through the AHP analysis. The result shows that, decentralized wastewater management, common biological based technologies and hybrid solution, has weighted 38.87% and 36.28 respectively on issue of provision of easy sludge control. The advanced MBR technology weighted (24.86%) on providing easy solution for sludge management. Reasons for favoring biological decentralized technology could be attributed with a reality that, more experts responded to these questionnaires are not more familiar with MBR technology. In Tanzania, leading technologies for wastewater treatment includes, waste stabilization pond, Constructed wetland and the basic septic tanks and pit.

Apart from sludge management, reuse of the treated wastewater is an important viewpoint of any eco-city. The planned eco-city has developed strategies and infrastructures for re-use of treated wastewater. It is a requirement that, an eco-city to promote re-use of treated wastewater to minimize the environmental impacts from excessive use of water resources. According to the wastewater re-use plan developed for this city, expected volume of wastewater of treated is 138,000m^3/day. Amount of treated wastewater calculated for re-use purpose is 62,500m^3/day (45%). The remaining 75,900m^3/day (55%) will be discharged into the sea. From the (45%) of treated water set for reuse, 17800m^3/day(28%) will be supplied to industrial areas to supplement water demand for industrial activities, while 44700m^3/day (72%) will be supplied for irrigation of city parks and landscape. A pipe network plan for supply of treated wastewater is already designed in the plan. Reasons for proposing a reuse of 45% of treated wastewater was not clearly stated from reviewed documents and interview. However; high cost of building another water supply network pipe to supply 100% (138,000m^3/day) of treated wastewater, could be one of the reason. Since the wastewater will be centralized, the pipe network for supplying treated wastewater for re-use will be longer. Based on existing waster demand for Dar es Salaam region, it is important to plan usage of large percent of treated wastewater in the proposed eco-city, instead of the 45% proposed. Dare es Salaam region, in which Kigamboni is within, is facing shortage of water supply to its resident; the city wide water supply coverage is less than 50% and is couples with water rationing whereby waste is supplied to people twice a week for 8 up to 12 hrs (EWURA 2016; NAOT 2012). With addition of new city of Kigamboni, water demand in Dar es Salaam will increase. Kigamboni on its own has no large intake of natural resources (rivers, reservoirs, lakes, e.t.c.) which can be used as source of water supply. The only dependable source of water for this new city is the ground water abstraction. Water authorities in Tanzania have approved abstraction of ground water at Kimbiji well field. This groundwater source, have a capacity to supply domestic water at (Qmax. =260,000litres/day) and other groundwater source is discovered at Mpera well field (Qmax=130,000litres/day) in Kigamboni area. The water demand for the new city, when is completed will be 181,500m^3/day (EWURA, 2016; NAOT, 2012). The main inherent risks are that, new city is in coastal area, extensive groundwater abstraction is not recommended because of the danger of city submergence, also intensive use of ground water for coastal cities could lead to sea saltwater intrusion in ground water due to fall of water table (Divakaran *et al*. 2013). International best practices need that, a sustainable city to use less than 10% groundwater for domestic supply. A comparison for easiness of providing to re-use of treated wastewater at an effective cost and wide coverage was made. The proposed MBR technologies based on centralized WWM, was compared with decentralized biological based technologies and the hybrid based management of WWM. The comparison was based on the response of the 20 experts of WWM; their response was analyzed through the AHP analysis. The result of analysis showing the percentage of weight among the three model of treatment show that, 38.87% 36.28 and 24.86% for decimalized or biological or natural technology, Hybrid and centralized MBR respectively. Reasons for favoring biological decentralized technology could be attributed its ability to produce similar effluent quality to MBR, at low cost. Meanwhile, this study suggest, rainwater harvesting plan to be introduced for this eco-city, as it could be used as one of sources and alternative for minimizing water demand management in new Eco city.

Examples of wastewater management in the other eco-cities

In Taijin eco-city, the water are collected and conveyed through the pipes installed underground to minimize evaporation before transported to the main reservoir. The emphasis is to ensure closing of water resource cycle in the city; a part of using rain water, other water comes from the treated wastewater. Water demand management is promoted, the recycled water from the water plant hence provides an another source of water, reducing overall demand on fresh water and alleviating water scarcity challenges in North China. The water conservation and reuse are promoted by implementing water conservation techniques, reclamation and/or recycling of domestic and industrial wastewater, rainwater harvesting, and desalination. Non-traditional water sources such as recycling and desalination is also used and it is projected to reach 50% (Keppel 2010). While in Dongtan eco-city, the city ambitions is to reach a zero waste policy, the plan is to collect 100% of the waste and wastewater and use 90% of waste to produce energy. Other produce of waste will be the generation of fertilizers, as the city goes for the organic farms. There no plan for building the landfill in this city because all waste is managed in one way or other are re-used. The city ambition also is to reduce its water consumption by 43% and water discharge by 88%. A dual piping system was designed to both water for potable use and reclaimed water for toilet flushing and farm irrigation. On the other hand, the city uses green rooftops as other means of meeting the city’s water demand through collecting and storing rainwater. All Sewage is designed to be treated in biological treatment systems (Cheng and Hu, 2010). The Caofedian eco-city, the key milestone set by the city is that, come year 2020 the rate of sewage disposal and the rate of recycling of water, and the reuse of treated water to reach 100%. The key milestone set by the city is that, come year 2020 the rate of sewage disposal and the rate of recycling of water, and the reuse of treated water to reach 100%. There are two wastewater treatment plant developed that are centralized, one hold the capacity of 85,000 m^3 of wastewater per day. This first plant covers 16 hectares in north part of the city. The second plant also have a design capacity of treating maximum of 85,000m^3 of wastewater per day is situated in the 10 hectares area in the northeast of the city. To ensure the rainwater is properly collected in community areas, special channels with filtration were installed to collect rainwater and do basic treatment like filtration. The water are then treated in the small treatment plants at community level and stored in the small pond that is linked to the nearby water landscape. This water is fully utilized for flushing, irrigation, carwash e.t.c. Their houses are designed, for grey and black water separation at household. The grey water is collected in the same system of rainwater and other one is taken to the central sewage treatment plant through gravity pipeline. The water which is treated and reused is monitored to ensure it meet the international standards, like World Health Organization, on the safe use of wastewater. Meanwhile the black water which was taken to the centralized wastewater treatment plant and treated the sludge from it is used to generate the biogas. The treated water itself is taken to the wetland for farther polishing and then is supplied back for reuse.

Besides issues of reuse of treated wastewater for new eco-city, energy demand by the wastewater treatment plant was also evaluated as an important environmental concern. Eco-city ought to strive for a wastewater technology with low requirement of energy use, as one of means to minimize its carbon footprint. About 50 - 60% of the cost of running of wastewater plant falls on energy. Greenhouse gas generation is one of the environmental problems that could be associated with excessive energy use by the wastewater treatment plant. The MBR is estimated to consume 0.42kw/m^3 treated (Chatterjee, 2013), this could amount of 57960KW/day for treating 138,000m^3 of wastewater estimated for this new city. Wastewater plant is supposed to treat wastewater for prevent water pollution while on other hand, because of the use of energy it can contribute to air pollution arising from generated from electricity production. In Tanzania, there are occasional incidences where electricity supply is intermittent; at some point it may end up to rationing. When such incidence happens, wastewater treatment plant will be affect as well, and most likely wastewater will be left untreated and discharged in the sea. Since, wastewater management is not one of priority sector for budgeting purposes in developing countries, minimum precautionary measure will be set to provide alternative energy e.g from generators. This and other reasons, make stakeholders to still think of a more natural technology with better performance to be feasible for this city.

Other than energy requirement issues, consistence of performance was another factors subjected for evaluation. The required wastewater treatment plant must be able maintain good performance over long-term of its operation with minimum frequency of shutdowns due to hardware or process problems. A comparison for the consistence performance was made between the proposed MBR technologies based on centralized WWM, decentralized biological based technologies and the hybrid based management of WWM. The comparison was based on the response of the 20 experts of WWM; their response was analyzed through the AHP analysis and the results are summarized on Figure 2. The hybrid option, in which different technologies mechanical and biological or different biological treatment technologies are combined show high consistence performance over long period of time in operations. Hybrid will withstand high flow of waste water, with minimum problems of plant shutdown because of mechanical issues and is more stable on weather variation. This is because hybrid options it will integrate one or more different technology with various management approach. The mechanical based technology like the proposed MBR will have low capacity of withstanding the high wastewater flow overlong period of operation.

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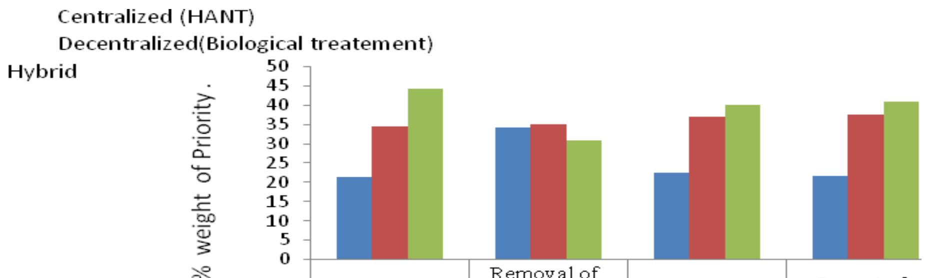

	Responds to high flow wastewater	Removal of toxic contamination (pesticides, heavy metals etc.)	High BOD or low BOD loading	Impact of performance due to weather variation
Centralized (HANT)	21.3	34.1	22.6	21.5
Decentralized(Biological treatement)	34.5	35	37.1	37.5
Hybrid	44.2	30.9	40.2	41

Figure 2: Indicators for consistence performance over long and short period of operation

To strengthen sustainability of the wastewater treatment systems in developing countries, choice of technology must consider the simplicity of technology. Simplicity of technology should be considered about its construction, operation and maintenance. Also, minimal expertise should be required for installation of different parts. Several indicators for the simplicity criteria were developed. Those indicators was subjected to a pair-wise comparison between the proposed MBR technologies based on centralized WWM, the other decentralized biological based technologies and the hybrid based management of WWM. Figures 3-4 give the result summary, in which biological based treatment technology score low complexity in construction, operational and maintenance requirement when compared to MBR. It is inarguably that, MBR in Tanzanian context is an advanced technology for municipal wastewater treatment. The local technicians and engineers will face complexities in term of plant system installation and system start up. This tell that, lack of local human resources will encourage demand of foreign expertise at some point manage this WWTP. Other challenges for operation of MBR plant is availability of the spare parts, in case of mechanical fault or replacement of the membrane, these spares will need to be ordered from abroad. This study, consider that, Appropriate technology is that, which effectively make use of available local resources for its operation. Although construction of this plant has not started, there are factors that, can limit progress of construction of this WWTP. For example, condition of the site, there are some land dispute yet to be settled completely, funding, availability of suitable companies (contractors), process type e.t.c. (Singhirunnusorn, 2009). Literature shows, that an MBR plant require more time of construction up to two years (Singhirunnusorn, 2009).

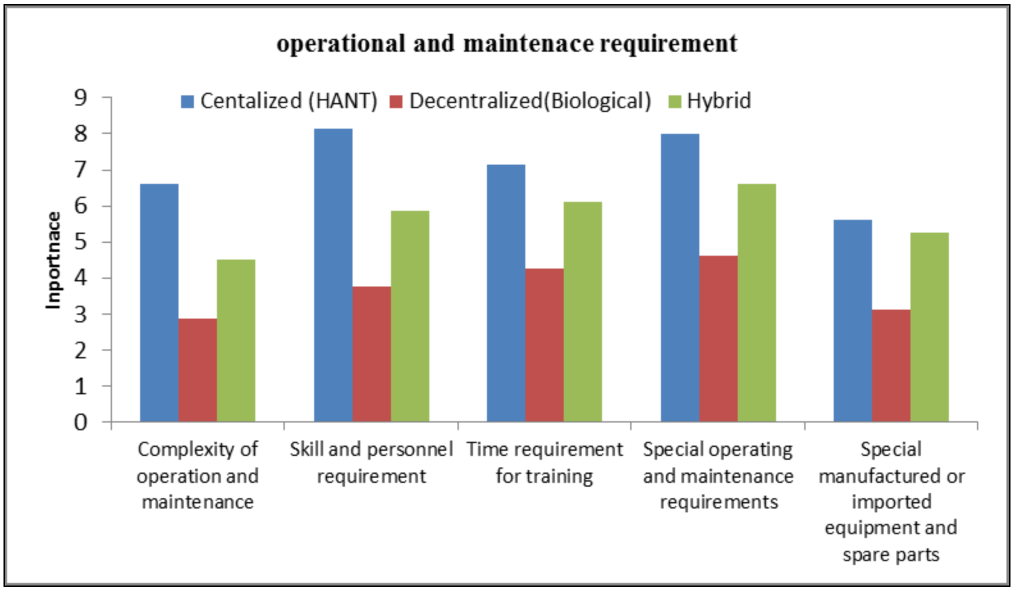

Figure 3: Operational and Maintenance requirement.

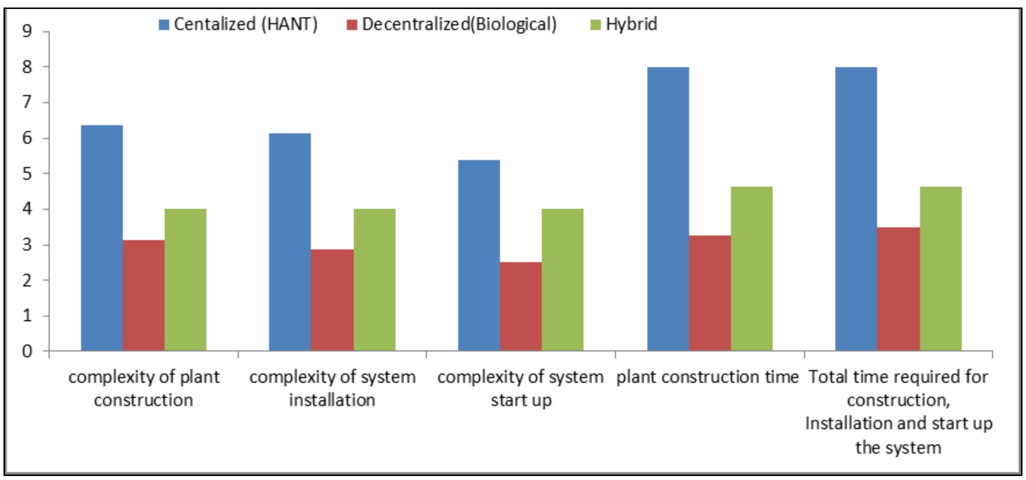

Figure 4: Ease of plant construction, system installation and start-up.

3.2.2 Economical Sustainability of the of the proposed wastewater treatment plant for Kigamboni city

For economic sustainability, the following factors were assessed; Affordability of the technology, land requirement, construction, operation and maintenance cost, human resources (labour) and materials. Land requirement was evaluated as part of economic sustainability indicators for wastewater treatment for this particular eco-city. The choice of wastewater treatment technology depends also on availability of land. While considering a certain technology it is important to consider size of treatment plant, type and process of treatment system (Singhirunnusorn, 2009). A new city master plan was reviewed to find out the land allocated for wastewater treatment. It was found that, two plots or sites are reserved for wastewater treatment plant, both sites sum up to 118,000 m^2 (11.8ha), the map showing wastewater infrastructure plan for this new city is shown in Figure 5. A comparison for the land requirement was made between proposed MBR technologies, biological based technologies (waste stabilization pond, constructed wetland, and anaerobic sludge digester) and the hybrid. The comparison was based on the response of the 20 experts of WWM; their response was analyzed through the AHP analysis. The result of analysis showing the percentage of weight among the three model of treatment show that, 40.4% , 36% and 23% for decimalized or biological technology, Hybrid and centralized MBR respectively. High requirement of land to decentralized wastewater based technology, common biological based technologies. The MBR technology has showed to need less land. The reasons stipulated in literature, show that, MBR plant like any other centralized mechanical wastewater treatment plant, have short hydraulic retention time (3-8) hrs. Therefore, it has long hydraulic loading and Solid retention time. Other system has much lower hydraulic retention time up to seven days so it will need more land (Muga and Mihelcic, 2008; Singhirunnusorn, 2009). Mostly, land requirement for natural treatment can reach ten times size of the land as compare with the mechanical treatment (Muga and Mihelcic, 2008). Table 9 provide some typical theoretical land size required for different wastewater treatment processes that can be required to treat the 138000m^3/day volume of wastewater. Small land requirement for the MBR is more favorable because of it will cause minimum environmental impacts during construction and operation. Also, it will support to conservation of existing wetland ecosystem and natural environment. Although biological technology requirement huge amount of land, opting it could lead to provision of more open green spaces e.g. use of constructed wetland, resident can use for amenity purpose and provides habitat for birds and other wild animals. According to eco-city master plan about 12.2 percent of the total land is reserved as an open space and eco- parks. About 600.6ha, is reserved for Open spaces including wetland , marsh and other important ecosystem and about 196.2 ha is reserved for Eco Parks, all these open spaces contribute to 12.2% of the total land of the eco-city which is 6494.4ha. Figure 5 is the map showing reserves open spaces and parks, most of these are located in places that are presently covered with swamps and wetland. If the government can go for the biological based treatment, there is possibility of integrating the land reserved for eco services, green area and existing swamps areas with wastewater treatment. A typical example of this approach is from the Putrajaya eco-city, this was the first Malaysian first known eco city. The city was, developed as a Federal Government Administrative Centre (Ho, 2006). Putrajaya eco-city consists of government departments, commercial offices, residential premises and recreational parks as well as water bodies. Green space occupy 30% of the land area of the city (Shutes, 2001). The city is designed to use eco-friendly wastewater treatment technologies; it adopted an integrated environmental management approach whereby the land use, sewerage, drainage, irrigation, lake and environment are linked. The manmade lake was built in this city; an important component of the lake is the 23 constructed wetlands were built for wastewater

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treatment in the 197ha land. Table 10 show the design features of this wetland and its related performance, final treated wastewater from the wetland is discharged into the lake. These 23 wetlands differ in term so of macrophyte planted, size, capacity, treatment load e.t.c. Managers of Putrajaya wetlands aim for many goals classified under three categories which are environmental, educational and recreational (Noor *et al*. 2011). In this city, serious water monitoring is done to ensure that, wetland effluent meet WHO standards before are released in the lake by which this lake is used for recreation purposes including swimming. So for Kigamboni eco-city, there is a possibility of making artificial lakes for storing treated wastewater and use it to enhance eco-tourism because the reserved land and climatic condition is more or less equal to that of Putrajaya. It is more convincing that; treated wastewater can be discharged to one of eco parks instead of discarding it in sea as it is in the current proposal.

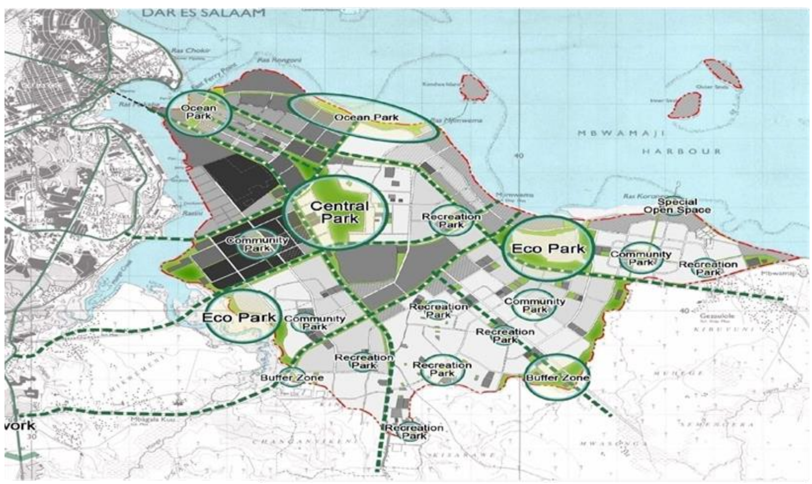

Figure 5: Map of Kigamboni showing open spaces and parks.

Table 9: Theoretical Land Requirement for different Technologies

Wastewater water treatment system	Description	Amount land required	References
MBR(HANT)	This is the land located for the wastewater treatment plant in Kigamboni according to the master plan. However the actual land will be less than this.	6ha	(URT, 2010)
Waste	Land requirement was estimated based	79.2 ha	(Kihila *et al*. 2014;

stabilization ponds	on the WSP constructed in Tanzania and other places.		Mara, 2013)
Constructed Wetland System	A study was done by an IHE/AIT masters student aiming was designing for constructed wetland. Land required for wetland based treatment in Dar es Salaam was calculated based on 1500 inhabitant. Result showed that for 1500 inhabitant the land required for wetland is 591.74m^2. After comparing for different CWs constructed in Tanzania, it is estimated that Kigamboni will need about 51.8ha	51.8ha	(Balthazar, 2014; Kihila *et al*. 2014; Kimwaga, *et al* 2013)
Decentralized Wastewater Treatment(DEWAT) based on Anaerobic Baffled Reactors(ABR)	Estimation of calculations was based on the existing DEWAT; sludge treatment plant based in Kigamboni.	33ha	Design, Constriction and project financing report for Kigamboni DEWAT (BORDA Tanzania, 2012)

Table 10: Design Parameters for Putrajaya Constructed Wetland for Wastewater Treatment

Design aspect	Values	Effluent quality
Area of wetland(ha)	14-54.1	
Volume(million litre)	130-1200	TSS=10.25mg/l -137.5 mg/l
Depth(m)	0.3-1.0 m, this is for macrophytes zone and 1.0 to 3.0m for open water zone	BOD=0.38 -1.65mg/l TP=84.32%
Mean residence time(days)	8.2 – 31.4 days	DO=0.78mg/l– 13.25mg/l
Hydraulic Loading rate(cm/day)	6.2 -15.1	

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Besides land requirement, another economic standpoint considered is the construct cost. The commended wastewater technology for an eco-city in developing countries need to exhibit competitive construction cost. Minimum cost is preferred for construction cost, operational and maintenance cost, energy cost, personnel and administration cost. Construction cost also depends on the capacity of the plant (m^3/day); level of treatment required; contents of wastewater e.g. domestic wastewater can be different from industrial wastewater (Singhirunnusorn, 2009). A final report of city master plan was reviewed to find the answer, how does cost aspect of wastewater treatment plant was featured in deciding wastewater technology for this eco-city. It was found that, cost related issue was not presented in this report as part criteria, although the report was the final one, issues of water was not scrutinized in detail. The report presented was based mainly on technical aspect for evaluation. Despite the fact that, it was not confirmed through interview and from reviewed document, it is possible that, government will further conduct a cost-benefit analysis of the selected technology before embarking on construction of the proposed technology. This study was not able to find out reasons for choosing or rather approving the plan without thorough analysis of cost. In developing countries, sometime choice of technology is influenced by political ambition; marketing strategy of companies from developed countries to sell their modern technology in developing countries e.t.c. The results from the survey conducted confirm that, MBR is more costly in term of construction cost compared with other technologies which are operated decentralized model and integrated. However, considering the economy of scale, decentralized system might incur high construction cost as well. To treat 138,000m^3/day using biological methods, will require construction several treatment units in different sites. Therefore, total sum of cost could be possibly more or equal to the MBR plant. The theoretical cost was established for each of the model. The basis was to get the construction cost of the plant which can treat same amount of wastewater per day (138,00m^3/day). Table 11, show the theoretical construction cost for wastewater treatment.

Table 11: Theoretical Construction Cost for different Technologies.

Wastewater water treatment system	Description	Amount millions(USD)	References
MBR (HANT)	Capital Cost Land cost ($\$m^{-3}$) =14 Building and Construction ($\$m^{-3}$)=540 Membrane ($\$m^{-3}$) =420 Total ($\$m^{-3}$) = 974	 134	Yoon *et al.* (2004)

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	Based on this, for the Kigamboni estimated with 138,000 m^{-3}) construction cost is 134millions		
Waste Stabilization Ponds	The cost for WSP and other technology is not uniform; it depends on the year and location, a country where the WSP was constructed. Normally labour and materials and other cost differ. Cited literature show that for WSP in USA the cost is estimated to 5.7 million for population more than 250,000. Since Kigmboni is estimated to cost about 500,000 people by 2030, this cost can also be adopted as an indication cost for WSP	5.7millions	(Singhirunnusorn, 2009; Butler *et al*. 2015; Mara 2013)
Constructed Wetland System	The cost for constructed wetland in Tanzania is estimated to be 60.2125m^{-2}. This includes the cost for site assessment, planning, designing, supervision, construction materials, labour charges, substrates or aggregates, macrophytes plants.	$6.0 million USD	(Kimwaga *et al*. 2013; Balthazar, 2014).
Decentralized Wastewater Treatment(DEWAT) based on Anaerobic Baffled Reactors(ABR)	UN-Habitat estimated cost for construction of ABR for developing counties to be $80/p.e. This could result for Kigamboni estimated	$40million	(Singh *et al*. 2009; UN-HABITAT, 2008)

Other than construction cost, operation requirement also need to be minimum. For Tanzania in particular, technology should also demand less expertise for its installation and operation. Comparing to mechanical based treatment technologies, natural process like WSP, wetland, ABR has less O&M demand by 55-70% (Singhirunnusorn, 2009). The theoretical operation and maintenance cost is shown in the table 12. Although some of the biological technology have low O&M cost, if are not operated and maintained properly, the resulting problems could lead to intense social-economic and environment problems. For, example, wetland based plant could experience problems of blockage and flooding/overland flow (Kimwaga *et al*. 2013). Other common problems of CW are the seepage of wastewater through wall or leakage. During rainfall some wetland experiences the storm water runoff. Blockage occurs due to introduction of solid waste in a wetland system.

Table 12: Theoretical Operational and Maintenance (O&M) cost for different technologies.

Wastewater water treatment system	Description	Annual O&M millions(USD)	References
MBR (HANT)	O&M Cost Chemical ($\$m^{-3}$)=0.00005 Membrane replacement ($\$m^{-3}$)=0.61 Energy ($\$m^{-3}$)=0.11 Sludge disposal ($\$m^{-3}$)=0.0022 Labour Total ($\$m^{-3}$)==0.273 Based on this, for the Kigamboni estimated with 138,000 m^{-3}) O&M cost is $37674	$14	(Yoon *et al*. 2004)
Waste Stabilization Ponds	The following equation was used to estimate the O&M of WSP. This equation was also used for similarly study done in Bangkok. Co &m =0.0178+4.08x10-6*F. 0.0178 + 4.08x10-6 * 138,000m^3/day	0.58 million	(Singhirunnusorn, 2009)
Constructed Wetland System(CWS)	From literature, the O&M cost estimate for CWS is estimated to less than $1500/ha/year. This makes new eco-city to cost about $78,000/year	0.078 million	(Kadlec, 1995)

Decentralized Wastewater Treatment(DEWAT) based on Anaerobic Baffled Reactors(ABR)	\$20m^3/day.	World Bank

For effective operations of wastewater treatment, availability of staff with relevant expertise is also considered in economic sustainability of wastewater treatment. The number of staffing required per plant is proportional to size of the plant, for example (Muga and Mihelcic, 2008). It require an average of 4 people to run a WWP with capacity of 3800m^3/day and average of 8 and 18 people for plant with capacity between (4,200-18,900) m^3/day and between (18,900- 37,900) m3/day respectively. WWTP with capacity above 378500m3/day requires least 315 staff (Muga and Mihelcic, 2008). The designed centralized plant for proposed Kigamboni eco-city will operate at 138,000 m^3/day of which will require between 51-130 total staff. Although biological based decentralized wastewater does not require more expertise to run the treatment plant but will require many staff in total because of spatial distribution of those treatments. On other hand, training requirement is necessary, for the operators to handle the wastewater plants properly. Dar es salaam Water Supply Company (DAWASCO) is the public authority that manages the daily wastewater activities in the city (EWURA, 2016). According to the interview made with wastewater department, the company if facing a challenge of engineers and technician's familiar with wastewater treatment technologies. In the country there a few engineers with academic knowledge to sophisticated technology, though they lack field practices as main existing technology in the country includes waste stabilization ponds, constructed wetland, anaerobic treatment e.t.c. so, level of education and understating of the treatment technology is important in determining type of wastewater treatment plant local people can operate. Lack of trained staff will lead to uniformed operation and management and as a result it affects the performance of the MBR plant, even if the MBR will be well designed and constructed.

3.2.3 Societal Sustainability of the of the proposed wastewater treatment plant for Kigamboni city

More public participation is required on every aspect of decision making process of the eco-city project, to reach the intended sustainability level. Document review and Interviews was done to determine public and stakeholder involvement level, in sanitation and wastewater management planning. According (Hakiardhi 2012; URT 2010), It was noted that, stakeholders was not effectively involved in decision making process related to selection of wastewater technology for this city. Decision making was mostly made at the top management of Ministry of Water and Ministry of land. The same finding was observed by (Flynn *et al.* 2016). For the case of Sino-

Singapore and Tianjin Eco-Cities in China whereby the top down initiative was applied in the planning process, in which planning process mainly involved few top political and influential leaders only. For Kigamboni eco-city, the principle of public participation was contravened from the beginning of the process of declaring Kigamboni area as a next future eco-city (Hakiardhi, 2012; URT, 2010). The flow of information and transparency was inadequate, as a result, Kigamboni resident have been aggressive and unhappy with project because they are not clear about their fate. To confirm the finding from documents, interviews with experts from universities (Ardhi University and University of Dar es salaam), Local Government Authority (Temeke Municipal Council), DAWASCO, National Environmental Management Council (NEMC), was made. The aim was to find the expert opinions on effects that could rise because of inadequate public participation for the future performance wastewater management in the new eco-city. All experts had no clear facts for elimination for public participation, on issues of wastewater management. Only assumptions were made that, consultant left out some key stakeholders because it was not part of terms of reference or rather; perhaps public consultation for wastewater is deferred for later stage of the project. Insufficient advice from the local expert, lead to reason that, decision made by authorities in Tanzania to accept the MBR technology relied mostly from advise of consultant. The consulting company, a Korea Land and Housing Corporation (LHC) could have been driven by the motive of introducing a Korean based technology for wastewater treatment in Tanzania. Possibly, future operation of wastewater treatment operations will get an opposition especially if the user fee for wastewater services will be high because people was not involved from the beginning.

Another situation that will capture public attention is the odour from wastewater plant. Odor is common and expected from all kind of wastewater treatment plants, even so, a preferable wastewater treatment technology for eco-city is expected to produce low level of odor nuisance. The approved plan for this eco-city has shown that, the MBR technology proposed for this city, is designed to operate from underground to minimize odour effect and to provide more open space. On the other hand, biological treatment e.g. using wetland has low odour potential as well because wastewater is undergone preliminary treatment before they are treated in the plant.

3.3. Strategies for Integrated three Alternatives (Centralized, Decentralized and Combined/Hybrid) based on SWOT analysis

Overall sustainability of all three alternatives for each treatment system was evaluated through, AHP process. The process includes scoring, weighting and ranking. Result of weight of each alternation expressed in percentage was 38.87%, 36.28 and 24.86% for decentralized or biological technology, Hybrid and centralized MBR respectively. MBR has scored low out the three; this result is mainly contributed with a fact that, MBR will have high economic impacts, this arising from its higher investments cost related to construction, operation and maintenance. Also, the MBR will have high energy demand compared with other and this affects its environmental sustainability. However, MBR will have fewer impacts on dour, land requirement and staff than other treatment plants. Despite the economic and environmental sustainability shortcoming of MBR the system will be efficient in removing pathogens, BOD and TSS.

Meanwhile, biological process like Waste Stabilization Pond, anaerobic digester, Constructed wetland, lagoons e.t.c. has more advantages including relatively lower capital cost, low demand of energy during its operation and good removal of BOD, TSS, pathogens, nitrogen, and phosphorus. Another social related advantage is that, most of these WWTP are run and management in cluster system are close to the community it increases reuse opportunities of the treated wastewater. Use of reclaimed water would become more cost-effective as effluent would be available near the potential points of use, thus decreasing the costs of reclaimed water distribution systems. The only problem is the huge demand for land, and in some cases it creates mosquito breeding if proper maintenance is not taken.

The result of this study, give a reflection that, biological based and hybrid based approach are more preferable for this eco-city. The other targets of this paper, is to initiate a discussion for the possibility of integrating biological based treatment system to get the best effluent for eco-cities in tropical countries. Integration provides combined advantage of the two or three systems of different technology. The integration of wastewater treatment system was also commended by (Kihila *et al*. 2014); Singh *et al*. 2009). As an example, (Singh *et al*. 2009) evaluated performance of a combination of anaerobic baffled reactors combined with hybrid constructed wetland system for the best performance, while (Kihila *et al*. 2014) evaluated a combined Waste Stabilization ponds (WSP) and Constructed wetland (CW) in Tanzania. The technology proposed in the hybrid system has proven to perform well in tropical environment; therefore a maximum advantage should be taken instead of going to the more sophisticated technology.

The first alternative is to integrate the ABR and the Constructed wetland (Figure 6). The BORDA based ABR that is currently working in Kigamboni is properly designed and effective in removal of both physical and chemical parameters such as TSS, BOD, COD and Total Nitrogen. The construction cost for ABR is estimated to be 80$ per person (this cost is based on construction cost used for ABR in Kigamboni, on year 2012). Performance of constructed wetland system in Tanzania, is well assessed and considered to perform well by several researchers, including (Kimwaga *et al*. 2013; Kihila *et al*. 2014; Balthazar, 2014).The estimates cost for CWs in Tanzania is estimated to 60.125$$m^2$ (Kimwaga *et al*. 2013). Therefore, this could be one of low cost alternatives for wastewater treatment in Kigamboni. The main advantage of this combination, it reduces construction complications. Also, good performance of ABR in removing TSS reduces clogging in the following CW. Similarly, the combination will minimizes land requirement by CWs. Meanwhile operation will not require high skilled personnel to handle.

The second alternative is to integrate WSP and CW (Figures 6 and 7). One of the examples of the hybrid WSP-CW which is in operation is found in Moshi Municipality, Northern part of Tanzania within the Kilimanjaro region. This hybrid wastewater treatment system is managed by the Moshi Urban Water and Sanitation Authority (MUWASA). Wastewater treated by this plant is collected with coverage of 46% of the municipality. This is a unique centralized biological wastewater treatment system in Tanzania, with such wide coverage. The hybrid WSP-CW is designed for $4500m^3$/day. The hybrid WSP-CW is made with an anaerobic pond, two facultative ponds and six maturation ponds. The facultative ponds are arranged in parallel whereas maturation ponds position in series. For this combined WSP-CW, the CW part is only connected at maturation pond number two, and the effluent is discharged in the fish pond downstream and other water is left for irrigation farms downstream. The capacity of the constructed wetland is $200m^3$/day. Apart from the effluent from the CW, the remaining treated wastewater from facultative ponds is directly released to the paddy farms. According to (Kihila *et al*. 2014), overall size of irrigated land is $121{,}405m^2$ and about 60 farmers are directly beneficially from this plant. The rice paddy in this place is grown twice per year, the size of farm plot ranges from 1619 to $3035m^2$ each and the production can reach up to 7500kg/ha. Meanwhile, there other crops planted beside the paddy, these crops include maize, beans, potatoes, different green vegetables including tomatoes. According to the study done by (Kihila *et al*. 2014) on the effluent quality of the hybrid WSP–CW treatment system and its appropriateness for irrigation purposes, the hybrid WSP-CW system reduce pollutants to allowable discharge standards and the farmers and other users has good opinion over the re-use of treated wastewater in agriculture (effluent from this WSP-CW hybrid in Moshi has been used for agriculture for over six years)

The third alternative for the hybrid combination is to combine the ABR, WSP and the MBR (figure 6), this an option that take advantage of both ABR and MBR, and the final polishing of treated water is done by the MBR, This option can lead to best effluent suitable for the eco-city, but with possibly high construction and maintenance cost, and huge need of land and human resource.

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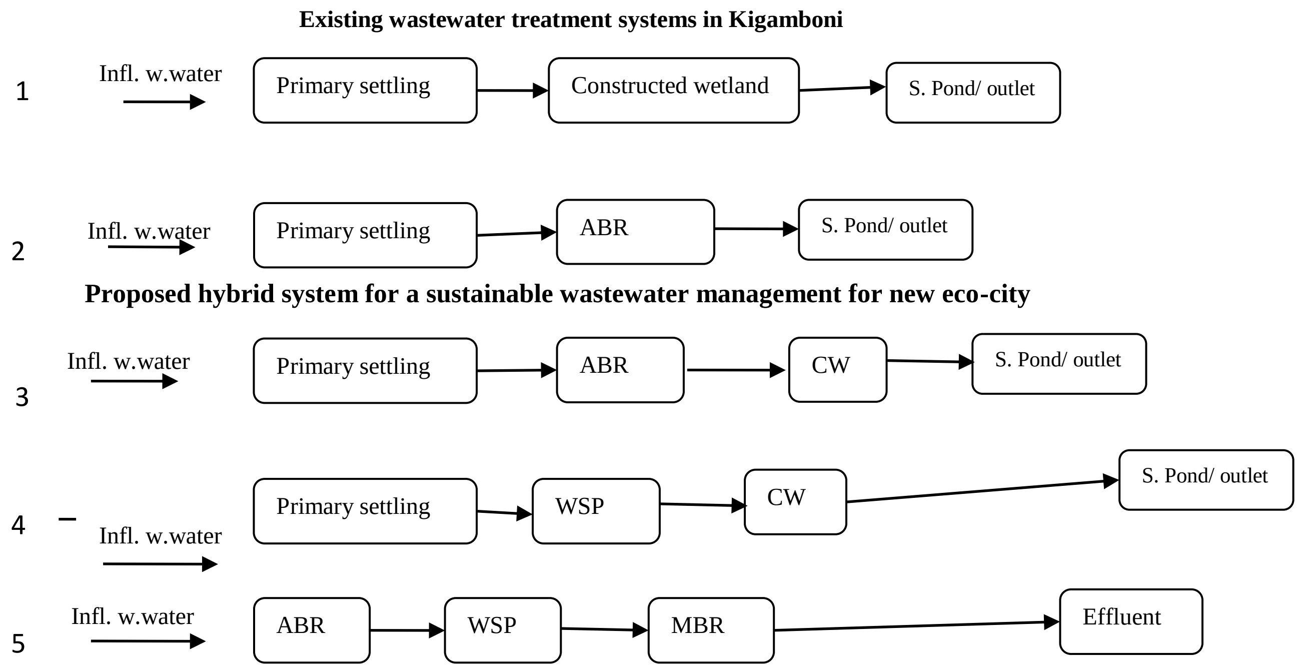

Figure 6: Existing and Theoretical approach on proposed sequence of wastewater treatment for eco-city of Kigamboni

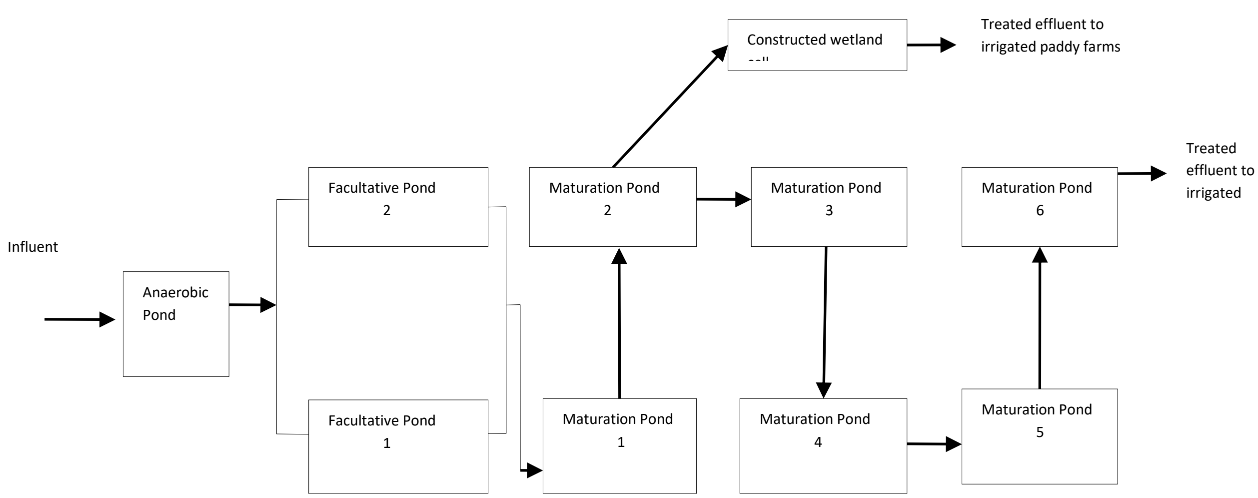

Figure 7: Hybrid WSP-CW

For Kigamboni eco-city, this hybrid combination can be recommended because is proven to perform well in for Moshi Municipality. The main, challenge of WSP-CW in the new city of Kigamboni will be availability of land. The land allocated for waste water treatment in Kigamboni is 11.8ha; this is a small land when considering such a combined treatments system. As an example, the WSP-CW constructed in Moshi required only 9.3 ha to treat 4500m^3/day. The volume expected for Kigamboni is 138,000m^3/day, this will require more than 200ha of land. However, the advantage of WSP-CW is that, construction can be done gradually, i.e. expansion can be done when it is needed unlike the MBR which should need completion of the entire plant to start working. With hybrid WSP-CW, different units can be built in a stepwise approach and this will reduces the need for instantaneous demand for investment.

SWOT analysis, as means to develop possible strategies to achieve sustainable goal for wastewater treatment for eco-city. The SWOT factors indicated on Figure 8 was used for developing four strategies. The SO strategies are strategies that use existing strength factors to Maximize available opportunity. WO strategy, are strategies to minimize weakness by optimizing the opportunities. ST strategy, are strategies that use strength to minimize threat and WT strategy, are strategies that minimize weakness and reduce the threats to minimal.

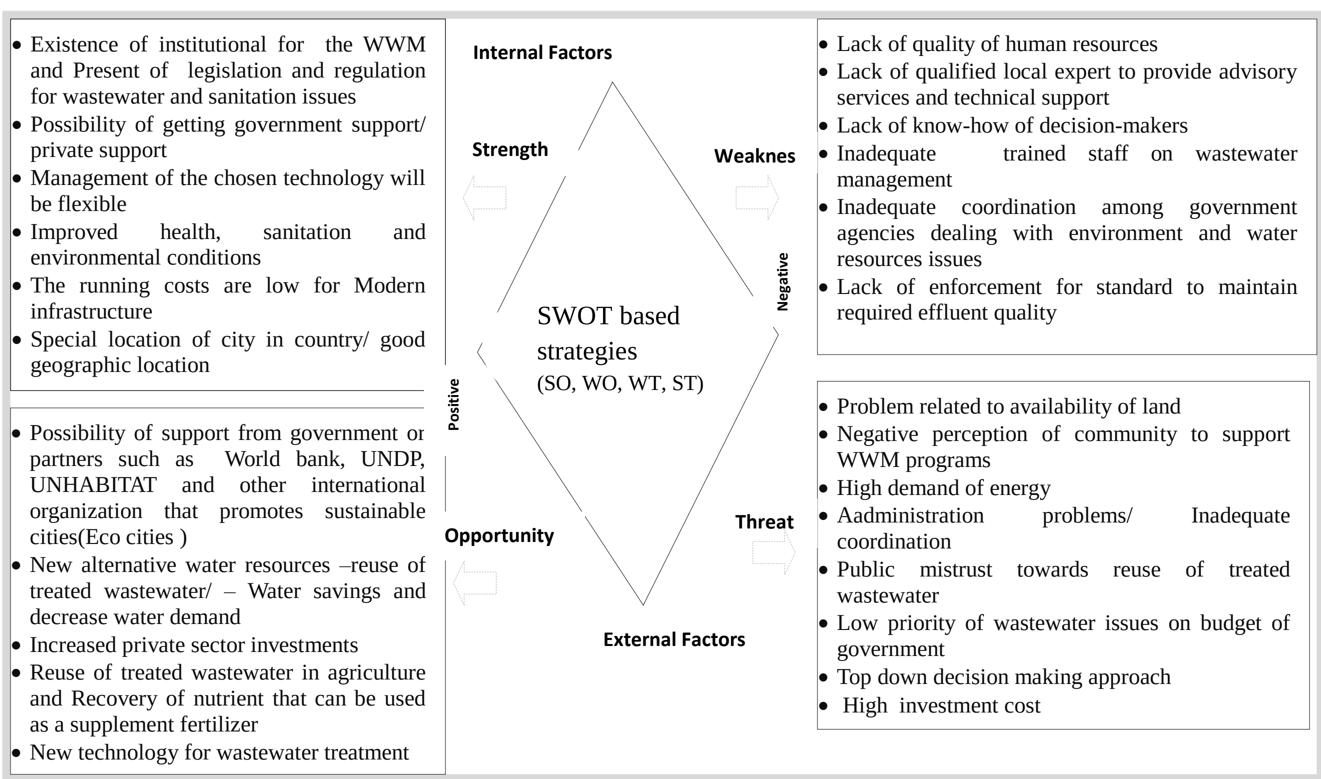

Figure 8: SWOT factors and strategies.

The first SO strategy is for government to develop policy and programs that will provide good investment environment for private sector to invest in the WWM or allow the joint venture, a Public-Private –partnership schemes. Effort has to be made to attract other partners like World Bank, UNDP, UNHABITAT and other international organization that promotes sustainable cities (Eco cities) to invest in this city. The government develop appropriate instruments including legislation and regulation that will support efficiency and effective management of wastewater in this new city. Flexible management and choice of treatment methods for city should prefer to increase the possibility of reuse of treated wastewater in agriculture and recovery of nutrient that can be used as a supplement fertilizer.

Likewise, WO Strategies includes developing strategies for special training and capacity building programs in order to increase number of capable human resources. This is because demand of expertise in field of sanitation and environmental engineering is increasing. The government should provide support for higher learning institutes to increase their enrolments for this cadre. On other hand, decision makers need to be well informed on appropriateness of different wastewater technology before they decide for choosing a WWT technology. Besides training, a strategy for developing suitable enforcement is required. Enforcement to ensure quality of the effluence is required, to ensure that, treated water meet effluent quality and is fit for reuse.

Similarly, the ST strategies, is to good business model, that will come with solution of how to curb issues of energy, investment cost in infrastructure and Operation and Maintenance, and administration. Also, operator need to show the value for money of the service such as how the health, sanitation and environmental conditions are improved and people are rescued from the risk of diseases. This will help to minimize the fear of people towards increased fees for wastewater services. Besides business, the awareness campaign strategies about the quality of the treated water and its benefit need to be established. The target audience have to be reached through all forms of media-e.g. TV, Brochures, newsletter and seminars.

Meanwhile as part of wastewater treatment strategies, the government needs to develop a clear implementation strategy, aiming to minimize overlapping of the roles and responsibilities between different institutions, for instances between central and local authorities. Meanwhile, the government should have a long-term strategy for training and building capacities of the officials who will be responsible for management of the new city's wastewater treatment plant. The government must support the authorities that deal with wastewater management in this city by allocating budget for putting infrastructures; wastewater issues are not much welcomed by private companies so the government should support.

4. CONCLUSION

The sustainability of wastewater treatment systems for the eco-city of Kigamboni was evaluated. The centralized MBR technology which is proposed for Kigamboni was assessed in comparison with the decentralized biological wastewater systems like Constructed Wetland, Waste

Stabilization Ponds and Anaerobic Baffled Reactors e.t.c. The evaluation also considered the relevance the hybrid wastewater treatment system that will include combination of two or more combination of technologies. Several sustainability indicators and criteria were used to gauge the comparison which based on the sustainability pillars of social, economical and environmental dimensions of wastewater treatment for the eco-city. The result of this study, give a reflection that, biological based and hybrid based approach are more preferable for this eco-city. The results and conclusions of this study are expected to bring new information to development of decision making in urban planning and environmental engineering field. The technologies suggested in this paper are more applicable in tropical countries. Therefore, findings and remarks of this paper can be adopted by engineers and other decision makers in tropical countries while designing and planning for new eco-cites. An integration of wastewater system that includes the needs of the community is more preferred for eco-city setting; for example, the provision for reuse of treated wastewater can be integrated with urban agriculture activities. Such integration could help the nutrient recycling, in which the nutrients are returned into the environment.

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