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# **Influence of Applying Value Engineering Concept in Project Case Study: Deir El Balah Desalination Plant**

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### **Authors' contributions**

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## **ABSTRACT**

One of the most important challenges that face the people in developing countries is the scarcity of natural water resources along with continuous growth of consumption level. A huge deficit in aquifers balance forces the authorities to look for an optimal alternative source to overcome the scarcity of water through seawater desalination. The aim of this research is to use the Value Engineering concept in desalination water station. A survey was conducted to elaborate the most important factors affecting the establishment of the desalination plant. Moreover, several interviews were conducted with experts in the field to crosscheck the validity of the survey results. The findings of field investigation were used in applying the Value-Engineering concept on a selected case study located in Gaza Strip: Deir El Balah desalination plant in order to examine the impact of application of Value Engineering on the project effective cost. It was found that there is direct impact in cost saving of approximately 10.33 % for the project cost in design and tendering stages. It was confirmed that applying Value Engineering is very helpful tool for such projects, which will lead to significant cost saving.

**Keywords:** *Value engineering; cost saving; desalination; Gaza.*

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## **1. INTRODUCTION**

Many regions of the world are facing formidable freshwater scarcity. The water resources are very limited and the consumption rate is hugely increased over the last few years. Good example for this phenomenon is Gaza Strip as the current context reflects the sufferance from shortage in the aquifers by 55 million cubic meters until 2017 [1]. Therefore, all relevant bodies working in water sector agreed on adopting the construction of central desalination plant as an exclusive solution to get over this problem [2].

However, the cost of desalination plants construction projects has been rapidly increased during the different plant life cycle. This may refer to different reasons, which depend on the project itself and /or other related circumstances; accordingly, it was very important to find an effective technique to face these phenomena, which may be presented by Value Engineering [3].

The value engineering technique is applied in most advanced countries. Applying Value engineering on desalination plant project using membrane system with Reverse Osmosis (RO) refer to its clear effect to analyze the life cycle cost of projects. The value engineering share significantly on the analysis of projects costs and then find the suitable solutions through saving various alternatives, with keeping functions and features that the owner of product or project looks to achieve, such as beauty, environment, safety, flexibility and other important factors [4].

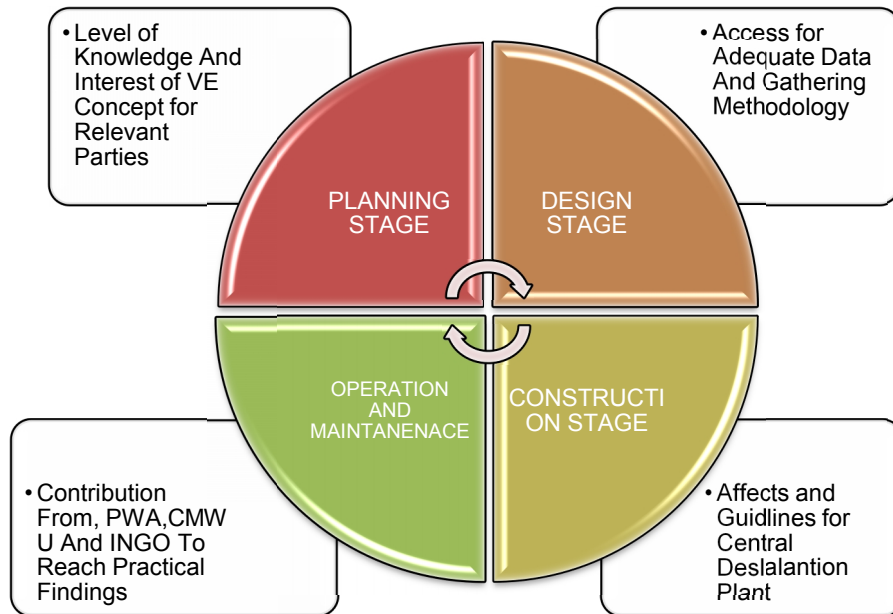
This research studied the impact of applying Value Engineering (VE) on selected case study: Deir El Balah desalination plant by identifying the most effective factors affecting water desalination in the plant in different stages based on the available information in this regard. The four stages was examined through a comparison model to elaborate the possibility of cost reduction using the value engineering technique which may be lead to significant considerations in establishing the central plant serving Gaza Strip.

The value engineering is new concept in the developing countries and practically not applied in most of the implemented or planned projects context. The application of this concept on the desalination plant may give guide for other researcher to extend this application in other projects. Fig. 1 indicated the four stages of the conceptual frame work of the intended study.

## **2. VALUE ENGINERRING (VE)**

There is a significant difference between cost reduction and Value Engineering. "Value engineering is not simply about money ...it's about value " [5]. It is the balancing formulated from the main three elements as indicated on the definition derived by SAVE organization "An organized effort directed at analyzing the function of products and services to achieve the desired functions and the essential characteristics at the best use of costs in accordance with the wishes and expectations of the user" [6]. Value engineering is an organized effort to innovate alternatives without compromising quality and basic functions [7].

Several organization and VE specialists described the process of applying VE. By going through these different methodologies, one may find that all of them agreed in the concept and main components of the process application, while some of them like to merge some stages and others go in further detailed tasks and activities. The SAVE international methodology was adopted.



**Fig. 1. Research conceptual framework**

## **2.1 Main Steps for VE According to Save International Approach [8]**

The VE Job Plan covers three major periods of activity: Pre-Study, the Value Study, and Post-Study. All phases and steps are performed sequentially. As a value study, progresses new data and information may cause the study team to return to earlier phases or steps within a phase on an iterative basis. Conversely, phases or steps within phases were not skipped.

### **2.1.1 Pre-study**

Preparation tasks involves six areas: Collecting/defining User/Customer wants and needs, gathering a complete data file of the project, determining evaluation factors, scoping the specific study, building appropriate models and determining the team composition. The User/Customer attitudes are compiled via an in-house focus group and/or external market surveys for first time projects such as a new product or new construction, the analysis may be tied to project goals and objectives. The results of this task were used to establish value mismatches in the Information Phase. There are both Primary and Secondary sources of information. Primary sources are of two varieties: people and documentation. People sources include marketing (or the user), original designer, architect, cost or estimating group, maintenance or field service, the builders, and consultants. Documentation sources include drawings, project specifications, bid documents, and project plans. Secondary sources include suppliers of similar products, literature such as engineering and design standards, regulations, test results, failure reports, and trade journals. Another major source is like or similar projects. Quantitative data is desired. Another secondary source is a site visit by the value study team.

The team, as an important step in the process, determines what will be the criteria for evaluation of ideas and the relative importance of each criterion to final recommendations and decisions for change. These criteria and their importance are discussed with the user/customer and management and concurrence obtained. The team develops the scope statement for the specific study. This statement defines the limits of the study based on the data-gathering tasks. The study sponsor must verify the scope statement based on the completion and agreement of the scope statement, the team may compile models for further understanding of the study. These include such models as Cost, Time, Energy, Flow Charts, and Distribution, as appropriate for each study. The Value Study Team Leader confirms the actual study schedule, location and need for any support personnel. The study team composition is reviewed to assure all necessary customer, technical, and management areas are represented. The Team Leader assigns data gathering tasks to team members so all pertinent data will be available for the study.

### **2.1.2 The value study**

The value study is where the primary Value Methodology is applied. The effort is composed of six phases: Information, Function Analysis, Creativity, Evaluation, Development, and Presentation.

#### *2.1.2.1 Information phase*

The objective of the Information Phase is to complete the value study data package started in the Pre-Study work. If not done during the Pre-Study activities, the project sponsor and/or designer brief the value study team, providing an opportunity for the team to ask questions based on their data research. If a "site" visit was not possible during Pre-Study, it should be completed during this phase.

#### *2.1.2.2 Function analysis phase*

The objective of this phase is to develop the most beneficial areas for continuing study. The team performs the following steps:

- Identify and define both work and sell functions of the product, project, or process under study using active verbs and measurable nouns. This is often referred to as Random Function Definition.
- Classify the functions as basic or secondary.
- Expand the functions identified in step 1 (optional).
- Build a function Model - Function Hierarchy/Logic or Function Analysis System Technique (FAST) diagram.
- Assign cost and/or other measurement criteria to functions.
- Establish worth of functions by assigning the previously established user/customer attitudes to the functions.
- Compare cost to worth of functions to establish the best opportunities for improvement,
- Assess functions for performance/schedule considerations.
- Select functions for continued analysis.
- Refine study scope.

### 2.1.2.3 Creative phase

The objective of the Creative Phase (sometimes referred to as Speculation Phase) is to develop a large quantity of ideas for performing each function selected for study. This is a creative type of effort, totally unconstrained by habit, tradition, negative attitudes, assumed restrictions, and specific criteria. No judgment or discussion occurs during this activity. The quality of each idea was developed in the next phase, from the quantity generated in this phase.

### 2.1.2.4 Evaluation phase

The Evaluation Phase are to synthesize ideas and concepts generated in the Creative Phase and to select feasible ideas for development into specific value improvement. Using the evaluation criteria established during the Pre-Study effort, ideas are sorted and rated as to how well they meet those criteria. The process typically involves several steps:

- Eliminate nonsense or “thought-provoker” ideas,
- Group similar ideas by category within long term and short term implications. Have one team member agree to “champion” each idea during further discussions and evaluations. If no team member so volunteers, the idea or concept is dropped,
- List the advantages and disadvantages of each idea,
- Rank the ideas within each category according to the prioritized evaluation criteria using such techniques as indexing, numerical evaluation, and team consensus,
- If competing combinations still exist, use matrix analysis to rank mutually exclusive ideas satisfying the same function,
- Select ideas for development of value improvement.

If none of the final combinations appears to satisfactory meet the criteria, the value study team returns to the Creative Phase.

### 2.1.2.5 Development phase

The Development Phase is to select and prepare the “best” alternative(s) for improving value. The data package prepared by the champion of each of the alternatives should provide as much technical, cost, and schedule information as practical so the designer and project sponsor(s) may make an initial assessment concerning their feasibility for implementation. The following steps are included:

- Beginning with the highest ranked value alternatives, develop a benefit analysis and implementation requirements, including estimated initial costs, life cycle costs, and implementation costs taking into account risk and uncertainty,
- Conduct performance benefit analysis,
- Compile technical data package for each proposed alternative,
- - a. written descriptions of original design and proposed alternative(s),
  - b. sketches of original design and proposed alternative(s),
  - c. cost and performance data, clearly showing the differences between the original design and proposed alternative(s),
  - d. any technical back-up data such as information sources, calculations, and literature,

e. schedule impact,

- Prepare an implementation Plan, including proposed schedule of all implementation activities, team assignments and management requirements.
- Complete recommendations including any unique conditions to the project under study such as emerging technology, political concerns, impact on other ongoing projects, marketing plans, etc.

#### *2.1.2.6 Presentation phase*

The objective of the Presentation Phase is to obtain concurrence and a commitment from the designer, project sponsor, and other management to proceed with implementation of the recommendations. This involves an initial oral presentation followed by a complete written report.

As the last task within a value study, the VM study team presents its recommendations to the decision making body. Through the presentation and its interactive discussions, the team obtains either approval to proceed with implementation, or direction for additional information needed.

#### **2.1.3 Post study**

The objective during Post-Study activities is to assure the implementation of the approved value study change recommendations. Assignments are made either to individuals within the VM study team, or by management to other individuals, to complete the tasks associated with the approved implementation plan.

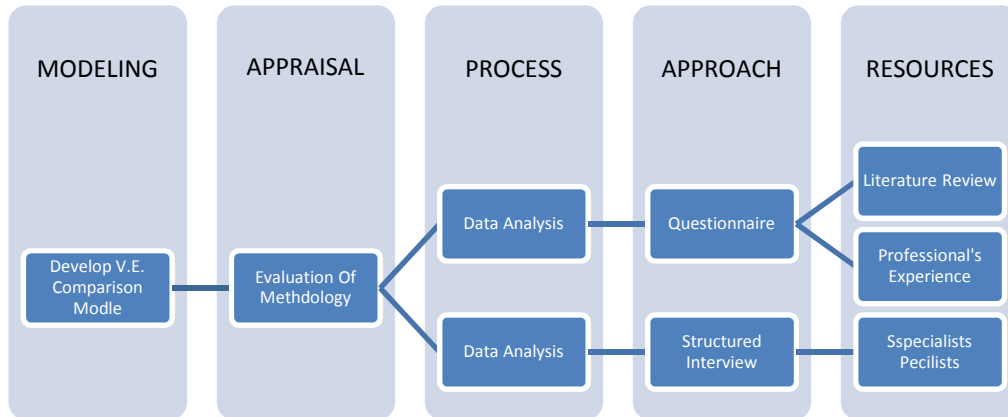
### **3. RESEARCH METHODOLOGY**

Based on the findings from literature review /available data, a questionnaire was formulated and distributed to relevant private and public sectors interested in water aspect. The questionnaire included three main parts: basic information, list of factors affecting the cost and function of the desalination plants, factors affecting desalination plants from the candidate points of view.

All experts in the field of seawater desalination, working in both public and private sectors deeply involved in water sector in Gaza strip were investigated. The specialists are approximately 40 persons with experience in water desalination or currently sharing in operating the desalination plant in Deir El Balah. 40 copies of the original questionnaire was distributed on the population, 37 copies were returned. 2 extra copies were excluded as they were unsuitable for the data analysis. The number of respondents was included in the data analysis was 35 of experts in the field of water desalination. Fig. 2 show: Methodology Flow Chart.

An intensive interview was conducted also, with specialist in this domain to cross check the results gained from the questionnaire analysis. The interviewees received in advance a brief description of the questionnaire contents to be prepared for the interview.

The conducted interviews were made on proper timing for the interviewees in order to get accurate results and their feedback regarding the findings and possible discrepancies.



**Fig. 2. Methodology flow chart**

### 3.1 Limitation of this Research

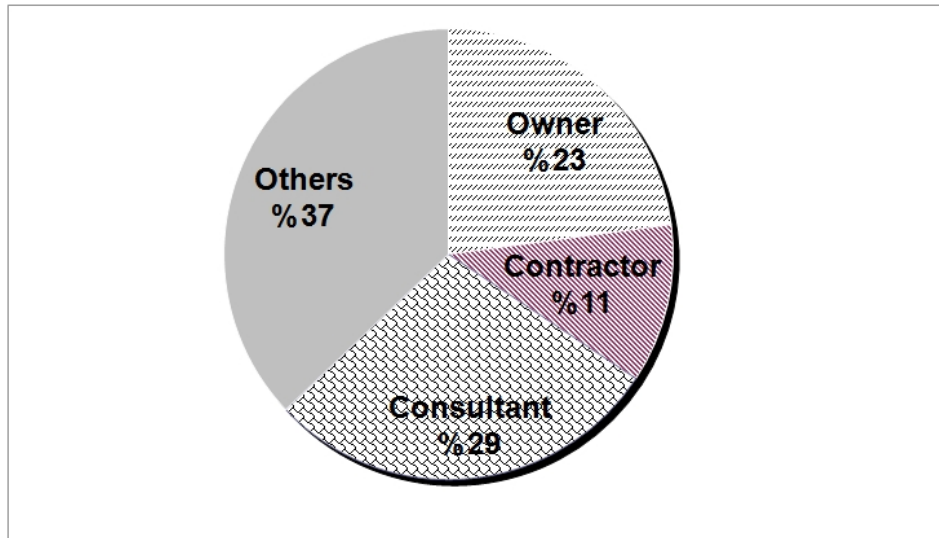
The implementation of Value Engineering is applicable to the project life cycle. Due to time limitation, this research will concentrate the study of applying of Value Engineering in design and tendering stage.

## 4. RESULTS AND ANALYSIS

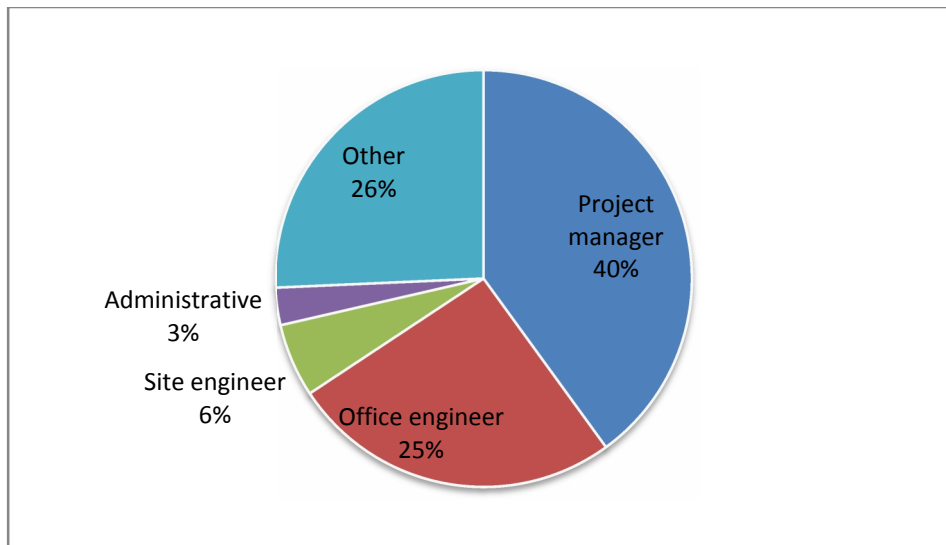
### 4.1 Questionnaire Results

In Fig. 3, it was noticed that the variety of organizations and companies in which the respondents are working. This will enrich the study and ensure of having good presentation for wide views. There is several potential prospective presented in the different public and private sectors in addition to the largest representative sector (others) which represents several organizations such as regulator bodies, International Non Government Organizations (INGO's) and National Government Organization (NGO,s) which are deeply involved in the field of study.

Fig. 4 indicated the position of the respondent: majority of the sample were project managers with rate equals 40%, 26% were office engineers, 6% were site engineers. Such finding was expected as the scope of study and the relevant experience to participate in this survey require persons in certain positions related mainly to wide experience in managing similar projects as projects managers and design experience such as office engineer.



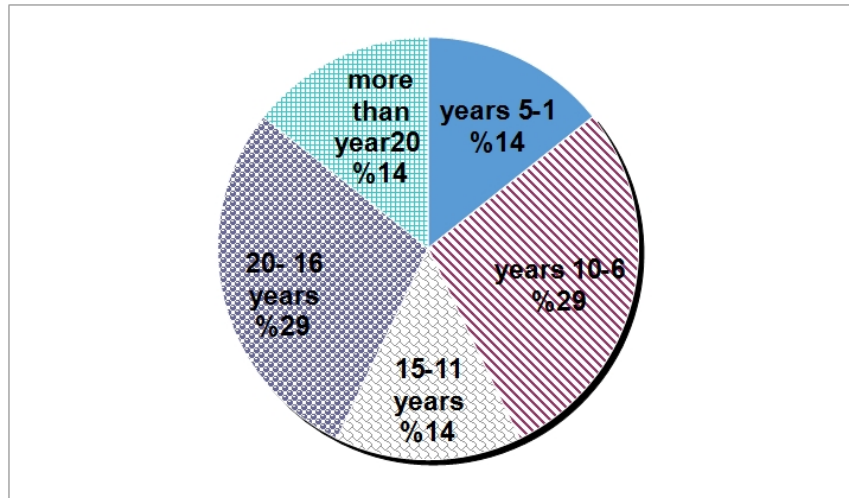
**Fig. 3. Type of the company or organization of the study sample**



**Fig. 4. Position in the company or organization of the study sample**

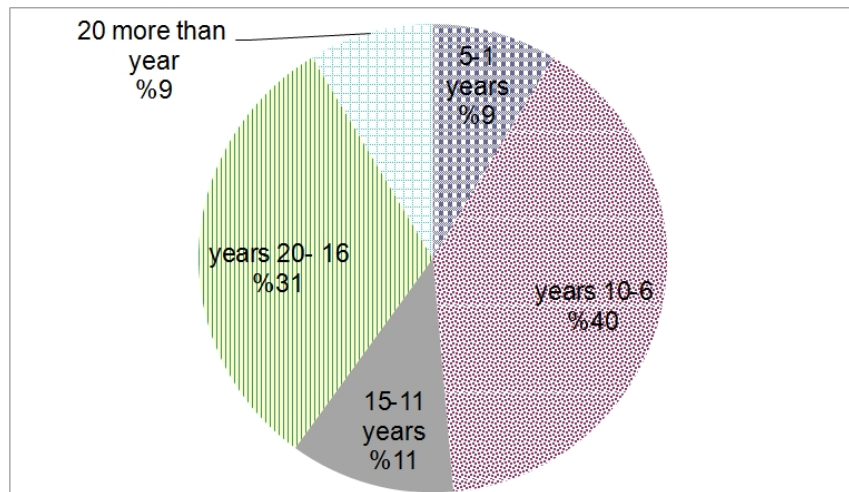
Fig. 5 illustrated the years of experience in field of water: reflection type of respondents position mentioned in Fig. 4, the majority was divided between two sectors. 29% of the study sample has experience for 6-10 years which represent mainly the office engineers. Similarly, 29% have 16-20 years of experience in the field of water, which represent the project managers working in the water sector.





**Fig. 5. Experience in the field of water (years) of the study sample**

Fig. 6 showed the relevant margins years of company experience. The majority of the sample having 6-10 years of experience with rate equals 40%. This implied that most of the company are newly participating in the water sector which are mainly the INGOs and consultant companies. 31% having 16-20 years of experience.



**Fig. 6. Experience of the company in the field of water (Years)**

To figure out the most important factor affecting the establishment of desalination plants, the followings were computed: the percentages, the percentage weights, means, and Standard Deviation (S.D) for each single factor, and total factors importance. Related results are shown in Table 1.

From Table (1), the most important six factors are: Factor No. 13, Power (electricity source) feeding the plant which came in the first place with mean value equals to 4.6 and percentage of weight 92.6%. This finding confirm the agreement and emphasize on the relevancy of the

power source and consumption aspect in decision making and its importance in playing a leading role in the production process and direct financial reflection on the tariff of cubic meter.

Factor No. 1, the nature, and location of the water (open source, shallow wells, etc.) feeding the plant, which came at the second place, with mean value 4.34, and percentage weight 86.9%. The majority of the experts agreed on this factor of importance due to its direct effect in terms of design of the desalination plant. The type of intake for the desalination, which will feed the plant, was subjected to several analyses. According the designer was considered the proper pretreatment needed for the plant and the adequate chemical additive's to be used in this stages prior to main treatment in order to eliminate or minimize the potential damages on the membrane (Reveres Osmoses "RO" Units).

Factor No.3 (Quality of water produced from the plant) which came at the third place with mean value equals 4.2 and percentage weight 84.0%. This factor is relevant to identify the number of stages and passes needed in the treatment plant. Based on the specified quality and criteria of the permeate (product) the designer will specify the number of membrane needed for each stage. The need for second or this pass is to reach to the required TDS amount. Obviously, this will influence highly the cost of establishing the plant and the operational and maintenance cost as well.

Factor No. 21 (Provision of land necessary for the construction of the plant) which came at the 4<sup>th</sup> place with mean value equals 4.20 and percentage weight 84.0%. This factor have a significant importance in Gaza Strip context due to the limitation of allocated lands for such projects. The problems that might be raised from the community due to their rejection of such project close to their agriculture land or residences. In other countries this factor may not take the same order in importance as such problem is not significant or even not existed due to the wide availability of free land owned to the government.

Factor No. 18 (Operation and maintenance cost) which came at the 5<sup>th</sup> place with mean value equals 4.17 and percentage weight 83.0%. The operation and maintenance cost in desalination plant is quite expensive and require plenty of money to ensure availability of enough stockpile of chemicals and spare parts for working pumps. Moreover, some of the chemical additives require special coordination and take long time to enter to Gaza Strip which make additional obstacle to the pretreatment process.

Factor No. 11 (Identify project risks) which came at the 6<sup>th</sup> place with mean value equals 4.0 and percentage weight 81%. All parties agreed that such projects need precise reading for different potential risks such community acceptance, completion with locally purchased water and environmental risks.

Interviews were conducted with selected focus groups results are reported as follows:

What is the importance of the participation of the parties in identifying the main elements for the plant?

To figure out the most important participation of the parties in identifying the main elements for the plant, the followings were computed: the percentages, the percentage weights, means and standard deviation for each single party, and the total importance of parties. Related results are shown in Fig. 8.

**Table 1. The results of weight for the factors affecting the establishment of desalination plants**

No.	Statement	Weak	Poor	Fair	Important	Very important	Mean	% Weight	Order
1	The nature and location of the water (open source, shallow wells, etc.)	0.0	0.0	14.3	37.1	48.6	4.34	86.9	2
2	The quality of Water feeding the plant	0.0	5.7	22.9	42.9	28.6	3.94	78.9	9
3	Quality of water produced from the plant	0.0	5.7	17.1	28.6	48.6	4.20	84.0	3
4	The nature of the distribution plant and its location close to the desalination plant	5.7	8.6	37.1	34.3	14.3	3.44	68.7	21
5	Licenses and legal framework for the establishment of desalination plant	0.0	0.0	31.4	51.4	17.1	3.86	77.1	12
6	The type of the project contract (lump sum, itemized boq contract, cost with fixed profit)	0.0	2.9	42.9	40.0	14.3	3.66	73.1	16
7	Type of tendering process (national tender, international tender, short list, direct awarding)	0.0	5.7	20.0	57.1	17.1	3.86	77.1	12
8	Implementation period	0.0	14.3	40.0	37.1	8.6	3.40	68.0	22
9	Productive capacity of the plant	2.9	0.0	22.9	45.7	28.6	3.97	79.4	8
10	The existence of competitive projects	5.7	2.9	48.6	28.6	14.3	3.43	68.6	20
11	Identify project risks	0.0	2.9	22.9	40.0	34.3	4.06	81.1	6
12	Preference and the desire of the owner of the project	5.7	5.7	48.6	31.4	8.6	3.31	66.4	23
13	Power (electricity source ) feeding the plant	0.0	2.9	2.9	22.9	71.4	4.63	92.6	1
14	The existence of employment and technical capacity for the implementation	0.0	5.7	20.0	48.6	25.7	3.94	78.9	9
15	The existence of employment and technical capacity for operation	5.7	0.0	20.0	51.4	22.9	3.86	77.1	12
16	Environmental impact of the plant	0.0	8.6	40.0	28.6	22.9	3.66	73.1	16
17	Water distribution network	0.0	5.7	37.1	45.7	11.4	3.63	72.6	18
18	Operation and maintenance cost	0.0	0.0	20.0	42.9	37.1	4.17	83.4	5
19	The initial treatment phase	0.0	11.4	22.9	42.9	22.9	3.77	75.4	15
20	Insurance for the plant and its equipment	0.0	8.6	40.0	37.1	14.3	3.57	71.4	19

21	Provision of land necessary for the construction of the plant	0.0	8.6	20.0	14.3	57.1	4.20	84.0	4
22	Equipment required for construction (available locally, need to import)	0.0	2.9	31.4	25.7	40.0	4.03	80.6	7
23	Disposal system of salty water	0.0	8.6	22.9	40.0	28.6	3.89	77.7	11
24	System followed to pay back the loan (if any)	0.0	22.9	25.7	48.6	2.9	3.3	66.3	24
<b>Average Importance of Factor</b>							3.84	76.8	-

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Fig. 7 showed the different factors ranked in descending order in accordance to their importance:

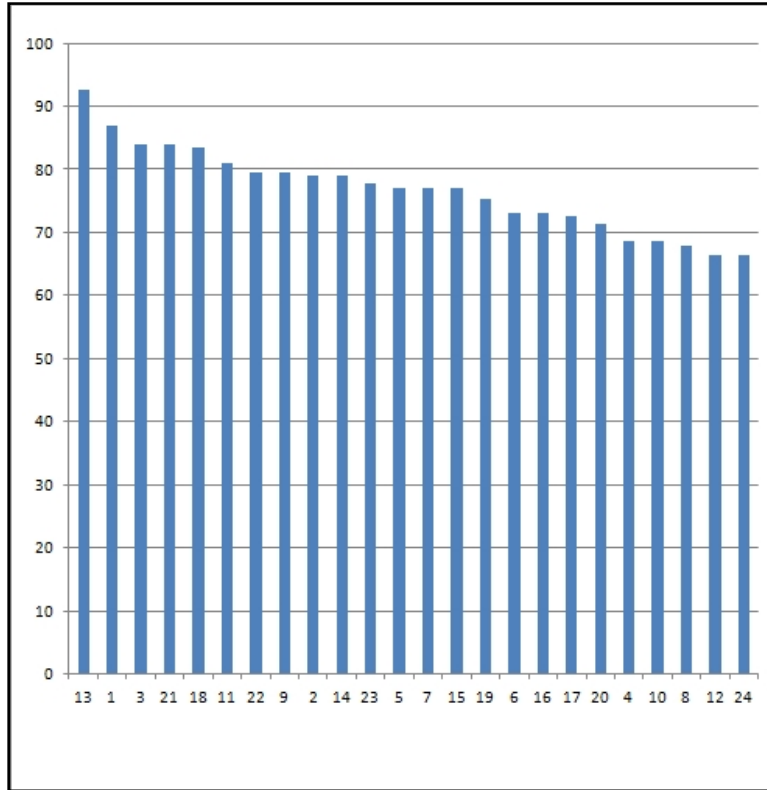


Fig. 7. Weights and orders for factors affecting establishment of desalination plants

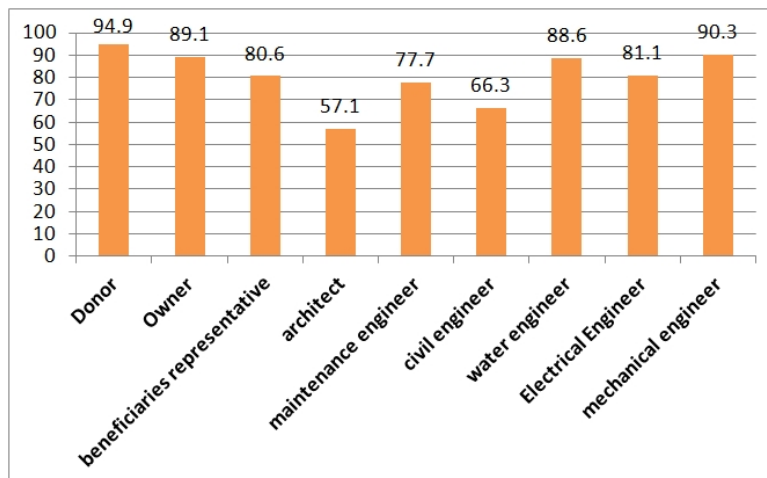


Fig. 8. Orders and percentages for party's participations importance

The most important three parties' participations are as shown in Fig. 8.

Party No. 1 (Donor) which came at the first place with mean value equals 4.7 and percentage weight 94.9%. Obviously, the donor is the key person on this issue as all remaining parties will respect his regulation and criteria, moreover the planner are governed by the budget limitation given from the donor. Accordingly, based on the donor the project planning, designing, and implementing phases will be affected positively or negatively.

Party No. 9 (The mechanical engineer) which came at the second place of importance in participation with mean value equals 4.5 and percentage weight 90%. The qualification and skills of the mechanical engineers are highly important in desalination project and decision making for identifying type and capacity of each instrument installed in the desalination units. In adequate calculation for any part will lead to real impact on the cost and may have serious financial consequences.

Party No. 2 (owner) which came at the third place of with mean value equals 4.4 and percentage weight 89%. The owner who will take over the project after completion will be responsible for the operation and maintenance aspects as well. Due to his participation is mandatory in all phases especially in the planning stage to ensure his satisfaction with the outcomes.

## **4.2 Interviews Analysis**

From the conducted interviews with the specialists, several points can be concluded as follow:

- Generally, the findings of the questionnaire conformed with the specialists expectations and expressed their satisfactions. However, the interviews lead to some additional points which considered as value added to the study:
- It is important to expand the sample to include external consultants or companies working abroad as they have wide experience in this sector while the expertise in Gaza strip still very limited.
- The location of the desalination plant is very important factor, as the usual practice in this aspect worldwide preferred to establish the plant close to the sea in order to eliminate the need of pressure line and reservoirs for storage purposes.
- It is important to ensure the reliability of cash flow through the project implementation phases in order to guarantee the continuity of good progress from the contractor side and not to suspend the work due to lack of fund.

## **4.3 Case Study**

This section discussed the application of the adopted value engineering procedures on the selected case study, the findings in this section covered the second objective of the research is to identify the impact of applying the value engineering methodology on the selected project: (Deir El Balah desalination plant). The selected project represents the second phase for the existing plant which intended to extend the provided production capacity of 2400 m<sup>3</sup>/day of potable water in addition to the current production of 600 m<sup>3</sup> / day produced by the existing plant.

Moreover, the master plan of the Deir El Balah desalination plant intended to implement a third phase in future with capacity of 3000m<sup>3</sup> /day to reach to a total production capacity of 6000 m<sup>3</sup>/day.

#### **4.3.1 V.E Technical supporting team**

In order to reach to the optimum scenario adopted from the application of the value-engineering concept on the selected case study, several contacts lines were established with experts and specialist in different field to consult them in results and take the advantage of their technical support in this regard.

The application of the Value Engineering study was conducted by adopting the methodology presented in SAVE international guidelines. Obviously, the study has taken into consideration what is suitable for the selected case study and possible parameters governing the context of study. To collect the needed information relative to the study, the experts and persons in charge who owned the different information for the project of extension of Deir El Balah desalination plant were approached. Telephone calls and personal meetings with relevant authorities' representatives were done.

The elements of the quality model were developed through a workshop with the project owner representative Costal Management Water Unit (CMWU). However, the findings obtained from the questionnaire were one of the main references for the level of importance of the model-adopted elements. Table 2 presented the main quality model elements.

#### **4.3.2 Cost estimate for master format (bill of quantities)**

The project bill of quantities is one of the main components of the project. CMWU cost estimate is presented against each item. The below bills will be formatted in the next section to uni-format bill of quantities in order to specify the controlling elements to be considered for the creativity phase and cost reduction based on the relativity to quality model presented above. Table 3 showed the summary of the project components associated with cost estimate.

#### **4.3.3 Uniformal presentation for the bill of quantities**

In order to specify the most items controlling the cost in accordance to Pareto Law. The standard BoQ to Uniformal BoQ contained 149 items was formulated. The Pareto law stated that 20% of the functions control 80% of the cost. To verify the validity of the law in this case, the uniformal BoQ items were sorted in descending order in terms of cost, by accumulating the cost of the uniformal items. According to Pareto law 20 % of the items in our case is 20 % of the 149 items, which equal to approximately to 30 items. In Table 4, the cost of the first 30 items out of 149 forms 1,692,700 USD of the total cost 2,171,409 USD represent percentage of 77.9 %. 30 of the functions form almost 78 % of the cost which is very close to the Perato law. The function listed in Table 4.

**Table 2. The main quality model elements**

No	Element	Level of importance	Findings from the questionnaire
	<b>Operations</b>		
	Operational effectiveness	Very high	The operational aspects appears high priority in the questionnaire findings such: power consumption, water location and sources
	Flexibility /expandability	High	The project represent the intermediate phase of the plant and must be expandable for the third phase requirements
	<b>Resources</b>		
	Capital cost	Very high	Budget limitation for this project : currently allocated 2.1 million USD and searching for potential donors for the third phase
	Operations and maintenance	Very high	Questionnaire findings
	Schedule	Fair	Questionnaire findings
	<b>Technology</b>		
	Security /safety	fair	The findings show that relevant insurances are not one of the priority as the components are already under the supplier and contractor warranty
	Engineering performance	High	Performance will lead to the expected outputs
	<b>Image</b>		
	Architectural view	Fair	The architectural view is not too much relevant to the main function of the project
	Community value	Very high	Due to the relevancy of the project to their needs and direct impact on their attractiveness to accept the project and purchase the produced water
	<b>Environmental impact</b>		
	Reflection on the environment	Very high	Not to cause pollution or environmental risk on the aquifer
	Land space	Very high	Questionnaire findings
	Considerable risks	Very high	Questionnaire findings



**Table 3. Summary of project bill of quantities**

<b>Upgrading and 2000m<sup>3</sup>/day expansion of sea water Ro Desalination plant-Deir Al Balah</b>		
<b>No.</b>	<b>Item Description</b>	<b>Total US\$</b>
	Drilling and equipping sea water beach well and pressure force main installations	215,160.00
2	Supply, install, and test factory assembled skids mounted Sea Water RO Desalination Plant	1,522,000.00
3	Quality Testing Units & Equipment	11,070.00
4	Spare Parts & Chemicals	50,090.00
5	Construction of RO Plant Building Fabric and Its Services	193,889.00
6	Generators and ancillary systems	179,200.00
<b>Total US\$</b>		<b>2,171,409.00</b>

**Table 4. Summary of recommended proposals for the bill of quantities**

<b>Propo sal No.</b>	<b>Proposal description</b>	<b>Advantage</b>	<b>Disadvantage</b>
Pro. 1	Redesign of the protection shed covering the Plant equipment	More Economic	None
Pro .2	Redesign of the used Reverse Osmosis by adopting the Pro-green RO instead of the Ordinary RO	More economic, Friend to environment, no chemical usage for pretreatment	New technology not used in Gaza before in spite of being adopted in many desalination plants world wide
Pro.3	Redesign of buffering tanks requested to supply and install of new FPR tanks with capacity of 40 m <sup>3</sup> and total number of 8 tanks by using the existing reservoir serving the original plant	More economic, less space occupation in the plant	May need more tanks in case of large extension in future
Pro.4	Reducing the capacity of the break water tank from 50 m <sup>3</sup> to 15 m <sup>3</sup>	More economic, less space occupation, easier for cleaning and maintenance works	None
Pro.5	Redesign of the needed capacity of new generator from 900 KVA as mentioned in the BoQ	More economic, ensure good operating conditions, long life for the generator, reduce the operation cost and need for spare parts	None

#### **4.3.3.1 Creativity phase**

The value engineering study is referred in this phase to the components of the items identified in Table 4. area of high cost or elements with potential improvements characteristics. The analysis of these components will be made on the base of keeping the same function at the level of owner importance degree illustrated in the quality model. The discussion objective is to creative possible alternative for these components whenever it is applicable with a presentation of its advantages and disadvantages. Several proposals were discussed and gathered from the experts. The proposals were developed and generated in Table 4.

#### **Presentation of the Proposals**

A detailed discussion was held regarding each proposal generated in Table 5. The discussion was considered both advantages and disadvantages as follow:

#### **Proposal No (1)**

The area of the shed that includes the equipment can be reduced from 1000m<sup>2</sup> to minimum of 700-m<sup>2</sup> taking into consideration the free space needed between the instruments and connections. This will affect the total cost estimate of the corrugated steel sheets used in the roof.

#### **Proposal No (2)**

Considering the Pro green system which is a good choice for main treatment process of sea water or brackish water. By considering the said RO, the system will gain several advantages over the ordinary one as follow:

1. No chemicals required unique ecological "green" pre-treatment & desalination processes.
2. Patented DOC (Direct Osmosis Cleaning) system
3. Long term energy consumption reduction
4. Chemical free membrane cleaning
5. Uninterrupted operation for stable performance
6. No infrastructure investment, reduced transportation, maintenance, and personnel costs.

**Table 5. Eliminated items from original BoQ due to redesign of RO unit**

Item	Description	Unit	Qty	Unit Price\$	Total US\$
1	Supply, install, and test Pre-Chlorination feed system Prominent or equivalent, injected upstream of the Raw water Tank. Required to sterilize the raw water, (1) duty metering pump , 0-7liter /hour, and tank level switch	Item	2	1,800	3,600
2	Supply, install, and test Coagulation feed system Prominent or equivalent, injected upstream of the Raw water Tank. Required to catch colloidal particulates, form floc, consisting of, (1) duty metering pump, 0-9 liters/hour, Static pipe inline mixer and tank level switch	Item	2	2,000	4,000
3	Supply, install, and test Feed pH adjustment Acid feed system Prominent or equivalent approved, injected upstream of the RO unit. Injection of acid solution is required to prevent the CaCO <sub>3</sub> precipitation in the RO membranes, (2) duty metering pumps 0-5liter/hour, tank motorized mixer and tank level switch	item	2	2,500	5,000
4	Supply, install, and test Antiscalant scale control feed system Prominent or equivalent, injected upstream of the RO unit. Injection of antiscalant solution is required to prevent CaCO <sub>3</sub> , CaSO <sub>4</sub> precipitation in the RO membranes, (1) duty 0-5 liter/hour metering pumps, , tank motorized mixer and tank level switch.	item	2	2,000	4,000
5	Supply, install, and test De-chlorination feed system Prominent or equivalent approved, injected upstream of the RO unit. Injection of sodium meta-bisulfite solution is required to protect the membrane from physical damage (1) duty metering pumps 0-4liter/hour, tank motorized mixer and tank level switch.	item	2	1,800	3,600
6	Dosing pump, complete	pcs	2	2,000	4,000
7	Wear & Tear Kit BETA	pcs	4	150	600.
8	Pressure Control Valve S-DL	pcs	2	200	400.
9	Wear & Tear Kit	pcs	2	120	240.
10	Pressure Control Valve S-DL	pcs	1	200	200.
11	Complete dosing pump	pcs	1	700	700.
12	Wear & Tear Kit	pcs	2	120	240.
13	Pressure Control Valve	pcs	1	250	250
14	Hydraulic Acid 30%wt	kg	3000	0.50	1,500
15	Sodium Metabisulfite powder	kg	500	4.00	2,000
16	Ferric Chloride 40% wt	kg	1000	2.00	2,000.
<b>Total saving USD</b>					<b>32,330</b>

The concept of technology based on providing additional feed channel spacers to the membrane layers and to outer warp, which will prevent more of undesirables particles to permeate from the membrane to next stage of treatment. This will lead to significant

elimination of pretreatment process of the feed water line as this process contained the injection of at least three chemical additives as follow:

- Hydrochloric acid: for PH adjustment of water in the pretreatment stage,
- Ferric Chloride: for flocculation of water molecules,
- Sodium Meta sulfite: for removal of chlorine.

Accordingly, the majority of the items related to pretreatment stage in this regard will be canceled in the original BoQ as indicated in Table 5.

The total saving resulted in capital cost will be 32,330 USD. Moreover, this will have also direct impact on the operational cost related to the chemical additives bags need on yearly bases.

the cost of doze of each chemical that will be eliminated due to the usage of pro-green RO will be saved, the chemical needed for pretreatment process used in feeding line of Deir El Balah Plant as per specifications of designer are items 1,3. By doing the necessary calculation to identify the yearly demand of these chemicals and the cost of each one, a total yearly saving of 127,650 \$ as illustrated in Table 6.

### **Proposal No (3)**

During the appraisal of the original design and Bill of quantities, it was noticed that designer requested an additional 8 FPR tanks with capacity of 40 M3 and total cost of 120, 000 USD as indicated in item (4) to receive the feeding water and store it prior to enter the pretreatment stage.

By evaluating the current situation in the original plant, it was noticed that existing reservoir serving the original plant can also receive the new feed line for the extension stage as this reservoir is used only as buffering tank (to synchronize between the inlet and out let flow ) and not originally designed as full capacity storage.

As a proof, the necessary calculation of the flow rate of new and original feeding lines to verify the adequacy of the current reservoir as indicated below:

Original reservoir capacity = 300 m3.

The permeate (product of treated water) from the original plant= 600 m3/day

Working hours of days are 23 hours (the remaining hour is for cleaning and flushing)

Hourly permeate = 600 /23 Hours = 26 m3/h.

Feed = (permeate /recovery)\*100

Feed = (26/0.4)\*100= 65 m3/h (original inlet flow to the reservoir)

Similarly, the feed of the new extension will be:

Permeate = 2400 m3/day = 104 m3/h

The recovery requested on the design is not less than 45%

Accordingly, Feed = (104 /0.45)\*100 = 231 m3/h (new inlet flow to the reservoir)

The total feed from both lines will be = 65+ 231 = 296 m/h less than the total capacity of the reservoir in addition to its usage as buffering tank only to synchronize between the inlet and outlet flow to feeding pumps. Accordingly, the tanks indicated in item 2.1.2(4) will be extra and can be eliminated.

**Table 6. Yearly operational cost saving from redesign of RO unit**

Type	Purpose	Dosing rate	Feeding Source Capacity M3/hr	yearly Demand (m3)	Avg Consumpt. rate (kg/m3)	Yearly Consumption (Kg)	Cost /kg	Total yearly Cost
		g/m3	Constant =200m3/h	200X23 HrX300 Day		Y.D.X Avg of Dozing weight	\$	\$
Hydro-chloric acid	PH adjustment for scale control	100 - 150	200	1,380,000	0.13	172,500	0.50	86,250
Ferric Chloride	Flocculation	5 –15	200	1,380,000	0.01	13,800	2.00	27,600
Sodiummetasulfite	Chlorine removal	2 – 3	200	1,380,000	0.00	3,450	4.00	13,800
Total Yearly saving from Chemicals								127,650

**Proposal No (4)**

Supplying and installing new breaking tank of capacity 50 m<sup>3</sup> between the first and second pass of RO Units are too large and can be reduced to 15 m<sup>3</sup> as maximum. As proof, the current flow rate (in/out) between the first pass and the second pass in the original plant is 35m<sup>3</sup>/h while the breaking tank capacity is only 2 m<sup>2</sup> in total without any deficits or over flow. By considering this fact, it was founded that the required capacity needed of the new breaking tank for the new in/out flow of 200 m<sup>3</sup>/h will be equal to  $(2*200)/35 = 11.4$  m<sup>3</sup>. The adequate commercial size available in the market will be 15 m<sup>3</sup>. The estimate cost of the 15 m<sup>3</sup> tank is 9,000 USD which make a total saving in this item of 30,000- 9,000= 21,000 USD.

**Proposal No (5)**

Supply and install new generator with capacity of 900 KVA, with an estimated cost of 150,000 USD. A revision of the required power demands to operate the entire system was made in details.

Based on the findings, the actual need of power capacity is 660 KVA, which has an approximate estimated cost quoted, from the suppliers as 105,000 USD. This lead to significant saving in capital cost of 45,000 USD. Moreover, a data was gathered from the supplier catalogues in order to calculate the saving from operational cost as follow:

- Generator with 900 KVA capacity consumes approximately 150 liter /hour
- Generator with 660 KVA capacity consumes approximately 80 liter /hour
- The hourly consumption difference is 70 liter /hour
- Based on the assumption of CMWU to operate the generator. For 8 hours only per day in accordance to GEDCO schedule for power cut off.
- The annual saving of operational cost will be = 8Hr X 70 lit X 300 Day X 1.2 \$ = 201,600 USD. Table 7. Show the summary of cost saving from all proposals.

**Table 7. Summary of cost saving from all proposals**

No.	Item	Before proposal	After proposal	Gross cost saving
1	Proposal No1	20,000	14,000	6,000
2	Proposal No2	32,330	0.0	32,330
3	Proposal No3	120,000	0.0	120,000
4	Proposal No4	30,000	9,000	21,000
5	Proposal No5	150,000	105,000	45,000
<b>Total of cost saving</b>				<b>224330</b>

Based on the results from the Table 7, the percentage of cost saving due to the five proposals was  $(224330/2171409)*100 = 10.33$  %.

The impact of applying the value engineering procedures on the project lead to significant cost reduction of 10.33 % of the estimated cost of the project in addition to the annual operational cost saved from proposals (2) and (5) of 329,250 USD.

## **5. CONCLUSION**

The following may summarize the research finding:

The application of value engineering on the selected case study has direct impact of cost saving of approximately 10.33 % for this project in addition to the annual operational cost of approximately 330,000USD.

For desalination plants, the Power source and consumption aspect is the most important factor affecting the decision-making. This factor has significant influence in specifying the specific cost for production and accordingly the tariff of cubic meter. Moreover, the power aspect is playing a leading role in identifying the type of technology used for desalination process.

The characteristics of "inlet flow" and "desired quality of the permeate" are governing the required stages of treatment and the needs for pretreatment and post treatments stages.

The allocation of necessary Land for establishing the desalination plant have a significant importance in Gaza Strip context due to the limitation of free lands and the problems that might be raised from the community due to their objection of such project it is close to their agriculture land or residences.

The experience in seawater desalination technology is somehow limited in Gaza to the experts such as projects managers and consultancy office engineers, other infrastructure engineers have limited knowledge in this field due to the limited number of projects implemented in this regard.

During the planning stage, it is important to identify the potential risk from establishing desalination plant, in particular the marketing possibility for the product, environmental impact, and community acceptance.

The donor play significant role in decision making as the planner and designer will consider in their arrangements the budget limitation and donor policy.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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