The Islamic University Gaza
Higher Education Deanship
Faculty of Engineering
Civil Engineering Department
Engineering Projects Management

الجامـــعة الإسلامية – غـــزة
عمـــادة الدراســات العليـــا
كلـــية الهنـدســــــــة
قســـم الهندســة المدنيـــة
إدارة المشـــاريع الهندسيـــة

A Framework for Value Engineering Methodology Application Using Building Information Modeling (BIM)

إطار عمل لتطبيق منهجية هندسة القيمة باستخدام نمذجة معلومات البناء

Aya Hasan Alkhereibi

Supervised by:

Dr. Khalid Alhallaq

Assistant Prof. of Construction Engineering and Management, IUG

A Thesis Submitted in Partial Fulfilment of Requirements for the Degree of Master in Engineering Project Management, Civil Engineering

January /2017

إقـــــرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

A Framework for Value Engineering Methodology Application Using Building Information Modeling (BIM)

إطار عمل لتطبيق منهجية هندسة القيمة باستخدام نمذجة معلومات البناء

أقر بأن ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وان هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل درجة أو لقب علمي أو بحثي لدى أية مؤسسة تعليمية أو بحثية أخرى.

DECLARATION

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Researcher's name :

Aya Hasan Alkhereibi

E-mail:

a9y0a_7sn@hotmail.com

Signature:

Date: **17/01/2017**

اسم الباحثة :

آية حسن الخريبي

البريد الإلكتروني:

a9y0a_7sn@hotmail.com

التوقيع:

التاريخ: **17/01/2017**

بسم الله الرحمن الرحيم

الجامعة الإسلامية غزة
The Islamic University of Gaza

مكتب نائب الرئيس للبحث العلمي والدراسات العليا هاتف داخلي 1150

الرقم: ج س غ/35/ Ref:

التاريخ: 2017/02/01م Date:

نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحثة/ **آية حسن أحمد الخريبي** لنيل درجة الماجستير في **كلية *الهندسة*** قسم الهندسة المدنية- إدارة المشروعات الهندسية وموضوعها:

اطار عمل لتطبيق منهجية هندسة القيمة باستخدام نمذجة معلومات البناء

A Framework for Value Engineering Methodology Application Using Building Information Modeling (BIM)

وبعد المناقشة العلنية التي تمت اليوم الأربعاء 05 جمادي الأولى 1438هـ، الموافق 2017/02/01م الساعة العاشرة صباحاً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

د. خالد عبد الرؤوف الحلاق	**مشرفاً و رئيساً**	....
أ.د. عدنان علي إنشاصي	**مناقشاً داخلياً**	....
د. ندين نبيل أبو شعبان	**مناقشاً خارجياً**	....

وبعد المداولة أوصت اللجنة بمنح الباحثة درجة الماجستير في **كلية *الهندسة*/ قسم <u>الهندسة المدنية- إدارة المشروعات الهندسية</u>.**

واللجنة إذ تمنحها هذه الدرجة فإنها توصيها بتقوى الله ولزوم طاعته وأن تسخر علمها في خدمة دينها ووطنها.

والله ولي التوفيق،،،

نائب الرئيس لشئون البحث العلمي والدراسات العليا

أ.د. عبدالرؤوف علي المناعمة

Abstract

Purpose: Value Engineering (VE) is frequently applied to construction projects for better recognition of project scope and for elimination of unnecessary cost without impacting the functional requirements of individual components of constructed facilities. Despite all benefits of value engineering application, it is not applied in the construction industry in Gaza Strip. Therefor the aim of this research is to propose a framework that facilitates VE methodology application using Building Information Modeling (BIM) techniques. To achieve this aim five objectives were carried out: i) to survey and investigate the importance of Value engineering application in Gaza Strip for construction projects management improvement; ii) to investigate the factors influencing Value Engineering studies and apply it to the proposed framework; iii) to study and extend the use of BIM models to collect input data for the assessment framework and to assist in the automating evaluation process; iv) to Embed an AHP program into the evaluation phase of VE job plan to rank the alternatives.

Design/methodology/approach: The researcher adopted both quantitative and qualitative research methods; it represents the use of quantitative research methods through the following tools: i) validity testing by consulting several experts in the field of construction management, ii) sample determination and due to the lack of experts in the field of value engineering in the Gaza Strip the researcher has adopted the sample of a snowball type, and then the questionnaire was distributed to the whole sample, which represents 25 individual of the population of the specialist construction management whom have knowledge in advance in value engineering. 20 questionnaire were collected out of 25 have been distributed, and finally the questionnaire was analyzed quantitatively in order to have meaningful data which was used in the next phase of the study methodology and results of a workshop stage.

All required data was prepared and gathered to conduct a value engineering workshop. The workshop has been combining quantitative and qualitative methods. Seven specialists in the construction industry whom experience more than 20 years were anticipated in the VE workshop. The proposed framework has been applied to a case study from the Gaza Strip to work on improving the basic functions of the elements under study by reducing cost without compromising the essential functions. BIM tool presented on Revit program was used for visualization terms and BPMSG program was used for AHP evaluation techniques.

Originality/ value: The research area is not common in Gaza Strip and it is highly needed due to the scarcity of funds for construction projects associated with high prices of building materials. Moreover, this study will add to the current body of knowledge about VE application in Gaza Strip. This study contributes significantly to consider BIM as a tool of speculation phase in VE job plan and AHP in the evaluation phase.

Findings: The study results concluded that the Value Engineering is still not commonly applied in the construction industry in the Gaza Strip. The study got the benefit from the results of the questionnaire to improve the performance of the workshop by focusing on the most important factors in the value engineering studies. As a result of this study, after the application of value engineering methodology using the proposed framework on a case study represented in a conference building the cost of the element under investigation was reduced by 57.5% without compromising the basic functions of the component.

Keywords: Value Engineering (VE), Building Information Modeling (BIM), Analytical Hierarchy Process (AHP)

الملخص

الغرض: يتم تطبيق هندسة القيمة (VE) على مشاريع البناء لتحديد نطاق المشروع بصورة اكثر دقة للتخلص من التكاليف غير الضرورية دون التأثير على الاحتياجات الوظيفية لعناصر المشروع قيد الانشاء. على الرغم من كل الفوائد من تطبيق الهندسة القيمية، إلا أنه لا يتم تطبيقها في صناعة البناء والتشييد في قطاع غزة. لذلك كان الهدف من هذا البحث هو اقتراح إطار عمل لتسهيل تطبيق منهجية باستخدام تقنيات نمذجة معلومات البناء. ولتحقيق هذا الهدف تم تنفيذ أربعة أهداف من: أ) دراسة وضع تطبيق هندسة القيمة في قطاع غزة لتحسين أداء المشاريع؛ ب) دراسة العوامل المؤثرة على دراسات الهندسة القيمية وتطبيقها على الدراسة. ج) دراسة استخدام نمذجة معلومات البناء لجمع المعلومات وتقييم الأداء وذلك للمساعدة في حوسبة عملية تطبيق منهجية هندسة القيمية جزئيا. د) تضمين استخدام عملية التحليل الهرمي في مرحلة مفاضلة البدائل وتقييمها في دراسة هندسة القيمة.

منهجية البحث: تهدف هذه الدراسة الى تقديم إطار عمل للمختصين والمهنيين في صناعة الإنشاء في قطاع غزة وذلك لتسهيل تطبيق منهجية هندسة القيمة. وذلك من خلال الحوسبة الجزئية لخطة العمل. تبنى الباحث في هذه الدراسة كلا من أساليب البحث الكمي والكيفي؛ وقد تمثل استخدام أساليب البحث الكمي من خلال الأدوات التالية: اختبار الصلاحية من خلال تقديم الاستبانة إلى عدة خبراء في مجال إدارة التشييد بالإضافة الى خبراء في مجال التحليل الإحصائي. تحديد الفئة المستهدفة والتي تشمل المختصين في صناعة الإنشاءات وإدارة المشاريع الانشائية ونظرا لقلة الخبراء في مجال هندسة القيمة في قطاع غزة فقد تم تبني اختيار عينة البحث من نوع كرة الثلج (Snowball) ، ثم تم اعتماد الاستبانة وتوزيعها على العينة كاملة والتي تمثل 25 شخص من مجتمع مختصين أدارة الانشاءات والذين لديهم معرفة مسبقة في هندسة القيمة. تم جمع 20 استبانة كعدد اجمالي من أصل 25 تم توزيعها، وأخيرا تم تحليل الاستبانة كميا وذلك لاستنباط نتائج ذات مغزى تم استخدامها في المرحلة التالية من منهجية الدراسة والتي تتمثل في ورشة العمل.

بعد أن قام الباحث بإعداد وجمع كافة المعلومات اللازمة لعقد ورشة عمل الهندسة القيمية تم الدمج بين البحث الكمي والنوعي من خلال ورشة عمل ضمت سبعة من مختصين صناعة الانشاءات ممن تزيد خبرتهم عن 20 عاما ولديهم معرفة مسبقة بالهندسة القيمية، تم تطبيق إطار العمل المقترح على حالة دراسية من قطاع غزة للعمل على تحسين الوظائف الأساسية للعناصر قيد الدراسة من خلال تقليل التكلفة دون المساس بالوظائف الأساسية.

قيمة البحث: وهذه الدراسة تضيف إلى الجسم الحالي من المعرفة حول VE تطبيق في قطاع غزة. وهذه الدراسة تساهم إلى حد كبير في تضمين BIM كأداة لمرحلة الابداع في خطة العمل لمنهجية هندسة القيمة وبرنامج التحليل الهرمي AHP في مرحلة التقييم.

النتائج: خلُصت نتائج البحث الى أن هندسة القيمة لازالت غير مطبقة بشكل واضح في قطاع الانشاءات في قطاع غزة، كما تم الاستفادة من نتائج الاستبانة في تحسين أداء ورشة العمل وذلك من خلال التركيز على أهم العناصر المؤثرة في دراسات هندسة القيمة. كما نتج عن هذه الدراسة أنه بعد تطبيق منهجية هندسة القيمية باستخدام إطار العمل المقترح على حالة دراسية متمثلة في مبنى متعدد الاستخدام تم تخفيق تكلفة العنصر قيد الدراسة بنسبة 57.5% دون المساس بالوظائف الأساسية للعنصر

الكلمات المفتاحية: الهندسة القيمية (VE)، نمذجة معلومات البناء (BIM)، عملية التحليل الهرمي (AHP).

بسم الله الرحمن الرحيم

{ وَمَا أُوتِيتُم مِّنَ الْعِلْمِ إِلَّا قَلِيلًا }

{And mankind have not been given of knowledge expect little}

[سورة الإسراء :آية 85]

صدق الله العظيم

Dedication

“To Whom Value in my life is beyond Engineering”

Aya Hasan Alkhereibi

Acknowledgements

Praise and thanks be to Allah the almighty who has helped me from the beginning to end to complete this research and bestowed on me uncountable boons including making others' help available, Alhamdulillah always and forever.

I am so grateful to Dr. Khalid AbdelRaouf Al-Hallaq, Assistant Professor of Civil Engineering/ Construction Management at Islamic University, Gaza, for his kind advice, useful critiques and guidance through all stages of development of this thesis.

I would also like to express my deep gratitude to Eng. Osama Hasan Alsadawi, General Director of Gaza Governorates, Palestinian Housing Council, Gaza, for his valuable and constructive advices and assistance from the beginning of planning and development of the methodology of this research. I thank him for his willingness to dedicate to me much of his time so generously. May Allah reward him with the best.

Advices given by Dr. Kamalin Sha'ath, Assistant Professor of Civil Engineering/ Construction Management and Ex. President of Islamic University, Gaza, have been of great help in the elimination of confusion at the beginning of the research in some basic things that identified the orientation of the research.

I also express the sincerest gratitude to Dr. Rifaat Rustom, Professor of Civil Engineering/ Construction Management IUG and president of the University Collage for Applied Science UCAS, Gaza, for his help in the evaluation of research methodology, and for his constructive critiques.

I appreciate all support that I have received from Zediah Company for Trading and Contracting family, I also take the chance to thank Eng. Ali Alnakhala Executive manager of Home office and Eng. Abdallah Sedodi for providing me by needed information.

I also would like to express my special thanks to Eng. Zohair Medoukh, Executive Manager of Universal Group for Engineering and Consulting for providing me with many useful advice and valuable orientation to this research.

I'm particularly grateful for the assistance given by Mr Mohammed AlAini, UNRWA, Gaza, by sharing his valuable knowledge and material about Value Engineering Job Plan Staff. Also, I am grateful to all those who participated in the response to the questionnaire and all organizations that cooperated with me.

I would like to express my sincere thanks to the people and institutions who contributed on one way or another in providing me by the necessary information and data during this work, I also thank Eng. Sirin Bohaissi, Ministry of General Works and Housing, and Eng. Ahmed Mughari, and Eng. Israa Abu Shanab.

Last but not the least; there are no words to describe how I'm so grateful to my beloved Father: Hasan Ahmed Alkhereibi and my beloved Mother Kamilia yousef Alkhereibi for the unceasing encouragement, support and attention throughout all my studies at university, and especially during writing this research. As well, my deep thanks must be expressed to my beloved brothers, sisters, and friends for everything.

Thank you,

Table of Contents

List of Tables

List of Figures

List of Abbreviations

VE	Value Engineering
BIM	Building Information Modeling
AHP	Analytic Hierarchy Process
RQ	Research Question
H	Hypothesis
FAST	Function Analysis System Technique
VE	Value Management
VA	Value Analysis
UCI	Uniform Construction Index
AIA	American Institute Of Architect
GSA	General Services Administration
F	Function
B	Basic Function
RS	Secondary Function
PERT	Program Evaluation and Review Technique
VEP	Value Engineering Proposal
LCC	Life Cycle Cost
VECP	Value Engineering Change Proposal
AEC	Architecture, Engineering, And Construction
3D	Three Dimensional
4D	Four Dimensional
MCDA	Multi Criteria Decision Making
CR	Consistency Ration
CI	Consistency Index
RI	Average Random Consistency
ANP	Analytic Network Process
SMART	Simple Multi Attribute Rating Technique
MAUT	Multi Attribute Utility Theory
VES	Value Engineering Specialist

Chapter 1

Chapter one: Introduction

This chapter is aimed to outline the theoretical part of the study. The problem statement was presented through highlighting the need for Value Engineering application in the construction industry in Gaza Strip, moreover challenges and barriers that affect value engineering methodology application, and the study was justified. In addition, this chapter included aim, objectives, key research questions, hypotheses, research design, and research contribution to knowledge along with the outline of the thesis were included in this chapter.

1.1 Background

Value Engineering is an organized/systematic approach directed at analyzing the function of systems, equipment, facilities, services, and supplies for the purpose of achieving their essential functions at the lowest life-cycle cost consistent with required performance, reliability, and quality. The implementation of the VE process on a problem typically increases some combination of performance, reliability, quality, safety, durability, effectiveness, or other desirable characteristics. Because costs are measurable, cost reduction is often thought of as the sole criterion for a VE application. However, the real objective of VE is value improvement, and that may not result in an immediate cost reduction.

In fundamental terms, VE is an organized way of thinking or looking at an item or process through a functional approach. It involves an objective appraisal of functions performed by parts, components, products, equipment, procedures, services, etc., anything that costs money. VE is performed to eliminate or modify any element that significantly contributes to the overall cost without adding commensurate value to the overall function, (Chougule, 2014).

Considering the degree of competition between construction firms, advantages in competition will be won by those companies who focus on performance improvement, customer satisfaction, reducing the costs and increasing the efficiency, and overlay try to purify their organizations and processes, (Shekari, 2009).

On the other hand, VE should be performed as early as possible before commitment of funds approval of systems, services, or design—to maximize results. Contribution of potential savings from VE applications is much greater at earlier stages of a project. When VE is applied later, two things increase: the investment required to implement any changes and resistance to changes (Atabay & Galipogullari, 2013)

A critical phase in the application of value engineering is generating innovative alternatives along with the evaluation of generated alternatives based on defined criteria for that purpose. So the success or failure of the VE study highly depends on the creative phase of the VE job plan. Instead of using the traditional brainstorming technique to generate ideas and solutions.

Construction projects are highly dependent on the qualitative decision making process due to experts' subjective judgments. To minimize subjective judgments of VE teams' members and to be able to better estimate projects' cost and time (Chung, 2009), the proposed framework can be applied to construction projects. The framework uses quantitatively derived data from the BIM programs combined with AHP and will improve Value engineering decision making process.

1.2 Problem statement

Despite its importance, VE methodology application has many obstacles such as; time-consuming processes, high costs, and the rarity of professionals. These factors substantially, affected the performance of the construction projects management in the Architecture, Construction and Engineering Architecture Construction and Engineering ACE industry in the Gaza Strip which resulted raising the costs, extending the project 's schedule, or decreasing the quality.

For this purpose, study aims to propose a framework for members of VE teams in the Construction industry in Gaza Strip to effectively implement the VE that may pave the way to start the application of the VE approach in their management policy.

1.3 Research Aim and Objectives

This study aims to propose framework for members of VE teams to effectively apply the VE through evaluating and comparing various alternatives of a project based on embedding BIM in the various phases of VE job plan (focused mainly on the performance, and project cost). In order to achieve the above aim the following objectives ***will be carried out***:

Objective 1: To survey and investigate the importance of Value engineering application in Gaza Strip for construction projects management improvement**.**

Objective 2: To investigate the factors influencing Value Engineering studies and apply it to the proposed framework.

Objective 3: To study and extend the use of Building Information Modeling BIM models to collect input data for the assessment framework and to assist in the automating evaluation process

Objective4: To Embed an Analytical Hierarchy Process AHP program into the evaluation phase of VE job plan to rank the alternatives.

1.4 Research questions and hypothesis

Research questions

Question 1: What is the level of awareness of VE application by professionals in Gaza Strip?

Question 2: What are the main factor influencing Value Engineering Studies in the construction industry firms in Gaza strip?

Question 3: What is the effect of the computerization using BIM of VE application in the construction projects of Gaza Strip?

Question 4: What is the effect of using AHP in the alternatives comparison accuracy?

Research Hypothesis

H1: project cost will be reduced 10% at least when Value Engineering methodology is applied at a significant level $\alpha >= 0.05$

1.5 Significant Original Contribution to Knowledge

- To develop a framework that can be of help to the value engineering team members in making value oriented decisions.
- To automate the process of alternative evaluations.

- To improve the visualization capabilities that can be used in the speculation phase of value engineering and -in some cases helping in generating innovative alternatives.
- Help designers, owners, and members of VE team have a similar picture of the project and can communicate with each other at the early phases of the project thus they can agree on selecting an alternative that can address owner's requirements of the project, suits owners desired criteria and satisfy designers.
- To be able to track the consequences of the changes VE team make on every alternative and to be able to follow up the results so they can build the alternative while they are aware of the effect of any single change.
- Make the most benefit from BIM model and to embed the desired defined criteria in the VE application process.

1.6 Research Methodology

The main objective of this research is to propose a framework for application of value engineering embedding BIM techniques through VE job plan phases. The framework provides VE team members with the ability to use an automated and comprehensive computational program that consider a wide range of aspects for evaluation and selection of optimum alternatives that satisfy the owners' requirements.

A questionnaire will be designed to linkage the data extracted from literature review with the situation of VE methodology application in the construction projects management in the Gaza strip, and to get the benefit of the professionals in regard of VE application and factors influencing VE Studies.

The value engineering analyzes the scope of the project to achieve the essential functions required without compromising the client objectives. A workshop consists of a Job Plan which is composed of six key steps as will be explained in detail in the literature review chapter, will be conducted in presence of highly qualified expertise in the construction industry.

One of the most critical phases in the application of value engineering is the evaluation of generated alternatives. For that purpose, the framework will be designed and developed to help the VE team to evaluate and rank different project components alternatives using multi-attributed criteria. The framework integrates BIM to provide visualization capabilities to assist designers and stakeholders in making related decisions. In addition; a case study will be taken to employ the proposed framework application and demonstrate its efficiency in the assessment of application of value engineering.

1.7 Research Design

Chapters of this study will be organized in a way that address the research objectives and introduce the proposed framework properly as following:

Chapter 1: Introduction

This chapter represents the background of the study. It guides the reader to the study subjects frequently. The problem statement, research aim, objectives, questions, hypothesis, contribution to knowledge, method, approach, methodology, and research design are also included in this chapter.

Chapter 2: Literature Review

Chapter two presents a review of the literature in value engineering (VE) methods along with Building Information modeling (BIM), Multi Attribute Decision Analysis and the (AHP) method in detail.

Chapter 3: Methodology

The structure of the research and methodology are presented in detail in Chapter three. This chapter also describes the outline of the framework which will be proposed in this study.

Chapter 4: Questionnaire Analysis

This chapter shows the questionnaire analysis and discussion and the main findings regarding the VE real situation in Gaza strip in addition to the factors influencing value engineering studies, beside the tools that may be used in the application of VE considering BIM.

Chapter 5: Case study

As a proof of concept, a case study is presented in chapter five.

Chapter 6: Results and recommendation

Chapter six includes the summary and concluding remarks of this study. Contributions and limitations of the proposed framework along with recommendations for future research work are also included in this chapter.

Chapter 2

Chapter Two: Literature Review

This chapter aims to establish a theoretical understanding of the concept of Value Engineering in construction projects. The areas of interest for literature review are: firstly, VE as a concept (definitions, VE features, phases, job plan, and VE functions), benefits of VE, barriers to VE applicability, and the use BIM techniques to assess value engineering team. Secondly the study investigated the use of AHP technique to serve the purpose of VE application in which differentiate various alternatives upon multiple criterion. The sources have mainly been passed on judicially academic research journals, refereed conferences, theses, reports/occasional paper, government publications, and books.

2.1 Value Engineering

In this section the researcher spots the light on the origin, definition, and techniques of the Value Engineering.

2.1.1 Historical Background

The concept of value engineering has existed for more than half a century (Rich, 2000), it had its origin during World War II at General Electric when innovation was required because of material shortages (Official, 2010). Some critical materials were difficult to obtain and many substitutions had to be made. Harry Erlicker, a vice president, observed that many times these changes resulted in lower costs and improved products. This encouraged him to seek an approach to intentionally improve a products value. He assigned Lawrence D. Miles, a staff engineer, the task of finding a more effective way to improve product value (Attarde, 2016).

In 1947, Miles and his team developed a gradually system called Value Analysis (VA), to analyze product cost and function to eliminate unnecessary costs. As a result of substantial investment, the new methodology was developed, tested, and proven to be highly effective. In 1952 VA began its growth throughout industry.

The Federal-Aid Highway Act of 1970 made the first Federal Highway reference to VE, requiring that "in such cases that the Secretary determines advisable plans, specifications, and estimates for proposed projects on any Federal-Aid system shall be accompanied by a value engineering or other cost reduction analysis. (UDTES, 2013)

2.1.2 VE: Definitions and Features

Amruta, (2014), defined Value Engineering as it is a creative and disciplined process which seeks to offer the client a reliable opportunity for cost savings without detriment to main functions or performance.

According to DOCD, (2006) Value Engineering can be defined as an organized, systematic, interdisciplinary problem solving approach basically based on analyzing the function of systems, equipment, facilities, services, and supplies for the drive of accomplishing their crucial functions at the lowest life-cycle cost reduction with required performance, reliability, quality, and safety.

Galipogullari, (2013) claims that the adoption of the VE process on a problem typically increases some combination of performance, reliability, quality, durability, effectiveness, or other desirable characteristics.

Value engineering basically stands to that any technique so useful should be applied to every stage of the normal day-to-day development of a construction projects. The application of this technique requires a certain amount of expense, which may get justified by potential cost savings (Alyousefi, 2011). Accordingly, there must be a recognized need for change and a distinct opportunity for financial benefit to deserve the added cost of a value engineering effort.

However, the real objective of VE is value improvement; by reducing costs and improving operational and administrative aspects and that may not outcome in an instantaneous cost reduction (Farahmandazad, 2015).

In ultimate terms, VE is an organized way of thinking or looking at an item or a process through a functional approach in respect of cost (Shekari, 2009).

2.1.3 Value Engineering Key Components

Conferring to SAVE, (2015) the following are the key components of Value Engineering:

Function, Sell: A function that provides a subjective expression of something that is to be achieved. In Function Analysis, sell functions are qualitative and are described using a passive verb and a non-measurable noun. Sell functions are also sometimes referred to as "aesthetic" functions.

Function, Work: A function that provides an objective expression of something that is to be accomplished. In Function Analysis, work functions are quantitative and are described using an active verb and a measurable noun. Work functions are also sometimes referred to as "use" functions.

Function, Worth: The lowest overall cost to perform a function without regard to criteria or codes.

Function Analysis System Technique (Fast): A graphical representation of the dependent relationships between functions within a project.

Cost: The expenditure of resources needed to produce a product, service, or process.

Cost, Lifecycle: The sum of all development acquisition, production or construction, operation, maintenance, use, and disposal costs for a product or project over a specified period of time.

Cost Model: A financial representation such as a spreadsheet, chart, and/or diagram used to illustrate the total cost of families of systems, components, or parts within a total complex product, system, structure or facility.

Job Plan: A sequential approach for conducting a value study, consisting of steps or phases used to manage the focus of a team's thinking so that they innovate collectively rather than as uncoordinated individuals.

Performance: The capacity of a product to fulfill its intended function. Factors such as reliability, maintainability, quality, and appearance are some examples.

Value: An expression of the relationship between function and resources where function is measured by the performance requirements of the client and resources are measured in materials, labor, price, time, etc. required to accomplish that function.

2.1.4 Value Engineering Job Plan

Value engineering is every so often done by systematically following a multi-stage job plan (Council, 2001). The early original system of VE was a six-step technique which was called the "value analysis job plan." Then later others have speckled the job plan to fit their constraints, table 2.1 illustrates the development of job plan stages.

Table (2.1): Historical Development for VE Job Plan

#	**Phase**	(Miles, Techniques of Value Analysis and Engineering, 1972)	**DOD HANDBOOK 5010.8-4 (1963)**	**DOD (USA META)** (1968	**E.D. Heller 1971** (Heller 1971)	**A.E. Mudge 1971**	**GSA.PBS** P **8000.1 1972**	**L.D. Miles** 1972 (Miles	**PBS VM workbook 1974**	**SAVE International** (SAVE, 2007)
1.	Orientation	√		√		√	√			
2.	Information	√	√	√	√	√	√	√	√	√
3.	Speculation	√	√	√	√	√	√	√	√	√
4.	Analysis	√	√	√		√	√	√	√	√
5.	Development		√	√	√		√	√	√	√
6.	Program planning	√								
7.	Evaluation				√	√		√	√	√
8.	Program Execution	√			√					
9.	Presentation						√		√	√
10	Summary and conclusion	√	√			√	√			
11	Follow up			√			√		√	

In this study the researcher considered the main job plan stages, information phase, functional phase, speculation phase, evaluation phase, development phase, and presentation phase, this will be discussed in detail in chapter three, see figure (2.1).

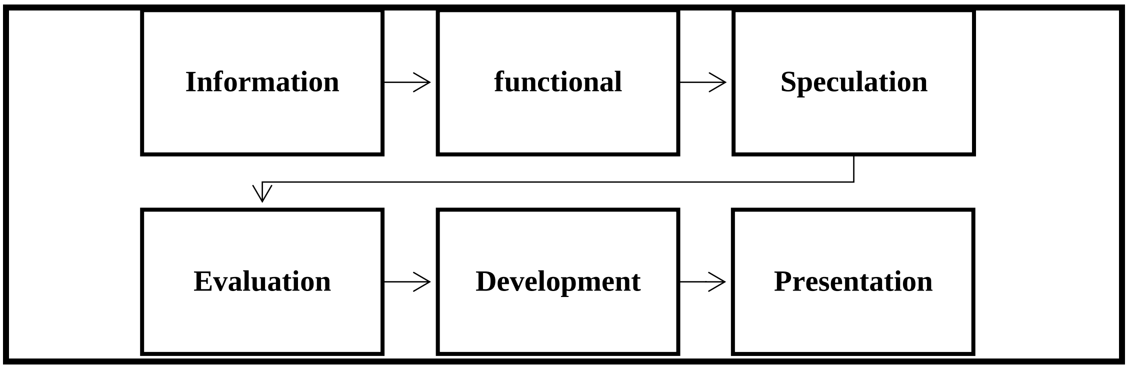


Figure (2.1): VE job plan phases

Chavan, (2013) presented four elementary steps in the job plan which are:

- ***Information gathering*****:** This asks what the requirements and preferences are for the object. Function analysis, an important technique in value engineering, is usually done in this initial stage. It attempts to determine what functions or performance features are significant. This stage should be saturated with as much information as possible. It asks questions like; what does the object do? What must it do? What should it do? What could it do? What must it not do?

- ***Functional phase:*** Function analysis is a key issue in VE. For this purpose, Function Analysis System Technique (FAST) is used to picture all the functions of a component's subsystem (process, etc.) showing their specific relationships to each other and clearly showing what the subsystem does.

- ***Speculation phase*****:** In this stage value engineering team ask; what are the various alternative ways of meeting requirements? What else will perform the desired function?
- ***Evaluation*****:** In this stage all the alternatives are assessed by evaluating how well they meet the required functions and how effective the cost savings will be.
- ***Presentation*****:** In the final stage, the optimum alternative will be selected and offered to the client for final decision.

2.1.5 Value Engineering Application

- **PRE-WORKSHOP PHASE**

Preparation tasks involve six areas: Collecting/defining client wants and needs, gathering a complete data file of the project, determining evaluation factors, scoping the specific study, building appropriate models, and determining the team composition (Alyousefi, 2011).

A. Collect client Attitudes

The objectives of client attitudes investigation are to: determine the prime client preferences of the project; define and rate the importance of features and characteristics of the project; and to compare the project with competition or through direct analogy with similar projects (Attarde, 2016). For first time the new projects analysis may be tied to project goals and objectives. The results of this task will be used to establish value mismatches in the Information Phase.

B. Gather a Complete Data File

There are both Primary and Secondary sources of information (Lee, 2010). Primary sources are of two varieties: people and documentation. People sources include client, original designer, architect, cost or estimating group, maintenance or field service, the builders (manufacturing, constructors, or systems designers), and consultants. Documentation sources include drawings, project specifications, bid documents and project plans.

Secondary sources include suppliers of similar products, literature such as engineering and design standards, regulations, test results, failure reports, and trade journals. Another major source is like or similar projects. **Quantitative data is desired,** and mostly used in this study.

C. Determine Evaluation Factors

The team, as an important step in the process, determines what will be the criteria for evaluation of ideas and the relative importance of each criteria to final recommendations and decisions for change. These criteria and their importance are discussed with the client and management and concurrence obtained. But in this study the adopted evaluation method is Analytical Hierarchy Process, because the evaluation will be upon multi criteria as will be shown in detail in section 2.4 of this chapter.

D. Scope the Study

The researcher develops the scope statement for the specific study. This statement defines the limits of the study based on the data-gathering tasks. The limits are the starting point and the completion point of the study. Just as important, the scope statement defines what is not included in the study.

E. Build Models

Based on the completion and agreement of the scope statement, the VE team may compile models for further understanding of the study. These include such models as Cost, Time, Flow Charts, and Distribution, as appropriate for each study.

F. Determine Team Composition, Wrap-Up

The Value Study Team Leader confirms the actual study schedule, location and need for any support personnel. The study team composition is reviewed to assure all necessary customer, technical, and management areas are represented. The Team Leader assigns data gathering tasks to team members so all pertinent data will be available for the study.

❖ **WORKSHOP PHASE**

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

2.2.5.1 Information Phase

The objective of the Information Phase is to complete the value study data package started in the Pre-Study work. If not done during the Pre-Study activities, the VE facilitator brief the value study team, providing an opportunity for the team to ask questions based on their data research.

The study team agrees to the most appropriate targets for improvement such as value, cost, performance, and schedule factors. These are reviewed with appropriate management, such as the project manager, value study facilitator, and designer, to obtain concurrence.

Finally, the scope statement is reviewed for any adjustments due to additional information gathered during the Information Phase. In this section, the preparation details for Construction Projects will be addressed, figure (2.2) shows information phase steps.

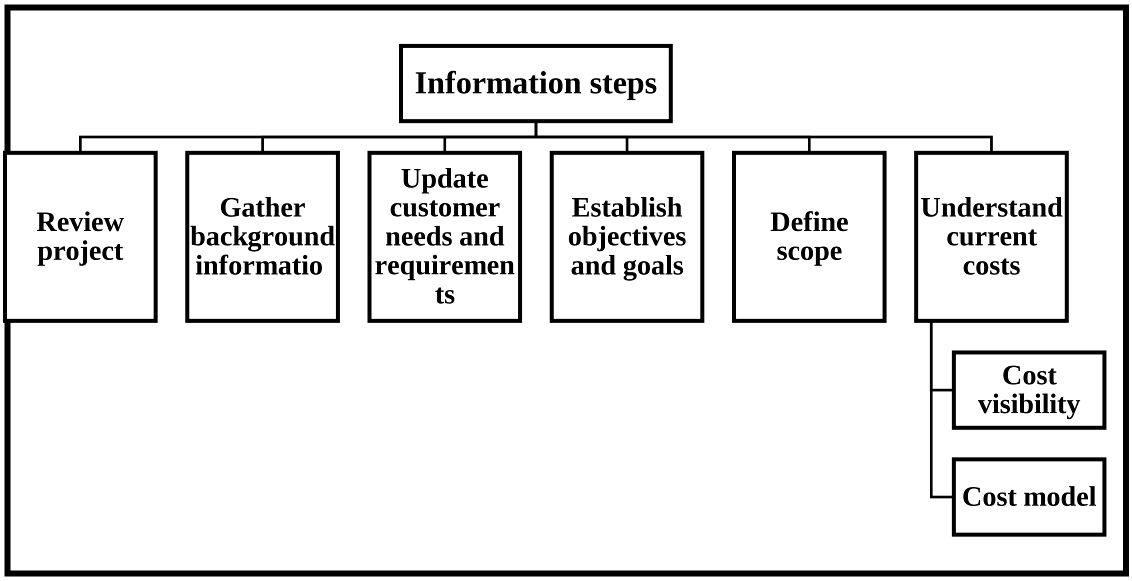


Figure (2.2): Information Phase Steps

A. Review project

Project review starts with identifying specifically the recommendations for improvements that the client is looking for (Assaf, 2000). A clear understanding of what the project is to be improved should first be understood.

The following information lists the specifics required in the preparation for a construction project VE study. This information should be assembled, reviewed and understood in advance of a VE workshop.

B. Gather Background Information

Once the project is clearly understood, pertinent data needs to be gathered to assure the team has sufficient information to properly conduct the study (Assaf, 2000). A checklist of data required is listed below:

- Description of project - Outline Specifications.
- Analysis of Design.
- Site and building drawings.

- Cost Model (preliminary cost estimates design level)
- Listing of all material and quantity requirements.
- Quality model (Client requirements and features).

C. Quality model (Update Client Needs and Requirements)

A key part of the project background information is client information. Understanding the project from the client point of view is important. Thus Quality model in important to be clarified in the early stages of VE job plan, figure 2.3 shows the main elements of quality model.

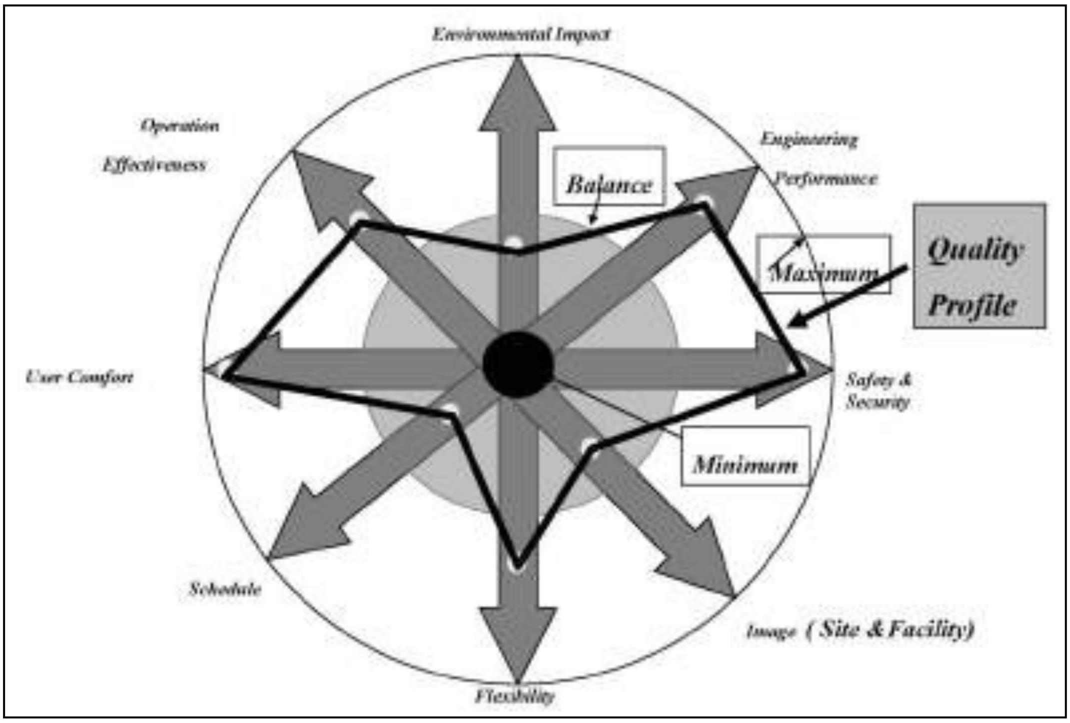


Figure (2.3): Quality Model

D. Establish Objectives and Goals

The basic objectives and goals of the team are usually provided to the team by client or the Value Engineering Specialist VES (Alyousefi, 2011). After reviewing the project background and based on the individual team members' knowledge of the project, objectives regarding life cycle cost, quality, constructability, construction time, environmental issues and future expansions are often important considerations. It is important that the team understand not only *what* they are studying, but *why*, if they are to make recommendations that can best improve the project.

E. Determine Scope

In order to solve a problem, the parameters of the study must be defined. It is important to know what is included in the study as well as the interface points. Typically, the scope includes not only the structure (main criteria) but also such items (sub-criteria) as site preparation, demolition, landscaping, provisions for future expansion and parking (Alyousefi, 2011).

F. Cost Model (Understanding Current Costs)

One of the substantial objectives of most Value Engineering studies is cost reduction beside performance improvement (DelI'lsola, 1969). While cost estimates are provided on new construction projects at a very detailed level, this cost data needs to be organized in a format that is helpful to rapid analysis.

Listed below are several important items to consider as the cost data is analyzed, Figure 2.4 shows the uniform of cost model.

- *Determine total cost*
- *Determine cost elements*
- *Determine cost within the scope of the project*

It is also important to understand reasons for unnecessary costs, while there are many reasons that unnecessary costs exist in products, processes or systems, the most frequent reasons will normally fall into one or more of the following reasons:

- Lack of idea
- Lack of information
- Temporary circumstances
- Honest wrong beliefs
- Habits and attitudes

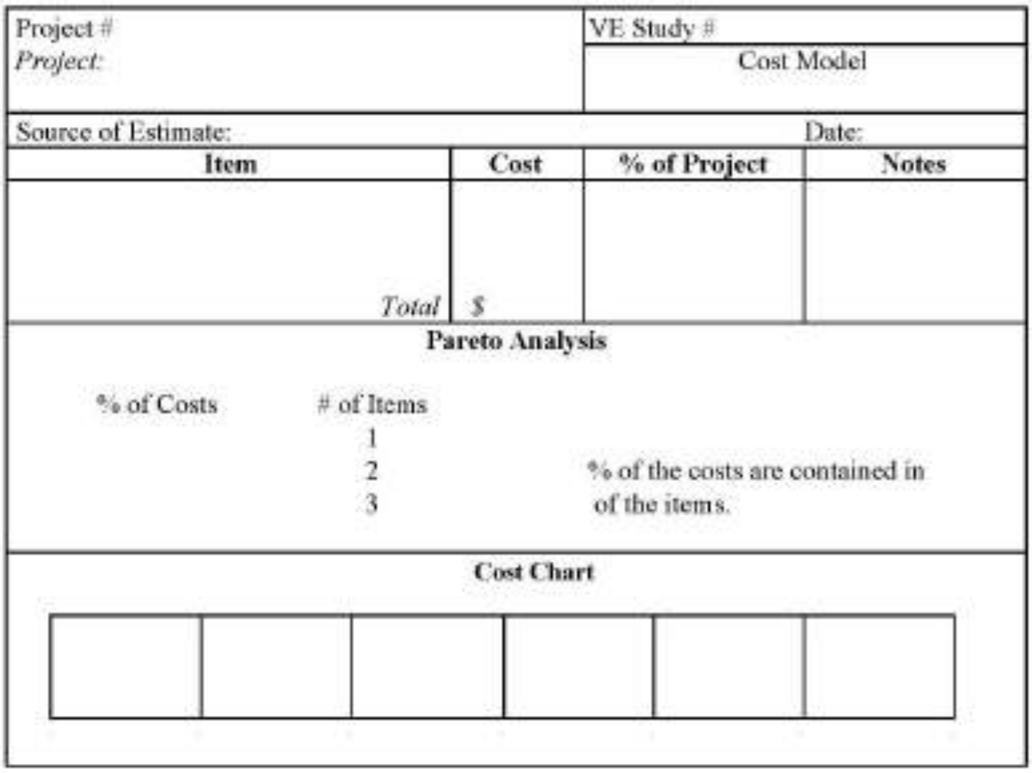


Figure (2.4): Cost Model

2.2.5.2 Function Analysis

Function Analysis techniques, figure (2.5), are used in defining, analyzing and understanding the functions of a project, how the functions relate to one another, and which functions required attention if the value of a project is to be improved (Li, 2008).

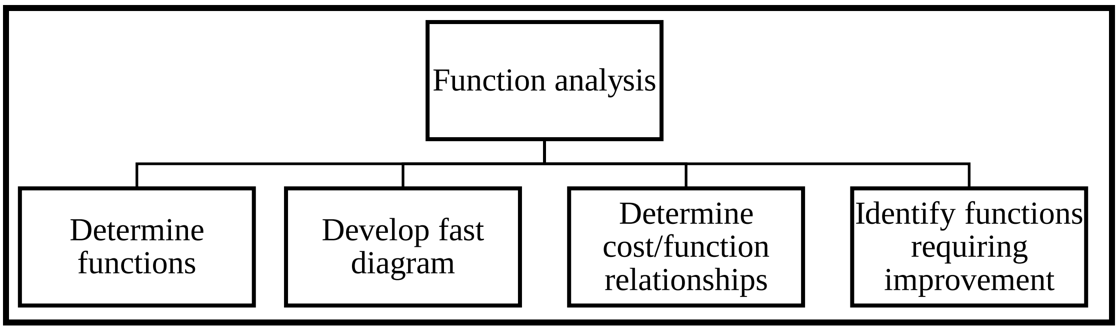


Figure (2.5): Function Analysis Steps

A. Determine Functions

In Value Management, the functions are determined by asking the question, "What does it do?". All designs, processes and procedures involve many functions. The team first determines the project functions (Berawi, 2009).

B. Defining Functions

All functions can be defined in two words - a Verb and a Noun. To state what something does in two words is sometimes difficult, but it helps to simplify terminology and create better understanding (Sung, *et al*., 2009). When choosing the words that define a function, make them as broad and generic as possible. Don't select words that predetermine the way the function should be performed.

C. Categorizing Functions

There are only two types of functions within the scope of a study item - Basic and Secondary.

- ***Basic function (b)*** is the specific work that a product, process, construction project, or procedure is designed to accomplish.
- ***Secondary functions (rs)*** are the other functions that the device performs and are subordinate to the basic function. They support the basic function and assist the product, process or procedure to work and sell. Secondary Functions may be required, aesthetic or unwanted. Required secondary functions are necessary to allow the basic function happen or happen better. Aesthetic secondary functions improve the appearance of the product and make it more desirable to the customer. Unwanted secondary functions are generally undesirable by-products of either the basic or other secondary functions and often require cost to minimize their impact.

Table (2.2): Function Wording

WORK FUNCTIONS			
Verbs		**Nouns**	
Absorb	Interconnect	Access	Light
Accommodate	Interrupt	Air	Liquid
Aid	Irrigate	Area	Loading
Allow	Landscape	Care	Loads
Amplify	Level	Building	Noise
Approve	Limit	Circuit	Odor
Assist	Locate	Color	Oxidation
Assure	Maintain	Communication	Pad

WORK FUNCTIONS			
Verbs		**Nouns**	
Change	Mix	Construction	Paint
Circulate	Modulate	Contacts	Panel
Clean	Monitor	Contamination	Parking
Clear	Mount	Corrosion	Personnel
Close	Move	Current	Piston
Collect	Open	Damage	Power
Conduct	Position	Decoration	Pressure
Connect	Preserve	Density	Protection
Construct	Prevent	Deterioration	Radiation
Contain	Protect	Direction	Repair
Control	Purify	Dust	Safety
Convert	Reduce	Egress	Seepage
Create	Remove	Emission	Site
Direct	Repair	Energy	Sound
Dissipate	Repel	Environment	Space
Distribute	Resist	Equipment	Stability
Enclose	Rotate	Flow	Status
Extinguish	Satisfy	Fluid	Supplies
Facilitate	Seal	Force	Task
Filter	Secure	Friction	Torque
Generate	Shield	Heat	Uniformity
Heat	Shorten	Horsepower	User
Hold	Store	Humidity	Variation
House	Support	Information	Vibration
Ignite	Suppress	Injury	Voltage
Illuminate	Suspend	Insulation	Volume
Install	Synchronize	Landscape	Water

D. Function Analysis System Technique (FAST Diagram)

FAST is an acronym for Function Analysis System Technique. The FAST Diagram is a powerful Value Management technique which (i) shows the specific relationships of all functions with respect to each other, (ii) tests the validity of the functions under study, (iii) helps identify missing functions, and (iv) broadens the knowledge of all team members with respect to the project. At first glance, FAST appears to be similar to a PERT chart of a flow chart. However, the basic difference between FAST diagramming and these other techniques is that FAST is function-oriented and not time-oriented. Figure (2.6) below displays the basic ground rules for developing a FAST Diagram.

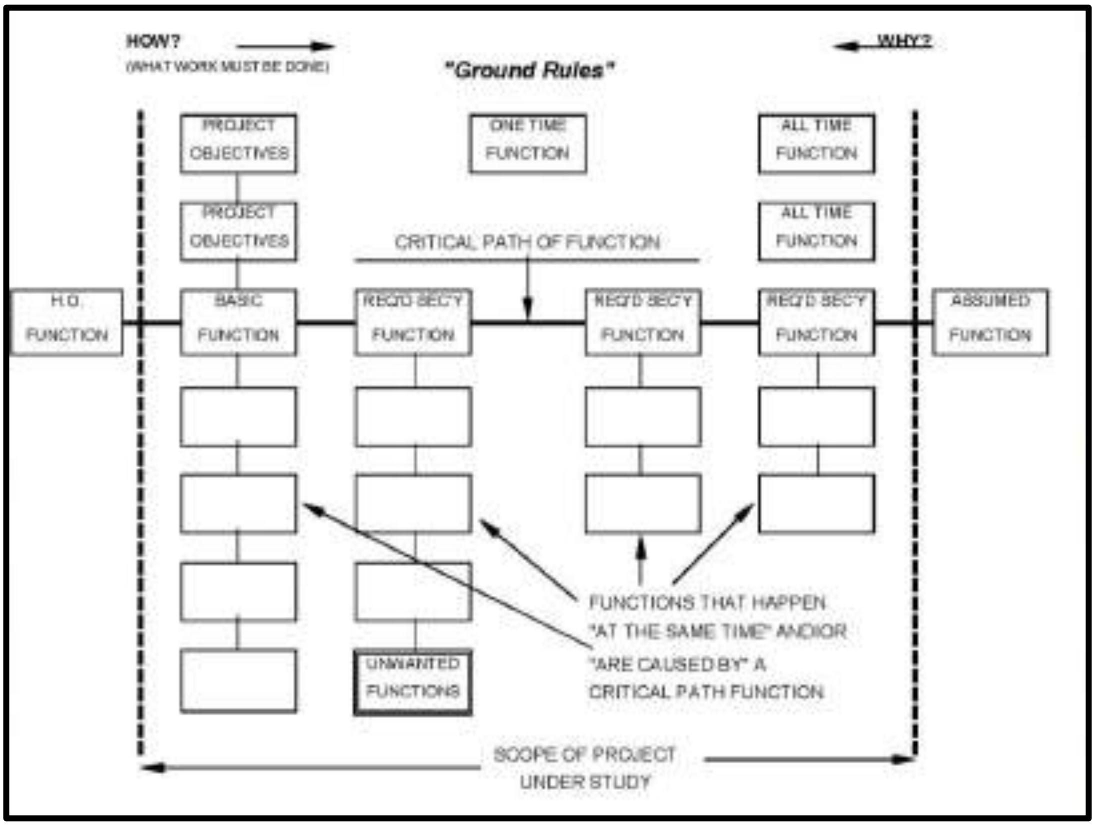


Figure (2.6): FAST Diagram

E. Cost-Function Relationships

The technique of establishing a Cost-Function Relationship:

- Is a marriage of the cost to function.
- Identifies the amount of cost doing Basic Function work vs. Secondary Function work.
- Identifies functions which represent "poor value".

- Points direction as to where to get to work first, second, etc.

2.2.5.3 Speculation Phase (Creative)

Project # *Project:*				VE Study # Cost/Function Analysis
Function = Active Verb + Measurable Noun *Kinds: (B)asic, (S)econdary, (R)equired (S)econdary, (U)nwanted*				
Function	Kind	Cost / % of Total	Worth / % of Total	Comments
Total				

Figure (2.7): Function/Worth Model

The objective of the speculation phase is to generate a large quantity of ideas. By developing many ideas, there is an opportunity to select the idea(s) that best meet the objectives of VE study. In this phase, Building Information Modeling BIM technique, will be embedded during the speculation process of the VE workshop. When starting a speculation session, there are three factors to be considered: the team, the problem, and the environment.

- ***Multi-Disciplinary Team***: The more diverse the experience and skills the team members have, the greater the resource for ideas.
- ***Problem Definition***: Do not look at the whole problem; rather, focus on key functions needing improvement. Address one function or topic at a time. The number of functions that require attention are determined in the Functional Analysis Phase of your study.
- ***Eliminate distractions***: Get away from your office, the phones and other distractions. You need to be able to devote full attention to the search for ideas if your quest is to be successful.

A. Generating Ideas

During a speculation session, it is necessary that the atmosphere is open, positive and receptive to the ideas being generated. Every idea needs to be verbalized. This may trigger another thought or idea in a teammate's mind and allow hitchhiking off your ideas. The fact that the idea may not be initially considered as a "solution" to the problem should not inhibit its inclusion on your list. The objective is to develop a long list of ideas, not answers. Each idea serves one of two purposes: **a potential solution or a stimulus for other ideas**

Too often people will only suggest ideas that they consider as possible solutions. These "ideas" are generally not much more than the traditional answers to the problem. To reach beyond this myopic tendency it is important that, for each function selected, a minimum of 100 ideas be generated.

Creative Session Ground Rules

Generating 100 ideas on any function or activity is made easier if you follow these four basic ground rules:

- Express the problem free from all specifications.
- Assume that every idea will work.
- Search for ideas with a competitive spirit.
- Capitalize on the mutual atmosphere of praise and encouragement.

In addition to these basic ground rules, the speculation session will be even more productive if the VES keep the speculation session moving quickly. It should not take any more than 20 to 30 minutes to generate 100 ideas.

2.2.5.4 Evaluation phase

The purpose of the Evaluation Phase is to systematically reduce the large number of ideas generated during the Speculation Phase to several concepts that appear promising in meeting the project's objectives. During the Evaluation Phase, the obvious nonsense ideas that were developed during speculating sessions will be eliminated, the ideas will be organized into logical groupings, then analyzed with respect to project criteria, and the best combination of ideas will be identified.

The evaluation process consists of four steps, as show in figure (2.8). The first three steps will satisfy the needs of most teams. The evaluation steps will be discussed separately in turn.

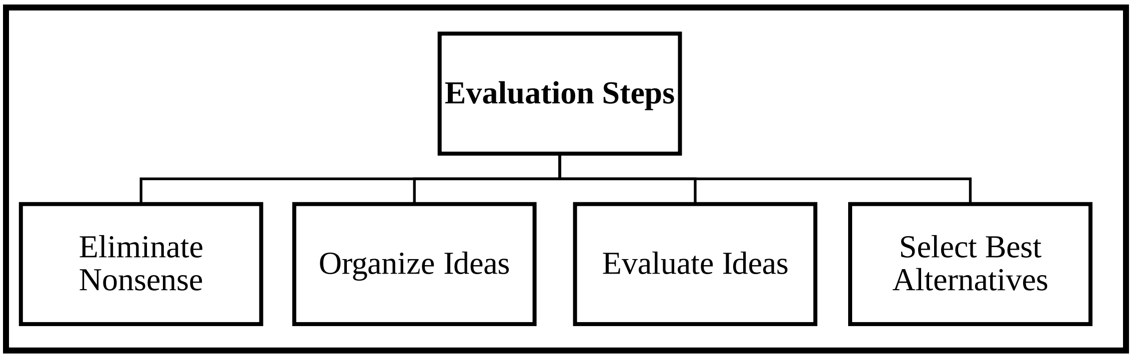


Figure (2.8): Evaluation Steps

The commonly used method in the ideas evaluation is the weighting and matrix method, but in the proposed framework the researcher proposes to use AHP method in the evaluation process, because the comparison between ideas considers multi criteria, thus the AHP method is the most suitable and accurate for this process.

Criteria Development for Evaluation

The ***cost*** of alternatives is the question that should be properly and objectively addressed; however, it worth noting if cost be considered as a single criterion in value engineering; it only makes sense in the requisite sense. Results of group investigation using experienced, multi-disciplinary teams, illustrate that value and economy of a project can be improved by generating alternatives with different design concepts, materials, and methods without compromising the function and value objectives of the client (Miles, 1972).

A client selects a product or uses a service to accomplish certain functions. These criteria are exclusively use and aesthetic. Once the concept, which is accomplishing the basic function, is generated, the choice of materials, shapes, assemblies, methods, functions, tolerances, etc. will be considered. Appropriate cost can also be lost in this work area depend on the client preferences.

Counting ***aesthetic*** as one of the criteria follows different patterns due to subjective nature of the aesthetic. Specific functions under the aesthetic category often suggest some better solutions. Some typical names are: Provide appearance, provide shape, Provide color, Provide features, Provide convenience, Reduce noise, Reduce size, Reduce thickness, Reduce time required, Reduce skill required. Sometimes costs spend on the aesthetic area bring the best value. It depends entirely on what the customer decides and chooses and is willing to pay for.

Value analysis studies have shown that appearance-design area brings great benefits. On the other hand, technical people focus on the development of ***performance***. It is a rather widespread belief at improved appearance and performance requires increased cost which is barely the case. Due to the inherent philosophy of value engineering, identifying and removing unnecessary cost, should improve the value without reducing in the slightest degree quality, safety, life, reliability, dependability, and the features and attractiveness that the customer wants (Miles, 1972).

There is no direct relation between cost and quality. Good quality means the selection of the best answers to the question of how to use materials, processes, parts, and human efforts to accomplish these functions. Constructability is defined as a measure of the ease or expediency with which a facility can be constructed (Anderson, et al., 1999).

The benefits of improved constructability have direct impact on the time, cost, quality, and safety performance of a project, along with other intangible benefits. According to Hijazi (2009) it was found that quantifying assessment of designs; constructability review; and implementation of constructability programmers, are the three most commonly employed approaches in measuring the improving constructability (Hijazi, 2009).

According to the previously defined criteria the researcher developed the evaluation parameters as cost, aesthetic, performance, constructability, and durability.

2.2.5.5 Development Phase

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

1. Beginning with the highest ranked value alternatives, develop a benefit analysis and implementation requirements, including estimated initial costs, life cycle costs, and implementation costs taking into account risk and uncertainty.

2. Conduct performance benefit analysis.
3. Compile technical data package for each proposed alternative:
   - written descriptions of original design and proposed alternative(s)
   - sketches of original design and proposed alternative(s)
   - cost and performance data, clearly showing the differences between the original design and proposed alternative(s)
   - any technical back-up data such as information sources, calculations, and literature
   - schedule impact

4. Prepare an implementation Plan, including proposed schedule of all implementation activities, team assignments and management requirements.

5. Complete recommendations including any unique conditions to the project under study such as emerging technology, political concerns, impact on other ongoing projects, marketing plans, etc.

2.2.5.6 Presentation Phase

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

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

The written report documents the alternatives proposed with supporting data, and confirms the implementation plan accepted by management. Specific organization of the report is unique to each study and organization requirements.

2.2.5.7 Life Cycle Costing

The life cycle cost (LCC) is the ultimate indicator of value to the client. It encompasses both initial costs and running costs. The LCC model considers optimum value because it considers all probable costs over the life of the facility. The LCC model can be based on either the annualized cost or the present worth approach (Shublaq, 2003). According to West Virginia Division of Highways (2004), the total cost of a project is composed of design cost, construction cost and operation and maintenance cost. From its records in highways, the construction cost does not exceed 50% of the life cycle cost.

Present worth of future annuities

In order to evaluate life cycle cost of a project, it is necessary to present expenditures at various periods of time in a way that reflects the value of money in relation to time. For this reason, LCC model can be based on either the annualized cost or the present worth approach. The following formulas for calculations of money equivalence at different times are used by LaGrega , Buckingham and Evan (1994).

Present worth analysis

The following formulas are used as present worth evaluation of future value, table (2.3):

Table (2.3): Present Worth Calculations

Year	**Amount at Beginning of Year**	**Interest Earned During Year**	**Compound Amount at the End of year**	
1.	P	Pi	P + Pi	= P(1+i)
2.	P(1+I)	P(1+i)1	P(1+i)+P(1+i)i	= $P(1+i)^2$
3.	$P(1+I)^2$	$P(1+i)^2I$	$P(1+i)^2+P(1+i)^2i$	= $P(1+i)^3$
N.	$P(1+I)^{n-1}$	$P(1+i)^{n-1}I$	$(P1+i)^{n-1}+P(1+i)^{n-1}i$	= $P(1+i)^n$ = F

The amount P is the present worth of today’s investment while the amount F is the future value.

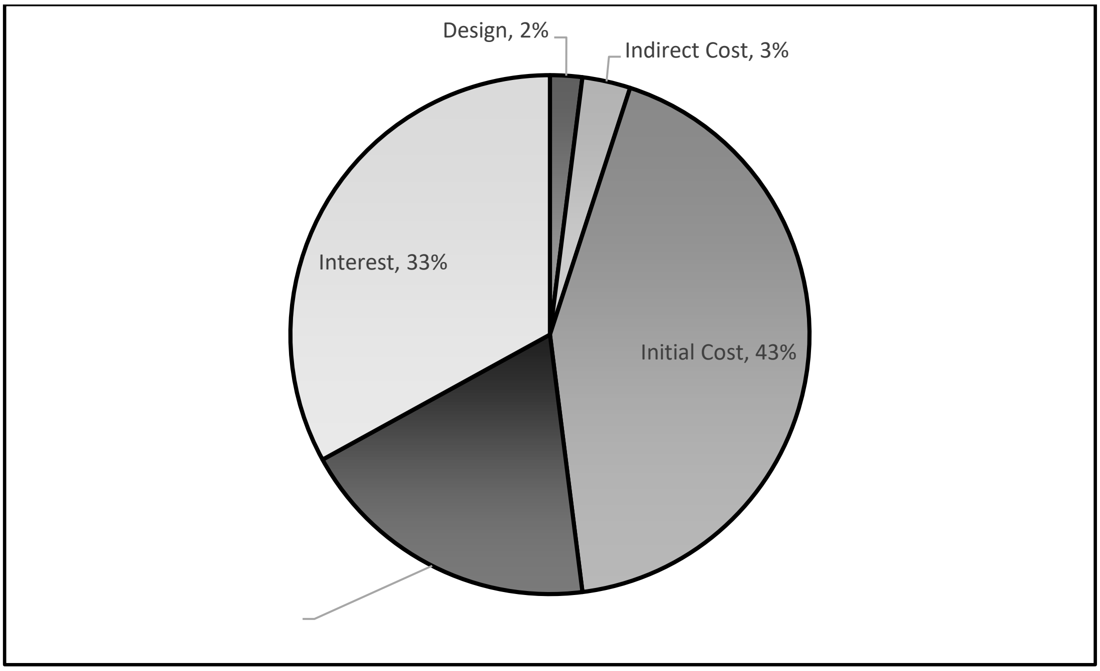


Figure (2.9): L.C.C for typical Building

❖ **POST- WORKSHOP PHASE**

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

While the VE Team Leader may track the progress of implementation, in all cases the design professional is responsible for the implementation. Each alternative must be independently designed and confirmed, including contractual changes if required, before its implementation into the product, project, process, or procedure. Further, it is recommended that appropriate financial departments (accounting, auditing, etc.) conduct a post audit to verify to management the full benefits resulting from the value methodology study.

2.1.6 Value Engineering Applicability

Referring to Attarde (2016), the VE methodology can be applied wherever cost and/or performance improvement is anticipated. That improvement can be measured in terms of monetary aspects and/or other critical factors such as productivity, quality, time, energy, environmental impact, and durability.

The Value Methodology is applicable to hardware, building or other construction projects, and to “soft” areas such as manufacturing and construction processes, health care and environment services, programming, management systems and organization structure. The pre-study efforts for these “soft” types of projects utilize standard industrial engineering techniques such as flow charting, yield analysis, and value added task analysis to gather essential data.

For civil engineering works, such as buildings, highways, factory construction, and water/sewage treatment plants, which tend to be one time applications, VE is applied on a project to project basis. Since these are one-time capital projects, VE must be applied as early in the design cycle as feasible to achieve maximum benefits (Pearson, 1969). Changes or redirection of design can be accomplished without extensive redesign, large implementation cost, and schedule impacts. Typically for large construction projects, specific value studies are conducted during the schematic stage and then again at the design development (up to 45%) stage. Additional value studies may be conducted during the construction or build phase.

For large or unique products and systems such as military electronics or specially designed capital equipment, VE is applied during the design cycle to assure meeting of goals and objectives. Typically, a formalized value study is performed after preliminary design approval but before release to the build/manufacture cycle. VE may also be applied during the build/manufacture cycle to assure that the latest materials and technology are utilized.

According to (Seidel, 2012) The top five frequently value engineered categories are site, electrical, HVAC, exterior walls and flooring finishes, each with more than 30 VE items and together they encompass more than 50% of the VE items. The five least often value engineered categories are elevators, fire protection, foundation, roof opening and canopy; in each of these categories there were only two or three VE items.

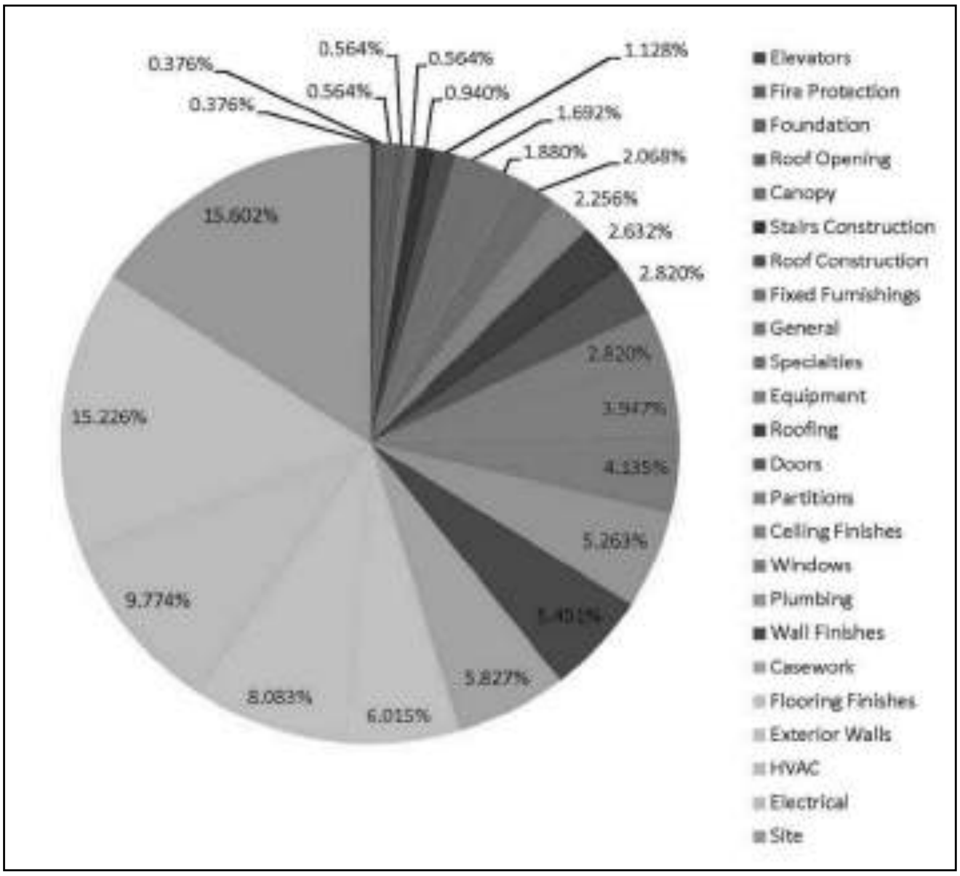


Figure (2.10): Frequently Value Engineered Categories

The following table (2.4) shows the main factors that affect applicability of Value Engineering methodology.

Table (2.4): Factors Affecting Value Engineering Applicability

	Factors	References
	Value Engineering Applicability barriers	
1.	Lack of local guidelines and information	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
2.	Lack of knowledge and practices	(Ali Bagheri Fard, 2013) (Amir Shekari, 2009) (Al-Yousefi, 2011) (Senay Atabay and Niyazi Galipogullari, 2013)
3.	Interruption to normal work schedule	(Ali Bagheri Fard, 2013) (Senay Atabay and Niyazi Galipogullari, 2013)
4.	Change in owners' requirements	(Amir Shekari, 2009) (Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972)
5.	Conflict of objectives by different project stakeholders	(Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
6.	Outdated standards and specifications	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
7.	Habitual thinking and negative attitude	(Amir Shekari, 2009) (Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972)

	Factors	References
8.	Lack of culture to accept the change	(Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
9.	Over-design and overestimating	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
10.	Lack of communication and poor human relations	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
11.	Lack of inventive ideas	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
	Value engineering applicability needs	
12.	The importance of adding Value Engineering Change Proposals (VECP) clause in the Contract Document	(Amir Shekari, 2009) (Ali Bagheri Fard, 2013) (Attarde P. N., 2016) (Chi-Sung In, 2009) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
13.	Necessity of the presence of a Value Engineering Certified Personnel in design team	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972)
14.	The necessity of providing Value Engineering training opportunities for experts and students	(Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)

	Factors	References
15.	The necessity of improving the communication and social skills of engineering students during their study	(Amir Shekari, 2009) (Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972)
16.	The criticality to provide the emergence of a diversity of procurement routes for projects	(Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972)
17.	The necessity of making clients more demanding and knowledgeable of the Value Engineering	(Ali Bagheri Fard, 2013) (Senay Atabay and Niyazi Galipogullari, 2013)
18.	Essentiality of updating standards and criteria in construction industry in the participants' countries	(Amir Shekari, 2009) (Ali Bagheri Fard, 2013) (Al-Yousefi, 2011) (Dina Mahmoud Mansour, 2013)
	Value Engineering application benefits	
19.	Reducing Construction Production Costs	(Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972)
20.	Finishing the Job before Time Schedule	(Ali Bagheri Fard, 2013) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)
21.	Quality Improvement and Correction	(Ali Bagheri Fard, 2013) (Amir Shekari, 2009) (Al-Yousefi, 2011)
22.	Reducing Mistakes and Deficiencies in Project Drawings to Minimum	(Amir Shekari, 2009) (Al-Yousefi, 2011) (Miles, Techniques of Value Analysis and Engineering, 1972) (Senay Atabay and Niyazi Galipogullari, 2013)

2.1.7 Factors influencing Value Engineering Studies

A rigorous measurement on the performance of VE studies is likely to improve the implementation of the VE application and enhance the confidence of clients about their investment in VE. The identification of the Factors Influencing VE studies is an essential first step in developing a proper application of it. This section aims to investigate the Factors Influencing VE studies for measuring the performance of VE studies in construction, and then the researcher will get the benefit of this investigation to implement it in the workshop phase.

Table (2.5): Factors Influencing Value Engineering Studies

#	**Factors Influencing Value Engineering Studies**	**Sources**
1.	Satisfaction of the time when the VE Workshop will be conducted	(Lin, 2009), (Khalid Al-Gahtani, 2015) (Attarde N. L., 2016) (Berawi M. A., 2009), (Maila Herrala, 2009), (Lin, 2009) (Chi-Sung In, 2009) (Chavan, 2013) (Attarde N. L., 2016)
2.	Disciplines of participants	(Khalid Al-Gahtani, 2015)
3.	Authority of key stakeholder participants	(Farahmandazad, 2015) (Attarde N. L., 2016)
4.	Years of professional experience of participants	(Khalid Al-Gahtani, 2015) (Lin, 2009)
5.	VE knowledge of participants	(Khalid Al-Gahtani, 2015) (Attarde N. L., 2016)
6.	Years of experience of facilitator	(Khalid Al-Gahtani, 2015)
7.	Qualification of facilitator	(Khalid Al-Gahtani, 2015)
8.	Client’s support	(Khalid Al-Gahtani, 2015)
9.	Client’s participation	(Khalid Al-Gahtani, 2015) (Attarde P. N., 2016) (Al-Yousefi, 2011)

#	Factors Influencing Value Engineering Studies	Sources
10.	Clear objectives of workshop	(Khalid Al-Gahtani, 2015) (Attarde P. N., 2016) (Lin, 2009) (Amruta Chougule A. K., 2014) (Boo Young Chung, 2009) (Chi-Sung In, 2009)
11.	Relevant departments' support	(Khalid Al-Gahtani, 2015) (Attarde N. L., 2016) (Lin, 2009) (Chi-Sung In, 2009)
12.	Time spent on preparation before workshop	(Khalid Al-Gahtani, 2015) (Attarde N. L., 2016) (Lin, 2009) (Chi-Sung In, 2009)
13.	Background information collected	(Khalid Al-Gahtani, 2015) (Lin, 2009)
14.	Number of pre-workshop meetings held	(Khalid Al-Gahtani, 2015) (Attarde N. L., 2016) (Lin, 2009) (Chi-Sung In, 2009)
15.	Number of related documents analyzed	(Khalid Al-Gahtani, 2015) (Attarde P. N., 2016) (Lin, 2009) (Boo Young Chung, 2009)
16.	Duration of each phase	(Khalid Al-Gahtani, 2015) (Attarde N. L., 2016) (Lin, 2009) (Boo Young Chung, 2009)
17.	Time keeping of each phase	(Khalid Al-Gahtani, 2015) (Attarde N. L., 2016) (Lin, 2009) (Chi-Sung In, 2009)
18.	Satisfaction of the techniques used in each phase	(Khalid Al-Gahtani, 2015) (Lin, 2009) (DellI'lsola, 1969) (Boo Young Chung, 2009) (Chi-Sung In, 2009)
19.	Interaction among participants in each phase	(Khalid Al-Gahtani, 2015) (Lin, 2009) (DellI'lsola, 1969) (Chi-Sung In, 2009)
20.	Client's objectives clarified	(Khalid Al-Gahtani, 2015) (Lin, 2009)

#	Factors Influencing Value Engineering Studies	Sources
21.	Project givens/assumptions clarified	(Khalid Al-Gahtani, 2015) (Boo Young Chung, 2009) (Boo Young Chung, 2009)
22.	Primary function identified	(Khalid Al-Gahtani, 2015) (Lin, 2009) (DelI'lsola, 1969)
23.	Total number of ideas	(Khalid Al-Gahtani, 2015) (Lin, 2009)
24.	Average numbers of ideas generated by each participant	(Khalid Al-Gahtani, 2015) (Lin, 2009) (Amir Shekari, 2009) (Boo Young Chung, 2009)
25.	Equal contribution of participants	(Khalid Al-Gahtani, 2015) (Lin, 2009) (DelI'lsola, 1969)
26.	Efficiency of idea generation	(Khalid Al-Gahtani, 2015) (Lin, 2009) (DelI'lsola, 1969)
27.	Duration to complete the report	(Khalid Al-Gahtani, 2015) (Lin, 2009) (DelI'lsola, 1969)
28.	Quality of the report	(Amruta Chougule A. K., 2014) (Khalid Al-Gahtani, 2015) (Lin, 2009)
29.	Percentage of action plan carried out	(Khalid Al-Gahtani, 2015); (Lin, 2009) (DelI'lsola, 1969)
30.	Proposed change on project investment	(Amruta Chougule A. K., 2014); (Khalid Al-Gahtani, 2015); (Lin, 2009)
31.	Proposed change on life-cycle cost	(Amruta Chougule A. K., 2014); (Khalid Al-Gahtani, 2015); (Lin, 2009)
32.	ROI of VM study, i.e., proposed savings/cost of VM	(DelI'lsola, 1969); (Khalid Al-Gahtani, 2015); (Lin, 2009); (DelI'lsola, 1969)
33.	Proposed change on design schedule	(Khalid Al-Gahtani, 2015); (Lin, 2009); (DelI'lsola, 1969)
34.	Proposed change on construction schedule	(Amruta Chougule A. K., 2014); (Khalid Al-Gahtani, 2015); (Lin,

#	Factors Influencing Value Engineering Studies	Sources
		2009); (Attarde N. L., 2016); (DelI'lsola, 1969)
35.	Reducing the difficulty of construction, i.e., rework times	(Amruta Chougule A. K., 2014); (Khalid Al-Gahtani, 2015); (Lin, 2009); (DelI'lsola, 1969)
36.	Improving the project quality	(Khalid Al-Gahtani, 2015); (Lin, 2009) (Attarde N. L., 2016); (DelI'lsola, 1969)
37.	Improving the project appearance	(Khalid Al-Gahtani, 2015); (Attarde N. L., 2016); (DelI'lsola, 1969)
38.	Identifying and clarifying the client's requirements	(Khalid Al-Gahtani, 2015); (Lin, 2009); (DelI'lsola, 1969); (Amruta Chougule A. K., 2014)
39.	Accelerating the decision making	(Khalid Al-Gahtani, 2015); (Lin, 2009) (Attarde P. N., 2016); (Amruta Chougule A. K., 2014)
40.	Improving communication and understanding among stakeholders	(Khalid Al-Gahtani, 2015); (Lin, 2009) (Burnside, 1969); (Decker, 1969); (Fridholm, 1969)
41.	Deliberating the alternatives	(Khalid Al-Gahtani, 2015); (Lin, 2009) (Amruta Chougule A. K., 2014) (Spear, 1969)
42.	Client's satisfaction	(DelI'lsola, 1969) (Khalid Al-Gahtani, 2015) (Lin, 2009) (Attarde N. L., 2016);
43.	Participants' satisfaction	(DelI'lsola, 1969) (Khalid Al-Gahtani, 2015) (Lin, 2009) (Attarde N. L., 2016) (Amruta Chougule A. K., 2014) (Blundell, 1969)

#	Factors Influencing Value Engineering Studies	Sources
44.	Facilitator's satisfaction	(Khalid Al-Gahtani, 2015) (Lin, 2009) (Attarde N. L., 2016) (DelI'lsola, 1969)

2.2 Building Information Modeling (BIM)

2.2.1 BIM Definition and concept

Building Information Modeling (BIM) is one of the most promising developments in the Architecture, Engineering, and Construction (AEC) industries. BIM simulates the construction project in a virtual environment. With BIM technology, an accurate virtual model of a building is digitally constructed. When completed, the computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication and procurement activities required to realize the building (Salman Azhar, 2008).

Moreover, Building Information Model is primarily a three-dimensional digital representation of a building and its intrinsic characteristics. It is made of intelligent building components which includes data attributes and parametric rules for each object.

Furthermore, BIM provides consistent and coordinated views and representations of the digital model including reliable data for each view.

This saves a lot of designer's time since each view is coordinated through the built-in intelligence of the model. According to the National BIM Standard, Building Information Model is "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" ((buildingSMART, 2012).

Building Information Modeling (BIM) is the process and practice of virtual design and construction throughout its life cycle. It is a platform to share knowledge and communicate between project participants (Cheng Zhang, 2016). In other words, Building Information Modeling is the process of developing the Building Information Model.

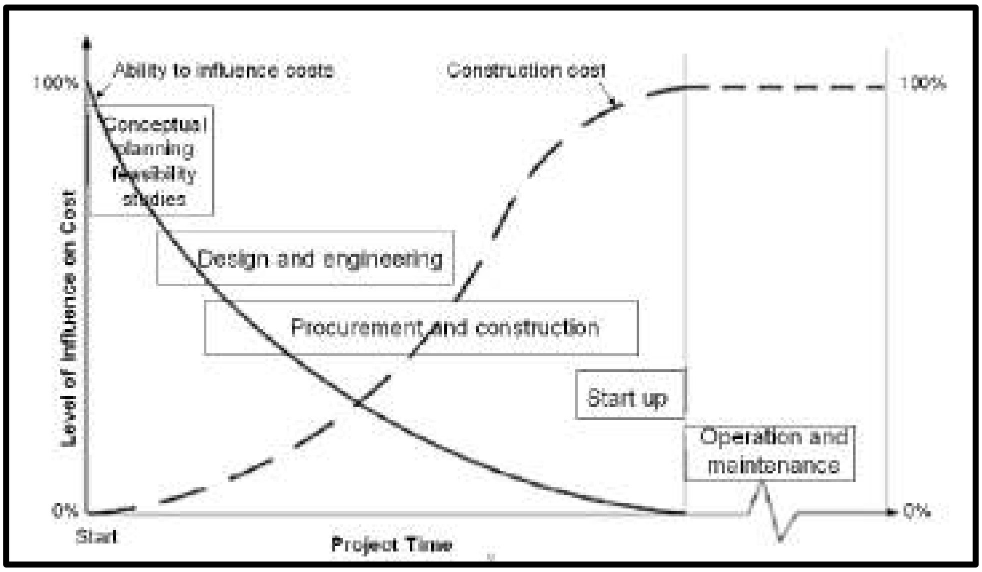


Figure (2.11): relationship between project lifecycle the influence on cost

2.2.2 BIM Tools

There are plenty of Building Information Modeling tools. This subsection will identify these products. The following table 2.6, depicts the BIM authoring tools and their primary functions. The list includes MEP, structural, architectural, and site work 3D modeling software. Some of these software are also capable of scheduling and cost estimation.

Table (2.6): BIM tools

Product Name	Manufacturer	Primary Function
Cadpipe HVAC	AEC Design Group	3D HVAC Modeling
Revit Architecture	Autodesk	3D Architectural Modeling and Parametric design.
AutoCAD Architecture	Autodesk	3D Architectural Modeling and parametric design.
Revit Structure	Autodesk	3D Structural Modeling and parametric design.
Revit MEP	Autodesk	3D Detailed MEP Modeling
AutoCAD MEP	Autodesk	3D MEP Modeling
AutoCAD Civil 3D	Autodesk	Site Development

Product Name	Manufacturer	Primary Function
Cadpipe Commercial Pipe	AEC Design Group	3D Pipe Modeling
DProfiler	Beck Technology	3D conceptual modeling with real time cost estimating.
Bentley BIM Suite (MicroStation, Bentley Architecture, Structural, Mechanical, Electrical, Generative Design)	Bentley Systems	3D Architectural, Structural, Mechanical, Electrical, and Generative Components Modeling
Fastrak	CSC (UK)	3D Structural Modeling
SDS/2	Design Data	3D Detailed Structural Modeling
Fabrication for AutoCAD MEP	East Coast CAD/CAM	3D Detailed MEP Modeling
Digital Project	Gehry Technologies	CATIA based BIM System for Architectural, Design, Engineering, and Construction Modeling
Digital Project MEP Systems Routing	Gehry Technologies	MEP Design
ArchiCAD	Graphisoft	3D Architectural Modeling
MEP Modeler	Graphisoft	3D MEP Modeling
HydraCAD	Hydratec	3D Fire Sprinkler Design and Modeling
AutoSPRINK VR	M.E.P. CAD	3D Fire Sprinkler Design and Modeling
FireCad	Mc4 Software	Fire Piping Network Design and Modeling
CAD-Duct	Micro Application	3D Detailed MEP Modeling
Vectorworks Designer	Nemetschek	3D Architectural Modeling
Duct Designer 3D, Pipe	QuickPen	3D Detailed MEP Modeling

Product Name	Manufacturer	Primary Function
Designer 3D	International	
RISA	RISA Technologies	Full suite of 2D and 3D Structural Design Applications
Tekla Structures	Tekla	3D Detailed Structural Modeling
Affinity	Trelligence	3D Model Application for early concept design
Vico Ofice	Vico Software	5D Modeling which can be used to generate cost and schedule data
PowerCivil	Bentley Systems	Site Development
Site Design, Site Planning	Eagle Point	Site Development

Revit Architecture provided by Autodesk Inc.-which will be used in this study- has built-in sequencing options to build a 3D model.

The researcher chose the Revit program in help of BIM wise for many reasons:

- High performance of 3D BIM Modeling
- The ability to add 4D and 5D to the same model.
- Quick changes to design, no repetitive tasks.
- Accurate estimation of quantities and cost

2.3 Multi Criteria Decision-Making Analysis

The process of making a decision is decomposition and synthesis. Thinking is identifying objects and ideas; Identifying is decomposing the complexity we face; Then is to fine the relation among the identified objects and synthesize them (Saaty T. L., 1990). Decisions are derived from the comparison of different points of views; some correspond with a certain decision and some against that. This clarifies the inherent of the decision making which is based on the plurality of points of view which cannot be defined as single criteria.

Therefore, for the last thirty years, a new approach for decision problems has come to the attention of researchers and practitioners. MCDA intuition is closely related to the way humans have always made decisions; thus, although there is a wide range of techniques and methods in this domain, the basic elements of decision making are very simple: alternatives, solutions and sequence of actions. With the ingredients given, MCDA helps decision maker mainly regarding choosing, ranking and sorting alternatives, (Chuck, 2011) This theory is used for modeling the unstructured problems in economics, social and management science (Saaty, 1990).

Decision making is identifying and choosing alternatives based on decision makers' preferences. Making a decision is when there are alternatives to be considered and the decision maker prefers to have a large number of alternatives as possible. Moreover, the alternative which is selected should be the one that best meet the objectives and desired values (Harris, 2012).

According to (Baker, et al., 2002)decision making should start with the agreement between decision makers and stakeholder on the definition of the problem, requirements, goals and criteria. Then it can proceed to a general decision making process following the steps indicate below (Baker, et al., 2002)

- Define the problem: This step aims to clarify the situation; A one sentence (problem statement) that illustrates the current condition and the desired condition.
- Determine requirements "Requirements are conditions that any acceptable solution to the problem must meet" (Baker, et al., 2002). Requirements are the necessity not the sufficiency.
- Establish goals: Goals are beyond the minimum essentials and requirements.
- Identify alternatives: Alternatives are the possibilities for changing the condition from the existing one to the desired one.
- Define criteria: Criteria should be defined according to the goal. Goals are represented in the form of criteria. These criteria should be discriminating since it is a measurement for the alternatives. In other words, alternatives are valuated based on the defined criteria. Criteria can be organized to the groups like a tree structure like: criteria, sub criteria, sub- sub criteria.
- Select a decision-making tool: Several tools are proposed for solving a decision problem which is a task that needs efforts. It depends on various factors such as the complexity of the problem or the objectives of decision maker.

- Evaluate alternatives against criteria: Every acceptable method of decision making evaluates alternatives against criteria. The assessment may be objective (factual), considering some commonly scale of measurement, e.g. money, or it might be subjective (judgmental), based on the subjective assessment of the evaluator.
- Validate solutions against problem statement: The selected alternative needs to be validated against the requirements and objectives of the decision problem. There is a possibility that the method of decision making was misapplied. Some of the Multi Attribute Making Models are described in the following pages.

2.3.1 MCDA Methods

2.3.1.1 Analytical Hierarchy Process (AHP)

Analytic Hierarchy Process is the most used tool in Multiple Criteria Decision Making. A large number of valuable researches have been published based on the theory of AHP in various fields such as planning, selecting the best alternative, resource allocations and optimization. Since the invention of the Analytic Hierarchy process, it has been of help to decision makers and researchers, (Omkarprasad, 2006). Choosing the factors that are effective in making a decision may be the most creative task. In AHP these factors are arranged in a hierarchic structure descending from an overall goal to criteria, subcriteria and then alternatives successively (Saaty, 1990)

Saaty developed the following steps for applying the AHP:

- Define the problem and determine its goal and objective.
- Construct the hierarchy from the top. The first level would be the objectives from the viewpoint of a decision-maker. The second level is the intermediate level which is the criteria on which subsequent levels depend. And the lowest level contains the list of alternatives. See Figure 2.12.

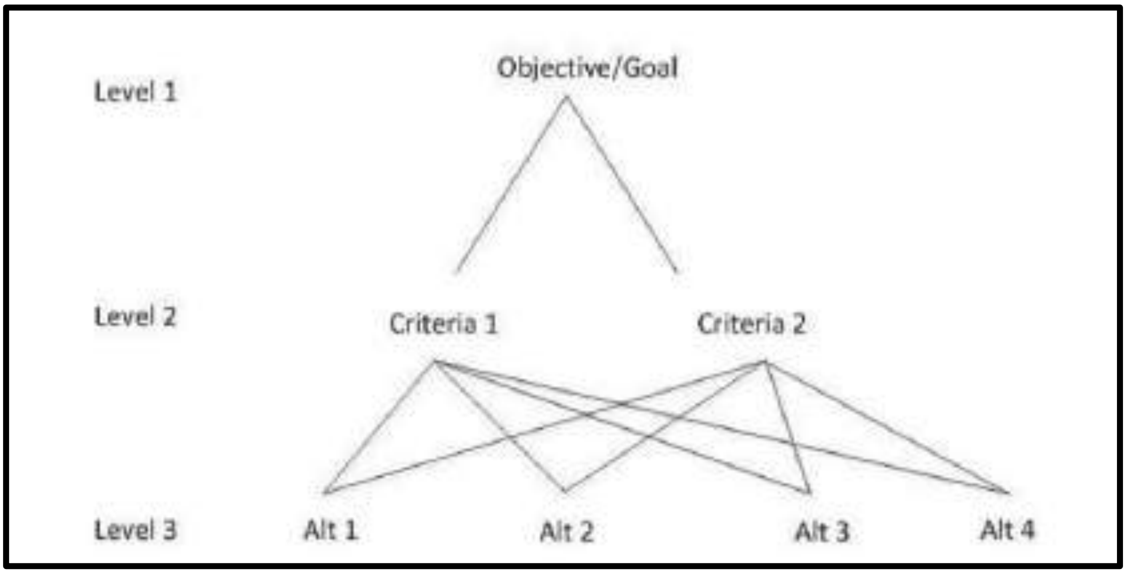


Figure (2.12): AHP criteria

- Construct matrices for a set of pair-wise comparison with the size of *n*n* in which *n* represents the number of the elements in the lower level along with one matrix for each element in the intermediate level. The intensity scale of importance has been broken down into a scale of 1-9, the highest ratio corresponds to 9 and equal importance corresponds to (Saaty, 1990).

The pair wise comparisons are done with respect of which element dominates the other.

- To develop the matrix in level 3, $n(n-1)/2$ judgments are required. Reciprocals are automatically assigned in each pair wise comparison.
- Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weigh eigenvector entries corresponding to those in the next lower level of the hierarchy.
- Once all the pair wise comparisons are done, the consistency is determined by using the eigenvalue, λ max, to calculate the consistency index. Consistency Ratios (CR) are used in order to measure the consistency of the judgments. Consistency Index, CI is calculated as: CI = (λ max-n)/ (n-1), where *n* is the matrix size. Consistency of the Judgment can be verified by comparing the consistency ratio (CR) of CI with its appropriate value in figure 2.13. The acceptable amount for CR is, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To have an acceptable consistent matrix, judgments should be revised and developed.

Average random consistency (RI)										
Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Figure (2.13): Average random consistency

AHP pursues two main goals: Assigning weights to the predetermined criteria; prioritizing or ranking alternatives to identify the key elements (Alamoudi, 2015). The priority vector is calculated by multiplying the *n* judgments of each row and taking the *nth* root, then normalizing the resulting numbers by dividing the sum of *nth* root column to every *n* judgment. This process is same for the alternatives comparing them one to another with respect to the criteria, in order to determine their relative value/importance for each criterion (Saaty, 1980). According to (Saaty, 1990), the AHP calculations are easily doable in the spreadsheets and refer to (Edwards, 1994)commercial software packages are available for the users in the market.

Converting subjective assessment of relative importance to a set of scores and goals is the main idea of the AHP approach (János, 2006). The extensive literature review of decision making reveals that most decision analysis models are quite subjective due to the subjective inherent of the decision making. However, every decision maker uses steps to identify and tackle the problems and establish a framework to yield the optimum or near optimum solution. The number of steps accomplished throughout the decision-making process should be selected wisely (Usman *et al*., 2015). Too few steps will not evaluate and address the problem properly and too man stages resulted in overanalyzing (Graham, 2012). Measurements in Paired comparisons in the AHP method are based on the observation of the relative importance of a property between two elements (Saaty, 1990). Aside from converting the subjective assessment to the weights and score which may be the most benefit of AHP, it has other advantages and disadvantages. Some of the advantages are:

- Allows the use of data, experience, insight, and intuition in a logical fashion.

- Measure the inconsistency of the judgments. The AHP model provides the user with the capability to measure the degree of inconsistent judgments and introduce the acceptable tolerance level for the inconsistency (Graham, 2012).

In terms of the method disadvantages:

- If any interdependencies exist among the criteria it does not consider in the method.
- The use of subjective judgment which is subject to human error and biases
- The reversal rank is not consistent when one criterion is added or removed

(Graham, 2012).

2.3.1.2 Analytic Network Process (ANP)

The Analytic Network Process (ANP) is built upon the foundation of AHP. According to (Saaty, 1990), ANP introduces a general framework to address the decisions, considering the possibility of dependency between the elements within a level. That is to say, ANP can be used without defining the hierarchical level. ANP framework represents a coupling made up of two parts. First is a network of criteria and sub-criteria that control the relative interaction which is a control hierarchy; second is a network of influence among the elements and clusters.

"ANP is a decision-making process tool that allows one to include all the factors and criteria, tangible and intangible which have bearing on making the best decision. The Analytic Network Process allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in human society, especially when risk and uncertainty are involved" (Saaty, 2008)

2.3.1.3 Simple Multi- Attribute Rating Technique (SMART)

Multi-Attribute Utility Theory (MAUT) is a quantitative comparison method. The method deals with the disparate measures. It amalgamates dissimilar measures along with individual priorities, into a cumulative preference. The foundation of MAUT is the use of utility functions. Utility functions are functions that transform unlike criteria to one common scale (0 to 1) which is known as the multi attribute "utility". Alternatives' raw data which are objectives and the analysts' opinion are converted to the utility score as soon as the utility functions are created (Edwards, 1994). When quantitative data are available for every alternative, utility function will be used for better estimates of the alternative performance.

A good sample of MAUT method is the Simple Multi Attribute Rating Technique (SMART). This method utilizes simple utility relationships. It generally uses five, seven, and ten point scale. In case the data does not distinguish effectively the SMART methodology allows the use of less scale range. When actual numerical data are not available, subjective cognitive are replaced and documented in the final output (Goodwin, 2004).

2.4.1.4 Sensitivity analysis

Values related to multi-attribute decision models are often subjective. There might be uncertainties in the weights of the criteria and the scoring values of the alternatives against the subjective (judgmental) criteria. The question is that how the decision model reflects the changes of some input parameters in the final ranking or the ranking values of the alternatives? (János, 2006).

When the variable is the value of the weight of a single criterion, the case is very simple. In terms of additive multi-attribute models, the ranking values of the alternatives follow a simple linear function of that variable and the sensitivity analysis can be applied using different graphical tools (Cory, 2001). Regarding a wide class of multi-attribute decision models the stability intervals or regions for the weights of different criteria should be determined (Thomas *et al*. , 2006). There are also other models available that deals with the more complex sensitivity analysis (János, 2006).

2.3.2 Benefits of AHP/ANP

Comparative study of AHP and ANP in multi-criteria decision shows some of the benefits of using these methodological approaches:

1. As compared to other MCDM approaches, AHP/ANP is not proportionately complicated, thus this can be of help to improve management understanding and transparency of the modeling technique.
2. They can mix quantitative and qualitative factors into a decision.
3. AHP/ANP use a hierarchical structuring of the factors involved. The hierarchical structuring is a natural problem-solving paradigm in case of complexity.
4. AHP has proved to be valid from the decision makers’ point of view as well in recent empirical studies.

5. AHP/ANP is a technique that can prove valuable in helping multiple parties (Stakeholders) arrive at an agreeable solution because of its structure. (Taslicali and Ercan , 2006)

2.4 Criteria Development

Value engineering is a problem-solving technique that utilizes quantitative methods and knowledge based decisions to improve owners' job satisfaction and help reduce unnecessary cost. A critical phase in the application of value engineering is the evaluation of generated alternatives based on the defined criteria for that purpose. To do so a multi attribute decision making environment should be provided as well as criteria that proved to be effective in the decision-making procedure. These criteria are not fixed and can be changed based on each owner preference.

"The main function of value analysis is to identify each element of function provided by each element of cost" (Miles, 1972) The purpose of each expenditure, no matter it is for hardware, the team work, a procedure, or so forth, is to accomplish a function. It is necessary to clarify the definition of function. Functions are divided into two types. Either or both affect the decision makers' selection.

After functions are identified, clarified, understood, and named, they can be classified as either basic or secondary functions. Basic functions are those functions for which the owners need device or service. Secondary functions are those functions allow the designers to choose different means to accomplish the basic functions.

The cost of alternatives is the question that should be properly and objectively addressed; however, it worth noting if cost be considered as a single criterion in value engineering; it only makes sense in the requisite sense. Results of group investigation using experienced, multi-disciplinary teams, illustrate that value and economy of a project can be improved by generating alternatives with different design concepts, materials, and methods without compromising the function and value objectives of the client (Miles, 1972).

A client selects a product or uses a service to accomplish certain functions. These criteria are exclusively use and aesthetic. Once the concept, which is accomplishing the basic function, is done, the choice of materials, shapes, assemblies, methods, functions, tolerances, etc. will be taken into account. Appropriate cost can a1so be lost in this work area depend on the client preferences.

Counting aesthetic as one of the criteria follows different patterns due to subjective nature of the aesthetic. Specific functions under the aesthetic category often suggest some better solutions. Some typical names are: Provide appearance, Provide shape, Provide color, Provide features, Provide convenience, Reduce noise, Reduce size, Reduce thickness, Reduce time required, Reduce skill required. Sometimes costs spend on the aesthetic area bring the best value. It depends entirely on what the customer decides and chooses and is willing to pay for.

Value analysis studies have shown that appearance-design area brings great benefits. On the other hand, technical people focus on the development of performance. It is a rather widespread belief at improved appearance and performance requires increased cost which is barely the case. Due to the inherent philosophy of value engineering, identifying and removing unnecessary cost, should improve the value without reducing in the slightest degree quality, safety, life, reliability, dependability, and the features and attractiveness that the customer wants (Miles, 1972).

There is no direct relation between cost and quality. Good quality means the selection of the best answers to the question of how to use materials, processes, parts, and human efforts to accomplish these functions. "Constructability" is the term used in the United States (US), where "Build ability" is the term rather use in Europe. Constructability is defined as a measure of the ease or expediency with which a facility can be constructed (Anderson, et al., 1999).

The benefits of improved constructability have direct impact on the time, cost, quality, and safety performance of a project, along with other intangible benefits. According to Zhang (2016) it was found that quantifying assessment of designs; constructability review; and implementation of constructability programmers, are the three most commonly employed approaches in measuring the improving constructability (Zhang, 2016).

2.5 Summary

This chapter reviewed the literature of Value engineering, building information modeling BIM, and analytical hierarchy process AHP. It concluded the basic VE job plan stages and techniques, and the main factors that inflecting VE studies. On the other hand, it discussed the BIM and AHP techniques and how could it be imbedded in the VE job plan to facilitate its application.

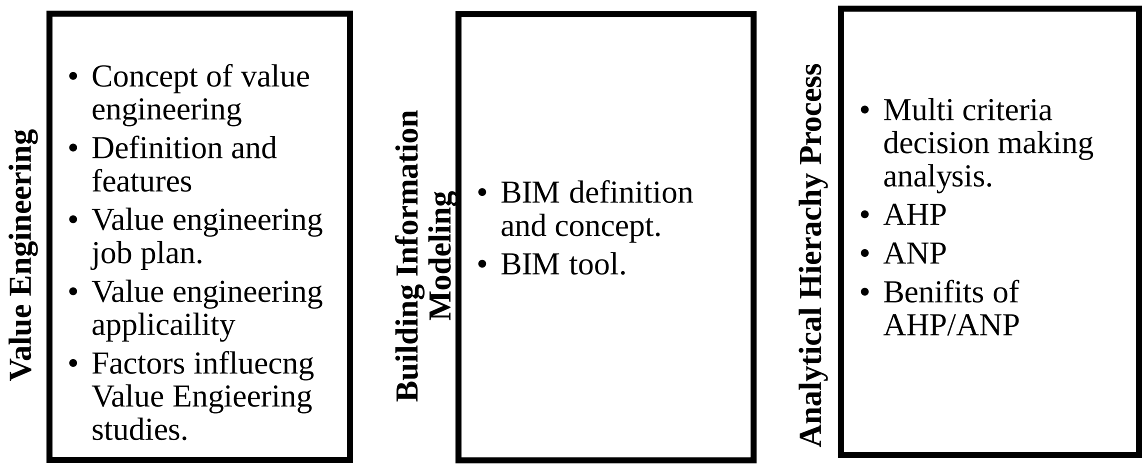


Figure (2.14): Literature Review Summary

Chapter 3

Chapter three: Research Methodology

This chapter presents the methodology that used in this study. The research methodology was selected in a term to satisfy the research aim and objectives in help to accomplish this study. This chapter included information about the research development, sampling procedures, data collection methods, questionnaire design and development, final content of the questionnaire, and analytical methods of data, moreover the VE workshop that was conducted to implement the proposed framework to approve its efficiency.

3.1 Methodology Sequence

Value engineering methodology is not commonly applied in Gaza Strip; thus this study aims to apply a framework that assist value engineering team to facilitate the value engineering methodology application.

As represented in the previous chapter, application of the Value engineering is essential for capital projects which require commitments of considerably large resources. Value engineering will help in developing better understanding and appreciation of the project scope of work and in reducing unnecessary cost without impacting the required functions of project components being considered. The absence of methods that improve application of value engineering has long been felt. Intellectual work should be done to enhance the capabilities of value engineering to choose the optimum alternative and to be able generate more innovative alternatives with respect to desired functions.

The framework proposed in this study can be of help to value engineering team members, design professionals, owners, and stakeholders. Selection of the optimum alternative based on multi-attributed criteria has always been an issue for design professionals and owners. There is no constant answer to this problem since the selection criteria and their relative weights vary from one project to another, in order to satisfy owners' construction needs and project targeted objectives.

The thesis introduces a framework to evaluate and compare different alternatives of a project based on the defined multi attributed criteria as well as integrate these alternatives with visualization capabilities. The framework suggests advanced means for VE team members to generate alternatives wisely and to assist designers and stakeholders in making related decisions. A set of tools and techniques has been used in this decision-making framework to assess several alternatives and support designers/owners to critique their choices, thus choose optimum one.

This chapter outlines the methodology implemented in making the framework. It uses a coded application of the AHP to help VE team in the evaluation of competing alternatives. The project BIM model using an Autodesk product; Revit 2016 has been used to support visualization and to extract data for cost estimating of the project. 4D modeling of the building and its components is done in BIM model.

3.2 Methodology Structure

Through this study the researcher employed many research tools. The research was designed by seven main steps as described below and shown in Figure 3.1.

First step: problem identification

It was initiated to define the problem, set the objectives and develop the research plan.

Second step: literature review

The study was mainly based on reviewing literature from scientific journals beside some books, theses and conferences papers. And about 43 factors influencing VE studies.

Third step: questionnaire development

In this step 5 experts of construction management; academic associated doctors, governmental and international professionals were consulted to evaluate the questionnaire and research methodology. The survey was subsequently modified before a final questionnaire was developed.

Fourth step: the main survey

In this step of the survey, a quantitative approach was utilized as the main statistical component in the study, to obtain qualitative data using postal questionnaire. A sampling strategy that suits the field of study and its reality in the Gaza strip will be used to ensure meaningful statistical analysis, which included distributing the questionnaire to the target groups. In order to obtain reliable and representative

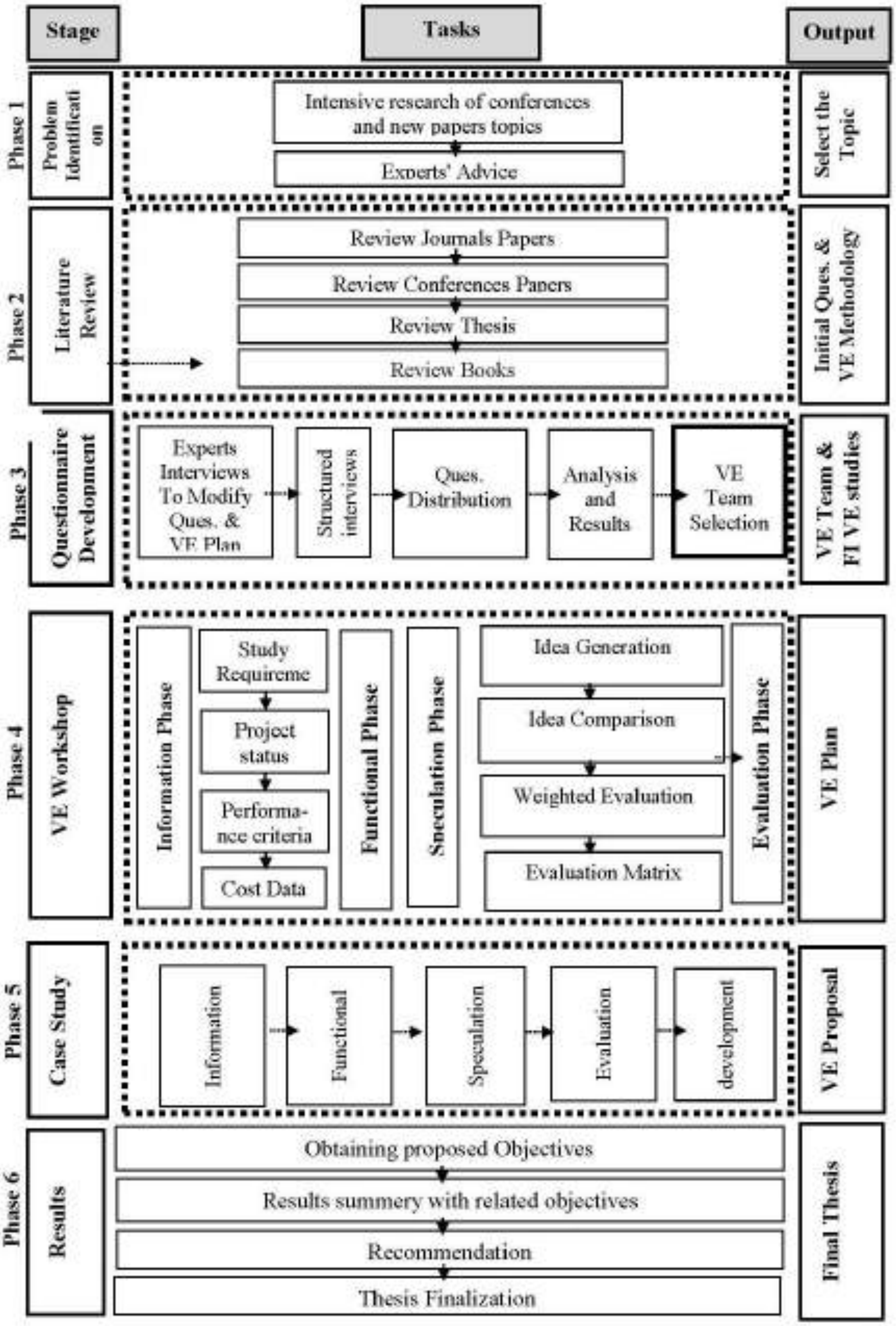


Figure (3.1): Methodology Flowchart

quantitative data, the questionnaires will be distributed to the mostly expertise professionals whom have a proper knowledge of VE.

Fifth step: results and discussion

Data collected will be analyzed using both descriptive and inferential tools of statistical software. The output of this analysis and discussion produced data that will be used in the next phase of this research, which is VE workshop.

Sixth step: VE Workshop

This phase of the research included conducting VE workshop in presence of VE expertise. This workshop went through six phases: information phase, function analysis phase, speculation phase, evaluation phase, and development phase.

Seventh Step: case study

The seventh step of this research contained adaption of a case study to approve the efficiency of the proposed framework.

Eighth step: conclusion and recommendations

This phase of the research included the conclusions and recommendations.

3.3 Research Period

The study started on February 2016 after the proposal was approved. The literature review was completed at the end of May 2016. The validity testing, piloting and questionnaire distribution and collection completed at the of July 2016. The analysis, discussion, conclusion, and recommendation were completed at November, 2016.

3.4 Research Location

The research was carried out in Palestine territory, in the Gaza Strip specifically in Gaza City.

3.5 Research Methodology Justification

The research area is not common in Gaza Strip and it is highly needed due to the scarcity of funds for construction projects associated with high prices of building materials. In addition, application of VE serves the construction industry in general. The groups that are anticipated to benefit from the research are the researchers, the experienced engineers, the owners of construction projects as well as the downers.

Moreover, the related data to this research were collected by using literature review in addition a postal questionnaire survey which was considered the most widely used data collection technique for conducting surveys was used to linkage the extracted data from literature review with Gaza Strip situation. Using postal questionnaire is mostly suited to surveys whose purpose and objectives are clear enough to be explained in a few paragraphs which are carefully chosen and guaranteed in this research. Moreover, it offers relatively high validity of results and a quick method of conducting the survey. Therefore, the researcher adopted this strategy.

Hence this study is about VE, the workshop method is the heart of VE, thus the workshop was conducted to deliver the research objective efficiently

Table (3.1): Research Methodology Justification

Research Method	Research Studies
Literature Review	Thomson, D., et al., (2006), (Amir Shekari, 2009) (Amruta Chougule A. K., 2014) (Attarde N. L., 2016) (Chavan, 2013) (Chi-Sung In, 2009) (Farahmandazad, 2015) (Galipogullari, 2013) (Harris, 2012) (Salman Azhar, 2008) (Tohidi, 2011), (Al-Yousefi, 2011) (Pearson, 1969) (Chuck Eastman, 2011) (Khalid Al-Gahtani, 2015) (Min-Jae Lee, 2010) (Tohidi, 2011) (Seidel, 2012)
Questionnaire	(Ali Bagheri Fard, 2013), (Farahmandazad, 2015) (Ali Bagheri Fard, 2013) (Baker, et al., 2002) (Chuck Eastman, 2011)
Workshop	Karim, S. et al., (2014), (DelI'lsola, 1969) (Amruta Chougule A. K., 2014) (Boo Young Chung, 2009)
Case Study	Li, X. (2008), (Attarde P. N., 2016) (Amruta Chougule A. K., 2014) (Boo Young Chung, 2009) (Farahmandazad, 2015)

3.6 Experts Consultation

For the evaluation and criticism of research methodology and questionnaire the researcher consulted senior professionals through, unstructured interviews. Before an interview, a summary of the proposed framework was submitted to each professional to be prepared to the interview. The outcome of this phase was improvement of the methodology and any needed amendment. Table 3.2 show the characteristics of the consulted professionals.

Table (3.2): Experts Consultation

No.	Qualification	Current Job title	Years of Experience
Expert A	M.Sc. Of Civil Engineering	Chairman of Palestinian consultation of housing.	More than 15 years.
Expert B	PHD. Of Civil Engineering	President of University Collage for applied science UCAS.	More than 15 years.
Expert C	PHD. Of Civil Engineering	Dean of Engineering Collage at Al-Aqsa University.	More than 15 years.
Expert D	PHD. Of Civil Engineering	Ex. President of Islamic University of Gaza IUG.	More than 15 years.
Expert E	PHD. Of Civil Engineering	Dean of Engineering Collage at Palestine University UP.	More than 15 years.
Expert F	M.Sc. Of Civil Engineering	General Manager of Universal Group UG.	More than 15 years.
Expert G	PHD. Of Civil Engineering	Minister Consultant for planning and international cooperation MPWH.	More than 15 years.

3.7 Questionnaire Design

A self-administered questionnaire was used for data collection. Three fundamental stages were taken for constructing the questionnaire:

1. Identifying the first thought questions.
2. Formulating the final questionnaire.
3. Wording of questions.

Identification of items for the study and preparation of questionnaire was a crucial step for the success of the research. Significant amount of work has already been done on items of VE application and there is a well-documented and peer reviewed set of those available items in the literature review in the previous chapter.

According to the review of literature related to VE application, a well-designed questionnaire was developed for the study. The questionnaire consisted of close-ended (multiple choice) questions. The questionnaire divided into four parts as follows:

- Part I: Questions Related to participant information and work experience
- Part II: Questions related to the VE methodology application
- Part III: Questions related to the VE & BIM tools used during VE application
- Part IV: Questions related to the Factors Influencing Value Engineering application.

The questionnaire was provided with a covering letter explaining the aim of the research, the security of the information in order to encourage a high response, and the way of responding. The variety in the questions aimed first to meet the research objectives, to cover the main questions of the study, and to collect all the necessary data that can support the results and discussion, as well as the recommendations in the research.

3.8 Sampling Procedures

As the VE topic is not commonly known among construction professional is Gaza Strip the most appropriate method for such a case according to Naoem, 2007 is the Snowball sample in which a small pool of initial informants to nominate, through their social networks, other participants who meet the eligibility criteria and could potentially contribute to the study.

3.9 Value Engineering Workshop

This section is pertinent to Speculation -creative- Phase of value engineering Job Plan. In this step value engineering team tries to generate various alternative and ideas with focus on the defined criteria. The VE team provides alternatives within the requisite area of the project. The alternatives should be generated in a way that improve value to the client and satisfy the clients' criteria while guarantee maximum value. In addition to special knowledge, sufficient tools and techniques are also needed so as to generate creative alternatives. No matter how experts are the value engineering team, there are some alternatives that always remain concealed.

The proposed method in this study tries to assist value engineering in generating creative alternatives. To accomplish the clients' desired functions, the creative concepts and essential knowledge should be integrated to provide customers with several function alternatives. In order to accelerate the creative activities firm action is needed. That is to say, every part of the VE job plan should be effectively used to achieve a high degree of value. Figure 3.2 describes the VE job plan in detail:

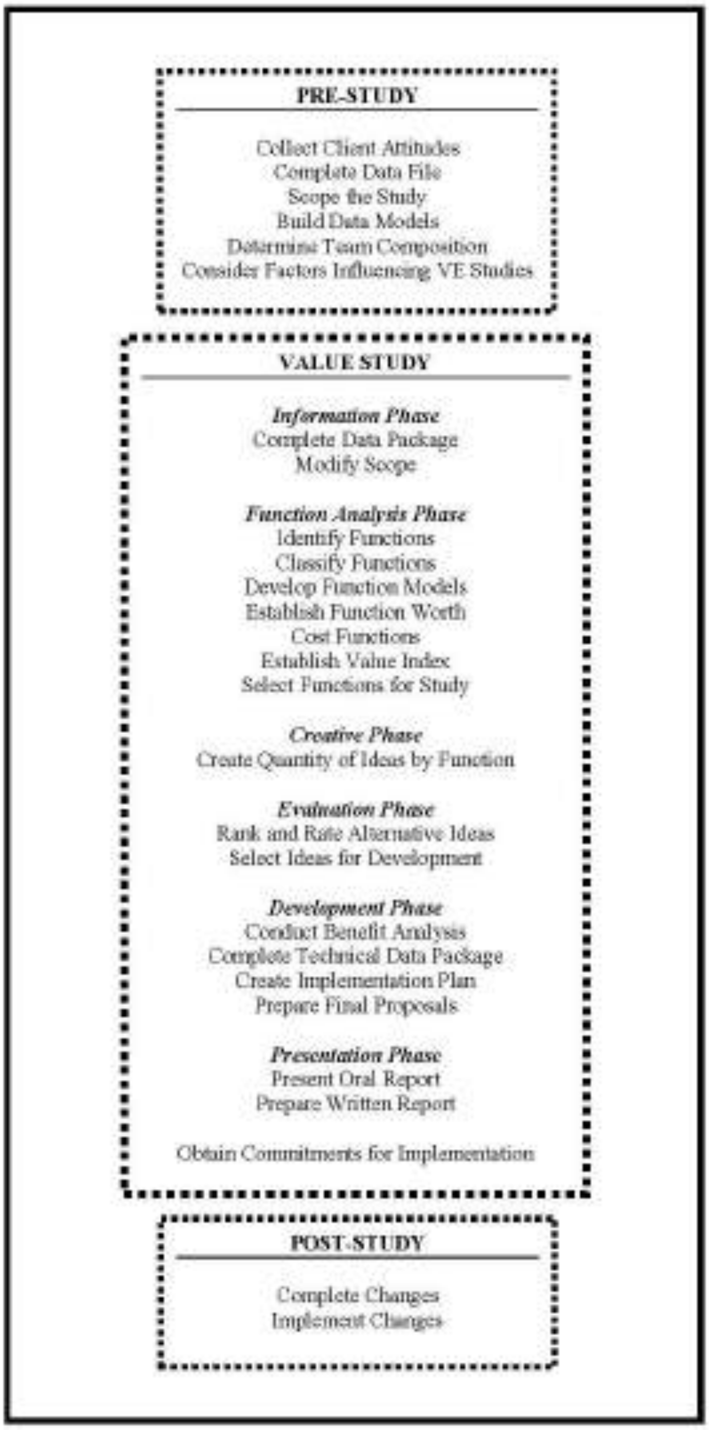


Figure (3.2): VE Job Plan

3.10 BIM models Development

For the study purpose the BIM model of the project's alternatives should be generated. 3D BIM models provide visualization capabilities for VE team. 3D views allow the VE team members to have a preview of the project prior to construction. That is to say, it provides a clear picture of the project; this will activate the imagination potential of the VE team members to be able to produce more innovative alternatives. In other words, having a clear, vivid imagination of the project, the process of generating creative alternative is eased by having the 3D views of the model available.

In the BIM models, specifications and properties of the components are embedded in the model, so a wide range of components with different materials is available for the VE team to examine alternate specifications for different components of the project with respect to preferred basic functions.

4D modeling of the project is also done in the BIM model. The 4th dimension that has been added to the model is cost. The BIM models provide quantity takeoff and schedule of components at every design stage of the project. So the cost estimate of each alternative can be calculated at every stage. By this opportunity, the cost of the alternatives generated, can be estimated at any stage through its producing process. The VE team will have a clear understanding about the consequences of the changes they make on every alternative so they can generate them wisely.

3.11 Criteria Assessment, Automated Alternatives Evaluation

Evaluation Phase of value engineering Job Plan is explained in this section. The main contribution of the study would be in the evaluation phase of the value engineering job plan.

Analytic Hierarchy Process (AHP) is a tool for Multiple Criteria Decision Making. AHP technique is applied in two steps. First the criteria are evaluated against each other to find their relative weight, and then the alternatives are assessed against each criterion in order to generate the score of each alternative. The criteria's weight is defined based on users' preferences.

Pairwise comparison is also performed for assessment of the alternatives being considered; this can be a time-consuming process in the application of the AHP; as users are required to answer each comparison twice in order to check the consistency of the answers provided.

The study proposes to use BPMSG program to ease the process of pairwise comparison for evaluating criteria to find their relative weight and automate the process of comparing alternatives in order to find the relative score of them and consequently provide a report for the VE team.

3.12 Application of VE Methodology on a case study

As a final step of the research, VE methodology was applied to a real project as a case study. The researcher chose a conference building in an educational complex that faced a crucial problem through its construction. Such step intended to clarify the proposed framework and the steps followed in application as well as to clarify the associated programs proposed by the researcher.

3.13 Summary

This chapter described the detailed adopted methodology of research. It included the primary design for the research, details of research location, target population, sample size, and response rate. Moreover, it defined the VE job plan and the scope of the case study that the pre-defined framework will be dropped on.

Chapter 4

Chapter Four: Questionnaire Analysis

A field survey was done to extract data from the VE expertise in the Gaza strip. This chapter included analysis and discussion of the results that have been collected from field surveys. A total of 20 completed copies had been returned, representing a valid response rate of 85.7% Data were analyzed quantitatively using (SPSS) including descriptive and inferential statistical tools. This chapter included the respondents' profiles and the way of implementing their work, quantitative analysis of the questionnaire, and finally the summary framework of the results.

4.1 Validity and Reliability of The Study

4.1.1 Questionnaire Validity

means to measure the response questionnaire prepared for the measure, has been to verify the validity of the questionnaire through the following:

4.1.1.1 Arbitrators Validity

The researchers presented the study tool in its initial group of arbitrators composed of members of the faculty specialists members at Islamic University of Gaza, it has asked a researchers from the arbitrators make their views known in the appropriate phrases to measure developed for him, and the clarity drafting statement and how suitable each statement for the area to which it belongs, and the insufficient of statements to cover all of the subjects of study, in addition to propose what they deem necessary to modify the formulation of statements or deleted, and based on the feedback and directions by arbitrators, the researchers adjustments agreed by the arbitrators.

4.1.1.2 Internal consistency validity

It was calculated Internal consistency for questionnaire paragraph on study sample amounting to (22), that by calculated correlations coefficient between each with total degree for each dimension, and table (4.1) shows that the correlation coefficients indicated significant at the level 0.05, where the probability value of each paragraph of less than 0.05 and so paragraphs of the questionnaire are validity to set the measure.

Table (4.1): Internal validity for questionnaire paragraph

No	Paragraph	Relation Coefficient	Significance level
First dimension: **Pre-workshop factors**.			
1	Clear objectives of workshop	0.40	0.000*
2	Client's participation	0.40	0.000*
3	Client's support	0.55	0.000*
4	Disciplines of participants	0.68	0.000*
5	Qualification of facilitator	0.41	0.000*
6	Relevant stakeholders' support	0.60	0.000*
7	Satisfaction of the time when the VE Workshop will be conducted	0.47	0.000*
8	Disciplines of participants	0.81	0.000*
9	Years of professional experience of participants	0.51	0.000*
10	Years of experience of facilitator (Value engineering specialist)	0.50	0.000*
11	Qualification of facilitator (Value engineering specialist)	0.67	0.000*
12	Number of pre-workshop meetings held.	0.52	0.000*
13	Time spent on preparation before workshop.	0.51	0.000*
14	Number of related documents analyzed	0.83	0.000*
Second dimension: Workshop factors.			
1	Background information collected	0.80	0.000*
2	Client's objectives clarified	0.81	0.000*
3	Interaction among participants in each phase	0.44	0.000*
4	Primary functions/processes identified	0.56	0.000*
5	Project givens/assumptions clarified	0.41	0.000*
6	Duration of each phase	0.50	0.000*
7	Satisfaction on the techniques used in each phase	0.78	0.000*

No	Paragraph	Relation Coefficient	Significance level
8	Primary function identified	0.71	0.000*
9	Number of ideas generated	0.75	0.000*
10	Equal contribution of participants	0.41	0.000*
11	Efficiency of idea generation	0.63	0.000*
Third dimension: Post-workshop factors.			
1	Percentage of action plan without uncertainty carried out	0.70	0.000*
2	Quality of the report	0.78	0.000*
3	Accelerating the decision-making	0.79	0.000*
4	Client's satisfaction	0.74	0.000*
5	Identifying and clarifying the client's requirements	0.82	0.000*
6	Improving communication and understanding among stakeholders	0.79	0.000*
7	Improving the project quality	0.83	0.000*

* Correlation is statistical significant at $\alpha \leq 0.05$

4.1.1.3 Structure Validity

Table (4.2) indicated that correlation coefficients between degree of each dimension of the questionnaire and the total degree for the questionnaire, the correlation coefficients have statistically significant at $\alpha \leq 0.05$,while the probability value for all paragraph less than 0.05.

Table (4.2): The correlations coefficient between five dimensions and the total degree of the questionnaire

Dimension	Relation Coefficient	Significance level
First dimension: **Pre-workshop factors**.	0.94	0.000*
Second dimension: Workshop factors.	0.95	0.000*
Third dimension: Post-workshop factors.	0.90	0.000*

* Correlation is statistical significant at $\alpha \leq 0.05$

4.1.2 The Reliability Of Study

reliability questionnaire means to give this questionnaire the same result if the redistribution of questionnaire more than time under the same the circumstances and conditions, or in the other words the reliability of questionnaire means stability in the results of the questionnaire and not change significantly as if it were re-distributed to the members of the sample several times during the time intervals certain.

4.1.2.1 Reliability by Cranach's Alpha Method

after the questionnaire applying, it was scaled the Cranach's alpha coefficient for the reliability measurement, While it was founded that the value of Cranach's alpha for the total questionnaire is 0.94, this express that the questionnaire having a high coefficient of reliability, this will clear through the table (4.3):

Table (4.3): express Cranach's alpha coefficient for the questionnaire Reliability scale

Dimension	Number of paragraphs	Cranach's alpha coefficient
First dimension: **Pre-workshop factors**.	14	0.83
Second dimension: Workshop factors.	11	0.84
Third dimension: Post-workshop factors.	7	0.85
Total questionnaire paragraphs	**32**	**0.94**

Analysis and Discussion

<u>Part I: participant information and work experience:</u>

1. Distribution the characteristics of the sample according Gender:

It's clear from the results in Table (4.4) that 80% are male, 20% are female.

Table (4.4): Distribution of the sample according Gender

Gender	Frequency	Percentage%
Male	16	80.0

Female	4	20.0
Total	**20**	**100.0**

2. **Distribution the characteristics of the sample according Educational qualification:**

It's clear from the results in Table (4.5) that 80% of the sample have Bachelor degree, 50% have master degree, while 20% have PHD degree.

Table (4.5): Distribution of the sample according Educational qualification

Educational qualification	Frequency	Percentage%
Bachelor	6	30.0
Master	10	50.0
PHD	4	20.0
Total	**20**	**100.0**

3. **Distribution the characteristics of the sample according Specialization:**

It's clear from the results in Table (4.6) that 15% of the sample their specialist Architecture, 75% Architecture, 5% Mechanical Engineering, and the same percentage 5% other specialist.

Table (4.6): Distribution of the sample according Specialization

Specialization	Frequency	Percentage%
Architecture	3	15.0
Civil Engineering	15	75.0
Mechanical Engineering	1	5.0
Other	1	5.0
Total	**20**	**100.0**

4. **Distribution the characteristics of the sample according Job Title**

It's clear from the results in Table (4.7) that 25% of sample are company Manager ,40% project Manager, 10% Site Engineer, 5% designer, while 20% others.

Table (4.7): Distribution of the sample according Job Title

Job Title	Frequency	Percentage%
Company Manager	5	25.0
Project Manager	8	40.0
Site Engineer	2	10.0
Designer	1	5.0
Other	4	20.0
Total	**20**	**100.0**

5. **Distribution the characteristics of the sample according Years of experience in the construction industry:**

   It's clear from the results in Table (4.8) that 25% of sample have less than 10 experience years, 10% from 10 -15 years, 15% from 15 to 20 years, while 50% more than 20 years.

Table (4.8): Distribution of the sample according Years of experience in the construction industry

Years of experience	Frequency	Percentage%
Less than 10 years	5	25.0
From 10 -15 years	2	10.0
15 -20 years	3	15.0
More than 20 years	10	50.0
Total	**20**	**100.0**

6. **Distribution the characteristics of the sample according the type of your organization:**

   It's clear from the results in Table (4.9) that 10% of sample work at governmental organization, 15% work at consultation office, 30% work at non-governmental organization, 35% work at contracting firm, while 10% work at other.

Table (4.9): Distribution of the sample according the type of your organization

The type of your organization	Frequency	Percentage%
Governmental organization	2	10.0
Consultation office	3	15.0
Non-governmental organization	6	30.0
contracting firm	7	35.0
Other	2	10.0
Total	**20**	**100.0**

7. distribution the characteristics of the sample according the organization's current size:

It's clear from the results in Table (4.10) that 45% of sample work at organization have less than 20 employees, 15% from 20-50 employees, while 40% more than 50 employees.

Table (4.10): Distribution of the sample according the type of your organization

The organization's current size	Frequency	Percentage%
Less than 20 employees	9	45.0
From 20-50 employees	3	15.0
More than 50 employees	8	40.0
Total	**20**	**100.0**

8. Size of your Organization projects during the last five years (in million dollar):

It's clear from the results in Table (4.11) that 5% of sample size of their Organization projects less than a 1 m$, 5% from 1-3 m$, 20% from 4-5 m$, while 70% more than 5 m$.

Table (4.11): Size of your Organization projects during the last five years (in million dollar)

Answer	Frequency	Percentage%
Less than a 1 m$	1	5.0

From 1-3 m$	1	5.0
From 4-5 m$	4	20.0
More than 5 m$	14	70.0
Total	**20**	**100.0**

<u>Part II:VE methodology application:</u>

A. Pre-Workshop Phase

1. The objective of the pre-workshop phase should be to:

It's clear from the results in Table (4.12) that 47.5% of sample response the objective of the pre-workshop to clarify the project background and required information., 12.5% response to explore owner preferences, 20.0% response to provide VE team with design information, and the same response to preparation of the models to be used in the workshop

Table (4.12): The objective of the pre-workshop phase should be to

Answer	Frequency	Percentage%
Clarify the project background and required information.	19	47.5
Explore owner preferences	5	12.5
Provide VE team with design information	8	20.0
Preparation of the models to be used in the workshop	8	20.0
Total	**40**	**100.0**

2. The most efficient parties to involve in the pre-workshop phase:

It's clear from the results in Table (4.13) that 27.0% of sample see that owner is the most efficient parties to involve in the pre-workshop phase, 16.2% response the beneficiaries, 21.6% Team leader, 10.8% response the team coordinator, 18.9% team members, while 5.4% think that the most efficient parties to involve in the pre-workshop phase is other parties.

Table (4.13): The most efficient parties to involve in the pre-workshop phase

Answer	Frequency	Percentage%
Owner (or owner representative)	10	27.0
Beneficiaries	6	16.2
Team leader	8	21.6
Team coordinator	4	10.8
Team members	7	18.9
Other parties	2	5.4
Total	**37**	**100.0**

3. **Which of the following models you think must be prepared at this stage by the facilitator (Value engineering specialist):**

It's clear from the results in Table (4.14) that 22.9% of sample think that the cost model has to be prepared at this stage by the facilitator, 20.0% think that the cost worth model, 25.75% think that function analysis model (FAST), 17.1% think that life cycle model, 8.6% think that Quality model, 5.7% think that others have to be prepared at this stage by the facilitator.

Table (4.14): Which of the following models you think has to be prepared at this stage by the facilitator (Value engineering specialist)

Answer	Frequency	Percentage%
Cost model	8	22.9
Cost worth model	7	20.0
Function analysis model (FAST)	9	25.7
Life cycle model	6	17.1
Quality model	3	8.6
Others (specify)	2	5.7
Total	**35**	**100.0**

B. Workshop Phase:

1. The project documents that should be prepared before workshop:

It's clear from the results in Table (4.15) that 32.6% of sample see that design drawings should be prepared before workshop, 23.3% cost estimation model, 18.6% Bill of quantities, 16.3% technical specifications, while 9.3% think that other documents should be prepared before workshop.

Table (4.15): The project documents that should be prepared before workshop

Answer	Frequency	Percentage%
Design Drawings	14	32.6
Cost Estimation model	10	23.3
Bill of quantities	8	18.6
Technical Specifications	7	16.3
Other	4	9.3
Total	**43**	**100.0**

2. During workshop, it is preferred determine the items under investigation via:

It's clear from the results in Table (4.16) that 28.0% of sample see that the items under investigation via owners preferences, and the same percentage see that via team members' judgments, 36.0% via pareto rule, while 8.0% via other criteria.

Table (4.16): During workshop, it is preferred determine the items under investigation via

Answer	Frequency	Percentage%
Owners preferences	7	28.0
Team members' judgments	7	28.0
Pareto rule	9	36.0
Other criteria (define)	2	8.0
Total	**25**	**100.0**

3. **The scope of computerization of workshop phase can be accepted for:**

It's clear from the results in Table (4.17) that 4.2% of sample see that the scope of computerization of workshop phase can be accepted for ideas visualization only, 8.3% alternatives generation., 16.7% cost estimation, 16.7% alternatives evaluation, while 54.2% see that all above .

Table (4.17): The scope of computerization of workshop phase can be accepted for

Answer	Frequency	Percentage%
Ideas visualization only.	1	4.2
Alternatives generation.	2	8.3
Cost Estimation	4	16.7
Alternatives Evaluation	4	16.7
All Above	13	54.2
Total	**24**	**100.0**

4. **Evaluation of ideas upon multi criteria can be effectively accomplished using:**

It's clear from the results in Table (4.18) that 20% of sample think that evaluation of ideas upon multi criteria can be effectively accomplished using weighting method, 40.0% matrix method, and 40.0% of sample think that evaluation of ideas upon multi criteria can be effectively accomplished using AHP method.

Table (4.18): Evaluation of ideas upon multi criteria can be effectively accomplished using

Answer	Frequency	Percentage%
Weighting method	4	20.0
Matrix method	8	40.0
AHP method	8	40.0
Total	**20**	**100.0**

C. Post Workshop Phase

1. Feedback of the efficiency of VE study is to be made to:

It's clear from the results in Table (4.19) that 15% of sample think that feedback of the efficiency of VE study is to be made to The value engineering specialist., 10.0% is to be made to the VE team, 50.0% is to be made to the owner, while 25.0% is to be made to the project manager.

Table (4.19): Feedback of the efficiency of VE study is to be made to

Answer	Frequency	Percentage%
The value engineering specialist.	3	15.0
The VE team	2	10.0
The owner	10	50.0
The project manager	5	25.0
Total	**20**	**100.0**

2. Other evaluations would be helpful for future development, like (more than one selection is possible):

It's clear from the results in Table (4.20) that 20% of sample see that other evaluations would be helpful for future development like the beneficiaries from the project, 70.0% response like the maintenance engineer/ company, 10.0% response like the architect.

Table (4.20): Other evaluations would be helpful for future development, like (more than one selection is possible)

Answer	Frequency	Percentage%
The beneficiaries from the project	4	20.0
The maintenance engineer/ company	14	70.0
The Architect	2	10.0
Total	**20**	**100.0**

<u>Part III: VE & BIM tools used during VE application</u>

1. Do you apply VE:

It's clear from the results in Table (4.21) that 40.0% of sample apply VE, while 60.0% don't apply VE.

Table (4.21): Do you apply VE

Answer	Frequency	Percentage%
Yes	8	40.0
No	12	60.0
Total	**20**	**100.0**

2. **Do you apply any of recommended BIM & VE Techniques in each phase of VE workshop:**

Table (4.22): Do you apply any of recommended BIM & VE Techniques in each phase of VE workshop

Workshop steps	Value Engineering & Building information modeling BIM Techniques					
	Pareto Diagram	Quality Model	Affinity Diagram	FAST Model	Rivet Program	RSmeans Program
	%	%	%	%	%	%
Data collection	15.8	26.3	26.3	15.8	10.5	5.3
Functions analysis	15.8	10.5	21.1	42.1	5.3	5.3
Creativity and ideas generation	5.3	26.3	31.6	10.5	26.3	0.0
Evaluation and selection	26.3	31.6	15.8	5.3	15.8	5.3
Searching and development	11.1	22.2	27.8	0.0	16.7	22.2
Proposals presentation	0.0	16.7	38.9	22.2	5.6	16.7

It's clear from the results in previous table in the following:

- 15.8% of sample apply paret diagram in data collection, 26.3% apply quality model , 26.3% apply affinity diagram, 15.8% apply FAST model , 10.5% apply rivet

Program , 5.3% apply RSmeans Program.

- 15.8% of sample apply paret diagram in functions analysis, 10.5% apply quality model , 21.1% apply affinity diagram, 42.1% apply FAST model , 5.3% apply rivet Program , 5.3% apply RSmeans Program.
- 5.3% of sample apply paret diagram in creativity and ideas generation, 26.3% apply quality model , 31.6% apply affinity diagram, 10.5% apply FAST model , 26.3% apply rivet Program , 0.0% apply RSmeans Program.
- 26.3% of sample apply paret diagram in Evaluation and selection, 31.6% apply quality model , 15.8% apply affinity diagram, 5.3% apply FAST model , 15.8% apply rivet Program , 5.3% apply RSmeans Program.
- 11.1% of sample apply paret diagram in searching and development, 22.2% apply quality model , 27.8% apply affinity diagram, 0.0% apply FAST model , 16.7% apply rivet Program , 22.2% apply RSmeans Program.
- There is no any individual of sample apply paret diagram in proposals presentation, 16.7% apply quality model , 38.9% apply affinity diagram, 22.2% apply FAST model , 5.6% apply rivet Program , 16.7% apply RSmeans Program.

Part IV: Factors Influencing Value Engineering application:

The researchers analysis the dimensions of the study, to see the reality of these dimensions when the study population, With the following results using T test for each sample (One Sample T test), to see if the arithmetic average of the degree of response of each paragraph of the questionnaire dimensions equal degree of neutrality is 3 or not, if the value of (p-value) (sig) more than the significance level, in this case be opinions the study population approaching degree of neutrality is 3, and if the value of (p-value) (sig) less than the significance level, in this case can determine if the average response increase or decrease the degree of neutrality, through a reference value if the reference test positive this means that the arithmetic mean of the response over the degree of neutrality, a 3 and vice versa, and can be explained the results of the analysis study dimensions through the following:

1. Analysis the paragraphs first dimension: Pre-workshop factors

By T test paragraphs first dimension was tested to see if the average degree of response of each paragraph of the dimension and the dimension in general has reached degree of neutrality is 3 or increased or decrease about it, it was found that the arithmetic mean of all paragraphs equal to 3.63, and standard deviation equal to 0.47, and the relative weight equal to 72.6%, and the value of test T equal to "6.001", and p- value equal 0.000, which is less than 0.05, which indicates that the average degree of response to the dimension of the "Pre-workshop factors" has increased the degree of neutrality is 3, and this shows approval of characteristic sample on this dimension, and the results are shown in Table (4.23).

Table (4.23): results of T test & arithmetic mean & relative weight for factors influencing VE application

No.	Paragraph	Mean	Standard deviation	Relative %Weight	T Test	Sig level
1	Clear objectives of workshop	4.35	0.67	87.0	9.000	0.000*
2	Client’s participation	4.00	0.79	80.0	5.627	0.000*
3	Client’s support	3.50	0.69	70.0	3.249	0.004*
4	Disciplines of participants	3.85	0.88	77.0	4.344	0.000*
5	Qualification of facilitator	3.60	0.75	72.0	3.559	0.002*
6	Relevant stakeholders’ support	3.45	1.00	69.0	2.015	0.058//
7	Satisfaction of the time when the VE Workshop will be conducted	3.60	0.75	72.0	3.559	0.002*
8	Disciplines of participants	3.65	0.75	73.0	3.901	0.001*
9	Years of professional experience of participants	3.60	0.82	72.0	3.269	0.004*
10	Years of experience of facilitator (Value engineering specialist)	3.80	0.95	76.0	3.760	0.001*

No.	Paragraph	Mean	Standard deviation	Relative %Weight	T Test	Sig level
11	Qualification of facilitator (Value engineering specialist)	3.60	0.68	72.0	3.943	0.001*
12	Number of pre-workshop meetings held.	3.35	0.88	67.0	1.789	0.090//
13	Time spent on preparation before workshop.	3.20	0.95	64.0	0.940	0.359//
14	Number of related documents analyzed	3.30	1.17	66.0	1.143	0.267//
Total degree		**3.63**	**0.47**	**72.6**	**6.001**	**0.000***

* arithmetic mean is statistical significant at $\alpha \leq 0.05$

// arithmetic mean is not statistical significant at $\alpha \leq 0.05$

2. Analysis the paragraphs second dimension: Workshop factors

By T test paragraphs second dimension was tested to see if the average degree of response of each paragraph of the dimension and the dimension in general has reached degree of neutrality is 3 or increased or decrease about it, it was found that the arithmetic mean of all paragraphs equal to 3.60, and standard deviation equal to 0.53, and the relative weight equal to 72.1%, and the value of test T equal to "5.138", and p- value equal 0.000, which is less than 0.05, which indicates that the average degree of response to the dimension of the "Workshop factors" has increased the degree of neutrality is 3, and this shows approval of characteristic sample on this dimension, and the results are shown in Table (4.24).

Table (4.24): results of t test & arithmetic mean & relative weight for workshop stage factors

No.	Paragraph	Mean	Standard deviation	Relative %Weight	T Test	Sig level
1	Background information collected	3.95	1.10	79.0	3.866	0.001 *
2	Client's objectives clarified	4.00	0.97	80.0	4.595	0.000 *
3	Interaction among participants in each phase	3.85	0.67	77.0	5.667	0.000 *
4	Primary functions/processes identified	3.65	0.67	73.0	4.333	0.000 *
5	Project givens/assumptions clarified	3.80	0.77	76.0	4.660	0.000 *
6	Duration of each phase	3.45	0.76	69.0	2.651	0.016 *
7	Satisfaction on the techniques used in each phase	3.40	0.60	68.0	2.990	0.008 *
8	Primary function identified	3.50	0.76	70.0	2.939	0.008 *
9	Number of ideas generated	3.25	1.07	65.0	1.045	0.309//
10	Equal contribution of participants	3.30	1.03	66.0	1.301	0.209//
11	Efficiency of idea generation	3.50	0.76	70.0	2.939	0.008 *
Total degree		**3.60**	**0.53**	**72.1**	**5.138**	**0.000***

* arithmetic mean is statistical significant at $\alpha \leq 0.05$

3. Analysis the paragraphs third dimension: Post-workshop factors

By T test paragraphs third dimension was tested to see if the average degree of response of each paragraph of the dimension and the dimension in general has reached degree of neutrality is 3 or increased or decrease about it, it was found that the arithmetic mean of all paragraphs equal to 3.76, and standard deviation equal to 0.65, and the relative weight equal to 75.1%, and the value of test T equal to "5.217", and p- value equal 0.000, which is less than 0.05, which indicates that the average degree of response to the dimension of the "Post-workshop factors" has increased the degree of neutrality is 3, and this shows approval of characteristic sample on this dimension, and the results are shown in Table (4.25).

Table (4.25): results of t test & arithmetic mean & relative weight for post-workshop factors

No.	Paragraph	Mean	Standard deviation	Relative Weight	T Test	Sig level
1	Percentage of action plan without uncertainty carried out	3.75	0.72	75.0	4.682	0.000*
2	Quality of the report	3.80	0.70	76.0	5.141	0.000*
3	Accelerating the decision-making	3.65	0.93	73.0	3.115	0.006*
4	Client's satisfaction	3.90	0.91	78.0	4.414	0.000*
5	Identifying and clarifying the client's requirements	3.75	1.02	75.0	3.290	0.004*
6	Improving communication and understanding among stakeholders	3.60	1.05	72.0	2.565	0.019*
7	Improving the project quality	3.85	0.88	77.0	4.344	0.000*
Total degree		**3.76**	**0.65**	**75.1**	**5.217**	**0.000***

* arithmetic mean is statistical significant at $\alpha \leq 0.05$

Chapter 5

Chapter Five: Case Study

Chapter five presents the application of the developed framework in a case example to demonstrate its use and capabilities and to illustrate the features of the proposed programs. The case study is implemented as per the same process explained in the methodology.

5.1 Background

The process starts when the VE team starts conduct the workshop, after the information phase in which the collected data was presented and discussed, then the function analysis of the selected items is made. Later on the VE decide to generate alternatives in support of the project's objectives. In this phase the need of collecting data required to generate the BIM and 4D model. The proposed framework suggests the use of Analytic Hierarchy Process AHP to evaluate data using Definite 3.1 program, while Autodesk Revit 2015 is used to assess the VE team in ideas visualization – in the case under investigation- while it could be used in ideas generation in other terms. The 4D model with the cost as the fourth dimension is made in the proposed framework.

The case study is about the building structural ceiling and VE team wants to find the best alternative for the ceiling structure trying different structural design and materials. Any data missing in the process of modeling the building is assumed. The following sections illustrate the implementation of the case study thoroughly.

5.2 Methodology application

5.2.1 Pre-Workshop Phase

As previously indicated in chapter 4 the main objective of this phase is to Clarify the project background and required information.

The researcher conducted the following data from many resources:

- Project documents; (drawings, specifications, soil investigation.)
- Unstructured interview with owner representative.
- Local authorities and institution,
- Project consultant representative.

Table (5.1): project Information

Project Description		
		Remarks
District:	Khanyounes	
City/Town:	Gaza	
Type of Project:	Conferences	
Street/Route:	-	
Location:	Palestine	
Total Cost:	$2,579,135.00	
Type of Funds:	Private fund	

5.2.1.1 Models Preparation

This section describes in detail the models were prepared by the researcher in advance to be used during the workshop stage.

Quality model

The quality model was developed in accordance with the owner representative through several meeting as indicated in figure 5.1 and table 5.2.

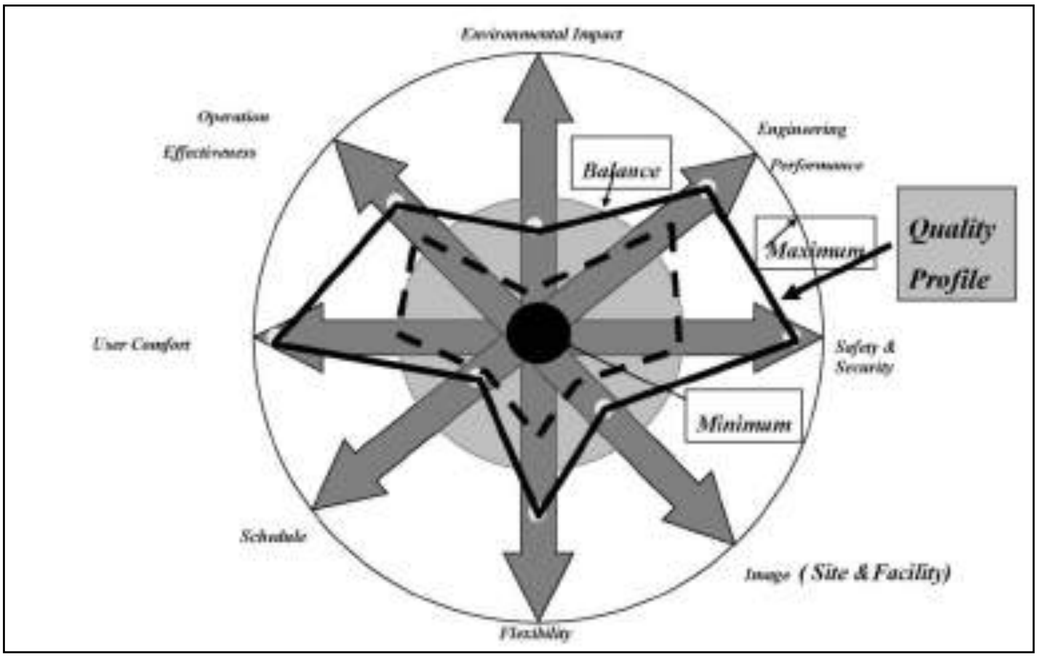


Figure (5.1): Quality Model

Table (5.2): Client Requirements (quality Model)

<table>
<tr><th>#</th><th colspan="3">Item</th><th colspan="2">Level of importance to the owner</th><th colspan="2">Level of evaluation to the preliminary design (from Owners' point of view</th></tr>
<tr><td>1.</td><td colspan="3">Engineering performance</td><td colspan="2">8</td><td colspan="2">7</td></tr>
<tr><td>2.</td><td colspan="3">Safety and security</td><td colspan="2">9</td><td colspan="2">6</td></tr>
<tr><td>3.</td><td colspan="3">Image (site& planning)</td><td colspan="2">4</td><td colspan="2">4</td></tr>
<tr><td>4.</td><td colspan="3">Flexibility</td><td colspan="2">7</td><td colspan="2">5</td></tr>
<tr><td>5.</td><td colspan="3">Schedule</td><td colspan="2">3</td><td colspan="2">4</td></tr>
<tr><td>6.</td><td colspan="3">User comfort</td><td colspan="2">9</td><td colspan="2">6</td></tr>
<tr><td>7.</td><td colspan="3">Operation effectiveness</td><td colspan="2">8</td><td colspan="2">5</td></tr>
<tr><td>8.</td><td colspan="3">Environmental impact</td><td colspan="2">5</td><td colspan="2">4</td></tr>
<tr><td colspan="8">Scoring Criteria</td></tr>
<tr><td colspan="2">Indication</td><td colspan="2">poor</td><td colspan="2">Fair</td><td colspan="2">Good</td></tr>
<tr><td colspan="2">Score</td><td>0</td><td>2</td><td>4</td><td>6</td><td>8</td><td>10</td></tr>
</table>

Cost Model

Cost estimation for the project under investigation where prepared by the consultant, cost data needs to be organized in a format that is helpful to rapid analysis using Pareto Analysis to identify the major elements of the project.

Listed below are most important items that were consider as the cost data is analyzed.

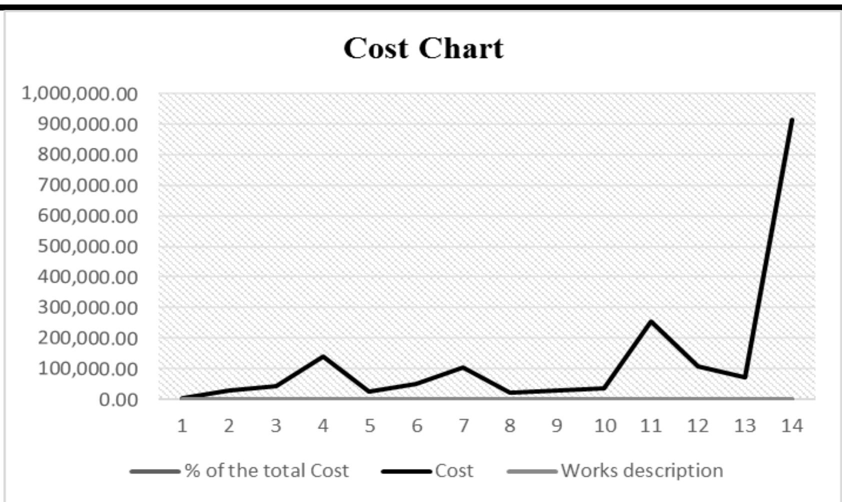
- ***Total Cost:***
- ***Cost Elements***
- ***Cost Within the Scope of the Project***

Table (5.3): Cost Model

Project: Conferences Building		**Cost Model**		
Source of estimation: Universal Group				
#	**Item**	**Cost**	**% of Project**	**Notes**
1.	Mobilization	$7,618.00	0%	-
2.	Concrete works	$1,102,730.00	43%	Selected
3.	Building Works	$114,000.00	4%	-
4.	Plastering works	$76,480.00	3%	-
5.	Tiles and Marble works	$221,288.00	9%	Selected
6.	Painting works	$38,345.00	1%	-
7.	Wood works	$30,623.00	1%	-
8.	Aluminum works	$146,818.00	6%	-
9.	Steel works	$27,255.00	1%	-
10.	Complementary works	$81,211.00	3%	-
11.	Isolation Works	$28,800.00	1%	-
12.	Outdoor works	$72,380.00	3%	-
13.	Mechanical Works	$379,152.00	15%	Selected
14.	Electrical works	$252,435.00	10%	Selected
	Total Cost in US$	$2,579,135.00	100%	

Pareto Analysis			
% of Costs	# of Items		
2	43%	Concrete works	-
13	15%	Mechanical Works	-
14	10%	Electrical works	-
5	09%	Tiles and Marble works	-

Project: Conferences Building	Cost Model
Source of estimation: Universal Group	



As shown in table 5.2 it appears that 4 items out of 14 affect 77% of the total cost, in another word, 28% of the items affects 77% of the Cost, this result approves the use of Pareto rule.

5.2.2 Workshop Stage

This stage is the core of the VE study. During this phase, the proposed framework, beside VE team play the main role of the study. The VE team consisted of professionals whom have a rich experience (more than 20 years), and can act efficiently through team work. The team characteristics and roles are indicated in the table 5.4 as follows:

Table (5.4): VE team characteristics

Specification	YOE	Qualification	Notes
Value Engineering Expert	25	Msc. Civil Engineering	Facilitator
Experienced Contractor	25	Bsc. Civil Engineering	Member
Senior Mechanical Engineer	26	Bsc. Mechanical Engineering	Member
Senior Structure Designer	22	Bsc. Civil Engineering	Member
Senior Civil Engineer	24	Bsc. Civil Engineering	Member
Financial Expert	17	Msc. Accounting	Member

5.2.2.1 Information Phase

During this phase of VE workshop, the VE team gathered all available data of drawings, specifications, cost estimation and the owners requirements (quality model), to ensure proper understanding of the project purpose and standards. After reviewing cost model for the project, it was found that the current design would result in a total cost of 2,579,135 US$. So, according to the PARETO rule, the Concrete of the building comprises 43% of the total cost. The VE team suggested to itemize the Concrete works BOQs to specify the items that will be under study.

5.2.2.2 Functional Analysis Phase

In this phase, the VE team starts the workshop with applying cost model with functional analysis to analyze the existing deign in terms of cost. To enable revision of each element of the project in terms of cost. The function analysis model was applied as shown in table 5.5. The worth is depending mainly on standards and estimated by VE team members. The table includes functional analysis of structure elements. For example, the function of the column is "load weight" and its classification is basic. By calculating cost/worth or the value index (VI), areas of high cost, or poor value, are determined. The team judgment was about either to re-design the structure element, or to replace the material.

Table (5.5): Function Analysis Table

Project:										Function Analysis
Function = Active Verb + Measurable Noun				*Kinds: (B)asic, (S)econdary, (R)equired (U)nwanted*						
system	**Sub-system**	**Component**	**Part**	**Function**		**Kind**	**Cost($)**	**Worth ($)**	**Value (Cost/Worth)**	**V**
Project										
	Building									
		Structure								
			Ceiling	Envelop	Space	B	231000	224000	1.03	Poor Value
			Ceiling	Protect	Users	S	167000	165000	1.07	Poor Value
			Marble	cover	areas	B	15500	14000	1.1	Poor Value
			Elevators	transfer	people	B	71400	65000	1.1	Poor Value
			Digital Conference System	Distribute	sound	B	85000	80000	1.06	Poor Value

5.2.2.3 Speculation Phase

In this phase the VE engineering used the available information, the VE team looked at the components of the items crucially affects the total cost or elements having improvement potential and those components that had alternatives were discussed. A group of ideas were generated to reduce high cost without affecting the basic functions. After discussing the generated ideas, the preliminary most accepted idea was taken to be applied on the BIM tools.

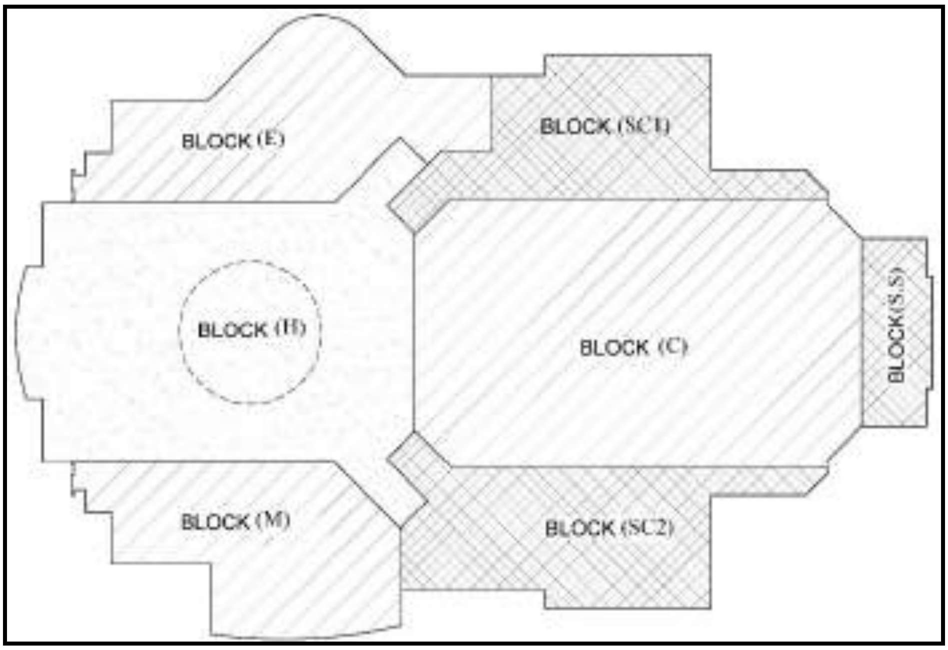


Figure (5.2): Project Layout

Alternative 1: Preliminary ceiling re-design

The preliminary ceiling design was consisted of typical concrete ceiling which consists of reinforced concrete 30MPa Compressive Strength, Including Formwork and reinforcement bars of high tensile steel grade 60, yield stress 410MPa Ditto but for Ribbed Slabs 32cm thick., hollow Blocks (40x25x24) Light weight, drop beams, drainage.

The VE found out that this design is not suitable for the maintenance of the conditioning system and the lightening system because it need additional steel structure for lifting the pipes, cables, etc.

Any problem will happen in the main beam can't be seen , so it is so dangerous in the future if any crack happen , so it is not suitable solution for this issue.

The VE suggested for this option to re-design the ceiling in a way that could reduce cost and accelerate maintenance without affecting the ceiling function, some of the VE team members were with this alternative and some were against, but the final decision postponed to the AHP evaluation phase for more accurate results..

Estimated total cost for this alternative = 1400*165 = 231000$

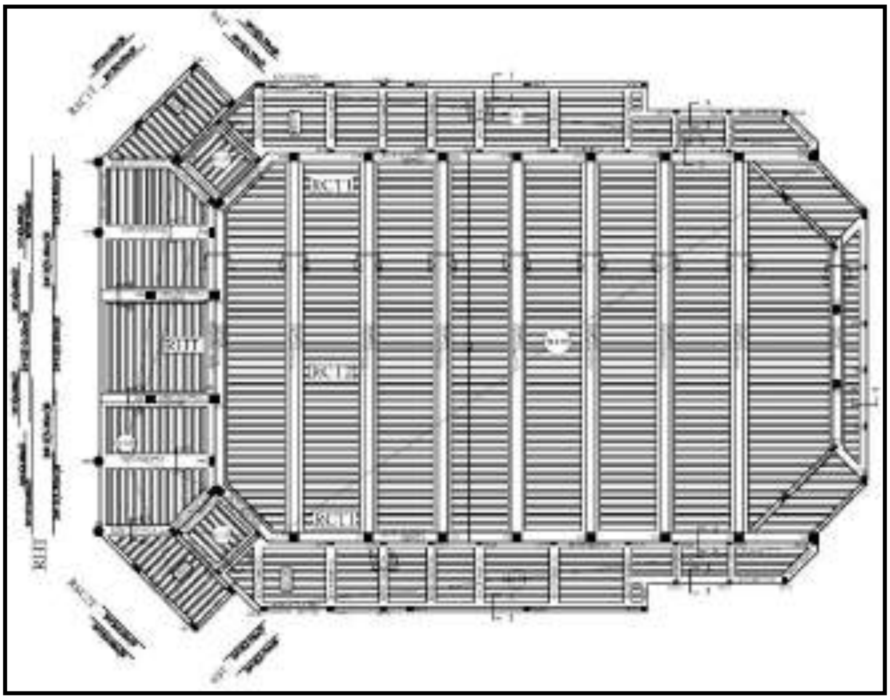


Figure (5.3): Ceiling Preliminary Design

Alternative 2: Galvanized corrugated sheet roofing

A galvanized steel structure could be used to cover the roof thus the ceilng basic function is to envelop the space and it has not a high loading function, the steel structure roof comprising the followings specifications as prposed by the VE team: -

- UB 406x178x74 (74.2kg /mr) for columns, fixed to concrete columns and steel frames, complete with 600x400x25mm gusset plates, fixed to base plate 600x400x6mm fixed to beam with anchor bars, including non-shrinkage grouts 2 cm thick

- UB 406x178x60 (60.1kg /mr) for rafters; triangle strengthening made from cut UBs 406x178x60 gusset UB; fixed together with two gusset plate size 930x180x20mm, fixed to steel columns and steel frames with two gusset plate size 840x180x20mm
- UB 203x133x30 (30kg /mr) for Eaves beams, fixed to steel post.
- 150X75X18 mm C-channel section galvanized steel for purlins.
- 80x80x4 profile for horizontal bracings and tie rod.
- **0.5 mm thick for external and 0.4mm thick for internal galvanized double corrugated roof sheeting (painted with 25 microns of Silicon Polyester paint from both sides,** (type is {PL 40 250/4} or equal approved) with 5 cm rock wool inner insulation ; including Galvanized steel screw with PVC rubber to prevent leakage
- 10% from the roof covering should be polycarbonate sheet 1mm thick
- Metal flashings, gutters, bracing, cleat angles and plates and any other materials needed to complete the works, priming all steel members using anti-corrosive products and painting.

Most of the VE team members initially applauded this alternative, the claims that the ceiling of the building under investigation doesn't load any critical loads and there is no chance for future vertical extension of the building so this alternative will be very efficient to perform the main functions, but the final decision postponed to the AHP evaluation phase for more accurate results..

Estimated total cost for this alternative = 1400 * 90 = 126000$

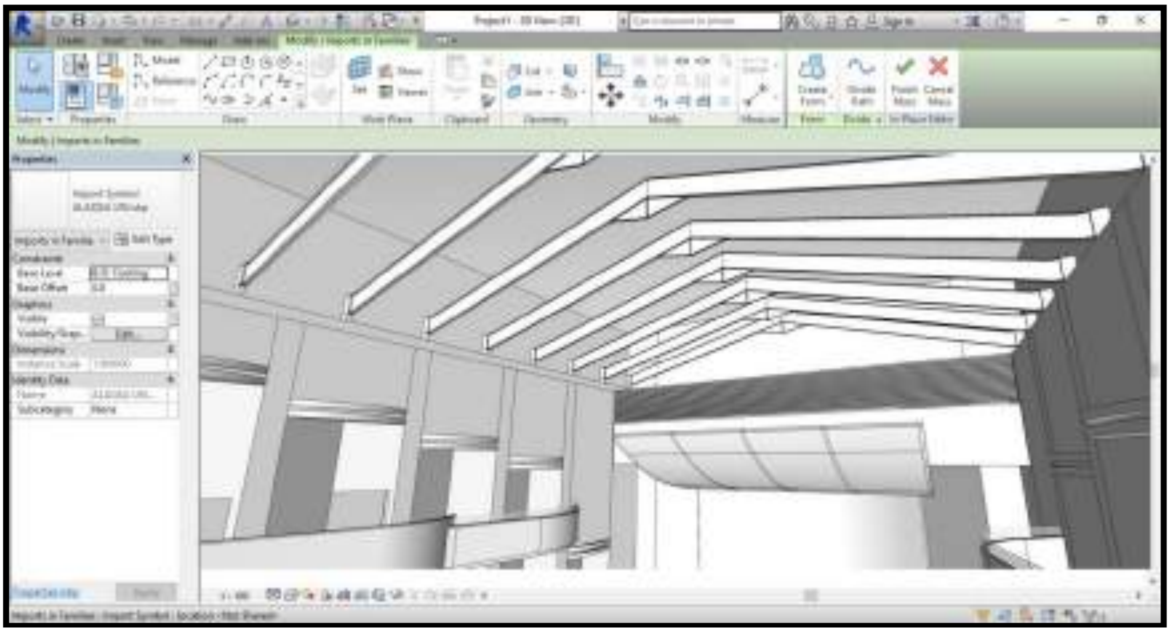


Figure (5.4): Main Steel Beams (Revit)

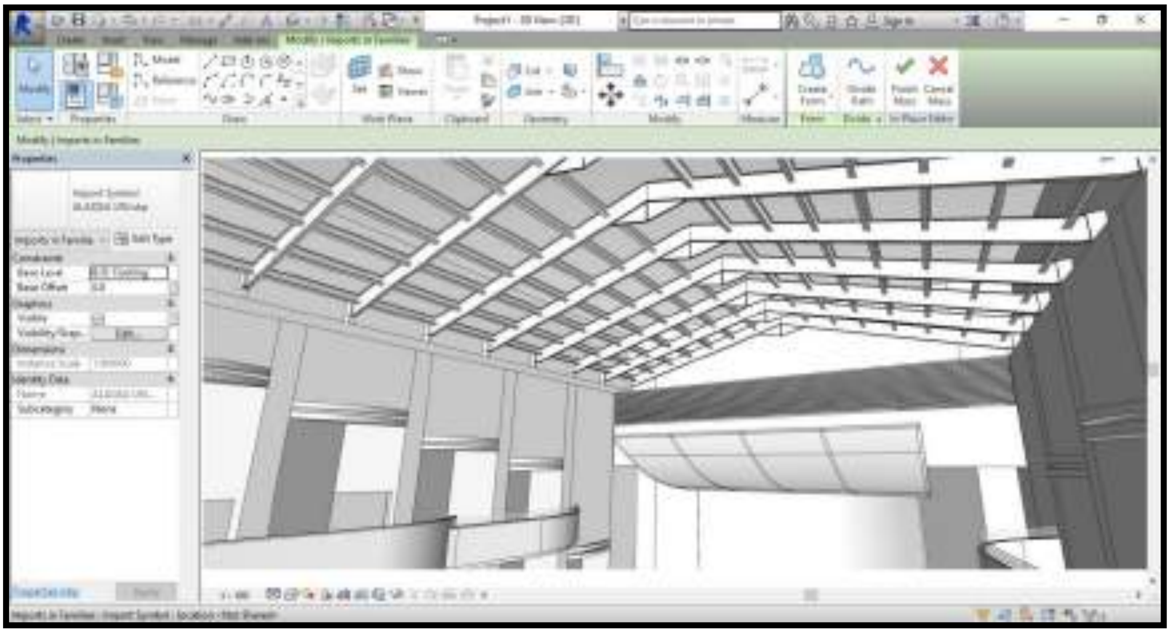


Figure (5.5): cross beams installed on the main beams

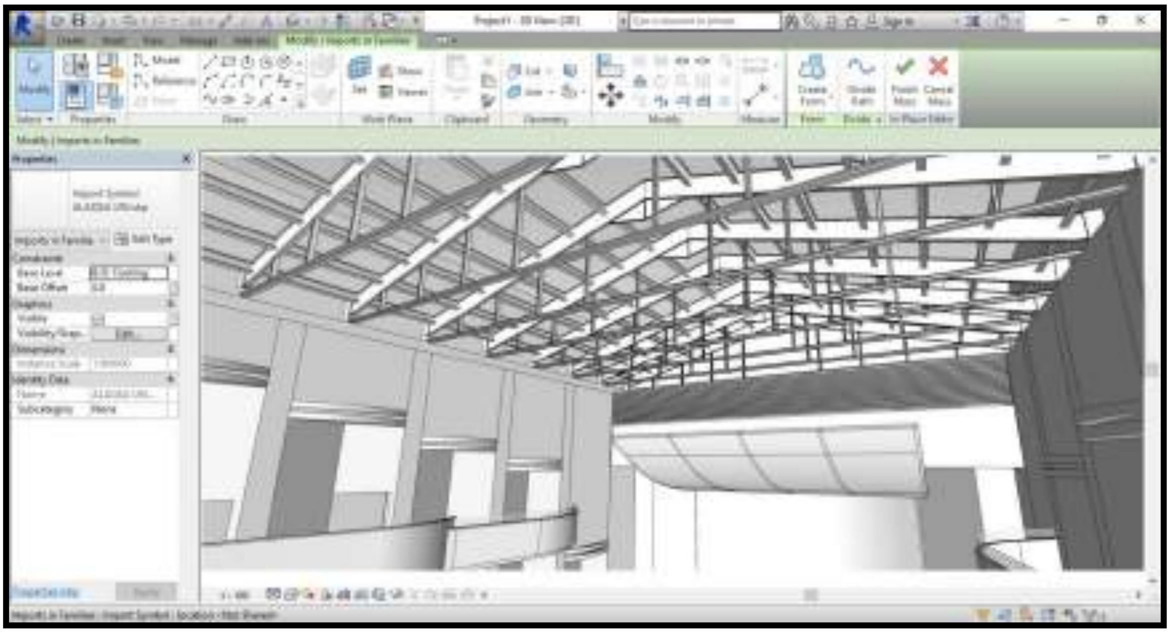


Figure (5.6): Concrete layer casted on the Galvanized Sheets

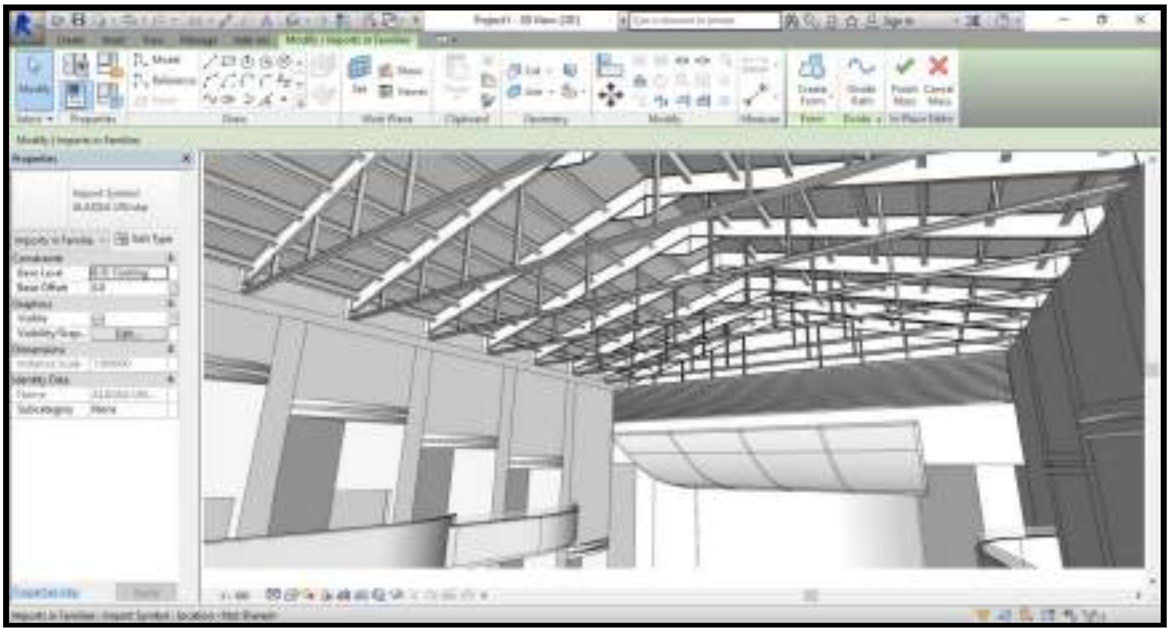


Figure (5.7): Galvanized Steel Sheets installed on the Cross Beams

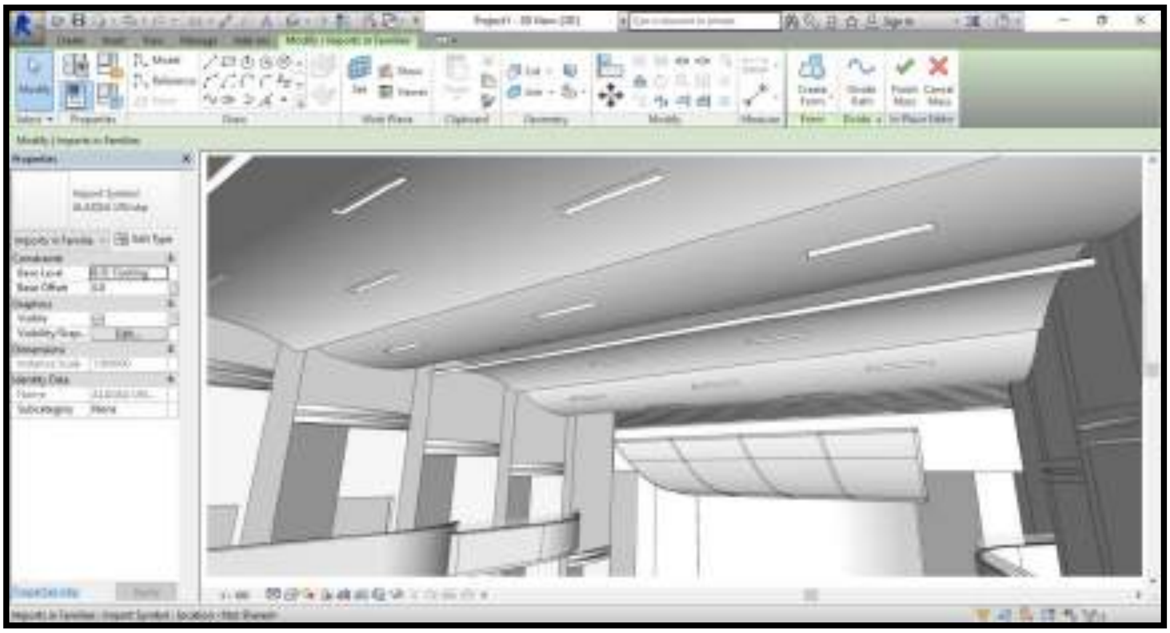


Figure (5.8): Interior Decoration Considering Sound Distribution

Alternative 3: Fire clay roofing

This alternative propose to execute the building ceiling of wooden trusses, covered by fire clay tiles and the VE team suggested to use Clay roof tiles 21x42cm "Tognano type" that could efficiently satisfy this case, on the other hand some team members found that this method doesn't suit this case, but the final decision postponed to the AHP evaluation phase for more accurate results..

Estimated total cost of this alternative 1400*70 = 98000$

5.2.2.4 Evaluation Phase

A critical phase in the application of value engineering is the multi-attributed evaluation of generated alternatives in the speculative phase. Cost is an essential criterion that plays an important role in the selection of the optimum alternative that guarantees best value based on the criteria used in this process.

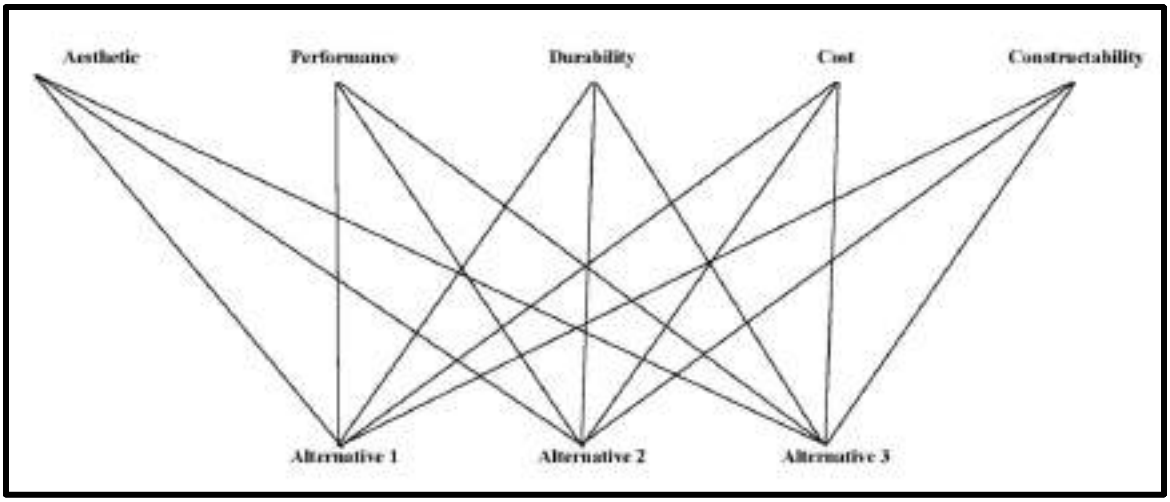


Figure (5.9): AHP Diagram

Pairwise Comparison among Criteria

A - Importance - or B?					Equal	How much more?
1	◉	Constructability	or ○	Aesthetic	◉ 1	○ 2○ 3○ 4○ 5○ 6○ 7○ 8○ 9
2	◉	Constructability	or ○	Performance	◉ 1	○ 2○ 3○ 4○ 5○ 6○ 7○ 8○ 9
3	◉	Constructability	or ○	Durability	○ 1	○ 2○ 3○ 4○ 5○ 6○ 7◉ 8○ 9
4	○	Constructability	or ◉	Cost	○ 1	○ 2○ 3○ 4◉ 5○ 6○ 7○ 8○ 9
5	○	Aesthetic	or ◉	Performance	◉ 1	○ 2○ 3○ 4○ 5○ 6○ 7○ 8○ 9
6	◉	Aesthetic	or ○	Durability	○ 1	○ 2◉ 3○ 4○ 5○ 6○ 7○ 8○ 9
7	○	Aesthetic	or ◉	Cost	◉ 1	○ 2○ 3○ 4○ 5○ 6○ 7○ 8○ 9
8	◉	Performance	or ○	Durability	○ 1	○ 2○ 3○ 4○ 5○ 6◉ 7○ 8○ 9
9	○	Performance	or ◉	Cost	○ 1	◉ 2○ 3○ 4○ 5○ 6○ 7○ 8○ 9
10	○	Durability	or ◉	Cost	○ 1	◉ 2○ 3○ 4○ 5○ 6○ 7○ 8○ 9

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

Table (5.6): resulting weights for the criteria based on the pairwise comparisons

Category		Priority	Rank	Number of comparisons	Consistency Ratio CR
1	Constructability	18.5%	4	10	3.4%
2	Aesthetic	21.5%	3		
3	Performance	22.8%	2		

4	Durability	5.5%	5		
5	Cost	31.7%	1		

Table (5.7): The resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3	4	5
1	1	1.00	1.00	3.00	0.50
2	1.00	1	1.00	3.00	1.00
3	1.00	1.00	1	7.00	0.50
4	0.33	0.33	0.14	1	0.20
5	2.00	1.00	2.00	5.00	1

Principal eigen value = 5.153

Eigenvector solution: 5 iterations, delta = 2.3E-8

Pairwise Comparison Due to Aesthetic Criteria

Table (5.8): Pairwise Comparison Due to Aesthetic Criteria

	A - Importance - or B?		Equal	How much more?
1	Concrete Ceiling Re-design	or Galvanized corrugated sheet roofing	1	2 3 4 5 6 7 8 9
2	Concrete Ceiling Re-design	or Fire Clay Roofing	1	2 3 4 5 6 7 8 9
3	Galvanized corrugated sheet roofing	or Fire Clay Roofing	1	2 3 4 5 6 7 8 9

CR = 0% Please start pairwise comparison

Table (5.9): resulting weights for the alternatives based on the pairwise comparisons

Alternative		Priority	Rank	Number of comparisons	Consistency Ratio CR
1	Concrete Ceiling Re-design	15.8%	2	3	0.1%
2	Galvanized corrugated sheet roofing	76.1%	1		
3	Fire Clay Roofing	8.2%	3		

Table (5.10): resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3
1	1	0.20	2.00
2	5.00	1	9.00
3	0.50	0.11	1

Principal eigen value = 3.001

Eigenvector solution: 2 iterations, delta = 9.4E-9

Pairwise Comparison Due to Performance Criteria

Table (5.11): Pairwise Comparison Due to Performance Criteria

	A - Importance - or B?			Equal	How much more?
1	(•) Concrete Ceiling Re-design	or	( ) Galvanized corrugated sheet roofing	(•) 1	( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9
2	(•) Concrete Ceiling Re-design	or	( ) Fire Clay Roofing	( ) 1	( ) 2 ( ) 3 ( ) 4 (•) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9
3	( ) Galvanized corrugated sheet roofing	or	(•) Fire Clay Roofing	( ) 1	( ) 2 ( ) 3 (•) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9

CR = 0.4% OK

Table (5.12): resulting weights for the alternatives based on the pairwise comparisons

Category		Priority	Rank	Number of comparisons	Consistency Ratio CR
1	Concrete Ceiling Re-design	47.2%	1	3	0.4%
2	Galvanized corrugated sheet roofing	44.4%	2		
3	Fire Clay Roofing	8.4%	3		

Table (5.13): resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3
1	1	1.00	6.00
2	1.00	1	5.00

3	0.17	0.20	1
Principal eigen value = 3.004 Eigenvector solution: 3 iterations, delta = 7.2E-9			

Pairwise Comparison Due to Durability Criteria

Table (5.15): Pairwise Comparison Due to Durability Criteria

	A - Importance - or B?		Equal	How much more?
1	● Concrete Ceiling Re-design	or ○ Galvanized corrugated sheet roofing	● 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	● Concrete Ceiling Re-design	or ○ Fire Clay Roofing	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ● 6 ○ 7 ○ 8 ○ 9
3	○ Galvanized corrugated sheet roofing	or ● Fire Clay Roofing	○ 1	○ 2 ○ 3 ○ 4 ● 5 ○ 6 ○ 7 ○ 8 ○ 9
CR = 1.9% OK				

Table (5.15): resulting weights for the alternatives based on the pairwise comparisons

	Category	Priority	Rank	Number of comparisons	Consistency Ratio CR
1	Concrete Ceiling Re-design	55.0%	1	3	1.9%
2	Galvanized corrugated sheet roofing	21.0%	3		
3	Fire Clay Roofing	24.0%	2		

Table (5.16): resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3
1	1	3.00	2.00
2	0.33	1	1.00
3	0.50	1.00	1
Principal eigen value = 3.018 Eigenvector solution: 3 iterations, delta = 1.7E-8			

Pairwise Comparison Due to Cost Criteria

Table (5.17): Pairwise Comparison Due to Cost Criteria

A - Importance - or B?			Equal	How much more?
1	○ Concrete Ceiling Re-design	or ◉ Galvanized corrugated sheet roofing	○ 1	○ 2 ○ 3 ○ 4 ◉ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	○ Concrete Ceiling Re-design	or ◉ Fire Clay Roofing	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ◉ 6 ○ 7 ○ 8 ○ 9
3	○ Galvanized corrugated sheet roofing	or ◉ Fire Clay Roofing	○ 1	○ 2 ◉ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
CR = 9.8% OK				

Table (5.18): resulting weights for the alternatives based on the pairwise comparisons

Category		Priority	Rank	Number of comparisons	Consistency Ratio CR
1	Concrete Ceiling Re-design	7.8%	3	3	9.8%
2	Galvanized corrugated sheet roofing	28.7%	2		
3	Fire Clay Roofing	63.5%	1		

Table (5.19): resulting weights are based on the principal eigenvector of the decision matrix

1	2	3	
1	1	0.20	0.17
2	5.00	1	0.33
3	6.00	3.00	1
Principal eigen value = 3.094 Eigenvector solution: 4 iterations, delta = 1.9E-8			

Pairwise Comparison Due to Constructability Criteria

Table (5.20): Pairwise Comparison Due to Constructability Criteria

A - Importance - or B?			Equal	How much more?							
1	Concrete Ceiling Re-design	or ● Galvanized corrugated sheet roofing	1	2	● 3	4	5	6	7	8	9
2	● Concrete Ceiling Re-design	or Fire Clay Roofing	● 1	2	3	4	5	6	7	8	9
3	● Galvanized corrugated sheet roofing	or Fire Clay Roofing	1	2	● 3	4	5	6	7	8	9
CR = 5.6% OK											

Table (5.21): resulting weights for the alternatives based on the pairwise comparisons

Category		Priority	Rank	Number of comparisons	Consistency Ratio CR
1	Concrete Ceiling Re-design	20.0%	2	3	5.6%
2	Galvanized corrugated sheet roofing	60.0%	1		
3	Fire Clay Roofing	20.0%	2		

Table (5.22): resulting weights are based on the principal eigenvector of the decision matrix

	1	2	3
1	1	0.33	1.00
2	3.00	1	3.00
3	1.00	0.33	1

Principal eigen value = 3.000

Eigenvector solution: 1 iterations, delta = 6.2E-33

5.2.2.5 Presentation Phase

The VE team had extensive discussion for the purpose of the final decision for each idea generated and accepted by the team. The final alternatives scoring is shown in table 5.23:

Table (5.23): Alternatives evaluation presentation (final Scores)

Alternatives	Aesthetic	Performance	Durability	Cost	Constructability	Final score
Concrete Ceiling Re-design	15.8%	47.2%	55.0%	7.8%	20.0%	29%
Galvanized corrugated sheet roofing	76.1%	44.4%	21.0%	28.7%	60.0%	46%
Fire Clay Roofing	8.2%	8.4%	24.0%	63.5%	20.0%	25%

5.3 Summary

After applying value engineering methodology using the proposed framework on the case study represented in a conference building the VE team recommended to replace the typical concrete ceiling by a galvanized corrugated sheet roofing which resulted a cost reduction by 57.5% without compromising the basic functions of the component, and that is the main principle of VE.

Chapter 6

Chapter Six: Conclusion and Recommendation

This chapter summarizes the research and provides a recommendations and conclusions for the application of value engineering methodology using building information modeling in the construction industry in Gaza strip. Also, this chapter includes research contribution to knowledge. By revisiting the research objectives and key findings, an overview discussed to assess the extent to which the research objectives were met.

6.1 Research Summary

This study presents a method to address the challenge faced by professional designers, stakeholders, owners, and members of the value engineering teams regarding the selection of the most suitable alternative that suit all the owners' requirement. It proposes framework in support of VE analysis. The framework is developed to embed BIM techniques in the various stages of VE job plan and to evaluate various alternatives based on the criteria considered for the desired function.

It should be noted that the evaluation process proposed in this research is a Value Analysis rather than Cost Analysis, since it accounts for other critical factors in the evaluation process. In other words, Value Engineering goes beyond cost engineering or cost-benefit analysis. Value engineering can be considered as a paradigm and umbrella that takes into account all aspects needed for evaluation.

This method uses the advanced technology tools used in the construction field like building information model (BIM) and 4D (3D plus cost) models. BIM model was used to provide visualization capabilities for VE team members, owners, and designers. 4D model was also used to analyze the cost of every alternative and find the relation of the components and cost of the project.

Evaluation of the alternatives with respect to the defined criteria is based on the analytical hierarchy process (AHP). AHP was used to find the relative weight of the criteria considered for the project, as well as assessing the alternatives score. Scale of the evaluation are Equal importance=1, Weak importance=3, strong importance=5, Very strong importance=7, Absolute importance=9. AHP will rank the alternative and provide a report as the model output.

The proposed methodology integrates the mentioned decision making techniques almost in real time. It combines BIM and 4D models and the cost is the fourth dimension. Providing value engineering teams with needed information from BIM, the model will ease the process of generating innovative alternatives for the and assist VE teams to make value driven decisions with regard to owner's desired criteria. The developed framework can quantify the subjective assessment of the criteria and automate the evaluation of the alternatives.

Owners, professional designers and more importantly the members of the value engineering teams can benefit from the proposed framework to improve the value of the project and reduce the unnecessary cost without impacting the functional requirement of the project. Moreover, the parties involved in the project, designers, owners and stakeholders will have the opportunity to communicate with each other at every stage of the project and will help them to have the same picture of the project and avoid any misunderstandings.

Finally, perhaps value engineering is no more than the formal application of standard problem solving to building design. However, the benefits of applying such an approach (VE) are undeniable; Designers are forced to take a step back and analyze and revise their work before leading to conclusions. The proposed methodology in this research provides the opportunity for value consultants to improve the VE job plan with application of the special techniques and the special knowledge in order to the develop value alternatives.

6.2 Conclusions of the research objectives, questions, and hypotheses

In achieving the aim of the research, four main objectives have been outlined and achieved through the findings of the analyzed questionnaires and the conducted workshop. These objectives are related with the research questions that were developed to increase one's knowledge and familiarity with the subject. The outcomes were found as following:

6.2.1 Outcomes related to objective one

***The objective was**: To survey and investigate the importance of Value engineering application in Gaza Strip for construction projects management improvement.*

The first research question: *What is the level of awareness of VE application by professionals in Gaza Strip?*

The study found put that the level of awareness of value engineering in the gaza strip is near to be poor that 60% of the sample -whom considered VE experts in the scope of gaza strip have never apply VE methodology

6.2.2 Outcomes related to objective two

The objective was: *To investigate the factors influencing Value Engineering studies and apply it to the proposed framework.*

The Second research question: *What are the main factor influencing Value Engineering Studies in the construction industry firms in Gaza strip?*

The study found out that the following ten factors are the main important factors that influencing VE Studies :

1 Clear objectives of workshop
2 Client's participation
3 Client's support
4 Disciplines of participants
5 Qualification of facilitator
6 Background information collected
7 Client's objectives clarified
8 Interaction among participants in each phase
9 Percentage of action plan without uncertainty carried out
10 Quality of the report

6.2.3 Outcomes related to objective three

The objective was: *To study and extend the use of BIM models to collect input data for the assessment framework and to assist in the automating evaluation process*

The third research question: *What is the effect of the computerization using BIM of VE application in the construction projects of Gaza Strip?*

The experts participated in the VE workshop found out that using BIM tools during VE job plan phases had facilitate the process and gave an accurate result rather than those processes that applied manually

6.2.4 Outcomes related to objective four

***The objective was**: To Embed an AHP program into the evaluation phase of VE job plan to rank the alternatives.*

***The Fourth research question:** What is the effect of using AHP in the alternatives comparison accuracy?*

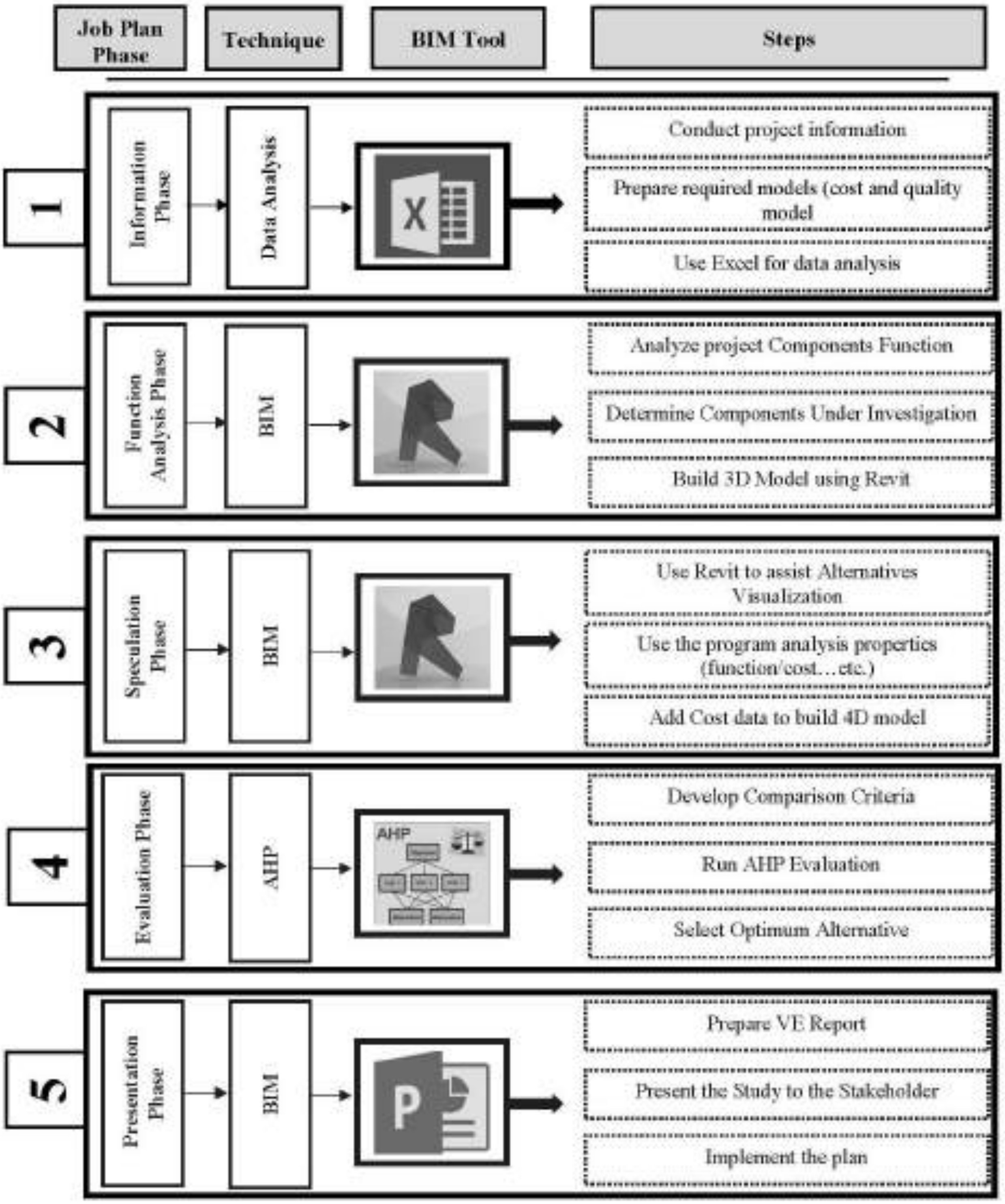
40% of the sample found out that using AHP in the evaluation is more efficient and give an accurate result rather than those processes of evaluation that applied manually.

6.3 Research Contributions

Large buildings projects require commitments of considerable large resources and the application of models such as that developed in this research can be of help to professionals in Architecture, Engineering and Construction industry in developing better understanding and appreciation of project scope of work and in reducing unnecessary cost without impacting the required functional requirements of project components being considered.

The presented framework contributes to the field of construction management by:

- Providing a tool that supports Value Engineering teams in the evaluation phase of VE job plan and facilitates speculation phase.
- Automating the assessment and evaluation procedure of competing alternatives in a timely manner.



[1] The framework is designed to be flexible that the user can use any other programs that suits the phase function, the programs proposed in this framework are not binding

Figure (6.1): Proposed Framework Flowchart

- Providing the opportunity for the VE team members to track and analyze the consequences of every single change they make in an alternative and identify the components that have the most impact on cost in near real time.
- Facilitating visualization capabilities that can be of help in emerging a mutual clear picture of the project among the VE team members, owners and designers. Moreover to assist VE team members in the process of generating creative alternatives in the speculation phase of VE Job plan.
- Broadening the use of object oriented models within VE context, well integrate BIM models with 4D presentation to provide a tool for Value Engineering team members to be able to evaluate alternatives automatically.

6.4 Recommendations for Future Researches

Despite the benefits model provide for the VE team members and enhance the speculation phase and evaluation phase of the VE Job plan, future works can be done to improve the implementation of the model and enrich the proposed methodology. Some of the recommendations that can improve the research in general are listed below:

- The framework is limited to building projects and cannot be applied in heavy constructions
- The framework is applied to a case example to show its benefits; however, more case studies can be conducted to better examine the proposed framework and to find its limitation in different projects
- The cost data considered for the case study take the direct cost into account. Moreover, life cycle cost is not included in the calculations.

References

AbuHamra, L. A. (2015). An investigation into Building Information Modeling (BIM) application in Architecture, Engineering and Construction (AEC) industry in Gaza strip. Gaza strip, Palestine.: Master thesis, Construction Project Management, Civil Engineering, Islamic University of Gaza (IUG),.

Alamoudi, M. B. (2015). Application of the Analytical Hierarchy Process (AHP) to Multi-Criteria Analysis for Contractor Selection. American Journal of Industrial and Business Management, 581-589.

Ali Bagheri Fard, K. G. (2013). Evaluating Effective Factors on Value Engineering Implementation in the context of Iran. Journal of Basic and Applied Scientific Research, ISSN 2090-4304.

Ali Kamil Taslicali , Sami Ercan . (2006). The Analytic Hierarchy & The Analytic Network Processes In Multicriteria Decision Making: A Comparative Study. Journal Of Aeronautics And Space Technologies, Volume 2 Number 4 (55-65).

Al-Yousefi, A. S. (2011). Value Engineering application benefits in Sustainable Construction. SAVE International .

Amir Shekari, S. F. (2009). A new approch to linking value engineering & lean metodology. Iran : 1 9th International Conference On Production Research.

Amruta Chougule, A. K. (2014). Application of Value Engineering Technique to A Residential Building –Case Study. International Journal of Innovative Research in Advanced Engineering (IJIRAE), 2349-2163.

Attarde, N. L. (2016). Application of Value Engineering in Commercial Building Projects. International Journal of Latest Trends in Engineering and Technology (IJLTET).

Attarde, P. N. (2016). Application of Value Engineering in Commercial Building Projects. International Journal of Latest Trends in Engineering and Technology (IJLTET).

Baker, D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J., & Sorenson, K. (2002). Guidbook to Decision Making Methods. USA: Department of Energy.

Behnam Atazadeh, Mohsen Kalantari, Abbas Rajabifard, Tom Champion, and Serene HO, Australia. (2016). Harnessing BIM for 3D digital management of stratified ownership rights in buildings. FIG Working Week CONFERENCE. Christchurch, New Zealand: researchgate.

Berawi, M. A. (2009). Establishing a Reliable Method of Distinguishing Functions and Processes. SAVE International.

Blundell, B. F. (1969). Factors Underlying Successful Value Engineering. Value Engineering ,.

Boo Young Chung, S. S. (2009). Applying Process Simulation Technique to Value Engineering Model: A Case Study of Hospital Building Project. IEEE transactions on engineering management.

Building SMART, N. I. (2012). National BIM Standard - United States™ Version 2.

Burnside, J. (1969). Organising the V.E.-Effort in a Company. Value Engineering.

Chavan, A. J. (2013, December). Value Engineering in Construction Industry . International Journal of Application or Innovation in Engineering & Management (IJAIEM).

Cheng Zhang, T. Z. (2016). Quantitative Assessment of Building Constructability Using BIM and 4D Simulation. Open Journal of Civil Engineering, 442-461.

Chi-Sung, Nam-kung, & Chang-Taek Hyun. (2009). A Study on the Consecutiveness of the Function Analysis and Idea Creation Phase with Function Integration (FI) and Hierarchical Value Engineering Concept Modules(HVECM). SAVE international .

Chuck Eastman, P. T. (2011). BIM Handbook A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. Hoboken, New Jersey: John Wiley & Sons, Inc.

Cory, C. A. (2001). Utilization of 2D, .3D, or 4D CAD in Construction Communication Documentation. IEEE.

COUNCIL, T. F. (2001). A Guide to Integrating Value Engineering, Life-Cycle Costing, and Sustainable Development . Washington: National Academy Press.

Decker, C. B. (1969). A New Breed . . . The Value Managers. Value Engineering.

Defense, D. o. (2011). Value Engineering: A Guidebook of Best Practices and Tools. USA: AREA STDZ.

DelI’lsola, A. J. (1969, Febreuary). Value Engineering Cost Effectiveness , A Tool for the Designer too. Value Engineering, pp261.

Department Of Civil Defence, U. (2006, may). Contractor's Guid to Value Engineering . Version 2.1.

Department, E. S. (2010). The Key Performance Indicator Evaluation Process (KPI Process). USA: University of Oxford .

Dina Mahmoud Mansour, I. A. (2013). Value Engineering Analysis in the Construction of Box-Girder Bridges. International Journal of Latest Trends in Engineering and Technology (IJLTET).

Edwards, W. (1994). Improved Simple Methods for Multiattribute Utility Measurement. Journal of Organizational Behavior and Human Decision Processespp: 306-325.

Farahmandazad, M. (2015). Developing a model for implementation of value engineering system for the construction projects of executing construction project-based companies (fourth factor) case study: construction projects of social security organization. Indian Journal of Fundamental and Applied Life Sciences, pp. 1403-1413.

fficials, A. A. (2010). Guidelines for Value Engineering. American Association of State Highway and Transportation Officials.

Fridholm, G. H. (1969). Value Engineering - Dynamic Tool for Profit Planning. Value Engineering.

Galipogullari, S. A. (2013). Application of Value Engineering in Construction. Journal of Traffic and Transportation Engineering,, pp. 39-48.

Goodwin, P. (2004). Decision Analysis for Management Judgment. England: John Wiley & Sons, Ltd.

Graham, A. (2012). Using an AHP/ANP Hybrid Methodology for Freight Transport Network Selection Towards Sustainable Transportation. The University of Texas.

Harris, R. (2012). Introduction to Decision Making. http://www.virtualsalt.com/crebook5.htm.

János Fülöp, D. R. (2006). Introduction to Decision Making Methods. Laboratory of Operations Research and Decision Systems, Computer and Automation Institute, Hungarian Academy of Sciences.

Khalid Al-Gahtani, I. A.-S. (2015). Key Performance Indicators for Value Management in Saudi Construction Industry. International Journal of Application or Innovation in Engineering & Management (IJAIEM).

Li, X. (2008). Application of Value Methodology to Improve Preservation of Infrastructural Assets in Rijkswaterstaat. Master thesis, Delft University of Technology.

Lin, G. (2009). Developing a Performance Measurement Framework for Value Management Studies in Construction. SAVE International,.

Maila Herrala, P. L. (2009). Information Value Attributes and Assessment Methods – A Construct from a Traffi c and Traveller Information Perspective. SAVE International, pp..

Miles, L. D. (1972). Techniques of Value Analysis and Engineering. New York: McGraw-Hill.

Min-Jae Lee, J.-K. L. (2010). Performance-Based Value Engineering Application to Public Highway Construction. KSCE Journal of Civil Engineering, 14(3):261-271.

Mohammed Balubaid, R. A. (2015). Application of the Analytical Hierarchy Process (AHP) to Multi-Criteria Analysis for Contractor Selection. American Journal of Industrial and Business Management , 581-589.

Omkarprasad S. Vaidya, S. K. (2006). Analytic hierarchy process: An overview of applications. European Journal of Operational Research, 1–29.

Omkarprasad S. Vaidya, S. K. (2006). Analytic hierarchy process: An overview of applications. European Journal of Operational Research, 169 1–29.

Pearson, N. (1969, Febreuary). An Application of Value Analysis to Building. Value Engineering, pp. pp 301.

Ranjbaran, Y. (2013). Integrated Computational Model in Support of Value Engineering. Montreal, Quebec, Canada: Master Thesis, Building, Civil and Environmental Engineering department,Concordia University.

Rich, N. (2000). Value Analysis, Value Engineering. Cardiff, United Kingdom: Lean Enterprise Research Centre.

Saaty, T. L. (1990). How to make a decision: The Analytical Hierarchy Process. Europcan Journal al Operational Research 48 , pp. 9-26.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. Int. J. Services Sciences.

Sadawi, U. E. (2008). A Value Engineering Methodology for Low Income Housing Projects in Gaza Strip. Gaza, Palestine: Islamic University Of Gaza.

Sadi Assaf, O. A.-T. (2000). Computerized System For Application Of Value Engineering Methodology. Journal Of Computing In Civil Engineering, Pp 206-214.

Saipol Bari Abd Karim, Mohammed Ali Berawi, Imran Ariff Yahya, Hamzah Abdul-Rahman and Othman Mohamed. (2007). The Integration Of Value And Risk Management In Infrastructure Projects: Learning From others. Quantity Surveying International Conference. Kuala Lumpur, Malaysia: Value Management Centre (VMC), Faculty of the Built Environment, University of Malaya.

Saipol Bari Abd Karim, Rabi'atul 'Adawiyah A. Rahmin, Mohd Suhaimi Mohd Danuri and Othman Mohamed. (2014). Developing the Value Management Maturity Model. Journal of Design and Built Environment.

Salman Azhar, A. N. (2008). Building Information Modeling (BIM): A New Paradigm for Visual. First International Conference on Construction in Developing Countries (ICCIDC–I). Karachi, Pakistan.

SAVE, I. (2015, March). Value Methodology Standard. SAVE International.

Seidel, J. K. (2012). Value Engineering Trends in the Construction Industry. The Ohio State University.

Senay Atabay and Niyazi Galipogullari. (2013). Application of Value Engineering in Construction Projects. Journal of Traffic and Transportation Engineering, ISSN 2328-2142, USA, pp. 39-48.

Sherif Attya Ahmed, Diaa Eldin Ibrahim, Laila M. khodeir. (2016). Effective usage of quality management tools in workshop phase of value engineering studies. Egypt, ResearchGate.

Simon A. Austin and Derek S. Thomson. (1999). Integral value engineering in design. COBRA 99 Conference. Loughborough, Leics., UK: Department of Civil and Building Engineering, Loughborough University.

Spear, D. F. (1969). S.P.C.L. - A New Approach to Value Engineering. Value Engineering.

Thomas L. Saaty and Luis G. Vargas . (2006). Decision Making With The Analytic Network Process Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks. United States of America: Springer Science+Business Media, LLC.

Tohidi, H. (2011). Review the benefits of using Value Engineering in Information. Procedia Computer Science 3, pp. 917–924.

Usman Aminu Umar, Nasir Shafiq, Amirhossein Malakahmad, Muhd Fadhil Nuruddin, Mohd Faris Khamidi, Syed Ahmad Farhan and Syed Shujaa Safdar Gardezi. (2015). 4D BIM Application in AEC Industry: Impact on Integrated Project Delivery. Research Journal of Applied Sciences, Engineering and Technology, 547-552.

All thanks and appraises belong to Allah

"Alhamdulillah"

Appendix I

Value Engineering Studies Glossary

Appendix II

Questionnaire

Appendix I

VE job plan glossary

COST

The expenditure necessary to produce a product, service, process or structure.

COST, DESIGN TO

A procedure which establishes an estimated cost objective for each project, then designs to that cost objective to produce a reliable product or service.

COST, LIFE CYCLE

The sum of all acquisition, production, operation, maintenance, use and disposal costs for a product or project over a specified period.

COST MODEL

A diagramming technique used to illustrate the total cost of families of systems or parts within a total complex system or structure.

COST/WORTH RATIO

The ratio used to determine the maximum opportunity for value improvement.

FUNCTION

The natural or characteristic action performed by a product or service.

FUNCTION, BASIC

The primary purpose or most important action performed by a product or service. The basic function must always exist, although methods or designs to achieve it may vary.

FUNCTION, SECONDARY

A function that supports the basic function and results from the specific design approach to achieve the basic function. As methods or design approaches to achieve the basic function are changed, secondary functions may also change. There are four kinds of secondary functions:

1. Required - A secondary function that is essential to support the performance of the basic function under the current design approach.

2. Aesthetic - A secondary function describing esteem value.

3. Unwanted - A negative function caused by the method used to achieve the basic function such as the heat generated from lighting which must be cooled.

4. Sell - A function that provides primarily esteem value. For marketing studies it may be the basic function.

FUNCTION MODELS

A graphical depiction of the relationships of the functions within a project. There are two commonly used styles:

1. Hierarchy - A vertical "tree" chart of functions. Recent practice has been to include within one branch user oriented functions such as assure convenience, assure dependability, assure safety, and attract user. Some practitioners prefer to lay out this model horizontally and refer to it as "user FAST."

2. Function Analysis System Technique (FAST) - A horizontal chart depicting functions within a project, with the following rules:

a. The sequence of functions on the critical path proceeding from left to right answer the questions "How is the function to its immediate left performed?"

b. The sequence of functions on the critical path proceeding from right to left answer the question "Why is the next function performed?"

c. Functions occurring at the same time or caused by functions on the critical path appear vertically below the critical path function.

d. The basic function of the study is always farthest to the left of the diagram of all functions within the scope of the study.

e. Two other functions are classified:

1) Highest Order - The reason or purpose that the basic function exists. It answers the "why" question of the basic function, and is depicted immediately outside the study scope to the left.

2) Lowest Order - The function that is required to initiate the project and is depicted farthest to the right, outside the study scope. For example, if the value study concerns an electrical device, the "supply power" function at the electrical connection would be the lowest order function.

JOB PLAN

A structured discipline to carry out a value study.

PERFORMANCE

The physical characteristics required to meet the users needs. Factors such as reliability, maintainability, quality and appearance are typical.

PRICE

A fixed sum of money expended by the user/customer to purchase the product under study.

PRODUCT

For the purposes of value studies, a product is the subject of the study. It may be a physical product such as a manufactured item, or a structure, system, procedure, or an organization.

SCOPE

The portion of the overall project that is selected for the value study. The analysis accepts everything within the defined scope in order to focus attention on the functions within those limits.

VALUE

The lowest cost to reliably provide the required functions at the desired time and place with the essential quality and other performance factors to meet user requirements.

VALUE, MONETARY

There are four classes of monetary value:

1. Use Value - The monetary measure of the functional properties of the product or service which reliably accomplish a user's needs.

2. Esteem Value - The monetary measure of the properties of a product or service which contribute to its desirability or salability. Commonly answers the "How much do I want something?" question.

3. Cost Value - The monetary sum of labor, material, burden, and other elements of cost required to produce a product or service.

4. Exchange Value - The monetary sum at which a product or service can be freely traded in the marketplace.

VALUE METHODOLOGY

The systematic application of recognized techniques which identify the functions of the product or service, establish the worth of those functions, and provide the necessary functions to meet the required performance at the lowest overall cost.

VALUE METHODOLOGY PROPOSAL

A proposal by the value study team to its management to provide one or more functions for financial and/or performance improvements and is within the current terms and conditions of the contract.

VALUE STUDY

The application of the value methodology using the VM Job Plan, and people previously trained in VM workshops.

VALUE METHODOLOGY TRAINING

There are two levels of SAVE International approved training specifically designed to provide the minimum knowledge of VM practice. It is expected that VM professionals, as in all professional fields, will continue to keep themselves current through seminars, conferences, and associated educational opportunities.

1. Value Methodology Workshop - The objective is to provide Value Methodology education to the degree that participants will be able to successfully participate in future value studies under the guidance of a qualified Value Specialist with minimum additional training. This is called the Module I program.

2. Value Methodology Advanced Seminar - The objective of this seminar is to extend the knowledge base of those wishing to become professionals in the value methodology field. Topics include both advanced methodology and areas of management. This seminar is referred to as the Module II program.

The seminar requires a minimum of 24 class hours. Module I is a prerequisite, and it is expected attendees will have enough practical experience in VM to contribute to the seminar.

VALUE ANALYST

Synonymous with Value Specialist.

VALUE ENGINEER

Synonymous with Value Specialist.

VALUE ENGINEERING CHANGE PROPOSAL (VECP)

A formal proposal submitted to the customer/user which requires their approval before implementing the VA change. The result will be a modification to the submitter's contract.

VALUE SPECIALIST

One who applies the value methodology to study and search for value improvement.

Appendix II

Questionnaire

The Islamic university of Gaza

Higher studies deanery

Faculty of engineers – master program

Engineering project management

A Framework for value engineering methodology application Using Building Information Modelling (BIM)

Description	This questionnaire investigates in help of the study "A Framework for value engineering application using BIM", it aims to evaluate the methodology of this research by a highly-qualified professional in construction management in Gaza strip, and will measure the factors influencing the performance for the proposed value engineering VE application framework in Gaza Strip.
Research Aim	The research aims to propose a framework for Value Engineering application using BIM
Target Group	Construction management and academic experts.
Methodology Description	This study mainly aims to apply a framework that assist value engineering team to facilitate the value engineering methodology application. The proposed framework in this research can be of help to value engineering team members, design professionals and owners and stakeholders. Selection of the (optimum) alternative based on multi-attributed criteria has always been an issue for design professionals and owners.

All appreciations and thanks for your contribution to support scientific research

Researcher: **Aya Hasan Alkhereibi**

Supervisor : **Dr. Khalid Al Hallaq**

Aug. 2016

For more accurate answers the following items needed to be clarified, please read it carefully and answer the questions below:

Value Engineering (VE) is an organized, systematic, interdisciplinary problem solving approach basically based on analyzing the function of systems, equipment, facilities, services, and supplies for the drive of accomplishing their crucial functions at the lowest life-cycle cost reduction with required performance

Building Information Modeling (BIM) The Building Information Model is primarily a three-dimensional digital representation of a building and its intrinsic characteristics. It is made of intelligent building components which includes data attributes and parametric rules for each object.

Analytical Hierarchy Processing (AHP) . Analytic Hierarchy Process is the most used tool in Multiple Criteria Decision Making. In AHP the factors which are effective in decision making are arranged in a hierarchic structure descending from an overall goal to criteria, subcriteria and then alternatives successively

Pareto Diagram based on the concept of (80-20), which means that 80% of the problem, is been caused by 20% of the reasons or items**.**

Quality Model (Star Model) Quality Model or star model is an evaluation toll that is based on identifying the quality key items (evaluation criteria) then the evaluation and to make a comparison between two items by identifying some of the criteria's were define from development team, and make a comparison and evaluation between two items before and after the development**.**

Affinity Diagram Affinity Diagram aim to organize and link a set of ideas in groups, usually it is coming after brainstorming sessions.

Rivet Revit Architecture provided by Autodesk Inc.-which will be used in this study-has built-in sequencing options. Each object can be assigned a phase. Revit then uses snapshots of the model for each phase creating a simple sequencing for the viewers.

RSmeans: RSMeans data is an estimation source which helps calculate the costs of construction prior to beginning construction. The database is used for a wide variety of construction types and can estimate based on overall materials, square footage and location. It can be used at almost any stage of cost planning but will become more accurate as the project progresses.

Part I: Questions Related to participant information and work experience

Please complete the following questionnaire with specific regard to the above enquiry, by placing a TICK √ in the appropriate box

1. **Name (Optional):**……………………………………………………………………………………..

2. **Gender:**
   - ☐ Male
   - ☐ Female

3. **Educational qualification:**
   - ☐ Bachelor
   - ☐ Master
   - ☐ PHD

4. **Specialization:**
   - ☐ Architecture
   - ☐ Civil Engineering
   - ☐ Mechanical Engineering
   - ☐ Electrical Engineering
   - ☐ Others (…………………………………………………………………………………..)

5. **Job Title for the participant who filling out the questionnaire:**
   - ☐ Company Manager
   - ☐ Project Manager
   - ☐ Site Engineer
   - ☐ Designer
   - ☐ Others (………………………………………………………………………………….)

6. **Years of experience in the construction industry for the participant who filling out the questionnaire:**
   - ☐ Less than 10 years
   - ☐ From 10 -15 years
   - ☐ 15 -20 years
   - ☐ More than 20 years

7. **The type of your organization**
   - ☐ Governmental organization
   - ☐ Consultation office
   - ☐ Non-governmental organization
   - ☐ Other (……………………………………...)

8. **The Organization's current size in which you operate:**
   - ☐ Less than 20 employees
   - ☐ From 20-50 employee
   - ☐ More than 50

employees

9. **Size of your Organization projects during the last five years (in million dollar):**

☐ Less than a 1 m$ ☐ From 1-3 m$

☐ From 4-5 m$ ☐ More than 5 m$

Part II: Questions related to the VE methodology application

Please complete the following questionnaire with specific regard to the above enquiry, by placing a TICK √ in the appropriate box (more than one answer is accepted)

Pre-Workshop Phase:

1. **The objective of the pre-workshop phase should be to:**
   - ☐ Clarify the project background and required information.
   - ☐ Explore owner preferences
   - ☐ Provide VE team with design information
   - ☐ Preparation of the models to be used in the workshop

2. **The most efficient parties to involve in the pre-workshop phase:**
   - ☐ Owner (or owner representative)
   - ☐ Beneficiaries
   - ☐ Team leader
   - ☐ Team coordinator
   - ☐ Team members
   - ☐ Other parties

   ……………………………………………………………………………………………

3. **Which of the following models you think has to be prepared at this stage by the facilitator (Value engineering specialist):**
   - ☐ Cost model
   - ☐ Cost worth model
   - ☐ Function analysis model (FAST)
   - ☐ Life cycle model
   - ☐ Others (specify):

   ……………………………………………………………………………………………........

Workshop Phase:

4. The project documents that should be prepared before workshop:

- ☐ Design Drawings
- ☐ Cost Estimation model
- ☐ Bill of quantities
- ☐ Technical Specifications

5. During workshop, it is preferred determine the items under investigation via:

- ☐ Owners preferences
- ☐ Team members' judgments
- ☐ Pareto rule
- ☐ Other criteria (define)

……………………………………………………………………………………………….

6. The scope of computerization of workshop phase can be accepted for:

- ☐ Ideas visualization only.
- ☐ Alternatives generation.
- ☐ Cost Estimation
- ☐ Alternatives Evaluation
- ☐ All Above

7. Evaluation of ideas upon multi criteria can be effectively accomplished using

- ☐ Weighting method
- ☐ Matrix method
- ☐ AHP method

Post Workshop Phase:

8. Feedback of the efficiency of VE study is to be made to:

- ☐ The value engineering specialist.

☐ The VE team

☐ The owner

☐ The project manager

9. Other evaluations would be helpful for future development, like (more than one selection is possible):

☐ The beneficiaries from the project

☐ The maintenance engineer/company.

☐ The Architect

☐ Others (define)

……………………………………………………………………………………………….

Part III: Questions related to the VE & BIM tools used during VE application

From your previous experience and VE & BIM techniques please answer question three by write your opinions or suggest benefits for using of the VE & BIM Techniques

Questions	**Answer**	
1- **Do you apply VE?**	Yes ( )	No ( )
Note: - If your answer is (yes), please answer the second question by placing a TICK √ in the appropriate box.		

	Workshop steps	**Value Engineering & Building information modeling BIM Techniques**					
		Pareto Diagram	Quality Model	Affinity Diagram	FAST Model	Rivet Program	RSmeans Program
2- **Do you apply any of recommended BIM & VE Techniques in each phase of VE workshop?**	1) Data collection						
	2) Functions analysis						
	3) Creativity and ideas generation						
	4) Evaluation and selection						
	5) Searching and development						
	6) Proposals presentation						

Part IV: Questions related to the Factors Influencing Value Engineering application.

Please complete the following questionnaire with specific regard to the above quiry, by placing a TICK √ in the appropriate box

Factors		**Indicator's Weighting**				
		Extreme ly	**Very Importa**	**Importa nt**	**Not Importa**	**Extreme**
Pre-workshop factors						
1.	Clear objectives of workshop					
2.	Client's participation					
3.	Client's support					
4.	Disciplines of participants					
5.	Qualification of facilitator					
6.	Relevant stakeholders' support					
7.	Satisfaction of the time when the VE Workshop will be conducted					
8.	Disciplines of participants					
9.	Years of professional experience of participants					
10.	Years of experience of facilitator (Value engineering specialist)					
11.	Qualification of facilitator (Value engineering specialist)					
12.	Number of pre-workshop meetings held.					
13.	Time spent on preparation before workshop.					
14.	Number of related documents analyzed					
Workshop factors						
15.	Background information collected					

16.	Client’s objectives clarified					
17.	Interaction among participants in each phase					
18.	Primary functions/processes identified					
19.	Project givens/assumptions clarified					
20.	Duration of each phase					
21.	Satisfaction on the techniques used in each phase					
22.	Primary function identified					
23.	Number of ideas generated					
24.	Equal contribution of participants					
25.	Efficiency of idea generation					
Post-workshop factors						
26.	Percentage of action plan without uncertainty carried out					
27.	Quality of the report					
28.	Accelerating the decision-making					
29.	Client’s satisfaction					
30.	Identifying and clarifying the client’s requirements					
31.	Improving communication and understanding among stakeholders					
32.	Improving the project quality					

Thank you for your participation