THE REPUBLIC OF TURKEY

İSTANBUL KÜLTÜR UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

THE IMPACT OF VALUE ENGINEERING ON MATERIAL SELECTION AN EXAMPLE FROM THE CONSTRUCTION INDUSTRY

MASTER OF SCIENCE THESIS

by Baraa A. S. QUFFA

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Department: Industrial Engineering

Program: Engineering Management

Supervisor: Assist. Prof. Dr Ibrahim Ethem TARHAN.

SEPTEMBER 2023

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TABLE OF CONTENTS

ACKNOWLEDGEMENT .... **iii**
TABLE OF CONTENTS .... **iv**
LIST OF TABLES .... **vi**
LIST OF FIGURES .... **vii**
LIST OF SYMBOLS .... **ix**
LIST OF EQUATIONS .... **x**
ÖZET .... **xi**
ABSTRACT .... **xiii**
1. INTRODUCTION **1**
1.1. Background to the Study 1
1.2. Statement of the Problem 2
1.3. Aim and Objectives 2
1.4. Research Map 2
2. LITERATURE REVIEW **4**
2.1. Origin and History of Value Engineering 4
2.2. Definition of Value Engineering 4
2.3. Value Engineering Terminology 7
2.3.1. The Main Difference Between Value Management and Reducing Costs 7
2.4. Importance of VE in the Construction Industry 8
2.5. VE in Construction Industry Around the World 11
3. METHODOLOGY **14**
3.1. The Application of VE 14
3.1.1. How to measure value 17
3.1.2. Value Main Elements 17
3.2. The Main Stages of Applying the Value Engineering Technique 18
3.2.1. The first stage: Pre-Workshop 19
3.2.2. The second stage: Workshop (Execution of the phase Job Plan) 20
3.2.3. The third stage: Post-Workshop 33
4. IMPLEMENTATION (CASE STUDY) **34**
4.1. Project Brief Information 35
4.2. Project Description 36

4.3. VE Study Team 36
4.4. Information Phase 38
4.5. Function Analysis Phase 41
4.5.1. Determine functions 42
4.5.2. Classification of functions 42
4.5.3. Function Analysis System Technique: FAST 58
4.6. Creativity Phase 59
4.6.1. Summary of Creativity Phase 65
4.7. Evaluation and Development Phase 65
4.7.1. First: Normative Assessment 66
4.7.2. Second: Comparative evaluation 75
4.8. Presentation and Implementation Phase 90
5. RESULT OF THE STUDY 96
6. RECOMMENDATIONS 100
6.1. Engineering Offices Recommendations 101
6.2. Recommendations to Governments (Owners of the Project) 102
7. CONCLUSION 103
BIBLIOGRAPHY 106

LIST OF TABLES

Table 2.1 The difference between value engineering and reducing costs. 7

Table 4.1 VE study team 36

Table 4.2 Cost estimate 39

Table 4.3 Area of study 40

Table 4.4 The analysis of the four highest-cost functions 42

Table 4.5 Team evaluation 60

Table 4.6 Normative assessment of the VE team for ceiling... 68

Table 4.7 Normative assessment of the VE team for wall 70

Table 4.8 Normative assessment of the VE team for HVAC 74

Table 4.9 Recommended alternatives. 75

Table 4.10 Summary of VE team alternative 91

Table 4.11 Summary of VE study 92

LIST OF FIGURES

Figure 3.1 The extent to which the different elements affect the cost of the project.......... 16

Figure 3.2 The relationship between the design stage and its cost in the project............... 16

Figure 3.3 Time when value engineering is performed in construction projects............... 17

Figure 3.4 Value's main elements.. 18

Figure 3.5 The Main stages of applying the value engineering technique......................... 19

Figure 3.6 Value methodology standards (SAVE International, 2020) 19

Figure 3.7 Job plan phases.. 20

Figure 3.8 Information form (Al-Yusufi, 2009). 22

Figure 3.9 Function analysis phases model (Al-Yusufi, 2009) 25

Figure 3.10 FAST plan diagram (Sundar, 2020) 26

Figure 3.11 Brainstorming form (Al-Yusufi, 2009)... 29

Figure 4.1 Value Engineering Job Plan (Al-Yusufi, 2009) 34

Figure 4.2 General plan of the project (Integrated Environment, 2023)............................ 37

Figure 4.3 Graphic of the project (Integrated Environment, 2023) 38

Figure 4.4 Diagram for MAGRABI office.. 59

Figure 4.5 The relationship between saving and budget cost 94

Figure 4.6 Wall finishes & Wall cladding.. 94

Figure 4.7 Ceiling finishes.. 94

Figure 4.8 MEP - HVAC savings 95

Figure 4.9 Total budget before and after the application of VE 95

Figure 5.1 Final project plan (Integrated Environment, 2023)... 97

Figure 5.2 Workshops (Integrated Environment, 2023).. 98

Figure 5.3 Workshops (Integrated Environment, 2023).. 98

Figure 5.4 Pictures from the site (Integrated Environment, 2023) 98

Figure 5.5 Pictures from the site (Integrated Environment, 2023) 99

LIST OF SYMBOLS

CAGR Compound Annual Growth Rate

VA Value Analysis

VE Value Engineering

VM Value Management

LIST OF EQUATIONS

Equation 1 Value Index 17

Üniversite	**: İstanbul Kültür Üniversitesi**
Enstitü	**: Lisansüstü Eğitim Enstitüsü**
Anabilim Dalı	**: Endüstri Mühendisliği**
Programı	**: Mühendislik Yönetimi**
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ÖZET

DEĞER MÜHENDİSLİĞİNİN MALZEME SEÇIMINE ETKISI İNŞAAT SEKTÖRÜNDEN BIR ÖRNEK

Baraa A. S. QUFFA

Değer Mühendisliğine olan ihtiyaç, büyük ölçüde %25'lik bir orana düşürülebilen inşaat giderleri harcamaları nedeniyle ortaya çıktı. Kalitesi düşük olan projelerin üretilmesi, hem üretim maliyetlerini yükseltmede hem de bakım giderlerinin kontrolünü güçlendirmektedir. Sonuç olarak, kalitesi düşük olan yapıların sürekli bakımlarının yapılması inşaat maliyetlerini yükseltmektedir. Sözü geçen bu problem, Değer Mühendisliğinin yöntem ve kavramları uygulanarak çözülebilir. Değer Mühendisliğinin uygulanması, yüksek kaliteyi korurken daha düşük maliyetle çözümler üretilmesini sağlar. Bu tezde, değer mühendisliği metodolojisinin inşaat projelerine uygulamanın etkisini bir vaka çalışması aracılığıyla cözümlenmesine gayret edilmiştir. Vaka çalışması için Suudi Arabistanda bulunan Magrabi inşaat projeleri ofisleri seçilmiştir. Çalışmanın sonucunda, Yüksek maliyetli malzemeleri belirlemek için Pareto'nun düşük değerleri kullanılarak, malzeme maliyetlerini toplam fiyatın %23,13 oranında azaltabileceğini kanıtlamıştır.

Anahtar Kelimeler: Değer mühendisliği, İnşaat Endüstrisi, Proje geliştirme, kaliteyi artırma, Düşük maliyet.

University	**: İstanbul Kültür University**
Instittute	**: Institute of Graduate Studies**
Department	**: Industrial Engineering**
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ABSTRACT

THE IMPACT OF VALUE ENGINEERING ON MATERIAL SELECTION. AN EXAMPLE FROM THE CONSTRUCTION INDUSTRY

Baraa A. S. QUFFA

The urgent need for Value Engineering has arisen due to the enormous expenditure in the construction industry, which could be reduced by up to 25%. This substantial spending is often accompanied by poor quality, leading to a constant need for reconstruction and maintenance. The methods and concepts of Value Engineering can be applied to address this issue. By using Value Engineering, solutions can be created that fulfill the same functional purpose at a lower cost while maintaining high quality. This can be achieved through an analytical study using a specific approach conducted by a multidisciplinary team to identify and classify the functions that the project performs. Profound methods can then be utilized to find innovative alternatives without compromising the basic requirements and quality. This research is dedicated to demonstrating the methodology of Value Engineering while highlighting its impact on construction projects through a case study: Magrabi Offices in Saudi Arabia. This paper used an organized multidisciplinary methodology to identify the project's main and secondary functions, then utilized Pareto's law to identify higher-cost materials. It was proven that finding low-cost equivalent materials could reduce the total price by 23.13%.

Keywords: Value Engineering, Construction Industry, project development, improving quality, low cost.

1. INTRODUCTION

1.1.Background to the Study

The construction industry is a significant factor in a nation's growth and economy, employing the second-largest number of trained and semi-skilled workers after agriculture. With the expansion of business prospects and labor migration, the need for commercial and dwelling spaces has increased, making the global housing industry expected to achieve $10.5 trillion by 2023, with a growth rate of 4.2% from 2018 to 2023. About 250 industries are directly or indirectly related to the housing industry, emphasizing its importance in the (Wood, 2021)

As governments allocate a large part of their budgets to fund the construction sector, it becomes critical to incorporate value engineering as a systematic approach to evaluate and identify project functions to eliminate obstacles and challenges that could lead to project delays or shutdowns, such as the expensive budget of projects like the Rusayl Project next to the King Abdullah Financial District in North Riyadh, Saudi Arabia

To balance low expenditure and high quality, there have been numerous efforts to reduce the cost of construction while maintaining the project's quality, making the implementation of Value Engineering principles and methodology an essential solution. Value engineering is a function-based approach that systematically recognizes, identifies, and classifies a product or service's function using coherent and applicable techniques and methodology. It helps find several valid alternatives to lower costs, increase quality, improve the project's objective and concept, and prolong its life cycle. It provides a clear base of consensus among project decision-makers, establishes a clear project objective, and provides creative thinking for design improvement. Value engineering uniquely provides a methodology through several tools and techniques for integration in the building process that no other management structure in construction can provide.

1.2. Statement of the Problem

The poor understanding and misuse of VE methodology by some engineers have led to negative consequences in the construction industry. Instead of using VE to improve the project's quality and functionality, some engineers have used it to avoid design modifications proposed by contractors and non-engineers. This misuse not only affects stakeholder and project owner satisfaction but also leads to project delays, failures, or even shutdowns. The lack of clear understanding among decision-making about the value engineering concept further compounds the problem, resulting in hesitancy and mistrust regarding its potential benefits and perceived extra costs. Consequently, this lack of trust and misunderstanding contributes to project failures and abandonment, which have a significant multiplier effect on the construction industry. Despite VE being widely recognized as a systematic approach that helps in decision-making and narrowing down options, doubts regarding its feasibility persist among many engineers. Addressing these issues is crucial to promote the effective and successful implementation of value engineering, particularly in the context of material selection, within the construction industry.

1.3. Aim and Objectives

Construction project budgets could easily be cut down by 10%-25% by implementing value engineering techniques while maintaining the main function and basic quality of the project. Many critics believe that a deep understanding of the VE approach will reduce project failure and increase project efficiency. Hence, this report will be dedicated to studying the impact of Value engineering on material selection and development of the construction industry on one hand.

1.4. Research Map

The first chapter will explain the concepts, techniques, and origins of value engineering and its impact on material selection. The second chapter will be dedicated to the methodology used to apply value engineering. The third chapter will focus on implementation and case studies, where Pareto's law, along with quantitative analysis of VE, is used on the Magribi Office project to reduce costs while maintaining quality. This will be followed by the presentation of results and study recommendations.

2. LITERATURE REVIEW

2.1. Origin and History of Value Engineering

Value Engineering as a body of knowledge has been formed and developed to systematically optimize the product, service, or project quality and performance without detrimentally affecting its quality (Chavan, 2013). Since its creation during the second world war by Lawrence Miles (Tufty, 1989), VE methodology has been prized for its ability to prolong a product life span and meeting beneficiaries needs. The first application of VE within the housing industry started in the "*Navy Facilities Engineering Command within the United States in 1963*" (Ahmed & Pandey, 2016). The application of this system in the housing and construction industry expanded rapidly because of becoming a mandatory requirement in many public projects within the USA. In 1996, US President signed into law an act requiring all executive agencies to adopt VE procedures, and therefore the estimated savings because of this measure were forecasted at US$2.19bn for 1996 alone (Karunasena & Gamage, 2017). The aim to include VE within the job scope of construction management services fueled the use of VE in this industry. After VE installed its roots in the construction industry, several approaches were developed by the joint effort of educational researchers and practitioners to accommodate the industry's particular qualities (Ahmed & Pandey, 2016). In 2020, professionals faced labor and material shortages due to the global impact of the COVID-19 pandemic. This unprecedented situation has affected manufacturing on a worldwide scale. As a result, there has been a growing need for increased Value Engineering studies and research, as industries seek more profound solutions and creative alternatives to navigate these challenging times (Shublaq, 2020).

2.2. Definition of Value Engineering

According to the society of American value engineers International SAVE, VE is defined as a systematic and structured approach that works on improving projects, products, and processes. VE can be implemented to analyze manufacturing products and process, design, and construction projects, in addition to business and administrative processes. The main advantage of VE is that its priority is to achieve balance amongst the required function, quality, safety, scope, and overall cost. If the right balance is achieved the project will reach its maximum value (SAVE International, 2020).

Another definition of VE that can be adopted in this thesis according to Dehmourdi et al. is "*the systematic application of recognized techniques which identify the function of a product or service, start a value for that function, and provide the necessary function at the least overall cost. In all instances, the required function should be achieved at the lowest possible life cycle cost consistent with requirements and/or performance, maintainability, safety, and aesthetics*." (Dehmourdi, Ravande, & Amin Alavi, 2014)

According to the Merriam-Webster dictionary, the word value indicates various notions that relate to the concepts of importance, esteem, or desirable (Merriam-Webster, 2021). When developing the notion of VE, many scholars took the desirability concept into account as Bertelsen and Emmitt who linked the concept of desirable value into customers' needs and expectations. They stated that without identifying the customer when determining a product value, value will remain undefined. Hence, Bertelsen and Emmitt and many other scholars provide a client-oriented VE approach (Bertelsen & Emmitt, 2005). Galipogullari, took the notion of VE into another level by stating that creating a space for VE process immediately affects the result and increases "*performance, reliability, quality, durability effectiveness, or other desirable characteristics*." (Galipogullari, 2013).

According to research by Miladi Rad & Aminoroayaie Yamini, VE is a systematic approach which works on analysing projects to achieve proper function with minimal cost. (Miladi Rad & Aminoroayaie Yamini, 2016)

In research from Elsonoki et al. (Elsonoki, Yunus, Yunus, & Hamid, 2020)VE is described as a practical management technique which enhances the basic function of projects and minimizes unneeded cost. Furthermore, VE was defined by scholars to be "an organized, innovative, problem-solving, and function-oriented process that uses a multi-disciplinary and proactive team approach for the achievement of best value for money in project delivery during both the design and construction stages. In this way, the process not only identifies but also removes unnecessary costs." (Elsonoki, Yunus, Yunus, & Hamid, 2020)

Based on research by Ramani & Pitroda, VE is defined as a management technique which seeks balance between function and cost (Ramani & Pitroda, 2015). They also believe that the reason behind the success of VE is its ability to cut down unnecessary costs while guaranteeing maximum function, performance, and quality.

VE must not be reduced as mare as a cost-cutting approach. Husseinb, Ibraheemb, Mohammedb and Youssef (Husseinb, Ibraheemb, Mohammedb, & Youssef, 2012) argue that Value engineering methodology goes beyond reducing cost, but rather it facilitates structural techniques that involve several evaluation models such as: comparative evaluation model, feasibility ranking model. studied that the foremost valuable alternative doesn't mean that of all-time low price, but it means alternative achieving as much as possible of the specified functions with lowest cost possible. It is critical to mention that to ensure maximum results from your project, VE should be implemented at an early stage. Moreover, the potential savings from the application of VE will be greater than the initial cost paid to apply it in the first place (Dehmourdi, Ravande, & Amin Alavi, 2014). VE is mainly focused on fulfilling maximum value at minimum cost. That is achieved by considering the function as one of the main objectives and adopting less expensive design alternatives that provide the same function.

VE is an expansion of a broader term called value analysis method (VA). L.D. Miles, a former employee at General Electric in the 1940s was the first person to the VA. Miles investigated the usage of alternative materials instead of the expensive materials in manufactured products. His investigation was the main reason behind the rationalization of industry until the 1960s when the concept of VE was introduced for the first time in America and expanded through Europe later (Leśniak & Lendo-Siwicka, 2018).

To conclude this point, it is fair to say that all mentioned definitions agree that VE is an important discipline that helps mainly in reducing the budget while maximizing the quality and value of the projects and meeting the requirements of the clients.

2.3. Value Engineering Terminology

Value methodology contains a wide range of concepts that contribute to the same function which is a management method that aims to create alternative and useful solutions that improve quality and lower cost. This section contains several terms and concepts developed by value mythology specialists (Al-Yusufi, 2009).

Value Analysis VA

The application of value methodology to an existing project, product, or service to achieve an increase in value.

Value Engineering VE

The application of a value methodology to a planned or conceptual project or service to achieve value improvement.

Value Management: VM

The application of a value methodology by an organization to achieve strategic value enhancement.

Value Methodology:

A systematic process applied by a multidisciplinary team to improve the value of projects through feature analysis. See value engineering, value analysis, and value management.

2.3.1. The Main Difference Between Value Management and Reducing Costs

The following table 2.1 contains a comparison between the application of value methodology and the process of cutting down the project's cost or budgets.

Table 2.1 The difference between value engineering and reducing costs.

#	Value Management	Reducing Costs
1.	Works on maintaining of improving quality while lowering the total costs	Works only on reducing costs at the expense of quality

#	Value Management	Reducing Costs
2.	Value management is pre planned within the first stages (designing stage).	Applied spontaneously as a reaction for exceeding the budget limits after finishing the designing stage.
3.	Structured approach using coherent methodology.	Lack structured approach and anyone can apply it.
4.	Depends on multidisciplinary and VE specialists.	Depends only on several under qualified individuals from the management department.
5.	Requires the Submission of a report and implementation program for the special department	Does not require a report

In Table 2.1 the differences between value engineering and Reducing Costs are shown as a means of reducing project budgets. Value engineering is a systematic approach, and its implementation does not affect quality.

2.4. Importance of VE in the Construction Industry

From recent research by Karunasena en Rajagalgoda Gamage (2017) value engineering is very important in the construction industry because it is considered to be the only technique that focuses on maximizing the value of the project whereas other techniques focus on for example on time and quality. Moreover, applying VE on construction projects can help cut down the cost by 26%, report a 40-50% increase in the operational performance and 30-50% increase in the quality of the final product (Karunasena & Gamage, 2017).

Despite all the positive impacts of applying VE on projects, VE is still a relatively new discipline, and many engineers discredit it as being only a marketing tool. 45% of engineers on the Engineering News Record's website thought that there is no significant and number-based benefit of applying VE on construction projects (Zhang, Mao, & AbouRizk, 2009).

Ahmed & Pandey (2016) explained that a shortage of management support isn't the main reason for the declining use of value engineering (VE) as a management tool. Instead, professionals working on the project must be aware of the opposing agendas that exist between design and management to utilize VE as a tool which will eventually aid the management during the development process. Even though all decisions made during the early phases of a project have an impact on all parts of the project, the industry does not devote enough attention to managing this stage in comparison to other phases.

Another factor that is hindering the implementation of VE is the misinterpretation of VE as a "cost-cutting" process which overshadows the most essential part of the VE approach: value and efficiency (Farahmandazad, 2015). Farahmandazad promoted the notion "cost effectiveness" to better understand the position of VE study within the project. Conducting a VE evaluation within the first stages of the project may end in eventually recommending increasing or decreasing the project total budget if the increase/ decrease of budget serves a vital benefit to the project. Altering the project budget is merely one possible aspect of the overall study, and it considers the life-cycle cost efficiency.

While the awareness of the importance of VE in the construction industry is rising, the actual implementation levels are still low in the industry. A recent research paper identified eight factors that are responsible for the low implementation of VE in construction industry: "(1) lack of awareness among clients, (2) uncertainty of outcomes, (3) additional costs involved, (4) lack of government support, (5) time consumed, (6) lack of expertise, (7) lack of regulations and (8) policy applications." (Elsonoki, Yunus, Yunus, & Hamid, 2020).

Many of the construction projects face the dilemma of unnecessary increased cost that VE helps detect and reduce. The reason behind this problem is mostly related to the lack of information and miss communication amongst the project manager owner and design manager, which eventually results in an increased overall cost of the project. The scholars were able to identify six most common reasons behind cost increase in construction projects namely: Shortage of information, Insufficiency to develop alternate solutions, instantaneous situations, truthful incorrect politics, new requirements by user or owner and lack of communication and coordination amongst the team working on the project. It is important to mention that value engineering's importance is not only limited to cost reduction but also it works on adding value to all types of construction projects and provides added quality within available funds and means (Dehmourdi, Ravande, & Amin Alavi, 2014). VE makes that possible by being applicable to all construction industry sections. Moreover, VE helps with cost reduction mainly by focusing on simplification, standardization and improving methods of production. In addition, VE helps in identifying areas of improvement within the project, develops better coordination between the owner, contractor, supervisor, and the rest of the team and finally it provides sufficient and true information to all parties involved in the project.

According to research VE was implemented for the purpose of cost reduction without any change to the initial design or value of the C.C road project. Based on the case study it can be concluded that VE can be applied during any stage of the project, but it is advised to apply it during the early stages conceptual and developmental. It is also important to never comprehend a project's value, design or quality when cutting down the budget (Mehta, Mehta, & Pitroda, 2020).

VE main objective is to provide alternatives that could solve a problem, minimize budget, and increase performance with always keeping project’s main function in mind. We can understand that VE is all about finding the balance point between function, quality, and cost. In addition, the implementation of VE results in improved quality, sooner completion, environmentally friendly solutions, less waste and finally cost reduction by 5-10% in overall project cost at least (Ramani & Pitroda, 2015).

Another research stressed on the importance of implementing VE during the early phases of the project because the employees and designers will be more flexible to accepting changes and modification and implementation is much simpler than later in the project. Moreover, the most common reasons behind failing to implement VE on construction projects are lack of belief in the effectiveness of VE and lack of acceptance to second opinion (Miladi Rad & Aminoroayaie Yamini, 2016).

Moreover, there was always the need to lower project budgets while not comprehending the main function and quality of the project. Therefore, VE was presented as a method which can be used to deliver maximum value with minimum cost. It was only until recently that both engineers and architects started prioritizing reliability and durability along with the function utility to optimize the cost (Rane & Attarde, 2016).

2.5. VE in Construction Industry Around the World

As mentioned earlier VE was applied in the beginning mainly in the manufacturing industry and was introduced for the first time in the construction industry by the United States Armed Procurement in 1968 (Fathoni, Zakaria, & Rohayu, 2013).

VE implementation becomes very important in countries that have faced unstable political and economic situations like Libya for example. Where VE was recently adopted by the contractors and government because it helps the country utilize its limited resources in the best way possible and cuts down all unnecessary costs and efforts while enhancing the overall value of construction projects (Elsonoki, Yunus, Yunus, & Hamid, 2020).

In Poland, the concept of VE was implemented for the first time in 1966 by the National Rail Carriage Factory in Wroclaw and is until today an important part of the construction projects. According to a survey conducted in Poland by Leśniak and Lendo-Siwicka (2018) 57% of the survey participants have heard of VE and 50% stated that VE is mainly used in lowering investment costs. The survey results show that regardless of the developing methods of VE there is still a low level of knowledge about VE among building contractors, investors, architects, and constructors in Poland (Leśniak & Lendo-Siwicka, 2018).

The application of VE in Southeast Asia (SEA) seems to be falling behind, especially in the construction industry. Based on a study conducted in 2004 half of the respondents (50%) identified VE as a "*cost cutting exercise*". The study concluded that both lack of knowledge, awareness, and training about VE among workers in the construction industry are the main reasons behind the limited application in (SEA) (Fathoni, Zakaria, & Rohayu, 2013).

In Oman, the construction industry was booming in recent years. The exceptional growth of the industry was a result of the oil reserves as Oman is a member of the Gulf Cooperation Council (GCC) (Al Amri & Marey-Perez, 2021). Moreover, the concept of VE is well-learned and practiced in Oman (Al-Saleh & Taleb, 2010). However, Al Amri & Marey-Pérez (2021) believe that there is yet a place for a better application of certain VE features in construction projects which will help minimize unnecessary costs and enhance functions which will result in more sustainability and growth.

In the United States of America, the application of VE on a wastewater treatment project by the U.S. Army decreased the overall budget by $200.000. Moreover, the operation and maintenance of the project were lowered by $4.4 million. On another occasion, VE was applied to the heating, ventilation, and air conditioning (HVAC) system of the Ritz Carlton Hotel in Miami. The re-evaluation process helped reduce the cost by $700,000 by substituting tools and modifying materials which resulted in quicker installation. This project was significantly important because the installation of the (HVAC) system was delayed over a year due to a lack of funds (Seidel, 2012).

According to Mwakasungula, G., & Mbewe, P. (2018), there are many reasons behind the limited application of VE in Nigeria. The most common ones are lack of understanding and knowledge about VE, lack of involvement of professionals, communication gap, and unstable economy in the country. The research also stated that the practice of VE is not well established or adopted by the construction consulting firms in the Malawi construction industry. Moreover, the research presented possible steps that could encourage the implementation of VE in the industry like integrating VE with other fields of engineering during the training period of professionals. Also fostering a competing environment in the industry among contracting firms to enhance innovation and excellence in the industry (Mwakasungula & Mbewe, 2018).

The application VE may require some additional cost, it is best to choose wisely which projects require VE evaluation more than others. The research suggested seven types of projects where applying VE is a good idea. These projects are namely costly projects, complex projects, repetitive costs, unique projects with new technology elements, projects with compressed design programs, and finally high visibility projects (Ilayaraja & Eqyaabal, 2015).

L. Rane, N., & Attarde, P. (2016) proposed recommendations to encourage VE practice in the construction industry. Firstly, by building a strong teamwork culture. Secondly, offering certifications to engineers who have leadership and communication skills. Lastly, obligating contractors to submit VE proposals for big projects (Rane & Attarde, 2016).

It is evident from previous studies on VE in the construction industry that the main barriers to its implementation in many countries are the lack of flexibility, government support, and understanding of the VE concept. Therefore, it is crucial to promote VE and increase awareness about it. This can be achieved through various means, such as offering training courses, organizing seminars and conferences, and providing postgraduate studies. Additionally, creating a competitive environment among contracting firms can encourage innovation and excellent services. By taking these steps, the construction industry can benefit from the use of VE, leading to improved project outcomes and increased customer satisfaction.

3. METHODOLOGY

VE applications are implemented in various engineering projects and constructions. They mainly rely on presenting ideas and alternatives to engineering works and systems that achieve the required functions at the lowest possible cost while maintaining the required level of performance and quality. VE uses several techniques to achieve this goal without any restrictions, whether they are standards, building regulations, or other controls if the alternative does not violate the main goal and function.

Approaches to VE vary in the methodologies used. This research will rely on qualitative analysis applied to a specific case study.

3.1. The Application of VE

VE is easily applicable during any stage of the project's so-called “development cycle.” But it is advised to apply VE during the conceptual stages to guarantee maximum benefits and cost reduction. Because during that stage the basic information is there but no major development took place regarding the design or resources. Therefore, defining and applying alternatives will be much easier. It is possible to apply VE more than once during the life of a project, but the early application of VE helps set everything right from the start and later application focuses more on polishing up the project based on new information. Moreover, VE can be applied during all stages of the project. Starting from the stage when the project is being drafted on paper, to designing, constructing, maintaining, and dealing with new challenges (Miladi Rad & Aminoroayaie Yamini, 2016).

Theoretically, value engineering methodology could be applied at any stage of the project, nevertheless practical experience shows that to achieve the highest financial and technical return, it must be applied at the very first stages of the project. Moreover, when applying value engineering early it would be easier to accept changes and modifications.

Several experts advise to conduct two value studies for each project as shown in the figure 1 below, the first value study before contracting with a designer which is before the (Programming Stage) prior to identifying the project goals and functions, the aim of the first study is to identify the owner's real intentions and aims of the project to establish some ground rules for the project. The second value study must be conducted after the initial conceptual stage of the project which is after establishing 25%-30% of the design, the aim of the second value study is to provide financial alternatives and to ensure that the project is established according to the initial ground roles design. The third suggested value study is conducted with the design technical review after establishing 80%-85% of the design, the aim of the third study is to ensure the application of the first and second value studies proposals and modifications approved by the owner (Al-Yusufi, 2009).

According to L. Rane & Attarde (2016), VE is easily applicable during any stage of the project's so-called "development cycle". But it is advised to apply VE during the conceptual stages to guarantee maximum benefits and cost reduction. Because during that stage the basic information is there but no major development took place regarding the design or resources. Therefore, defining and applying alternatives will be much easier. It is possible to apply VE more than once during the life of a project, but the early application of VE helps set everything right from the start and later application focuses more on polishing up the project based on new information. VE can be applied during all stages of the project. Starting from the stage when the project is being drafted on paper, to designing, constructing, maintaining, and dealing with new challenges (Miladi Rad & Aminoroayaie Yamini, 2016).

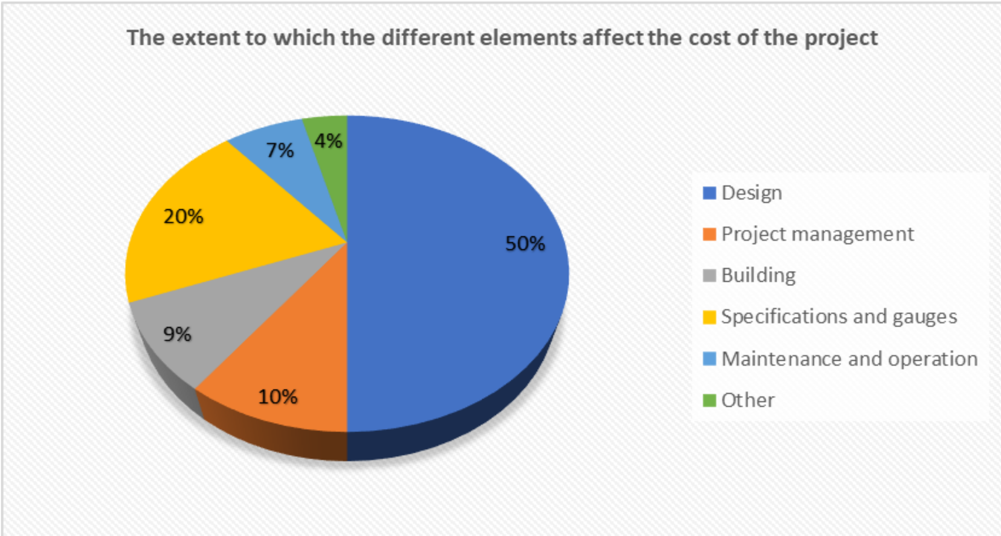


Figure 3.1 The extent to which the different elements affect the cost of the project

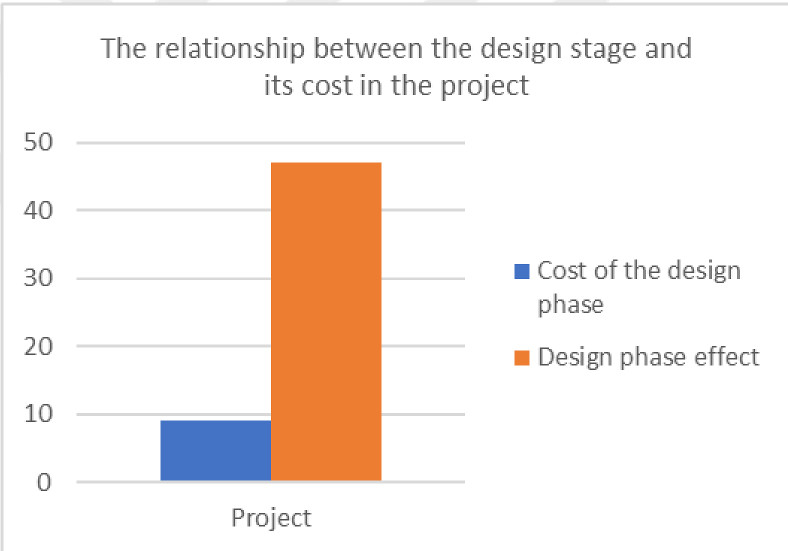


Figure 3.2 The relationship between the design stage and its cost in the project

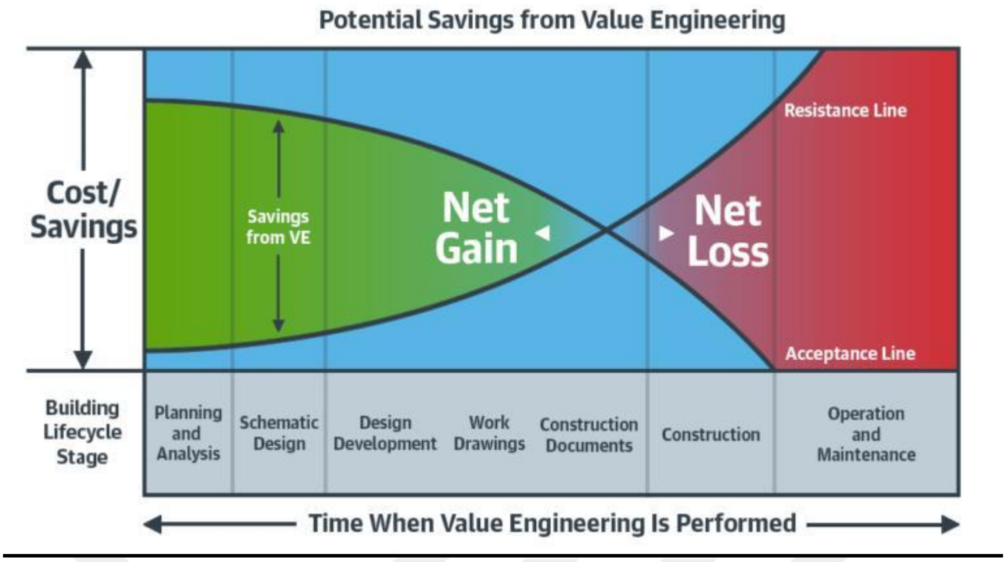


Figure 3.3 Time when value engineering is performed in construction projects (Gordian, 2023)

This graph illustrates the transition between value engineering financial gain and loss presentations.

3.1.1. How to measure value

Measuring a project/ product/ service's value depends on measuring three essential elements, total cost, function, and quality. The relationships between those elements are demonstrated in the following figure:

$$Value\ Index = \frac{Function + Quality}{Total\ cost}$$

Equation 1 Value Index **(Al-Yusufi, 2009)**

3.1.2. Value Main Elements

Function: It is the purpose for which the product, project, or administrative process was found.

Quality: The accomplishment of a project, product, or service's the required limit of performance or functions over its life span and it means the special requirements, expectations, and desires of the beneficiary.

Total Cost: The total amount required to acquire the project, component, commodity, or service or its production, and it includes direct costs such as the cost of land, design, and construction, and indirect costs such as the cost of financing, operation, maintenance, and post-purchase costs.

Value Index: It is a comparison between the actual or estimated cost and the cost required to achieve the intended function. It's used to determine how well a given alternative or system performs in terms of value.

According to The National Economic and Development Authority (NEDA), the concept of the Value Index is described as *"A ratio that expresses function worth ÷ function cost. This ratio plays a crucial role in identifying opportunities for value enhancement, typically identified during the Function Analysis Phase"* (NEDA & AusAID, 2009).

A measure or index of value is used for comparison between several alternatives or systems by applying that equation.

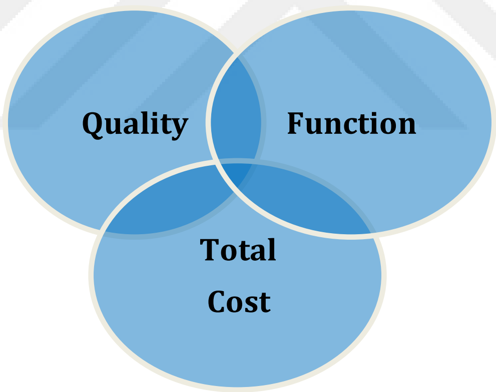


Figure 3.4 Value's main elements

3.2. The Main Stages of Applying the Value Engineering Technique

When a project is chosen to apply the value study, a work plan with a specific timetable is designed, which consists of three basic stages:

- Pre-Workshop (Preparation).
- Workshop (Execution of the six phase Job Plan).
- Post-Workshop (Documentation and Implementation).

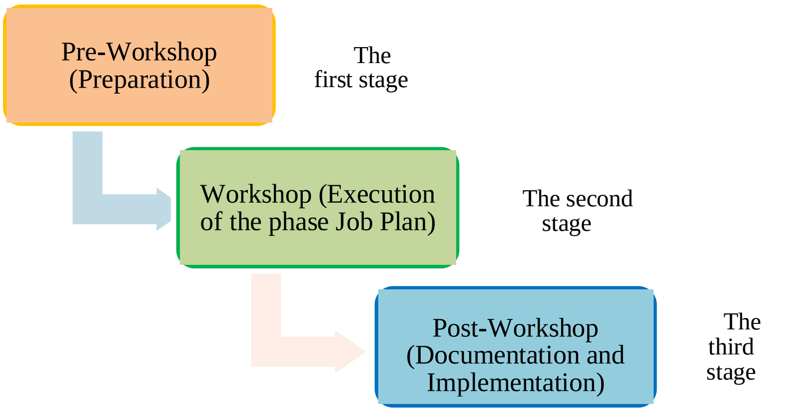


Figure 3.5 The Main stages of applying the value engineering technique.

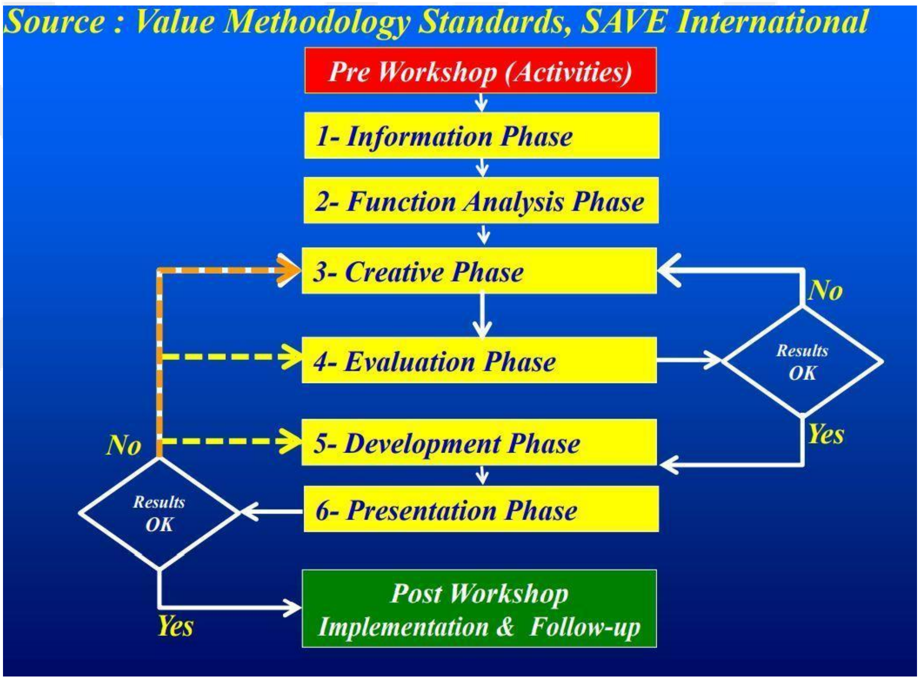


Figure 3.6 Value methodology standards **(SAVE International, 2020)**

3.2.1. The first stage: Pre-Workshop

The success of the value study depends mainly on good preparation, at this stage where all obstacles are removed and the picture is clarified in addition to providing the necessary information and documents to conduct value studies, which precedes the stage of holding the workshop directly, and the most important procedures at this stage:

- Selection of a multidisciplinary team.
- Review the project and the field of study and ensure that all necessary documents related to the project are complete.
- Setting the timetable for the beginning and end of value study phases.

3.2.2. The second stage: Workshop (Execution of the phase Job Plan)

The team applies the value engineering methodology to the project, an organized methodology consisting of several sequential stages (the job plan phases) as follows:

1. Information Phase.
2. Function Analysis Phase.
3. Speculation & Creativity.
4. Evaluation Phase.
5. Development Phase.
6. Presentation Phase.
7. Implementation Phase.

Figure 3.7 Job plan phases

First Phase: Information

Before starting the study, it is important to gather information to give the team a greater awareness of the problem, and it forms the cornerstone on which the study is based, and the aim of it is to get acquainted with all the information related to the project and to familiarize the members of the study team with all the project details and material by examining the project documents and understanding them fully concerning the technical, physical, and economical aspects, by dividing it into parts that are easy to study.

It is possible to classify the priority of the entail study components by applying the Pareto principle formed by the Italian economist Vilfredo Pareto, Pareto principle "states that for many outcomes roughly 80% of consequences come from 20% of the causes", which helps to concentrate on most expensive elements first, this can be applied to construction projects, usually 15-30% of the elements of any project represent 60-80% of the costs (Ahmed & Pandey, 2016).

Information Sources

Sources of information differ according to the project type, field of work, and costs. The most important sources of information are as follows:

- Stakeholder interviews:

Interviews with project stakeholders such as clients, architects, engineers, contractors, can provide valuable insights into their perspectives, expectations, and concerns regarding the project.

- The user or the ultimate beneficiary

The information must be gathered, as well as the opinions of the ultimate user or beneficiaries, supposedly the project is building a school, and the needs and opinions of the schoolteacher and students must be considered.

- Specifications and Standards

Most of the specifications used are taken from other countries such as Britain. Therefore, information must be recollected, and specifications must be reconsidered because perhaps some of the beneficiaries are setting the specifications and standards despite their lack of technical ability.

- Project documents

This includes project plans, specifications, drawings, contracts, estimates, and bills of quantities.

- Work Team

The presence of a multidisciplinary team of experts is an important source of information gathering.

- Site visits

Visiting the site will provide a visual understanding of the facilities, and the value engineering team must discuss and document their observations from the site after the visit.

Information gathering steps:

- Examine the project documentation.
- Define the list of the required information.
- Determine the requirements of the beneficiary.
- Determine the goal of the study.
- Estimating and analyzing costs
- Determine the field of work.

Information Form Study Title		Consultation &Document Record
Information Source Name ,Title ,Organization Or Reference Document.	Phone No. If Applicable	Major Points of Data

Figure 3.8 Information form **(Al-Yusufi, 2009)**.

Information models:

There are several project models that differ from one project to another and help provide the necessary information in an organized manner.

1. **Costs Model:**

It is a graphic representation of the project components in the form of an organizational structure to help the study teams to determine the signed savings and places of increases that must be focused on. The actual cost is set through the priced tables of quantities or through the estimates made by the designer for the various project components, and through a database, cost, and the experience of the value study team. The due cost is estimated at the lowest cost to achieve the function, considering the unified cost system during the value study of cost estimation.

2. **Unified standard cost model**

It was called the standardized model, as some organizations in America developed it, the purpose of which is to prepare a budget for the project and estimate the cost of implementation, and what distinguishes this model is the possibility of estimating the cost at any stage of the project's life. It is also referred to as master format. This model is used in CSI Institute Specifications Constriction.

Spaces model

It is a graphic representation that distributes the spaces allocated to each of the components of the project in the form of an organizational structure, the goal of which is to facilitate the analysis of the design and judge the extent of the balance between the areas of the different elements in the project.

Energy model

It is a graphical representation of all the quantities of energy used in each component of the project in the form of an organizational structure designed to help the study team control the energy costs of the project and achieve savings over the life span of the project.

3. **Quality model**

It is a graphical representation formed by a value study team and is approved by the owner, it is used as a criterion for the required quality to be achieved in the project and to evaluate the various alternatives. The owner, user, operation maintenance officer, and designer responsible for implementation must participate in the workshop for developing this model.

4. **Risk Model**

A model is used to identify and measure the risks that the project could be exposed to control them and reduce them to acceptable levels.

Second Phase: Function Analysis

The function analysis phase is the cornerstone on which value studies rely. This stage distinguishes the methods used to control costs, improve value, or raise the level of quality by identifying and understanding the project's functions and the relationship between those functions. When the function of the project is determined, all the components of the project are identified, and the functions of these components and elements are determined accordingly.

Within this phase, functions are defined and described with an active verb and a measurable name. This phase ends with a clear and documented profile of the areas that provide the most opportunity for improvement.

Function Classification

- Primary function

It is the basic service of the project, whether it is a use or aesthetic function, which is the component that without which the product or the commodity does not work.

- Secondary function

It is a function that helps and supports the primary function and makes it meet the desires of the beneficiary or the user.

- Secondary function (required)

It is the secondary function that is considered supportive and complementary to the primary function.

Function Analysis Phase model

Project:
Date:

item:
Basic Function:

no	item	Function		current value	Due value	Current / Due Ratio	Notes
		verb	Noun				
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Total							

Figure 3.9 Function analysis phases model **(Al-Yusufi, 2009)**

Function Analysis System Technique: FAST

It is a graphical technique to show the logical sequence of relationships between the project or product functions that have already been defined according to priority and dependence until reaching the main function, through the question (*how*) that starts from the left field of study and asks how the function should be implemented, and the question (*why*) why the function should be performed that starts from the right-hand field of study and a. This model was developed by Charles W. Bytheway (Bytheway, 2017).

This model helps:

- Determine the relationship between functions.
- Test the accuracy of function identification and classification.
- Help searches for missing functions.

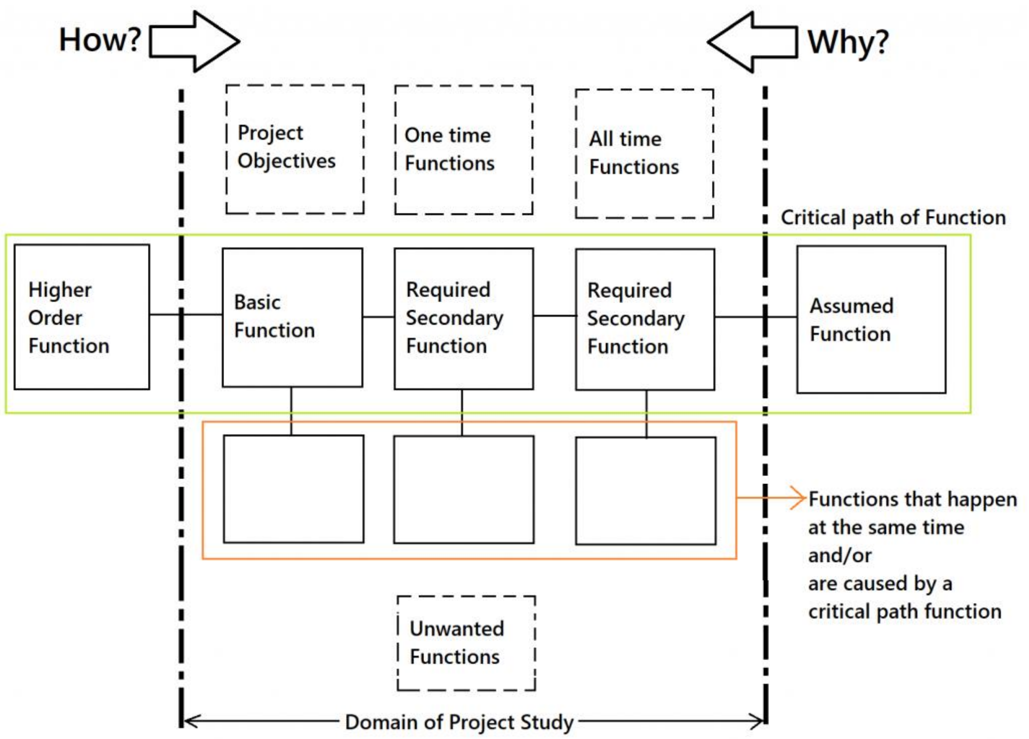


Figure 3.10 FAST plan diagram **(Sundar, 2020)**

Third Phase: Speculation & Creativity

After completing the previous phases, the study team becomes fully aware of the project, and the contemplation and creativity phase begins. The aim of this phase is to generate a large number of creative ideas and proposals to solve problems, the find the best solutions and appropriate alternatives to the basic function at the lowest total cost while minimizing the negatives and enhancing the positives as much as possible. This is achieved by holding a meeting for the value study team, reviewing the offered functions, brainstorming, and documenting the best ideas and alternatives that perform the same function.

VE relies on human creativity to generate and implement VE proposals, based on intelligent interactions during the VE workshops. The most important factors for the success of the contemplation and creativity phase are dynamism, teamwork, and positive thinking.

Stages of the creative process:

1. Preparation stage, which is the stage in which the problem is defined, where the creative person collects information, skills, and previous experiences required for the creative process.
2. The latency stage, which is the stage of waiting, waiting, and analyzing the information about the problem and synthesizing it to find and generate ideas.
3. The brightening stage, which is the stage of the creative spark and the creation of new ideas that lead to the solution.
4. The verification and implementation stage are the last stage of the creative process, in which the idea is tested and then, the solution is tested, and the success is achieved according to the established criteria.

Obstacles to creativity:

- Rejection of alternative solutions.
- Perception obstacles.
- Resistance to Change: Resistance from team members or stakeholders to new ideas or alternative solutions
- Cultural barriers.
- Affective-behavioral obstacles.
- Lack of Support and Resource

Creative methods:

There are many creative approaches to problem-solving, and the most suitable methods for value engineering are:

Analytical method: It is a method of problem-solving that is closer to self-style thinking through which the problem is defined, and a direct solution is found based on mathematical experiments and calculations. At the end of the process, one solution is obtained.

Collective method: It is one of the methods of the collective process for problem-solving. This method depends on creative thinking that exceeds the limits of facts or information known or previously established. It requires a high degree of eliciting relationships, whether in formulating assumptions or arriving at an innovative product. This method aims to come up with several solutions that fulfill the required purpose, and usually, there may not be one perfect solution to the problem. Collective method usually depends on either mind mapping or brainstorming.

- Mind Mapping

A visual technique that helps explore relationships between ideas, concepts, and functions by creating a hierarchical structure of interconnected nodes.

- Brainstorming

A technique for generating and stimulating thought and creativity to solve many different scientific and life problems, with the intention of increasing the capabilities and mental processes, and it is a method based on stimulating someone's ideas through another person's ideas, and it consists of an average of 5-9 people sitting around a round table presenting their ideas at a time to solve a specific problem while keeping away from criticism.

The team leader begins presenting the problem and begins by retrieving the project information by drawing part of the (Fast Diagram) functions, explaining the higher goal, the primary function, and some secondary functions.

Then begins proposing solutions to perform the function and it is important to register ideas, to generate many creative ideas and possible solutions.

no	The idea	Advantages	Disadvantages	scores

Figure 3.11 Brainstorming form **(Al-Yusufi, 2009)**

Fourth Phase: Evaluation

The aim of this phase is to evaluate and assess the ideas presented and choose the best ones from the large number that were recorded in the previous phase (the creativity phase) in terms of performing the function, quality, required performance, and applicability. The selected ideas will be developed in the next phase. The team categorizes the ideas, disregards those that turn out to be insignificant or not worthy of further study and focuses on those that represent the greatest potential for cost savings and high quality.

Evaluation steps

The following are the evaluation steps followed:

- Initial examination of ideas and thoughts.
- Combining similar and identical ideas to reduce the number of ideas.
- Identify the idea sponsors.
- Determine evaluation criteria, which is a set of criteria by which the ideas can be judged for feasibility.
- Eliminate unusual thoughts.

Final evaluation to choose the best ideas and determine the responsibility for development. The aim is to choose the best ideas from the large number that were recorded in the previous phase (the creativity phase) in terms of performing the function, the quality, required performance, and the most applicable. The team will focus on those ideas that represent the greatest potential for cost savings and high quality. Then, the ideas will be transferred to the next phase for development and converting them into practical value proposals.

Techniques for assessing and selecting ideas.

There are many techniques and methods for evaluating ideas in value engineering studies, including the following:

1. Comparative evaluation

The process of comparing the proposed ideas is carried out by documenting them and categorizing them as positive or negative based on the criteria for achieving the function, meeting the beneficiaries' requests, the impact of the idea on the project's progress, the total cost, the potential savings, the likelihood of success, and the time required for implementation. Scores are then assigned for each idea based on these criteria, and the best idea is selected at the end.

2. Feasibility Ranking

The study team evaluates the ideas and judges them according to their novelty, the possibility of acceptance and application, and the time and cost required for implementation. Each idea is given a score, and the scores are collected and used to calculate a rating for each idea. The idea with the highest rating is chosen.

3. Evaluation by vote

This method is used when it is difficult to reach a consensus result.

4. Weight evaluation

To choose the best alternative among several alternatives that achieve the same function, various criteria are considered, and they are assigned different mathematical weights based on their importance and impact. This is achieved through techniques such as architectural weighting and matrix analysis and evaluation process.

5. Normative assessment

Normative assessment is a method used in value engineering to evaluate the performance of a product or system against established standards or norms. The goal of normative assessment is to identify areas where the product or system can be improved to meet or exceed these standards, while determining the most cost-effective way to achieve these improvements. This may involve identifying opportunities for cost savings, performance enhancements, or improvements in reliability, quality, or safety.

Fifth Phase: Development

The goal of this phase is to determine the best-proposed alternatives that were selected in the previous phase according to the available information by conducting a detailed technical and economic analysis of the alternatives and developing an implementation plan where the selected ideas are converted into viable proposals. The proposals are supported with explanations, graphics, and overall cost estimates. The findings and results of the developmental stage must be carefully measured against and compared with the projects requirements and specifications selected during the Functional Analysis Phase. The decision-making process must be documented to clarify how the result was reached, including information shared and discussed, demonstrating the concepts' *practicality*, and confirming assumptions and engineering judgment, conducting life-cycle cost analysis, and preparing ideas. Finally, an implementation plan is developed.

Sixth Phase: Presentation

It is a summary of the value study and its results presented to the owner or decision-making bodies. The main objective of the presentation phase is to provide alternatives to the project’s stakeholders and decision-making bodies.

In the presentation phase, the team will provide several proposals that maintain value and express the project's aims more efficiently than the originally suggested solutions. During this phase, decision-makers and stakeholders can evaluate, analyze, and ask questions to the team. The project team must answer all questions, accompanying their explanations with supporting documents, whether with technical or financial information.

The Presentation Phase of a VE workshop generally consists of:

- Prepare the presentation.
- Presentation to Decision-Makers.
- Project History.
- Functions analyzed.
- Base design and offered alternatives.
- How do the study conclusions meet the success requirements established for the project?
- Project cost analysis and summary of benefits.
- Develop an implementation plan.
- Several sketches, schedules, and diagrams to clearly understand the suggested proposals and assumptions.

- Most importantly, cost comparison studies are based on special calculations.

Seventh Phase: Implementation

It is the final phase of the value engineering process, and the objectives of the value study cannot be achieved without implementing the suggestions. This phase begins after the presentation of proposals and recommendations and obtaining written approval of the chosen ideas.

Objectives of the implementation and follow-up phase:

- Establishing practical procedures to ensure the implementation of recommendations and proposals with the participation of the work team to ensure the best implementation of the proposals.
- Follow up the application and monitor results.
- The continuity of the application of value engineering.

Value Engineering Proposal

It is divided into two parts:

1. General recommendations

Recommendations that do not require drastic changes and therefore do not need to alter the current situation, as they focus on improving methods of implementation, materials, equipment, specifications, and so on.

2. Value engineering change proposals

Proposals and ideas that lead to radical changes and modifications to the original design or some of its elements, and require modifications to the contract and its accompanying documents such as specifications, plans, quantities, etc.

Value Engineering proposal implementation plan

- Choose the appropriate method for the application.
- Determine the potential effects of changes.
- Preparing an analytical study for the cost of the application.
- Preparing a timetable for the steps required to implement the proposal.

- Anticipate potential application obstacles and find solutions to overcome them.
- Determine the person or agency responsible for the application and the required materials, formats, and necessary documents.

3.2.3. The third stage: Post-Workshop

At this stage, a final report is completed and submitted which contains the proposals and results of the study that have been reached, along with all the documents and analyses that were used during the conduct of the study. The report may also include recommendations for working to solve any problems that may arise during the application of the selected proposals.

4. IMPLEMENTATION (CASE STUDY)

Several construction companies were contacted to obtain the necessary documents and bill of quantities (BOQ). Only a few companies responded by sending the required documents, and after careful evaluation, one project was selected for this value engineering study: The Integrated Environment Company, a construction services company based in Saudi Arabia.

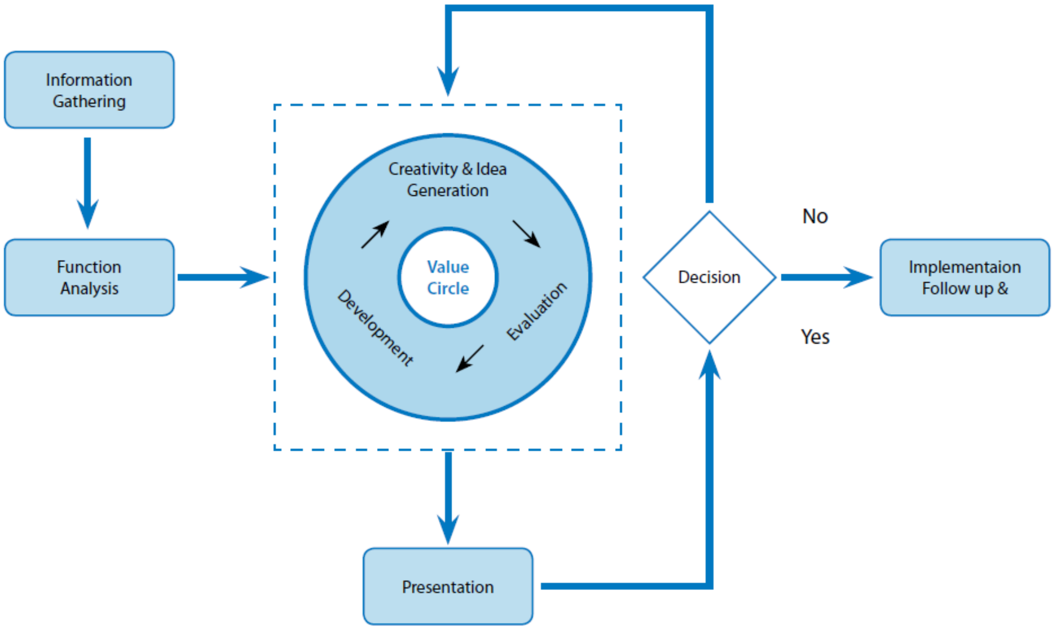


Figure 4.1 Value Engineering Job Plan **(Al-Yusufi, 2009)**

VE applications are implemented through holding workshops, in which a selected work team is assigned according to the type of project and the stage of the study. The team is led by a qualified value specialist who will be working according to the following steps:

1. Preparing for the study by reviewing all project documents and papers, comprehending them from all sides, completing any incomplete information or documents, making cost estimates, calculating quantities, areas, etc.
2. Analyzing quantities and functions according to the Pareto Law to identify the high-cost places.
3. Analyzing the functions and components of the project. Defining each component functionally with only two words: a verb (active) and a noun (standard). Then, classify the functions into primary or secondary functions.

4. Drawing up a plan using a FAST diagram to arrange and link the project functions, define them functionally, and select the work field for study.
5. After completing the function analysis stage, the creativity stage begins by presenting ideas and alternatives. Each alternative will be evaluated, considering the advantages and disadvantages, and choosing the most suitable solutions according to the agreed specifications and standards.
6. Evaluating and developing ideas into realistic proposals and alternatives suitable for application, preparing calculations and justifications that confirm this, and estimating the functional and financial returns resulting from the proposals.
7. After combining the final value proposal, a report is prepared explaining the results of the value study, supported by graphics and tables.
8. Notifying the project owner of the study, setting a date for presenting the results in the presence of the decision-maker, discussing the results with the stakeholders, and developing a plan to implement the agreed proposals.

4.1. Project Brief Information

The project is the completion of the head office for one of the most famous centers for eye care and glasses in Saudi Arabia, Magrabi. The materials are carefully selected and of high quality to create a distinguished work environment and stimulate innovations in the field of eyecare and eyewear.

Project Name	: Magrabi Corporate Office
Project Budget	: 2,309,955.09 SAR
Owner	: Magrabi Company
Designer	: Elie Metni Architects
Contractor	: Integrated Environment Company (Integrated Environment, 2023)
Project Duration	: 4 Months

4.2. Project Description

The project area is 640 m2. The project is located in Laysen Valley Building in Riyadh, Saudi Arabia. The project consists of a reception, two large meeting rooms, two small meeting rooms, two bathrooms for men and women, and a large hall containing three workshops, a kitchen, a prayer room for men, a prayer room for women, a multi-use place, an IT room, an archive room, a terrace, and outside sitting areas for smoking and eating. It also includes two emergency stairs and two elevators.

4.3. VE Study Team

The team comprises experts from different disciplines, including engineering, architecture, construction, finance, and management. The team members bring their experience to the table to help identify and evaluate alternatives for a project to optimize its value.

The team leader is responsible for coordinating the efforts of the team members, facilitating meetings and workshops, and communicating the study findings to stakeholders. The team members work together to define the project's objectives and requirements and analyze the options regarding their costs, benefits, and risks.

Table 4.1 VE study team

NO	Job Title	position
1	Civil engineer specializing in VE (CVS)	The team leader
2	Civil Engineer	Team coordinator
3	Architectural Engineer	Member
4	Electrical Engineer	Member
5	Mechanical engineer	Member

NO	Job Title	position
6	Ranch manager	Member

Table 4.1 shows the details of the value engineering team. The team must be multidisciplinary and lead by a certified value engineer.

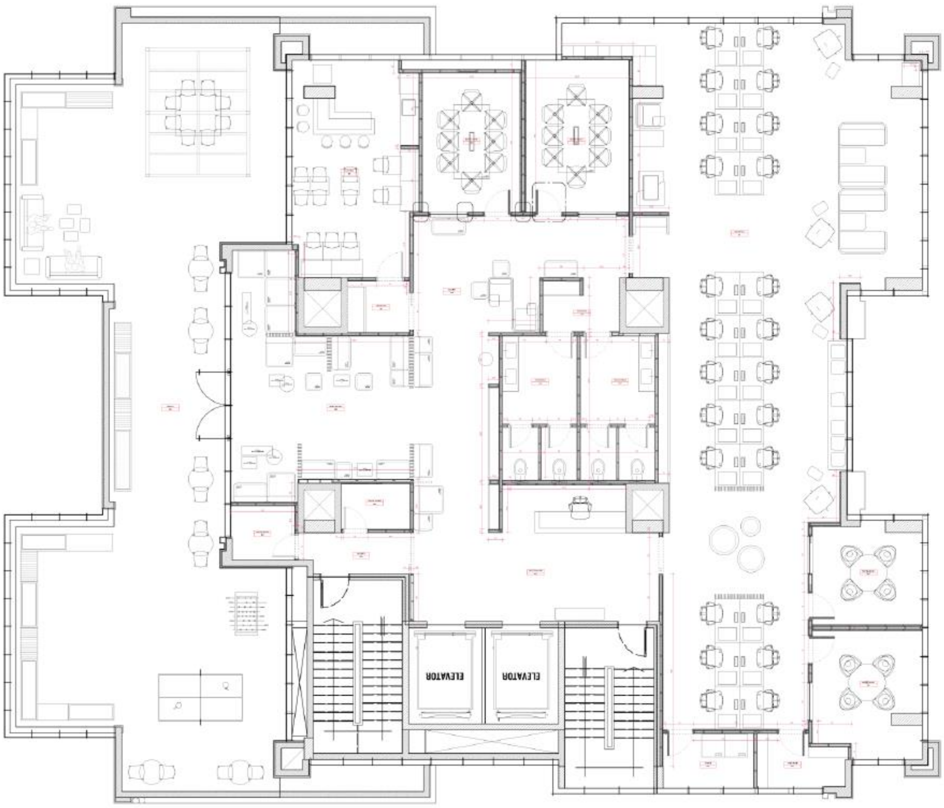


Figure 4.2 General plan of the project **(Integrated Environment, 2023)**

Figure 4.3 Graphic of the project **(Integrated Environment, 2023)**

4.4. Information Phase

At this phase, the project documents submitted by the owner were studied and examined, which included:

1. Contract.
2. Design drawings.
3. Specifications.
4. Bill of quantity.
5. Market prices.

The study team analyzed the information contained in the project documents and collected other relevant information from the owner and other parties. They also conducted interviews with all parties involved in the project to determine its objectives and identify the most significant obstacles they faced. Importantly, the team sought the opinion of the end user.

Subsequently, the team meticulously documented all the information collected to gain a comprehensive understanding of the project from all angles. This was followed by classifying the information and identifying the elements included in the project, as well as initiating the analysis of project costs based on the bill of quantities.

Table 4.2 Cost estimate

Magrabi Corporate Offices				
Laysen Valley				
Project SQM: 640 m^2				
S.NO.	**Description**	**Items No.**	**Amount (SAR)**	**Percentage**
1.0.0	Mobilization	1	40,375.00	1.95%
2.0.0	Floor Finishes	6	176,350.00	8.52%
3.0.0	Ceiling Finishes	6	258,710.00	12.49%
4.0.0	Wall Finishes & Wall Cladding	13	503,395.00	24.31%
5.0.0	Joinery - Counters & Props	5	106,400.00	5.14%
6.0.0	Doors, Windows & Gates	4	71,080.00	3.43%
7.0.0	Plumbing & Fixtures	24	95,690.00	4.62%
8.0.0	MEP - HVAC	12	353,530.00	17.07%
9.0.0	MEP - Electrical & Low Current Work	43	376,330.00	18.17%
10.0.0	Fire Fighting System (Site Issues)	5	50,170.00	2.42%

Magrabi Corporate Offices				
Laysen Valley				
Project SQM: 640 m^2				
S.NO.	**Description**	**Items No.**	**Amount (SAR)**	**Percentage**
11.0.0	Fire Alarm System	7	38,750.00	1.87%
Total Work			2,070,780.00	100%
Discount 3%			62,123.40	
Total After Discount			2,008,656.60	
VAT 15%			301,298.49	
Grand Total			2,309,955.09	

The Table 4.2 shows the main item with the total costs for each item and Based on Table the area of study is limited to the following items mentioned below:

Table 4.3 Area of study

No	**Description**	**Amount (SAR)**	**Percentage**
1	Ceiling Finishes	258,710.00	12.49%
2	Wall Finishes & Wall Cladding	503,395.00	24.31%

No	Description	Amount (SAR)	Percentage
3	MEP - HVAC	353,530.00	17.07%
4	MEP - Electrical & Low Current Work	376,330.00	18.17%
Total		1,491,965.00	72.04%

Most of the value engineering studies tend to focus on the high-cost areas of a project. Upon studying the estimated breakdown, the team observed as shown in table 4.3 that three items out of eleven accounted for 59.56% of the total cost. This finding suggests that 20% of the project components constitute 60% of the overall expenditure, aligning closely with the Pareto Law principle, which states that roughly 80% of consequences result from 20% of causes. The team also identified a fourth high-cost item that could be included, bringing the total project cost to 72.04%.

The study will prioritize the analysis of these high-cost items, examining their functions to identify cost-effective alternatives that maintain high quality.

4.5. Function Analysis Phase

Through this phase, the unnecessary functions are identified in addition to other required functions not achieved in the project. This phase answers two questions:

- What is the required function of each element (from the point of view of the owner and the beneficiary)?
- What is the function from the point of view of the designer (implemented on the ground)?

At this stage, the functions of the project are identified, understood, analyzed, and the relationship between them is realized, through the following steps:

A. Determine functions.
B. Classification of functions
C. Linking functions to the FAST diagram
D. Choosing the functions that can be improved.

4.5.1. Determine functions

Functions can be defined by asking the question, "What does the function do?" or "What is the purpose of using...?" A function represents the intended purpose for which a product or project was created and can be described using a two-word sentence. The first word (verb) indicates an abstract event or activity, such as teaching or building. The second word (noun) is a measurable or countable entity, such as heat or buildings.

4.5.2. Classification of functions

Functions vary according to their importance, and there is more than one function for a specific element. Therefore, we need to classify these functions in order to get a better understanding of their feasibility. The functions are analyzed according to the following categories:

A. Basic function
B. Secondary function
C. Secondary function (required)

To define functions, we ask the question, "Is it possible to work without this function?" If the answer is "no", then the function is Basic. To determine the required secondary function, we ask the question, "Is it possible to achieve the Basic function without this function?" If the answer is “no”, then a secondary function (required).

Table 4.4 The analysis of the four highest-cost functions

Item	NO	Description	Function		Type
			Verb	Noun	
3.0.0 Ceiling Finishes	3.0.1	**C01** Supply and installation of 12mm Fire-Rated Perforated Gypsum Board Ceiling with braces furring channel, anchorages and including all the required material and equipment	Coverage	Ceiling	Basic

Item	NO	Description	Function		Type
			Verb	Noun	
		needed. As per approved design and plans.			
	3.0.2	Supply and install White Paint from Jotun after putty and sanding including, two (2) layers of paint and One (1) layer of base with putty, with all the required equipment and material. As per approved design and plans.	Improve	Appearance	Secondary (required)
	3.0.3	**C02** Supply and installation of Wood Wool Board (1.2 * 0.6) Ceiling with braces furring channel, anchorages and including all the required material and equipment needed. As per approved design and plans.	Coverage	Ceiling	Basic
	3.0.4	**C03** Supply and installation of 12mm Fire-Rated Gypsum Board Ceiling with braces furring channel, anchorages and including all the required material and equipment needed. As per approved design and plans.	Coverage	Ceiling	Basic

Item	NO	Description	Function		Type
			Verb	Noun	
	3.0.5	Supply and install Moisture-Resistant White Paint from Jotun after putty and sanding including, two (2) layers of paint and One (1) layer of base with putty, with all the required equipment and material. As per approved design and plans.	Coverage	Ceiling	Secondary (required)
	3.0.6	**C04** Supply and Installation of Wooden Grain Wood Wool Ceiling Panels (0.3 * 0.6), along with hooks and ceiling stud, including all the required material and equipment needed. As per approved design and plans. Samples to be approved by client.	Coverage	Ceiling	Secondary
4.0.0 Wall Finishes & Wall Cladding	4.0.1	**W01** Supply and Installation of 12mm Fire-Rated Gypsum Double Layer Board **Cladding** fixed with 8mm metal studs and anchorage. Including all the required material and equipment needed. As per approved design and plans.	Division	Spaces	Basic

Item	NO	Description	Function		Type
			Verb	Noun	
	4.0.2	**W02** Supply and Installation of 12mm Fire-Rated Gypsum Double Layer Board Wall P**artitions** fixed with 8mm metal studs and anchorage. Including all the required material and equipment needed. As per approved design and plans.	Division	Spaces	Basic
	4.0.3	Supply and Install High quality core material 7cm Rockwool panels 1.2mx0.6m density 40kg for sound insulation. Including all the required material and equipment needed. As per approved design and plans.	Insulation	Sound	Secondary (required)
	4.0.4	**W03** Supply and Install 12mm Cement Board Double Layer fixed with 8mm metal studs and anchorage. Including all the required material and equipment needed. As per approved design and plans.	Division	Spaces	Basic
	4.0.4'	**W03'** Supply and Install 12mm Cement Board Single	Division	Spaces	Basic

Item	NO	Description	Function		Type
			Verb	Noun	
		Layer fixed with 8mm metal studs and anchorage. Including all the required material and equipment needed. As per approved design and plans.			
	4.0.5	**W04** Supply and Install HPL Panels Wood Texture for Bathrooms Divider as per approved design and plans. Including all the required material and equipment needed. Samples to be approved by client.	Improve	Appearance	Secondary
	4.0.6	**W05** Supply and Install Grade A Porcelain size (0.60m x 0.3m) as per approved design and plans. Including all the required material and equipment needed. Samples to be approved by client. Supplied by Beit ElEbaa (Spanish).	Improve	Appearance	Basic
	4.0.7	**WP01** Supply and install White paint from Jotun after putty and sanding including, two (2) layers of paint and One (1) layer of base with	Improve	Appearance	Secondary (required)

Item	NO	Description	Function		Type
			Verb	Noun	
		putty, with all the required equipment and material. As per approved design and plans.			
	4.0.8	**WP02** Supply and install Moisture-Resistant Washable White paint from Jotun after putty and sanding including, two (2) layers of paint and One (1) layer of base with putty, with all the required equipment and material. As per approved design and plans.	Improve Proofing	Appearance Water	Secondary (required)
	4.0.9	**GP01** Supply and Install Glass section 12mm thick Tempered Glass Windows Tinted with 3mm Sticker. Including all the required material and equipment needed, as per approved design and plans.	Filling	Void	Basic
	4.0.10	**W06** Supply and Install Fire-Resistant Wooden Panels White or Brown for Corridor, Workstation, Reception walls as per approved design and plans. Including all the	Insulation Improve	Sound Appearance	Secondary

Item	NO	Description	Function		Type
			Verb	Noun	
		required material and equipment needed. Samples to be approved by client.			
	4.0.11	**W07** Supply and Install Fire-Resistant Wooden Louvers for Partitions between rooms as per approved design and plans. Including all the required material and equipment needed. Samples to be approved by client.	Improve	Appearance	Secondary
	4.0.12	**W08** Supply and Install Wood Acoustical Panels Cladded on the Walls of Meeting Room Size (2.44*0.13) as per approved design and plans. Including all the required material and equipment needed. Samples to be approved by client.	Improve	Appearance	Secondary
8.0.0 MEP-HVAC	8.0.1	Supply and install concealed VRF AC (Daikin)Indoor units- included fitting, insulation, drain lines, and all necessary for operation with **5.0 tons** refrigeration. The contractor should provide the HVAC system layout showing	Control	Temperature	Secondary (required)

Item	NO	Description	Function		Type
			Verb	Noun	
		details for the system including, ducting, air supply grilles, according to the provided designs.			
	8.0.2	Supply and install concealed VRF AC (Daikin) Indoor units- included fitting, insulation, drain lines, and all necessary for operation with **2 tons** refrigeration. The contractor should provide the HVAC system layout showing details for the system including, ducting, air supply grilles, according to the provided designs.	Control	Temperature	Secondary (required)
	8.0.2	Supply and install Wall Mounted Split AC (Daikin) Indoor units - included fitting, insulation, drain lines, and all necessary for operation with **2 tons** refrigeration. The contractor should provide the HVAC system layout showing details for the system including, ducting, air supply grilles, according to the provided designs.	Control	Temperature	Basic

Item	NO	Description	Function		Type
			Verb	Noun	
	8.0.3	Supply and install concealed VRF AC (Daikin) Outdoor units- included fitting, insulation, drain lines, and all necessary for operation with **15 tons** refrigeration. The contractor should provide the HVAC system layout showing details for the system including, ducting, air supply grilles, according to the provided designs.	Control	Temperature	Basic
	8.0.4	Supply and install concealed VRF AC (Daikin) Outdoor units- included fitting, insulation, drain lines, and all necessary for operation with **20 tons** refrigeration. The contractor should provide the HVAC system layout showing details for the system including, ducting, air supply grilles, according to the provided designs.	Control	Temperature	Basic
	8.0.5	Galvanized steel metal duct complete with insulation fitting, hangers, and support,	Transport	Air	Secondary (required)

Item	NO	Description	Function		Type
			Verb	Noun	
		varies diameters according to HVAC layout.			
	8.0.6	Air distributing linear supply grille 3 slots.	Distribution	Air	Secondary
	8.0.7	Air distributing linear return grille 3 slots.	Distribution	Air	Secondary
	8.0.8	Exhaust fans- Inline for WCs. (American Roof Type) (1000 CFM)	Suction	Fan	Secondary (required)
	8.0.8	Exhaust fans fresh air- Inline for WCs. (American Roof Type) (1000 CFM)	Suction	Fan	Secondary (required)
	8.0.9	Galvanized steel metal duct complete with insulation fitting, hangers, and support, varies diameters according to HVAC layout for exhaust ducts.	Transport	Air	Secondary (required)
	8.0.10	Square or Round exhaust grills 30x30 cm.	Distribution	Air	Secondary
9.0.0 MEP-Electrical & Low	9.0.1	**PANELBOARDS:**			Basic
	9.0.2	Supply, Installation, Testing and Commissioning with Main and Branch Circuit Breakers, Including Plated			

Item	NO	Description	Function		Type
			Verb	Noun	
Current Work		Bus Bars, Earth & Neutral Bar, Supports, Grounding, Internal Wirings and Other Accessories Required to Complete the Work as Per Drawings & providing all the necessary to complete the job.			
	9.0.3	Panel Boards for lighting, power & AC, ABB	Distribution	Current	Basic
	9.0.4	**CABLING:**			Secondary (required)
	9.0.5	(4CX25mmsq. XLPE/PVC/CU/) +E.1CX16mmsq.PVC/CU for DB's	Transfer	Current	Secondary (required)
	9.0.6	(4CX16mmsq. XLPE/PVC/CU/) +E.1CX25mmsq.PVC/CU for AC outdoor	Transfer	Current	Secondary (required)
	9.0.7	(3CX6mmsq. XLPE/PVC/CU/) for exhaust fan & Kitchen	Transfer	Current	Secondary (required)
	9.0.8	**CABLE TRAYS**			Secondary
	9.0.9	Supply Install, And Connect, The Cable Trays of			

Item	NO	Description	Function		Type
			Verb	Noun	
		Galvanized Steel Type, Including All the Supports, Covers Were Indicated and All Related Accessories, & providing all the necessary to complete the job.			
	9.0.10	Supply and installation of Cable Tray 30 X 100 X1.5mm with cover for Power Cables	Coverage	Cables	Secondary
	9.0.11	Supply and installation of Cable Tray 20 X 100 X1.5mm with cover for Data Cables	Coverage	Cables	Secondary
	9.0.12	**SOCKET OUTLETS**			Basic
	9.0.13	Supply, Installation, Testing and Commissioning of Wall / Floor / Ceiling Mounted Type Socket Outlets, Switches Including Wirings, Trays, Conduiting Grounding, Metal Boxes and Other Required Accessories in Accordance with The Drawings & providing all the necessary to complete the job.			

Item	NO	Description	Function		Type
			Verb	Noun	
	9.0.14	Single Electrical sockets outlet, installed on the walls mounted (Legrand)	Connection	Current	Basic
	9.0.15	Single Electrical sockets outlet, installed on Desk mounted (Legrand)	Connection	Current	Basic
	9.0.16	Single Electrical sockets outlet waterproof, installed on the walls mounted (Legrand)	Connection	Current	Basic
	9.0.17	EWH Outlet	Heating	Water	Secondary (required)
	9.0.18	Commando Socket 16A For Server room	Connection	Current	Secondary
	9.0.19	Commando Socket 32A For Server room	Connection	Current	Secondary
	9.0.20	**DISCONNECT SWITCH**			
	9.0.21	Supply, Installation, Testing and Commissioning of Safety Switches Including Cables, Trays, and Accessories.			
	9.0.22	Disconnect switch, non-fused, 32A, 3P, 600V	Secure	Current	
	9.0.23	**LIGHTING SYSTEM:**			

Item	NO	Description	Function		Type
			Verb	Noun	
	9.0.24	**L-01:** Supply and install Electrical Power Point Only & Fixing Round Ceiling (110 MM Día) Frame Fixed on Gypsum with LED Lamp spot. Including all the required material and equipment needed, as per approved design and plans. (Third Fix to be Supplier by Client)	Lighting	Area	Basic
	9.0.25	**L-02**: Supply and install Linear Suspended Type with LED Lamp Including all the required material and equipment needed, as per approved design and plans. (Third Fix to be Supplied by Client)	Lighting	Area	Basic
	9.0.26	Emergency light	Lighting	Area	Secondary (required)
	9.0.27	Supply and install of Single Switches in Office and Meeting Rooms Including in Cafeteria all the required material and equipment	Connection	Current	Secondary

Item	NO	Description	Function		Type
			Verb	Noun	
		needed, as per approved design and plans.			
	9.0.28	**IT & IP TELEPHONE System:**			Basic
	9.0.29	**Passive part**			
	9.0.30	Supply, install, connect, test and commission, a complete data system including conduits, boxes cables (CAT6) and all related accessories, & providing all the necessary to complete the job.			
	9.0.31	Wall Mounted IP Data Outlet Only Conduit and Fitting and Faceplate	Connection	Current	Basic
	9.0.32	Data Outlet for floor boxes Only Conduit and Fitting and Faceplate	Connection	Current	Basic
	9.0.33	Data Outlet for Access control	Connection	Access	Secondary (required)
	9.0.34	Data Outlet for WIFI	Connection	WIFI	Secondary
	9.0.35	HDMI point (Legrand)	Connection	Current	Secondary
	9.0.36	USB outlet point	Connection	Current	Secondary

Item	NO	Description	Function		Type
			Verb	Noun	
	9.0.37	Supply of Data Server rack (h:42 U 1968 MM, W:600 MM; D:1000mm)	Supplied By Client		
	9.0.38	**IP telephone**	Basic		
	9.0.39	Cisco IP telephone for the Workstations, Reception, and meeting rooms.	Supplied By Client		
	9.0.40	Supply and install Door Access ZKT Multi-Biometric MB10 with four (4) type verification modes, Face ID, RFID, Fingerprint, and pin code. Including all the required material and equipment needed, as per approved design and plans	Supplied By Client		
	9.0.41	Supply and install Automatic (Sensor) push button door opener. Including all the required material and equipment needed, as per approved design and plans	Opennig	Door	Secondary
	9.0.42	Supply and install Door Magnetic locks for Tempered Glass doors and Wooden doors. Including all the	Locking	Door	Secondary

Item	NO	Description	Function		Type
			Verb	Noun	
		required material and equipment needed, as per approved design and plans			
	9.0.43	Supply and install Control Door Access Software system for integration of access points to control time schedules and private entry. Including all the required material and equipment needed, as per approved design and plans	Supplied By Client		

Table 4.4 shows the analysis of the four highest-cost functions and determines their importance for choosing the functions that can be modified, hence, they do not affect the project. This will be further explained in FAST diagram.

4.5.3. Function Analysis System Technique: FAST

After completing the identification and classification of functions, it is necessary to link them to each other and clarify the relationships between them. This helps to expand understanding and awareness of the study field.

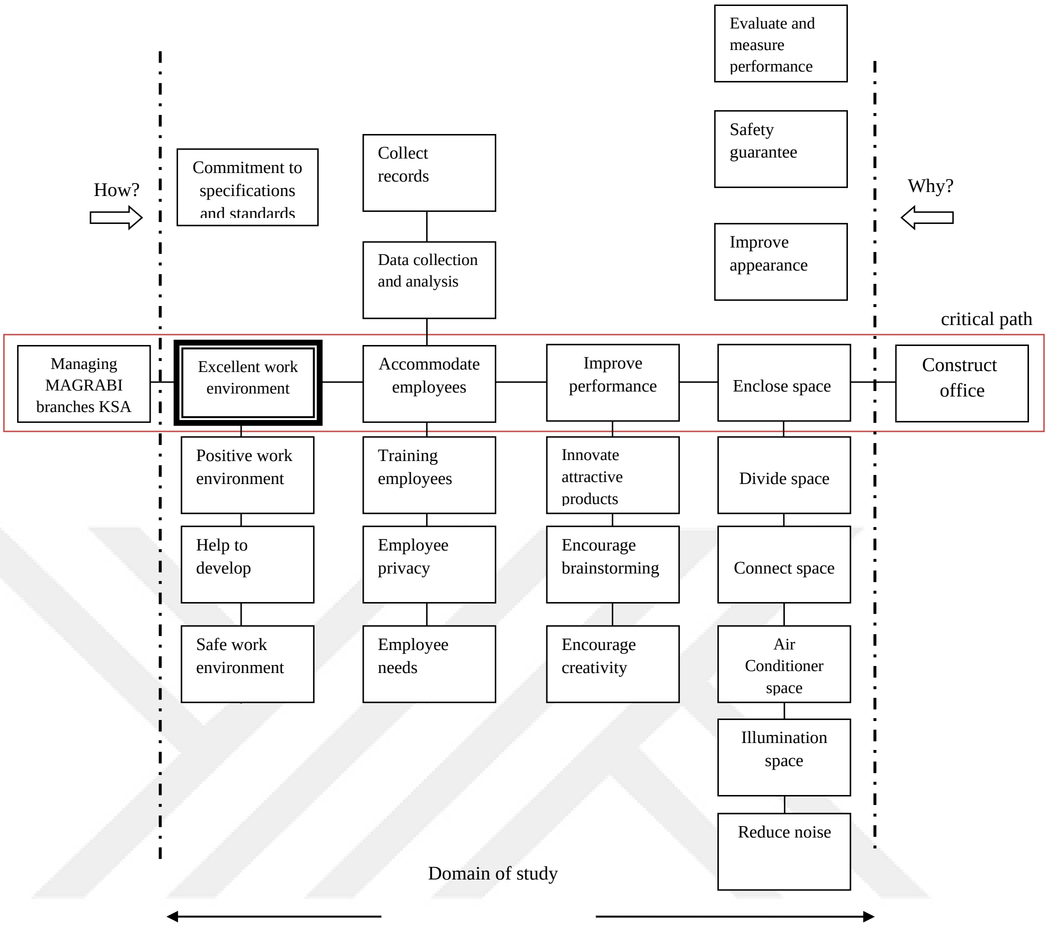


Figure 4.4 Diagram for MAGRABI office

As shown in Figure 4.4, the functions were analyzed and classified, and the critical path was determined. The critical path starts from the highest goal of the project, which is managing Magrabi branches in KSA, and it ends with the construction of the office.

4.6. Creativity Phase

The problem was described through the analysis of the function, and the team members began reviewing the FAST diagram to identify the higher goal, the primary function, and some secondary functions. They displayed the project function according to the bill of quantities. The team started generating a large number of creative ideas and proposals to find the best appropriate solutions and alternatives that fulfill the basic function at the lowest total cost, while minimizing the negatives and maximizing the positives. They utilized the brainstorming method. The brainstorming techniques used were:

- Team effort.
- Freewheeling creative session (no judgment/critique).
- Generating as many ideas as possible (all accepted).
- Recording the ideas to trigger new ideas, combinations, and later development. proofread

Many ideas were proposed, amounting to 53 ideas that included the components of the project solving the highest cost functions (Ceilings, Walls, MEP - HVAC, Electricity). What is required at this phase is to find many possible solutions and alternatives, and this is done through 3 stages:

1. Obtaining intuitive and familiar traditional ideas, in which, 12 ideas were collected.
2. Ask some creative questions to get many different and strange ideas, in which 41 ideas were collected.
3. Merging duplicate ideas, deleting ideas that are impossible to achieve, in which 21 ideas. A form was distributed to the team to record the advantages and disadvantages of each idea, to help choose the best ideas in the evaluation and development phase.

Table 4.5 Team evaluation

No	The idea	Advantages	Disadvantages	Scoure
A	**Ceiling Finishes**	The VE team discussed the best and least expensive materials for the Ceiling. The materials used, and their alternatives were presented for comparison.		
1	12mm Perforated Gypsum Board	- Hide lighting and extensions - Improve appearance - High sound insulation	Higher cost	8

No	The idea	Advantages	Disadvantages	Scoure
2	12mm Gypsum Board	- Hide lighting and extensions - Improve appearance - lower cost	Normal sound insulation	9
3	Wood Wool Board (1.2 x 0.6)	- Improve appearance - Hide lighting and extensions - Sound insulation	Higher cost	8
4	Wooden Grain Wood Wool Ceiling Panels (0.3 x 0.6)	- Improve appearance - Sound insulation	Higher cost	7
5	Flat Foam Acoustical Ceiling Panels (0.3 x 0.6)	- Improve appearance - Sound insulation	Lower cost	8
6	Dropped ceiling (0.6 x 0.6) Perforated	- Improve appearance - Hide lighting and extensions - Sound insulation	Lower cost	9
B	**Wall Finishes & Wall Cladding**	The VE team discussed the best and least expensive materials for the Wall, and the materials used, and their alternatives were presented for comparison.		

No	The idea	Advantages	Disadvantages	Scoure
6	12mm Gypsum Double Layer Board Cladding	- Spaces division - High sound insulation	Higher cost	8
7	12mm Gypsum Double Layer Board Wall Partitions	- Spaces division - High sound insulation	Higher cost	8
8	12mm Gypsum Single Layer Board Wall Partitions	- Spaces division - sound insulation	Lower cost	9
9	12mm Cement Board Double Layer	- Spaces division - High sound insulation	Higher cost	8
10	12mm Cement Board Single Layer	- Spaces division - High sound insulation	Lower cost	9
11	HPL Panels Wood Texture for Bathrooms Divider	- Improve appearance	Higher cost	7
12	Porcelain size (0.60m x 0.3m)	- Improve appearance - water insulation - Moisture insulation	Higher cost Heavy	9
13	Glass section 12mm thick	- Closing Void	Heat entry	10

No	The idea	Advantages	Disadvantages	Scoure
	Tempered Glass Windows Tinted with 3mm Sticker	- Improve appearance		
14	Wooden Panels White or Brown for Corridor, Workstation, Reception walls	- Improve appearance - Sound insulation	Higher cost	8
15	Wooden Louvers for Partitions between rooms	- Improve appearance	Higher cost	8
16	Wood Acoustical Panels Cladded on the Walls (2.44 x 0.13)	- Improve appearance - Sound insulation	Higher cost	7
17	WPC Panels	- Improve appearance - Sound insulation	Lower cost	9
18	WPC Louvers for Partitions between rooms	- Improve appearance	Lower cost	9
19	WPC Acoustical Panels	- Improve appearance	Lower cost	9

No	The idea	Advantages	Disadvantages	Scoure
C	**MEP - HVAC**	The most important question discussed by the VE team is what the best and suitable type for the project is, is it DX or VRF?		
20	VRF AC (Daikin)	Modern system	Systems are more complex	7
		multiple indoor units connected to a single outdoor unit	Higher cost	
		They can operate in both heating and cooling mode at the same time	-	
		Used in larger buildings	-	
21	DX AC (Daikin)	Single refrigerant loop to cool and heat a building	Lower cost	9
		Systems are simple, reliable, and commonly used	Old system	
		Used in small buildings	-	
D	**MEP - Electrical & Low Current Work**	Many ideas have been put forward, related to replacing the quality of sockets and switches, or changing the lighting system. After discussion, it was noted that most elements in electricity are basic and the qualities used are good, and it is important that the quality of electricity is		

No	The idea	Advantages	Disadvantages	Scoure
		high, so modifying it will not be very useful, and most of the elements were supplied by Client.		
*Score 10 = most acceptable			*Score 1 = least acceptable	

Table 4.5 showing some of the ideas that were put forward through the creativity phase.

4.6.1. Summary of Creativity Phase

After reviewing the FAST diagram and studying all the items of quantities, a set of ideas and alternatives to the materials used were developed. One of the most important observations is the high interest in insulation that is exaggerated in the project, and this will be evaluated in the evaluation and ideas development Phase.

4.7. Evaluation and Development Phase

Ideas were put forward and evaluated in the previous phase, and the best ones were selected based on the team's perspective, using a voting process for each idea. In this stage, a comparison will be made between the alternatives and proposed ideas, considering their ability to fulfill the required functions and their total cost.

The key objective at this stage is to prepare a report that includes actionable proposals to facilitate the presentation of ideas to decision-makers. Specific forms will be created for everyone within the value engineering team, tailored to their respective areas of expertise.

The evaluation will be carried out using two methods: normative assessment and comparative evaluation, accompanied by explanations and visual aids such as pictures or charts.

4.7.1. First: Normative Assessment

The normative assessment is used to compare alternatives by evaluating quality, function, and project cost using **Equation 1** V=(F+Q)/C and they will be placed in a comparison table to identify the best possible alternatives.

Calculation of Function:

The function calculation involves the following steps:

a. The Value Engineering team establishes fundamental criteria for the evaluation, organizing them into a matrix. The alternatives are then compared within the matrix, based on the importance assigned to each criterion, to determine their relative performance.

b. Assigning Function Weights: The Value Engineering team assigns relative weights to each function (criterion) based on the evaluation matrix. These weights reflect the significance of each function in achieving the project's objectives.

c. Evaluating Alternatives Based on Criteria: The alternatives are evaluated based on the criteria chosen earlier. A scale of 1 to 5 is used for this evaluation, with 1 representing poor performance and 5 representing excellent performance. The Value Engineering team assesses each alternative and multiplies the evaluation score by the respective weight for each criterion.

d. Summing Up Function: The weighted scores of all functions are summed up to obtain the function score for each alternative.

Calculation of Quality:

Quality evaluation is measured on a scale from 100 to 500, where 100 represents poor quality and 500 represents excellent quality. The evaluation is based on the two specific criteria:

a. Sustainability: The Value Engineering team assesses the sustainability of each alternative, considering factors such as environmental impact, compatibility with ecological systems, and the product's expected lifespan.

b. Ease of Operation and Maintenance: The alternatives are evaluated based on how easy they are to operate and maintain after implementation. This evaluation considers factors such as simplicity of operation, accessibility for maintenance, and potential downtime for maintenance.

The quality evaluation was based on the input from experts, the Value Engineering team, the owner's requirements, and with reference to the Saudi Standards and Metrology Organization."

Value Index Calculation:

To obtain the value index for each alternative, the following formula is used:

Value Index (V) = (Quality Score + Function Score) / Total Cost

a. The Quality Score is the score obtained from the quality evaluation on a scale of 100 to 500.

b. The Function Score is the sum of the weighted scores of all functions for each alternative.

c. Total Cost is the overall cost associated with each alternative.

This value index is used to determine the best alternative. The alternative with the highest value index is selected as the best choice for the construction project.

The normative Assessment or "Quality Based Selections (QBS) Matrix" methodology was applied in this study by referring (Al-Yusufi, 2009), the president of SAVE-International in Saudi Arabia. The QBS Matrix was implemented based on the tables proposed by Al-Yousifi, which facilitated the comparison between alternatives and the subsequent selection of the optimal alternative. Furthermore, references were made to the book "Value Methodology: A Pocket Guide to Reduce Cost and Improve Value Through Function Analysis" to verify the equations and applications (Bolton, J. D., Gerhardt, D. J., & Holt, M. P., 2009).

The Value Engineering team must be well-informed about the project's objectives, the owner's requirements, and relevant industry standards.

The implementation method considers factors such as the impact on project quality, implementation time, availability of skilled workforce, and appropriate mechanisms.

Table 4.6 Normative assessment of the VE team for ceiling

Ceiling Finishes								
A. Hide lighting and extensions	**A**				**2** points for Major Preference			
B. Aesthetics	**A/2**	**B**			**1** point for Minor Preference			
C. Sound insulation	**A/1**	**C/1**	**C**		**1** point each for Same preference			
D. Implementation Method	**A/D**	**B/D**	**C/1**	**D**				
Weight	**4**	**1**	**2**	**2**	**F**	**Q**	**C (SAR)**	**V=F+Q/C**
Weight Percentage	**45**	**11**	**22**	**22**	Function Points	Quality out of 500	LCC/100	Value index
12mm Fire-Rated Perforated Gypsum Board	4	4	4	3	378	420	824.1	0.96
Function importance degree%	180	44	88	66				
12mm Fire-Rated Gypsum Board	4	3	2	4	345	300	301.5	2.1
Function importance degree%	180	33	44	88				
The value index of the alternative has the highest degree (2.1), it is considered the best option.								
Wood Wool Board (1.2 x 0.6)	4	4	5	4	422	400	1,131.5	0.72
Function importance degree%	180	44	110	88				
Dropped ceiling (1.2 x 0.6) Perforated	4	3	4	3	367	280	310	2.08
Function importance degree%	180	33	88	66				
The value index of the alternative has the highest degree (2.08), it is considered the best option.								

<table>
<tr><th colspan="9">Ceiling Finishes</th></tr>
<tr><td>A. Hide lighting and extensions</td><td>A</td><td></td><td></td><td></td><td colspan="4" rowspan="4">2 points for Major Preference
1 point for Minor Preference
1 point each for Same preference</td></tr>
<tr><td>B. Aesthetics</td><td>A/2</td><td>B</td><td></td><td></td></tr>
<tr><td>C. Sound insulation</td><td>A/1</td><td>C/1</td><td>C</td><td></td></tr>
<tr><td>D. Implementation Method</td><td>A/D</td><td>B/D</td><td>C/1</td><td>D</td></tr>
<tr><td>Weight</td><td>4</td><td>1</td><td>2</td><td>2</td><td>F</td><td>Q</td><td>C (SAR)</td><td>V=F+Q/C</td></tr>
<tr><td>Weight Percentage</td><td>45</td><td>11</td><td>22</td><td>22</td><td>Function Points</td><td>Quality out of 500</td><td>LCC/100</td><td>Value index</td></tr>
<tr><td>Wooden Grain Wood Wool Ceiling Panels (0.3 x 0.6)</td><td>2</td><td>4</td><td>4</td><td>3</td><td rowspan="2">288</td><td rowspan="2">380</td><td rowspan="2">382.5</td><td rowspan="2">1.74</td></tr>
<tr><td>Function importance degree%</td><td>90</td><td>44</td><td>88</td><td>66</td></tr>
<tr><td>Acoustical Ceiling Panels (0.3 x 0.6)</td><td>2</td><td>2</td><td>3</td><td>3</td><td rowspan="2">244</td><td rowspan="2">300</td><td rowspan="2">102</td><td rowspan="2">5.3</td></tr>
<tr><td>Function importance degree%</td><td>90</td><td>22</td><td>66</td><td>66</td></tr>
<tr><td colspan="9">The value index of the alternative has the highest degree (5.3), it is considered the best option.</td></tr>
</table>

Table 4.7 Normative assessment of the VE team for wall

Wall Finishes & Wall Cladding								
A. Spaces division	**A**				**2** points for Major Preference			
B. Aesthetics	**A/2**	**B**			**1** point for Minor Preference			
C. Sound or water insulation	**A/1**	**C/1**	**C**		**1** point each for Same preference			
D. Implementation Method	**A/D**	**B/D**	**C/1**	**D**				
Weight	**4**	**1**	**2**	**2**	**F**	**Q**	**C (SAR)**	**V=F+Q/C**
Weight Percentage	**45**	**11**	**22**	**22**	Function Points	Quality out of 500	LCC/100	Value index
12mm Fire-Rated Gypsum Board Double Layer Cladding	4	4	5	4	422	400	147.9	5.5
function importance degree%	180	44	110	88				
12mm Fire-Rated Gypsum Board Single Layer Cladding	4	4	3	4	378	300	102	6.64
Function importance degree%	180	44	66	88				
The value index of the alternative has the highest degree (6.64), it is considered the best option.								
12mm Fire-Rated Gypsum Double Layer	4	4	5	4	422	400	970.2	0.84
Function importance degree%	180	44	110	88				
12mm Fire-Rated Gypsum Single Layer	4	4	3	4	378	300	574.2	1.18
Function importance degree%	180	44	66	88				

Wall Finishes & Wall Cladding								
A. Spaces division	**A**				**2** points for Major Preference			
B. Aesthetics	**A/2**	**B**			**1** point for Minor Preference			
C. Sound or water insulation	**A/1**	**C/1**	**C**		**1** point each for Same preference			
D. Implementation Method	**A/D**	**B/D**	**C/1**	**D**				
Weight	**4**	**1**	**2**	**2**	**F**	**Q**	**C (SAR)**	**V=F+Q/C**
Weight Percentage	**45**	**11**	**22**	**22**	Function Points	Quality out of 500	LCC/100	Value index
The value index of the alternative has the highest degree (1.18), it is considered the best option.								
12mm Cement Board Double Layer	4	4	5	4	422	400	82.5	9.96
Function importance degree%	180	44	110	88				
12mm Cement Board Single Layer	4	4	3	4	378	300	49.5	13.7
Function importance degree%	180	44	66	88				
The value index of the alternative has the highest degree (13.7), it is considered the best option.								
HPL Panels Wood Texture for Bathrooms	0	5	4	4	231	420	243	2.67
Function importance degree%	0	55	88	88				
Porcelain size (0.60m x 0.3m)	0	3	3	3	165	300	50.4	9.22
Function importance degree%	0	33	66	66				
The value index of the alternative has the highest degree (9.22), it is considered the best option.								

<table>
<tr><th colspan="9">Wall Finishes & Wall Cladding</th></tr>
<tr><td>A. Spaces division</td><td>A</td><td></td><td></td><td></td><td colspan="4">2 points for Major Preference</td></tr>
<tr><td>B. Aesthetics</td><td>A/2</td><td>B</td><td></td><td></td><td colspan="4">1 point for Minor Preference</td></tr>
<tr><td>C. Sound or water insulation</td><td>A/1</td><td>C/1</td><td>C</td><td></td><td colspan="4">1 point each for Same preference</td></tr>
<tr><td>D. Implementation Method</td><td>A/D</td><td>B/D</td><td>C/1</td><td>D</td><td colspan="4"></td></tr>
<tr><td>Weight</td><td>4</td><td>1</td><td>2</td><td>2</td><td>F</td><td>Q</td><td>C (SAR)</td><td>V=F+Q/C</td></tr>
<tr><td>Weight Percentage</td><td>45</td><td>11</td><td>22</td><td>22</td><td>Function Points</td><td>Quality out of 500</td><td>LCC/100</td><td>Value index</td></tr>
<tr><td>Fire-Resistant Wooden Panels</td><td>0</td><td>5</td><td>4</td><td>4</td><td rowspan="2">231</td><td rowspan="2">320</td><td rowspan="2">986</td><td rowspan="2">0.56</td></tr>
<tr><td>Function importance degree%</td><td>0</td><td>55</td><td>88</td><td>88</td></tr>
<tr><td>Fire-Resistant WPC Panels</td><td>0</td><td>3</td><td>3</td><td>4</td><td rowspan="2">187</td><td rowspan="2">400</td><td rowspan="2">464</td><td rowspan="2">1.2</td></tr>
<tr><td>Function importance degree%</td><td>0</td><td>33</td><td>66</td><td>88</td></tr>
<tr><td colspan="9">The value index of the alternative has the highest degree (1.2), it is considered the best option.</td></tr>
<tr><td>Fire-Resistant Wooden Louvers Partition</td><td>4</td><td>5</td><td>4</td><td>4</td><td rowspan="2">411</td><td rowspan="2">300</td><td rowspan="2">636.3</td><td rowspan="2">1.11</td></tr>
<tr><td>Function importance degree%</td><td>180</td><td>55</td><td>88</td><td>88</td></tr>
<tr><td>Fire-Resistant WPC Partition</td><td>4</td><td>3</td><td>3</td><td>4</td><td rowspan="2">367</td><td rowspan="2">400</td><td rowspan="2">333.3</td><td rowspan="2">2.3</td></tr>
<tr><td>Function importance degree%</td><td>180</td><td>33</td><td>66</td><td>88</td></tr>
<tr><td colspan="9">The value index of the alternative has the highest degree (2.3), it is considered the best option.</td></tr>
</table>

Wall Finishes & Wall Cladding								
A. Spaces division	**A**				**2** points for Major Preference			
B. Aesthetics	**A/2**	**B**			**1** point for Minor Preference			
C. Sound or water insulation	**A/1**	**C/1**	**C**		**1** point each for Same preference			
D. Implementation Method	**A/D**	**B/D**	**C/1**	**D**				
Weight	**4**	**1**	**2**	**2**	**F**	**Q**	**C (SAR)**	**V=F+Q/C**
Weight Percentage	**45**	**11**	**22**	**22**	Function Points	Quality out of 500	LCC/100	Value index
Wood Acoustical Panels Size (2.44x0.13)	0	5	4	4	231	300	678.5	0.78
Function importance degree%	0	55	88	88				
WPC Acoustical Panels Size (2.44x0.13)	0	3	3	4	220	400	265.5	2.33
Function importance degree%	0	66	66	88				
The value index of the alternative has the highest degree (2.33), it is considered the best option.								

Table 4.8 Normative assessment of the VE team for HVAC

MEP – HVAC								
A. Maintenance	**A**				**2** points for Major Preference			
B. Aesthetics	**A/2**	**B**			**1** point for Minor Preference			
C. Cooling quality	**A/C**	**C/1**	**C**		**1** point each for Same preference			
D. Installation method	**A/D**	**B/D**	**C/1**	**D**				
Weight	**3**	**1**	**3**	**2**	**F**	**Q**	**C (SAR)**	**V=F+Q/C**
Weight Percentage	**33**	**11**	**33**	**23**	Function Points	Quality out of 500	LCC/100	Value index
VRF AC (Daikin) Outdoor units with 20 tons refrigeration.	4	4	4	4	400	420	1,316	0.62
Function importance degree%	132	44	132	92				
XD AC (Daikin) Indoor and Outdoor units with 5 tons refrigeration	4	3	4	3	366	350	526	1.36
Function importance degree%	132	33	132	69				
The value index of the alternative has the highest degree (1.36), it is considered the best option.								
VRF AC (Daikin) Outdoor with 15 tons refrigeration.	4	4	4	4	400	420	965	0.84
Function importance degree%	132	44	132	92				
XD AC (Daikin) Indoor and Outdoor units with 2 tons refrigeration	4	3	4	3	366	350	495	1.45

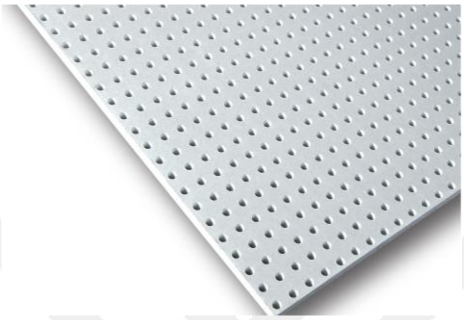
MEP – HVAC								
A. Maintenance	**A**				**2** points for Major Preference			
B. Aesthetics	**A/2**	**B**			**1** point for Minor Preference			
C. Cooling quality	**A/C**	**C/1**	**C**		**1** point each for Same preference			
D. Installation method	**A/D**	**B/D**	**C/1**	**D**				
Weight	**3**	**1**	**3**	**2**	**F**	**Q**	**C (SAR)**	**V=F+Q/C**
Weight Percentage	**33**	**11**	**33**	**23**	Function Points	Quality out of 500	LCC/100	Value index
Function importance degree%	132	33	132	69				
The value index of the alternative has the highest degree (1.45), it is considered the best option.								

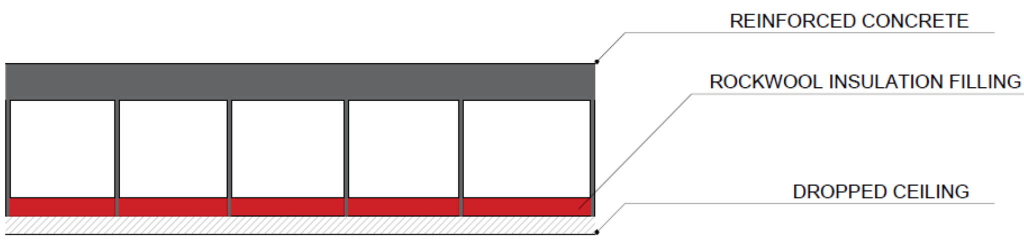
4.7.2. Second: Comparative evaluation

After completing the normative assessment, a comparative evaluation is conducted to justify the selection of alternatives. This evaluation includes visual aids such as drawings, pictures, and financial cost analysis. The results are then organized in a presentable format to effectively communicate the alternatives to the project's decision-makers. The aim is to transform the alternatives into feasible proposals that can be implemented.

Table 4.9 Recommended alternatives.

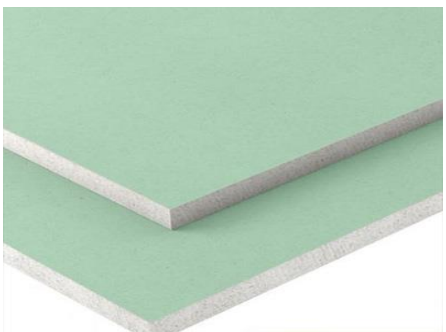
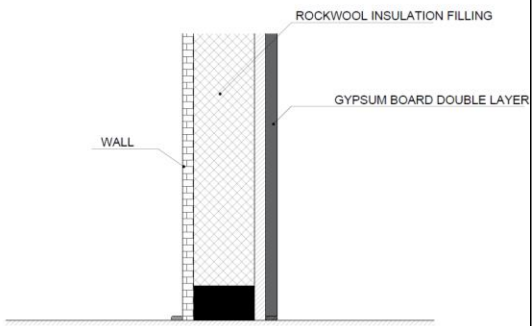
VE Team alternative			
Project	Magrabi Offices	Section:	Ceiling Finishes
Current Item:		Alternative Item:	

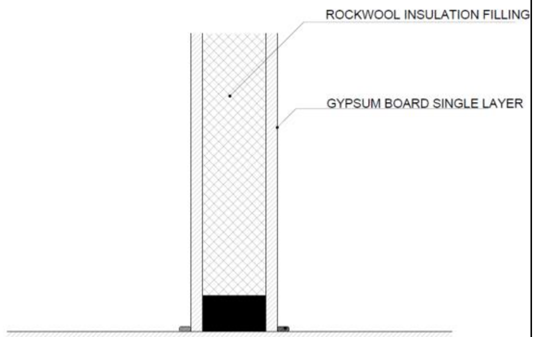
VE Team alternative	
12mm Fire-Rated Perforated Gypsum Board Ceiling with braces furring channel	12mm Fire-Rated Gypsum Board Ceiling with braces furring channel
Pictures For Current Item:	Pictures For alternative Item:
	
Justification	
Both gypsum boards and perforated gypsum boards can be used in the construction of ceilings Perforated gypsum boards were used because of their sound insulation and decoration effects. After examination, it was found that there is an insulating layer on top of the boards, so the presence of perforated boards is unnecessary, especially since they do not affect the basic functions of the project, and they are usually used in restaurants or theaters. Gypsum is more common in residential and commercial buildings.	
Quantity	201 m^2
Current Item Cost	SAR 82,410
The Cost of the alternative Item	SAR 30,150
Savings cost	SAR 52,260
Alternative	

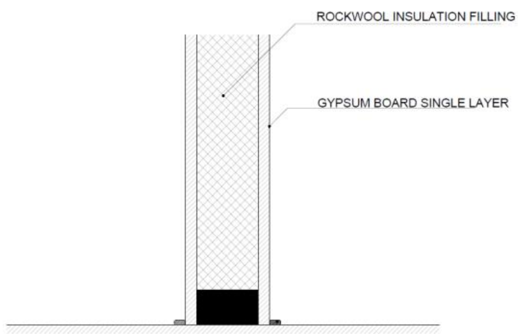
<table>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td>Project</td><td>Magrabi Offices</td><td>Section:</td><td>Ceiling Finishes</td></tr>
<tr><td colspan="2">Current Item:</td><td colspan="2">Alternative Item:</td></tr>
<tr><td colspan="2">Wood Wool Board (1.2 x 0.6) Ceiling with braces furring channel</td><td colspan="2">Dropped ceiling (1.2 x 0.6) Perforated</td></tr>
<tr><td colspan="2">Pictures For Current Item:</td><td colspan="2">Pictures For alternative Item:</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">
</td></tr>
<tr><td colspan="4">Justification</td></tr>
<tr><td colspan="4">One of the most important features of the Wood Wool Board is the lightweight and flexibility that is often used for acoustical paneling, insulation, and decorative applications. Its high cost is making it a popular choice for theatres and auditoriums, but not recommended in offices.

The best option is the perforated board. It also has the advantage of ventilation and sound absorption due to the series of holes. The perforated ceiling is commonly</td></tr>
</table>

<table>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td colspan="4">used in commercial and public spaces such as offices, schools and its cost is much lower.</td></tr>
<tr><td colspan="2">Quantity</td><td colspan="2">155 m2</td></tr>
<tr><td colspan="2">Current Item Cost</td><td colspan="2">SAR 113,150</td></tr>
<tr><td colspan="2">The Cost of the alternative Item</td><td colspan="2">SAR 31,000</td></tr>
<tr><td colspan="2">Savings cost</td><td colspan="2">SAR 82,150</td></tr>
<tr><td colspan="4"></td></tr>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td>Project</td><td>Magrabi Offices</td><td>Section:</td><td>Ceiling Finishes</td></tr>
<tr><td colspan="2">Current Item:</td><td colspan="2">Alternative Item:</td></tr>
<tr><td colspan="2">Wooden Grain Wood Wool Ceiling Panels (0.3 x 0.6)</td><td colspan="2">Acoustical Ceiling Panels (0.3 x 0.6)</td></tr>
<tr><td colspan="2">Pictures For Current Item:</td><td colspan="2">Pictures For alternative Item:</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">Justification</td></tr>
<tr><td colspan="4">The Wood wool ceiling was used here mainly for aesthetic purposes as well as sound absorption. The proposed alternative is the best and least expensive which</td></tr>
</table>

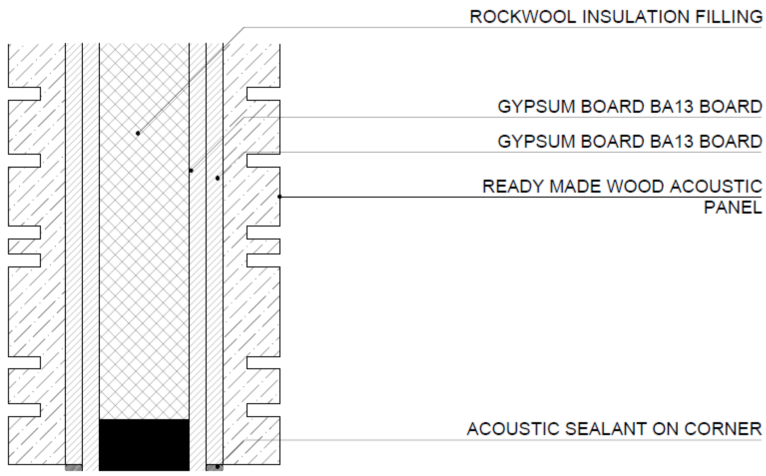
<table>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td colspan="4">is the acoustical ceiling because it gives a beautiful shape, it is also very useful for sound insulation as well as improving sound quality. Acoustical ceiling is preferable in offices.</td></tr>
<tr><td colspan="2">Quantity</td><td colspan="2">52 m^2</td></tr>
<tr><td colspan="2">Current Item Cost</td><td colspan="2">SAR 38,250</td></tr>
<tr><td colspan="2">The Cost of the alternative Item</td><td colspan="2">SAR 10,200</td></tr>
<tr><td colspan="2">Savings cost</td><td colspan="2">SAR 28,050</td></tr>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td>Project</td><td>Magrabi Offices</td><td>Section:</td><td>Wall Finishes & Wall Cladding</td></tr>
<tr><td colspan="2">Current Item:</td><td colspan="2">alternative Item:</td></tr>
<tr><td colspan="2">12mm Fire-Rated Gypsum Double Layer Board Cladding</td><td colspan="2">12mm Fire-Rated Gypsum Single Layer Board</td></tr>
<tr><td colspan="4">Pictures For Current Item:</td></tr>
<tr><td colspan="2"></td><td colspan="2">
</td></tr>
<tr><td colspan="4">Justification</td></tr>
<tr><td colspan="4">Double gypsum boards were used here for sound insulation reasons, along with the cladding. This addition is not necessary, it does not contribute to the basic</td></tr>
</table>

<table>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td colspan="4">functions of the project. Especially since there is insulation inside the gypsum Rockwool panels with 1.2mx0.6m density of 40kg, therefore it is sufficient to have single boards.</td></tr>
<tr><td colspan="2">Quantity</td><td colspan="2">102 m^2</td></tr>
<tr><td colspan="2">Current Item Cost</td><td colspan="2">SAR 14,790</td></tr>
<tr><td colspan="2">The Cost of the alternative Item</td><td colspan="2">SAR 10,200</td></tr>
<tr><td colspan="2">Savings cost</td><td colspan="2">SAR 4,590</td></tr>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td>Project</td><td>Magrabi Offices</td><td>Section:</td><td>Wall Finishes & Wall Cladding</td></tr>
<tr><td colspan="2">Current Item:</td><td colspan="2">alternative Item:</td></tr>
<tr><td colspan="2">12mm Fire-Rated Gypsum Double Layer Board Wall Partitions</td><td colspan="2">12mm Fire-Rated Gypsum Single Layer Board Wall Partitions</td></tr>
<tr><td colspan="4">Pictures For Item:</td></tr>
<tr><td colspan="2"></td><td colspan="2">
</td></tr>
<tr><td colspan="4">Justification</td></tr>
<tr><td colspan="4">Double gypsum boards were used here for sound insulation reasons. This addition is not necessary, it does not contribute to the basic functions of the project.</td></tr>
</table>

<table>
<tr><th colspan="3">VE Team alternative</th></tr>
<tr><td colspan="3">Especially since there is insulation inside the gypsum Rockwool panels with 1.2mx0.6m density of 40kg, and therefore it is sufficient to have single boards.</td></tr>
<tr><td colspan="2">Quantity</td><td>396 m^2</td></tr>
<tr><td colspan="2">Current Item Cost</td><td>SAR 97,020</td></tr>
<tr><td colspan="2">The Cost of the alternative Item</td><td>SAR 57,420</td></tr>
<tr><td colspan="2">Savings cost</td><td>SAR 39,600</td></tr>
<tr><th colspan="3">VE Team alternative</th></tr>
<tr><td>Magrabi Offices</td><td>Section:</td><td>Wall Finishes & Wall Cladding</td></tr>
<tr><td colspan="2">Current Item:</td><td>Alternative Item:</td></tr>
<tr><td colspan="2">12mm Cement Board Double Layer</td><td>12mm Cement Board single Layer</td></tr>
<tr><td colspan="3">Pictures For Item:</td></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="3">Justification</td></tr>
<tr><td colspan="3">Double Cement boards were used here for sound insulation reasons. This addition is not necessary, it does not contribute to the basic functions of the project. Especially since there is insulation inside the Cement Rockwool panels with 1.2mx0.6m density of 40kg, and therefore it is sufficient to have single boards.</td></tr>
</table>

<table>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td colspan="2">Quantity</td><td colspan="2">30 m^2</td></tr>
<tr><td colspan="2">Current Item Cost</td><td colspan="2">SAR 8,250</td></tr>
<tr><td colspan="2">The Cost of the alternative Item</td><td colspan="2">SAR 4,950</td></tr>
<tr><td colspan="2">Savings cost</td><td colspan="2">SAR 3,300</td></tr>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td>Project</td><td>Magrabi Offices</td><td>Section:</td><td>Wall Finishes & Wall Cladding</td></tr>
<tr><td colspan="2">Current Item:</td><td colspan="2">Alternative Item:</td></tr>
<tr><td colspan="2">HPL Panels Wood Texture for Bathrooms</td><td colspan="2">Porcelain size (0.60m x 0.3m)</td></tr>
<tr><td colspan="4">Pictures For Item:</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">Justification</td></tr>
<tr><td colspan="4">HPL Panels were used to hide the doors and improve the aesthetic appearance, it is also moisture resistant. On the other hand, their cost is very high. HPL Panels is not necessary, it does not contribute to the basic functions of the project. Taking into consideration that porcelain was installed in the floors and walls of the bathroom, it is moisture resistant and gives the aesthetic shape and the required quality, therefore it is preferable to be used instead of HPL Panels.</td></tr>
</table>

VE Team alternative			
Quantity		18 m^2	
Current Item Cost		SAR 24,300	
The Cost of the alternative Item		SAR 5,040	
Savings cost		SAR 19,260	
VE Team alternative			
Project	Magrabi Offices	Section:	Wall Finishes & Wall Cladding
Current Item:		Alternative Item:	
Fire-Resistant Wooden Panels		Fire-Resistant WPC Panels	
Pictures For Item:			
			

VE Team alternative	
 	
Justification	
Wooden panels were used to improve the appearance by covering the walls, hiding the doors, and for sound insulation. The team prefer to use WPC panels because they serve the purpose of aesthetic appearance, and for their durability, low maintenance, easier to clean, moisture resistant, and less expensive.	
Quantity	116 m^2
Current Item Cost	SAR 98,600
The Cost of the alternative Item	SAR 46,400
Savings cost	SAR 52,200

VE Team alternative			
Project	Magrabi Offices	Section:	Wall Finishes & Wall Cladding
Current Item:		Alternative Item:	
Fire-Resistant Wooden Louvers for Partitions between rooms		Fire-Resistant WPC for Partitions between rooms	

<table>
<tr><th colspan="4">VE Team alternative</th></tr>
<tr><td colspan="4">Pictures For Item:</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">Justification</td></tr>
<tr><td colspan="4">Wooden Louvers for partitions were used to improve the appearance between rooms. The team prefer to use WPC for partitions because they serve the same aesthetic purpose, and for their durability, low maintenance, easier to clean, moisture resistant, and less expensive.</td></tr>
<tr><td colspan="2">Quantity</td><td colspan="2">303 m^2</td></tr>
<tr><td colspan="2">Current Item Cost</td><td colspan="2">SAR 63,630</td></tr>
<tr><td colspan="2">The Cost of the alternative Item</td><td colspan="2">SAR 33,330</td></tr>
<tr><td colspan="2">Savings cost</td><td colspan="2">SAR 30,300</td></tr>
<tr><td>Project</td><td>Magrabi Offices</td><td>Section:</td><td>Wall Finishes & Wall Cladding</td></tr>
<tr><td colspan="2">Current Item:</td><td colspan="2">Alternative Item:</td></tr>
<tr><td colspan="2">Wood Acoustical Panels Cladded on the Walls of Meeting Room Size (2.44x0.13)</td><td colspan="2">WPC Acoustical Panels Cladded on the Walls of Meeting Room Size (2.44x0.13)</td></tr>
</table>

VE Team alternative	
Pictures For Item:	
	
Justification	
The high cost of this item is because it is ordered from outside the country for its unique type. Wood Acoustical Panels were used to clad the walls of the meeting rooms, which gives them a wonderful aesthetic appearance and helps in improving and insulating the sound inside the room. The use of this specific item is not necessary, it does not contribute to the basic functions of the project. Instead, it was proposed to use WPC Acoustical Panels because it serves the same aesthetic purpose, sound insulation, low maintenance, easier cleaning, moisture resistance, and less cost.	
Quantity	59 m^2
Current Item Cost	SAR 67,850
The Cost of the alternative Item	SAR 26,550
Savings cost	SAR 41,300

VE Team alternative			
Project	Magrabi Offices	Section:	MEP - HVAC
Current Item:		Alternative Item:	
VRF AC (Daikin) Outdoor units - included fitting, insulation, drain lines,		XD AC (Daikin) Indoor and Outdoor units - included fitting, insulation, drain	

VE Team alternative	
and all necessary for operation with 20 tons refrigeration.	lines, and all necessary for operation with 5 tons refrigeration
Pictures For Item:	
	
Justification	
The VE team discussed the use of the air conditioning system function, the specifications and equipment of the building. In the VRF system, the external device is purchased separately from the internal device due to its high cost, unlike the XD system, in which both devices are purchased at once. The proximity of the roof was also considered, which is relevant to the extensions used in DX. The building consists of 4 floors, ground, first, second (Magrabi office), third, roof, so the distance is not far to justify the use of VRF system. Hence, there is a possibility to accommodate outdoor air conditioners on the roof after agreeing with the building manager. Therefore, the use of the VRF system is not necessary. It can be replaced by the DX system, which performs the same efficiency and quality at a much lower cost.	
Quantity	4
Current Item Cost	SAR 95,000

VE Team alternative	
	The outdoor device has been completely canceled and the price of the XD device has been increased to meet the need
As we explained earlier, there is a separate cost for indoor devices and a separate cost for outdoor devices.	
The prices allocated for indoor devices	SAR 36,600 + 95,000 outdoor
The new price for indoor and outdoor devices	SAR 52,600
Savings cost	SAR 79,000

VE Team alternative			
Project	Magrabi Offices	Section:	MEP - HVAC
Current Item:		Alternative Item:	
VRF AC (Daikin) Outdoor units - included fitting, insulation, drain lines, and all necessary for operation with 15 tons refrigeration.		XD AC (Daikin) Indoor and Outdoor units - included fitting, insulation, drain lines, and all necessary for operation with 2 tons refrigeration	
Pictures For Item:			
			

VE Team alternative	
Justification	
The VE team discussed the use of the air conditioning system function, the specifications and equipment of the building. In the VRF system, the external device is purchased separately from the internal device due to its high cost, unlike the XD system, in which both devices are purchased at once. The proximity of the roof was also considered, which is relevant to the extensions used in DX. The building consists of 4 floors, ground, first, second (Magrabi office), third, roof, so the distance is not far to justify the use of VRF system. Hence, there is a possibility to accommodate outdoor air conditioners on the roof after agreeing with the building manager. Therefore, the use of the VRF system is not necessary. It can be replaced by the DX system, which performs the same efficiency and quality at a much lower cost.	
Quantity	6
Current Item Cost	SAR 65,000 The outdoor device has been completely canceled and the price of the XD device has been increased to meet the need
As we explained earlier, there is a separate cost for indoor devices and a separate cost for outdoor devices.	
The prices allocated for indoor devices	SAR 31,500 + 65,000 Outdoor
The new price for indoor and outdoor devices	SAR 49,500
Savings cost	SAR 47,000

Table 4.9 shows the comparison between the alternatives. It is included with pictures and illustrations, in addition to cost details. The aim is to present these tables to decision makers.

MEP – HVAC:

DX (Direct Expansion) systems and VRF (Variable Refrigerant Flow) systems are both types of HVAC (heating, ventilation, and air conditioning) systems that are used to provide conditioned air in buildings. Both system types are designed to be efficient and flexible, but they differ in how they operate and the types of environments in which they are typically used in.

VRF systems, use multiple indoor units connected to a single outdoor unit. VRF systems are more complex and expensive than DX systems, and they can be used to cool or heat multiple zones within a building, and they can operate in both heating and cooling modes at the same time. VRF systems are often used in larger commercial and industrial buildings. DX systems, on the other hand, use a single refrigerant loop to cool and heat a building. DX systems are simple, reliable, and commonly used in residential and small commercial buildings.

In summary, DX systems are simpler, cheaper, and more commonly used in small buildings, while VRF systems are more complex, more expensive, and more commonly used in larger buildings. Both types of systems have their own advantages and disadvantages, and the best choice depends on the specific needs and requirements of the building.

4.8.Presentation and Implementation Phase

A summary of the value study and its results is presented to the owner or decision-makers. This includes a comprehensive report that highlights the cost savings, improved functionality, and other benefits that will be achieved through the recommended changes. The main objective of the presentation phase is to provide alternatives to the project's stakeholders and decision-making bodies, supported by graphics, tables, and plans. The team will present the proposed alternatives and engage in discussions with decision makers and stakeholders. The team is responsible for answering all questions and providing supporting documents, including technical and financial information. Once the management approves the recommended changes, the implementation phase begins. This involves coordination with the project team to ensure timely and efficient implementation of the changes.

This includes updating project plans, schedules, and budgets, as well as making any necessary adjustments and procuring materials or equipment.

Overall, the presentation and implementation phases are crucial for realizing the benefits of value engineering, ensuring the project's completion within the designated timeframe and budget.

Table 4.10 Summary of VE team alternative

Summary of VE Team alternative				
No	**Description**	**Current Cost (SAR)**	**Alternative Cost (SAR)**	**Saving Cost (SAR)**
3	**Ceiling Finishes**	233,810	71,350	162,460
3.1	12mm Fire-Rated Gypsum Board	82,410	30,150	52,260
3.2	Dropped ceiling (1.2 x 0.6) Perforated	113,150	31,000	82,150
3.3	Acoustical Ceiling Panels (0.3 x 0.6)	38,250	10,200	28,050
4	**Wall Finishes & Wall Cladding**	374,440	183,890	190,550
4.1	12mm Fire-Rated Gypsum Single Layer Board	14,790	10,200	4,590
4.2	12mm Fire-Rated Gypsum Single Layer Board Wall Partitions	97,020	57,420	39,600
4.3	12mm Cement Board single Layer	8,250	4,950	3,300
4.4	Porcelain size (0.60m x 0.3m)	24,300	5,040	19,260
4.5	Fire-Resistant WPC Panels	98,600	46,400	52,200
4.6	Fire-Resistant WPC for Partitions	63,630	33,330	30,300

4.7	WPC Acoustical Panels Size (2.44x0.13)	67,850	26,550	41,300
8	**MEP – HVAC**	228,100	102,100	126,000
8.1	XD AC (Daikin) Indoor and Outdoor units with 5 tons refrigeration	131,600	52,600	79,000
8.2	XD AC (Daikin) Indoor and Outdoor units with 2 tons refrigeration	96,500	49,500	47,000

Table 4.10 shows the cost of saving after applying the value engineering methodology to the items that have been focused on.

Table 4.11 Summary of VE study

Summary of Value Engineering Study					
No	**Description**	**Budget cost (SAR)**	**Saving Cost (SAR)**	**Total Cost after VE (SAR)**	**Saving %**
1	**Mobilization**	40,375	0	40,375	0%
2	**Floor Finishes**	176,350	0	176,350	0%
3	**Ceiling Finishes**	258,710	162,460	96,250	7.85%
4	**Wall Finishes & Wall Cladding**	503,395	190,550	312,845	9.2%
5	**Joinery - Counters & Props**	106,400	0	106,400	0%
6	**Doors, Windows & Gates**	71,080	0	71,080	0%

Summary of Value Engineering Study					
No	**Description**	**Budget cost (SAR)**	**Saving Cost (SAR)**	**Total Cost after VE (SAR)**	**Saving %**
7	**Plumbing & Fixtures**	95,690	0	95,690	0%
8	**MEP - HVAC**	353,530	126,000	227,530	6.1%
9	**MEP - Electrical & Low Current Work**	376,330	0	376,330	0%
10	**Fire Fighting System (Site Issues)**	50,170	0	50,170	0%
11	**Fire Alarm System**	38,750	0	38,750	0%
TOTAL		**2,070,780**	**479,010**	**1,591,770**	**23.13%**

Table 4.11 shows the cost difference before and after applying the value engineering methodology in the items that have been focused on according to Pareto's law, and it shows the percentages of saving obtained.

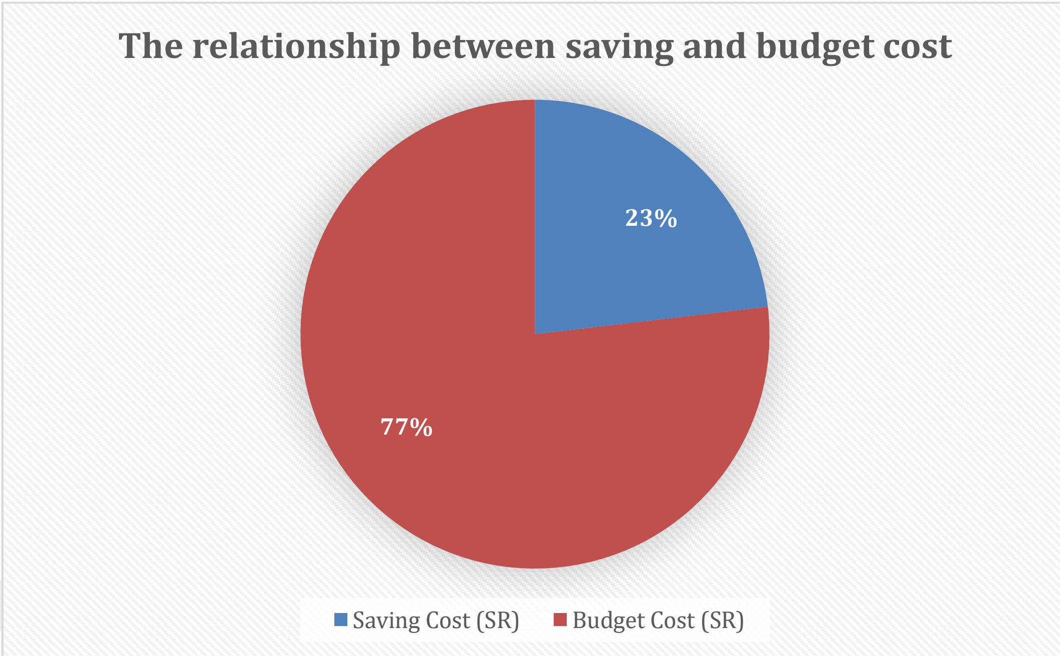
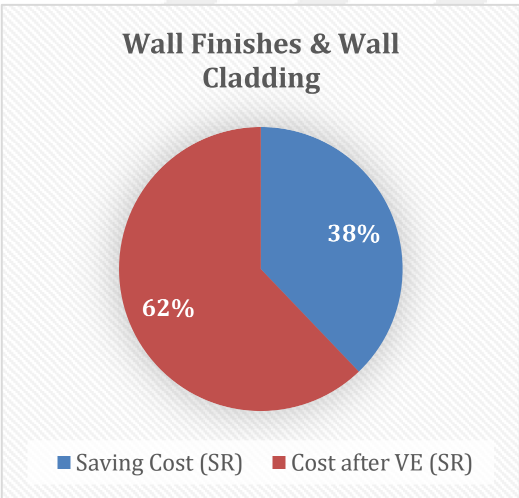


Figure 4.5 The relationship between saving and budget cost



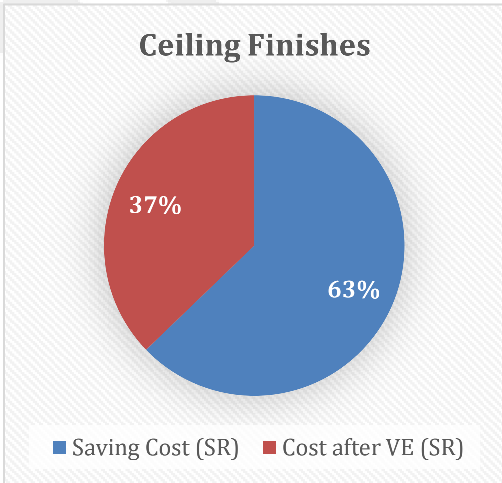


Figure 4.6 Wall finishes & Wall cladding

Figure 4.7 Ceiling finishes

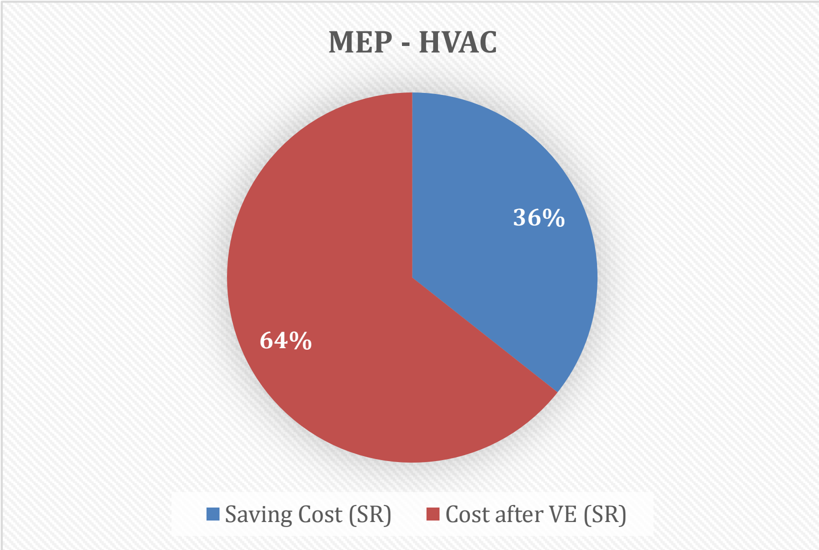


Figure 4.8 MEP - HVAC savings

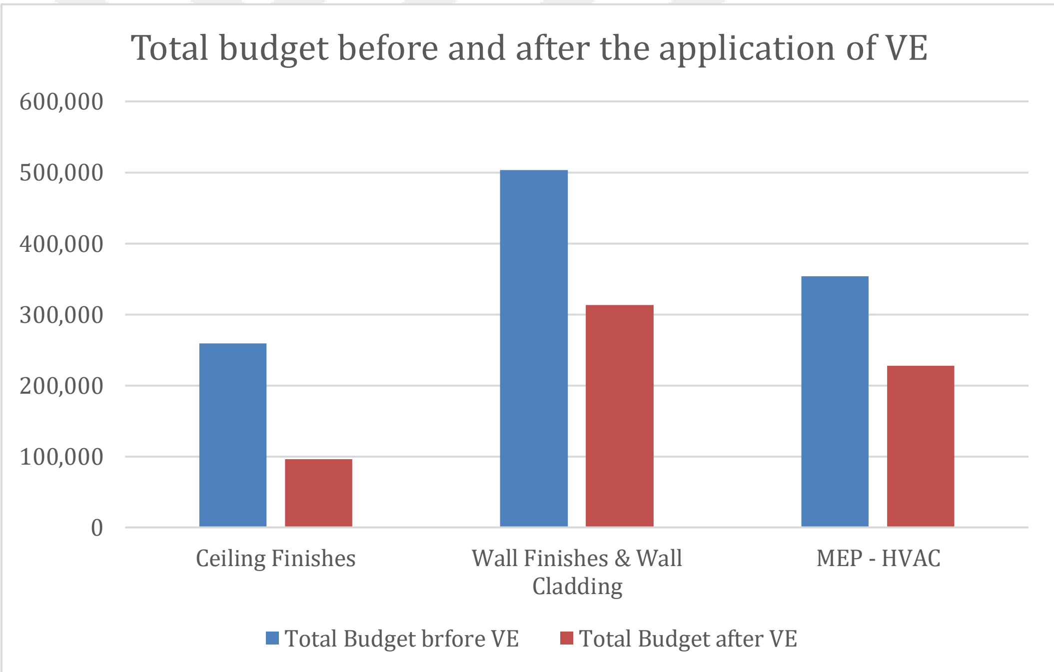


Figure 4.9 Total budget before and after the application of VE

5. RESULT OF THE STUDY

According to the Pareto Law, value engineering was applied to the highest-cost elements in the project. Therefore, the study focused on the three elements with the highest value, utilizing VE techniques. As depicted in the tables and diagrams, 12 out of 21 ideas were selected based on their applicability and alignment with the project's requirements.

Subsequently, the normative assessment approach was employed for material analysis and to select the optimal alternative by evaluating the project's quality, function, and total cost using the value equation V=(F+Q)/C.

After selecting the best alternatives, a comparative evaluation was conducted to justify the alternatives' selection and present the results to decision-makers. This evaluation includes visual aids and financial cost analysis.

By implementing value engineering, a cost savings of 479,010 SAR, equivalent to a rate of 23.13%, was achieved while maintaining the same quality and basic functions.

The objectives of the value studies cannot be accomplished without implementing these alternatives and recommendations, along with obtaining written approval for the selected ideas. Once the recommendations are accepted, it is crucial to provide training to the operatives and other relevant personnel and maintain regular follow-up with the implementation.

This can be achieved by:

- Develop an implementation plan in collaboration with the work team to ensure optimal outcomes for the alternatives.
- Monitoring the application and evaluating the results.

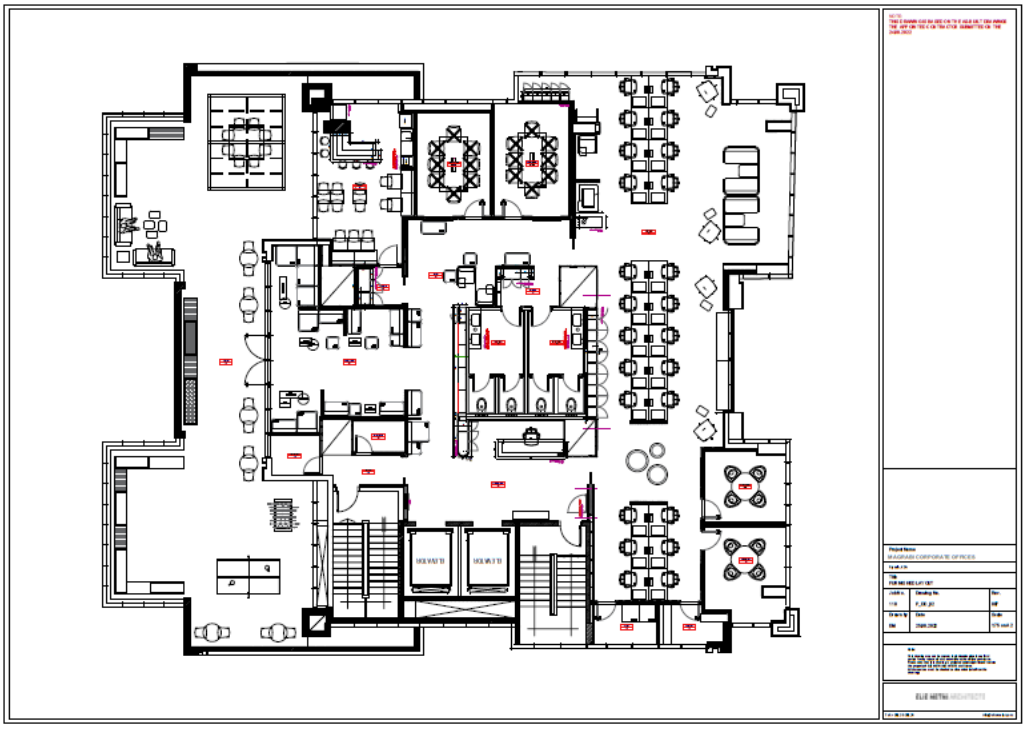


Figure 5.1 Final project plan (Integrated Environment, 2023)

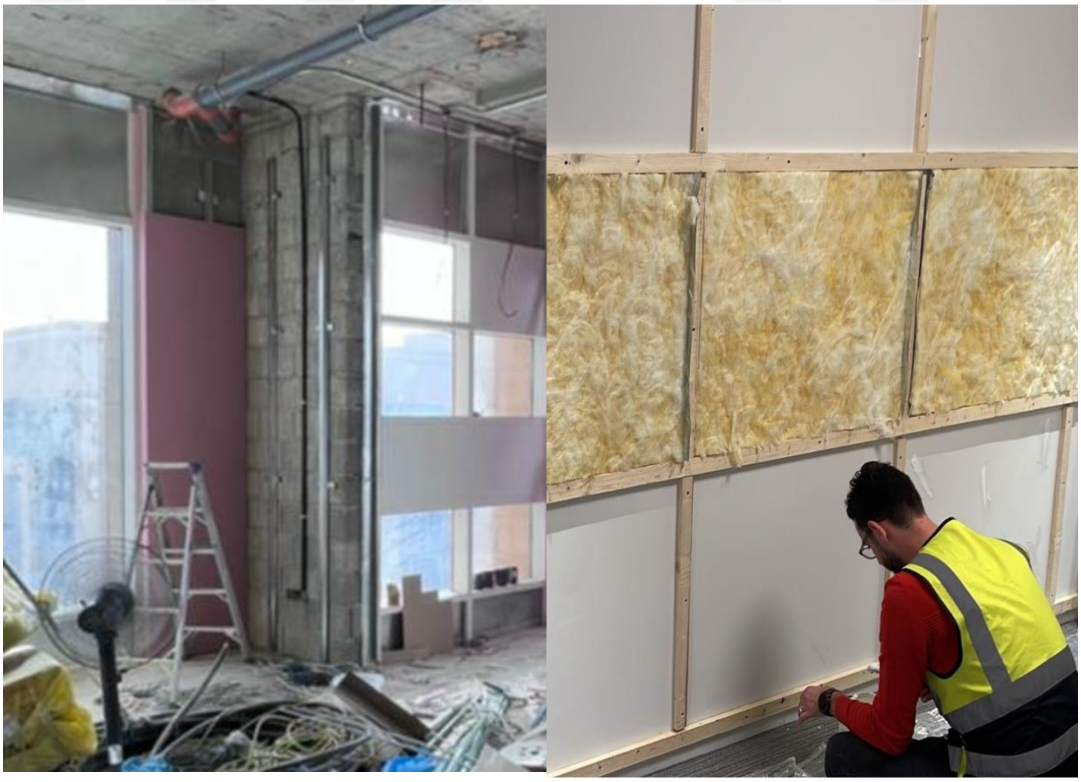


Figure 5.2 Workshops **(Integrated Environment, 2023)**

Figure 5.3 Workshops (Integrated Environment, 2023)

Figure 5.4 Pictures from the site (Integrated Environment, 2023)

Figure 5.5 Pictures from the site **(Integrated Environment, 2023)**

6. RECOMMENDATIONS

1. **Emphasize the importance of value engineering in the construction industry:**
   The findings of the thesis have shown that applying value engineering saved about 23% of the total cost. Therefore, it is a crucial tool that can help improve material Selection in the construction industry. It is imperative to underscore the significance of value engineering in facilitating informed and cost-effective material choices for enhancing decision-making and fostering development within the construction industry.
2. Based on the results of the case study, it is advisable to implement the value engineering methodology in larger construction projects, with a specific focus on material selection, especially in finishing works, as they contain many secondary functions that can be replaced with alternatives or modified in the architectural plans during the design phase. It is recommended to use local alternatives and avoid imports as much as possible.
3. Encourage future researchers to dive deeper into the realm of value engineering, particularly as it relates to material selection in high-cost construction projects. Expanding the body of knowledge through additional case studies will contribute to reducing construction expenses further.
4. Raise awareness among all project stakeholders, including clients, contractors, and consultants, regarding the significant advantages of employing value engineering in material selection. Highlight how it positively impacts project costs, quality, and schedules, fostering a culture of value-conscious decision-making.
5. Engineers should embrace value engineering as a tool to enhance project quality and functionality rather than merely as a means to avoid proposed design modifications. Encourage engineers to play a proactive role in suggesting value-driven material selections.
6. Given the specialized skills required, invest in training and education programs for professionals in the construction industry. This includes organizing workshops, seminars, and online courses to nurture expertise in material-focused value engineering.

7. Collaboration and communication are critical for successful value engineering projects. Encourage project teams to work together and communicate openly throughout the project and promote the involvement of all stakeholders in the value engineering process, ensuring that material selection aligns with project goals and expectations
8. It is important to develop metrics to evaluate the impact of value engineering on material selection decisions in the construction industry. These metrics will serve to monitor progress, pinpoint areas for enhancement, and demonstrate the value of value engineering in material optimization.
9. Encourage the integration of the value engineering approach into the design phase of the project to avoid design modifications and delays later.
10. Changing design materials based solely on numerical considerations should be discouraged. Such a shift in material design based solely on numbers can profoundly affect the entire project and strip it of its unique features. Striking a balance between efficient performance, quality, and appealing design is crucial for the success of construction projects, and value engineering plays a significant role in achieving this balance.

At the end of this study, we conclude with the following recommendations. Section 6.1 presents useful recommendations for engineering offices responsible for design and construction projects, whereas Section 6.2 presents directions for the government (owners) of the project.

6.1. Engineering Offices Recommendations

- Ensure the integration of value engineering methodology into the early stages of all projects, emphasizing the selection of materials that enhance both quality and cost-effectiveness.
- Focus on a comprehensive evaluation of project costs, encompassing lifecycle, direct and indirect costs, and operational expenses, with special attention to material choices.
- Advocate for the adoption of value engineering as an essential tool for enhancing material selection, thereby improving project quality, cost-efficiency, and adherence to schedules.

6.2. Recommendations to Governments (Owners of the Project)

- Promote the utilization of value engineering as a mean to elevate material selection within the construction industry. Incentives such as tax incentives or grants can encourage companies to implement value engineering in their projects.
- Establish guidelines and standards for the use of value engineering in the construction industry. This could include requirements for the use of value engineering on certain types of projects, such as mega projects, as well as guidelines for the implementation of value engineering.
- Support research and development in the field of value engineering. This could be institutions and research projects, providing grants to universities and research institutions, and collaborating with industry stakeholders to identify areas for research.
- Provide support and funding for training engineers and industry stakeholders in the Value Engineering methodology and facilitate the necessary procedures that help in its implementation in the construction industry.
- Increase the number of qualified individuals in value engineering applications, which is one of the requirements for the correct application of the value engineering method. This can be achieved by teaching value engineering methodology to students in universities and colleges, such as engineering, commerce, and business administration.

7. CONCLUSION

Value Engineering is based on a deep analysis of the problem, followed by a genuine search for effective solutions instead of relying on traditional answers, within an organized work plan. This framework is used in countless fields to maximize value without ignoring expenditure.

It is estimated that nearly 50% of construction projects in the United States of America use some form of value engineering (Growth Opportunities in the Global Construction Industry, 2021). Nevertheless, implementing value engineering needs to be institutionally organized and applied by decision-makers, whether in the public or private sectors. More importantly, the significant benefits of applying value engineering must be known and acknowledged by decision-makers, owners, and contractors. Engineers must also believe in the essential role of Value Engineering and the importance of integrating management concepts with engineering solutions. By enhancing creative thinking, unnecessary time, money, and effort could be saved, while quality is preserved, which in turn will reflect on societies and the development of nations.

Considering that most decision-makers and project owners have limited knowledge of the proper alternatives in the construction industry specifically, it is recommended to assign a multidisciplinary value engineering committee to decide on preferable alternatives that do not alter the fundamental functions of the project. This is necessary due to the high budgets of construction projects with additional expenses that could be reduced through several value approaches, such as finding low-cost alternatives for secondary functions and utilizing local materials instead of importing expensive ones.

There is unquestionably a profound influence of material selection on the construction industry, and this is precisely where value engineering comes into play, it serves as a method to enhance material selection without compromising quality. (Roveda, 2018)

Value engineering not only aims to optimize costs but also to enhance the selection of materials used in construction. It promotes the use of materials that meet structural and functional requirements. As it focuses on identifying suitable materials that align with the project's objectives and cost-effectiveness. By carefully analyzing material properties, durability, availability, and environmental impact, value engineering can lead to well-informed decisions regarding material selection.

This study aims to investigate the feasibility and applicability of value engineering methodology in the construction industry by implementing it in a specific case study. The case study was conducted on Integrated Environment for Architectural Contracting, a small to medium-sized Saudi-based company that specializes in the construction and architectural sectors. According to the project manager, Engineer Moayed Maswadi, the company had a portfolio of projects worth 10-15 million Saudi Riyals in 2022. The use of Integrated Environment's data provided a comprehensive examination of the feasibility and applicability of value engineering in the construction industry.

This study is based on implementing the value engineering methodology on a specific case study to verify the feasibility of its application and to prove the general objective of the study. The methodology consisted of collecting data on the project, then conducting substantial function analysis using Pareto's law to focus on high-cost functions. This was followed by applying the FAST model to understand the functions accurately and specifically and selecting main and secondary functions. Then, unusual ideas and creative alternatives were created that reduce costs but do not affect the basic functions. These creative ideas were evaluated using a normative assessment that depends on the analysis of materials based on their function, quality, and cost. This evaluation involved applying a value index equation to various material alternatives to select the best-suited materials. Material quality was assessed according to the following criteria: sustainability, easy to maintain and operate. On the other hand, the second part of the equation is the functionality of materials. The function was assessed according to the following criteria: extensions, aesthetics, sound insulation, implementation method, space division, cooling quality.

Following this assessment, the chosen materials were thoughtfully organized in a manner suitable for presentation. This presentation was enriched with visual aids, illustrations, and clear explanations, emphasizing the reasons behind material selections. Additionally, detailed financial analyses of these materials were conducted, prepared, and included in the presentation for the benefit of decision-makers.

By presenting the materials with comprehensive financial analyses and supporting visuals, the decision-makers were equipped with a thorough understanding, facilitating their well-informed choices in the decision-making process. After applying value engineering to Magrabi Office, 23.13% was saved without altering the required function. This finding proves the main claim put forward in the introduction that value engineering could reduce 10%-25% of construction project budgets.

The timing is essential to this outcome. Applying value engineering during the first stages of the project has a far greater effect on the project than in later stages. This study recommends applying the value engineering methodology during the design stage, where project data is sent to the value engineering team to be analyzed by each member accordingly.

Regulating VE within the construction industry will raise competition between companies, while costs will decrease remarkably. More importantly, systematic work will enhance quality. This would bring contractors to a brand-new level of quality and professionalism, which will reflect customer satisfaction and the whole future of the country.

While VE relies essentially on human creativity, this study recommends connecting the value engineering methodology with AI technology. This could increase creative ideas and alternatives, as well as facilitate its use within larger governments and the public sector, which will develop the global construction industry.

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