Integration Sustainability Water System Performance and Customer Satisfaction Based on Quality Function Deployment

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Abstract:

Most of the communities of scientific strongly recommends the adoption of indices for the monitoring evaluation of progress towards sustainable systems development and considers that indicators of TQM are powerful decision-making tools. The sustainability is a great challenge to water systems (WSs). The greatest challenges are in the fields of planning and management. With a steep increase in the demand for water, the contemporary management of WSs is committed toward sustainable development of such products. At recent researches reveal that numerous global attempts have been made to the sustainability of WSs. However, water quality concerns have not yet been sufficiently addressed by integrations between operation, maintenance, management with customer satisfaction. Through a point view of industrial engineering, the technique of Quality Function Deployment (QFD) with its application are summarized toward sustainability of water systems performance. This research to detect the sustainability was applied in one of WSs in Ramadi City / Iraq because it is plagued by technical, anthropogenic and environmental driving forces and its performance has fallen below the standard in recent years.

The methodology summarizes the process of translating customer needs (CNs) and sustainability factors (***F***) and into a specific change in Technical Requirements (TRs) or sustainability parameters ***(P)*** that are expected to solve WS problems and recommend solutions to the water system manager.

This study provides a methodology can making decision to formulated strategic alternatives plans via sustainability factors (Fs) in operation, management and maintenance (OMM) (F7,F5,F8) (12.32,10.695,10.695) respectively with Sustainability Parameters (Ps) of Technical Requirements (P7,P2,P14,P4,P1), (9.4, 8.9, 8.7, 8.5, 8.4) to solve the WS Problems and recommend solutions to WS managers. The robust decision making includes on that the integration in operation, maintenance and management for the more effective and improve customer satisfaction.

The sustainable water supply involves a sequence of combined actions and not isolated strategies, it is fundamental to enhance operation and maintenance performances of water utilities, as well as improving the capacity of the workforce to understand and operate the system.

Keywords: Water Sustainability, Quality Function Deployment, Customer Satisfaction, Water Distribution Network, Decision Making.

1. INTRODUCTION

The Sustainable is become highly significant worry worldwide, due to an upsurge in depletion of naturalist resources such as water. A meaning of sustainability emphasizes the development of systems, products and processes performance toward societal healthy aspects. Many organizations are increasingly adopting one or more the tools of TQM and methods to enhance CNs, increase operational improve and effectiveness quality.

The terms “sustainability” can take on a variety of meanings and are viewed as ranges of implementation. In sustainability combines three aspects, environmental sustainability, economic sustainability and social sustainability. the first, which refers to maintaining our natural environment for future generations, both social and economic sustainability ensure that have a sustainable economy for our society. Figure 1 shows the relationship between these three meanings of sustainability[1,2].

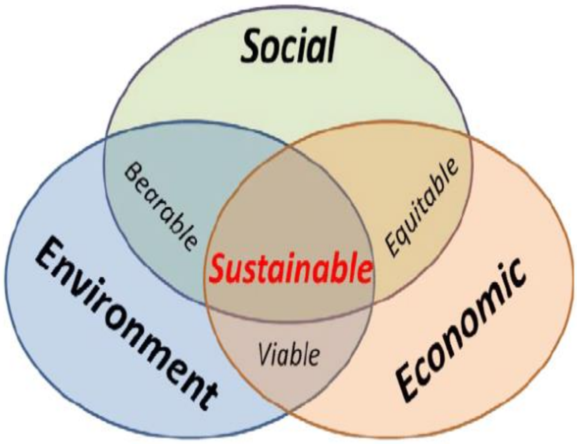

Fig. 1 shows the relationship between three aspects of sustainability[1].

The QFD technic is one of important tools widely used in TQM management for translating the Voice of Customer (VOC) into functions and technical features that meet with customer expectations. QFD is called a “customer-driven improvement planning tool” that can help different companies to understand the CNs and to find out possible means to accomplish them effectively and efficiently[3]. An extensive review of QFD technic literature can be found in Lai-Kow and Lu [4] and Shahin [5]. The issues related to WS sustainability concerns are getting more attention from companies and government in many countries. The managers of WS are enhancing their operations and strategies to be more sustainable conscious [2,6]. There for the sustainable of WS is a key contributor to this study to the WS sustainability and to the public health. Application of QFD in sustainability researches is one of the latest growing fields of study. The authors have been made attempt to collect substantial information over the feasibility of implementation of QFD to sustainability of WS.

The QFD expressed relationships between CNs and TRs using linguistic terms. Then scaling this linguistic terms into crisp values. Shahin [5], proposed a comprehensive comparing QFD with other quality approaches the author has been found that QFD is the most applicable technique for quality design and customer satisfaction subjects. Zuluaga, el at [8], address the solutions of leakage in water system by used QFD. Susana et al. [7] presented a review of WS in large network project and discuss the effect of maintenance on the performance of WSs and water quality.

This study indicated that QFD is a suitable technique for translating the voice of customers into technical languages to set optimal solutions. Very few researches handled the implementation with respect to QFD with sustainability.

2. PROBLEM STATEMENT

The large Water Treatment Plant (WTP) in Ramadi City /Iraq is plagued its performance has fallen below the standard in recent years. The existing WS problem negatively affects in terms of the poorness of water quality and increased costs of maintenance and water losses in the network, thus causes to reduce customer satisfaction. Many of water systems performance in Iraq has fallen below because they plagued by internal parameters either technical and anthropogenic or environmental influential. Therefore, there need arises to use flexible measurement approach addresses of integration and improving that goal themselves (such as water quality, operation time, easy maintenance, etc.) through the sustainability parameters (***Ps***) and sustainability factors (***Fs***) which may be adjusted according to the sustainability characteristics for the quality improvement for sustainability WS toward customer satisfaction which are highly priority .

In addition, the prior studies did not address the Integration the Management, Operation and Maintenance (OMM) with fulfil customer satisfaction in the sustainability of WS Performance discussed sufficiently which is being addressed in the present study.

3. OBJECTIVES OF RESEARCH

The originality of proposed methodology is to integrate the voice of the customer in operations, management and maintenance (OMM) for water system (WS) with its technical requirements (TRs) and to develop an action plan toward water sustainability. The other goals are:

1) Identify important customer needs (internal and external) represent sustainability factors (***F***s) corresponding to sustainability parameters (***Ps***) represent technical requirement in infusing sustainability characteristics in WS.
2) Prioritize parameters (***P***s) influencing the sustainable performance of WS based on sustainability factors (***F***s) of customer needs (CNs) pertaining to OMM by TQM tools.
3) To Formulating strategic alternatives plans via sustainability factors (***F***s) which represented a voice of customer CNs in operations, management and maintenance (OMM) through sustainability parameters (***P***s) of Technical Requirements TRs.
4) To robust decision making by integration the internal and external factors (***F***s) with customer satisfaction.
5) Determine the most important factors which lead to customer satisfactions.

4. STATISTICAL PERFORMANCE FACTORS AND PARAMETER

The factors and parameters impacting the development of the performance of WS have been identified from the literature. Some literature have discussed factors or parameters or both affecting the sustainable development of products. There are very few researches that specified the importance of factors and parameters sustainable development of WS[5,4]. The Sustainability Factors and Parameters (Ps and Fs) have been largely specified into various dimensions of WS sustainability. The relevance of P and F to this research has been handled and listed as in Table 1.

5. DEVELOPED METHODOLOGY

The proposed methodology consists of six matrices that are linked together to integrating the expectations of external customers (CNs) and internal customers (OMM) with technical required TRs and develop an action plan that meets the needs of both customers toward water sustainability.
The developed methodology is based on QFD applications and integrating the tools of quality such as Affinity Diagram (AD) and Pareto Analysis (PA) into the QFD technics. the brainstorming were also managed by design team to distinguish and set targets to the solution TRs.

Table 1. the factors and parameters influencing sustainability of systems.

Dimension	Parameters/factors	Description	Study
Functionality and ergonomics	Durability // ease of use, maintainability/ serviceability, upgradability	To be ensured the WS is easy to use and maintenance, since it has a high significant effect on durability of the product; the maintenance extends the product life, thereby ensuring sustainability characteristics of the product; the products are designed with modularity (standard) features to enable upgradability	Susana et al. [7](2015)
Economic efficiency	Potential financial costs, downtime minimization	The potential costs comprise by the managers for adopting sustainability culture; emphasis of the WS performance should be at minimal downtime to enable increased productivity.	Jung, & Kim [9] (2018)
Environmental aspects	Less grow bacteria, eutrophication, human toxicity	The adverse effects of water quality are a significant factor influencing WS sustainability; waste water need to be treated before releasing it to the river water. That is a severe sustainability concern and an important sustainability parameter.	Liviu et al. [12](2014)
Resource utilization and economy	Operation, installation and training cost, material utilization, power consumption and efficiency.	The WS installation, operation and maintenance of WS should be simplified to minimize cost ; the material type, cost and quantity affect overall sustainability of the WS; the energy consumed by the WS should be controlled.	Susana et al. [7](2015)
Societal impact	The operational safety, ethical responsibility	Quality and safety is an organizational level of external factors and internal parameters that ensures safety and healthy environment to the customer and avoids any safety hazards; ethical responsibility is a major social dimension which drives the organization (of WS) toward being more socially responsible through creating feedback options with customers.	Raid et al.[13] (2013)
	Robust of WS	Robust product is the parameter of direct effects for sustainability WS.	Siir et al.[6] (2018)
Optimization and distribution	Chemical and physical parameters	Chemical and physical parameters have a significant effect on sustainability of WS, and they are very important at the institutional level to optimal performance of WS. It is important to ensure reasonable percentage (standard) of Chemical and physical materials to meet with customer satisfaction.	Behailu et al.[14](2017)
	Demand, capacity and transport mode	These factors are dependent on both input (demand) and output (capacity) streams. Suitable policies are developed for efficient the production and transportation of water in network of WS.	Amalia et al.[15](2017)
	Lower energy and materials consumption	The amount of energy consumed of the WS should be reduced significantly by selecting renewable alternatives of both materials and facilities.	Jung, & Kim,[9] (2018)
modern technology	Reduction in resource use	it has to be using modern technology to minimization of usage of resources (water) will enable securing needs for the future generation	Raid et al.[13] (2013)

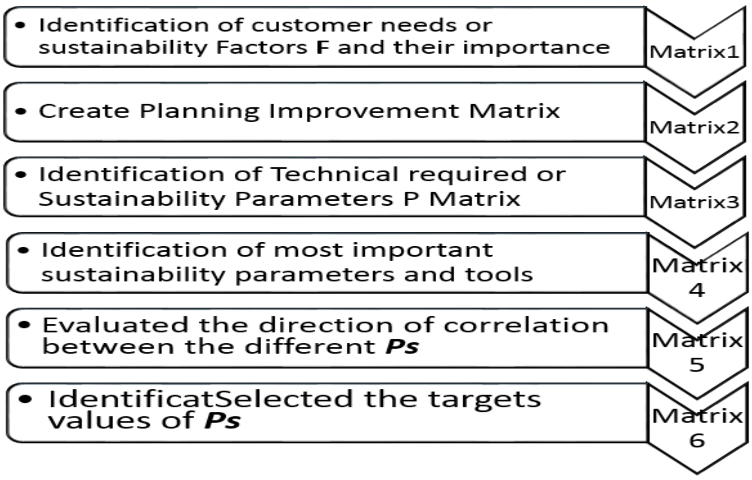

Fig. 2 flowchart stepwise described algorithm of methodology

A stepwise described algorithm of the methodology is in the following sections and simply presented as a flow chart in Figure (2).

1- Generation Matrix for Sustainability Factors (F) of CNs or WHATs: is to distinguish the customer needs and to investigate their needs "WHATs" or sustainability factors.[3] Two approaches are used; First Questionnaires and surveys were used to distinguish the requirements of the operation, maintenance and management of OMM representatives. And then one-to-one interviews were used to give a better perception of CNs. To generated the matrix:

Firstly: determine *F*s based on Table 1, which represents the dimensions of quality, determine Linguistically Factors (LF) for WHATs, and then translate LF into value numbers based on Table 2 [3].

Table 2. translate linguistic factors to value numbers.

Linguistic Factors	Symbol of LF	Value No.
Very Unimportant	VU	0
Quite Unimportant	QU	0.2
Unimportant	U	0.35
Some important	SI	0.5
Moderately Important	MI	0.65
Important	I	0.8
Very Important	VI	1

The secondly: identify Customer Relative Importance (CRI) indicator for each ***Fs*** based on information and perception from the surveys and one-to-one meetings as indicated by the symbols of scale in Table (2). Translate CRI to Value CRI (VCRI) based on scale Table.3. Calculate Average of VCRI[15].

$$(\mathrm{AVCRI})_i = (1/K) * \sum_{CN=1}^{K} (\mathrm{VCRI})_i \quad (1)$$

where: I=No. of ***Fs***. K=No. of CN=1,2,…,K, And i=1,2,3...,I

Finally, estimate the Importance Weight (IW) values (1-5) by the experts QFD team. Then ranking AVCRI in order on Importance Weight scale[3].

Table 3 translate linguistic SR to value numbers.

Linguistic Of SR	Symbols	Value SR
Very Weak	VW	1
Weak	W	3
Moderate	M	5
High	H	7
Very High	VH	9

The Pareto method analysis: The data gathered from customers were organized and summarized in Pareto method to identify the vital water system problems WSP. Some of problematic elements that need to focus in the current impact on WSP. By Pareto method, the percentage of (80-20) rule is applied to identify the vital few from the trivial many.

The Affinity diagram (AF): This one of TQM tools which has allowed the QFD team to sort the ideas of CNs to be prepared for (WHATS) matrix of HOQ. Also allowed the team of QFD to grouped CNs in a logical factors LF manner that is to perceive and then used in the later decisions making[7].

2 .The matrix of The planning for improvement strategy: generated by experts QFD team for planning the needs improvement the implicating product or service, in this study the WS [12]. The values are estimated by the experts QFD team (such as the planning Customer Satisfaction rating (CSR) and improvement level of the Demand Point (DP)). Based on CSR and DP, the improvement factors (OF) indices that will be adopted in the selection solutions of different WS alternatives and calculated as follows[7]:

$$\text{ImF} = ([\text{Planned CSR} - \text{Existing CSR}] \text{x } 0.2) + 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The overall weighting OW of each ***F*** is calculated as:

$$\text{OW} = \text{WI} * \text{ImF} * \text{DP} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Percentage of Total Weighting is calculated as:

$$\text{WT\%} = (\text{OW}/\Sigma\text{OW}) \text{x } 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3- Matrix of Selecting the technical requirement (HOWs): represented how the QFD team responded to each Ps. To this goal, a specialized expert of QFD team of the WS studies the identified ***P***s or "WHATs". In this matrix, the ***P***s for (HOWs) will generation[15].

4- Matrix of Evaluated interrelationships between Fs and Ps: used to assess the relationships between Ps and Fs ranking by five degrees and these values are also performed by the experts of QFD team it required deep knowledge in OMM. Firstly, estimate the Strength Relationship of TS linguistically, translate TS into numbers based on Table 3 calculate Value of Technical Requirements P indicator or (VP) which represent the influence of ***Ps*** on ***Fs*** [7].

$$(VP)_j = \sum_{i=1}^{I} (P)_i * WI_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$(AVP)_{j=} (VP)_j \Big/ \sum_{j=1}^{p} (VP)_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where p = No. of HOWs and j = 1, 2, . , p.

Calculate Scaled AVP to find a ranking of HOWs.

$$(SVP)_j = (AVP)_j / \text{max. } (AVP)_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

5-Matrix of Evaluated the direction of correlation between the various Ps: that have been previously developed based on the sustainability factors of WHATTs. For this goal, the impact of each ***P*** is tested on other ***P***s and the correlation is assessed as one of three levels; direct (+), inverse (-), or none( )[13].

6-Matrix of Selected the values of the target of *Ps*: by selecting and setting values (qualitative or quantitative) of ***P****s* of TRs. All values are set by the QFD team and should be approved by the manager for implementation. The technical priorities (**TP**) of all ***P****s* are calculated with weighting as follows[13]:

$$(TP) = \Sigma \text{ (Relationship x WI)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The percentage of total priority is:

$$TP \% = (TP / \Sigma\, TP) \text{ x } 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The **TP** is put into an action plan prepare for deployment based on their priority.

Methodology, calculations and analysis of results were built using an Edraw QFD program.

6. Implementation of methodology in a case study

The researchers identified 150 indicators related to water use and management. These indicators were assessed by experts that evaluated whether they fulfill the three sustainability criteria: environmental, social and economic.

The methodology of detection sustainability was applied in of water system (the large water treatment plant) at AL-Ramadi Iraq which include (pumps, pipes, chlorine system, filters .. etc.). Key influential parameters for sustainable development of WS have been identified from the past literature. Surveyed customers contain internal customers (Operations and Maintenance (O&M) and management) as well as external customers (household, hospitals and government buildings). Gathering CNs data from both internal and external customers as following.

External customers: By surveying customers were also asked to identify the type of water service, Water supply interruption, quality, pressure, water quality, times of supply, the frequency of supply, bacteria in water, breakage in the network and other issues or concerns.

Internal customers: after identifying the concerns of external customers, specialises in the maintenance and operation departments of the plant were interviewed. The both departments' representatives (O&M) were asked for their feedback of; Durability, Water quality, Operational, Repairs and Maintenance, Handling and Assembly and Cost.

Constructing the methodology matrices: the starting is determining a hierarchical tree or affinity diagram (AD) based on Table 1. The O&M experts were able to connect the concerns of the external customers with performing WS versus their multiple failure causes. As shown in Figure 3, a Pareto chart presented the results of ranking various type of WS defects**.**

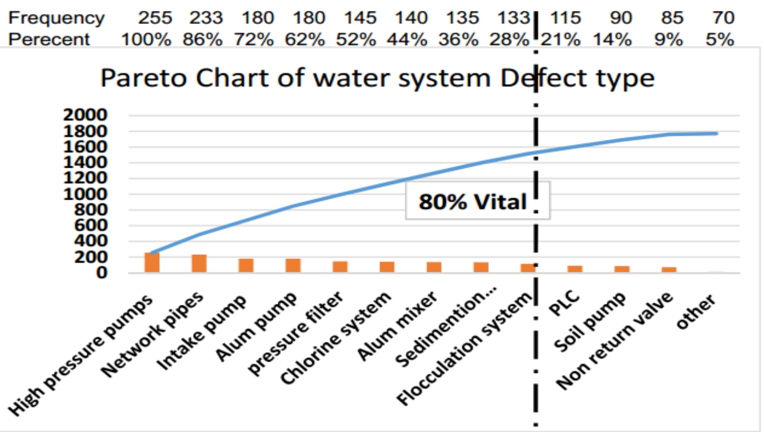

Fig. 3: Pareto chart of various WS defects.

In Fig.3 showing nine defects of WS represent the vital parameters (80% of overall defects). The ranking of defects will help later to identify the priorities of the action plan as it is a typical challenge of sustainability parameters *Ps* for the QFD team to address all causes of WS defects. The QFD team conducted brainstorming session to categorize different the technical causes of WS defects which influence OMM and reported in Figure 4.

Matrix 1: based on the report of the QFD team and Table 1, a set of definite CNs (***F***s) are expressed at each identified group of the AD as shown in Table 4.

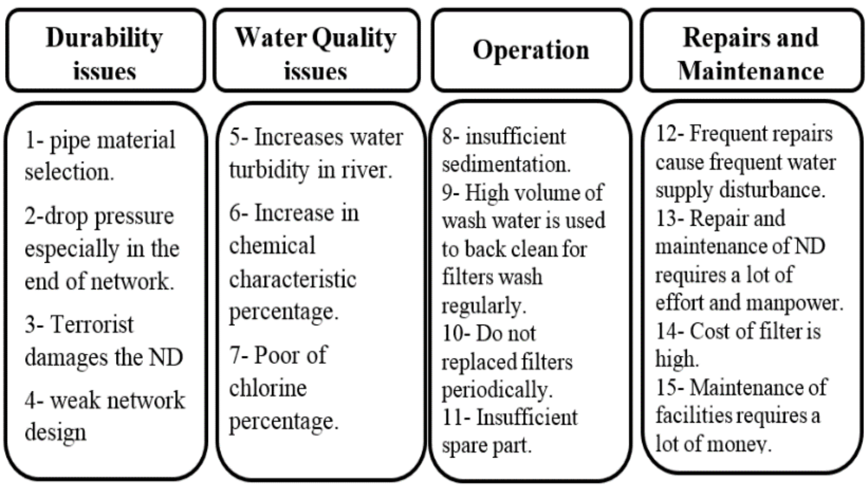

Fig.4: affinity diagram for categorizing different WS issues.

Table 4. generated Customer Needs Matrix (sustainability factors ***F***s) for WS.

sustainability factors Matrix or WHATs		Factors
Durability	Less breakages in ND	F1
	Less grown coliform bacteria at end ND	F2
	Robust design of ND	F3
water Quality	Preserve the high quality of water coming from the distribution water main (NO contamination)	F4
	Prevent Increase in chemical characteristic percentage.	F5
	Decrease the contains of water impurities	F6
Operation	Increase frequency water supplying	F7
Repairs and Maintenance	Provision of spare parts	F8
	Easy to repair procedure in case of damage	F9
Handling & Assembly	Use facilities that require lowest overall skill of labor requirement (in case of emergency)	F10
	Part of facilities should be easy to repair	F11
Cost	Minimal repair and maintenance cost	F12
	Minimal cost of leaked water	F13

The result of AVCRI with scale for each ***F***s by using Equ.1 and summarized in Table 5. The highest order of the AVRCI of ***F***s are (F5,F7,F10, F4, F12,F13,F9).

Table 5 Rank and scale of AVCRI for each sustainability factors of WHAT

F	F5	F7	F10	F4	F12	F13	F9	F8	F1	F11	F6	F3	F2
AVCRI	0.845	0.843	0.843	0.842	0.841	0.841	0.841	0.840	0.830	0.783	0.782	0.720	0.620
scale WI	5	5	4	5	5	5	5	5	4	3	3	2	1
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13

Matrix 2: by Using Equs.2,3,4 with details in Table 5 .

The results are listed in Table 6 A and B (planning matrix). The rank of ***F***s are (F7,F8.F5,F9,F13, F4,F12).

Table 6: A)The planning matrix for improvement strategy and
B)rank of the relative importance of sustainability factors.

A

F	CSR of WTP & ND	Projects planned For CSR	Improvement variable	Demand Point (DP)	Scale of WI	Overall Weighting (OW)	Total weight (WT%)
F1	3	5	1.4	1	4	5.6	7.487
F2	3	4	1.2	1	1	1.2	1.604
F3	4	4	1	1	2	2.0	2.674
F4	4	5	1.2	1	5	6.0	8.021
F5	2	5	1.6	1	5	8.0	10.695
F6	1	5	1.8	1	3	5.4	7.219
F7	1	5	1.8	1	5	9.0	12.032
F8	2	5	1.6	1	5	8.0	10.695
F9	2	4	1.4	1	5	7.0	9.358
F10	3	4	1.2	1	4	4.8	6.417
F11	1	4	1.6	1	3	4.8	6.417
F12	2	3	1.2	1	5	6.0	8.021
F13	2	4	1.4	1	5	7.0	9.358

B

Sustain ability Factors	Total weight (WT%)	Rank
F7	12.03	1
F8	10.70	2
F5	10.70	3
F9	9.36	4
F13	9.36	5
F4	8.02	6
F12	8.02	7
F1	7.49	8
F6	7.22	9
F11	6.42	10
F10	6.42	11
F3	2.67	12
F2	1.60	13

Matrix 3: The QFD team was able to separate sixteen ***P***s in response to the thirteen ***F***s specified CNs as in Table 7. then explore technical solutions alternative for improving WS performance.

yTable 7: sustainability parameters ***P***s of TRs or "HOWs".

Increase water sterilization	Used the standard limitations of the alum quantity	Use non corrosive material that releases dangerous toxins	Used the standard limitations of the chlorine quantity.	Use the high pumping exceed of 120m to insure reach the water at end ND	Frequently of wash back for filters unite	Increase operating times	Use of different pipe material that aren't broken easily.	Use material of pipes that has high Quality	Use a flexible material with jointing.	Use ND design that can easily isolate damaged portions	Added the chlorine in primary sedimentation	Use new model filters to increase filtration efficiency	Schedule Training of crew OMM.	Use the computer aided control.	creation the chemical and physical lab
P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
Sustainable Parameters Technical Requirement (TRs) or HOWs.															

Matrix 4: by using Equs.5,6 discussed in the methodology the res the results listed in Table 8.

Table 8: scale and rank of VP,AVP and SVP for each sustainability parameter .

P	P7	P2	P14	P4	P1	P8	P15	P13	P12	P16	P11	P3	P9	P10	P6	P5
VP	238	226	221	215	212	155	150	145	138	138	130	128	125	119	115	79
AVP	0.094	0.089	0.087	0.085	0.084	0.061	0.059	0.057	0.054	0.054	0.051	0.051	0.049	0.047	0.045	0.031
SVP	1.000	0.950	0.929	0.904	0.891	0.651	0.630	0.609	0.580	0.580	0.546	0.538	0.525	0.500	0.483	0.332

From Table 8, (P7, P2, P14, P4, P1) are considered the most important of ***P***s for engineering specifications in the WS. which has great effects on achieving the customer desires**.** In another meaning their strong relation between (F7 and (P7, P2, P14, P4, P1)) and so on for other factors Fs.

Matrix 5: The results of six matrices of methodology as shown in Fig 5, the correlation is expressed in the roof of the QFD matrix. (for example) P3, P5, P9, P10 have not to conflict on other parameters. That means that they are not important (non-contradiction) when planned to improve these parameters to enhances the performance of WS. This matrix helps the QFD team to best understand the connection between various requirements of ***P***s and greatest importantly avoid any unnecessary spikes in cost.

Matrix 6: The final matrix: The QFD team sets the design targets that make sure that ***F***s of CNs are addressed efficiently. And then the priorities are calculated based on the procedure explained in the methodology section. From Table 8 and using Equs.8,9; the importance of the related TRs. Table 9 shows the results of TP% design target matrix.

Table 9: rank and scale of TR % for each sustainability parameters with the target

P	P7	P2	P14	P4	P1	P8	P15	P13	P12	P16	P11	P3	P9	P10	P6	P5
TP	238	226	221	215	212	155	150	145	138	138	130	128	125	119	115	79
TP%	9.4	8.9	8.7	8.5	8.4	6.1	5.9	5.7	5.4	5.4	5.1	5.1	4.9	4.7	4.5	3.1
Target	10	8	9	5	9	4	4	4	4	4	8	6	4	4	8	4
Rank	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

The highest relative importance of TRs is (P7, P2, P14, P4, P1) which need to put into an action plan really for deployment based on their priority. The QFD team can recommend improved these techniques to enhance the quality of WS performance of the case study. When comparing TR% with the design target, conclude that some parameters (P7, P14, P1) do not accomplish the target designed. Therefore, those parameters are considered the most important sustainability parameters on the WS which has great effects on system performance.

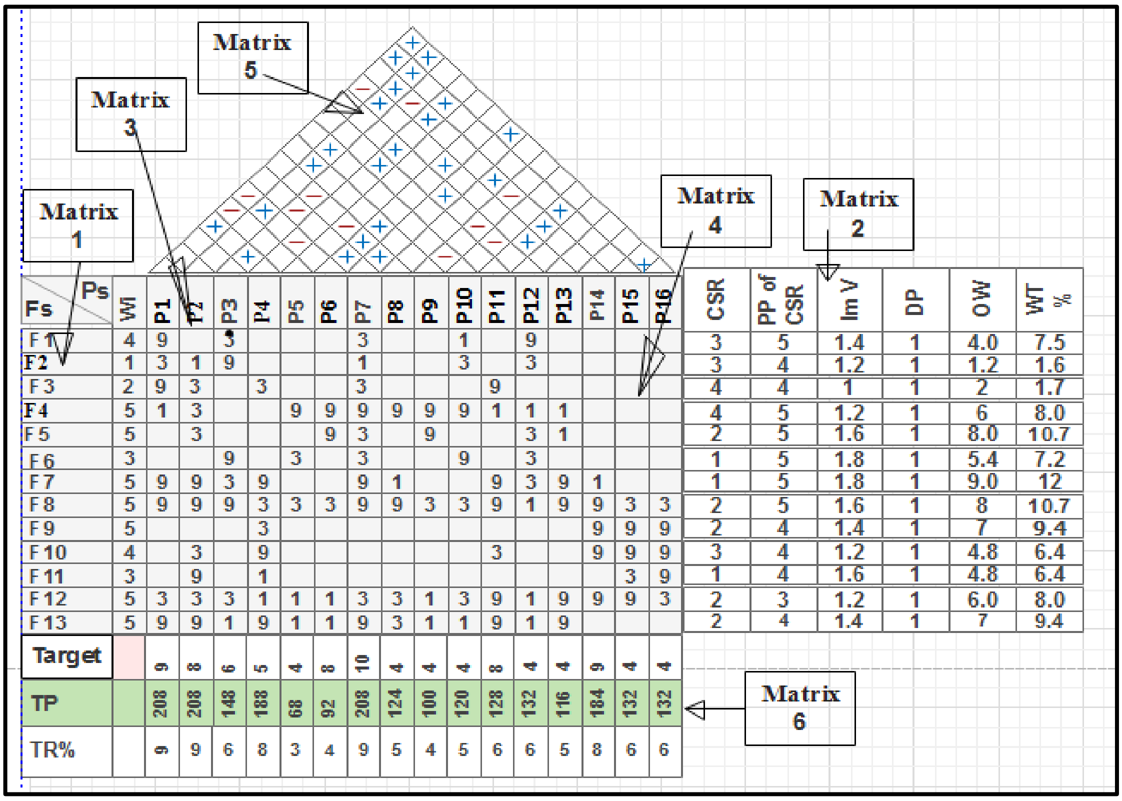

Fig.5: results of six house of quality of methodology

7-Results and Analysis

The objectives of this research were constructed based on the industrial engineering perspective. These objectives were to reduce deceleration in the performance of WS and increase quality water and sustainability by enhancing the technical standards used.

From Table 6 the important sustainability factors ***Fs*** by Customer Relative Importance (CRI) indicator are (F5, F7, F8, F4, F12, F13, F9) and from Table 6 the improvement factors (ImF) indicator (F7, F8.F5, F9, F13, F4, F12), when filtered out the Influential factors will show in Fig 6 which must be developed and improved. The very important factors are (F7, F5, F8) then (F9, F13) based on Pareto rule where others can exclude from the improvement plan. The result will help the head of management to an emphasis on high important sustainability factors.

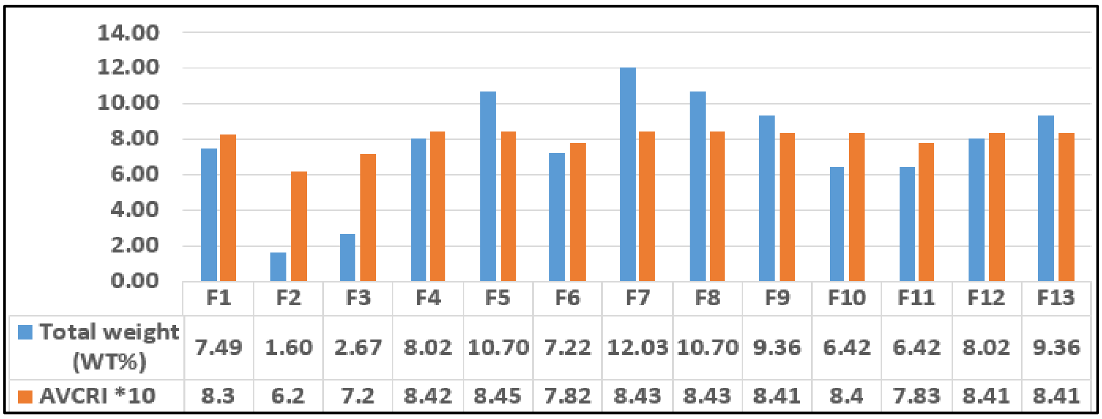

Fig 6: comparing the two results of sustainability factors.

From the fig.7 the most important Ps by indicator (VP) for technical specifications are ‘Increase operating times P7’,‘Used the standard limitations of the alum quantity P2’, ' Schedule Training of crew OMM' P14', "Used the standard limitations of the chlorine quantity P4", "Increase water sterilization P1" with values (9.4, 8.9, 8.7 and 8.5) respectively. Which has great effects on achieving the customer desires? The growing concern for OMM are responsible for (P1, P7, P14 and P7) will be lead to the sustainability characteristics for sustainability WS performance toward customer satisfaction.

These results of (Fs &Ps) should be taken to improve and converted them into an action plan that when applied will enhance the performance sustainability of the WS. These Ps of technical requirements were confirmed by the QFD team and subject matter experts from operation, maintenance and management departments. Depended on these result, the Priorities scores of the implementation plan strategy was set to take place in the following three stages as in fig 7:

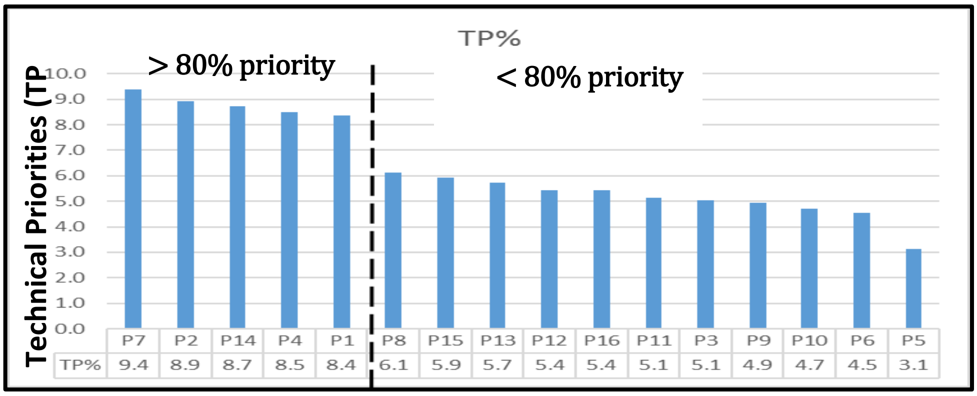

Fig.7: the Priorities scores of the implementation plan strategy

Stage 1: Focus on improving ***P***s of TR with >80% priority as (P7, P2, P14, P4, P1).

Stage2: Focus on improving ***P***s of TR with10%<80% priority as (P8, P15). The QFD team can recommend improved these techniques to enhance the quality of WS performance in the future plan.

Stage 3: Keep improving standards afterwards continually.

The results of this particular case study signify the growing awareness about sustainability and environmental issues among customers.

8-CONCLUSIONS

In this research, a developed methodology based on QFD approach is utilized within the framework of TQM to improve the sustainability of WS performance. Results of external customer survey revealed that the customers being supplied with water from the distribution network have the highest dissatisfaction rates. The majority of problems of WS that the characteristics of treated water such as physical and chemical are not within the expectations. The methodology Formulated strategic alternatives plans via sustainability factors (***Fs***) in operations, management and maintenance (OMM) with sustainability parameters (***Ps***) of Technical Requirements to solve the WS Problems and recommend solutions to WS managers. The robust decision making includes on that the integration in operation, maintenance and management for the more effective and improved customer satisfaction.

The final result that a sustainable water supply involves a sequence of combined actions and not isolated strategies, it is fundamental to enhance operation and maintenance capabilities of water utilities, as well as improving the capacity of the workforce to understand and operate the system. It can be perceived that QFD opens a wide opportunity for application in the sustainable development of WS in future.

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