Value Engineering Applications to Improve Value in Residential Projects

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Abstract: Value engineering is a powerful approach for cost saving and quality improvement. Especially since the construction industry holds a significant weight with respect to the worldwide economy. Currently, value engineering does not influence just project costs and quality, but also it proved to have positive impacts on the environment and the worldwide trend of green construction. Value engineering takes into consideration both the initial and life-cycle costs. This paper presents three case studies of value engineering applications in the architectural and electromechanical disciplines in a real large-scale residential project. In these case studies, the methodologies and calculations of the value engineering study are presented. The overall estimated savings of the project resulting from the full value engineering study ranged between 20% to 50% percent of the element cost; hence a significant reduction in the overall project cost. The paper then provides a semi-generic recommendation matrix for design alternatives in various disciplines and their summarized advantages on residential projects. The provided matrix shall assist designers at very early design stages to produce economically and aesthetically efficient design modules.

Keywords: Value engineering, savings, construction, cost.

1 Introduction

Value Engineering (VE), also referred to as Value Methodology (VM) or Value Analysis (VA), is a systematic process to improve the value of a project through the analysis of its functions. Value is defined as a fair return or equivalent in goods, services, or money for something exchanged [1]. In other words, value is the ratio of function to cost; where the value is increased by either increasing the function or reducing the cost, or by both. Value Engineering was conceived in the days of World War II in the 1940s by Lawrence D. Miles; who was at that time the purchasing department manager at General Electric, which was a major defense contractor having shortage of strategic materials needed to produce their products due to the war. Mr. Miles formulated the concept of function analysis, which is the key foundation of VE. Mr. Miles studied the functions of products, and he indicated that clients purchase products either for the work they perform or for their aesthetic merits. So he investigated alternatives for the purpose of increasing the value while achieving the same functions without compromising the quality [2].

The VE methodology is generic in nature, which makes it applicable to almost all types of construction projects. Not only VE has significant advantages in functional improvements, cost reduction, and quality enhancement, but also studies have demonstrated that it leads to more effective teamwork and improved communication among stakeholders [6]. Individuals sometimes mix up between VE and cost reduction, however there is a significant different. The sole purpose of cost reduction studies is the cost reduction. So quality and even function might be sacrificed in the process. While on the other hand, the goal of VE studies is to increase value without sacrificing the function or the quality.

According to Cheah and Ting (2005) [6], there is a lack of knowledge about VE in some regions such as the South East Asian region. Accordingly, it is important to educate parties about the benefits and methodologies of VE. It also necessary to motivate parties to include VE provisions in contracts. As for the MENA region, a conference held on March 2009 "Arbitration and recent trends of the International Federation of Consulting Engineers contracts FIDIC and value engineering" was a pilot step to discuss the importance of the Value Engineering to measure the project efficiency. Al-Yousefy (2000) [7] presented a survey result done over 512 projects in KSA and Gulf Countries; and results were that: 61% of the owners were not satisfied about their projects as the projects are not reflecting the function required, 26% of the owners were partially satisfied as they were consulting professionals and, 13% were satisfied as they did specify their needs and objectives from the start. Still no comprehensive studies have been conducted in Egypt to investigate the understanding and application of Egyptian parties of VE. But, it can be in inferred, given the experience of the authors in the field, that most Egyptian stakeholder does not have sufficient knowledge on VE; which causes significant inefficiencies in designs.

Although the VE methodology of SAVE International is well established, some researchers shaped other methodologies and models for VE. Zhang et al. (2009) [8] introduced a methodology and tool set for generating innovative ideas and solutions for VE cases in a systematic approach and generic principles. However, that model does not use numerical analysis to provide quantifiable results of values and savings. Yet, it provides very creative solutions that are beneficial in the first steps of VE, which are the steps involving identifying functions and finding alternatives. Marzouk (2011) [9] presented a model that aids in the application of value engineering in construction projects. The main model modules were concordance indices estimation, discordance indices estimation, credibility scores estimation, distillation procedure, and complete ranking. However, the model falls short to highlight some of the main tasks of the VE such as the function analysis and the relevant comparative ranking of the alternatives.

The use of the VE methodology formulated by SAVE International is not prevalent in Egypt due to the lack of understanding of that methodology. Practitioners find themselves jeopardizing the quality and even some of the element functions for the sake of cost reduction. Moreover, they don't seem to provide creative alternatives due to the formulation of non-coordinated teams although team formulation determines the success or failure of a VE study. The construction sector is one of the most dynamic sectors in the Egyptian economy and has been growing rapidly since the 1980s. In 2000, the Egyptian construction market ranked 36th in the global construction market, constituting 0.4% of this market, for a value of $12.711 billion. Despite its fall from its 1998 ranking of 33rd, the Egyptian construction market actually increased in size by 23%. Egypt has a growth market in the construction that contains small, medium and mega scale projects in all sectors. Therefore the VE represents a crucial need to be applied in all projects from conceptual phase in order to achieve the maximum efficiency from the required function. This paper demonstrates the VE methodology by SAVE International and provides two case studies in the architectural and electromechanical disciplines for a residential project. The paper then provides a semi-generic recommendation matrix for design alternatives in various disciplines and their summarized advantages on residential projects. The provided matrix shall assist designers at very early design stages to produce economically and aesthetically efficient design modules.

2 VE Methodology

For any certain project, the VE study is applied by a multidisciplinary team to improve its value. SAVE International sets 6 sequential phases for performing a successful VE study. The phases are distributed in 3 stages; pre-workshop stage, workshop stage, and post-workshop stage. The methodology of the SAVE International VE studies, including stages and phases, is shown in Figure 1.

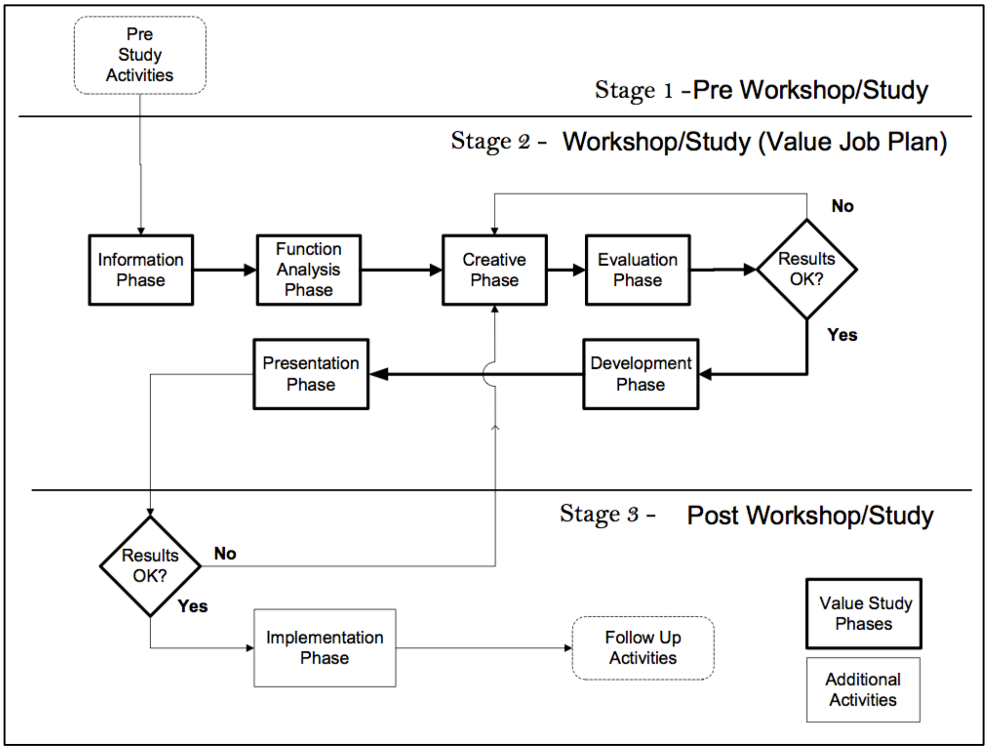

Figure 1: Value Study Process Flow Diagram by SAVE International

The scope of this paper covers the phases of the workshop stage (stage 2); which are the most technical in nature.

2.1 Information Phase

The purpose of this phase is to identify the constraints influencing the project decisions. The team collects data about project scope, schedule, budget, costs, risk, strategic objectives, and logistical needs. Tools such as SWOT analysis (Strengths, Weaknesses, Opportunities and Threats), tear down analysis, and Pareto analysis are used in this phase to ensure proper data collection and project understanding. The main outcome of this phase to the ensure that the team members have the same understanding of the project, leading to better derivation of creative alternatives in later stages with minimizing mismatches.

2.2 Function Analysis Phase

The purpose of this phase is to understand the project from a functional perspective, thus identifying the project intended functions [1]. In this phase, the functions are identified and classified. Functions are to be in a certain format where only two words are used in the function; a verb and a noun. For example, one of the functions of HVAC system is to "comfort user". Another example of a function of the interior design is "enhance inner view". The mostly used function model is the Function Analysis System Technique (FAST), developed by Mr. Charles W. Bytheway in 1964. The FAST diagram links the simply expressed verb-noun functions to describe complex systems. It has many symbols and notations. But the probably the most important information to know is that it answers three primary questions; how, why and when as shown in Figure 2. For further demonstration, the FAST diagram for a sample project is presented in Figure 3.

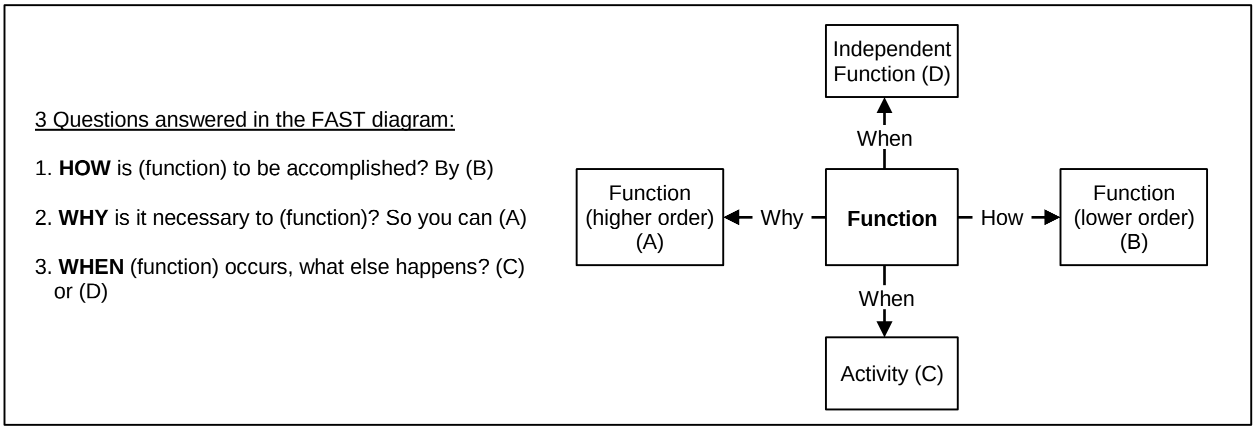

Figure 2: FAST diagram determinate logic

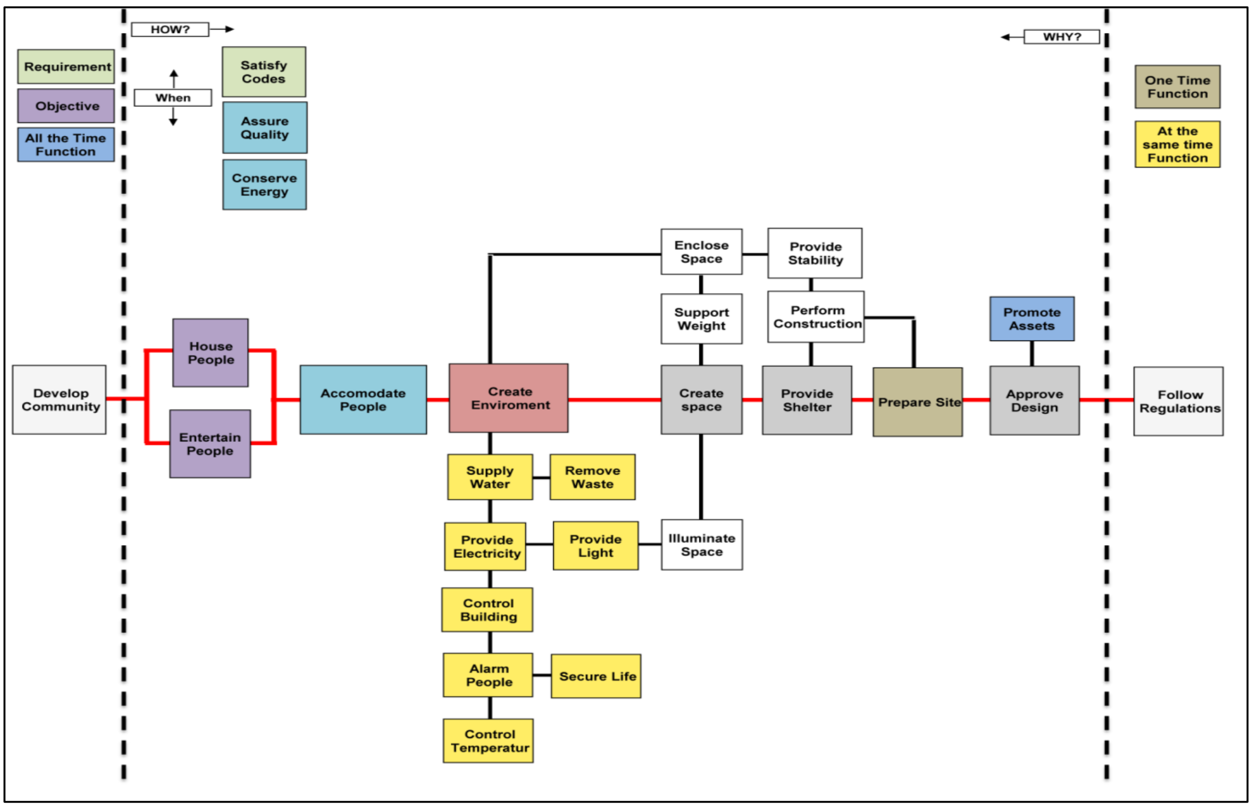

Figure 3: FAST diagram for a sample project

2.3 Creative Phase

The purpose of this phase is to produce a number of alternatives to perform the same functions. Some well-recognized techniques are recommended to be used in this stage such as brainstorming, Gordon technique, nominal group technique, TRIZ, and Synetics. There are not much rules in this stage as it is the most creative phase of all.

2.4 Evaluation Phase

The purpose of this phase is to evaluate the obtained ideas and reduce their quantity to a short list of ideas with the greatest potential to improve the project. Then this short list of alternatives is the one that is going to be studied in details in the later phases. It would be highly inefficient to thoroughly study each of the alternatives directly from the creative phase, as the number of ideas is large and many of them is not even beneficial for the project value, hence the need for the evaluation phase to filter out the non-beneficial ideas. Some of the tools that can be used in this phase are Pugh analysis, Kepner-Tregoe matrix, life cycle costing, choosing by advantages (CBA), and value metrics.

2.5 Development Phase

The aim of this phase is to provide further analysis to the list of ideas with the highest merit into value alternatives from the evaluation phase. The ideas are developed further into value alternatives that clearly stated so that the stakeholders have clear understanding of their impacts, savings, and effects on value. According to SAVE International, the obtained alternatives should include text, sketches, diagrams, assumptions, supporting calculations (including capital cost and O&M cost), vendor information, cost comparison work sheets, and other information which may be necessary to convey the intent of the alternative. This phase is the most demanding in terms of calculations.

2.6 Presentation Phase

In this phase, the results of the development phase are presented to the decision makers to assist them get the best understanding of the different VE alternatives and their short-term and long-term benefits. In this phase as well, an anticipated implementation plan is outlined.

Although there are several other methodologies for VE studies, authors, throughout the several VE studies that they have performed in the Middle East region, have concluded that the methodology formulated by SAVE International provides the most reliable results throughout its generic nature and highly organized comprehensive techniques. The discussed case studies are conducted using the SAVE International standards of VE.

3 Case Studies

3.1 Case No.1: Use of acrylic paint with ceramic tiles in the walls of wet areas in residential compounds.

The project under the study is a luxurious residential compound including 758 villas of different designs and styles to meet all needs and tastes, ranging from duplex villas to single villas. In the original design for the wet areas as kitchens and bathrooms, the architectural consultant proposed the use of ceramic tiles to cover the internal walls for decorative and functional purposes. The ceramic tiles were to cover the complete walls height. The following paragraphs provide a summary of the steps taken in the different phases of the VE study.

3.1.1 Information Phase:

At the start of the VE study, the project was in the design development phase. The VE team gathered all available data and drawings and met with the decision makers of the project owners to ensure proper understanding of the project purpose and standards. After preparing a cost model for the project, it was found that the current design would result in a total cost of SAR 719 Millions; with 52% of the cost on the architectural system. So, according to the PARETO model, the architectural system is the one that should be targeted most in the VE study because of its significant percentage in the cost. For this case study in the paper, the VE study of the finishing material of the walls of the wet areas is presented.

3.1.2 Function Analysis

The Basic Function for the finishing material is “cover structure”; and the primary secondary function is “enhance inner-view”. Based on this Basic Function the different alternatives were discussed.

3.1.3 Design Study

The original design for wet areas was to cover the total height of walls with ceramic tiles. The VE team generated many alternative ideas during the creative phase using brainstorming techniques and these ideas were recorded on the Idea Evaluation forms. The ideas were then discussed, and the advantages and disadvantages of each were listed. The team compared each of the ideas with the baseline concept to determine whether it was better than, equal to, or worse than the original concept (1-5). The team reached a consensus on the ranking of the idea. High-ranked ideas would be developed further; low-ranked ones with a score of 3 and less were dropped from further consideration. The VE team studied the original design considering the technical and financial sides. The following points were discussed:

- The aesthetic value of the bathroom considering the luxuriousness of the Residential compound.
- The installation of the ceramic tiles and the required precision and accuracy to have a neat look.
- The cost of the dry and installation for the Ceramic Tiles versus the acrylic paints.
- The Acrylic paint is much faster and easier to be installed than the ceramic, considering the time factor.
- When combining the Ceramic tiles with the acrylic paint it increases the aesthetic value for the area while maintaining the efficiency and the basic function for each material.

3.1.4 The QBS Study model:

The VE team studied the original design versus the two following alternatives:

- **<u>Alternative 1:</u>** The ceramic cladding covering 65% of the wall height to be covering the part of the walls in direct contact with the water and the rest will be acrylic paint.
- **<u>Alternative 2:</u>** The complete wall height will be acrylic paint.

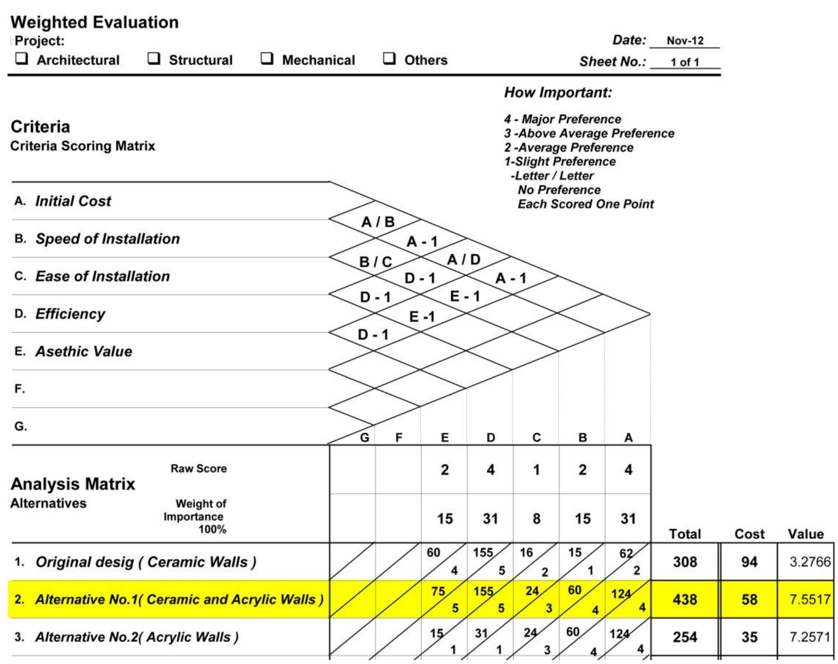

Figure 3: QBS Model comparing between the alternatives of the internal wall covering for the wet areas

To compare between the alternatives, a QBS weighted evaluation matrix is used. The QBS matrix is utilized to transform the non-monetary ideas into numbers, and to preform comparative evaluation of alternatives both qualitatively and quantitatively, resulting at the end to a number representing the value of each alternative; where the alternative with the highest value is the optimum one.
After using the QBS matrix to evaluate the different alternatives versus the original design it was found that Alternative No.1 is achieving the highest value considering the cost and all other parameters that can have a major influence on the efficiency and the basic function.

3.1.5 Case No.1 Conclusion:

After the study it was clear that:

- The acrylic paint has an initial cost much lower than the ceramic tiles in the walls.
  - Acrylic paint supply, apply and overhead = 35 SAR/m^2
  - Ceramic Tiles Supply, apply and overhead (considering the tile sizes specified by the consultant 40*40) = 94 SAR/m^2
  - The savings achieved from applying Alternative No.1 reached 50%
- When Applying the Proposed Design with the same criteria to any space there will be savings achieved reaching 40-50% according to the ceramic tiles sizes while maintaining the function and quality of the original design.

3.2 Case No.2: Air-cooled chillers to be replaced by Water-cooled chillers

This Case Study is studying the HVAC in a residential and commercial complex in a very distinguish zone in Egypt that excels with its historical era and its sea view. Therefore the project is considered to be a modern landmark in the area expressing the current modernism and development. The Original Design is as follows: commercial and retail area shall be equipped with a complete central air conditioning system. As for the residential units the original design is considering the DX Split system.

3.2.1 Function Analysis:

The Basic Function for the HVAC system is “Control Climate”; and the primary secondary function is “Provide Comfort”. Based on this Basic Function the different alternatives were discussed.

3.2.2 Design Study:

The Value Engineering team proposed the Water Cooled Chillers to be used as a central air condition in the retail and commercial area. These systems are more commonly found in large HVAC installations, given their efficiency advantages. The components of the chillers (evaporator, compressor, an air- or water-cooled condenser, and expansion device) are often manufactured, assembled, and tested as a complete package within the factory. These packaged systems can reduce field labor, speed of installation and improve reliability. Another benefit of a chilled-water applied system is refrigerant containment. Having the refrigeration equipment installed in a central location minimizes the potential for refrigerant leaks, simplifies refrigerant handling practices, and typically makes it easier to contain a leak if one does occur.

3.2.3 The Cost model:

The VE team studied the original design versus the two following alternatives shown in Table 1:

- The DX Split Unit System.
- The Water Cooled Chillers.

Table 1: Cost model comparison between HVAC alternatives

DEVELOPMENT PHASE - LIFE CYCLE COST (Present Worth Method)

PROJECT: Marseilia Florence Proposal No. Date 20/09/2012				Alternative 1 Dx Split Unit System		Original Design Air Cooled Chillers		Alternative 2		Alternative 3	
Capital Cost				Est.	PW	Est.	PW	Est.	PW	Est.	PW
A)	Dx Split Unit System			2,275,000.00	2,275,000.00						
B)	Air Cooled Chillers					4,875,000.00	4,875,000.00				
C)	Water Cooled Chillers							6,530,000.00	6,530,000.00		
D)											
Replacement/Salvage Costs		Year	Factor								
A)	repair and spare parts	2	1.0500	82,000.00	86,100.00	120,000.00	126,000.00	170,000.00	178,500.00		
B)	repair and spare parts	4	1.1580	82,000.00	94,956.00	120,000.00	138,960.00	170,000.00	196,860.00		
C)	repair and spare parts	6	1.2760	82,000.00	104,632.00	120,000.00	153,120.00	170,000.00	216,920.00		
D)	replacementreplacement	7	1.3400	2,275,000.00	3,048,500.00	120,000.00	160,800.00	170,000.00	227,800.00		
E)	repair and spare parts	10	1.5510	82,000.00	127,182.00	120,000.00	186,120.00	170,000.00	263,670.00		
F)	repair and spare parts	12	1.7100	82,000.00	140,220.00	120,000.00	205,200.00	170,000.00	290,700.00		
G)	replacementreplacement	14	1.8860	2,275,000.00	4,290,650.00	120,000.00	226,320.00	170,000.00	320,620.00		
H)	repair and spare parts	16	2.0790	82,000.00	170,478.00	120,000.00	249,480.00	170,000.00	353,430.00		
I)	repair and spare parts	18	2.2920	82,000.00	187,944.00	120,000.00	275,040.00	170,000.00	389,640.00		
J)	repair and spare parts	20	2.5270	82,000.00	207,214.00	120,000.00	303,240.00	170,000.00	429,590.00		
							-				
F)	Salvage (neg. cash flow)	20	2.5270	(100,000.00)	(252,700.00)	(250,000.00)	(631,750.00)	(200,000.00)	(505,400.00)		
Total Replacement/Salvage PW Costs					8,457,876.00		2,024,280.00		2,867,730.00		
Operation/Maintenance Cost		Escl. %	Factor								
A)	energy fees 5 years	5.000%	3.546	1,430,000.00	5,070,780.00	1,265,000.00	4,485,690.00	890,500.00	3,157,713.00		
B)	energy fees 10 years	5.000%	7.108	1,430,000.00	10,164,440.00	1,265,000.00	8,991,620.00	890,500.00	6,329,674.00		
C)	energy fees 15 years	5.000%	9.899	1,430,000.00	14,155,570.00	1,265,000.00	12,522,235.00	890,500.00	8,815,059.50		
D)	energy fees 20 years	5.000%	12.011	1,430,000.00	17,175,730.00	1,265,000.00	15,193,915.00	890,500.00	10,695,795.50		
Total Operation/Maintenance (PW) Costs					46,566,520.00		41,193,460.00		28,998,242.00		
Operation/Maintenance Cost		Escl. %	Factor								
A)	Water fees 5 years	2.000%	3.808		-		-	106,000.00	403,648.00		
B)	Water fees 10 years	2.000%	8.162		-		-	106,000.00	865,172.00		
C)	Water fees 15 years	2.000%	12.110		-		-	106,000.00	1,283,660.00		
D)	Water fees 20 years	2.000%	15.680		-		-	106,000.00	1,662,080.00		
Total Operation/Maintenance (PW) Costs					-		-		4,214,560.00		
	Total Present Worth Life Cycle Costs				57,299,396.00		48,092,740.00		42,610,532.00		
	Life Cycle (PW) Savings										

3.2.4 Case No.2 Conclusion:

After the study the owner chose to install water-cooled chillers for the commercial area and that's for the following reasons:

- The water film coefficient is 10 times better than air film coefficient so the heat transfer properties are higher than the air-cooled heat transfer properties given the same area and temperature.
- The system efficiency of the Air Cooled Chiller, for 24 hour operation in coastal areas the wet bulb temp is almost high so the night working time will not effect on the electrical consumption as it may still high as at day time. Considering the Air Water Chiller for 24 hour operation in coastal areas the electrical consumption saving is higher than air-cooled chillers because the properties of water don't change at night.
- Regarding the System life time; Air cooled chillers have lower life time especially for coastal areas due to environments and the climate. Water-cooled chillers have higher life-time and higher efficiency.
- Electrical power consumption: The air-cooled chillers use high electric power for each ton (1.2 KW / TR). So the electrical power consumption is higher than water-cooled. Water-cooled chillers use lower electric power for each ton (0.75 KW / TR). So the electrical saving is high.
- When discussing the noise; the Air-cooled chillers are noisy than water cooled chillers. Water-cooled chillers are less noisy than air cooled chillers.
- Although the initial cost for the Air Cooled Chillers is lower than the Water Cooled Chillers but over the LC of the Water Cooled chillers are less expensive by 15-20%

4 Semi-generic Recommendation Matrix for Design Alternatives

Table 2 provides a semi-generic recommendation matrix for design alternatives in various disciplines and their advantages on residential projects. The provided matrix shall assist designers at very early design stages to produce economically and aesthetically efficient design modules.

Table 2: Semi-generic Recommendation Matrix for Design Alternatives

No	Design Alternatives
1	The treated wastewater can be used for the flush tanks in the units and the irrigation system in landscape. **Advantages:** reduction in water consumption, and improvement of environmental considerations,
2	Changing the panic device horizontal push bar hardware to a regular handler for door type 2. Advantages: reducing initial cost and providing more safety.
3	Use painted wrought iron for the stairs handrails instead of the stainless Steel handrails. **Advantages**: reduction in initial cost without affecting life-cycle cost.
4	Use acrylic paint with the ceramic tiles in the wet areas wall. **Advantages**: reduction in cost whilst maintaining the aesthetic value.
5	Use ceramic tiles in the living, dinning and bedrooms area instead of porcelain floor tiles. **Advantages**: reduction in cost whilst maintaining the aesthetic value.
6	Use anti slip tiling in the showers instead of marble shower. **Advantages**: reduction in cost whilst maintaining the aesthetic value.
7	Reduce the excessive structural design. **Advantages**: reduction dead loads resulting in reduction in concrete and steel quantities. Better environmental and financial impacts.
8	Remove the water-resistant gypsum board from the W.C areas, and lowering the slab 15-20cm. **Advantage**: removal of the false ceiling cost.
9	Glass or wall mounted ex-fans for toilets instead of ceiling mounted. **Advantages**: reduction in cost and prevention of openings in external elevations.
10	Change the Aluminum sections from SHUCO Sections to other suppliers. **Advantages**: reduction in cost whilst maintaining the aesthetic value.
11	Changing the structure roof system from hallow blocks to solid slab. **Advantages**: reduction dead loads resulting in reduction in concrete and steel quantities. Better environmental and financial impacts.
12	Solar water heaters instead of electric heaters. **Advantages**: reduction in electricity consumption and maintenance cost. Increase in life-time by 50 years.
13	Rainwater collected to be used in irrigation for landscape or as grey water for flush tanks. **Advantages**: reduction in water consumption and improvement of environmental considerations.
14	Collect the A/C drainage system to be used in the irrigation. **Advantages**: reduction in water consumption and waste material whilst improvement environmental considerations.
15	Using stainless steel elevated tanks instead of Fiberglass tanks. **Advantages**: better durability and ease of maintenance.
16	Green roofs with plant species that need low irrigation rate. **Advantages**: better thermal insulation, thus less energy consumption.
17	Separate the waste and soil collected from ground floor from the waste and soil collected from other floors. **Advantages**: improved performance and avoidance of sanitary blockage.
18	Collect the waste from kitchens on separate line not on floor drain. **Advantages**: improved performance and avoidance of sanitary blockage.
19	Provide sound insulation in the duplex types in the common walls. **Advantages**: better privacy.
20	Wiring for lighting to be 3 mm^2 not 4 mm^2. **Advantages**: same function with less cost.
21	Use PVC/PVC for incoming cable instead of XLPE/PVC. **Advantages**: same function with less cost.
22	Put rating of spare C.B. for all ratings in panel board. **Advantages**: for ease of maintenance.

No	Design Alternatives
23	Maximum number of connected lighting fixtures to be not more than 10 lighting fixtures. **Advantages**: for safety according to standards.
24	Rating current of circuit breaker for lighting circuits to be 16A not 20A. **Advantages**: for safety according to standards.
25	Providing f.c.o. at the beginning and ends for all drainage pipes. **Advantages**: improved performance and avoidance of blockage.
26	Sandwich-paneled composite load-bearing walls instead of concrete skeleton. **Advantages**: significant reduction in construction cost and time (up to 50% reduction)
27	Reduce the thickness of the outer slab-on-grade for the parking from 200mm to 150mm. **Advantages**: reduction in cost.
28	Reduce the thickness of the slab on grade from 150mm to 100mm and remove the reinforcement. **Advantages**: reduction in cost.

5 Conclusion

Value engineering is a powerful approach for cost saving and quality improvement. Despite its world-wide known benefits, it is not applied in proper methodologies in Egypt and it is usually mixed-up with the concept of cost saving; thus practitioners find themselves reducing cost on by jeopardizing important elements such as quality and function. This paper illustrated the VE methodology provided by SAVE International, which is considered the official society for value engineering practitioners, and provided two case studies where such methodology was successfully applied resulting in cost savings and quality improvements whilst maintaining the design functions. In the projects that the case studies were extracted from, the result of the full VE studies that were made reached 19% cost reduction in the total project cost; which is a very significant percentage. The paper then provided a semi-generic recommendation matrix for design alternatives in various disciplines and their advantages on residential projects. The provided matrix shall assist designers at very early design stages to produce economically and aesthetically efficient design modules.

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