Ain Shams University
Faculty of Engineering
Architecture Department

Integrating Value Engineering in the design of Intelligent Buildings

A Thesis submitted to the Faculty of Engineering in the partial fulfillment of the requirements for the degree of Master of Science in Architecture.

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Dedication…

I dedicate this thesis to my Family, especially…

My dear Father, Mother and Brothers,
And
My supporting Wife and lovely Sons…

Every one of you had set an example in a way that brought along this success, without your continuous support, patience, love and sacrifice; it would have been a lot harder for me to be who I am.

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Statement

This Thesis is submitted to Ain Shams University, Faculty of Engineering in partial fulfillment of the requirements of Master of Science Degree in Architecture.

The work included in this thesis was accomplished by the researcher at the Department of Architecture – Faculty of Engineering – Ain Shams University, in the period between "2006 – 2012". No part of this thesis has been submitted for a degree or a qualification at any other University or Institute.

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Abstract

There is undefined relation between the value engineering concepts and the intelligent building in optimizing the value and cost of the building during its life cycle time. The research aims at defining the architectural parameters that achieve the integration of value engineering in the design of intelligent buildings.

The research study the value engineering methodology application and techniques and focuses on the life cycle costing technique defining and explaining the methodology of calculations of this technique as it is used in the analytical application.

The research discuss the intelligent buildings from an economic perspective illustrating the design criteria of these buildings and the market demand for the intelligent building demonstrating the reasons for extra initial cost and the reduced life cycle cost.

The research presents a value engineering study for two traditional buildings, illustrating the step of application of the value engineering methodology and the techniques used. The analytical study aims at highlighting the architectural value engineering proposed ideas that affect the life cycle cost of the building.

The research also analyzes local case studies buildings applying value engineering study for the façade elements of the building and studies the consequences of using the proposed intelligent alternatives suggested by the value engineering on the life cycle cost of the building.

Finally, the research introduced a set of conclusions and recommendation to motive the design of intelligent buildings under the scope of value engineering and the research suggests a “value engineering check list for intelligent buildings”

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Introduction

Introduction

The successive rapid development of information and technology revolution remarkably affects the daily life of various aspects. This revolution had a clear effect on the construction systems and building materials, which resulted in conversion of buildings from traditional buildings to intelligent buildings.

The intelligent buildings have principles and unique design basis, which support the building with vital effective systems and automated controls for the purpose of supporting its functions and activities. Besides, the necessity of conserving energy, and directing towards making use of renewable resources, the intelligent buildings fulfilled this purpose with its smart systems to exploit the available abilities. Taking in consideration, the high price of this type of buildings as the systems used in it is highly complicated technique but it aims to achieve savings on the long-run.

On the other hand, the value engineering; it is a unique process and comprehensive revolution that seeks to reduce expenses as far as the function is accurately achieved. The value engineering is concerned with quality and performance providing more money instead of wasting it in vain. The concept of value engineering study with its wide scope includes not only the initial cost but also the life cycle cost of the building.

Both noble concepts' scope along the whole life cycle of the building, targeting the optimization of building quality and its life cycle cost.

Problem Statement

The fact that the new technologies affect the building design field towards the intelligent buildings and on the other hand, the increased initial cost of these buildings drives the investor away from the initiating of such buildings.

The fact that construction investment is tremendously increased during the last decade. This fact emphasizes the need to optimize the project's cost with such techniques of value engineering, which could realize potential savings during project life cycle.

The fact that the value engineering studies for traditional buildings concentrates mainly on initial cost savings, as it is the eye-catching figures for the owner although the LCC is an integral part of the value engineering studies and techniques.

The research problem is the undefined relation between the concepts of value engineering and intelligent buildings in optimizing the value and the cost of the building during its life cycle time.

Research Goal

The research aims at defining the architectural elements that achieve the integration of value engineering strategies in the design issues of intelligent buildings.

The main goal is fulfilled through a group of secondary goals:

- Define the value engineering strategies and applying methodologies.
- Determine the basis and standards of the life cycle cost calculations.
- Study the design criteria of intelligent buildings from an economic perspective.
- Analyze applied examples aiming to identify the following:
  - Present the procedures and the results of value engineering application in optimizing the building life cycle cost.
  - Present the consequences of applying the intelligent alternatives on the life cycle cost of the intelligent buildings.
- Deduce the relation of value engineering integration in intelligent Buildings.

Research Scope and Limitations

- Research Scope

1. Studying the architectural elements that achieve the integration of value engineering in intelligent buildings
2. Studying and analyzing case studies of intelligent buildings where varies intelligent features and systems are implemented. The research focuses on applying the value engineering study on the architecture elements of the façades only.

- Research Limitations

1. The value engineering Study is only concerned in the design stages and not during or after construction.
2. The analytical examples are concentrated on the public buildings.

Research Hypothesis

The main hypothesis of the research is applying the intelligent buildings features under the value engineering perspective, this integration will optimize the value and life cycle cost of the building.

Research Methodology

The research relied on three approaches:

- **Theoretical approach (Chapter 1 & 2)**

This approach is used to study the value engineering by defining, explaining and demonstrating its study phases, job plan and techniques. Besides, Studying the life cycle cost showing its applications, considerations and the relationship to the value engineering. Then Knowing the intelligent building's design criteria and the economic vision of these buildings on its life cycle.

- **Analytical approach (Chapter 3 & 4)**

This approach is used to present two sets of analytical examples:

- Analyzing the application of value engineering in the design on previous tradition projects, analyzing them and study the results of this application on the life cycle cost of the building.
- Analyzing two case studies of intelligent buildings in Egypt, evaluating them according to the intelligent building's design criteria, and study the effect of applying value engineering proposed intelligent features on the life cycle cost of the building.

- **Deductive approach (Conclusions & Recommendations)**

This approach is used to join the results abstracted from analyzing the previous examples, and got into conclusions in the form of "value engineering check list for intelligent buildings". Then set of recommendations enhancing the integration of value engineering and intelligent buildings.

Research Contents

The research consists of four chapters further to the Introduction and the conclusions & Recommendations. The introduction includes the research problem, goals, scope and methodology.

Chapter 1: Value Engineering and Life Cycle Cost Analysis

The first chapter discusses the value engineering methodology and techniques and discusses the life cycle cost analysis.

Chapter 2: Intelligent Buildings in Economic Perspective

The second chapter discusses the economic issues of intelligent building's and highlighting the design criteria of these buildings.

Chapter 3: Value Engineering Applied Examples

The third chapter includes a practical value engineering application implemented on previous projects and the research highlights the areas of life cycle cost savings.

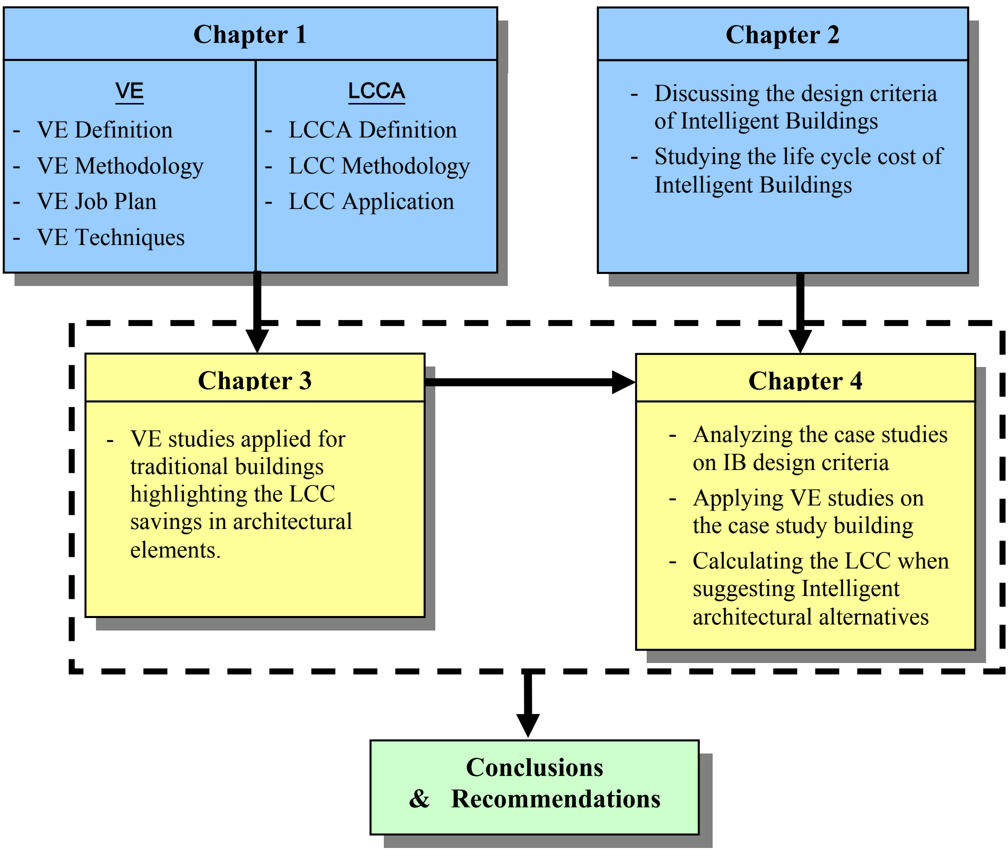
Chapter 4: Value Engineering Case Studies for Intelligent Buildings

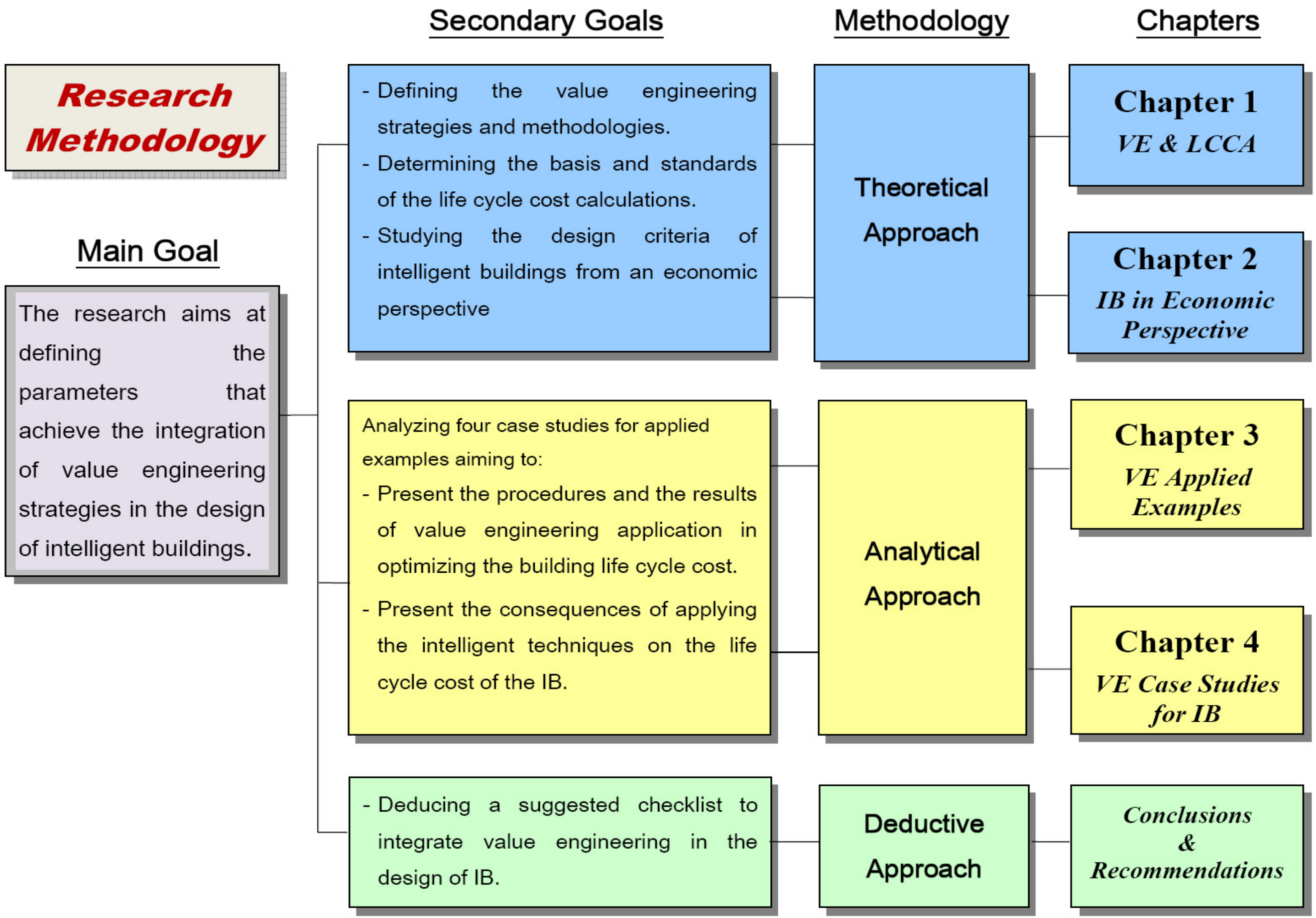
The fourth chapter includes a case study of intelligent building, analyzing them with the abstracted criteria of intelligent building and evaluating the façade elements through the value engineering techniques of life cycle cost analysis.

Conclusions and Recommendations

The research presents a set of conclusions, and of a suggested checklist of integrating value engineering in the design intelligent buildings. Besides, a set of recommendations for the field of construction and for the future studies.

Research Structure




Research Methodology
Main Goal
The research aims at defining the parameters that achieve the integration of value engineering strategies in the design of intelligent buildings.
Secondary Goals
- Defining the value engineering strategies and methodologies.
- Determining the basis and standards of the life cycle cost calculations.
- Studying the design criteria of intelligent buildings from an economic perspective
Analyzing four case studies for applied examples aiming to:
- Present the procedures and the results of value engineering application in optimizing the building life cycle cost.
- Present the consequences of applying the intelligent techniques on the life cycle cost of the IB.
- Deducing a suggested checklist to integrate value engineering in the design of IB.
Methodology
Theoretical Approach
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Deductive Approach
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VE & LCCA
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Literature Review

(Meetkees, O. 1997) prepared a Ph. D. study involving the utilization of VE approach to planning and design phases of long span bridges. He has discovered that VE application aid planners and designers achieve optimal planning, design and construction solutions. He studied one of the vital and largest long span bridges in Egypt, El-Moneeb Bridge, including a full and comprehensive analysis particularly studying planning alternatives and its effect on the level of traffic services. Long term and short term losses due to poor planning were also estimated with consideration to time value of money.

(Amen, A. 1998) proposed the utilization of VE approach as a development technique to assist developing the architectural product being designed and the design process itself in the open and urban spaces. He displayed three samples of new developed cities in Egypt, in which he utilized the VE to define the most low cost and higher quality design solution, in the way of remove all unnecessary cost and the creative alternatives of the designed solutions. The result of the study shows how efficient the utilizing VE in the early design stages is to avoid the unnecessary costs generated from the late decisions.

(Omar, A. 2004) emphasized the value engineering methodology is the way to solve the medium cost housing problems in Egypt. As the problem in his view represented in the unnecessary cost that associate the design decisions of the housing projects and cause the status in housing market. The value engineering could propose the optimum solutions with the lower cost and higher quality, by evaluating the three approaches of the housing problem, design approach, social approach, and economical approach.

(Nassef, A. 2006) constructed a computer model to go systemically through the VE steps especially for the construction of universities buildings type, using the bank of ideas generated from the field investigation for 23 of selected samples represent a certain segment of firms and projects in Egypt.

(Felex, M. 2007) proposed the utilization of VE approach as a cost oriented technique that could realize the sustainable development of the ancient buildings. She found the problem of historical buildings recovery is the associated unnecessary costs, maintenance costs and the life cycle cost of such buildings. It proposed the integration of both the value engineering methodology and the building recovery methods to abstract the optimum methodology of historical buildings recovery that could focus on the building associated costs and eliminate such costs.

(Wassef, A. 2008) established a comprehensive view of a strategy for office building design that does not consider the cost element alone, but deals with it as a component of an integrated system that produces a balanced working environment. Moreover, the research aimed to help the architects in achieving a high performance workspace with the lowest possible cost without affecting the needed quality.

Literature Conclusion:

Previous researches discussed the value engineering for design phases and construction, other researches have studied intelligent buildings with its various techniques. As for this research, it is a link point, which deals with the VE concept and methodology to get benefits from it in designing intelligent buildings with sufficient costs to the investor, and verifying the relationship between the intelligent building and the life cycle cost.

Chapter 1

Value Engineering and Life Cycle Cost Analysis

1.1- Introduction

The fact that the design process of buildings faces many obstacles, especially that of intelligent buildings, where sophisticated techniques and materials are needed. On the other hand, the expenses of such type of buildings are relatively high. From this point, the value engineering is a proven evaluation technique that could optimize the design decisions with the lowest overall cost.

This chapter discusses the value engineering, its terminology, definition and historical development, objectives and the methodology. It illustrates the value engineering job plan that achieves the methodology. This chapter addresses the life cycle cost analysis in details, as it is one of the value engineering techniques that are linked to the intelligent building's concept.

1.2 Value Engineering Terminology and Definition

Value studies are known with different terminologies, value analysis, value management, value control and value engineering. The term Value Engineering is synonymous with value management, value analysis, and value control. Some of these terms were coined to minimize confusion about the word engineering. (1)

The definition was regularized by pronouncing that value analysis "VA" is a term used when this technique is applied on an existing product while the term value engineering "VE" is used when applied at the design stage. (2)

Value analysis "VA" is the border concept of these value studies, from the management side it is Value Management "VM", and is named Value engineering "VE" from the engineering's point of view.

The scope of this study is the design of intelligent buildings. Subsequently, the thesis will use the terminology Value engineering (VE) in all its chapters.

There are varies references defining VE with synonymous meaning; these definitions are stated in "Appendix 1.1". After reviewing the VE definitions, the research select a definition where all meanings are integrated, it is as follows:

It is a professionally applied, function-oriented, systematic team approach used to analyze and improve value in a product, facility design, system or service, a powerful methodology for solving problems and/or reducing costs while improving performance/quality requirements.(3)

Value of an item = performance of its function / cost - eq. 1.1

(1) SAVE, Value standard and body of knowledge, 2007.

(2) Anil Kumar Mukhopadhyaya, Value Engineering Mastermind- From concept to VE certification.

(3) www.wendt.library.wisc.edu/miles/index.html, (accessed Oct. 2010)

1.3 VE History and Development

VE has its foundation in the manufacturing sector of North America, initially called Value Analysis (VA). VA concept evolved in 1940 during World War II at the general electric company (GEC) when shortage of strategic materials and labors forced the introduction of many substitutes that perform the same function. The company's purchase engineer* developed a system of techniques -which is called first value analysis- that made significant improvements happen systematically rather than by accident. Then these methods were adapted to other productive processes. (1)

In 1954, US Department of Defense became the first US government organization to implement a formal program of VA; they applied VA to cost improvement during design. At that time, the name was changed to VE for an administrative reason that engineers were considered the most appropriate persons to undertake the task: (2)

- In 1958, the American Society of Value Engineering (SAVE) is established. In 1963, The VE concept is introduced for the construction industry into the Navy Facilities Engineering Command, principally through the introduction of Department of Defense, VE incentive provisions in construction contractors.
- Then, in 1968, the Public Building Services was the first agency to utilize VE requirements during Architect/Engineering contracts.
- In 1970, the US congress endorsed VE by recommending its use on federal aid highway projects.
- In 1972, the next large expansion of VE occurred in the firm of Construction Management (CM) with a VE requirement written into the required scope of work for CM services.
- In 1975, the US department of transportations' federal high way administration awarded a contract to a private firm to conduct its national training program.

Outside the US, the Japanese introduced VE in 1970 through the auspices of Institutes of business and management of Tokyo. In 1978, Italians began utilizing VE through the firm called Chemint of Milan. In Canada, the British Columbia Building Corporation established a VE program in 1978. The Australians followed in 1979. In Saudi Arabia, the General Directorate of Military Works has had a fulltime program for VE since 1989.

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1982, P.1.

(2) Kelly,J. Best Value in Construction 2002, London: RICS foundation science LTD, P 77.

* Mr. Lawrence D. Miles, a purchase engineer of the GEC, was assigned the task which was defined as "Finding a more effective way to improve a product value". He is considered the Father of VE.

Fig 1.1 illustrates the VE development milestones in the US and outside the US. The historical background of VE and development emphasizes that it is applicable in all sites that is seeking for improving value and optimizing the cost, using the tool of analyzing the functions. Especially the general orientations these days are saving the environmental resources that lead the designer to analyzing the function carefully to implement it with the lowest energy consummation accordingly with lowest life cost available. On the other hand, the investors in the building construction field need to optimize their investments; the VE is a management tool that can achieve this goal. (1)

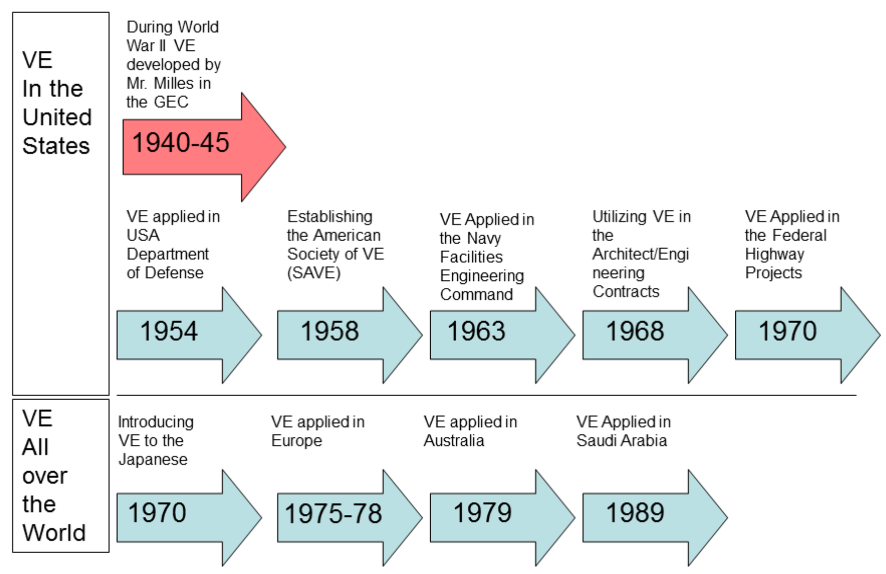

Figure 1.1: VE milestone (By Researcher)

1.4 VE objectives

The main objectives in the VE are optimizing the 3 factors mentioned in the definition and illustrated in the following equation: (2)

$$\text{Value} = \text{Function} / \text{Cost} \qquad \text{- (eq 1.2)}$$

1.4.1 Value

The true value of an activity or product is its relationship to its perceived worth as opposed to its life-cycle costs. When an item has a value greater than 1.0, then the item is perceived to be a fair or good value. When an item

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1982, P.1.

(2) Anil Kumar Mukhopadhyaya, Value Engineering Mastermind- From concept to VE certification.

has a Value is less than 1.0, the item is perceived to be a poor value or bad value. [1]

1.4.2 Function

The function of a product involves many features. The most common cited are: benefits received, services obtained, satisfaction of the product performance, quality, safety, and convenience. The function of the product is a measure of what is in it for the customers involved. It is a measure of how well the end product meets the involved essential needs and the added desires of those that have a voice in the product selection or its use. A product must always supply the essential need, or its worth will be poor. [2]

1.4.3 Cost

The true cost of an item is not just the amount of money that is paid immediately. Much more is involved is its long-term effects. The initial costs plus these long-term costs is called life-cycle costs. These include things like the time involved to get the project done, the people needed (number, expertise and etc…), the degree of difficulty involved, availability of money or other resources, the amount of maintenance needed, and the money that must be expended and kept in reserve[2]

The main goal of VE is the identification and removal of unnecessary costs. The unnecessary costs are those costs that do not contribute in the essential functions, reliability, quality and maintainability. These costs are that add nothing to the value of the project.

There are unnecessary costs that can be classified according to the area or field in which it occurs or found are as follows: [3]

a) Unnecessary attributes:

These are the costs of attributes which provide no useful function.

b) Unnecessary specification:

These are the costs due to needlessly expensive materials and/or specified component.

c) Poor buildability:

These are the costs due to a failure in considering construction implications of design choices.

d) Unnecessary life cycle cost:

These are the costs due to failure in consideration future operations; costs of design choices.

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(1) www.value-eng.com (accessed October 2010)

(2) ibid.

(3) Connaughton, J. & Green, S., Value Management in Construction: a client's guide, London, Construction Industry research and Information Association, 1996, P 37.

e) Unnecessary opportunity cost:

These are the costs of losing potential revenue. Failing of generate revenue is just important as wasteful expenditure.

The unnecessary costs occur due to many factors as an unnecessary material, component and poor design. Other factors which create unnecessary costs include the following: (1)

- Lack of information.
- Lack of ideas.
- Lack of time (Time Pressure).
- Lack of communication & coordination.
- Negative attitudes
- Wrong beliefs
- Strict adherence to requirements.
- Single solution fixation.
- Outdated standards or specifications.

Value, Function and Cost are the VE fundamentals, VE techniques are the approach to achieve a number of objectives. They can save money, reduce time; improve quality, reliability, maintainability and performance.VE can also extend to the project resources, financial, manpower and material, by eliminating unnecessary or excessive cost without sacrificing quality or function. (2)

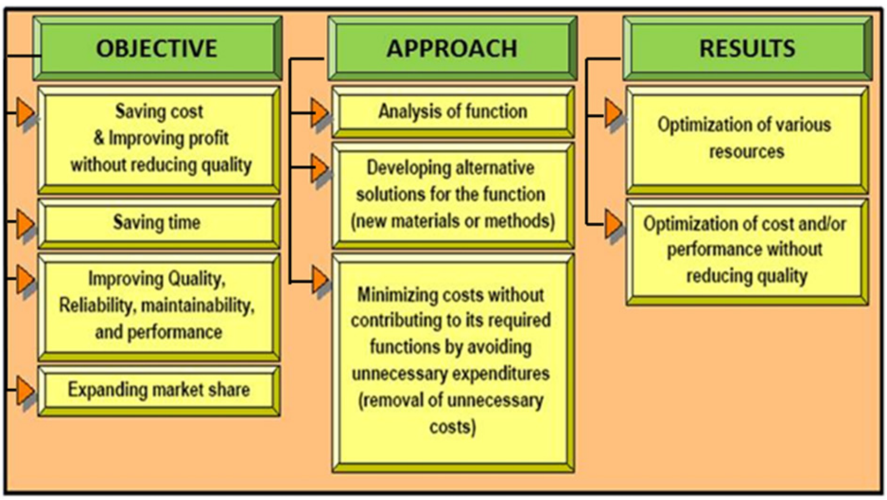


Table 1.1: VE Objective, approach and result (3)

(1)Mukhopadhyaya, Anil Kumar, VE Mastermind, from concept to VE certification, India, New Delhi, Chairman Enterprises,2009, P 40,41.

(2) www.value-eng.com (Accessed October 2010)

(3) Prof Mohamed Askar, Training Course in VE Techniques, Cairo University, April 2005.

Three Basic elements provide a measure of value to the user: Function, Quality and Cost. The following relation can express these elements:

$$\text{Value} = \frac{\text{Function} + \text{Quality}}{\text{Cost}} \quad \text{(eq 1.3)}$$

(1)

Where:

Function: The specific work that a design/item must perform.

Quality : The owner's or user's needs, desires, and expectations.

Cost : The life cycle cost of the product.

This expression is in the form of a ratio and can be improved as per the modification(s) stated as:

1. The function is improved, but the cost remains the same.
2. The function is the same, but the cost decreases.
3. The function is improved and the cost reduces.
4. The function is improved at a greater pace than the cost increase.
5. The function is reduced and the cost reduced at a faster pace.

	Function & Quality	Cost	VE
1	Improvement	Decreased	VE Objective
2	Improvement	Constant	
3	Improvement	Reduced	
4	Improvement	Increased	Not Preferable
5	Decreased	Decreased	Refused

Table 1.2: VE Objective (By Researcher)

Table 1.2 summarizes the interaction in-between the poles of VE and how it affects the value. Thought from a mathematical point of view, all the mentioned expressions are correct, but from the VE parlance, the forth expression is accepted but not preferred because VE is not as traditional cost reduction methods, while the fifth expression is not acceptable. This is because in any way the function can't be reduced or in other words the items can't be made less reliable. (2)

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P.xix.

(2) Mukhopadhyaya Anil Kumar, VE Mastermind, from concept to VE certification, India, New Delhi, Chaman Enterprises,2009.

1.5 VE and Traditional Cost Reduction

It is essential to confirm that VE is not a traditional cost reduction (CR) management method. Table 1.3 shows the differences between VE and CR.

	VE	CR
Definition	An organized effort directed at analyzing the functions of projects for the purpose of achieving the necessary functions at lowest overall cost, consistent with achieving essential characteristics.	A cost cutting technique, which focuses on parts which might result in quality or performance reduction in order to meet the goal of reducing the budget, by the amount or percentage, set by management.
Characteristics	Focus on making explicit the client's function requirements.	Focus on cost reduction or substitutions.
	Study the function of an object and ask: Why should it do and How can its function be performed better or for less?	Study the structure of an object and ask: What is it? How can we make it cheaper?
	It is critical to appreciate that VE is not: • What is already done naturally • Merely an attempt to remove "gold-plating" • A means of reducing costs by substitutions which do not meet the client's requirements, i.e. Lower performance.	Traditional CR approaches don't typically have the following features: • Function orientation. • Use a multi-discipline team work approach. • Use of specific VE techniques such as function analysis.
	Consider the balance among three major elements of any project (function, Cost and quality)	Delete parts or elements of the project (essential elements) or replacing specified items with cheaper ones.
	VE seeks effectiveness.	CR focuses on efficiency.

Objectives	Increase value, reducing cost without affecting or reducing quality, reliability, by either making the performance of a design, space better, and/or the cost of it is less. i.e., cost is the only aspect which can be reduced.	Reduce cost which in many cases reduce the quality and consequently reduces the value of the product.
	Provides multi-disciplinary reviews at milestone points.	Consist of one-step procedure.

Table 1.3: A comparison between VE and CR [1]

1.6 Interacting Concepts with VE

Two concepts of building's life cost are interacting with VE: the Life Cycle Cost (LCC) and the Whole Life Costing (WLC).

The concept of the building's life cost with both terminologies -Life Cycle Cost (LCC) and Whole Life Costing (WLC) - are interacting concepts with VE, as follows:

- **LCC:** is an economic assessment of an item, area, system, or facility that considers all the significant costs of ownership over its economic life, expressed in terms of equivalent currency of money. [2]
- **WLC:** is an economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability.

The difference between LCC and WLC is that: Life cycle costs are those associated directly with constructing and operating the building; while whole life costs include other costs such as land, income from the building and support costs associated with the activity within the building. The expertise of the construction industry is best placed to deliver life cycle costs, which its clients can then use to calculate whole life costs. [3]

Figure 1.2 illustrates that WLC considers LCC. It is very difficult to take decisions at the feasibility stage related to the whole life of a proposed building with any degree of confidence. The reason is that it could change owner, occupier and function several times during the building life cycle.

(1) Alsheash, S. (1993) Why some managers think in VE as a CR. In proceedings of the 1993 International Conference of the SAVE, Florida, 1993.

(2) Sieglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program, P.17

(3) www.willmottdixongroup.co.uk, (accessed in October 2011)

As a VE tool, LCC enables the team to measure the quality of an alternative and assists decision makers in evaluating VE recommendations. LCC analysis should be performed before any major decisions are made regarding large construction projects that involve significant follow-on costs. To perform accurate LCC analysis, the VE team must have detailed information about the economic life of the project or facility, the operating cost, the anticipated rate of return on investment, and even the owner's cost of money. (1)

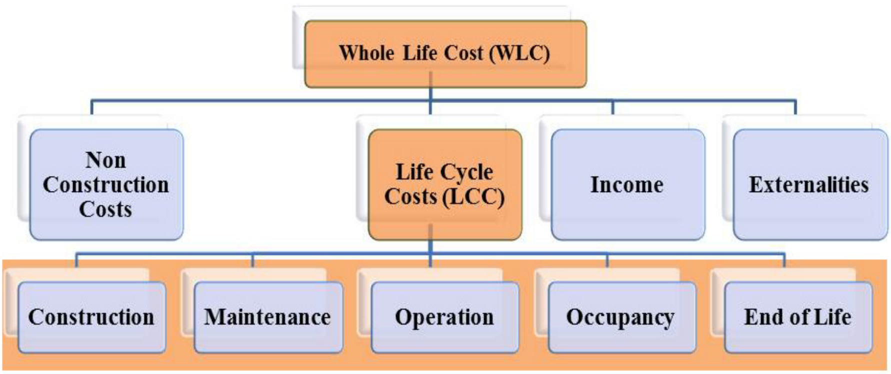
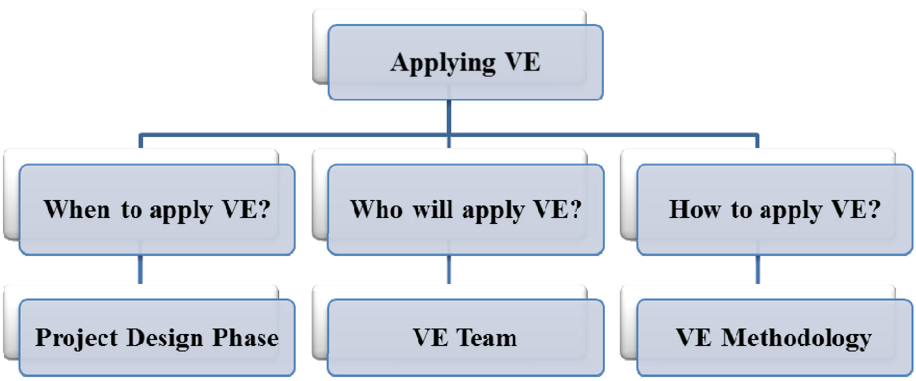


Figure 1.2: WLC and LCC (2)

The VE team has to consider the LCC that includes all significant costs – initial and future costs- as illustrated in figure 1.2, all these costs have to be calculated to a common baseline (i.e. net present value).

1.7 Applying VE

While thinking in applying VE, there are three questions that have to be answered: When to apply VE, Who will apply VE and How to apply VE?



(1) Prowler, D. Whole Building Design. Washington, DC: National Institute of Building Sciences, Steven Winter associated, Inc. 2007.

(2) www.willmottdixongroup.co.uk, (accessed March 2011)

First: When to apply VE? It should be performed in the early stages of design phases - before commitment of funds, approval of systems, services, or design - to maximize the results. The potential for savings, as shown in fig. 1.3 is much greater the earlier VE is applied. When VE is applied in later stages, The investment required to implement any changes increase and resistance to change increase. (1)

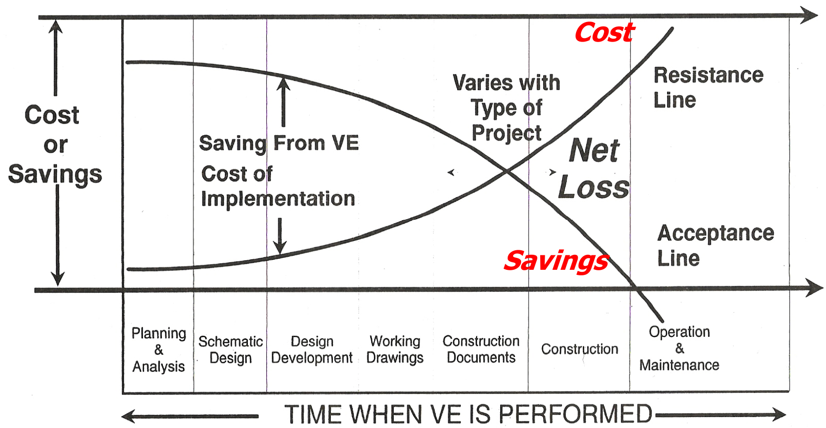


Figure 1.3: Potential saving for VE applications (2)

Second: Who will apply VE? A VE Team that presents different project's disciplines is the approach to make a successful VE study. Fig 1.4 illustrates that Using the team approach is a proven way of overcoming many obstacles. The individual effort is costly, inefficient, and incomplete while the team effort concentrates on problem solving techniques to break through obstacles. (1)

To assure free thinking and unbiased opinions, it is recommended to use the mixture of people from inside and outside the project design team, considering also experienced engineers from other Company offices. A good rule to follow is to seek out team members with equal or better qualifications than the original design team. The specialists whom the team consists of are shown in fig 1.5.

The VE Consultant with a specific expertise in all aspects of VE should be considered to lead a workshop in order to structure the approach, streamline the process and to improve the effectiveness of the program.

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997. P xix

(2) Ibid, P xxiii

(3) Ibid, P xxii

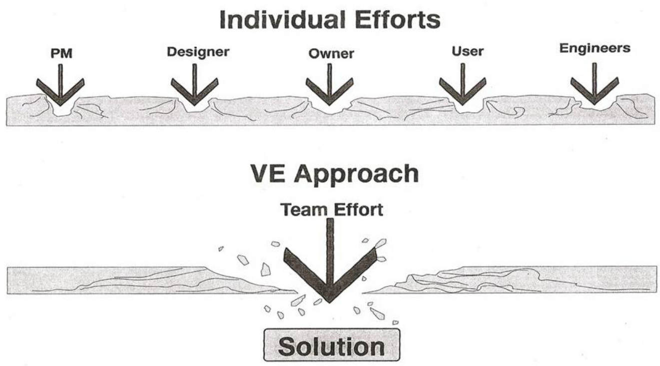


Figure 1.4: Effect of VE team approach [1]

The cooperation of the owner contributes significantly to the success of the VE exercise and to the ultimate acceptance and implementation of final VE recommendations.

The team members are selected on a basis of subject evaluated, however, the Project Engineering Manager and Process Supervisor shall participate whenever any design aspects are reviewed. The same applies for Procurement Manager and Construction Manager in their domains. The Project Director/Manager will not be a member of the value engineering team. He will in most cases perform the role as a team sponsor and will attend a kick-off and wrap-up meeting as an observer, ensure the availability of task force resources to the team. [2]

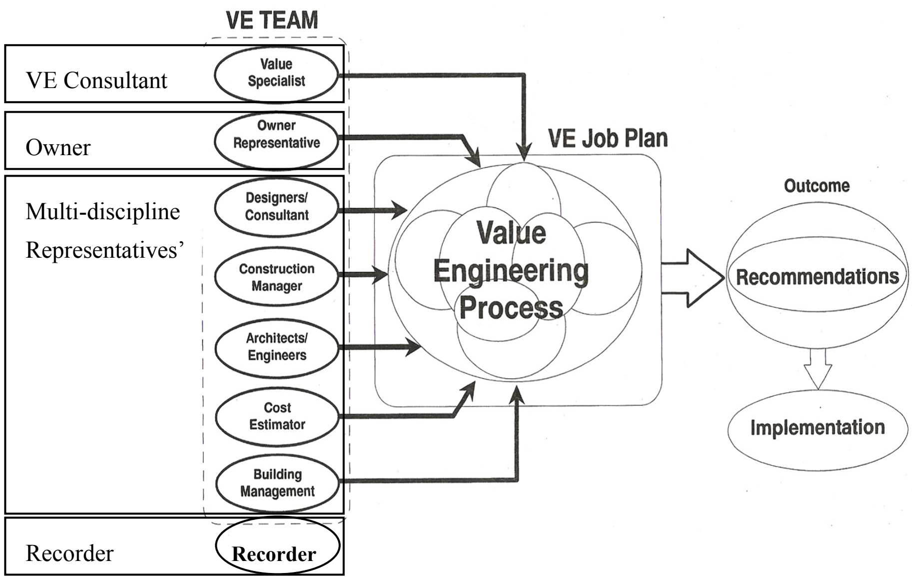


Figure 1.5: VE Team members applying the Job Plan [3]

(1) Ibid P xxv

(2) Ibid, P xxiii

(3) Ibid, P xxvi

Whereas decision makers' have different impact on the project cost Fig 1.6 shows whose decision has the most influence over the expenditure of funds during the life cycle cost of a facility.

As illustrated in the fig 1.6, as the owner and the designer have the biggest influence respectively. This emphasizes what is elaborated before in fig 1.3, where the maximum savings are from the planning and analysis phase to before the beginning of the construction phase, where the owner and the designer are the main decision makers in these phases of the project. This may guide the team to work on these zones with the main decision makers as to get the maximum savings.

Regarding the total cost for a facility, the consultant's fee represents the smallest expenditure of all of the initial costs. Consultants' decisions influence about 50% of the facility's total costs. Therefore, the optimum results can be expected when resources are set aside for VE early in the design process, focusing on owner and consultant impact. (1)

On the other hand the operation and maintenance have the lowest influence on decision making but it must be taken in to consideration although of its lowest influence, as it plays the longest role through the life cycle of the project.

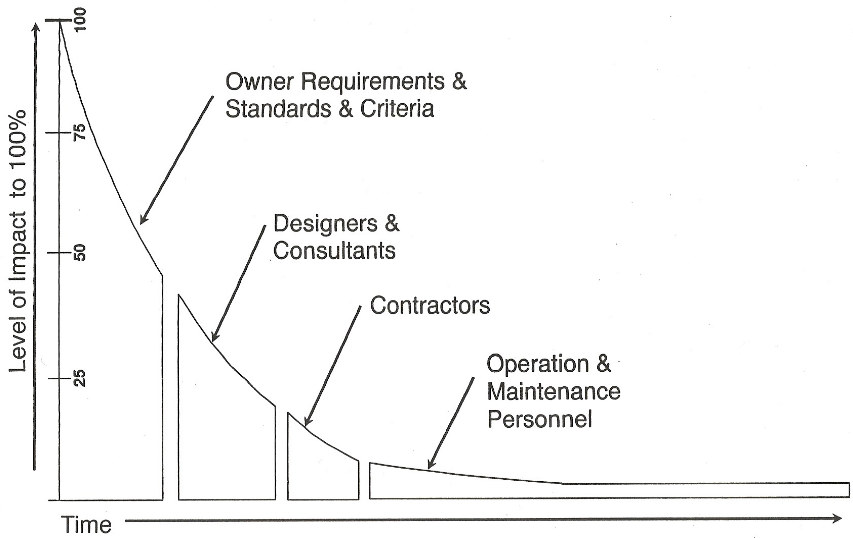


Figure 1.6: Major decision makers' influence on facility cost (2)

Value Team members are expected to participate in a Value Study in the following ways: (3)

- Participate in all meetings

(1) Ibid P xxii

(2) Ibid, P xxiv

(3) SAVE International, Value standard and body of knowledge, 2007. P21.

- Gather information as requested
- Analyze information
- Identify functions
- Evaluate ideas using their experience and expertise
- Develop alternatives
- Present results

The Team Members' Responsibilities are as follows: [3]

a) Keeping accurate notes as assigned by team leader.

b) Consulting with team leader on any problem that may handicap progress.

c) Showing respect through timely attendance.

d) Sharing workload equally whenever possible.

e) Being willing to admit if they don't know; but strive to get the answer. Don't be afraid to make mistakes.

f) Staying focused - avoid tangents - follow the basic problem-solving steps and get help from Value Team Leader on what techniques may be most suitable for the particular problem.

g) Conserving time discussing whether or not a step should be used; do it and evaluate it all after the entire workshop.

h) Understanding the approach being taught and its purpose, including the reason for each step and the technique being applied.

i) Doing the job together as a team. Don't force individual solutions - sell them! Remember, there can be more than one solution to a problem.

j) Being a good listener; don't cut people off and don't second guess what other people are going to say and what they are thinking.

Concerning the third question How to apply VE? There is a methodology to apply VE. The VE methodology will be explained in details in the following part of this chapter.

(1) Ibid.

1.8 VE Methodology

The core of VE is in its organized methodology, by which the functions are deeply analyzed in order to exclude the unnecessary costs and optimizing the value.

The VE methodology is the task done by the VE team. First the team prepares the VE records which identify the points that will be held in the heart of the workshop through the VE job Plan.

1.8.1 VE Records

All VE team members should look for innovations and improvements and bring those to the attention of the Project Manager on the special “Value Engineering Record” form. The form should be completed by the value specialist in sufficient details and submitted to the Project Manager for review and decision. The Project Manager shall register the form and decide on further disposition. Improvement ideas that are accepted by the Project Manager will be covered on a Change Request This request is subjected to the team as to start the VE workshop. (1)

1.8.2 VE Workshop

As elaborated above, the VE covers almost every aspect of design phases that is from conceptual and project specification phase, detailed design, and selection of materials, constructability, operations and maintenance. Value and quality do not conflict, but a balance needs to be established based upon experience and owner direction. While the early stages of engineering and design provide the most opportunities for affecting the value elements, VE should be considered at all stages of the project.

VE should be planned in various sessions in the stages of the project when the maturity of design info is suitable for this exercise. A multi-discipline team must be established to formalize and document the value analysis.

The VE workshop allows the team to evaluate the information in a structured format. The objectives and scope of the subject evaluated are analyzed using the VE functional approach.

The current design is evaluated against the functions identified by the team, to check for technical, cost optimization and other considerations to ensure the optimum design has been presented. Any alternatives are also evaluated identifying the benefits and risks of any changes to the alternative design.

The components for a successful VE program are an organized, multi-disciplinary approach in which there is an open door policy for ideas to be input by every team member regardless of rank in the project. Creative thinking must be encouraged and brainstorm techniques shall be used.

(1) www.red-bag.com/jcms/index.php/general-procedures. (accessed October 2010)

It is necessary to outline project constraints prior to the value engineering workshop. In this way the value engineering team does not make recommendations that are contrary to the design of the client. (1)

1.8.2.1 VE Execution Process (VE Job Plan)

The VE job plan is a systematic means for carrying out a value analysis study, and also the sequence in which they must be performed. It is a road map to follow. (2)

The job plan is a step-by-step application of all the techniques in an organized manner. Although it is fundamentally systematic, its value may be enhanced considerable by flexible application. This does not mean that steps can be omitted indiscriminately nor than they can be used in a random sequence. (3)

Every project to a certain extent is unique. Therefore VE activities will be customized to fit the projects unique needs. Mr. Miles' original job plan system was a six-step procedure which he called the "value analysis job plan”. Others have varied the job plan to fit their constraints. Depending on the application, there may be four, five, six, or more stages. However VE job plan is divided by the VE pioneers to several steps, Table 1.4 illustrates the development of the job plan steps and process according to the VE pioneers opinion.

From the comparison shown in table 1.4, all the phases are basically similar in approach and sequence. The original system was a six-step procedure which is called the "value analysis job plan"

(1) www.red-bag.com/jcms/index.php/general-procedures. (accessed October 2010)

(2) Thomas King, Principles of Value Analysis/Engineering, Dallas: Society of American Value Engineers, 1979, P 3.

(3) Edward Heller. Value Management: Value and Cost Reduction, London: Addison-Wesley Publishing co., 1971, P 51.

	Lawrance D. Miles 1967	Blyth & Woodward 1967	Arthur E. Mudge 1971	Edward D. Heller 1971	Thomas R. King 1979
1	Orientation phase		Project selection phase		
2	Information phase	Information phase	Information phase	Information phase	Information gathering phase
3			Function phase		Function analysis phase
4	Speculation phase	Creative Phase	Creation phase	Creative phase	Creative phase
5	Analytysis planing phase	Analytical phase	Evaluation phase	Evaluation phase	Analytical phase
6	Program excution phase	Execution phase	Investegation phase	Investegation phase	
7	Status summary & conclusion phase	Recommendation phase	Recommendation phase	Reporting phase	
8				Implementaion phase	Implementaion phase

	Zimmerman & Hart 1982	Alphonse Dell' Isola 1982	Lawrance D. Miles 1989	Alphonse Dell' Isola 1997	Save, Intenational 2007
1					
2	Information phase	Information phase	Information step	Information gathering step	Information gathering phase
3			Analysis step	Creative & idea generation	Function analysis phase
4	Creative phase	Speculative Phase	Creative step		Creative phase
5	Judgement phase	Analytical phase	Judgment step	Analyze ideas/evaluation &	Analytical phase
6	Development phase	Proposal phase	Development planning step	Development of proposal	
7	Recommendation phase	Final report phase		Presentation/implementation &follow up	
8					Implementaion phase

Table 1.4: VE job Plan steps according to pioneers point of view (1)

(1) Adapted from thesis of: Amr Hassan M. Hassan, "The Impact of the VE on the Decision Making and the Development of the Construction Industry" M.Sc Thesis, Faculty of Engineering, Architectural Department, Ain Shams University 2010.

Through the job plan the study identifies the key areas of unnecessary cost and seeks new and creative ways of performing the same function as original part, process or material. It allows the study team to go further than the usual design process. (1)

As illustrated before, the job plan is an organized problem solving approach that separates VE from other cost cutting exercises. The simplest job plan follows 5 steps approach as stated by Alphonse Dell'Isola in 1997:

a) Information gathering step.
b) Creativity and idea generation.
c) Analyze ideas/evaluation & selection.
d) Development of proposal.
e) Presentation/ implementation & follow up.

The research will discuss each step illustrating what are the activities of the team, the objective, and key questions that should be discussed, ending with the output in each step.

Table 1.5 illustrates the VE team members working in the five steps of the job plan. A detailed job description for each member in the team will be discussed in managing the VE study phases.

Table 1.6 summarizes the VE job plan, sorting the objectives, questions and the techniques used to achieve each step successfully.

	Job Plan Steps	***Team members applying the steps***
1	Information and gathering	Multi-discipline Representatives' (Designers/Consultant, Construction Manager, Architects/Engineers, Cost Estimator, Building Management)
2	Creativity and idea generation	
3	Analyze ideas/ evaluation and selection	
4	Development of proposal	
5	Presentation/ implementation & follow up	VE Consultant (Value Specialist)

Table 1.5: VE Team applying the job Plan (By Researcher)

(1) Larry W. Zimmerman & Glen D. Hart. VE: A practical Approach for Owners, Designers and Contractors, New York, Van Nostrand Reinhold Co., 1982, P 32.

a) Information gathering step.

Team activity: The team review and define the current conditions of the project and identifies the goals of the study. (1)

Objective: Understanding the current state of the project and constraints that influenced project decisions. (2)

Key questions: (3)

- What are the functions that being provided?
- What do the functions cost?
- What is the functions worth?
- What are the functions that should be accomplished?

Output:

This step brings all team members to a common, basic level of understanding of the project, including tactical, operational, and specifics of the subject. The functional understanding establishes the base case to identify and benchmark alternatives and mismatches and set the agenda for innovation.

b) Creativity and idea generation step.

Team activity: The team employs creative techniques to identify other ways to perform the project's function(s). (1)

Objective: Generating a number of ideas related to other ways to perform functions. (2)

Key questions: (3)

- What else will perform the function?

Output:

The team develops a broad array of ideas that provide a wide variety of possible alternative ways to perform the function(s) to improve the value of the project.

c) Analyze Ideas/Evaluation & selection step.

Team activity: The team defines the project functions using a two-word active verb/ measurable noun context. The team reviews and analyzes these functions to determine which need improvement, elimination, or creation to meet the project's goals. (1)

Objective: Reducing the number of ideas that have been identified to a short list of ideas with the greatest potential to improve the project. (2)

Key questions: (3)

- Which idea will perform the required function?

(1) SAVE, Value standard and body of knowledge, 2007. P5.

(2) ibid P 14-16.

(3) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P 64.

- How might each idea be done to work?

Output:

The team produces a focused list of concepts that warrant quality time to develop into value-based solutions that can be implemented into a project or a project feature.

d) Development of proposal step.

Team activity: The team develops the selected ideas into alternatives (or proposals) with a sufficient level of documentation to allow decision makers to determine if the alternative should be implemented. (1)

Objective: developing the ideas through further analyzing to develop a short list of ideas and develop those with merit into value alternatives. (2)

Key Questions: (3)

- How will the new idea work?
- Will it meet all the requirements?
- How much will it cost?
- What is the LCC impact?

Outputs:

The Value Study team creates alternatives and low, medium, and high-risk scenarios and offers these alternatives to senior management as options that address the Pre-Workshop strategic objectives.

e) Presentation/ Implementation & follow up.

Team activity: The Facilitator - team leader - develops a report and presentation that documents and conveys the adequacy of the alternative(s) developed by the team and the associated value improvement opportunity. (1)

Objective: Presenting value alternatives to management team and other project stakeholders or decision makers. (2)

Key Questions: (3)

- Why is the new idea better?
- What are the advantages/disadvantages and the specific benefits?
- What is needed to implement the proposal?

Outputs:

Ensure management and other key stakeholders understand the rationale of the value alternatives. Also generate interest to implementation.

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(1) SAVE, Value standard and body of knowledge, 2007. P5.

(2) ibid P 14-16.

(3) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P 64.

VE Job Plan steps	Information gathering step	Creativity and Idea generation step	Analyze ideas / evaluation & selection	Development of Proposal	Presentation / implentation & follow up
Objectives	• Provide an information base. • Describe problems. • Select areas with saving potenials. • Define functions. • Re-evaluate the criteria and constrains of the original design.	• Introduce new ideas to perform the basic function. • Introduce lower-cost alternatives. • Enhance optimum solutions for the design problems.	• Evaluation and selection of best cost saving alternatives. • Refining ideas to meet necessary environmental and operating conditions. • Optimize the owner performance needs.	• Presentation of the best alternatives to the decision maker. • Present a plan for implementing the proposal.	• Define and qualify results • implement ideas. • Validate Results. • Feedback system initiated for future projects.
Questions	• What functions are being provided? • What do the functions cost? • What is the functions worth? • What functions must be accomplished?	• What else will perform the function?	• Will each idea perform the required function? • How might each idea be made to work?	• How will the new idea work? • Will it meet all the requirements? • How much will it cost? • What is the LCC impact?	• Why is the new idea better? • Who must be sold on the idea? • What are the adv./disadv. and the specific benefits? • What is needed to implement the proposal?
Techniques	• Information Gathering. • Function Analysis (FAST). • Graphical Analysis. • Estimate Targets by making models: - Space Model. - Cost Model - Energy Model - LCC Model	• Creative thinking processes. (e.g. Brainstorming) • Create ideas with deferred judgment.	• Life cycle costing (LCC). • Weighted constrains evaluation. • Quality model to optimize the owner needs. • Consulting (manufacturers, contractors and specialists)	• Narrative reports - Describe changes. - Estimate benefits. - List advantages/disadv.. • Schematic overlays -Making sketches. - Add illustrations • Graphics	• Bid analysis. • Life cycle costing (LCC). • On site evaluation. • Post occupancy evaluation.
Methodology of VE Job Plan	Recycling of ideas and Information				

Table 1.6: VE Job Plan Methodology [1]

(1) Alphonse Dell'Isola, Value Engineering, New York: Van Nostrand Reinhold Co., 1982.

Figure 1.7 presents the cycle of the VE job plan commencing with the first step of information gathering where analysis of the function takes place then the three steps of creating, evaluating and developing of the proposed idea. All steps are performed sequentially as a VE study progresses new data and information may cause the study team to return to earlier steps within a step on iterative basis.

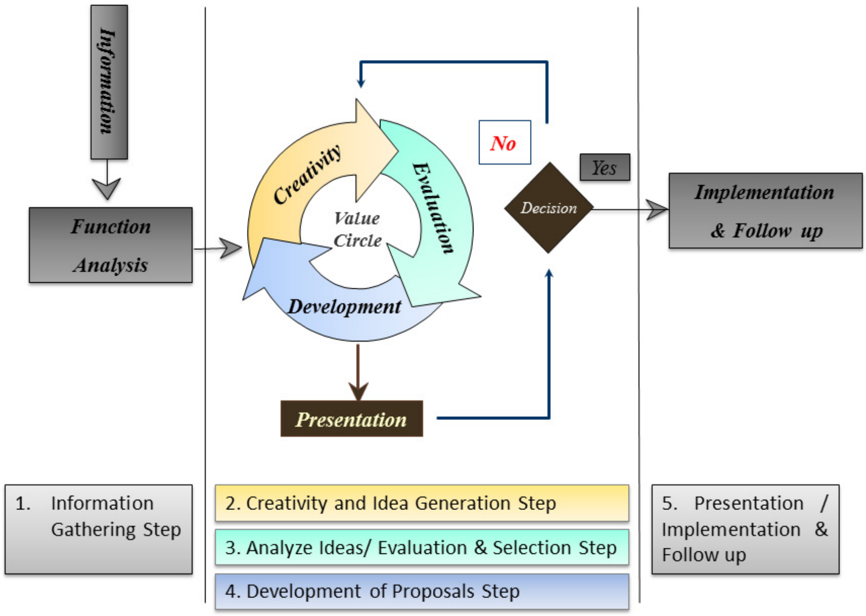

Figure 1.7: VE Job Plan (1)

The proposed ideas developed in step four were presented in standard sheets. These sheets were used to document the VE proposed ideas. "Appendix 1.2" demonstrates the sheets. The first sheet illustrates the original design, proposed design explaining the advantages and disadvantages of the design suggestion and discussing the motives of the proposed ideas ending with the cost summary. The second sheet illustrates sketches for the proposed design when available. The third sheet is the cost work sheet that presents the calculations and compares the initial cost and LCC of the original design with the proposed idea, ending with the potential savings achieved in each idea.

(1) Dr Mohamed Al-Ashkar, Center of Planning and Architecture Studies Training Course 2008.

1.8.3 Reporting

Besides the final reports from each formal VE Workshop following regular reporting will apply:

- Monthly summary timed for inclusion in the monthly report and for inclusion in Company Management Project Reviews.

- End of job summary report.

Log shall be maintained of all VE workshop items and forms including the following: [1]

- Entry number.
- Items considered.
- Items accepted/rejected.
- Recommendations on timing of implementation of accepted items Total Installed Cost reductions arising from the value engineering activities.

1.9 VE Check List

As the VE methodology is an organized process, a checklist is established covering all the building's elements. The checklist in table 1.7 was derived from the "MASTER UNIFORMAT" that classifies the building elements into 17 divisions (General requirements, site work, concrete, masonry, metals, wood & plastic, thermal & moisture protection, doors & windows, finishes, specialties, equipment, furnishings, special construction, conveying systems, mechanical, electrical, security system). These divisions were organized by major products and trades associated with construction.[2] The reason for using the checklist is to ensure that all alternatives for the elements of significant cost in the building are analyzed in the creativity phase of the job plan.

VE Check List			1 General Conditions	2 Site Work	3 Concrete	4 Masonry	5 Metals	6 Wood-Plastic	7 Thermal & Moisture	8 Doors & Windows	9 Finishes	10 Specialties	11 Equipment	12 Furnishings	13 Special Construction	14 Conveying Systems	15 Mechanical	16 Electrical	17 Security Systems
			Master Format Devisions																
A- SUBSTRUCTURE	Foundations	Standard Foundation		■	■	■													
		Other Foundation		■			■												
		Slab to Grade		■	■				■										
	Basement Construction	Basement Excavation		■	■				■										
		Basement Wall			■	■			■										
B- SHELL	Superstructure	Floor Construction			■		■	■											
		Roof Construction			■		■	■											
	Exterior Enclosure	Exterior Walls			■	■	■	■	■		■	■							
		Exterior Windows								■									
		Exterior Doors								■									
	Roofing	Roof Coverings						■	■										
		Roof Openings								■		■							
C- INTERIORS	Interior Construction	Partitions				■	■	■	■	■	■	■							
		Interior Doors								■									
		Specialties				■	■	■				■							
	Stairs				■		■	■			■								
	Interior Finishes	Wall Finishes			■			■			■								
		Floor Finishes			■	■		■			■	■							
		Ceiling Finishes			■			■			■								
D- SERVICES	Conveying Systems															■			
	Plumbing																■		
	HVAC														■		■		
	Fire Protection											■					■		
	Electrical	Electrical Services & Distribution																■	
		Lighting & Branch Wiring																■	
		Communication & Security																■	■
		Other Electrical Systems																■	
E- EQUIPMENT & FURNISHINGS	Equipment			■									■		■				
	Furnishings							■						■					
F- SPECIAL CONSTRUCTION & DEMOLITION	Special Construction														■				
	Selective Building Demolition			■															
G- BUILDING SITEWORK	Site Preparation			■															
	Site Improvements			■	■	■	■	■				■							
	Site Mechanical Utilities			■									■		■		■		
	Site Electrical Utilities			■														■	
	Other Site Construction			■											■		■		

Table 1.7: VE Checklist

(1) Michael Dell'Isola, Value Engineering application using UNIFORMAT II, SAVE conference 1998.

1.10 VE Special Techniques

While VE is studying the function and the cost worth these functions, the pioneers develop several techniques in order to break down each function, aiming to control the cost through analyzing it carefully and estimating the cost of each discipline. These techniques could be used together or separately through the job plan steps, realizing the cost savings and the added value.

Figure 1.8 illustrates the varies VE techniques and in which step of the job plan it is applied, the research will briefly illustrate the life cycle cost (LCC) technique as the research used in analyzing the case studies. The other VE techniques are defined and explained in "Appendix 1.3".

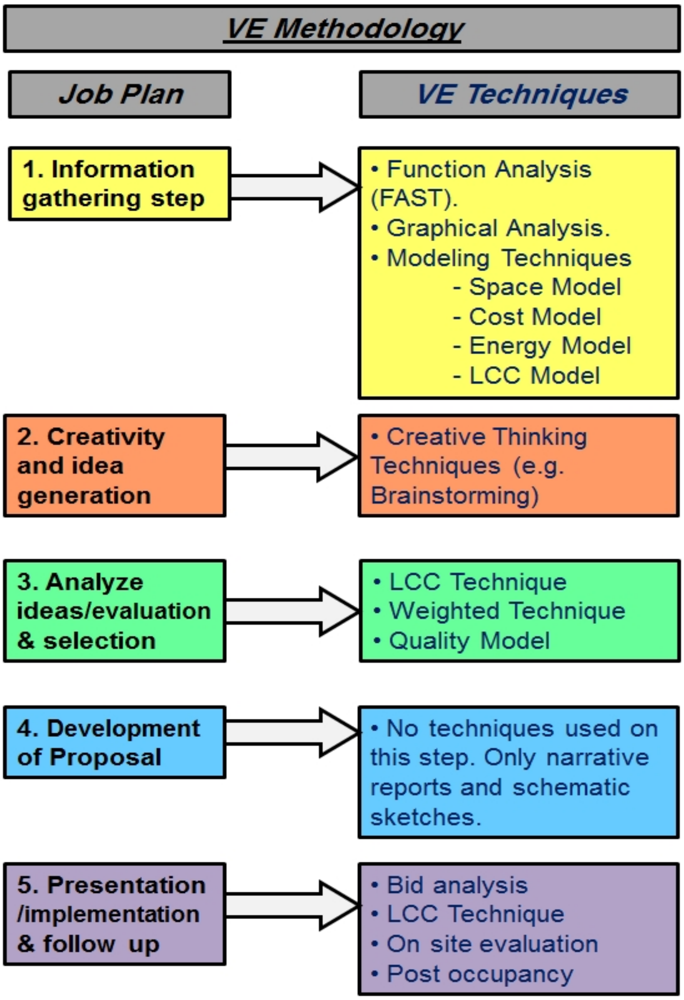

Figure 1.8: VE Techniques in the job plan steps [1]

(1) Alphonse Dell'Isola, Value Engineering, New York: Van Nostrand Reinhold Co., 1982.

LCCA is applied to any economic study – project or facility- in which higher initial costs are traded for reduction of future cost obligations. This defines the integration of its concept with the architecture concept in designing intelligent buildings. LCCA is suitable for the evaluation of building design alternatives that satisfy the required level of the building performance.

The objective of this chapter is to present a review that identifies life cycle and life cycle cost analysis. Explaining why, when, and how is it applied and calculated, explaining its logic methodology and illustrating engineering economics' fundamentals that should be applied in this analysis. The chapter includes an example illustrating briefly the calculation steps done in comparing between alternatives in the LCCA.

1.11 Overview on Life Cycle Cost Analysis

Life cycle cost analysis (LCCA) is an economic method of project evaluation in which all costs arising from owning, operating, maintaining are considered. LCCA is particularly suitable for the evaluation of building design alternatives that have different initial investments costs; different operating, maintenance, and repair costs including energy and water usage. LCCA can be applied to any capital investment decision in which higher initial costs are traded for reduced future cost obligations.

LCCA provides a significantly better assessment of long term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run. (1)

1.11.1 Life Cycle Cost Definition

Life cycle cost (LCC) is an economic assessment of an item, area, system, or facility that considers all the significant costs of ownership over its economic life, expressed in terms of equivalent currency of money. LCC is a technique that satisfies the requirements of owners for adequate analyses of total cost. (2)

LCC has a unique opportunity to connect initial cost and ownership costs to optimize total cost. LCC can be performed on large and small buildings or on isolated building systems such as HVAC, Lighting, Glazing, etc.

The broad objectives of a life cycle costing are as follows: (3)

- The cost or benefit deriving from disposal of assets at the end of its life.
- Enabling investment decision to be made more effectively, taking into account all costs that may arise from it.

(1) Sieglinde K. Fuller & Stephen R. Peterson, Life Cycle Costing Manual for the Fedral Energy Management Program, P.17

(2) Alphonse Dell'lsola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 12.

(3) Chanter Barrie – Swallow Peter, Building Maintenance Management, P99.

-Considering the impact of all costs, rather than just capital costs.

-Providing information that can contribute to the more effective management of the completed building.

-Assisting in the evaluation of alternative solutions in project's procurement to specific design problems.

1.11.2 LCC Applications

It's clear that life cycle costing can be a critical component in analyzing design solutions and in ultimately providing improved quality facilities. There appear to be three basic opportunities for life cycle costing to impact delivery:

a. By owners emphasizing performance and quality in systems, facility design, and operations and maintenance procurements, and potentially requiring bids based on LCCA for selection.

b. By owners including life cycle costing impact in initial design selections.

c. By designers emphasizing life cycle performance when presenting competing design solutions.

Energy conservation projects provide excellent examples for the application of LCCA. There are abundant opportunities for improving the thermal performance of building envelope components (e.g., walls, windows, roofs) in new and existing buildings to reduce heat loss/gain. Similarly, there are many alternative heating, ventilating, and air conditioning (HVAC) systems which can maintain acceptable comfort conditions throughout the year, some of which are considerably more energy efficient (or use less expensive fuels) than others. When energy conservation projects increase the initial capital cost of a new building or incur retrofit costs in an existing building, LCCA can determine whether or not these projects are economically justified from the investor's viewpoint, based on reducing energy costs and other cost implications over the project life or the investor's time horizon. (1)

1.11.3 LCC Application in the Design Process

The earlier LCC considerations are include in the planning and design process, the greater the potential cost savings that can be expected.(2)

Figure 1.9 illustrates the relation between the application of LCCA and the design phases of any project.

(1) Sieglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program, P.17

(2) Alphonse Dell'lsola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 17

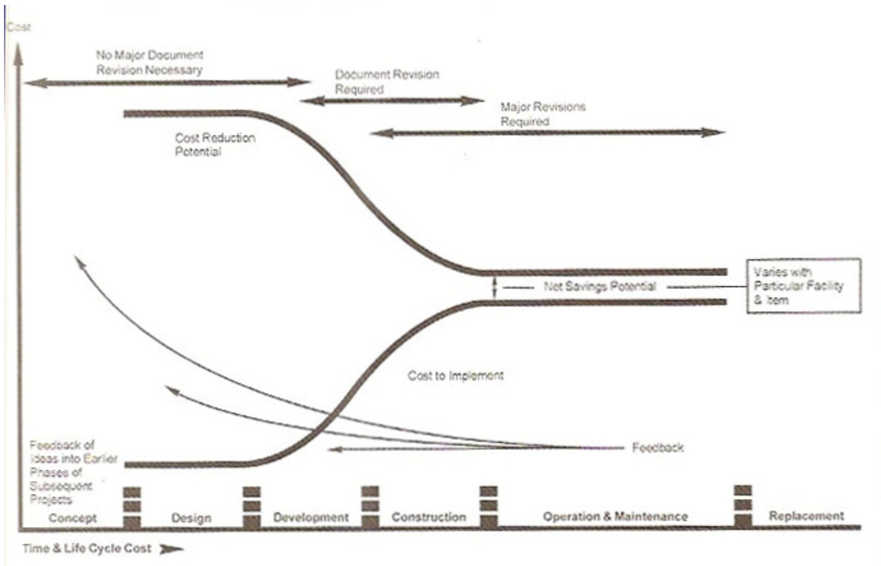

Figure 1.9: Phase Cost Reduction, Facilities Construction [(1)]

LCC -in many cases- is applied to a single discipline, this leads to distractive solutions. Fig 1.10 illustrates the design decision-makers' influence on total building costs. It portrays the design decision process as team effort in which there are various disciplines making decisions. [(1)]

The owner's requirements and the architectural design have the major influence on the total cost of the building, while the mechanical and electrical decisions have the least influence on the cost of the building; on the other hand the building industry seems to be moving towards oriented solution to environmental problems and the application of LCC is centered on energy conservation, with the mechanical engineers providing the lead. The best solutions will be provided only when all participants collaborate as a team and seek an optimum solution for the total problem.

(1) Alphonse Dell'lsola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 17.

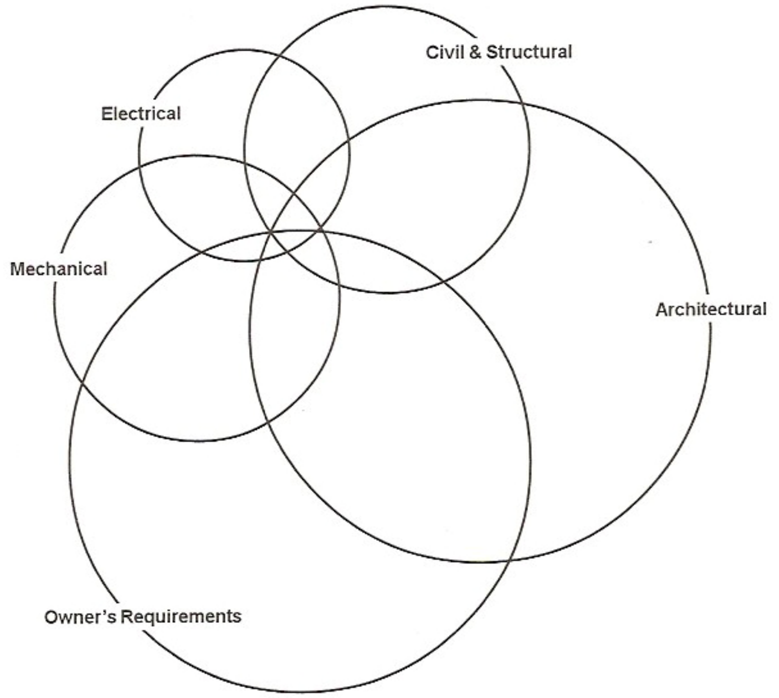

Figure 1.10: Decision Makers' impact on total building cost (1)

One of the reasons for unnecessary costs is the uni-discipline approach used by most designers, these unnecessary costs occur especially where decision areas overlap.

In some cases, such as highly-automated office facilities and high-tech laboratories, the design of mechanical-electrical systems takes precedence over architecture design. To take the maximum advantages of LCC, the techniques should be applied at the earliest stages of the design concept, particularly during planning and budgeting, preliminary design, and design development phases. The cost of changing a design increases significanly with time. LCC exercises that are undertaken during the construction phase or owning and operation phases produce limited results, and they are beneficial only in providing data for future projects. (2)

1.11.4 LCC Considerations

The cash flow in figure 1.11 presents the different costs taken in LCC calculations, and as it is stated in the LCC definition that all costs over a specific period of time must be expressed in terms of equivalent currency of money in the present worth value.

(1) ibid, P 17.

(2) Alphonse Dell'lsola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P112

Figure 1.11: Cost Considerations [(1)]

There are two major cost categories by which projects are to be evaluated in a LCCA. They are initial expenses and future expenses. *Initial Expenses* are all costs incurred prior to occupation of the facility. *Future Expenses* are all costs incurred after occupation of the facility.

As stated before that LCC take all costs arising from owning, operating, maintaining in consideration over a specific period of time, this specific period is called the study period which is the second component in the LCC equation. All these are defined as follows:

a) Study Period: is the period of time over which ownership and operations expenses are to be evaluated. Typically, the study period can range from 20 to 40 years, depending on owner's preferences, the stability of the user's program, and the intended overall life of the facility. While the length of the study period is often a reflection of the intended life of a facility, the study period is usually shorter than the intended life of the facility. [(2)]

b) Initial Cost: Include the owner's costs associated with initial development of a facility, such as project costs (fees, real estate, site, etc…) and construction costs.

c) Future Cost: Include all costs that appear after finishing the construction phase.

- *Maintenance costs* include the regular custodial care and repair, annual maintenance contracts, and salaries of facility staff performing maintenance tasks.

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(1) Hank Bonstedt, Life Cycle Cost Analysis for Bridges, In Search of Better Investment and Engineering Decisions, 1998.

(2) Life Cycle Cost Analysis Handbook, state of Alaska, Education support services/ facilities, 1999, P 5.

- *Operation costs* (including energy) are annual cost used to keep track of such items as fuel and salaries are required to operate the facility. All operation costs are to be discounted to their present value.
- *Financing costs* include the costs of any debt associated with the facility's capital costs.
- *Replacement costs* are anticipated expenditures to major building system components that are required to maintain the operation of a facility. All replacement costs are to be discounted to their present value prior to addition to the LCCA total.
- *Residual Value*: is the net worth of a building at the end of the LCCA studies period, the residual value can be positive or negative, a cost or a value. A negative residual value indicates that there is value associated with the building at the end of the study period; a positive residual value indicates that there are disposal costs associated with the building at the end of the study period.
- *Tax elements*: deals with the cost impact of the tax laws. These costs must be continually reviewed as tax laws change. (1)
- *Associated costs*: is concerned with different expenses and income such as insurance, income and staffing and personnel costs related to functional use.

Once all pertinent costs have been established and discounted to their present value, the costs can be summed to generate the total life cycle cost of the project alternative. After this has been done for all the viable project alternatives, a summary of the results should be prepared. The summary of project alternatives should compare the total life cycle costs of Initial Investment, Operations, Maintenance & Repair, Replacement, and Residual Value of all the project alternatives. (2)

It is anticipated that the project alternative with the lowest overall life cycle cost will be the optimum project alternative presented.

Figure 1.12 illustrates the types of costs that any LCC study may consider.

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(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P112

(2) Life Cycle Cost Analysis Handbook, state of Alaska, Education support services/facicilities, 1999, P 14.

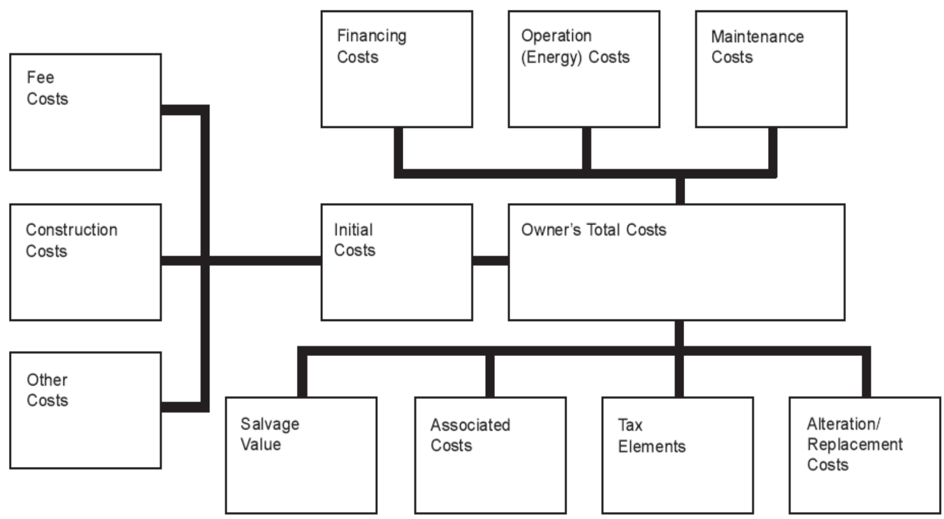

Figure 1.12: LCC Elements (1)

The "Appendix 1.4" lists the LCC categories for initial and future expenses that are addressed in the LCCA.

1.11.5 LCC Procedures

The following steps are the LCC logical thinking procedure from defining the problem till selecting the optimum alternative. As it stated by Fuller as LCC key steps (2):

1. Define problem and state objective.
2. Identify feasible alternatives.
3. Establish common assumptions and parameters.
4. Estimate costs and times of occurrence for each alternative.
5. Discount future costs to present value.
6. Compute and compare LCC for each alternative.
7. Compute supplementary measures if required for project prioritization.
8. Asses uncertainty of input Data.
9. Take into account effects for which dollar costs or benefits cannot be estimated.
10. Advise on the decision.

(1) Alphonse Dell'Isola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 13.

1.12 LCC and VE

VE may utilize life cycle costing in developing the lowest cost of ownership, except in those cases where initial cost reductions are the owner's major consideration. The primary focus of VE is analyzing the function and elimination or modification of unneeded functions in seeking out the optimum course of actions that satisfies the true function requirement, while the primary focus of LCC is to determine which of several courses of actions would be the least costly over a specified period of time. (1)

VE can be used to complement a life cycle cost analysis when selected LCC alternatives cannot be adopted without exceeding the project budget. VE can be utilized to reduce initial cost of design features other than those under study in LCCA. If the VE effort results in sufficient reduction in initial cost, then the selected LCC alternatives can be adopted.

The Inter Relationship of VE and LCC is graphically illustrated in fig 1.13

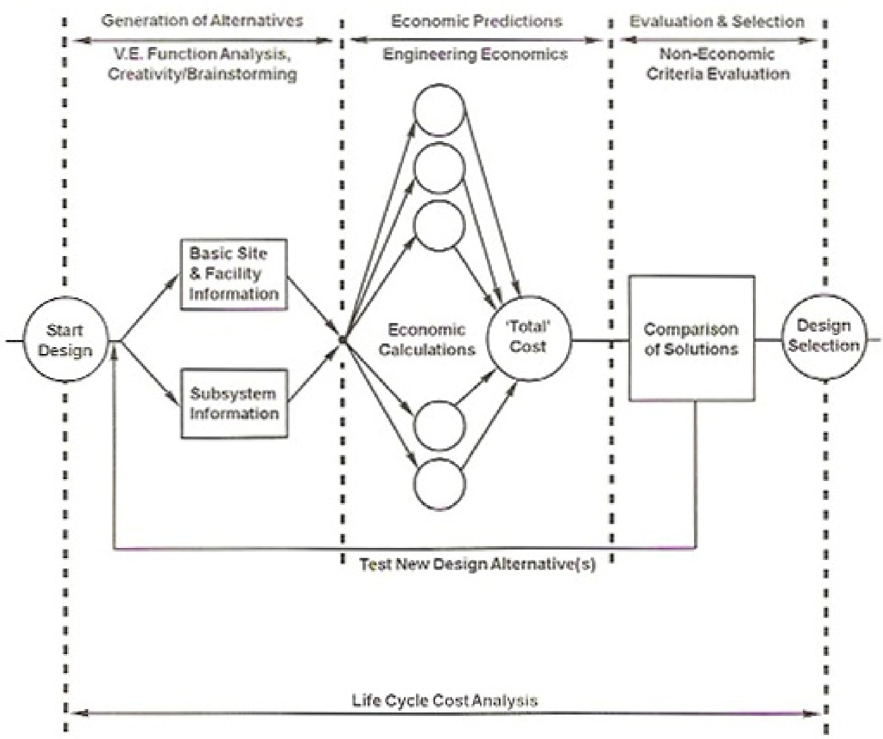

Figure 1.13: Interrelationship of VE and LCC (1)

(1) Sieglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program, P.17

(2) Alphonse Dell'Isola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 13.

The figure is presenting at one end is the start of the design process, and at the other end is the ultimate design selection, between is the LCCA process. In developing the design selection, the basic site and facility program information is combined with the subsystem information to generate alternative solutions. It's in the generation of the alternative solutions that the VE methodology should be utilized. After developing alternatives, the process focuses on economic analysis; at this point the LCC is performed on the alternatives using the principles of engineering economic – which will be explained in the fundamental financial analysis tools used to calculate LCC – the results are expressed as the total life cycle cost of each competing alternative. (1)

In making an economic analysis, the designers are not required to take the lowest cost alternative, because the lowest cost alternative is not always the optimum. Normally there are non-economic considerations such as aesthetics, politics, safety, and the environmental issues that must be taken in consideration, therefore after the LCC are estimated, there must be an evaluation from a non-economic criterion and from this evaluation the optimum design could be selected.

1.12.1 Comparison of LCCA and VE

Both LCCA and VE are analysis techniques whose goal is to reduce the cost of ownership of a facility. The differences are summarized in table 1.8.

LCCA focuses on the costs of feasible design alternatives –alternatives that meet the minimum functional and technical requirements of the project design– with the objective of identifying the least-cost alternative. Little attempt is made to challenge the necessity for a particular function, or to change any previously identified functional requirement. VE analysis, on the other hand, focuses on the functions themselves, identifying the essential functions, and eliminating or modifying nonessential functions that represent unnecessary costs. Moreover, in too many cases, VE analysis if most often limited to savings in initial cost, whereas LCCA affects savings in the total cost of ownership. (2)

1.12.2 Combined Use of LCCA and VE

Because the emphasis of LCCA is on costs, while the emphasis of VE is on functions, the two methods of analysis are different and distinct. However, because functions give rise to costs, the two methods complement each other. For example, LCCA is used to identify high-cost, but marginal functions –candidates for elimination or modification through VE analysis– in projects whose budgets are in danger of being exceeded. Conversely, VE is very useful when a particular alternative, selected through LCCA, has a high (over-budget) initial cost, but low subsequent costs. Then, if a VE

(1) ibid, P 23.

(2) ibid, P 64.

analysis can produce a sufficient reduction in the initial costs of other design features, the selected alternative could be implemented to minimize the total cost of ownership of the project as a whole. [1]

	VE	LCCA
Focus on:	Function	Total cost of a facility
Challenge:	Reducing cost and maximizing function	Reducing total cost, margining the functional requirement
Tool:	Analyzing the function eliminating and modifying non-essential functions that represent unnecessary costs.	Identifying high cost spots the project and study alternatives that have low running cost.
Main Savings' Area:	Initial cost	Total Cost of ownership

Table 1.8: Comparison of VE and LCC (By Researcher)

1.13 LCC Methodology

LCC methodology is divided into 3 major steps to move form inputs to the output. Fig 1.14 illustrates the LCC logical steps methodology

First requirement is the input data, second is generating the alternatives. While the third one is LCC comparisons which is applied in two phases; Economic and Non-economic comparisons. The economic comparison to evaluate the alternative to get the lowest optimum alternative, then the non-economic comparison is made to evaluate the assumptions about component costs balanced with function, technology, safety and aesthetic factor of the project.

The resultant weighted choice is proposed to be the lowest optimum alternative which represents the best choice balanced costs and non-economic criteria.

(1) ibid, P 64.

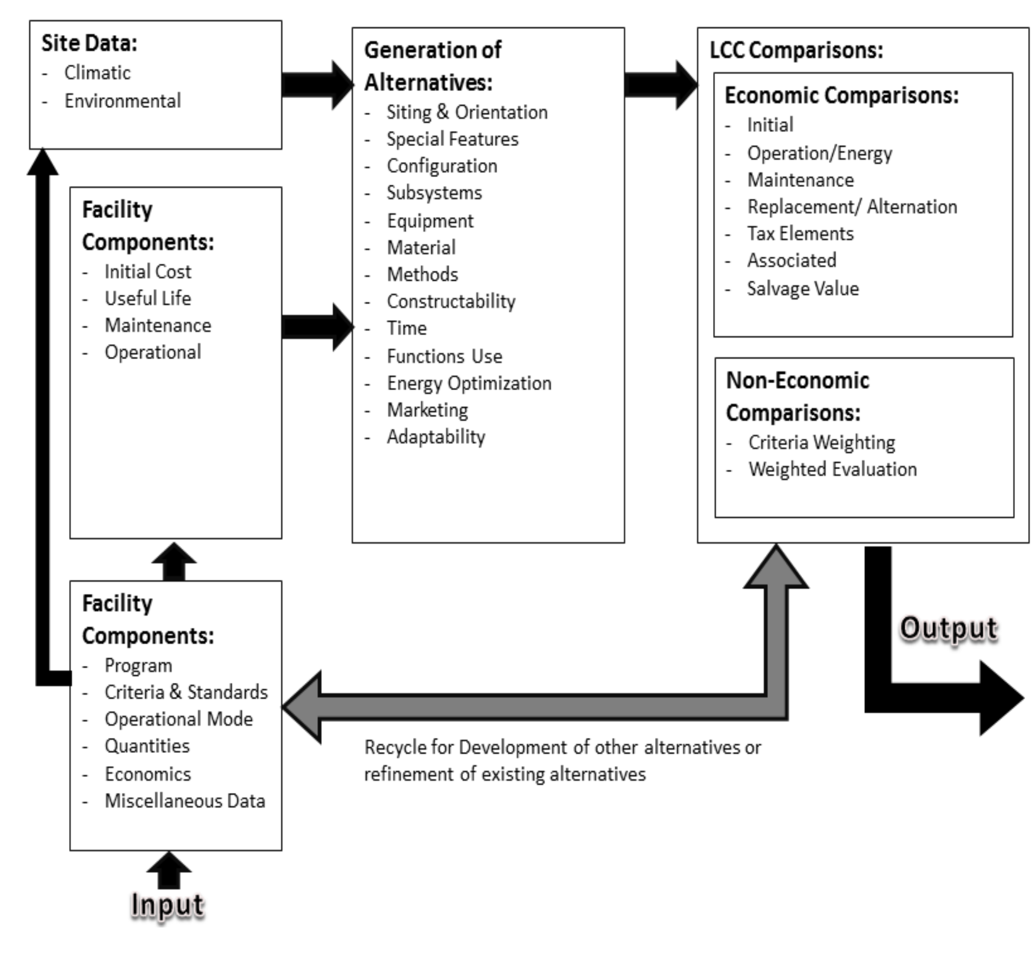

Figure 1.14: LCC Logical Methodology (1)

1.14 LCC Fundamentals

The LCCA –as stated in the definition- is the cost centered engineering economics analysis where there are many elements affecting this analysis depending on different factors such as: the power of money, the inflation rate, costs that have to be incurred/non incurred, even the life of construction and the analysis period. All these concepts and the computation that follows from are the foundation of an LCCA which will be explained briefly in this part of the chapter.

As illustrated in fig 1.15, the two main axes that LCCA exposes are *Time* and *Cost.* The key elements of the LCCA is arranged below regarding to its tendency either to the time or to the cost, except the time value of money which has common links with both of them.

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P122

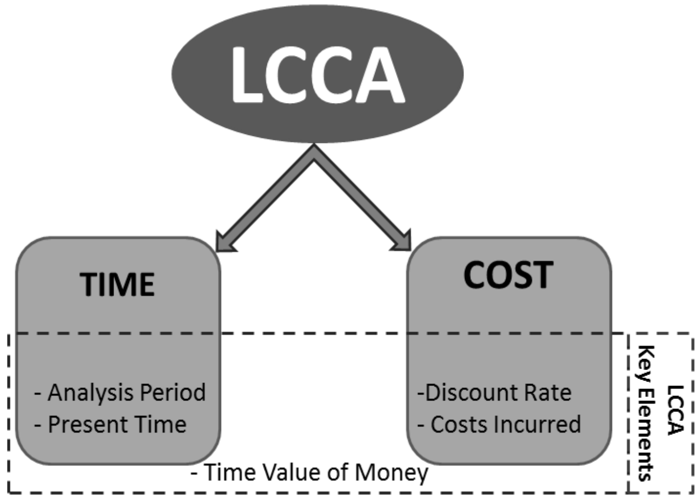

Figure 1.15: LCCA Fundamentals (By Researcher)

The key elements of LCCA are those that affect the manner in which the analysis will be conducted. A decision concerning each key element must be made before the LCCA can be performed. Table 1.9 illustrates six questions and each of these questions concerns one key element. (1)

	Question	Key Element
1	What analysis approach is to be used?	Time Value of Money
2	What is a realistic discount rate for use in the analysis?	Discount Rate
3	How are the effects of inflation and increases in individual costs to be taken into account?	
4	Over what specific period of time are the total costs of ownership to be determined?	Analysis Period
5	When is that time period to begin?	Present Time
6	What type of costs are to be included in the analysis. & what costs may be ignored?	Initial & Running Costs

Table 1.9: Fundamental Questions and LCCA Key elements (By Researcher)

(1) Alphonse Dell'Isola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 28.

1.14.1 Time Value of Money

We cannot add or subtract money –costs or expenses- not paid in the same time because the dollars spent at different times have different values due to the economic factors. It is the ability of money to earn money and thus increase in the amount over time; this is referred to as the time value of money.

It is defined as the time-dependent value of money, reflecting the opportunity cost of capital to the investor during that time period. (1)

In determining the total cost of ownership, the design professional is concerned with a number of sums that are invested at various times, this is driven in the form of cash flow diagram, Interest formulas or tables.(2)

- *Cash flow diagrams* help in sorting out and keeping track of both out of money and in.
- *Interest formulas* are simple mathematic equations that can be used to compute the amount to which a single investment or a series of equal investments will grow.
- *Interest tables* may be used for the same purpose of the formulas and require a minimum of computation.

Life cycle costs include both costs today and future costs, Interest formulas or tables are used to make this equivalent with respect to time. There are two methods commonly used for converting present and future costs of an item, system, or a facility to a common basis are the Present Worth and the Annualized methods, both methods account for the time value of money, and therefore are interchangeable as measures the LCC.(3)

1.14.1.1 Present worth method

The present worth (PW) method allows conversion of all present and future costs to a single point in time which is the beginning of the base year. Each uniform annual payment (energy, maintenance) and each one-time payment (replacement, salvage value) has been assumed to occur at the end of the year. All the money spent is converted to the present value by multiplying to the PW factor.

1.14.1.2 Annualized method

The annualized method is also used to convert money expended over various points in time to an equivalent cost. This method converts all costs to an equivalent uniform annual cost.

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(1) Sieglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program, P.GL-6

(2) Alphonse Dell'Isola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P. 36

(3) ibid, P 37

1.14.2 Analysis Period

The analysis period is the number of years over which the total cost of ownership will be determined for various alternatives. Five of the common used criteria for establishing the analysis period are defined below. (1)

a) ***Component life***: If the several alternatives being considered all have same economic life, then that life may be used as analysis period

b) ***Common multiple of component lives***: If the design alternatives have different economic lives, it may be possible to choose the analysis period as a multiple of these lives. Example: the economic lives of two carpeting alternatives are 8 years and 12 years, 24 year analysis period was selected as a common multiple of the two lives.

c) ***Facility life***: If the analysis period is based on the technological or useful life of the facility as a whole. This criterion has the advantage of reflecting the total Facility life and allowing the comparison of alternative life cycle costs over that life.

d) ***Investment or mission life***: If the analysis period is established by limiting it to some investment or mission life for the facility. This is the expected number of years until the owner's investment objective is fulfilled, and it depends mainly on that objective, it can be long term or short term period. This criterion for analysis period selection most truly reflects the investment objective, provided all parties involved in the project agree on the objective.

e) ***Arbitrary life***: It is selected when there is good reason to maintain a facility for an indefinite time. The analysis period might simply be established b organizational policy or as the limit of a planning horizon. This criterion provides a commonality among projects and among organizational units, but it does not take into account such important considerations as component life and facility life or mission.

It should be noted that, no matter how the analysis period is selected, costs that are to be incurred far in the future become inconsequential both in size and in their effect on the LCCA, whether the present worth or annualized analysis approach is used.

1.14.3 Present Time

The present time marks the beginning of the analysis period. It is also the time for which baseline costs are quoted. Present time is usually chosen from among the points identified in figure 1.16.

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(3) ibid, P 38

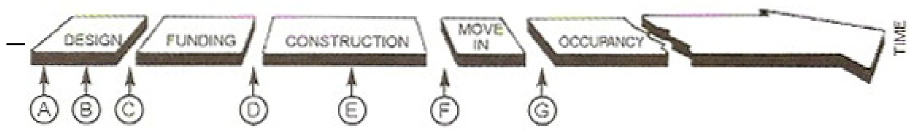


Figure 1.16: Present Time Diagram [1]

The most common choices for the present time are point B (during design), point E (during construction), and point G (the beginning of occupancy). The selection of point B normally results in the most realistic baseline costs. Baseline costs for points subsequent to point B are increasingly unreliability, as are projection made from them.

All of these points could be chosen as the present time, but for all except point G, where two steps would be required to discount recurring costs. This is because the recurring costs begin at time G, and the formulas for both present worth and annualized method automatically assume this point G to be the present worth. [2]

1.14.4 Discount Rate

The discount rate is a special type of interest rate which is related to the time value of money. The discount rate "d" is used like the interest rate "i" shown in the equation of finding the present value received or paid at a future point in time.

Each of discount formulas shown in table 1.10 includes a future amount or an annually recurring amount, and a formula which can be used to compute a corresponding discount factor, the computed discount factor is a scalar number by which amount is multiplied to get its present value. [3]

The four discount factors shown in the table are those most often used in LCCA:

- Single Present Value (SPV) factor.
- Uniform Present Value (UPV) factor.
- Uniform Present Value factor modified for prices escalation (UPV*)
- FEMP UPV* factor for use with energy cost.

For the FEMP (federal energy management program) UPV* factors are pre-calculated factors used by the Federal Government issued yearly, based on the current discount rate and on energy prices escalation rates. Current

(1) Alphonse Dell'Isola, Life cycle costing for facilities, USA, construction publisher & consultant, 2003, P 63.

(2) Ibid.

(3) Sieglinde K. Fuller & Stephan R. Petersen, Life Cycle Costing Manual for the Federl Energy Management Program, P. 3-4

FEMP UPV* factors are published in the annual supplements to handbook 135, these factors when multiplied by the annual energy cost yield the present value of energy costs for the number of years indicated.

Present-Value Formulas and Discount Factors for Life-Cycle Cost Analysis.

PV formula for one-time amounts

The **Single Present Value (SPV) factor** is used to calculate the present value, PV, of a future cash amount occurring at the end of year t, F_t, given a discount rate, d.

$$PV = F_t \times \frac{1}{(1+d)^t}$$

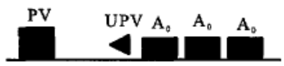
$$PV = F_t \times SPV_{(t,d)}$$

PV formula for annually recurring uniform amounts

The **Uniform Present Value (UPV) factor** is used to calculate the PV of a series of equal cash amounts, A_0, that recur annually over a period of n years, given d.

$$PV = A_0 \times \sum_{t=1}^{n} \frac{1}{(1+d)^t} = A_0 \times \frac{(1+d)^n - 1}{d(1+d)^n}$$

$$PV = A_0 \times UPV_{(n,d)}$$

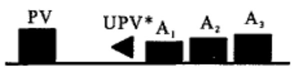


PV formula for annually recurring non-uniform amounts

$$PV = A_0 \times \sum_{t=1}^{n} \left(\frac{1+e}{1+d}\right)^t = A_0 \frac{(1+e)}{(d-e)}\left[1 - \left(\frac{1+e}{1+d}\right)^n\right]$$

The **Modified Uniform Present Value (UPV*) factor** is used to calculate the PV recurring annual amounts that change from year to year at a **constant** escalation rate, e (i.e., $A_{t+1} = A_t \times (1+e)$), over n years, given d. The escalation rate can be positive or negative.

$$PV = A_0 \times UPV^*_{(n,d,e)}$$



PV formula for annually recurring energy costs (FEMP LCCA)

The **FEMP UPV* factor** is used to calculate the PV of annually recurring energy costs over n years, which are assumed to change from year to year at a **non-constant** escalation rate, based on DOE projections. FEMP UPV* factors are precalculated for the current DOE discount rate and published in tables Ba-1 through Ba-5 of the Annual Supplement to Handbook 135.

$$PV = A_0 \times UPV^*_{(reg,\ ft,\ rt,\ d,n)}$$

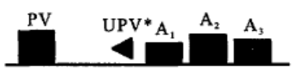


Table 1.10: Discount Factors for LCC calculations [1]

(1) Sienglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program, P. 4.

1.14.5 Costs

They are the raw material of LCCA, and the costs form the basis for the comparison of the alternatives. All significant costs attributable to a facility are normally considered for inclusion in LCCA. Initial and future costs are included which are previously stated in LCC considerations. This part is presenting different costs' types which are necessary for classifying it either to include or exclude while making the analysis. Each type is defined and an example is stated to clarify each concept.

- ***a)*** ***Common costs:*** It is not necessary to estimate all costs. Those types of costs which are common to all alternatives, with no differences in magnitude, can be excluded. The results will not be affected by this exclusion in terms for the relative economic ranking of the alternatives.

Example: Two alternative hot water systems that have the same impact on size of maintenance staff. In this case it is not necessary to even consider maintenance staff costs in the LCCA.

- ***b)*** ***Collateral costs:*** They are costs that are not directly attributable to the system being analyzed. If the collateral costs are small enough, it can be excluded from the analysis.

Example: In the evaluation of various lighting systems, some alternatives may have differing ceiling and HVAC interface costs. Because these costs are also an important consideration in the selection of the most LCC effective lighting system, they are included in the analysis. The ceiling and HVAC costs here are commonly referred to as collateral costs to the lighting systems

- ***c)*** ***Sunk costs:*** They are costs that have been incurred before LCCA is begun. Only the costs that are expected to be incurred during the life cycle of the analysis (after the present time) are included in the cost estimates of alternatives. Therefore, sunk costs are never included in an LCCA.

Example: In a study of two HVAC systems, even though a large amount of design time may have been spent on one system, this design cost would not be included in the analysis. On the other hand, the redesign costs associated with the other alternative are normally included in the LCCA.

- ***d)*** ***Continuing costs:*** Costs are incurred in a facility throughout its life cycle. These costs should be reflected in the analysis at the time in which they occur. This is rarely done, however the standard procedure is to accumulate costs over some period of time and to charge all of these costs incurred as a single lump sum cost at the midpoint of the time period, but may also be charged at the beginning or the end of the time period. The additional accuracy provided by charging all the costs at the exact time is very small for the LCCA. Therefore, the additional computational effort required is not warranted.

1.15 Life cycle Cost Calculation

To calculate the LCC, first we compute the present value of each cost to be incurred during the study period, using the discount rate. Then the sum of these present values for each alternative equals its LCC. If other performance features are similar among the alternatives, the alternative with the lowest LCC is the most cost effective alternative for the application studied and it is the preferred one.

1.15.1 LCC general Formula

The following is the general formula for the LCC present value model:

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1 + d)^t} \qquad \text{- eq 2.1}$$

- Where:

LCC = Total LCC in present value amount of a given alternative
Ct = Sum of all relevant costs, including initial and future costs, less any positive cash flows, occurring in year t.
N = Number of years in the study period,
D = Discount rate used to adjust cash flows to present value.

1.15.2 LCC for Building Related Projects

The general LCC formula shown in equation 2.1 requires that all costs be identified by year and by amount. This general formula requires extensive calculations, because of the longtime of the study period that the LCCA covers. Initial and future costs must first be calculated in the present value at the base time of the analysis, including inflation, escalation and interest rates. All these calculations will be explained in the LCC fundamentals.

A simplified LCC formula for computing the LCC of a facility –including energy conservation- in a building: [1]

$$LCC = I + Repl - Res + E + W + OM\&R \qquad \text{- eq 2.2}$$

(1) Sienglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program, P. 4-5

- Where:

LCC	= Total LCC in present value amount of a given alternative
I	= Present value investment costs
Repl	= Present value capital replacement costs
Res	= Present value residual value (resale value, scrap value, salvage value) less disposal costs
E	= Present value energy costs
W	= Present value water costs
OM&R	= Present value non fuel operation, maintenance, and repair costs

This simplified formula takes advantage of UPV factors to compute the present value of annual recurring costs, whether constant or changing. The LCC can be calculated with the annual amount in the base year and the corresponding UPV factor needed to be identified to the number of years of the study period. (2)

1.16 Application of LCC to Buildings (1)

The application of the LCC concept to buildings is graphically illustrated by Figure 1.17, which shows hypothetical ownership costs of an office building using present worth concepts. The figure indicates that for the buildings type and data used, approximately 40% of the total cost of ownership is in initial cost, 28% of the cost of ownership is in financing (cost of money), and 22.5% is in annual maintenance and operation charges. The remaining amounts are for design, indirect costs, and alterations and replacement costs.

The data of costs on which the figure is based are as follows:

Initial cost of building per sq. ft :	\$80/ft.^{2} (\$861/m^2)
Building size:	100,000 ft.^{2} (9,290m^2)
Cost of Real Estate (not included):	0
Interest rate:	12%
Life cycle:	20 years
Cost of maintenance, operations, etc.:	Average\$6.00/ft.^{2} (\$64.58/m^2)
Design:	4.5%
Indirect construction costs:	10%
Alteration and replacement costs:	\$1,500,000 every ten years

(1) ibid.

(2) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P134

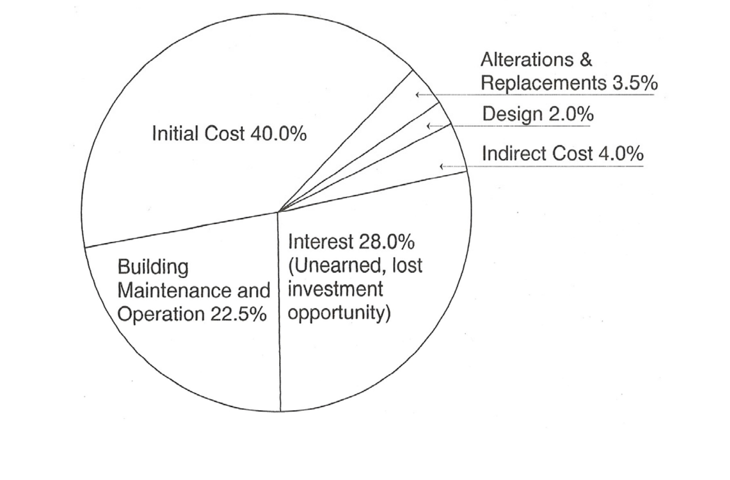


Figure 1.17: Cost of Ownership using PW concept for a typical office building (1)

- Cost of Ownership Calculations:

a. Present worth of initial costs equals cost per unit area times building size.

Initial Costs =$ 80/ft.^{2} x 100,000 ft.^{2} = $ 8,000,000

($ 861/m^2 x 9290 m^2= approximately $ 8,000,000).

b. Present worth of annual costs equals the area times the annual cost times the present worth of $ 1.00 payable periodically (PWA) 12% interest rate from the table of (Compound interest Factors) in "Appendix 1.5" .

Annual cost = 1000,000 ft.^{2} x $ 6.00 x 7.47 (PWA) = $ 4,482,000

or approximately (9290 m^2 x $ 64.58 x 7.47 PWA).

c. Present worth of financing costs equals present worth of financing for estimated initial costs and annual costs.

Present worth of the interest costs for the estimated costs equals the present worth of annual difference of payoff with interest, less the payoff without interest. Annual charges with interest equals initial costs times periodic payment necessary to pay off loan of $ 1.00 (see the table of Compound interest Factors - Periodic Payment- in the Appendix).

$8,000,000 x 0.134 = $ 1,072,000/year.

Annual charge without interest equals initial costs divided by number of years: $ 8,000,000/20 = $ 400,000/year.

Difference = $ 1,072,000- $ 400,000/year = $ 672,000/year, which is the annual value of interest.

(1) ibid.

Present worth of annuity, interest = $ 672,000 x (PWA) 7.47= $ 5,019,840, approx. $ 5,020,000

Present worth of interest (financing) of annual costs equals annual financing costs times' present worth of $ 1.00 payable periodically (see the table of Compound interest Factors (PWA) in the Appendix).

Annual financing charge=12% x $ 600,000 = $120,000.

Present worth = $ 120,000 x (PWA) 7.47 = $ 7.47 = $ 537,840 (approximately $540, 0000.

Total present worth of financing costs= $ 549,999 + $ 5,020,000= $ 5,560,000.

d. Other Costs

- Design costs= design percentage times initial costs = 4.5% x $ 8,000,000 = $ 360,000.
- Indirect cost = indirect cost percentage times initial costs = 4.5% x $ 8,000,000 = $ 800,000.
- Present worth of alteration and replacement costs = cost in future year (2) times present worth of $ 1.00 due in the future.
- Present worth of alteration and replacement costs = $ 1,500,000 x 0.322 (PW for tenthly year) = $ 483,000.

  $ 1,500,000 x 0.104 (twentieth year) = $ 156,000

- Total PW Alterations and Replacement= $ 483,000 + $ 156,000 = $ 639,000.

Summary of Costs:	Present Worth	Percent of Total
Initial Costs	$8,000,000	40.0 %
Annual Costs	4,482,000	22.5 %
Financing Costs:		
Initial	5,020,000	
Annual	540,000	28.0 %
Other Costs:		
Design	360,000	2.0 %
Indirect	800,000	4.0 %
Alteration and Replacement	639,000	3.5 %
Total: (Present worth) Total Cost of Ownership	$19,841,000	100.0 %

1.17 Summary

VE plays a critical role in managing the value and cost of the building that meets the owners' goal. VE improve the value and optimize the cost through analyzing the functions by its creative techniques.

The Time, Team and techniques have a significant effect on the results of the VE study, subsequently each study must work within these constrains in order to get out the maximum benefits of the VE application.

The LCCA is one of the VE techniques that focus on the total cost. It concentrates on optimizing energy consumption, maintenance, operation costs, and alternation expenses. This opens a link to integrate VE with intelligent buildings, where both points on the long-term investments.

The LCCA is important for investing in the building construction field, by which the investor can see a full scope for his project and correctly allocate his money.

Chapter 2 discusses the intelligent buildings from an economic perspective in order to highlight the LCC of these buildings compared to the traditional buildings.

Chapter 2

Intelligent Buildings in Economic Perspective

Chapter 2: Intelligent Building in Economic Perspective

2.1 Introduction

This chapter focuses on the economic aspects of the intelligent building (IB), presenting the intelligent features of IBs and explaining the reasons of extra cost and the potentials of savings during its life cycle.

The end of the chapter demonstrates an example of IB, analyzing the LCC of the IB and comparing it with that of the Non-IB.

2.2 IB Definition

The building has to be designed "intelligent" from the first draft on the drawing board. Far more than the technical systems must be considered when designing an intelligent building. An intelligent Building is not only the building itself and the systems installed. There must be a commitment from the developer / owner that this will be maintained as an intelligent building. (1)

IB is a building that integrates technology and process to create a facility that is safer, more comfortable and productive for its occupants, and more operationally efficient for its owners. Advanced technology -combined with improved processes for design, construction and operations- provide a superior indoor environment that improves occupant comfort and productivity while reducing energy consumption and operations staffing. (2)

2.3 Historical Models of IB

The history of the IB can be divided into three distinct periods. (3)

2.3.1 Automated buildings

The US tax laws in 1980s helped to support an explosive growth in speculative office buildings. The result was an over-supply of office space in some cities and competition for tenants in other cities to minimize the period it took to fill new buildings. Developers saw the provision of “Building intelligence” in buildings and the services made available to tenants, as a mean of giving their building a marketing edge over those of their competitors.

(1) www.automatedbuildings.com (Article Sep 1999) accessed Jan 2012.

(2) www.intelligent-building-dictionary.com (accessed June 2011).

(3) Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in Soth East Asia, E & FN spons, London 1998, P 1-3.

This automated building (1981 – 1985) is a collection of innovative technologies.

2.3.2 Responsive buildings

In the mid of 1980s, the limitations of purely technological definitions of building intelligence began to become apparent. Researchers examined the interaction between organizations, buildings and information technology in the context of a rapidly changing work environment. In the light of this, definitions of building intelligence were then modified to include an additional dimension "responsiveness to change". The IB must respond to user requirements at a number of levels, relating to the life cycle of different building elements such as shell, services, scenery and settings as illustrated in figure 2.1.

This responsive building (1986 – 1991) is a collection of technologies able to organizational change over time.

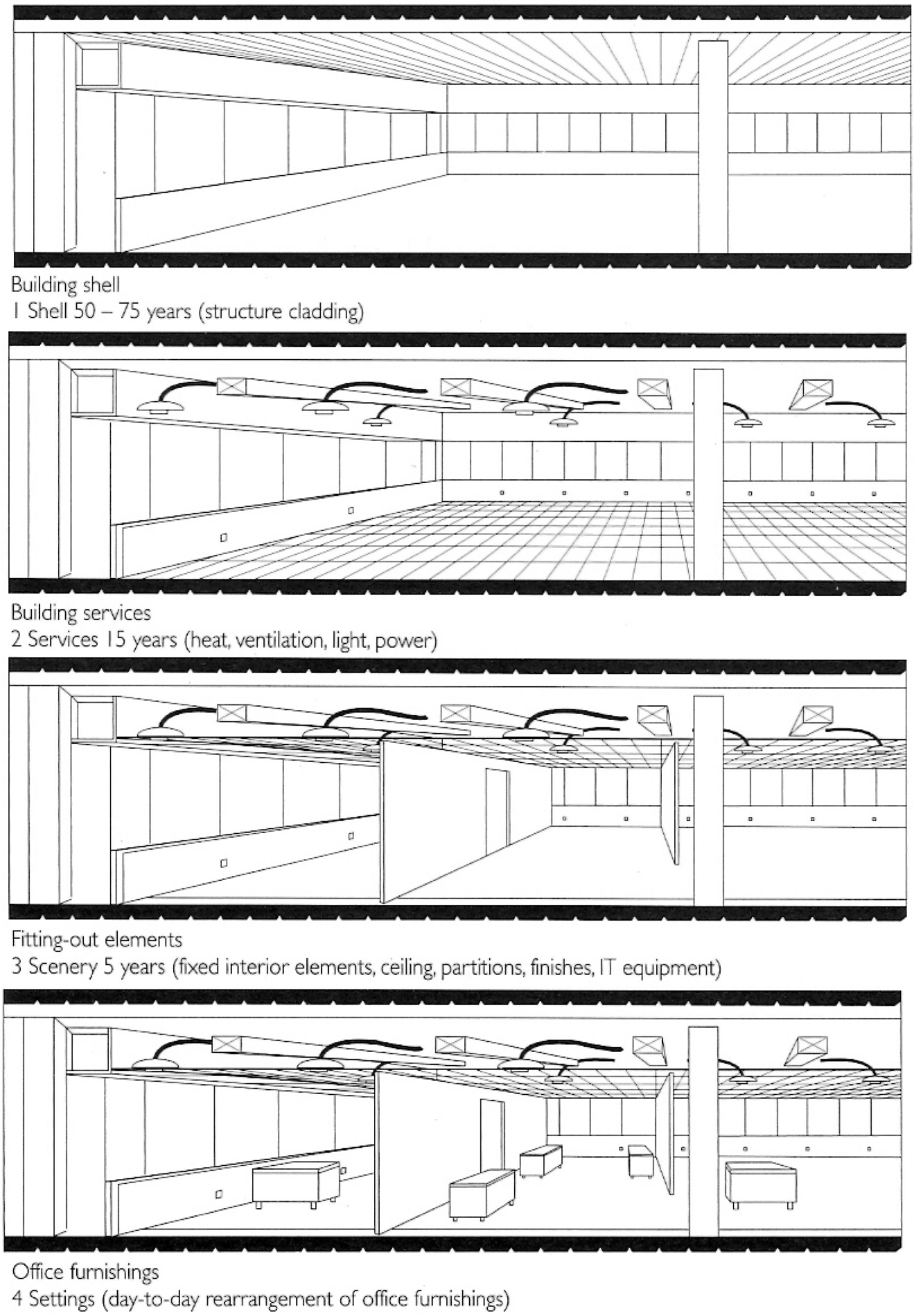


Figure 2.1: Building supply life cycles (shell, services, scenery and settings) [(1)]

(1) Ibid, P2

2.3.3 Effective buildings

In 1992, the IT consultants in Europe developed of the concept of building intelligence, which was fundamentally different from earlier concepts. In this model, the focus was on the building occupants and their tasks rather than on computer systems. Information technology was acknowledged as one of the ways in which the building can help, or hinder, the occupants, but it is not the reason for the building's existence.

Table 2.1 illustrates the latest IB model, which states that the three main goals of an organization occupying a building are building management, space management and business management.

a) **Building managemen**t: is the management of the building physical environment using both human systems (facilities management) and computer systems (Building automation system - BAS).

b) **Space management:** is the management of the building internal spaces over time. The overall goals of effective space management are the management of change and the minimization of operating cost.

c) **Business management:** is the management of the organization's core business activities. In most cases, this can be characterized as a combination of the processing, storage, presentation and communication of information.

Each of the three organizational goals can be translated into a number of key tasks such as environmental systems, the management of change, the minimization of operating costs and the processing, storage, presentation and communication of information. Table 2.2 summarizes the three models of IBs.

INTELLIGENT BUILDING GOALS	Building management	Space management	Business management
INTELLIGENT BUILDING TASKS	Environmental control of building / User control of building systems	Management of change (capacity, adapability, flexibility, manageability) / Minimisation of operating costs	Processing, storage and presentation of information Internal and external communications
INTELLIGENT BUILDING ATTRIBUTES	Design strategies and building shell attributes		
	Facilities management strategies		
	Building automation systems (BAS)	Computer Aided Facility Management systems (CAFM)	Communications (including office automation, A/V and business systems)

Table 2.1: The IB model of building intelligence [(1)]

Years	IB Model		Definition
1981-1985	**Automated Buildings**		*An Intelligent building is a collection of innovative technologies*
	IB Features	Building management Office automation Communications	
1986-1991	**Responsive Buildings**		*An intelligent building is a collection of technologies able to respond to organizational change over time*
	IB Features	Building management Office automation Communications Responsive to change	
1992-Now	**Effective Buildings**		*An intelligent building provides a responsive effective and supportive environment within which the organization can achieve its business objectives. The intelligent building technologies are the tools that help this to happen*
	IB Features	Building management Space management Business management	

Table 2.2: Models of IB [(2)]

[(1)] Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in Soth East Asia, E & FN spons, London 1998, P 3.

[(2)] Ibid.

Although the successful use of advanced technologies, including IT, is the main feature of IB, the implementation of technologies should not be the objective of IBs. Performance is definitely a key objective of intelligent buildings, although performance can be interpreted very differently as discussed above. As regards the hardware facilities, intelligent buildings cannot be separated from the architecture design, building façades and materials, which are among the essential elements of IBs. [1]

2.4 Building life Cycle

The building consists of various components; each of these components has a specific life cycle that contributes in determining the life cycle of the building.

From analyzing figure 2.2, IT items have a short life cycle because of its rapid development, and during the life cycle of the skeleton of the building. Other items may have to be replaced twice or more which means that the life cycle of a building is loosely defined with average number of years over which the element is expected to last. However, more precise definitions were stated as follows[2]:

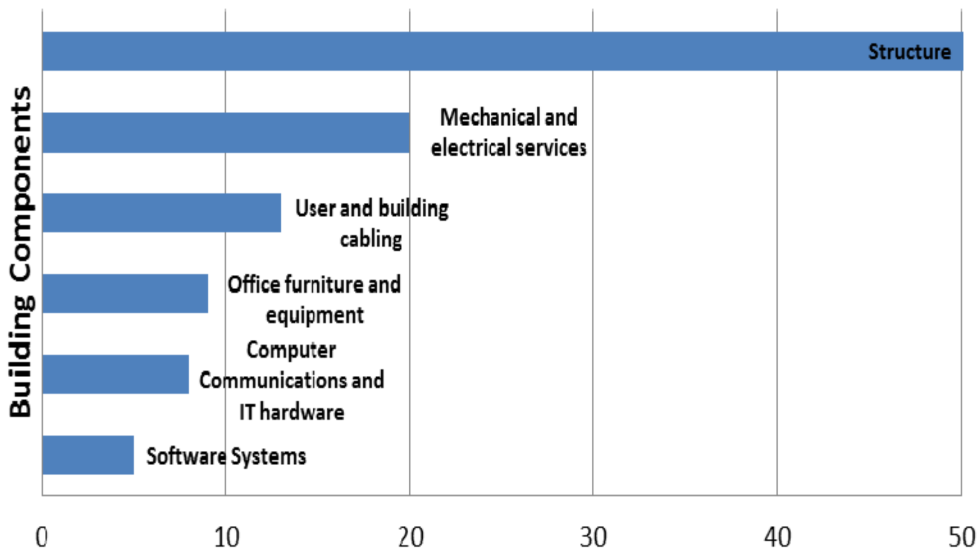


Figure 2.2: Life Time of Building Components [3]

(1) Ibid.

(2) Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in Soth East Asia, E & FN spons, London 1998, P 1-3

(3) Ibid.

- ***The Technological life*** of an item is the estimated number of years until technology causes the item to become obsolete.

- ***The Useful life*** of an item is the estimated number of years during which it will perform its function according to some established performance standard.

- ***The Economic life*** of an item is the estimated number of years until that item represents the least expensive method of performing its function.

However the detailed definitions stated above. No business area is built to last over 150 years, whereas other buildings have a designed life of only 30 years. The commercial life cycle of a building is different and has a longer life cycle than real estate and buildings. Some buildings are lower than their useable life; shopping center cycle is 11 years, an office building is 20 years, a warehouse is 25 years, and most commercial buildings cycle somewhere in between. (1)

2.5 IB Design Issues

The whole issue of IB is different, the theory of IB design; where human designers produce an architecture which is itself intelligent, rather than just an assembly of intelligent components. **(2)**

The idea is presented by integrating all design issues (Architecture, Structural, Mechanical, Electrical and IT issues) in order to achieve comfort through providing a responsive, effective and supportive environment within which the organization can achieve its business objectives.

The IB design features are drawn from the following references:

- The structure of IB from Intelligent Building Institute of USA (IBI).(3)
- The buildings' systems and structural features of Building Owners and Managers Association (BOMA)*. (4)
- The research of the IB Asia team who studied the IB in South East Asia and after selecting and analyzing set of IBs from various aspects (systems used, LCC, Building efficiency, stuff productivity,

(1) Flanagain, R. etal, Life Cycle Costing, P44-45.
(2) Albert Ting & Wai Lok Shan, Intelligent Building Systems, USA, 1999. P. 20.
(3) Ibid.
(4) www.boma.org (accessed November 2011).

etc…). As a conclusion of this study, it highlights some issues, which should be in the Intelligent Building's design. (1)

The research will make use of the IB features drive from the previous sources and use it as criteria for evaluating the IB in the case studies. These criteria are classified in five main categories: Site, Architecture, Building Mechanical services, Electrical, and Information Technology issues. Figure 2.3 illustrates the IB criteria.

An IB does not have to involve high levels of technology. A simple adaptable building form, combined with appropriately specified building services and technologies should still be able to result in a high-quality business value IB. At the building site and architecture level, the "intelligence" of the building can largely be judged independently of the current occupants, as the key issues are accessibility and adaptability.

At the level of building services and technologies, however, the likely requirements of the current occupants or those of potential tenants must be considered. The life cycle of these elements is shorter than that of the building shell or skin (15-20 years for major service elements). The right match between organizational requirements and building design and specification is critical to achieving the occupiers' current and future business objectives.

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(1) Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in Soth East Asia, E & FN spons, London 1998, P 146

- The (BOMA) is an international federation of more than 100 local associations and affiliated organizations. Founded in 1907, its 16,500-plus members own or manage more than nine billion square feet of commercial properties. BOMA International's mission is to enhance the human, intellectual and physical assets of the commercial real estate industry through advocacy, education, research, standards and information. BOMA International is a primary source of information on building management and operations, development, leasing, building operating costs, energy consumption patterns, local and national building codes, legislation, occupancy statistics, technological developments and other industry trends.

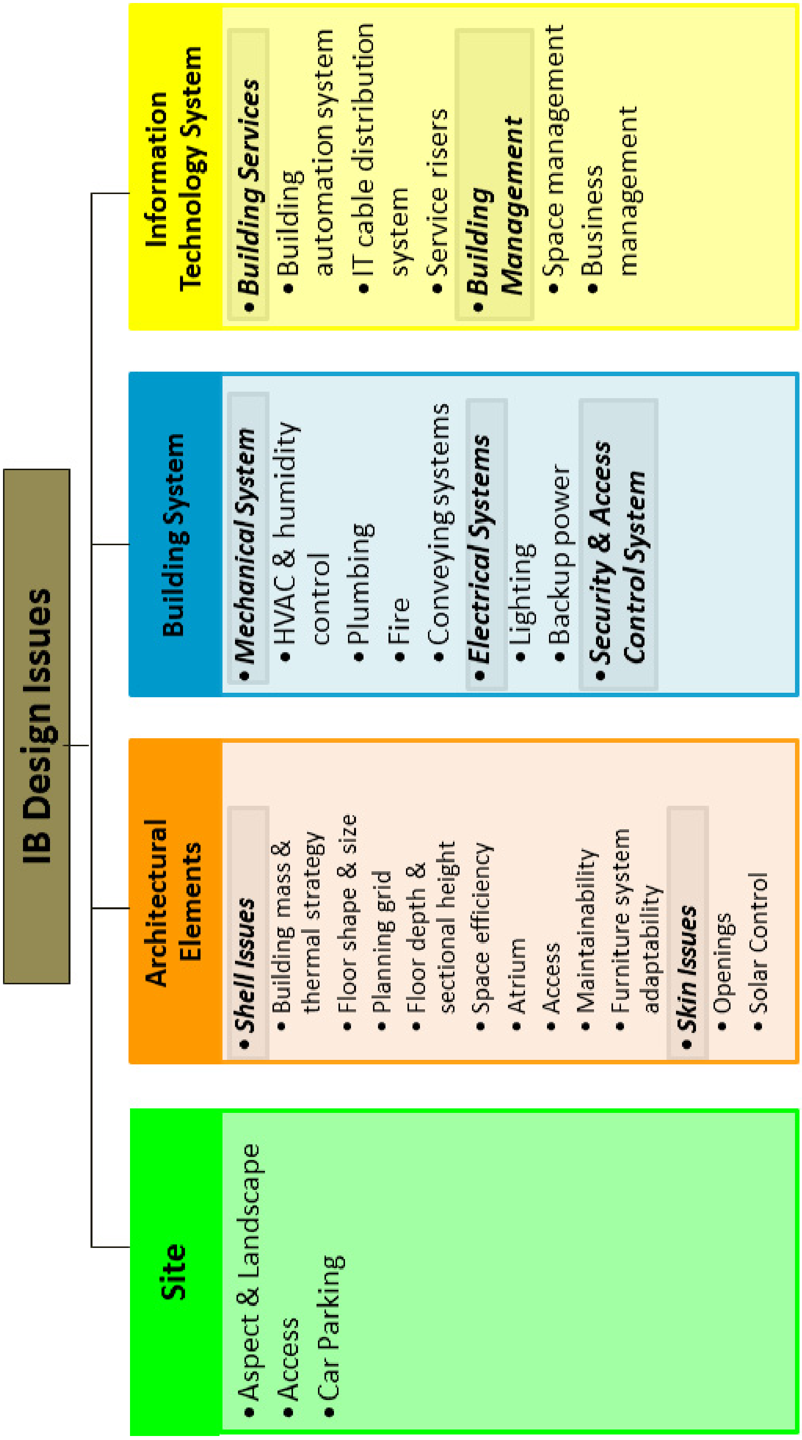

Figure 2.3: IB Design Issues (By Researcher)

2.5.1 Site Issues

The following illustrates the different criteria that contribute in the IB design from the site issues.

2.5.1.1 Aspects and landscape

The surrounding buildings should not be within 15m of each façade to allow reasonable views and daylight penetration. For the main façade it is desirable to have good aspect over main thoroughfares with well-landscaped ground where external seating, water features to other public art.

2.5.1.2 Access

The distance to main road or motorway should be less than 2Km, rail/metro stops should be within 500m of the site, bus stops within 200m.

2.5.1.3 Car parking

In inner city sites, it may be appropriate to provide limited on-site car parking for visitors or senior staff but high-standard public car parks should be available within 100m of the site. While out of town sites car parks should be provided at 1:100-130 m2 GIA in Asia, 1:20-25 m^2 GIA in Europe.

2.5.2 Architectural Elements

Intelligent architecture refers to built-forms whose integrated systems are capable of anticipating and responding to phenomena, whether internal or external, that affect the performance of the building and its occupants. Intelligent architecture relates to three distinct areas of concern that are design, use of technology and maintenance of the building. (1)

The architectural issue is analyzed under 3 main elements: the Shell, Core, and Skin. The following illustrates the different criteria that contribute in the IB design.

2.5.2.1 Shell Issues

a) Building mass and thermal strategy:

The building shape and orientation should be considered when planning the thermal environment with walls, roof, windows and building mass integrated to optimize heat gains and losses throughout the year.

(1) Shengwei Wang, Intelligent Buildings and Building Automation, Spon Press , 2010, P 4.

b) Floor shape and size:

The floor shape and size affects the ease of internal communications and circulation routes around the building. Floor plate sizes of 1500-2500 m^2 will meet the requirements of most market sectors.

Regarding the floor shape, a basic square and rectangular shape provides the most usable internal space, while the irregular and complicated external shapes which is often used to provide a building with its individuality, while this may be achieved it often brings with it penalties in limiting the design of the offices arrangement and may result in unusable floor spaces.

c) Planning grid:

The planning grid is used to logout a range of components and building systems such as partitions, raised floors and false ceiling tiles. Architecturally the planning grid is determined according to the function of the building. The structural grid should be a multiple of the internal planning grid to tie in with ceiling, partition and other building components.

For office buildings, the planning grid for most uses is 1.35m or 0.9m, both allows 2.7m offices and the structural grid should be at least 9m of clear span from façade to core which granite no columns in general open office space.

d) Floor depth and sectional height:

The depth of space is dependent on a wide variety of factors such as aspects, the possibility of natural lighting and ventilation, is necessary to differentiate between buildings that are “glass to glass” and those, which are “glass to core” in plan configuration. The majority of typical building types will be a combination of both measures. Different floor depths allow different space planning options.

“Glass to Glass” depths of up to 13.5m combined with “slab to slab” height 3.6-4.5m, or a “Glass to Core” depth of 6-12m with a “Slab to Slab” height of 3.8-4.5m.

e) Space efficiency on a typical floor:

Landlord efficiency: It is the net internal area (NIA) divided by the gross internal area GIA (NIA/GIA). It should ideally be 80-83% if the building has more than 12 floors, 83-87% for 4-12 floors height and greater than 87% if the building has less than three floors.

Tenant efficiency: It is the proportion of rented space that is actually usable. It is calculated by dividing the usable area (net internal area - primary circulation space) by the net internal area. The tenant efficiency should be at least 84% in buildings of all heights.

f) Atrium:

If there is an atrium in the building, it should be of an appropriate size and shape where the primary goal of an atrium is to bring daylight down to the center of the building. The atrium width is a minimum of 6m wide in a three-storey office building increasing to 12m for high-rise buildings.

g) Access:

Staff and visitors access: The main entrance should be located clearly visible from street level and the car park. There should be a drop-off point for visitors near the main entrance and covered access to the building. The entrance should be an automatic revolving or sliding door with a wind lack lobby. The approach to reception should be clearly identifiable and the lift lobby should be nearby.

Disable access: There should be through the main entrance with appropriate facilities provided to allow this.

Goods access: There should be a separate goods vehicle entrance with easy access from the street and waiting space. The goods entrance should be covered by CCTV cameras or include other security measures able to control access to and exit from the building by this route. The loading bay should contain a goods handling area and secure storage area. The goods lift should be near the goods entrance, it should serve all floors with enough area for furniture and equipment.

h) Maintainability:

Truly intelligent architecture incorporates intelligent facility management (FM) processes. For a design to be intelligent, it must take into consideration the life cycle of a building and its various systems and components. Although an intelligent building may be complex, it should be fundamentally simple to operate, be energy and resource efficient, and easy to maintain, upgrade, modify and recycle.

Materials and equipment that require complex maintenance and unhealthy cleaning agents, and building components that should be treated as hazardous waste in the recycling process (e.g. mercury in light- bulbs) would not be used in a fully developed intelligent architecture.(1)

The IB should have a maintenance strategy for the exterior and the interior of the building. All part should be easily accessible (façade, atrium wall and roof areas, etc..). For the interior maintainability, adequate spaces should be

(1) Shengwei Wang, Intelligent Buildings and Building Automation, Spon Press, 2010, P 4.

provided for cleaner's rooms and equipment and for exterior maintainability cradle is used for façade maintenance and cleaning.

j) Furniture systems adaptability:

The furniture system should be able to be easily reconfigured to reflect new working groups or work practices (for example increased number of meetings or rearrange office disks). It also needs to be able to cope effectively with diverse IT systems and provide an ergonomic and safe environment in which office automation equipment can be used. As part of this role the furniture may form part of the services distribution system for voice, data, and power. It should be noted that the ability to handle IT well may cause conflict with the need for rapid configuration, so an appropriate balance will need to be reached.

2.5.2.2 Skin Issues

The intelligent skin is defined as a composition of construction elements confined to the outer; it is the building envelope -weather protecting zone- of a building that perform functions that can be individually or cumulatively adjusted to respond predictably to environmental variations, to maintain comfort with least use of energy. (1)

The character of this building envelope will be affected dramatically by the development of IB. Façades designed to integrate a host of emerging technologies will have an inherent 'intelligence' and be able to respond automatically, or through human intervention, to contextual conditions and individual needs. Intelligent façades currently can:

- be centrally controlled while still providing the occupant with the ability to manually override the system;
- change their thermo physical properties such as thermal resistance, transmittance, absorbance, permeability, etc.
- modify their interior and exterior color and/or texture.
- function as communicating media façades with video and voice capabilities.
- change optical properties and allow the creation of patterned glazing, providing the opportunity for dynamic shading and remote light control.

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(1) Michael Wigginton and Jude Harris, Intelligent Skins, London, 2002. P.23.

The effective IB façade necessitates the central controls for intelligent façades that will respond to climatic conditions by transforming the building envelope to optimize heating and cooling loads, daylight utilization and natural ventilation. [(1)]

The following illustrates the different criteria that contribute in the IB design from the skin issues.

a) Openings:

Natural ventilation is part of the servicing strategy it should be considered as an integral part the base building design and careful consideration should be given to issues such as: the building plan form, ventilation rate, cross-ventilation, the quality of incoming air, provision for fire ventilation where necessary, the use of building mass, volume and exposed surfaces in cooling, and the control links between windows and other vents and the building automation system.

To maximize the servicing options for potential tenants the building skin should include opening windows wherever practical. In difficult environments such as very tall buildings, inner city locations (which tend to be noisy and polluted) and in extreme climates this is unlikely to possible or desirable.

b) Solar control:

Due to its high intensity, direct solar radiation is potentially the most significant external source of energy, which contributes to cooling loads. Although windows typically cover a relatively small fraction of a building surface, heat gain through them can be very significant as conventional windows offer little resistance to radiant heat transfer.

One method to prevent overheating is the use of shading. There is a very wide variety of shading devices: shutters, permanent or movable louvers, heavy structural or light solar protection devices. Solar shading design must take into consideration the needs for natural day lighting and allow for winter passive heating in cooler climates.

A combination of adjustable external and internal blinds are likely to provide good protection against heat gain and glare while permitting user control of lighting levels. The use of tinted or polychromic glass may reduce hear gain and glare but temper both sunlight and daylight indiscriminately.

[(1)] Shengwei Wang, Intelligent Buildings and Building Automation, Spon Press , 2010, P 5.

2.4.3 Building Systems

The following illustrates the different criteria that contribute in the IB design from the building systems issues.

2.4.3.1 Mechanical systems

a) HVAC and humidity control:

The key of HVAC systems in IBs is to be an energy efficient system. It is controlled centrally by a building management system with the temperature set in a number of zones on each floor. If an individual wanted to modify the local environment, the building management department would need to be contacted.

To cope with more varied working patterns and individual preferences in working environments there is user pressure towards providing more flexible HVAC controls. The HVAC system should either be fully zoned with individual controlled of temperature and ventilation throughout the building or the zones should be up to 75 m^2 in size. The controls, which may be provided by a telephone or PC interface to the BA system or more directly using an infrared device, should be user friendly and there should be provision for out-of-hours use by individuals or small groups provided on each floor. Separate metering should be possible for potential sub-tenancies.

In the IB the AHU is in each floor not centralized on mechanical floor. The percentage of Humidity is controlled. The fresh air intake either to be centralized on roof upper floor or to be from each floor but not below the 3^{rd} storey to prevent pollution.

b) Plumbing system:

the intelligent plumbing systems seeking for conserving water sources by using automatic sensors installed in faucets and toilets, collecting the rain water and water drain from AC units to use in the planted areas.

c) Fire system:

The design of fire systems generally depends on meeting the local codes, sprinklers should be throughout the building and halon system or CO_2 fire suppression systems are the supplementary in some special spaces such as computer rooms and equipment's rooms.

Fire alarm generally appears on the BA system or fire system console first so the Staff can access to check, and using the BA system to shut the HVAC system down, return lifts to ground level and operate the smoke exhaust system. The BA system can link the fire alarm automatically with the local fire station.

d) Conveying System:

The sophistication of vertical transportation systems is related to the size of the building. The IB elevators that groups passengers by floor destination and provides minimum waiting time was generally seen as the most important criterion for judging the effectiveness of the lift system. The lifts are connected to the BA system or lift control system to monitor and optimize performance and have direct link to the lift maintenance company.

2.5.3.2 Electrical systems

a) Lighting System:

Lighting attitudes are changing due to the increasing uses of IT at the workplaces. The overall lux level has dropped to approximately 350-400 lux to avoid glare and reflection problems for screen users. In addition, the type of lighting tends to be uplighters or low glare fluorescent luminaires. Additional lighting can be provided using task lights which provides the light where it is needed and the user can control it or by automatic on/off sensors in the light systems.

As the range of work settings in the office environment increases (for example desks, group areas, meeting spaces, computer areas) or as space is reconfigured more frequently to meet different needs it is important that the lighting levels can also change to meet different requirements. The use of dimmers and automatic switching through the building automation system will become increasingly important in making the building more responsive to the needs of the users.

b) Power:

The IB should be provided by two power inlets. Besides, a power provision system should be done for the organizations where IT is critical to their functioning. This may include a standby generator and an uninterruptible power supply (UPS) with up to 2-hour battery backup for IT and emergency system.

2.5.3.3 Security and access control system

The level of security required in a building varies widely depending on organizational type and location. Security systems can range from simply having a security guard patrolling that premises at night to sophisticated access control and surveillance systems using numeric access codes, card access systems or radio tags and cameras which can be linked into the BA system or controlled separately from a security center. The integration of the security system with the other building systems may reduce the number of people required to monitor the various systems and may reduce the amount of human intervention required. An event detected by one system sensor can be programmed to trigger a reaction in every separate system.

2.5.4 Information Technology services

The mere availability of a large variety of smart materials and intelligent technologies often results in their use in inappropriate situations. Integrating intelligent technologies with an intelligent built form that responds to the inherent cultural preferences of the occupants is a central theme in intelligent architecture. As an example, in areas where people place a high premium on operable windows for conservation of electricity, the most appropriate and efficient air- conditioning strategy for a building may be the use of thermal mass and night- time free cooling instead of a high- tech air-conditioning system. In other cases, the use of carefully selected electric lighting and environmental control strategies may be more appropriate[(1)].

The following illustrates the different criteria that contribute in the IB design from the IT issues.

2.5.4.1 Building Services

The building services can only be assessed in terms of how well they meet the requirements of the building occupants. The building services includes the fundamental uses in each business organization such as computer facilities, telephones, facsimiles, voice, data and video communications, etc…

a) Building automation system (BAS):

Building services controls are evolving from being large and centralized control systems to smaller, more flexible systems often with individual controllers on items of plant. Information is passed from theses controllers via a data network back to a central building automation (BA) system on a PC where action can be taken if a problem arises.

Applications such as environmental services control, fire detection, security, lighting and preventative maintenance can be included in a BA system but the amount of integration between the sub systems depends on local regulation and user preferences. Even where it is not possible to integrate the building sub-systems into a single BA system it is important to ensure that key data can still pass between the independent sub-systems. In the future there is likely to be increasing integration between building management and

[(1)] Shengwei Wang, Intelligent Buildings and Building Automation, Spon Press , 2010, P 5.

general IT systems, to the extent that data from both may be carried on the same local area network.

b) IT Cable distribution system:

Structured cabling systems are the norm in most IB but there is still a variety of different cable types and methods of distributing the cables around the building floor by raised floor, perimeter of floor trunking or ceiling. The choice for cable types is based on IT requirements were as the method of distribution is related to building characteristics such as sectional height, depth and degree of centralization. The overriding issue in IB is how easy is it to modify or reconfigure the system to meet the present and future needs.

The structured cable system should provide one voice and one data outlet per 5-10 m^2 i.e. the outlets are covering area on a 3 m grid base. There should also be easy access to cable routes and 50% spare capacity in cable containment.

c) Service risers

The services risers should make up approximately 1.5-2% of GFA on a typical floor and there should be at least two separate riser locations to increase resilience in case of fire or other major problems. There should be a separate riser for voice and data communications and its room is at least 2x1m that should be provided to serve every 500-1000 m^2 of floor space. These communications rooms should be located such that the length of cable runs does not exceed 50 m.

2.5.4.2 Building Management

The building, space and business management are the core of the effective building model.

a) Space Management Systems:

Computer Aided design (CAD) systems can be used to produce layout plans, take-off areas and produce furniture and equipment inventories. Facilities management information systems includes a wide range of graphic and non-graphic data applications such as lease management systems, organizational, building and equipment databases and cost monitoring systems. Cable management systems can be used both for cable and network design and the recording of patching changes in structured cabling systems.

These systems are becoming increasingly necessary for the effective management of buildings if they are to meet rapidly changing user requirements. It is imperative that data on the space management systems is accurate and up to date at all times and there should be a high level of integration between the space management systems and other business resources departments that will need to access data from the space managements systems on a regular basis.

b) Business Systems

Business Systems is an umbrella term, which covers the applications traditionally included in “office automation” together with more advanced systems such as video conferencing in house broadcast systems, smart cards and optical document scanning and retrieval systems.

Audio-visual systems are an essential part of modern communications, control and decision-making. Typically, they are used for presentations, communications with other locations, education and training, remote security control and command, control and strategic decision-making. Advanced audio-visual systems such as those provided for boardrooms decision rooms, building automation control rooms, audio-visual theaters, meeting rooms, training rooms and teleconferencing facilities, require adaptable spaces with integrated cable management to house the necessary equipment. Larger areas should be planned from an early stage of building designs. Access, information display, site lines, projection distance, lightening, acoustics, heating, ventilation, air-conditioning and cable infrastructure all need to be considered.

According to the forgoing criteria, the IB’s specifications are formulated in tables 4.3 illustrating the features of the main 4 issues.

	1- SITE	
	Aspects and Landscape	Public art, water features and external seatings. surrounding buildings should not be within 15m of each façade.
	Access	main road within 2km/ rail or metro within 500m/ busstop within 200m
	Car Parks	Provided at 1/ 100 m^2
	2- Architectural Elements	
Shell	Bldg mass & Thermal strategy	Building mass shape and Orientation
	Floor Shape & Size (typical)	Square or Rectangular,1500- 2500 m^2
	Planning grid	Adjustable grid to furnishing requirements
	Floor depth &	6 -12m glass to core, 12-15m glass to glass
	Sectional height	3.80 - 4.20 m Slab-to-slab 2.70 -2.90 m Floor-to-ceiling
	Landlord efficiency	80 - 82 %
	Tenant efficiency	84 - 88 %
	Atrium	Minimum of 6m wide in a three-storey building & 12m for high-rise buildings.
	Access- staff and visitors	Medium specification reception area, separate receptions for major tenants possible
	Access – disabled access	Barrier-free entry through main entrance
	Access – goods entrance/ lifts	Separate goods entrance with loading bay and adjacent lift
	Maintainability	Façade maintenance by roof cradles
Skin	Glazing	Double glazing, tinted glass
	Opening windows	None
	Solar shading	Internal Blinds
	3- Building Systems	
Mechanical	HVAC systems	100% air-conditioned VAV system
	Air handling units	On each floor
	Fresh air intake	Centralized on roof or upper floor
	Plumbing	Automatic sensors installed in faucets & toilets.
	Conveying System	The lift system is intillegent traffic optimization system, linked to BAS
	Fire Systems	Sprinklers throughout. Smoke detectors. Integrated public address systems with limited zoning. CO_2 to special areas. linked to BAS and to main fire station
Electrical	Lighting	Zoned fluorescent 400-500 lux at desk. Dimmable in selected areas & automatic on/off sensor for light system
	Back up power	UPS with up to 2-hour battery backup for IT and emergency system.
Securit	Security system and access control	CCTV and electronic control to selected areas
	4- IT Services	
Building Services	BA systems	Zoned (up to 150 m^2). Limited user access control per zone. PC-based system covering lighting/ HVAC/ energy management. Linked to lifts and fire systems
	Telecommunication Infrastructure	Single building entry for telecommunications
	Equipment rooms	One per floor
	Cable types	Optical fibre bakbone, structured copper horizontals
	Cable distribution system	Raised floor/ trunking/ tray
	Services risers	More than 1 riser for voice and data communications, 1-2% of GFA
	Floor termination	2 outlets per 10 m^2
Management	Space management	Intregrated CAD database, assest management system
	Business systems	Some AV conference facilities

Table 2.3: IB Design Criteria (By Researcher)

2.6 Economic Vision of IB

The whole life cost of IB is an important issue to study, as the judging between growing initial costs and reduced running costs creates the economic issue of IB. besides, Nowadays the demand to information technology in business field is increasing resulting in a demand to an IB where these IT requirements are integrated. In addition to increasing the productivity in the workspace in IB's environment.

2.6.1 The Market's Demand to IB

The enhanced comfort, flexibility, and building responsiveness associated with IB technologies are among the most important features building tenants expect to have in their workplace. The Building Owners and Managers Association (BOMA) published a survey in 1800 companies across the United States in 1999 identifying the building features office tenants view as important for their offices. Office tenants ranked comfort issues highly in this portion of the survey. A large percentage 99% of respondents asserted the importance of building [(1)].

2.6.2 Reasons of extra cost in IB

IBs are generally more expensive to build than conventionally designed buildings. However, the benefit of IB infrastructure results in much lower life cycle costs and improved profitability due to the potential for higher rents.

2.6.2.1 Initial costs

While some IB design techniques actually reduce capital cost through sharing of components, sensors, and networks, overall capital costs for IBs are generally much higher than those for conventional buildings. The following characteristics of IBs contribute to incremental capital costs[(2)]:

a) Systems Integration Design: IBs capital costs are generally higher due to the increased time devoted to integrating building systems. The integrated

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[(1)] "What Office Tenants Want: 1999 BOMA/ULI Office Tenant Survey Report." BOMA International Foundation: New York (2000).

[(2)] www.boma.org (accessed October 2011).

design process calls for several additional meetings between building team members, and many iterations of building design.

b) Direct Digital Control (DDC): DDC-Based Building Automation System. Incremental costs for full-DDC systems vary significantly based on a buildings complexity. As buildings grow in size and complexity, the incremental cost of DC systems becomes comparable to that of pneumatically controlled systems.

c) Added Points in the Building Automation System (BAS): IBs usually add control points not generally found in conventionally designed buildings, such as day lighting controls with dimmable electronic ballasts, occupant-sensing controls, and thermostats for all zones of the building. These non-standard controls lead to higher capital costs.

d) Structured Cabling System (SCS): When designed correctly, capital costs for the SCS are comparable to those for distributed cabling systems. However, with SCSes, initial costs for telecommunications cabling are often paid by the building owner rather than by the tenant. The owner recovers these costs by augmenting lease prices.

IB infrastructure is least expensive when it is planned from the earliest phases of the design process. Architectural design for conventional buildings is generally not intended to accommodate a structured cabling system or raised access floors. Therefore, adding intelligence to an existing building is quite costly from an architectural perspective. Further, changing our existing pneumatic controls in a building system can add exorbitant cost, whereas installation of a new full-DDC system has relatively low capital costs. In addition, the high costs associated with premature replacement of cabling systems justify the installation of high-bandwidth systems in new buildings[(1)].

2.6.3 Savings in IB

Although there is extra cost in constructing IBs, on the other hand savings in IBs are significant in the operating and churn costs of the plant.

2.6.3.1 Operating cost savings

Operating cost savings achieved through IBs' infrastructure, more than make up for the incremental capital costs. Improved HVAC and lighting controls, along with smart metering technologies, can significantly reduce both energy and maintenance costs. An appropriately designed BAS with smart

[(1)] www.energydesignersources.com (accessed November 2011).

metering capabilities can be programmed to provide load management to minimize peak load. In the new deregulated energy market, peak demand charges are likely to escalate rapidly, particularly during summer months when buildings have the highest peak load. Therefore, IBs capable of controlling peak demand will have substantially lower demand charges. The BAS for IBs can further contribute to energy cost savings by lowering building energy consumption. Improved scheduling functions available through the BAS limit energy use by turning off unneeded equipment. The BAS also expedites the repair of malfunctioning components, thereby eliminating the energy losses that are prevalent among poorly maintained systems.

Additional operating cost savings are achieved through the reduced maintenance and facilities management costs associated with the BAS. Troubleshooting is accomplished through the BAS rather than by local testing of individual components of building systems. Further, consolidation of controls systems into one location reduces the labor required for monitoring systems and changing control parameters(1).

2.6.3.2 Churn cost savings

Churn costs are costs associated with adding, moving, or changing workspaces within an office. The flexibility of IBs reduces the time and effort required for adding or moving workspaces. Conventional buildings often provide cabling through ceilings and walls. Relocation of horizontal cabling in these buildings is very costly because walls must be torn apart, reassembled, and repainted. The access floor systems that are used in IBs provide the means for instant relocation of cabling and electrical wiring as well as power outlets and telecommunications jacks. In cases where plenum-based under floor air distribution is employed, air terminals can also be relocated quickly(2).

2.7 IB Example: Ruffino Pacific Tower

This case study is an applied example of IB and the impact of intelligent design on the LCC of the building. The data collected for this case study is derived from the research done by the IB Asia Team where the detailed data is collected throughout questionnaires covering the general cost issues,

(1) Ibid
(2) Ibid

construction cost data, running/maintenance cost and all relative building's date(1).

Reference Case: In order to recognize the percentages of saving in different costs of the IB, the research compares the LCC of IB to a Reference case for a traditional Non-IB.

Reference case description: A mid-rise concrete-framed tower of 23 floors, each of 1000m^2, approximately 21000m^2 gross internal area. The skin comprises tiled precast panels with 30% glazed curtain walls. It is located in one of the business centers where the case study of the IB was located.

Cost Modeling: In order to create the LCC of each case study building, the team used two soft wares for cost modeling. The "**space wrap**" cost modeling program is a building costing system. It represents physical form through either costed or measured building elements and calls them up in a series of patterns, it proved an idea tool to use on IBs' data, enabling the required filters and loops to be incorporated to generate an elemental cost plan for each case study building. The "**Build care**" is the second software that is set out to calculate the cost of construction, running and maintenance of building over a defined period, which is 30 years, in this case study and represent it in net present values (NPV).

Currency Conversion: The different countries represented in the study do not have common countries, so the US$ is accepted as a reference currency where all costs are converted to it.

Time Conversion: All costs are brought to the third quarter of 1995 taking in consideration the inflation factors for each country which were used to generate multiplying factors for each case study initial capital cost.

Fig. 2.4 represents graphically the LCC of the Non-IB in a chart diagram.

The construction cost for the case study excludes the land purchase cost and landscape treatments. The maintenance cost includes the combination of all technical and associated administrative actions intended to retain an item in, or restore it to a state which it can perform its function, besides the replacement cost that include the change of any item or equipment on the life cycle of the building.

(1) Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in Soth East Asia, E & FN spons, London 1998, P 1-3

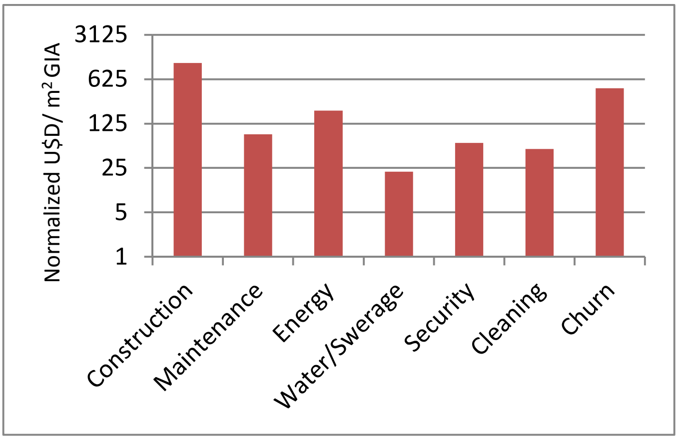


Figure 2.4: Reference case LCC (1)

The running costs are those cost centers that directly relate to the operations of the building such as energy, water, sewerage and cleaning, security and churn. Energy is the most cost effective center in the running cost. The water and sewerage costs are variable according to the building location and the resource that the building relied on, while the security and cleaning costs have less significance cost in the region where the case studies are located.

Building Information:

Architect: Adrian Wilson In. Consultant

Location: Manila, Philippines

Completion date: 1993

Building size: 49253 m^2 GIA

No. of floors: 41 floor (161 m height)

Figure 2.5: Ruffino Pacific Tower (2)

(1) Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in South East Asia, E & FN spons, London 1998, P 109.

(2) www.wikipedia.org (accessed Dec. 2011)

The tower is a steel structured skeleton and it has built to with stand 200km/hr hurricane winds and earthquakes. It is one of the first buildings in the Manila market to provide high level of tenant features [(1)]

Table 2.4 illustrates the features of the Ruffino Tower from the issues studied before (site, architecture, services, and IT).

Figure 2.5 represents graphically the LCC of the Ruffino tower, In order to understand the figures of the IB it is compared with that of the Non-IB.

Figure 2.6 compares the LCC of the Ruffino Tower with the reference case building. It is recognized that the capital construction costs of the intelligent building is 11% more but the running cost is significantly less.

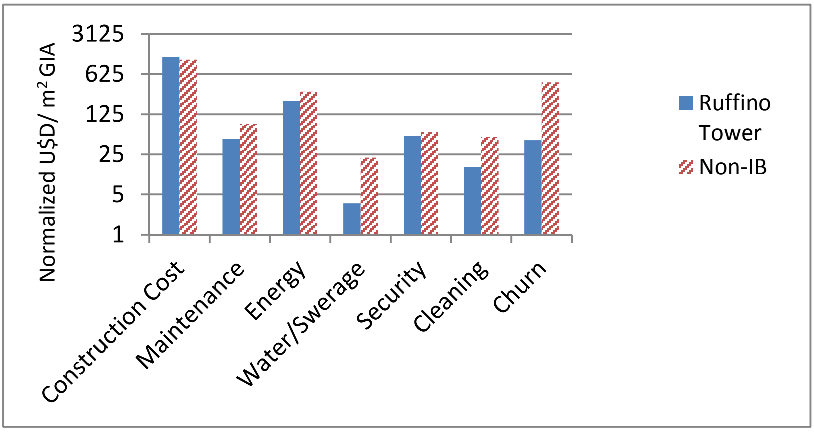


Figure 2.6: LCC of Ruffino Tower and Non-IB (By Researcher)

(1) Ibid.

	1- SITE	
	Aspects & Landscape	No external landscaping, Central business district
	Access	main road within 2km/ rail or metro withi 500m/ busstop within 200m
	Car Parks	Provided at 1/ 59 m^2 (using hydrolic car lifts)
	2- Architectural Elements	
Shell	Bldg mass & Thermal strategy	
	Floor Shape & Size (typical)	Square plan, 947 m^2 GIA with central core
	Planning grid	
	Floor depth	10.5m depth glass to core
	Sectional height	3.29 m Slab-to-slab 2.43 m Floor-to-ceiling
	Landlord efficiency	82 %
	Tenant efficiency	87 %
	Atrium	No Atrium
	Access- staff and visitors	Good vehicle and pedestrain
	Access – disabled access	Disabeled access through car park
	Access – goods entrance/ lifts	No goods lift or lading bay
	Maintainability	Roof Cradle for the façade clearing
Skin	Glazing	Single glazed (low E), 100% on all façades Tinted Glass
	Opening windows	None
	Solar shading	Usind internal blinds and No external shading devices
	3- Building Systems	
Mechanical	HVAC systems	100% air-conditioned VAV unitary system
	Air handling units	4 each floor
	Fresh air intake	From roof floor
	Plumbing	-N/A-
	Conveying System	Gearless lifts, zoned, separate lift optimization system, no goods lift
	Fire Systems	Sprinklers throughout. No link to fire station
Electric	Lighting	Linear fluroescent, low-glare luminaires, 500 lux at the desk
	Back up power	-N/A-
Security	Security system and access control	CCTV and guard patrols, tenant card access systems
	4- IT Services	
Building Services	BA systems	PC system, single workstation, separate data network
	Telecommunication Infrastructure	
	Equipment rooms	Main equipment rooms in basement, some space in risers
	Cable distribution system	Ceiling distribution to wall and column outlets
	Service Risers	Two risers dedicated to communications
	Floor termination	One voice and data outlet per 20 m^2, data to tenant requirements
Mang.	Space management	No space management system
	Business systems	Some AV conference facilities

Table 2.4: Ruffino Tower IB Criteria (By Researcher)

The percentage of savings appears in table 2.5. The churn, cleaning and maintenance cost are extremely effective, and security is 15% less than Non-IB reference case. The water consumption is 84% less as the use of water supplies drawn from the building's artesian wells* shows a marked benefit in running cost. Although no savings appear in the energy consumption, but it should be taken in consideration that the reference case is 30% glazing while the Ruffino Pacific Tower is 100% glazing façades.

	Savings (%)
Construction	No savings
Maintenance	46%
Energy	No savings
Water/Sewerage	84%
Security	15%
Cleaning	66%
Churn	90%
Demolition	No savings

Table 2.5: Savings in Ruffino Tower

The previous analysis of the IB case study emphasizes the savings achieved by the IB in the running costs. Besides, the deduction that the main architecture tool in the IB that has a big influence on the running costs of the building is the facades. This guided the next part of the thesis to apply few changes -within the skin's intelligent features- in the façade of an existing building and study the changes in initial cost and running costs.

2.8 Summary

This chapter presented the economic aspects of the IB, explaining the reasons of extra cost and the areas of savings in these buildings.

This chapter summarizes the design criteria of intelligent buildings and arranges it in a table classifying it under four main titles.

It also discusses an example to present the costs of IB compared with traditional buildings, in order to emphasize the importance of studying the LCC while making the decision in IB investments.

*Artesian wells: wells from which water flows under natural pressure without pumping. It is dug or drilled wherever a gently dipping, permeable rock layer (such as sandstone) receives water along its outcrop at a level higher than the level of the surface of the ground at the well site.

Chapter 3

Value Engineering Applied Examples

Chapter 3: Value Engineering Analytical Examples

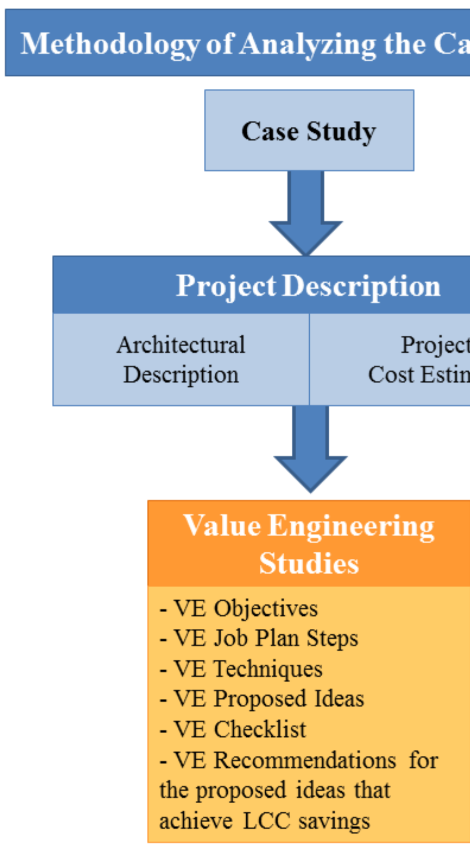
3.1 Introduction

This chapter illustrates two applied examples for VE studies: The Capital Tower Project in Amman and the National Eye Hospital in Cairo. The VE took place during the construction document stage. The analysis goes through the two cases with respect to the theoretical approach in chapter 1.

3.2 Case studies

The analysis commences with defining the project, and then the cost estimate for the project explaining the motives of the owner to make VE and the VE objectives that the team sets to achieve the owner's goal. The study goes through the VE methodology demonstrating the techniques used and the documents that present the team effort.

All the proposed ideas are presented pointing out the performance benefits and potential savings. The analysis used the VE checklist to demonstrate the area that the VE proposed ideas have covered. The research Selected few items that achieve LCC savings to be explained in details.



3.2.1 Capital Tower Project "CTP"

Location: Amman, Jordan

Architect: Foster & Partners

Consultant: Buro Happold

Project Manager: Projacs JV Arabtech Jardeneh

Date: 2007 until now

Building Area: 74108 m^2

No. of Floors: 52 Floors

Figure 3.1: Capital Tower Project (1)

3.2.1.1 Project Description

The Capital Tower Project, Amman forms a part at the western end of a master plan for redevelopment of the Abdali district in central Amman. It is an office building project, consists of main tower pedestrian plaza and beneath the buildings is a common basement covering the full extent of the plot. It is an office building project, consists of main tower (Tower 1A) and two adjacent buildings (1A1 & 1A2). These buildings are connected at their primary entrance level by an elevated pedestrian plaza and beneath the buildings is a common basement covering the full extent of the plot.

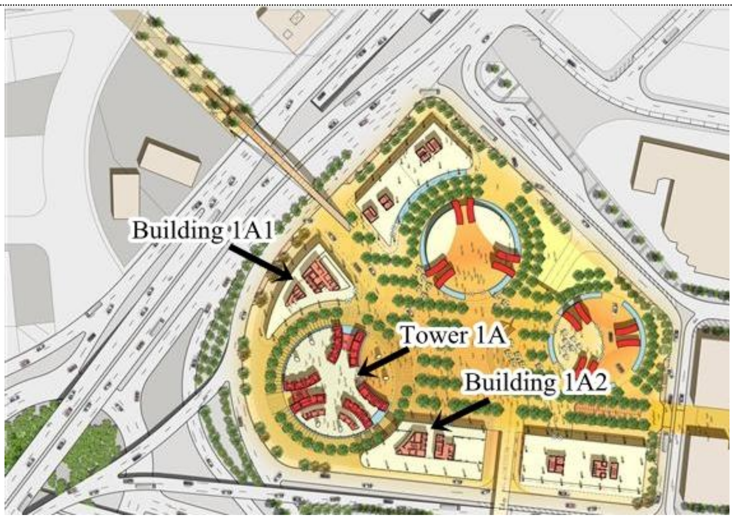


Figure 3.2: Plot 1A master plan (2)

(1) http://www.skyscrapercity.com (accessed Oct. 2011)

(2) www.fosterandpartners.com (accessed Jan. 2012)

Tower 1A: The center point of the plot is a 220m high tower, circular in plan with a floor area of 74,108m². It is located in the southwest corner of the plot with its center directly on axis with the "Pedestrian Spine" sector. The tower plan is divided into three segments giving the impression of three linked narrower towers. These segments terminate at different levels, each tapering at its top.

Building 1A1: Building 1A1, a low-rise seven storey building, sits to the north west of the tower. The two Building 1A2 and 1A1 form a "wall" to the pedestrian plaza, protecting it both from the trafficked streets and the sun during the hottest part of the day. The area of this building is 5,817 m2.

Building 1A2: Building 1A2 is to the east of the tower. It has eight stories: seven above plaza and one below. The area of this building is 7,733 m2.

Basements: The basement covers the extent of Plot 1A. It serves the three buildings with no internal separation. The basement area is 55360 m^2. The car parking is designed to meet 1 space / 75 m^2 GIA.

The project is divided into phases, phase one is Tower 1A and the VE study is only for the tower and not including the other buildings.

3.2.1.2 Cost Estimate

The estimate cost at the end of the scheme design phase was $147 million and upon pricing the BOQ at the end of the detailed design, the figures jumped to $213 million. The owner rejected these figures and clearly stated that they were not ready to go forward in the project with this cost. After applying the VE studies to the project, the figures show $171 million, which is around 20% savings. The pie chart illustrates the percentage of elements' cost.

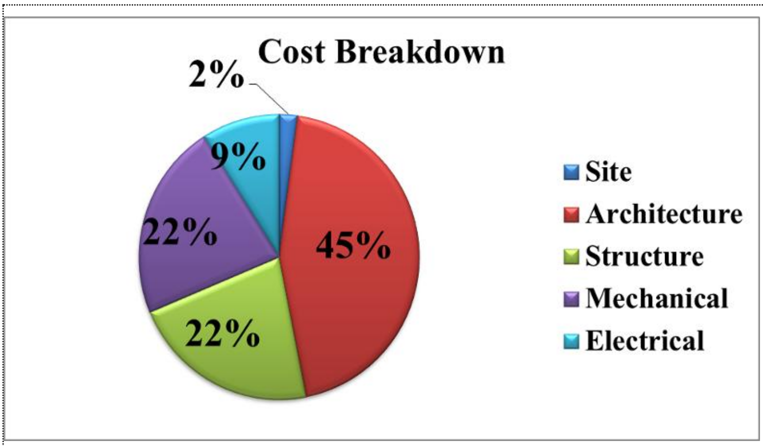


Figure 3.3: CTP Cost break down (By Researcher)

(1) http://www.skyscrapercity.com (accessed Oct. 2011)

(2) www.fosterandpartners.com (accessed Jan. 2012)

3.2.2.3 VE Objectives

The VE team summarizes the objectives to maximize value for this project by the following: (1)

- Reduce capital cost to meet ROI expectations (target 15-20%).
- Identify ways to improve constructability.
- Identify ideas to reduce the construction schedule.
- Maintain the design uniqueness of this project.

3.2.1.4 VE Job Plan

The VE study go through the 5 steps of the job plan (Information gathering step, Creativity and idea generation, Analyze ideas/evaluation and selection, development of proposals, presentation) applying some techniques in order to analyze the function maximizing the value and reducing the cost. Figure 3.4 illustrates the documents that were the output in each step of the job plan according to the applied techniques.

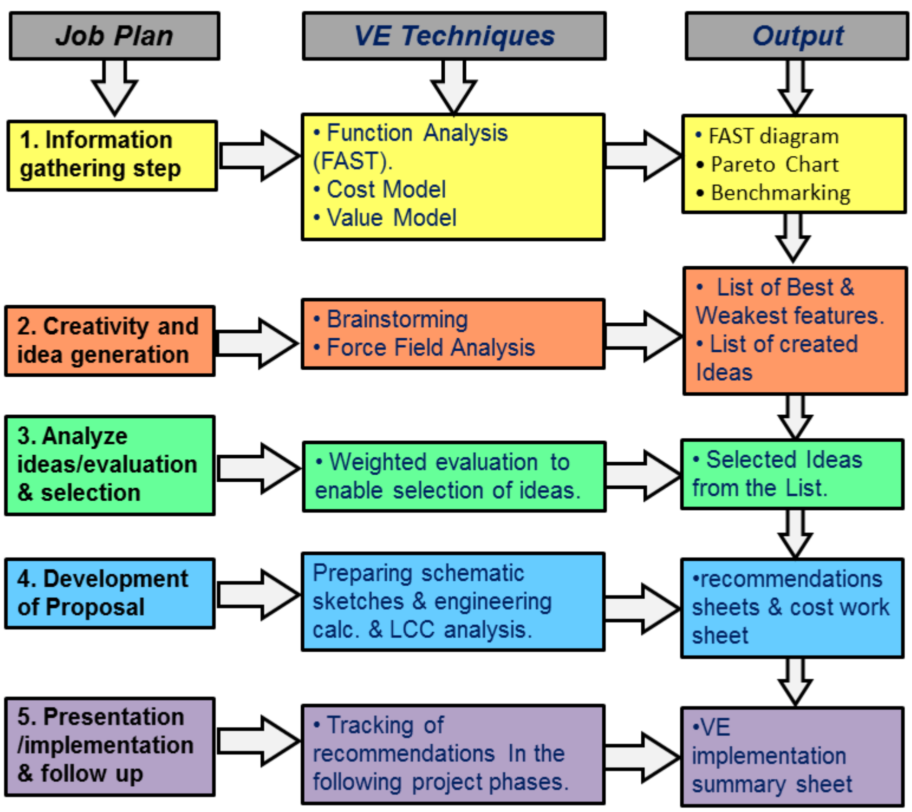


Figure 3.4: CTP VE document (By Researcher)

(1) Capital Tower Project, VE Report by Kirk Association, LLC, Dubai 2006.

The research presents a sample from the documents of the first step of the job plan that is the information-gathering step. The two documents that were prepared in this VE study were the FAST diagram and the Pareto diagram. The FAST diagram in figure 3.5 is prepared to understand the overall purposes of the project. It describes the essential functions of the project that will "achieve return on investment and attract tenants".

The value model is responsible for the economic criteria. All of the economic factors associated with the project such as (utility rates, discount rates, taxes, escalation rates, etc…) have been summarized for reference. The team developed the benchmark criteria from similar projects (completed or designed in 2005) to help in understand the relative cost of the project.

The Pareto diagram in figure 3.6 was prepared from the cost model, comparing the unit cost of each division in the B.O.Q with the cost worth that is the market's average cost of similar projects in the region. This is to understand the total construction costs for the project.

The Pareto diagram recorded the difference in cost between the case study and the average prices of the market and the item "Doors and Windows" showed a big difference. This was due to the sophisticated glazing system used in the facades. The team worked on this division specially the glazing system of the façade, not reducing the cost but maximizing the value of the expensive glazing system used in the building. The team recorded the idea as a suggestion in the recommendations.

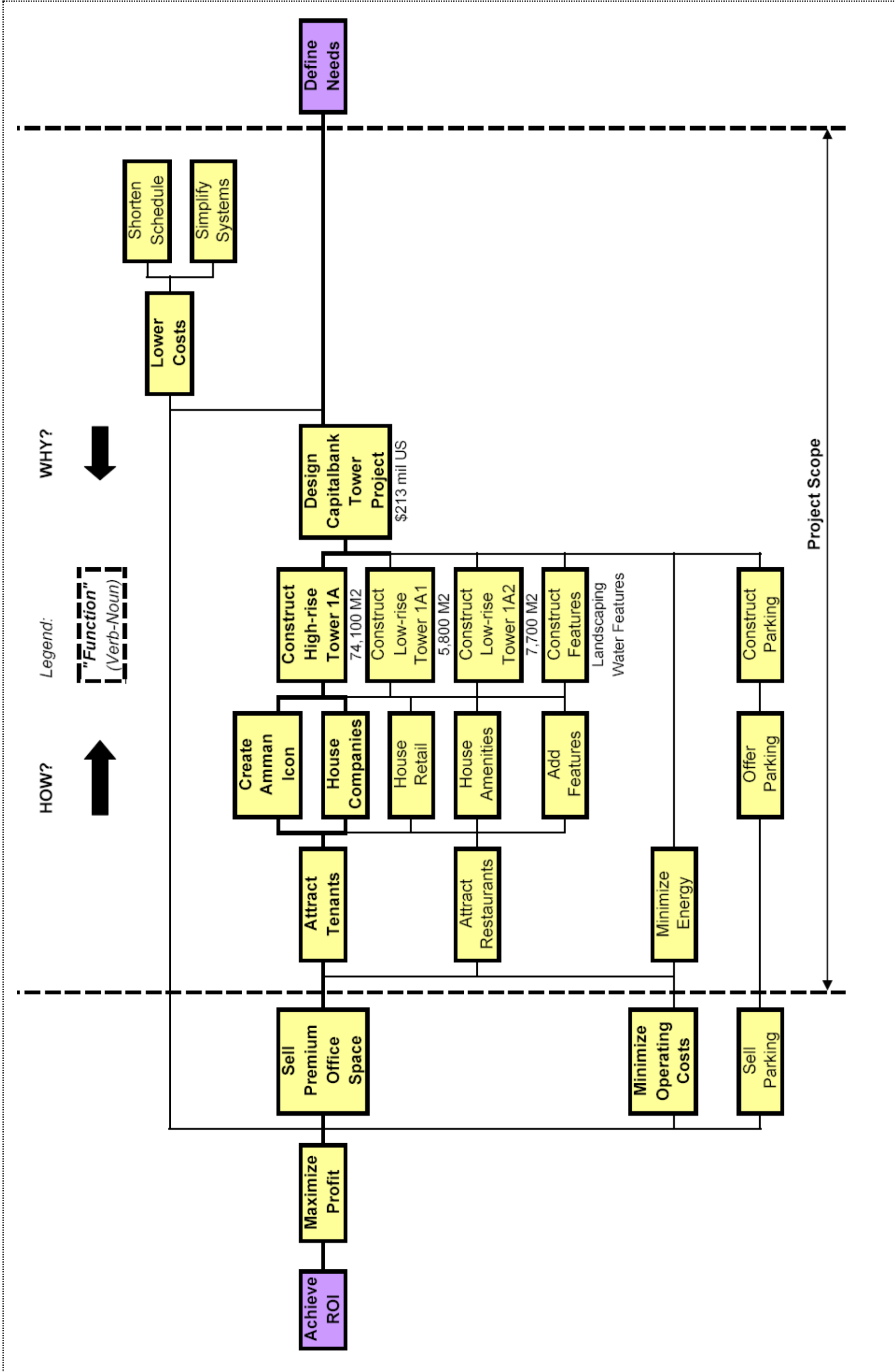


Figure 3.5: Capital Tower Project FAST Diagram (1)

(1) Capital Tower Project, VE Report by Kirk Association, LLC, Dubai 2006.

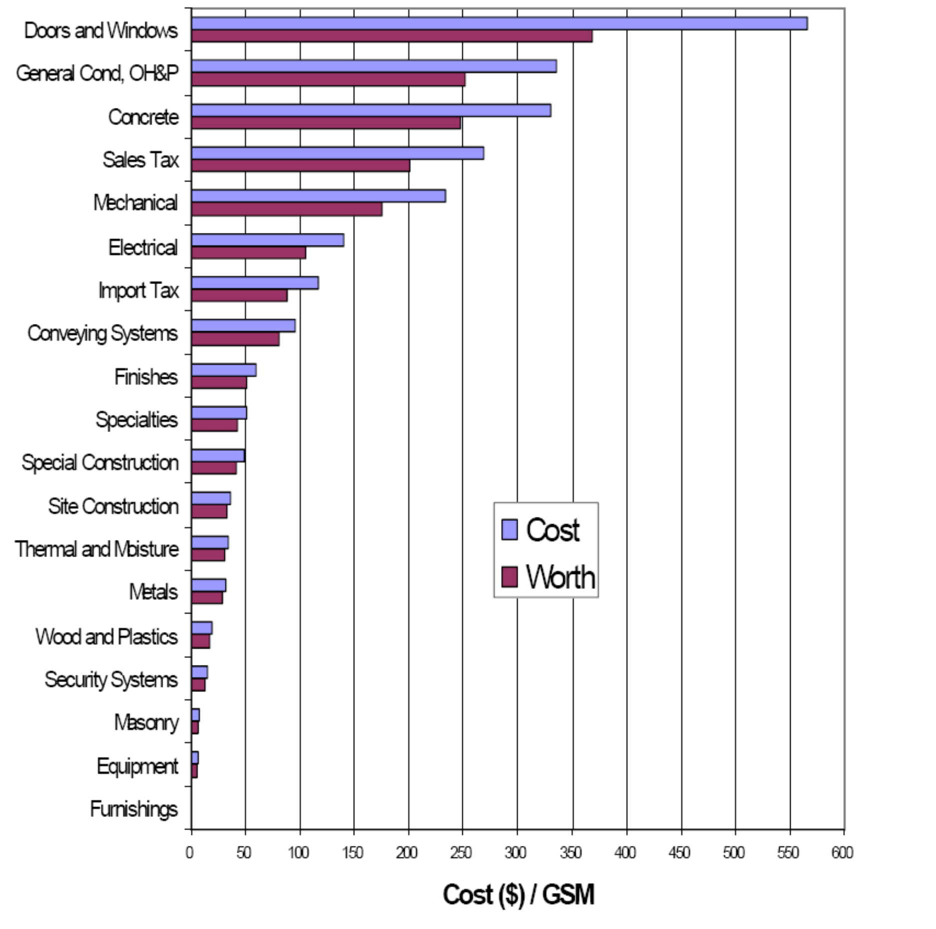


Figure 3.6: Cost Model Pareto Chart [1]

3.2.2.5 VE Proposed Ideas

The team prepared a set of ideas, and it was presented under the following categories:

- Civil / Landscape / Site
- Architecture
- Structure
- Mechanical
- Plumbing
- Electrical
- General

(1) Ibid

Table 3.1 summarizes the items of the VE recommendations under the forgoing classification. The table demonstrates the performance benefits and the potential savings (Initial & LCC savings) for each item. The proposed ideas that causes increase in the initial cost are mentioned in the table as a "Design Suggestion". While the items that the VE team selected for implementation are in the last column presenting the calculated initial and LCC savings.

The total savings appeared is 20% divided as follows:

- 11% Site = $ 6,195,400
- 15 % Architecture = $ 8,845,600
- 20% Structure = $ 11,721,200
- 5% Mechanical = $ 2,763,250
- 23% Plumbing = $ 1,740,700
- 7% Electrical = $ 4,179,310
- 19% General = $ 10,625,300

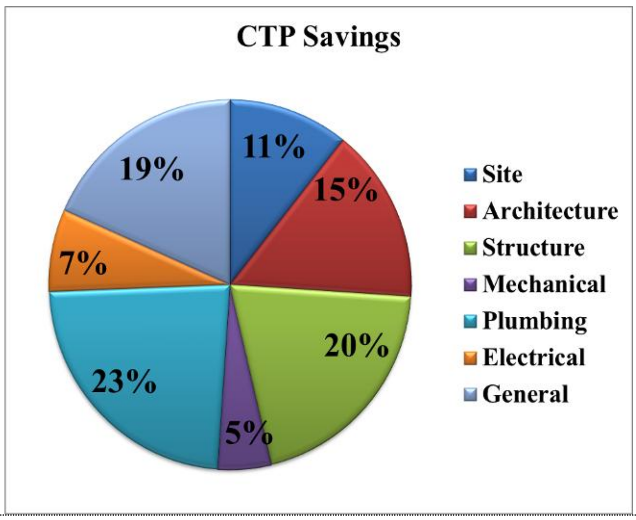


Figure 3.7: CTP Savings (By Researcher)

The "General" Item states the following: Adjusting the price of curtain wall and shading assembly from $1200 to $1000 per sqm. It is considered an architectural element savings. Accordingly, the architectural elements savings shows 15+19 = 34%. The savings appear from the façade elements shows 92% from the architectural and general elements, which is equal to 31% from the total savings the VE team achieved.

No.	Idea Description *ilo = in lieu of*	Performance Benefits							Potential Savings ( ) indicates cost increase		VE Teams Selected Implementioin Items	
		Revenue	Marketability	Less Risk	Schedule	Maintainability	Energy	Other	Initial	LCC	A. Maximum Initial Savings	B. Maximum LCC Savings
Civil / Landscape / Site (C)												
64	Add drop off and access to Tower 1A		+			+	+	Improved comfort	Design Suggestion	Design Suggestion		
76	Extend basement to common property areas and reduce basement levels			+	+			Reduces parking levels	$3,117,500	$3,117,500	$3,117,500	$3,117,500
115	Eliminating shoring and use sloped excavation to 5-7m (rest is rock)				+			Not used on adjacent project	$930,000	$3,077,900	$930,000	$3,077,900
Architectural (A)												
3	Consider using "active" curtainwall system	+	+			+	+	Improved CW performance	Design Suggestion	Design Suggestion		
10	Consider conducting exterior thermal facade modeling			+			+	Validates performance	Design Suggestion	Design Suggestion		
11	Consider eliminating inner pane of glazing and use insulated glass only					+		Reduces schedule	$2,125,000	$2,125,000		
14	Use GRP panels for sun shade elements				+	+	+	One piece component	$4,157,400	$5,175,300	$4,157,400	$5,175,300
30	Reduce floor to floor height to 3325mm ilo current 3925mm	+						Potential added revenue	$0	Added Revenue	$0	Added Revenue
72	Replace vertical wood ribs with alternate material system			+	+			Simplifies construction	$999,100	$999,100	$999,100	$999,100
77	Use pre-cast string frames and steps for staircases ilo pre cast flights and single section cut treads				+			Reduces schedule	$5,100	$5,100	$5,100	$5,100
83	Use 2600mm ceiling height ilo 2700 mm				+			Simplifies construction	$769,400	$769,400		
110	Add pantries in each floor		+					Adds feature to space	Design Suggestion	Design Suggestion		
118	Make 1A1& 1A2 roof elements out of concrete ilo steel				+			Uses common elements	$438,900	$438,900	$438,900	$438,900
125	Eliminate waste receptacles in each toilet areas and use one combined waste receptacle					+		Reduces items to be installed	$174,900	$174,900	$174,900	$174,900
134 & 136	Change EWS - 2 & 6 glass specifications							Initial Cost	$2,052,300	$2,052,300	$2,052,300	$2,052,300
135	Redesign the internal system at Curtainwall EWS 1E				+		+	No thermal break CW profile	$475,500	$475,500		

Table 3.1a: VE Recommendation Items

No.	Idea Description *ilo = in lieu of*	Performance Benefits							Potential Savings ( ) indicates cost increase		VE Teams Selected Implementioin Items	
		Revenue	Marketability	Less Risk	Schedule	Maintainability	Energy	Other	Initial	LCC	A. Maximum Initial Savings	B. Maximum LCC Savings
Structural (S)												
23	Consider post-tensioned structural slab system ilo standard cast in place design		+		+			Increased time to market	$2,610,000	$2,610,000	$2,610,000	$2,610,000
31	Reduce the thickness of the vertical elements as the structure moves upward				+			Added space in upper floors	$434,800	$434,800	$434,800	$434,800
32	Reduce the slab thickness				+			Initial Cost	$384,900	$384,900		
33	Reduce the thickness of the raft foundation				+			Initial Cost	$311,300	$311,300	$311,300	$311,300
34	Use Post tension flooring system in the basements				+			Reduced schedule	$1,650,000	$1,650,000		
36	Use flat slab in parking levels (conventional) ilo drop beams				+			Reduced schedule	$1,340,900	$1,340,900	$1,340,900	$1,340,900
139	Remove the formwork cost from the original BOQ			+	+			Reduced schedule	$5,671,000	$5,671,000	$5,671,000	$5,671,000
140	Consider using steel reinforcement with 460 mpa strength				+			Simpler construction	$1,353,200	$1,353,200	$1,353,200	$1,353,200
141	Use flat plate flooring system in buildings 1A1 and 1A2 instead of conventional slab with beams				+			Reduced schedule	$377,000	$377,000		
Mechanical (M)												
2	Consider changing design temperature to 23°C ilo 21°C				+		+	Reduced energy	$701,600	$701,600		
26	Omit thermal insulation from the toilet exhaust ductwork				+			Initial Cost	$75,700	$75,700	$75,700	$75,700
27	Omit CO2 detection system in parking areas				+			Initial Cost	$238,000	$238,000	$238,000	$238,000
28	Reduce fresh air intake to 10L/person (make non-smoking) ilo 18L/person as designed		+	+		+	+	Cleaner indoor air quality	$252,700	$1,554,100	$252,700	$1,554,100
40	Omit central hot water heating system, use localized electric storage and heating				+			Tenant operated	$480,300	$480,300	$480,300	$480,300
126	Eliminate fire rated ductwork				+			Reduces schedule	$2,104,500	$2,104,500		
129	Use GRP tanks ilo steel for fire fighting needs				+	+		Requires less maintenance	$407,600	$407,600		
138	Eliminate fire suppression in electrical rooms				+			Not required	$270,500	$270,500	$270,500	$270,500

Table 3.1b: CTP VE Recommendation Items

No.	Idea Description *ilo = in lieu of*	Performance Benefits							Potential Savings ( ) indicates cost increase		VE Teams Selected Implementioin Items	
		Revenue	Marketability	Less Risk	Schedule	Maintainability	Energy	Other	Initial	LCC	A. Maximum Initial Savings	B. Maximum LCC Savings
143	Consider procuring mechanical services from within the region								$1,446,500	$1,446,500	$1,446,500	$1,446,500
Plumbing (P)												
44	Use PPE piping for domestic hot & cold water				+			Same performance	$1,107,100	$1,107,100	$1,107,100	$1,107,100
62	Use HDPE for drainage piping ilo cast iron				+			Same performance	$633,600	$633,600	$633,600	$633,600
63	Eliminate the insulation for the cold water piping				+			Not required	$117,700	$117,700		
65	Delete thermostatic mixing value & check valve for wash basins & use traditional mixing valves				+			Uses common practice	$345,700	$345,700		
Vertical Transportation (VT)												
1	Consider adding express elevator to top.		+					Direct upper access	Design Suggestion	Design Suggestion		
55	Confirm detail of vertical traffic analysis (30 now, vs. less)							Varies service to building	$2,904,800	$2,904,800		
Electrical (E)												
41	Consider procuring electrical services from within the region						+	Lower loads	$792,000	$792,000	$792,000	$792,000
42	Reduce number of CCTV cameras				+	+		Simpler system	$147,500	$147,500	$147,500	$147,500
46	Use aluminum lightning protection components in lieu of copper where appropriate							Initial Cost	$15,400	$15,400	$15,400	$15,400
47	Consider using aluminum bus ilo copper			+	+			Initial Cost	$196,000	$196,000	$196,000	$196,000
48	Consider using aluminum cable in lieu of copper for main feeder			+	+			Initial Cost	$140,000	$140,000	$140,000	$140,000
49	Reduce form of the main boards from an assembly type 4 form 6 to form 3b				+	+		Simpler system	$255,600	$255,600	$255,600	$255,600
50	Consider 1,000 KVA in lieu of 1,500 KVA				+	+		Simpler system	$142,500	$142,500	$142,500	$142,500
51	Confirm need for 3 - 1.5MVA emergency generators		+		+		+	Less Maintenance	$1,226,600	$1,226,600	$1,226,600	$1,226,600
52	Review distribution of bus bar in the basement				+			Simpler system	$47,100	$47,100	$47,100	$47,100
53	Reduce / centralize fire Alarm control panel in tower				+			Avoids confustion	$300,000	$300,000	$300,000	$300,000

Table 3.1c: CTP VE Recommendation Items

No.	Idea Description *ilo = in lieu of*	Performance Benefits							Potential Savings ( ) indicates cost increase		VE Teams Selected Implementioin Items	
		Revenue	Marketability	Less Risk	Schedule	Maintainability	Energy	Other	Initial	LCC	A. Maximum Initial Savings	B. Maximum LCC Savings
58	Address telecom / data considerations in the core project	+	+	+				Supports Icon services	Design Suggestion	Design Suggestion		
67	Optimize the number of Auto Transfer Switches (ATS)				+	+		Easier to install	$207,900	$207,900	$207,900	$207,900
88	Use PVC conduit versus galvanized iron				+	+		Improved availability	Design Suggestion	Design Suggestion		
89	Use FP200 fire resistent cables in lieu of mineral insulated copper cladding (MICC)				+	+		Simpler system	Design Suggestion	Design Suggestion		
91	Optimize use of motion detectors / light sensors				+			Extends luminaire life	$37,200	$37,200	$37,200	$37,200
96	Review number and or location of speakers				+	+		Simpler system	$100,700	$100,700	$100,700	$100,700
97	Review philosophy of containment (cable trays, trunks)				+			Simpler system	$568,600	$568,600	$568,600	$568,600
144	Substitute stainless steel generator exhaust by steel with rockwool insulation and aluminium jacketing							Initial Cost	$44,600	$44,600	$44,600	$44,600
<u>General (G)</u>												
22	Adjust price of curtainwall and shading assembly from 1200 JD to 1000 JD (still conservative)			+				Confirmed pricing	$10,625,300	$10,625,300	$10,625,300	$10,625,300
109	Ensure use of regional contractor to reduce constructability issues			+	+			Ensures constructability	Design Suggestion	Design Suggestion		
124	Identify additional amenities not currently provided or discussed	+	+					Potential tenant improvements	Design Suggestion	Design Suggestion		
131	Consider reviewing the overall GCOH&P / key unit prices in the BOQ and add escalation			+				Reduces risk	$0	$0	$0	$0
137	Consider getting additional quotes for the curtainwall system as designed			+				Confirmed pricing	$29,593,500	$29,593,500		
Summary of VE Recommendations								*Savings Potential*			$42,947,800	$47,415,000
Potential Revised Cost of Project:						(per BOQ)		$213,960,429	(includes Savings Potential)		$171,012,629	20%

Table 3.1d: CTP VE Recommendation Items

3.2.2.6 VE Checklist

Table 3.2 demonstrates how the VE checklist covers the different elements in the project. The three items that have LCC savings are highlighted and they will be presented in details in the VE recommendations.

The Capital Tower Project - Amman

VE Check List

Category	Element	Sub-element	Items in VE Recom.	Initial Cost Savings	LCC Savings
A- SUBSTRUCTURE	Foundations	Standard Foundation			
		Other Foundation			
		Slab to Grade			
	Basement Construction	Basement Excavation			
		Basement Wall			
B- SHELL	Superstructure	Floor Construction			
		Roof Construction			
	Exterior Enclosure	Exterior Walls			
		Exterior Windows			
		Exterior Doors			
	Roofing	Roof Coverings			
		Roof Openings			
C- INTERIORS	Interior Construction	Partitions			
		Interior Doors			
		Specialties			
	Stairs				
	Interior Finishes	Wall Finishes			
		Floor Finishes			
		Ceiling Finishes			
D- SERVICES	Conveying Systems				
	Plumbing				
	HVAC				
	Fire Protection				
	Electrical	Electrical Ser. & Distribution			
		Lighting & Branch Wiring			
		Communication & Security			
		Other Electrical Systems			
E- EQUIPMENT & FURNISHINGS	Equipment				
	Furnishings				
F- SPECIAL CONSTRUCTION & DEMOLITION	Special Construction				
	Selective Building Demolition				
G- BUILDING SITEWORK	Site Preparation				
	Site Improvements				
	Site Mechanical Utilities				
	Site Electrical Utilities				
	Other Site Construction				

Table 3.2: CTP VE Checklist (By Researcher)

3.2.2.7 VE Recommendation

The research presents the three items that achieve LCC savings in details, they are as follows:

1- Consider using active curtain wall system.

2- Use GRP for sunshade elements.

3- Reduce fresh air intake from 18L /person to 10L/person.

Two items from the foregoing selected items are concerned with the façade, and the third item with the HVAC system.

The following sheets in figure 3.8 demonstrate the VE recommendation sheets. The first sheet illustrates the original design, proposed design explaining the advantages and disadvantages of the design suggestion and discussing the motives of the proposed ideas ending with the cost summary. The second sheet illustrates sketches for the proposed design. The third sheet is the cost work sheet that presents the calculations and compares the initial cost and LCC of the original design with the proposed idea, ending with the potential savings achieved in each idea.

Value Engineering Recommendation

Project: **Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2** **VE No.**

Item: **Consider using "active" curtainwall system** **3**

Original Design

The current system uses an insulated glazing element, a shade, and then an interior single glazing component. It is not designed as a active system and utilizes a metal shading device to provide visibility while reducing while heat gain.

Proposed Design

Make the exterior skin an active curtainwall system. This is becoming widely used in premium buildings as it ventilates the cavity between the insulated and single glazing components. This keeps the cavity air moving and provides superior interior comfort without having to use reflective or shading glass coatings.

Advantages and Disadvantages

Advantages:

- Improves interior comfort
- Saves energy (minimal)
- Improves marketability of the tower
- Maintains the exterior wall character
-

Disadvantages:

- Will require modifications to the envelope design
- May add costs to the mechanical system.
- Efficiency of this system is reduced due to solutions of heat gain using the sun shades (metal panels)

Discussion

The general consensus from the VE team, in discussions with the design team, is that this change will save some initial capital. It is hard without detailed study to determine the effectiveness of this system for this project. The VE team does believe the long term impacts for energy savings warrant further study. This means that this system will be installed by the landlord instead of the tenant.

Life Cycle Cost Summary

	Initial Cost	Life Cycle Cost
Original Design		
Proposed Design		
Potential Savings	**Design Suggestion**	

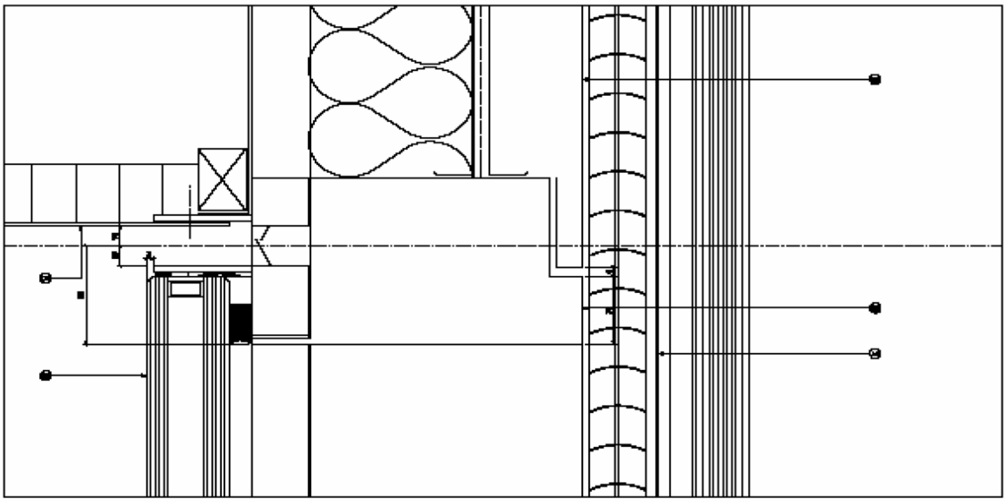
Figure 3.8-a1: CTP VE Recommendation Sheet

Sketch Worksheet

Project: Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2 — VE No. 3

Item: Consider using "active" curtainwall system

■ Original Design ☐ Proposed Design



ginal Design ■ Proposed Design

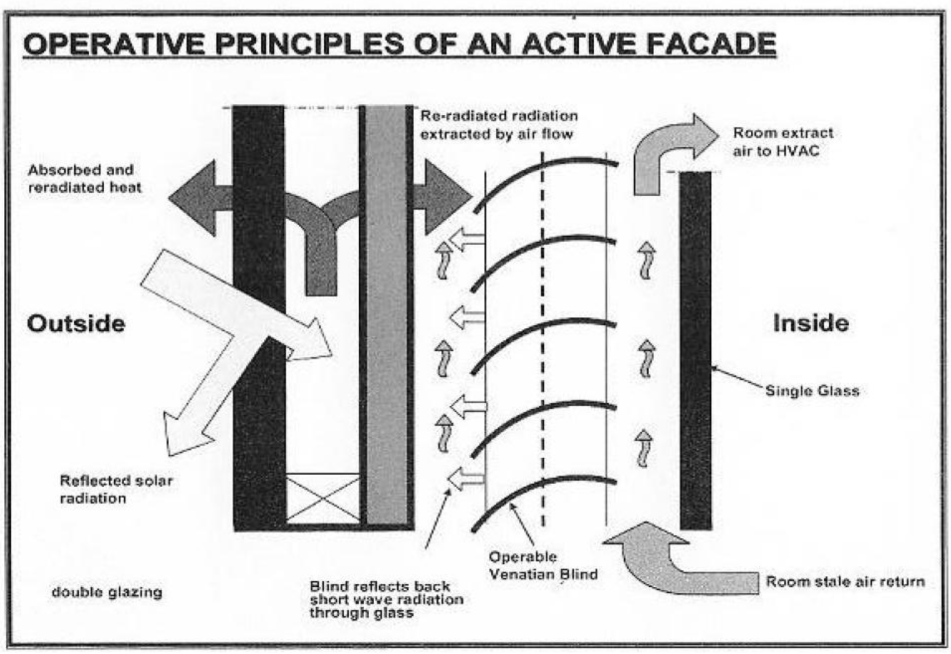


Figure 3.8-a2: CTP VE Recommendation Sheet

Value Engineering Recommendation

Project: **Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2** **VE No.**
Item: **Use GRP panels for sun shade elements** **14**

Original Design

Uses solid anodized aluminum sheets with honeycomb backing that must be bent and seamed. This process is difficult to manufacture and it is believe to create some significant fabrications challenges. The profile add ons are another problem of fixing and sealing the joints has not been resolved. No sealing the joints will detract from the buildings appearance as it will create streaking in wet weather or airborne sand. The current installation involves direct anchoring to the curtain wall (bulky transport, transportation difficulties).

Proposed Design

Use GRP (glass fiber reinforced polyester). This solution would all the panels to be a single fabrication process. The only initial cost is the wood mold so a maximum of 24 - 50 depending on the variations in the exterior wall. The fabrication also would mean a contiguous panel with no internal seams to leak. The thermal properties would be far superior to aluminum sheet. The panels would also be fixable and removable. Transportation could be stacked with separation sheets and easily transported.

Advantages and Disadvantages

Advantages:

- Much quicker fabrication
- Reduced Initial costs
- No thermal conductivity
- Quicker installation (all one piece)
- Better transportation capabilities

Disadvantages:

- Finish durability is yet to be long term tested (10 years proven?, 20 years unproven)
- Architects reservations on Warrantee
- Subject to fading
- Questions have been raised about the impact resistance of the product

Discussion

GRP has been extensively used on major projects in the Gulf Region. Examples include: Ski Dubai and Autodrome in Dubai. This product has been extensively applied in combination with aluminum panels with identical appearance. The coordination of this design and sourcing is not within the curtainwall expertise; it is recommended that this be done by a consultant specializing in this area. It is recommended that the finish using a color that can be injected in the jell during fabrication to ensure color all the way through the panel instead of a surface treatment.

Life Cycle Cost Summary

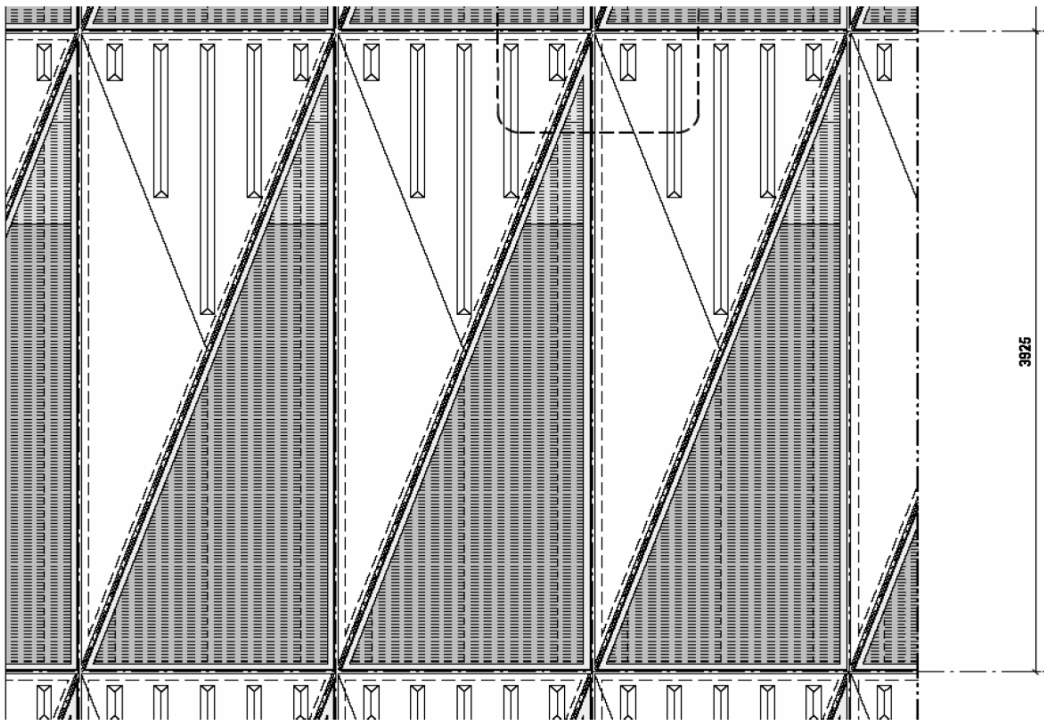
	Initial Cost	Life Cycle Cost
Original Design	**39,867,600**	**64,857,800**
Proposed Design	**35,710,200**	**59,682,500**
Potential Savings	**4,157,400**	**5,175,300**

Figure 3.8-b1: CTP VE Recommendation Sheet

Sketch Worksheet

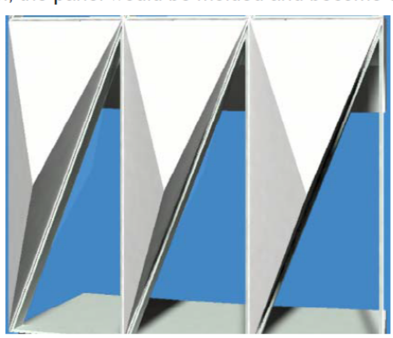
Project: Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2 — VE No. 14
Item: Use GRP panels for sun shade elements

■ Original Design ☐ Proposed Design



In Original Design, panel is assembled from multiple pieces

In Proposed Design, the panel would be molded and become one piece component



Suggested GRP Cladding panels for the facade

Figure 3.8-b2: CTP VE Recommendation Sheet

LIFE CYCLE COST ANALYSIS (LCCA)

Project/Location: Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2

Item: Use GRP panels for sun shade elements

VE No. **14**

Description:					Original Design		Proposed Design	
Project Life Cycle =	50 Years							
Discount Rate =	7.00%							
Present Time =	Date of Occupancy							
INITIAL COSTS		**Quantity**	**UM**	**Unit Price**	**Est.**	**PW**	**Est.**	**PW**
A.	Original Design	1	LS	$39,867,600	39,867,600	39,867,600	0	0
B.	Proposed Design	1	LS	$35,710,200	0	0	35,710,200	35,710,200
C.						0		0
D.						0		0
E.						0		0
F.						0		0
G.						0		0
H.						0		0
I.						0		0
J.						0		0
Total Initial Cost						**39,867,600**		**35,710,200**
Initial Cost PW Savings (Compared to Original Design)								**4,157,400**
REPLACEMENT COST/ SALVAGE VALUE								
	Description	**Year**		**PW Factor**				
A.	Refinish GRP Panels	20		0.2584		0	1,785,510	461,409
B.	Refinish GRP Panels	40		0.0668		0	1,785,510	119,237
C.	Update Aluminum Panel finish	25		0.1842	1,993,380	367,278		0
D.						0		0
E.						0		0
F.						0		0
G.						0		0
H.						0		0
I.	Salvage Value					0		0
Total Replacement/Salvage Costs						**367,300**		**580,600**
ANNUAL COSTS								
	Description	**Escl. %**		**PWA**				
A.	Energy 2% savings	4.0%		26.303	936,120	24,622,882	889,314	23,391,738
B.		0.0%		13.801		0		0
C.		0.0%		13.801		0		0
D.		0.0%		13.801		0		0
E.		0.0%		13.801		0		0
F.		0.0%		13.801		0		0
Total Annual Costs (Present Worth)						**24,622,900**		**23,391,700**
Total Life Cycle Costs (Present Worth)						**64,857,800**		**59,682,500**
Life Cycle Savings (Compared to Original Design)								**5,175,300**
				PP Factor				
Total Life Cycle Costs (Annualized)				**0.0725**	**4,699,586**	**Per Year**	**4,324,585**	**Per Year**

PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

Figure 3.8-b3: CTP VE Recommendation Sheet

Value Engineering Recommendation

Project: **Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2** — **VE No. 28**

Item: **Reduce fresh air intake to 10L/person (make non-smoking) ilo 18L/person as designed**

Original Design

Using 18 L/s/person and allows smoking inside the building.

Proposed Design

Consider a smoke free building and decrease the outdoor ventilation value to 10 L/s/person. This practice of a non smoking building is in agreement with many of the international communities, with the list growing each day.

Advantages and Disadvantages

Advantages:

- Energy Saving
- Lower initial cost
-
-
-

Disadvantages:

- Smokers lounges will be required
-
-

Discussion

Designer recommended a minimum of 12 L/s/person to maintain good quality air systems. Design team agreed on 10 L/s/person. Cost per ton is based on local project experience from the VE team members. The Petronas Towers in Malaysia have used the practice of smoking rooms in a high rise.

Life Cycle Cost Summary

	Initial Cost	Life Cycle Cost
Original Design	0	1,301,400
Proposed Design	(252,700)	(252,700)
Potential Savings (Estimated)	252,700	1,554,100

Figure 3.8-c1: CTP VE Recommendation Sheet

LIFE CYCLE COST ANALYSIS (LCCA)

Project/Location: Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2

Item: Reduce fresh air intake to 10L/person (make non-smoking) ilo 18L/person as designed

VE No. 28

Description:				Original Design		Proposed Design	
Project Life Cycle = 50 Years							
Discount Rate = 7.00%							
Present Time = Date of Occupancy							
INITIAL COSTS	**Quantity**	**UM**	**Unit Price**	**Est.**	**PW**	**Est.**	**PW**
A. Original Design	1	LS	$0	0	0	0	0
B. Proposed Design	1	LS	($252,700)	0	0	(252,700)	(252,700)
C.					0		0
D.					0		0
E.					0		0
F.					0		0
G.					0		0
H.					0		0
I.					0		0
J.					0		0
Total Initial Cost					**0**		**(252,700)**
Initial Cost PW Savings (Compared to Original Design)							**252,700**
REPLACEMENT COST/ SALVAGE VALUE							
Description		**Year**	**PW Factor**				
A.					0		0
B.					0		0
C.					0		0
D.					0		0
E.					0		0
F.					0		0
G.					0		0
H.					0		0
I. Salvage Value					0		0
Total Replacement/Salvage Costs					**0**		**0**
ANNUAL COSTS							
Description		**Escl. %**	**PWA**				
A. Energy Savings (943 tons)		0.0%	13.801	94,300	1,301,410		0
B.		0.0%	13.801		0		0
C.		0.0%	13.801		0		0
D.		0.0%	13.801		0		0
E.		0.0%	13.801		0		0
F.		0.0%	13.801		0		0
Total Annual Costs (Present Worth)					**1,301,400**		**0**
Total Life Cycle Costs (Present Worth)					**1,301,400**		**(252,700)**
Life Cycle Savings (Compared to Original Design)							**1,554,100**
Total Life Cycle Costs (Annualized)			**PP Factor 0.0725**	**94,299**	**Per Year**	**(18,311)**	**Per Year**

PW: Present Worth
PWA: Present Worth of Annuity
PP: Periodic Payment

Figure 3.8-c2: CTP VE Recommendation Sheet

Cost Worksheet

Project: Capitalbank Amman Tower 1A and Buildings 1A1 and 1A2

Item: Reduce fresh air intake to 10L/person (make non-smoking) ilo 18L/person as designed

VE No. 28

Original Design

	Quantity	Unit	Unit Cost	Total
Subtotal				0
Markup	0.0%			0
(Installation, Contingencies, Shipping)			**Total Cost**	**0**

Proposed Design

	Quantity	Unit	Unit Cost	Total
Reduced ventilation / tonnage equipment	943	tons	(267.90)	(252,700)
* Based on 1900JD per ton R.				
Subtotal				-252,700
Markup	0.0%			0
			Total Cost	**(252,700)**

Potential Savings

Potential Savings	**252,700**

Figure 3.8-c2: CTP VE Recommendation Sheet

3.2.2 National Eye Hospital (NEH)

Location: Cairo, Egypt

Architect & Consultant: Engineering Consultant Group - Egypt "ECG"

Project Manager: Egyptian Canadian Project Managers "EGYCAN"

Date: Dec 2011 till now

Building Area: 12620 sqm

No. of Floors: 3 underground & 4 above ground

Figure 3.9: NEH in Cairo [(1)]

3.2.2.1 Project Description

The National Eye Hospital (NEH) is an under construction hospital project. The project consists of one building of three underground floors of 6225 m^2 and four above ground floors of 5729 m^2 and a roof floor of 1116 m^2 for mechanical equipment. The VE study took place during the construction document phase.

3.2.2.2 Cost Estimate

The estimated cost at the end of the schematic design phase was 80 million EGP and upon pricing the BOQ at the end of the detailed design, the figures jumped to 120 million same items were cancelled by the owner to reach 103,250,000 EGP. VE study is applied by the project manager (EGYCAN) and the consultant (ECG) to drop the figures to 85,300,000 EGP.

(1) EgyCan office, January 2012.

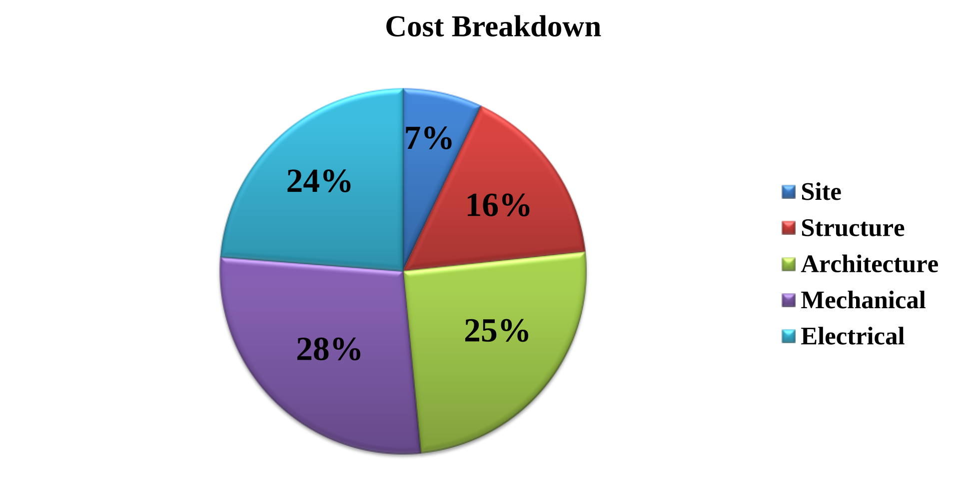


Figure 3.10: NEH Cost break down (1)

3.2.2.3 VE Objectives

The VE team aim at meeting the owners budgets without affecting the value and the standard of the project by the following:

- Reduce initial cost to meet expectations (target 20%).
- Identify ways of materials replacement.
- Maintain the high standard of the hospital.

3.2.2.3 VE Job Plan

The VE study go through the VE methodology reaching to the recommendations in the following areas: architectural, mechanical, plumbing and electrical elements. In this case study, the VE study didn't give attention to the LCC calculations and savings through the proposed ideas. All potential savings appeared in the initial cost and the ideas that have LCC saving is mentioned but it was not calculated.

3.2.2.4 Cost Model

The Cost Model in figure 3.11 compared the unit cost of each division in the B.O.Q. with the cost worth that was estimated by project manager "EgyCan" for similar projects in the region. This is to understand the total construction costs for the project.

The Pareto diagram illustrates the price per square meter. The electromechanical divisions are the highest cost regions.

(1) VE Report for the NEH, EgyCan office, January 2012.

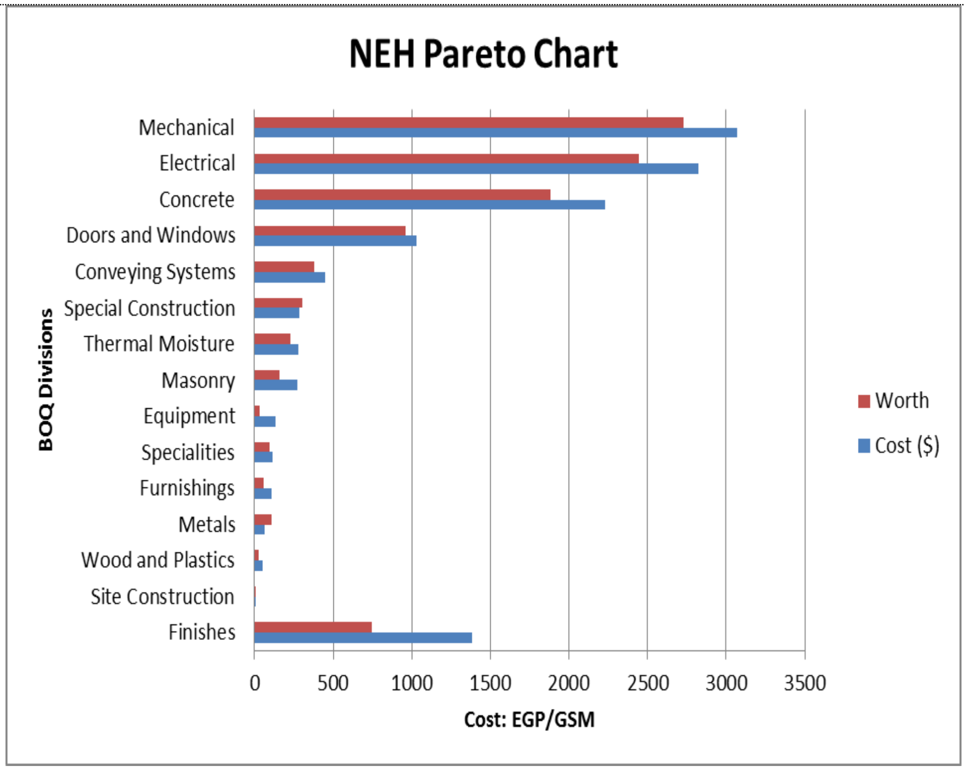


Figure 3.11: NEH Cost Model Pareto Chart [1]

3.2.2.5 VE Proposed Ideas

Table 3.3 summarizes the architectural, mechanical, plumbing and electrical proposed ideas. The table demonstrates the performance benefits and the potential savings for each item.

The total savings appeared is 20%, divided as follows:

- 41 % Architecture = EGP 4,489,978
- 24% Mechanical = EGP 2,667,000
- 2% Plumbing = EGP207,000
- 13% Conv. Sys. = EGP1,400,000
- 20% Electrical = EGP 2,271,687

The savings appear from the façade elements shows 3% from the architectural elements' savings, while the item that the VE team kept as a design suggestion in changing the type of bricks will achieve a LCC saving according to the improvement of the cooling loads, but it is not calculated in this study.

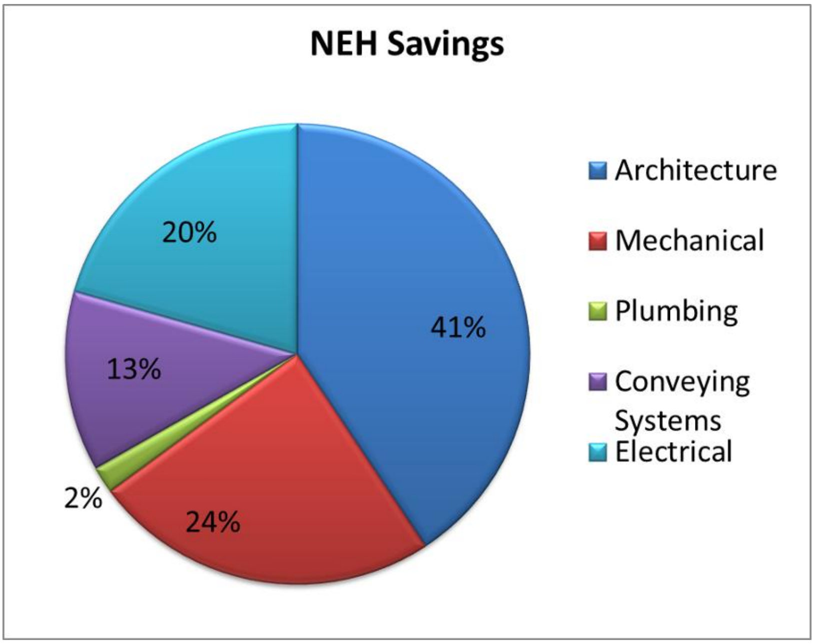


Figure 3.12: NEH Cost Model Pareto Chart

No.	Idea Description ilo = in lieu of	Performance Benefits: Revenue	Performance Benefits: Less Risk	Performance Benefits: Schedule	Performance Benefits: Maintainability	Performance Benefits: Energy	Potential savings () indicates cost increase: Initial	Potential savings () indicates cost increase: LCC	VE Teams Selected Implementation Items: A. Maximum Initial Savings	VE Teams Selected Implementation Items: B. Maximum LCC Savings
	1) Architectural									
A 01	Replace cavity wall with AAC "autoclaved aerated concrete blocks" and use light weight AAC instead of concrete hollow blocks					+	(85,080)	-	Design suggestion	
A 04	Using GRC instead of GRP						63,275	63,275	63,275	63,275
A 05	Replacing the water proofing system by Combo Roof from Henkel-Polybit			+	+		151,714	151,714	151,714	151,714
A 08	Optimizing the hardware selection & Relaxing the proposed fire strategy		+	+	+		623,242	623,242	623,242	623,242
A 12	Omitting the thermal break from the windows			+	+		9,213	9,213	9,213	9,213
A 15	Changing the curved curtain wall to faceted curved curtain wall		+				80,268	80,268	80,268	80,268
A 17	Setting the required tiles with further clarification to be provided to the contractor		+	+						
A 20	Maintaining the same flooring design but with straight lines "Omit curved cuttings"			+			37,924	37,924	37,924	37,924
A 21	Replacing Decorative Epoxy terrazzo flooring with homogenous high performance, anti-static heavy duty floor covering with a polyurethane reinforcement		+	+	+		2,913,135	2,913,135	2,913,135	2,913,135
A 23	Allow for exposed grid instead of concealed joints		+				39,960	39,960	39,960	39,960
A 26	Remove aluminum strip false ceiling from laundry room & receiving dirty room			+	+		119,462	119,462	119,462	119,462
A 28	Remove mineral fiber tiles ceiling from general stores, workshops, medical record room & boiler HVAC			+	+		147,962	147,962	147,962	147,962
A 29	Replacing air foils louver blades by extruded aluminum profiles				+		15,071	15,071	15,071	15,071
A 32	Changing Stainless steel wall guard to vinyl acrylic "acrovyn"				+		388,752	388,752	388,752	388,752
	2) Mechanical									
M 02	Omitting the standby chiller			+			1,905,000		1,905,000	1,905,000

Table 3.3a: NEH VE Recommendation Items

No	Idea Description ilo = in lieu of	Performance Benefits					Potential savings () indicates cost increase		VE Teams Selected Implementation Items	
		Revenue	Less Risk	Schedule	Maintainability	Energy	Initial	LCC	A. Maximum Initial Savings	B. Maximum LCC Savings
M 05	Omitting the standby cooling tower			+			762,000	762,000	762,000	762,000
	3) Plumbing									
P 03	Using a Triplex Instrument air compressor system instead of the Quadruplex system				+		207,000	207,000	207,000	207,000
	4) Vertical Transportation									
V 05	Using Simplex system ilo Duplex system				+		Design Suggestion	Design Suggestion	Design Suggestion	Design Suggestion
V 11	Exporting from Spain & Italy ilo USA & Germany		+				1,400,000	1,400,000	1,400,000	1,400,000
	5) Electrical									
E 03	Omitting Fire Alarm System / Remote Led		+	+			104,500	104,500	104,500	104,500
E 05	Using 3 Small distributed systems in the Public Address System				+		348,300	348,300	348,300	348,300
E 08	Using Cat 6 FTP horizontal cabling instead of Cat6a in Outlets		+				132,160	132,160	132,160	132,160
E 11	Using Cat 6 FTP horizontal cabling instead of Cat6a in Patch panels		+		+		41,580	41,580	41,580	41,580
E 14	Using Cat 6 FTP horizontal cabling instead of Cat6a in Patch cords		+		+		61,337.5	61,337.5	61,337.5	61,337.5
E 17	Using OM3 technology instead of OM4 for Fiber Optic cables		+				11,200	11,200	11,200	11,200
E 18	Using 1*24 core cable instead of 2*12 core for Fiber Optic cables						4,800	4,800	4,800	4,800
E 21	Reducing the quantity of PTZ outdoor cameras (6 cameras)			+	+		132,000	132,000	132,000	132,000

Table 3.3 b: NEH VE Recommendation Items

No	Idea Description	Performance Benefits					Potential savings () indicates cost increase		VE Teams Selected Implementation Items	
		Revenue	Less Risk	Schedule	Maintainability	Energy	Initial	LCC	A. Maximum Initial Savings	B. Maximum LCC Savings
E 25	Reducing the quantity of outdoor cameras (2 cameras)			+	+		18,000	18,000	18,000	18,000
E 26	Using fixed cameras instead of PTZ (one camera)						5.000	5.000	5.000	5.000
E 30	Reducing storage capacity to be 15 days instead of 30 days						15,000	15,000	15,000	15,000
E 33	Reducing the quantity of Work Stations with 19" monitor						25,000	25,000	25,000	25,000
E 35	Using stand alone on very high secured doors with keypad card readers instead of full online system						629,000	629,000	629,000	629,000
E 38	Omitting light current points (52 point)						36,400	36,400	36,400	36,400
E 41	Omitting firefighting system (63 point)						44,100	44,100	44,100	44,100
E 43	Omitting Master Clock System						310,500	310,500	310,500	310,500
E 47	Emptying conduits Master Clock System						280,500	280,500	280,500	280,500
E 50	Reducing the quantity of Bath room units (18 unit)						18,000	18,000	18,000	18,000
E 53	Reducing the quantity of Nurse stations(2 units)						20,000	20,000	20,000	20,000
E 55	Reducing the quantity of Room Lamp (24 unit)						24,000	24,000	24,000	24,000
E60	Using IF system instead of RF system						50,000	50,000	50,000	50,000
	Total						**15,819,000**	**15,819,000**	**15,819,000**	**15,819,000**

Table 3.3 c: NEH VE Recommendation Items

3.2.2.6 VE Checklist

Table 3.4 illustrates the VE checklist and highlights the items that were covered in the VE study. The item that has LCC savings was marked and figure 3.9 is the VE recommendation sheet for this item.

The National Eye Hospital - Cairo

VE Check List

			Items in VE Recom.	Initial Cost Savings	LCC Savings
A- SUBSTRUCTURE	Foundations	Standard Foundation			
		Other Foundation			
		Slab to Grade			
	Basement Construction	Basement Excavation			
		Basement Wall			
B- SHELL	Superstructure	Floor Construction			
		Roof Construction			
	Exterior Enclosure	Exterior Walls			
		Exterior Windows			
		Exterior Doors			
	Roofing	Roof Coverings			
		Roof Openings			
C- INTERIORS	Interior Construction	Partitions			
		Interior Doors			
		Specialties			
	Stairs				
	Interior Finishes	Wall Finishes			
		Floor Finishes			
		Ceiling Finishes			
D- SERVICES	Conveying Systems				
	Plumbing				
	HVAC				
	Fire Protection				
	Electrical	Electrical Ser. & Distribution			
		Lighting & Branch Wiring			
		Communication & Security			
		Other Electrical Systems			
E- EQUIPMENT & FURNISHINGS	Equipment				
	Furnishings				
F- SPECIAL CONSTRUCTION & DEMOLITION	Special Construction				
	Selective Building Demolition				
G- BUILDING SITEWORK	Site Preparation				
	Site Improvements				
	Site Mechanical Utilities				
	Site Electrical Utilities				
	Other Site Construction				

Table 3.4: NEH VE Checklist (By Researcher)

3.2.2.7 VE Recommendations

The research presents the item that achieves LCC savings in details, it is as follows:

1- Replace cavity wall with AAC "autoclaved aerated concrete blocks" and use "light weight AAC" instead of concrete hollow blocks.

Autoclaved aerated concrete in figure 3.13 is a versatile lightweight construction material and usually used as blocks. Compared with normal (ie: "dense" concrete) aircrete has a low density and excellent insulation properties. Autoclaved aerated concrete blocks are excellent thermal insulators and are typically used to form the inner leaf of a cavity wall. They are also used in the outer leaf.(1)

The idea was a design suggestion from the VE team as it will not achieve an initial cost savings but the team recommended it because of its effect in improving the cooling loads and subsequently reducing the running cost.

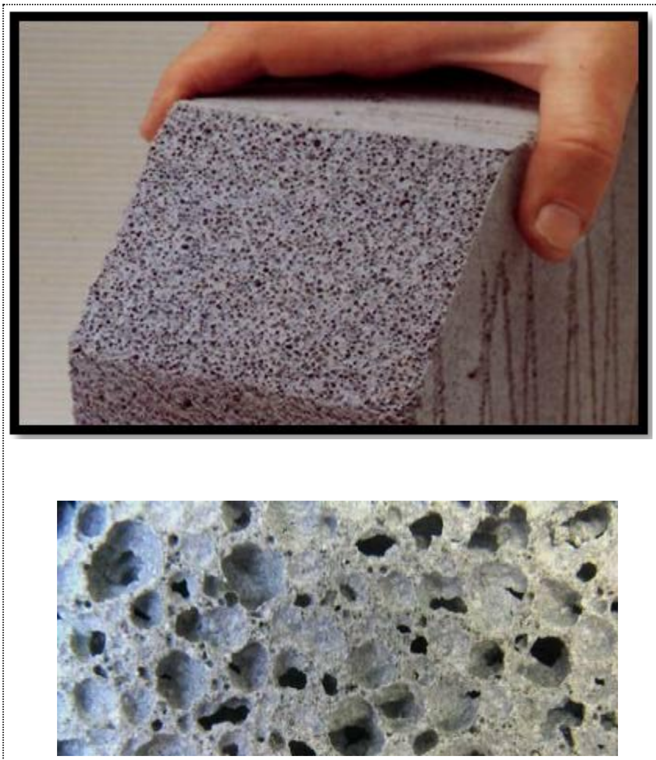


Figure 3.13: Autoclaved Aerated Concrete Blocks (2)

(1) http://www.understanding-cement.com (accessed March 2012)

(2) Ibid.

Value Engineering Recommendation

Project: National Eye Hospital — VE Rec. No.
Item: Changing the hollow concrete block — **AR 01**

Original Design

The external facades Masonry work was concrete hollow block

Proposed Design

The proposed design is to use light weight autoclaved aerated concrete blocks *ilo* concrete hollow block

Advantages & Disadvantages

Advantages:
Saves energy
Improves cooling load

Disadvantages:
Requires modifications to HVAC design
4 % Increase in the initial cost

Discussion

The VE believe the long term impact of energy saving results in LCC saving while the Initial Cost of the proposed design isincreased by 4%

Life Cycle Cost Summary

	Initial	Annual O&M
Original		
Proposed		
Savings		

PW Annual Savings at (Factor)
Total Savings (Initial + PW Annual)

Design Suggestion

Figure 3.14: NEH VE Recommendation Sheet

3.3 Data Analysis of Case Studies

- The two case studies applied the VE studies in the construction document phase, because in this phase of the project the actual estimated cost appears. This estimated cost usually exceeds the budget cost estimated by the owner. This late application of VE is considered in a critical point of the project phases which
- The VE study was the owner's desire to meet the budget without affecting the quality and value of his investment. This made applying the VE depends on the owner's awareness and not a normal procedure to be done systematically by the consultant or the project manager.
- The items that showed increase in the initial cost were excluded from the VE calculations and remarked as a "Design suggestion" although it was noted that the item would achieve energy savings.
- The LCC savings that appeared in the case studies does not exceed 10% from the total potential savings. This may be due to the owner's objective to reduce the initial cost, besides the sophisticated calculation of LCC.
- Table 3.5 illustrates the item that the VE study included and specially the items that achieved LCC savings.

	Capital Tower Project (CTP)	National Eye Hospital (NEH)
1) Items that the VE study	• Civil/Site/Landscape • Architecture • Structure • Mechanical • Plumbing • Electrical • General	• Architectural • Mechanical • Plumbing • Electrical
2) Items that achieve savings LCC	• Using active curtain wall systems. • Using GRP panels for sun shade elements. • Reducing fresh air intake to 10L/person instead of 18L/person by making nonsmoking internal environment.	• N/A

3) Items that were suggested to achieve LCC saving but not calculated	• Consider conducting exterior thermal façade modeling • Consider changing design temperature to 23° instead of 21°	• Consider Using lightweight autoclaved concrete clocks instead of concrete hollow blocks.

Table 3.5: Comparison of VE items of case studies (By Researcher)

3.4 Summary

This chapter presented the VE study applied for two different projects. It emphasizes how the VE can reduce the costs without affecting the quality.

The case studies demonstrate how the VE is practically applied, following the methodology and using the techniques to improve the value and optimize the cost of the building.

The chapter presented the items that applied the LCCA in details. The forms used is presented and the sheets of detailed calculations done by the VE team are also presented.

It is concluded that the VE studies for traditional buildings concentrates mainly on initial cost savings, as it is the eye-catching figures for the owner although the LCC is an integral part of the VE studies and techniques.

From this point, Chapter 4 introduces a VE study for two IBs analyzing an item that affect the LCC of the building.

Chapter 4

Intelligent Buildings in Economic Perspective

Chapter 4: VE Case Studies for IB

4.1 Introduction

After studying the value engineering and the Intelligent Buildings and finding that, the life cycle cost is a comment area where both concepts can integrate. This chapter focuses on analyzing two case studies of IB in Egypt. The study commences with evaluating the building according to the IB design criteria illustrated in chapter 2, and then sets a VE study highlighting the effect of applying intelligent features on the LCC of these buildings.

4.2 Objective of the Case Study

This chapter commence with analyzing two of the IB in Egypt evaluating the building by measuring its features with the IB's design criteria. The study is looking forward to deducing the benefit and savings with applying VE methodology through proposing intelligent ideas of IBs.

This is through analyzing and evaluating of the architectural Issues of the building from a VE point of view to seek for improving the value and reducing the LCC by proposing alternatives from the intelligent features.

4.3 Selection Criteria of buildings in the case study

Some constraints and limits have been established for the selection of the projects analyzed in the case study of this chapter. These limits are:

- ***a.*** ***Time Limits:*** The projects analyzed should be built up within the current decade.
- ***b.*** ***Applying IB's features:*** The example should apply some of the IB features discussed in chapter 4.
- ***c.*** ***The project location and scale:*** To ensure the importance of comparative analysis of the projects, it would be preferred that they are of the same scale, but different design features. At the same time, the selected IBs are in same location, as to be under the same regulation and same cost data, to enable for a meaningful comparison.

After addressing the above mentioned bases and constraints for selecting the buildings of the case study. "Smart Village" is the selected location since:

- It is the first technology, Business Park built in Egypt.
- It is an extra ordinary example of Egypt's high tech infrastructure, economic incentive packages and commitment of the future. Smart Village project provides a high tech environment.
- Its aim is to provide an enhanced and advanced work environment appropriate with scientific research demands.

After specifying the area for the case study "Smart Village", two buildings were selected according to these criteria:

1- "Engineering Consultant Group" ECG Building.

2- Beltone Building

Figure 4.1 shows the location of these buildings on the village map.

Engineering Consultant Group Building Beltone Financial Building

Figure 4.1: Smart Village Map [(1)]

4.4 Methodology used in analyzing the building

The methodology used in analyzing the buildings of the case study follows these steps:

First: Defining the Building information

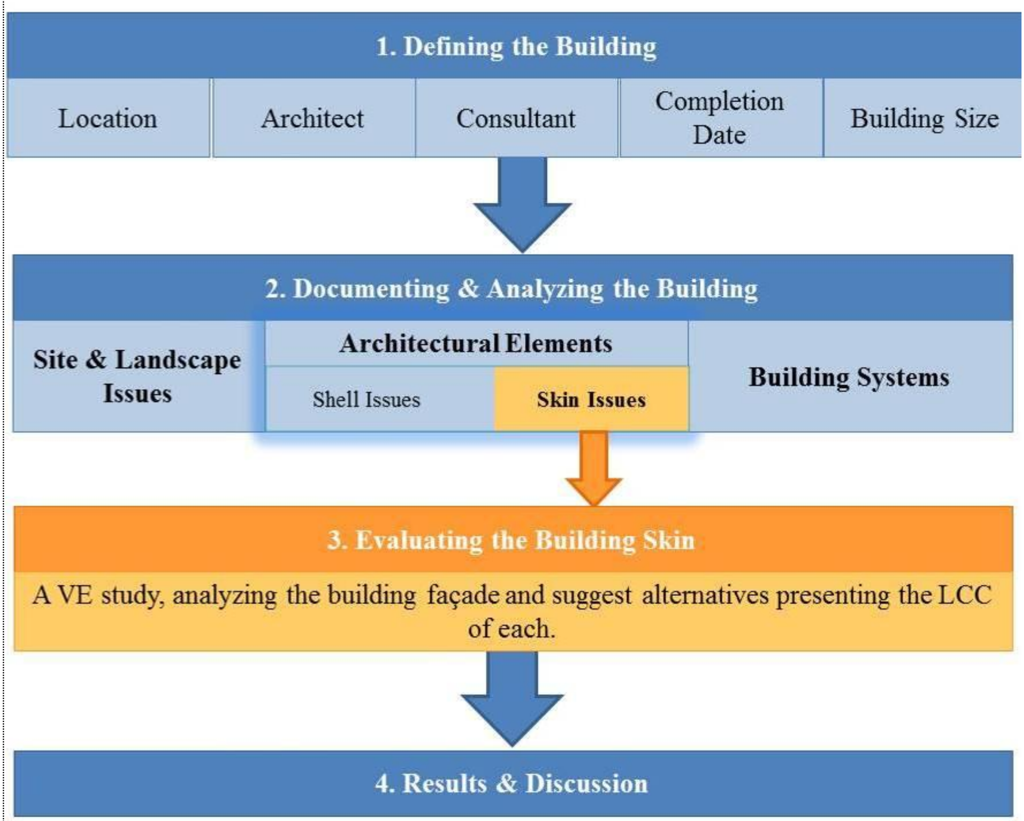
Second: Documenting and analyzing the IB features

Third: Evaluating the building skin from a VE point of view and studying the effect on the LCC when intelligent alternatives are applied. The research used the **Glasswizard;** a computer software making quick simulation for energy performance and structural analysis of glass. The research made use of this software to monitor the energy performance with different glazing alternative and the effect on the LCC of the building.

Fourth: A comparative analysis between the buildings of the case study Ending with conclusions that are deduced from the comparative analysis of the case studies.

(1) www.smartvillage.com (accessed January 2012)

The following diagram illustrates the methodology of case study analysis.



4.5 VE Proposed Ideas

The VE proposed idea for the building façade is to suggest the use of two intelligent glazing alternatives and calculates the differences in initial cost and in running cost according to the bases of LCC calculations. The first alternative is a Low E double glass, and the second alternative is an Electro-chrome glass as in figure 4.17. It is an intelligent glazing technique provides the normal transparent glazing to shift from clear to dark blue depending on ambient sunshine and atmosphere. Many thin layers (around 1µm thick) deposited in between glass layers by high technological coating manufacturing process.

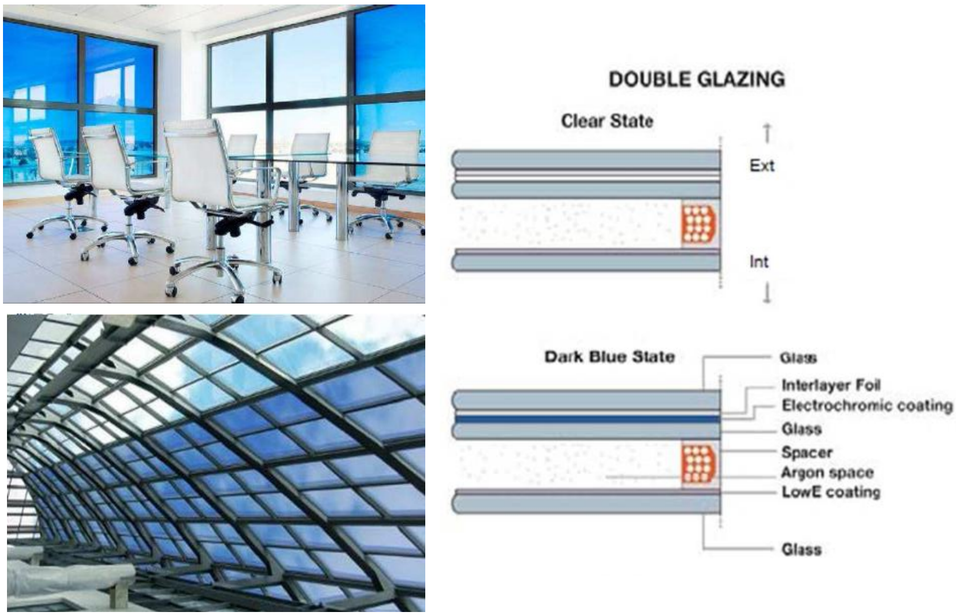


Figure 4.13: Electro-chrome Glass (1)

The **Glasswizard** is the software used to monitor the energy performance and calculate the HVAC running cost. The software provided two issues: First, simulating energy performance of the façade according to the specification of glass, percentage of glazed area in the façade, shading devices, building location and orientation. The result is estimating the HVAC tonnage and its electrical consumption. The estimated tonnage given above is only for heat gain through glazing only and does not include other internal loads and heat gains from other elements such as occupants, equipment, etc.

Second, calculating the running cost for HVAC and electricity by defining the unit rate in ton refrigerant (TR) and kilowatt per ton refrigerant (KW/TR). The estimated LCC is calculated for the desired duration according to the working hours through the year.

The following is the analysis for the two selected buildings in the case study.

(1) www.saint-gobain.com

4.6 Engineering Consultant Group (ECG) Building

ECG is a pioneering engineering company providing high-quality engineering consultancy services to its clients. The head office of the company is at smart village business park.

4.6.1 Building Information

Location: Smart Village – Giza, Egypt.

Architect: Engineering Consultant Group

Completion Date: March 2010

Building Size: 15538 m^2 GIA. (8505 above ground & 7033 underground)

No. of Floors: 6 floors (2 underground & 4 above ground)

Initial cost: 74,250,000 EGP (in March 2010)

Running Costs: 3,564,000 EGP/ year (Calculated in Dec 2011)

Figure 4.3: ECG Building Smart Village

4.6.2 IB Features

The research demonstrates the main four elements of the IB in analyzing the ECG building.

4.6.2.1 Site Issues

a. ***Aspects and Landscape:*** External landscape around the building with seating area but no water features due to the regulation of the Smart village. The nearest building to the western façade is 25 m away and more than 40 m from the eastern façade.

Figure 4.4: ECG Landscape

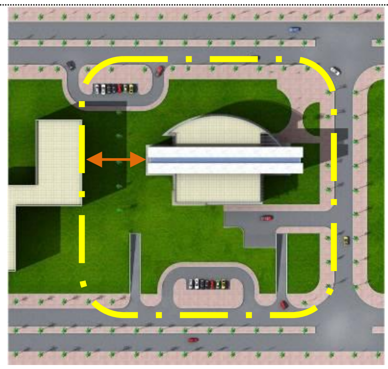


Figure 4.5: ECG Layout

b. ***Car Parking:*** Few parking spaces outside the building but the main parking area in the basement, it provides at 1/47 m^2 GIA. The car parking has 180 car (83 space in the 1st Basement and 97 in the 2nd Basement)

c. ***Access:*** Main road within 2 km and private bus stops inside the smart village but no rail access

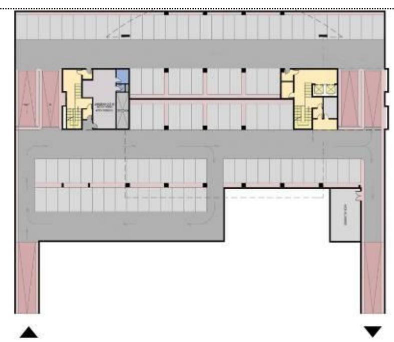


Figure 4.6: ECG 1st Basement Plan

4.6.2.2 Architecture elements

a) Shell Issues:

- ***Building mass & Thermal strategy:*** A cubic glass form with linear louvers shading the west, south and east elevations. The square shape enhances the thermal strategy of the building, since the square has the least external perimeter and accordingly decreases the areas exposed to external environment.

- ***Floor Shape & Size:*** Square shape 2125 m^2 GIA with 2 side cores.
- ***Planning Grid:*** 60 cm and the structural grid is 8.4*12m.
- ***Floor Depth:*** 20m glass to core
- ***Slab to Slab height:*** 3.80 m
- ***Floor to Ceiling height:*** 2.85 m
- ***Landlord efficiency:*** 80%

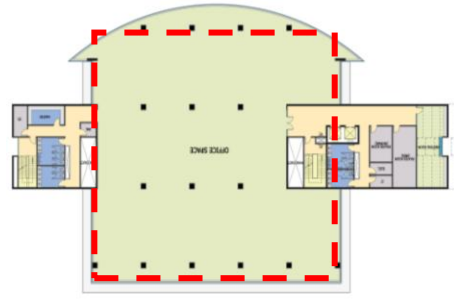


Figure 4.7: ECG Typical Floor

- ***Access:*** There are two separate entrances to access the building. The main entrance to the building is for the visitors and staff and it was equipped with ramp for disable. The goods entrance is a secondary one from the back area.
- ***Maintainability:*** Façade maintenance by using external ropes.
- ***Furniture system adaptability:*** The building design is for an open office spaces, and it is the tenant's opportunity to furnish upon their needs. Using of raised floor in the office areas facilitate the adaptability of the furniture.

b) Skin Issues:

- ***Openings*:** No openings in all facades, that results in the absence of natural ventilation. The permanent use of air-conditioning system accordingly increases the running cost of the building.

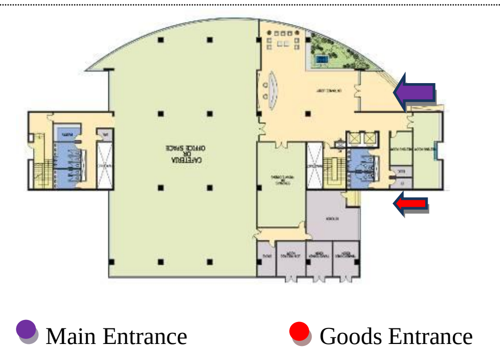


Figure 4.8: ECG Ground Floor Plan

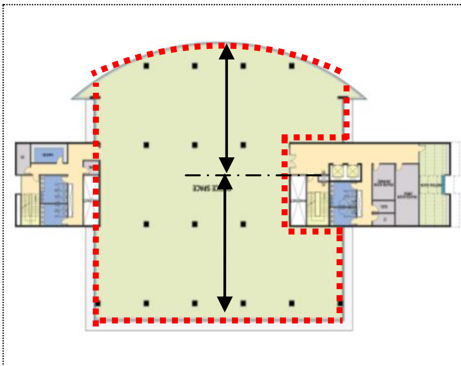


Figure 4.9: ECG Typical Floor

- ***Solar control:*** 57% of the façade's area is tinted double glass. The South elevation is 50%, North elevation is 57%, East and West elevations are 60%. Louvers on south, east, and west elevations.

Figure 4.10: ECG Northern Elevation

Figure 4.11: Louvers on South, East and West Elevations

Figure 4.11 illustrates the horizontal louvers on the southern elevation. The spacing in between was not well located, as the upper louver did not affect in shading the useable area of the façade.

4.6.2.3 Building Systems

a) Mechanical systems

HVAC system: The building is fully air-conditioned, the HVAC Systems with fresh air intake from the roof floor and VAV System is used to make the AC system energy efficient.

Plumbing system: The building has two water supplying sources, clear water and gray water for planting; no automatic sensors are installed neither in the sanitary ware nor in the water fixtures.

Fire system: The water sprinklers are throughout the building, CO_2 fire suppression systems are in equipment's room. The fire alarm system is linked to the BA system and it is linked to the main fire station.

Conveying system: Three elevators serving the building linked to the BA system. The specification of the lifts are: elective/selective lift and it is not linked to the BA system.

Service Risers: Two risers dedicated to electrical power and light current serving each equipment room.

Two cores are serving the building; staircase, bathrooms and HVAC duct are in each core. The western core includes the electrical and IT rooms.

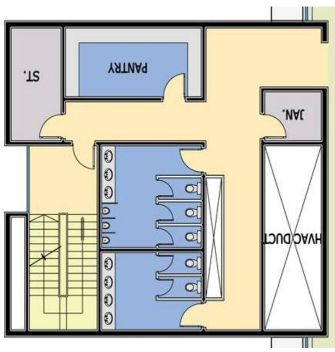


Figure 4.12: Building Western Core

Figure 4.13: Building Eastern Core

b) Electrical systems

Lighting system: is traditional linear fluorescent, 500 lux at the desk as per the IES standards for office buildings. Lighting control through standard manual light switches except for the second floor, light sensors were used for the top management department.

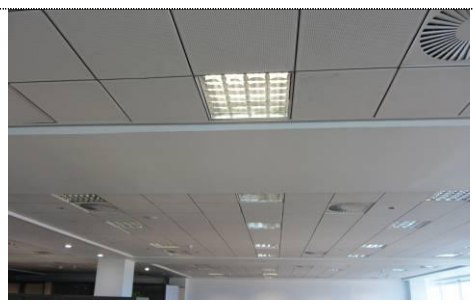


Figure 4.14: Lighting system in Office space

Power Strategy: is drawn from providing the building with two separate power inlets, besides a generator for the backup power source. UPS system is used for IT and emergency system.

c) Security and access control

Securing the building by having a security guard patrolling, CCTV cameras covering the entrances, exits and corridors of the building, and no electronic access control system in the building.

Figure 4.13 illustrates the CCTV cameras located in the entrances of each floor.

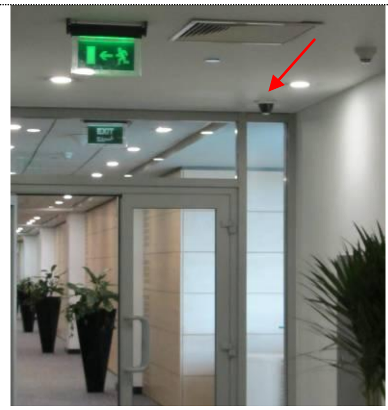


Figure 4.15: CCTV Security system.

4.6.2.4 IT Services

The BA system in the building integrates with the HVAC, conveying system and fire system.

Cable distribution system through the raised floors and the false ceiling trays, this provides the user with flexible furnishing and the structured cable system provides one voice and data outlet each $9m^2$.

Main equipment rooms in the ground floor, small rooms in the core serving each floor.

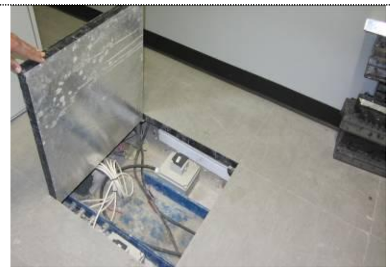


Figure 4.16: Cables Distribution system.

Table 4.1 summarize the ECG building's features, and evaluate the features either its intelligent (I) or not (N).

	ECG Building Intelligent Features		I	N
	1- SITE			
	Aspects and Landscape	External landscape, and seatings surrounding buildings within 30 m of western façade.	+	
	Access	main road within 2km/ Private bus services for the village	+	
	Car Parks	Provided at 1/ 47 m^2	+	
	2- Architectural Elements			
Shell	Bldg mass & Thermal strategy			
Shell	Floor Shape & Size (typical)	Square plan, 2125 m^2	+	
Shell	Planning grid	Arch. grid 60 cm, str. grid 8.4*12m	+	
Shell	Floor depth &	20 glass to core		+
Shell	Sectional height	3.80 m Slab-to-slab	+	
Shell		2.80 m Floor-to-ceiling	+	
Shell	Landlord efficiency	80 %	+	
Shell	Tenant efficiency	85 %	+	
Shell	Atrium	No Atrium		+
Shell	Access- Staff and Visitors	Medium reception area, separate receptions for tenants.	+	
Shell	Access – Disabled access	Free entry through main entrance	+	
Shell	Access – Goods entrance/ lifts	Separate goods entrance	+	
Shell	Maintainability	Façade maintenance by external ropes		+
Skin	Glazing	Double glazing, tinted glass	+	
Skin	Opening windows	None		+
Skin	Solar shading	External horizontal louvers and Internal blinds		+
	3- Building Systems			
Mechanical	HVAC systems	100% air-conditioned VAV system	+	
Mechanical	Air handling units	5 AHU on the roof floor		+
Mechanical	Fresh air intake	Centralized on roof or upper floor	+	
Mechanical	Plumbing	two water supplying sources, clear and gray water. No automatic sensors installed in faucets & toilets.		+
Mechanical	Fire Systems	Sprinklers throughout. Smoke detectors. CO_2 to special areas. linked to BAS but not linked to main fire station	+	
Mechanical	Vertical transportation	The lift system is intillegent traffic optimization system, linked to BAS	+	
Electric	Lighting	Zoned fluorescent 500 lux at desk with manual switches		+
Electric	Power Strategy	Backup generator & UPS system provides up to 1 hour battery backup for IT and emergency system.	+	
Security	Security system and access control	CCTV and guard patrols, & No electronic access control		+
	4- IT Services			
Building Services	BA systems	No centeralized system. Individual system for HVAC, landscape lighting and fire system.		+
Building Services	Telecommunication Infrastructure	Single building entry for telecommunications		+
Building Services	Equipment rooms	One per floor	+	
Building Services	Cable types	Copper bakbone		+
Building Services	Cable distribution system	Raised floor/ tray	+	
Building Services	Floor termination	1 outlets per 9 m^2	+	
Building Services	Services risers	2 separate risers for elec. and data communications, $<$ 1% of GFA	+	
Mn.	Space management	No computerized facility management system		+
Mn.	Business systems	AV conference facilities on each floor	+	

Table 4.1: ECG IB Features (By Researcher)

4.6.3 Initial and Running Cost

The building initial cost was 74,250,000 EGP in March 2010, the annual running cost of the building was 3,564,000 at the end of 2011. Table 4.2 illustrates the annual running cost of different elements and the cost per meter is calculated regarding to the above ground gross internal area.

	Annual Cost (EGP/ year)	%	Annual Cost EGP / m^2
Electricity	316,000	9 %	37.2
HVAC	1,820,000	51%	214
Conveying Lifts	42,000	1.3%	5.0
Water	24,000	0.7%	2.8
Cleaning	528,000	15%	62.0
Security	384,000	11%	45.0
Maintenance	450,000	12%	53.0
TOTAL	**3,564,000**	**100%**	**419.0**

Table 4.2: Running Costs of ECG Building (1)

It is recognized that the running cost of HVAC system is around 50% from the building's total running cost, and according to the previous analysis for the service strategy and the solar control of the building skin. It is 57% glazing area of the façade without openings. It was clear that the glazing specification has a significant effect on the thermal performance of the interior spaces of the building, which results in the increase of the running cost to this figures.

The research selected the skin issues, applied VE studies for the building façade, and suggested the proposed ideas, evaluating the performance of the alternatives, and calculating the effect on the LCC of the building.

4.6.4 VE application

The idea for the building façade that were mentioned above in the VE proposed ideas suggest the use of the two intelligent glazing alternatives. The following tables illustrate the input and output data on the software *Glasswizard.* Tables 4.3a,b illustrate the inputs defining the building and the skin issues emphasizing on the specifications of the facades. Then the table 4.3b presents the glass specifications of the base case and the proposed alternatives.

(1) ECG administration office, Maintenance department, Smart Village, January 2012

Tables 4.4a,b,c present the initial cost of glazing alternatives and the initial and running costs of HVAC system required to each glazing alternative.

Project Name	ECG HQ	**Architect**	ECG
Builder	OCI	**Consultant**	ECG
Location (m)	Giza	**Operation Time**	9am to 5pm
Air Conditioner Type	-User Defined- (3.52 kWhr/TR)	**Operating Days In Week**	5
Cost of Electricity	6.9	**Months Of Operation**	Jan - Dec

Glazed Area (sq.m)			
North Area	**693**	**South Area**	**693**
East Area	**360**	**West Area**	**360**
North West Area		**South West Area**	
North East Area		**South East Area**	

Projection factor of shading device			
North		**South**	**0.3**
East	**0.3**	**West**	**0.3**

Gross wall Area (sq.m)	**4200**	**WWR %**	**50**

Table 4.3a: Building facades' specifications

Type of Glazing	Outer Glass Specification	Inner Glass Specification	Solar Factor	U-Value $W/m^2 K$	Light Transm. (%)
Base Case Tinted Double Glass	Tinted Glass 6mm	Clear 6mm	0.37	3.8	39
Low-E Tinted Double Glass	Tinted Low-E 6mm	Clear 6mm	0.23	1.6	39
Electro Chrome Tinted Double Glass	Double Glass 2x6mm	Clear Low-E 6mm	0.04	1.0	variable

Table 4.3b: Glass specifications

Type of Glazing	HVAC TR [1]	HVAC Investment (EGP)	Glazing Investment (EGP)	HVAC & Glazing Total Investment (EGP)	HVAC Running cost/annum (EGP)
Base Case Tinted Double Glass	79	1.96 million	694,980	2.65 million	1.82 million (263151 Kw/hr)
Low-E Tinted Double Glass	46	1.15 million	1.04 million	2.19 million	1.1 million (158,897 Kw/hr)
Electro Chrome Tinted Double Glass	22	544,057	16.85 million	17.39 million	413,636 (59,947 Kw/hr)

Table 4.4a: Initial and Running Costs

[1] The HVAC Tonnage is estimated from the heat gain from glazing only

Type of Glazing	Extra Glazing Investment (EGP)	Savings in HVAC running cost/annum (EGP)	Savings in HVAC Investment (EGP)	Net Investment [2] (EGP)
Base Case Tinted Double Glass	-base-	-base-	-base-	-base-
Low-E Tinted Double Glass	347,500	719,356	807,524	No extra expenditure
Electro Chrome Tinted Double Glass	16.15 million	1.4 million	1.41 million	14.74 million

Table 4.4b: Savings in Initial and Running Costs

[2] Extra Glazing Investment - Savings in HVAC investment

Type of Glazing	Savings in HVAC running cost	LCC Savings in Operational cost [3] PW (EGP)	Operational Payback [4]	NET Payback [5]
Base Case Tinted Double Glass	-base-	-base-	-base-	-base-
Low-E Tinted Double Glass	40%	6,13 million	6 Month	No extra expenditure
Electro Chrome Tinted Double Glass	77%	10,65 million	11 Year 6 Month	10 years 6 Month

Table 4.4c: LCC Savings and Payback Period

[3] *Considered 20 years*
[4] *Considering Savings in Running Cost only*
[5] *Considering Savings in Running Cost & HVAC Investment*

The bar charts in figure 4.18 illustrate the relation between the initial cost of investment in HVAC and Glass. In addition, the chart below illustrates the relation between the total initial costs of HVAC and glass with the annual running cost.

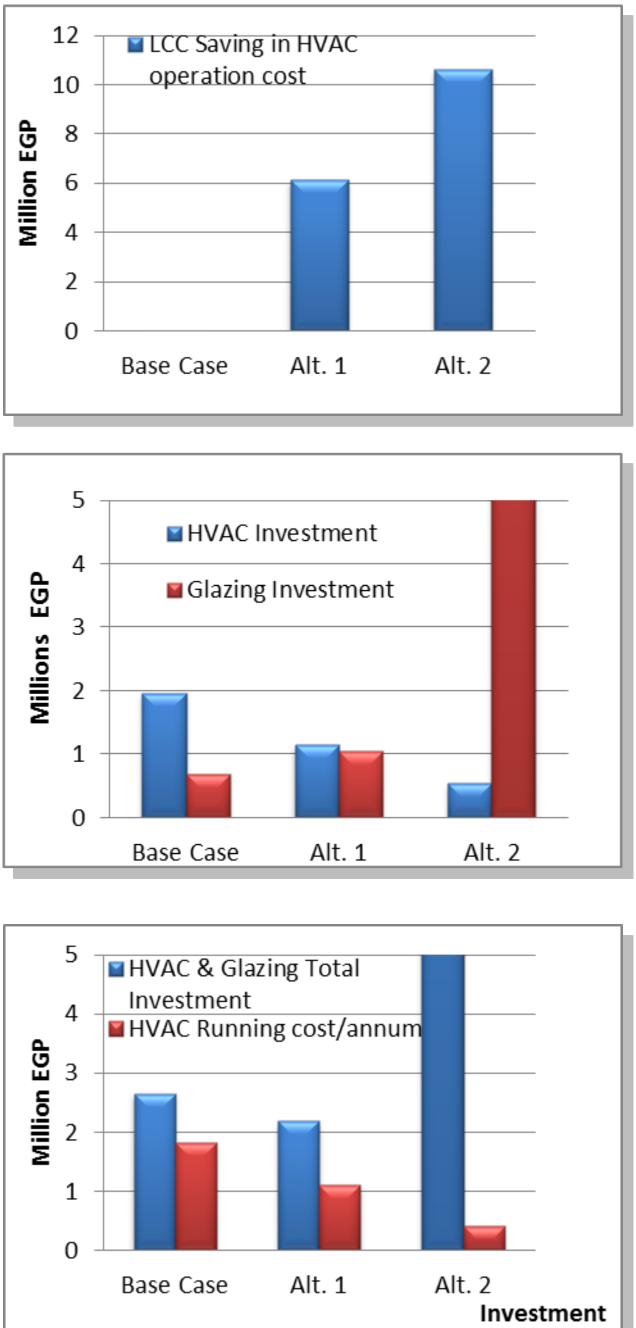


Figure 4.18: Glazing& HVAC Initial and running cost (By Researcher)

The LCC calculations and the VE study is presented on the standard sheet and formats in figures 4.19 and 4.20. The LCC calculation in figure 4.19 presents the calculation for the suggested two alternatives compared with the existing case, which is named “Base case”. The calculation was done on life cycle of 20 years, because the life cycle time of the mechanical systems is estimated to be 20 years. Thus, the calculations avoid adding the replacement cost of the HVAC system

LIFE CYCLE COST ECG Building, Smart Village, Giza VE Rec. No.

(PRESENT WORTH METHOD)

Project ECG Building Location Smart Village - Giza PROJECT LIFE CYCLE (YEARS) 20 DISCOUNT RATE (% in decimals) 10%			ORIGINAL Tinted Double Glass		ALT. 1 Low-E Tinted Double Glass		ALT. 2 Electro-Chrome Tinted Double Glass	
Construction Costs			Est.	PW	Est.	PW	Est.	PW
A) Original Base Case			695,000	695,000				
B) Low E Glazing					758,000	758,000		
C) Electro-Chrome Glazing							16,850,000	16,850,000
D)								
E)								
F)								
Other Initial Costs								
A) HVAC Base Case			1,960,000	1,960,000				
B) HVAC for Alt. 1					1,150,000	1,150,000		
B) HVAC for Alt. 2							544,057	544,057
Total Initial Cost Impact (IC)				**2,655,000**		**1,908,000**		**17,394,057**
Initial Cost PW Savings						**747,000**		**(14,739,057)**
Replacement/Salvage Costs	Year	Factor						
A)								
B)								
C)								
D)								
E)								
F)								
G)								
H)								
Total Replacement/Salvage PW Costs								
Operation/Maintenance Cost	Escl.0%	PWA						
A) District chiller consumtion		8.510	1,820,000	15,488,200	1,100,000	9,361,000	569,000	4,842,190
B) Electrical consumtion		8.510						
C)								
D)								
E)								
F)								
G)								
Total Operation/Maintenance (PW) Costs				15,488,200		9,361,000		4,842,190
Total Present Worth Life Cycle Costs				**18,143,200**		**11,269,000**		**22,236,247**
Life Cycle (PW) Savings						**6,874,200**		**(4,093,047)**

PW - Present Worth PWA - Present Worth of Annuity

Figure 4.19: ECG Building LCC Calculations for Alternatives (By Researcher)

The Low-E glass showed the best LCC according to the HVAC performance and with a payback period of 6 month calculated on savings in the running cost only, while the Electro-chrome showed the best performance but a higher LCC.

Value Engineering Recommendation

Project:	ECG Building	VE Rec. No.
Item:	Change type of glass with intelligent alternatives	**Ar-01**

Original Design

The original design is using double glass: outer lite 6mm tinted glass (silvery blue), inner lite 6mm clear glass and 12 mm (dehydrated) inter space.

Thermal performance:

Shadding coefficient 0.43, U-value 2.8 W/m^2.K, Relative heat gain 297 W/m^2.

Visible light performance:

Light transmittance 37%, Light reflection (external) 16%, Light reflectance (internal) 32%

Proposed Design

The proposed design is to use Intelligent glazing systems. It is proposed to use double glass (LOW E) in the south, east and west facades with the following performance.

Thermal performance:

Shadding coefficient 0.27, U-value 1.6 W/m^2.K, Relative heat gain 205 W/m^2.

Visible light performance:

Light transmittance 39%, Light reflection (external) 9%, Light reflectance (internal) 16%

Advantages & Disadvantages

Advantages:

Improves interior comfort
Saves energy
Improves cooling load

Disadvantages:

Requires modifications to the envelope design
Increase in the initial cost
Reduce light transmittance by 12%

Discussion

The VE believe the long term impact of energy saving results in LCC saving while the Initial Cost of the proposed design is increased.

Life Cycle Cost Summary

	Initial	Annual O&M
Original	2,655,000	15,488,200
Proposed	1,908,000	9,361,000
Savings	747,000	6,127,200
PW Annual Savings at (10%)		6,127,200
Total Savings (Initial + PW Annual)		6,874,200

Figure 4.20: ECG Building VE Recommendation Sheet (By Researcher)

4.7 Beltone Building

The building is the new HQ of "Beltone Financial company" in the 6th of October, Smart Village in Cairo. The design brief called for a clear and strong identity that would distinguish the building from the surrounding developments. The architecture had to provide a light and spacious environment with good visual and spatial connectivity while also representing the young, creative and confident business culture of the client.(1)

4.7.1 Building Information

Location: Smart Village – Giza, Egypt

Architect: Swanky Hyden Connell International

Consultant: Engineering Consultant Group

Completion Date: March 2010

Building Size: 14490 m^2 GIA (7750 underground & 6740 above ground)

No. of Floors: 6 floors (3 underground & November 4 aboveground)

Initial cost: 12,200,000 EGP (in 2009)

Running Costs: **2**,788,000 EGP/ year (Calculated in November 2011)

Figure 4.21: Beltone Building Smart Village (2)

(1) www.worldarchitecturenews.com (accessed February 2012)

(2) Ibid

4.7.2 IB Features

The research demonstrates the main four elements of the IB in analyzing the ECG building.

4.7.2.1 Site Issues

a. Aspects and Landscape: External landscape around the building without seating area and no water features due to the regulation of the Smart village. The nearest building to the southern façade is 20 m away and more than 40 m from the other façades.

Figure 4.22: Beltone Layout

b. Car Parking: Available public parking spaces outside the building but the main parking area for the employees is in the basement, it provides at 1/40 m^2 GIA. The car parking has 167 cars (41 spaces in the 1st Basement, 50 spaces in the 2nd Basement and 76 in the 3rd Basement)

Figure 4.23: Beltone 3rd Basement Plan

c. Access: Main road within 2 km and private bus stops inside the smart village but no rail access

4.6.2.2 Architecture elements

a) Shell Issues:

- Building mass & Thermal strategy: The building is in a rectangular plan shape, the atrium in the middle of the two wings and one core serving the building at the eastern façade.

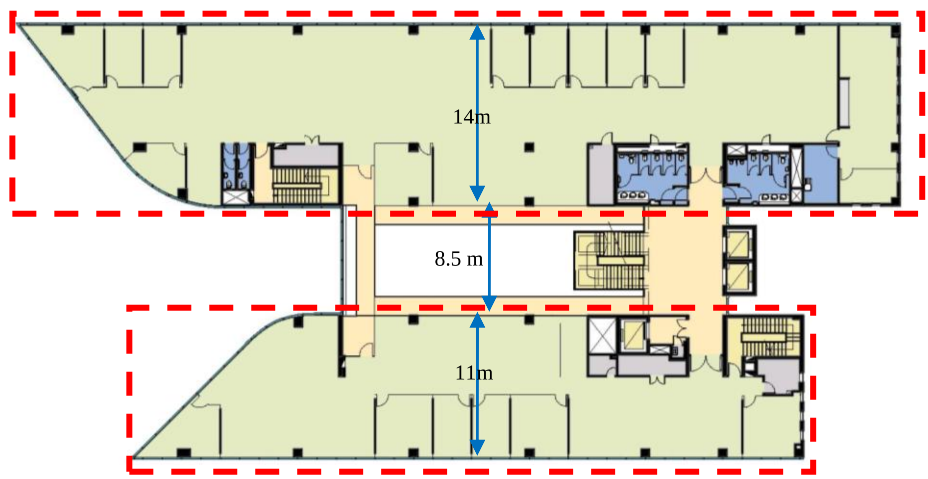


Figure 4.24: Beltone Typical Floor

- ***Floor Shape & Size:*** Two rectangular plots with an atrium in-between.
- ***Planning Grid:*** 90 cm and the structural grid is 5.4 m
- ***Floor Depth:*** 11- 14 m glass to core.
- ***Slab to Slab height:*** 4.10 m
- ***Floor to Ceiling height:*** 2.80 m
- ***Landlord efficiency:*** 80%
- **Atrium:** The atrium in the building is bringing daylight down to the center of the building. The atrium width is 8.5 m wide in the four storey office building. The presence of the atrium increases from natural light penetrating the building and reduces from the use of artificial light, subsequently decreases the running cost of artificial lighting.

Figure 4.25: Beltone Atrium

- ***Access:*** There are two separate entrances to access the building. The main entrance to the building is for the visitors and staff and it was equipped with ramp for disable. The goods entrance is a secondary one from the back area.

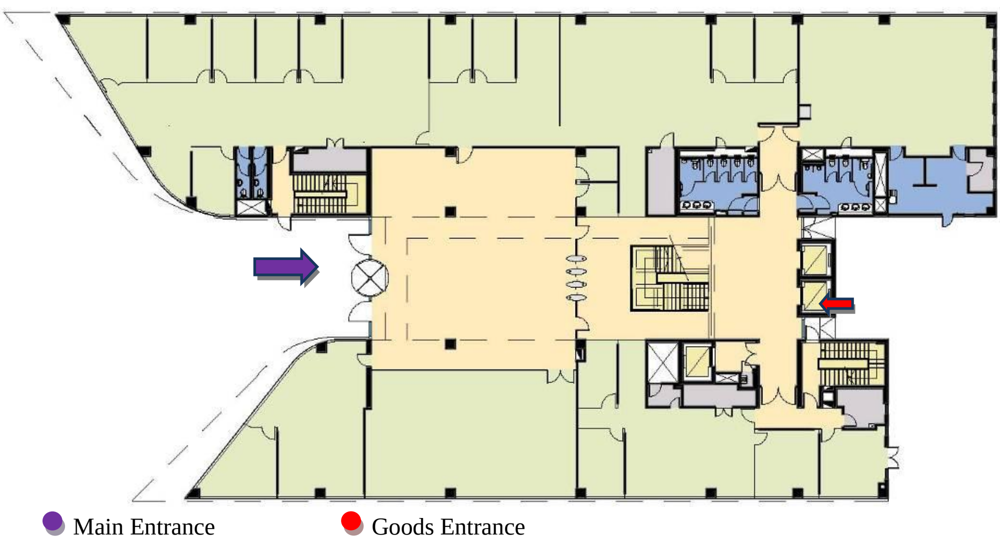


Figure 4.26: Beltone Ground Floor Plan

- ***Maintainability:*** Façade maintenance by using external ropes.
- ***Furniture system adaptability:*** The building design is for an open office spaces. Using of raised floor in the office areas facilitate the adaptability of the furniture.

b) Skin Issues:

- *Openings*: No openings in all facades, that results in the absence of natural ventilation. The permanent use of air-conditioning system accordingly increases the running cost of the building.

- *Solar control:* 100% of the façades area is tinted double glass. The manual internal blinds are used to provide the user with light and solar control.

Figure 4.27: Beltone Elevation

4.7.2.3 Building Systems

a) Mechanical systems

HVAC system: The building is fully air-conditioned, two air conditioning system are used in the building, the fan coil units for the office spaces and the AHU for fresh air. The system using the fan coil units reduces the HVAC running cost as it is more controlled for the office rooms.

Plumbing system: The building has two water supplying sources, clear water and gray water for planting; no automatic sensors are installed neither in the sanitary ware nor in the water fixtures.

Fire system: The water sprinklers are throughout the building, CO_2 and FM200 fire suppression systems are in control room and equipment's room.

The fire alarm system is linked to the BA system and it is linked to the main fire station.

Conveying system: Three elevators serving the building linked to the BA system. The specification of the lifts are: elective/selective lift and it is linked to the BA system.

b) Electrical systems

Lighting system: is traditional linear fluorescent, 500 lux at the desk as per the IES standards for office buildings. Lighting control through standard manual light switches except for the client suite in the third floor, the automatic light sensors were used.

Lighting is partially integrated with the BA system, as it is controlled to automatic shut down after working hours.

Figure 4.28: Lighting system in Office space

Power Strategy: is drawn from providing the building with two separate power inlets, besides a fully loaded generator for the backup power source. UPS system up to 30 min. is used for the data center and essential loads for employees.

c) Security and access control

Securing the building by having a security guard patrolling, CCTV cameras covering the entrances, exits and corridors of the building.

Electronic access control system is for the main entrance of each wing of the offices spaces, and for the UPS room and the data center room in the building.

4.7.2.4 IT Services

The BA system in the building is zoned by wings of the plan. PC based system integrating with the HVAC, water pumps conveying system and fire system.

Optical fiber cables backbone and structured copper in horizontal distribution. The cable distribution through the raised floors and the false ceiling trays, this provides the user with flexible furnishing and the structured cable system provides one voice and data outlet each 10 m^2.

Main equipment rooms in the first basement floor, small rooms in the core serving each floor.

Service Risers: Two risers dedicated to electrical power and light current serving each wing of the building and connected to the equipment's room. One core is serving the building where the staircase, bathrooms and HVAC duct are implemented.

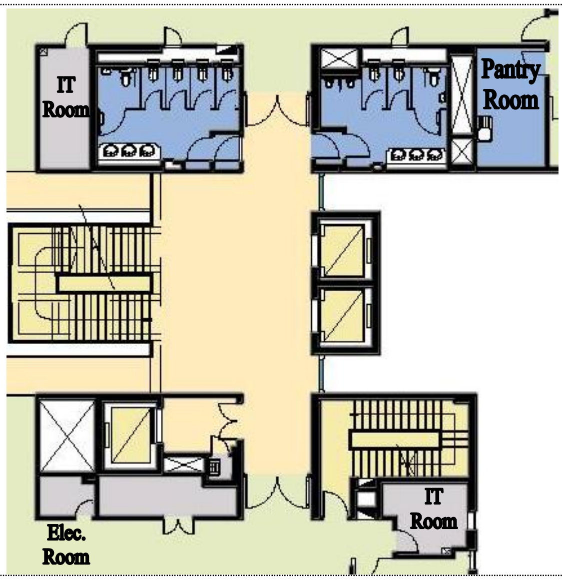


Figure 4.29: Beltone Core

Table 4.5 summarize the ECG building's features, and evaluate the features either its intelligent (I) or not (N).

	ECG Building Intelligent Features		I	N
	1- SITE			
	Aspects and Landscape	External landscape, and seatings surrounding buildings within 30 m of western façade.	+	
	Access	main road within 2km/ Private bus services for the village	+	
	Car Parks	Provided at 1/ 40 m^2	+	
	2- Architectural Elements			
Shell	Bldg mass & Thermal strategy			
	Floor Shape & Size (typical)	Rectangular plan, 1685 m^2	+	
	Planning grid	Arch. grid 90 cm, Str. grid 5.4	+	
	Floor depth &	11-14 glass to core		
	Sectional height	4.10 m Slab-to-slab	+	
		2.80 m Floor-to-ceiling	+	
	Landlord efficiency	80 %	+	
	Tenant efficiency	85 %	+	
	Atrium	8.5 m width Atrium		+
	Access- Staff and Visitors	Big reception area.	+	
	Access – Disabled access	Free entry through main entrance	+	
	Access – Goods entrance/ lifts	Separate goods entrance	+	
	Maintainability	Façade maintenance by external ropes		+
Skin	Glazing	Double glazing, tinted glass	+	
	Opening windows	None		+
	Solar shading	No external louvers and Internal blinds		+
	3- Building Systems			
Mechanical	HVAC systems	100% air-conditioned FAHU system	+	
	Air handling units	AHU on the roof floor		+
	Fresh air intake	Centralized on roof or upper floor	+	
	Plumbing	Two water supplying sources, clear and gray water. No automatic sensors installed in faucets & toilets.		+
	Fire Systems	Sprinklers throughout. Smoke detectors. CO_2 to special areas. linked to BAS and linked to main fire station	+	
	Vertical transportation	The lift system is intillegent traffic optimization system, linked to BAS	+	
Electrical	Lighting	Zoned fluorescent 500 lux at desk with manual switches		+
	Power Strategy	Backup generator & UPS system provides up to 30 min battery backup for IT and emergency system.	+	
Security	Security system and access control	CCTV and guard patrols, & electronic access control to special areas.		+
	4- IT Services			
Building Services	BA systems	No centeralized system. Individual system for HVAC, landscape lighting and fire system.		+
	Telecommunication Infrastructure	Single building entry for telecommunications		+
	Equipment rooms	One per floor	+	
	Cable types	Copper bakbone		+
	Cable distribution system	Raised floor/ tray	+	
	Floor termination	1 outlets per 9 m^2	+	
	Services risers	2 separate risers for elec. and data communications, $<$ 1% of GFA	+	
Mn.	Space management	No computerized facility management system		+
	Business systems	AV conference facilities on each floor	+	

Table 4.5: Beltone IB Features (By Researcher)

4.7.3 Initial and Running Cost

The building initial cost was 120,200,000 EGP in November 2009, the annual running cost of the building was 3,564,000 at the end of 2011. Table 4.6 illustrates the annual running cost of different elements and the cost per meter is calculated regarding to above ground gross internal area 6740 m^2.

	Annual Cost (EGP/ year)	%	Annual Cost EGP / m^2
Electricity	244,000	9 %	36.3
HVAC	1,120,000	41%	166.0
Conveying Lifts	47,000	1.7%	7.0
Water	18,000	0.65%	2.7
Cleaning	586,000	21.5%	87.0
Security	310,000	11.5%	46.0
Maintenance	400,000	14.65%	59.0
TOTAL	**2,725,000**	**100%**	**404**

Table 4.6: Running Costs of Beltone Building (1)

It is recognized that the running cost of HVAC system is around 41% from the building's total running cost, and according to the previous analysis for the service strategy and the solar control of the building skin. It is 100 % glazing area of the façade without openings. It was clear that the glazing specification has a significant effect on the thermal performance of the interior spaces of the building, which results in the increase of the running cost to this figures.

The research applied VE studies for the building façade, and suggested the proposed ideas, evaluating the performance of the alternatives, and calculating the LCC of each alternative

4.7.4 VE Application

The VE proposed idea for the building façade suggests the use of the two intelligent glazing alternatives in the previous case study and calculates the differences in initial cost and in running cost according to the bases of LCC calculations.

The LCC calculations in figure 4.31 and VE study is presented on the VE recommendation sheet in figure 4.32, and the software calculations in table 4.7 comparing the two alternatives with the existing glass as a base case.

(1) Beltone administration office, Engineering department, Smart Village, January 2012

The following tables illustrate the inputs (Tables 4.7) and the outputs (Tables 4.8) from the software *Glasswizard:*

Project Name	BELTONE	**Architect**	SWANKE HAYDEN ARCHITECTS
Builder	OCI	**Consultant**	ECG
Location (m)	Giza	**Operation Time**	9am to 5pm
Air Conditioner Type	-User Defined- (3.52 kWhr/TR)	**Operating Days In Week**	5
Cost of Electricity	2.3	**Months Of Operation**	Jan - Dec

Glazed Area (sq.m)			
North Area	**1075**	**South Area**	**1075**
East Area	**620**	**West Area**	**568**
North West Area		**South West Area**	
North East Area		**South East Area**	

Projection factor of shading device			
North		**South**	
East		**West**	

Gross wall Area (sq.m)	**3618**	**WWR %**	**92**

Table 4.7a: Building facades' specifications

Type of Glazing	Outer Glass Specification	Inner Glass Specification	Solar Factor	U-Value $W/m^2 K$	Light Transm. (%)
Base Case Tinted Double Glass	Tinted Glass 6mm	Clear 6mm	0.37	3.8	39
Low-E Tinted Double Glass	Tinted Low-E 6mm	Clear 6mm	0.23	1.6	39
Electro Chrome Tinted Double Glass	Double Glass 2x6mm	Clear Low-E 6mm	0.04	1.0	variable

Table 4.7b: Glass specifications

Type of Glazing	HVAC TR [1]	HVAC Investment (EGP)	Glazing Investment (EGP)	HVAC & Glazing Total Investment (EGP)	HVAC Running cost/annum (EGP)
Base Case Tinted Double Glass	133	1.53 million	1.1 million	2.63 million	1.12 million (485,181 Kw/hr)
Low-E Tinted Double Glass	79	901,145	1.65 million	2.55 million	680,950 (296,065 Kw/hr)
Electro Chrome Tinted Double Glass	36	407,305	26.7 million	27.11 million	229,710 (99,874 Kw/hr)

Table 4.8a: Initial and Running Costs

[1] The HVAC Tonnage is estimated from the heat gain from glazing only

Type of Glazing	Extra Glazing Investment (EGP)	Savings in HVAC Investment (EGP)	Savings in HVAC running cost/annum (EGP)	Net Investment [2] (EGP)
Base Case Tinted Double Glass	-base-	-base-	-base-	-base-
Low-E Tinted Double Glass	550,770	625,564	434,969	No extra expenditure
Electro Chrome Tinted Double Glass	25.6 million	1.12 million	886,206	24.48 million

Table 4.8b: Savings in Initial and Running Costs

[2] Extra Glazing Investment - Savings in HVAC investment

Type of Glazing	% Savings in HVAC running cost	LCC Savings in Operational cost [3] PW (EGP)	Operational Payback [4]	NET Payback [5]
Base Case Tinted Double Glass	-base-	-base-	-base-	-base-
Low-E Tinted Double Glass	39%	3.74 millions	1 Year 3 Month	No extra expenditure
Electro Chrome Tinted Double Glass	79%	7.59 millions	28 Year 10 Month	27 years 7 Month

Table 4.8c: LCC Savings and Payback Period

[3] *Considered 20 years*
[4] *Considering Savings in Running Cost only*
[5] *Considering Savings in Running Cost & HVAC Investment*

The bar charts in figure 4.30 illustrate the relation between the initial cost of investment in HVAC and Glass. In addition, the chart below illustrates the relation between the total initial costs of HVAC and glass with the annual running cost.

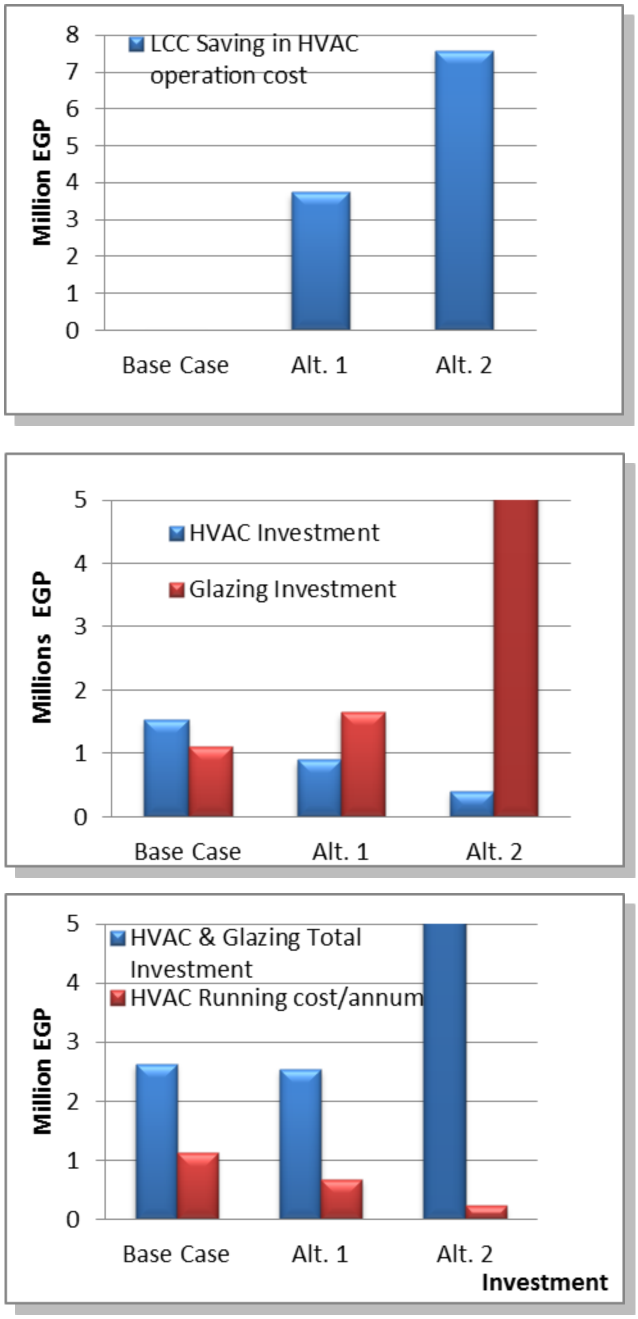


Figure 4.30: Glazing& HVAC Initial and running cost (By Researcher)

LIFE CYCLE COST Beltone Building, Smart Village, Giza — VE Rec. No. AR -01

(PRESENT WORTH METHOD)

Project: Beltone Building Location: Smart Village - Giza PROJECT LIFE CYCLE (YEARS): 20 DISCOUNT RATE (% in decimals): 10%			ORIGINAL Tinted Double Glass		ALT. 1 Low-E Tinted Double Glass		ALT. 2 Electro-Chrome Tinted Double Glass	
Construction Costs			Est.	PW	Est.	PW	Est.	PW
A) Tinted Double Glass			1,100,000	1,100,000				
B) Low E Glass					1,650,000	1,650,000		
C) Electro-Chrome Glass							26,700,000	26,700,000
D)								
E)								
F)								
Other Initial Costs								
A) HVAC Base Case			1,530,000	1,530,000				
B) HVAC for Alt. 1					901,145	901,145		
B) HVAC for Alt. 2							407,305	407,305
Total Initial Cost Impact (IC)				**2,630,000**		**2,551,145**		**27,107,305**
Initial Cost PW Savings						**78,855**		**(24,477,305)**
Replacement/Salvage Costs	Year	Factor						
A)								
B)								
C)								
D)								
E)								
F)								
G)								
H)								
Total Replacement/Salvage PW Costs								
Operation/Maintenance Cost	Escl.0%	PWA						
A) District chiller consumtion		8.513	1,120,000	9,534,560	680,950	5,796,927	229,710	1,955,521
B)								
C)								
D)								
E)								
F)								
G)								
Total Operation/Maintenance (PW) Costs				9,534,560		5,796,927		1,955,521
Total Present Worth Life Cycle Costs				**12,164,560**		**8,348,072**		**29,062,826**
Life Cycle (PW) Savings						**3,816,488**		**(16,898,266)**

PW - Present Worth PWA - Present Worth of Annuity

Figure 4.31: Beltone Building LCC Calculations for Alternatives (By Researcher)

Although the differences in the percentage of glass between the two cases, the Low-E glass also showed the best LCC according to the HVAC performance and with a payback period of 1year and 3 months, calculated on savings in the running cost only, while the Electro-chrome showed the best performance but a higher LCC.

Figure 4.32 illustrates the VE recommendation sheet for the selected glazing system on the standard VE format.

Value Engineering Recommendation

Project: Beltone Building VE Rec. No.
Item: Change type of glass with intelligent alternatives **Ar-01**

Original Design

The original design is using double glass: outer lite 6mm tinted glass (silvery blue), inner lite 6mm clear glass and 12 mm (dehydrated) inter space.

Thermal performance:

Shadding coefficient 0.43, U-value 2.8 W/m^2.K, Relative heat gain 297 W/m^2.

Visible light performance:

Light transmittance 37%, Light reflection (external) 16%, Light reflectance (internal) 32%

Proposed Design

The proposed design is to use Intelligent glazing systems. It is proposed to use double glass (LOW E) in the south, east and west facades with the following performance.

Thermal performance:

Shadding coefficient 0.27, U-value 1.6 W/m^2.K, Relative heat gain 205 W/m^2.

Visible light performance:

Light transmittance 39%, Light reflection (external) 9%, Light reflectance (internal) 16%

Advantages & Disadvantages

Advantages:

Improves interior comfort
Saves energy
Improves cooling load

Disadvantages:

Requires modifications to the envelope design
Increase in the initial cost
Reduce light transmittance by 12%

Discussion

The VE believe the long term impact of energy saving results in LCC saving while the Initial Cost of the proposed design is increased.

Life Cycle Cost Summary

	Initial	Annual O&M
Original	2,630,000	9,534,560
Proposed	2,551,145	5,796,927
Savings	78,855	3,737,633
	PW Annual Savings at (10%)	3,737,633
	Total Savings (Initial + PW Annual)	3,816,488

Figure 4.32: Beltone Building VE Recommendation Sheet (By Researcher)

4.8 Results and Discussion

The electro-chrome glass showed over expected initial cost as it is an exported material and it is not locally manufactured.

Savings appears for these cases are related to the rates of electricity and HVAC consumptions in the smart village, which are very high related to other locations in Egypt.

The same VE study may show better results if the application excludes the northern and eastern elevations.

Although the differences between the two cases in the percentage of glazing area on facades, the savings in the HVAC running cost is nearly about 40% with the Low E glass and 78% with the electro-chrome glass.

4.9 Summary

This chapter presented two case studies of IBs in Egypt where the IB design criteria was analyzed and a VE study was set to analyze the benefits of using intelligent alternatives and present the consequences on the LCC of the building.

The study realized the importance of the intelligent features in the building and its effect on the LCC of the building and suggested a VE checklist for IBs. This is to integrate the management concept of VE with the architectural concept of IB.

The following introduces a set of Conclusions and Recommendations to motivate the application of VE and the design of intelligent buildings in new constructed projects.

Conclusions & Recommendation

❖ Conclusions

The study reaches a set of conclusions and classifies it as follows:

- **Value Engineering**

▪ Applying VE studies to the building in the primary design phases is an essential procedure for the architect, consultant to implement in the selection of the major building's materials.

▪ Increasing the initial cost of the building that is due to investment in some elements that have direct effect on the running cost is not considered an increase in the building total cost, especially if these elements affect the indoor environmental performance of the building.

▪ The LCC technique is a proper VE technique that can be used to convince the owners to invest in IBs. It is also a project management tool that integrates with the architecture concept of designing intelligent buildings, where higher initial costs are traded for the target of reducing the future costs.

- **Intelligent Buildings**

▪ The need for IB is a necessity, as these buildings achieve the demand of the growing use of technology and the importance of conserving energy. On the other hand, the ideal indoor environment that provides productive workspaces can help in solving the problems of staff performance.

▪ The evaluation of the investments in IB should be judged on a wide scope covering the life cycle of the building and not only the initial cost. Therefore, applying of the VE studies specially the LCCA is an essential step in the primary design phases of IB to evaluate this type of buildings.

▪ The building's value should increase as its intelligence increases without the necessity of increase of its life cycle cost.

▪ The IB's comfort indoor environment and productive workplace, besides the savings in the running cost, encourages the architects and the owners to look carefully for investing in this type of buildings.

▪ The design of IB is an architectural tool to construct a building that follows the VE management concept with maximum value and minimum LCC cost.

▪ A proposal of a "*VE checklist for IB*" is concluded. It combines the principles of VE with the design criteria of IB and results in integrating both concepts. It is applicable to use in the design of IB in Egypt, and can be used to evaluate the new constructed IB seeking for optimization of the value and the life cycle cost of the building.

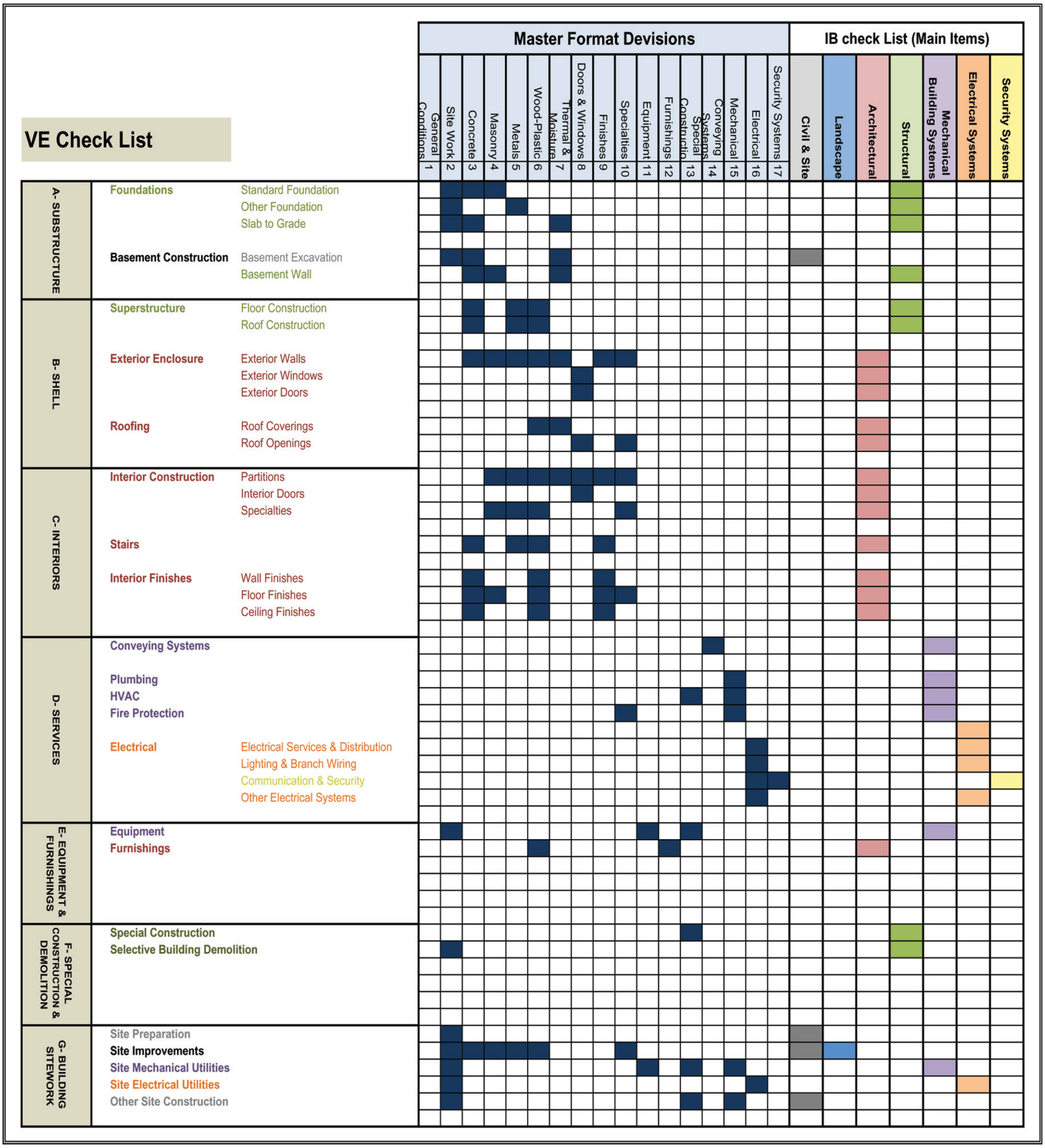
VE Checklist for IBs

The VE checklist presented in chapter 1 covering all the project's divisions (The 17 divisions of the MASTER UNIFORMAT). The research proposes a ***"Suggested VE Checklist for IBs"*** by combining the principles of VE checklist with the elements of the design criteria of IB. This will result in integrating both concepts to create a checklist, which can be applied in the design of IBs under VE management concept. The highlighted items in the list below illustrate the new items that were added to the normal VE checklist.

VE Check List for IB

CIVIL & SITE		Demolitions Mobilization & demobilization Excavation Isolation
LANDSCAPE		Soft & Hard Scape Ramps & Stairs Entrance Approach Car Parking Planting **water & light control**
ARCHITECTURAL ELEMENTS	Shell	Areas Heights **Floor shape** **Planning grid** **Landlord & Tenant efficiency** Finishing Materials internal partitions Doors Roof & SkyLights
ARCHITECTURAL ELEMENTS	Skin	Masonary Work Claddings Glazing & Shading **Openings for natural ventilation** Maintenance
STRUCTURAL ELEMENTS	Foundations	Standard Foundation Special Foundations
STRUCTURAL ELEMENTS	Str. System	System Columns & Beams Slabs Roof **Structural grid**
MECHANICAL SYSTEMS	HVAC	HVAC System **VAV system** Air Distribution Ducts Layout **Fresh air intake** **Link to the BA system**
MECHANICAL SYSTEMS	Plumbing	Water Supply System Water Drainage System Sanitary ware Fixtures **sensors for water consumtion**
MECHANICAL SYSTEMS	Fire System	Fire Detection System Water Pipes Sprinklers **Link to the BA system**
MECHANICAL SYSTEMS	Conveying Systems	Lift types **Link to the BA system**
ELECTRICAL SYSTEMS	Power	Inlet Cables Loads Cables Distribution System **Backup power Provision**
ELECTRICAL SYSTEMS	Lighting System	Light Fixtures Lamps **Lighting control system** **Link to the BA system**
Security SYSTEMS		CCTV Cameras Layout Access Control System **Link to the BA system**
Building Services	IT Services	**BA system** **Space management** **Buisness management system** **Telecommunication Infrastructure** **Equipment room** **Cable types** **Cables Distribution System** **Audio/video services** **Service risers**
General		Expenses & Profit Margin General Project Cost Unit Price in the BOQ

Table 4.4: VE Checklist for IB


VE Check List
Master Format Devisions
IB check List (Main Items)
General Conditions 1
Site Work 2
Concrete 3
Masonry 4
Metals 5
Wood-Plastic 6
Thermal & Moisture 7
Doors & Windows 8
Finishes 9
Specialties 10
Equipment 11
Furnishings 12
Special Construction 13
Conveying Systems 14
Mechanical 15
Electrical 16
Security Systems 17
Civil & Site
Landscape
Architectural
Structural
Mechanical Building Systems
Electrical Systems
Security Systems
A- SUBSTRUCTURE
Foundations
Standard Foundation
Other Foundation
Slab to Grade
Basement Construction
Basement Excavation
Basement Wall
B- SHELL
Superstructure
Floor Construction
Roof Construction
Exterior Enclosure
Exterior Walls
Exterior Windows
Exterior Doors
Roofing
Roof Coverings
Roof Openings
C- INTERIORS
Interior Construction
Partitions
Interior Doors
Specialties
Stairs
Interior Finishes
Wall Finishes
Floor Finishes
Ceiling Finishes
D- SERVICES
Conveying Systems
Plumbing
HVAC
Fire Protection
Electrical
Electrical Services & Distribution
Lighting & Branch Wiring
Communication & Security
Other Electrical Systems
E- EQUIPMENT & FURNISHINGS
Equipment
Furnishings
F- SPECIAL CONSTRUCTION & DEMOLITION
Special Construction
Selective Building Demolition
G- BUILDING SITEWORK
Site Preparation
Site Improvements
Site Mechanical Utilities
Site Electrical Utilities
Other Site Construction

Recommendations

The study reaches a set of recommendations and classifies it as follows:

- **Design & Construction Field**

- The VE methodology and techniques should be more actively utilized in the field of construction in Egypt. In order to realize the benefits of analyzing the functions and its consequences in the value and cost of the buildings.
- VE studies for the project in its primary design phases should be an essential document for the Architect to present in order to insure that the investments are not wasted in vain.
- The awareness of the short and long-term benefits of the value engineering studies should be spread.
- The LCCA should be considered while selecting the materials and systems that affect the running cost of the building.

- **Academic & Research Field**

- Encouraging the academic researches, trainings and practice in these fields.
- Introducing new subjects and programs for the construction management science to the undergraduate architecture schools.
- Future researches can:

  Study the integration of VE and intelligent buildings within the scope of the other architecture elements rather than the façade.

  Study the relation between VE and other types of buildings such as sustainable and high-tech buildings.

  Include the cooperation of electro-mechanical disciplines with the architecture researches to enhance the results.

Appendix

1.1 VE Definitions:

The following are varies definitions of VE.

Definition by: The Society of American Value Engineers (SAVE):

Value Engineering is a function-oriented, systematic team approach to providing value to a product, system, or service. Often this improvement is focused on cost reduction; however, improvements such as customer perceived quality and performance are paramount in the value equation. Simply stated, Value Engineering is more than a cost-reduction methodology. It is a systematic approach for identifying and solving problems. (1)

Definition by: The Federal Acquisition Regulations:

Value Engineering is an organized effort to analyze the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving essential functions at the lowest life-cycle cost consistent with required performance, quality, and safety. (2)

Definition by: The Zimmerman and Hart definition:

Value Engineering is a proven management technique using a systematized approach to seek out the best functioned balance between the cost, reliability and performance of a product or project. The programmers seek to improve the management capability of people and promoting progressive change by identifying and moving unnecessary costs. (3)

Definition by: The US Department of Defense (DOD):

Value Engineering is an organized effort directed to analyze the functions of systems, products, specifications, standards, practices and procedures for the purpose to satisfy the required function at the lowest cost of ownership without reducing needed quality. (4)

Definition by: Lawrence D. Miles:

Value Analysis constitute a function based thinking system to identify and remove all unnecessary cost while keeping and enhancing all quality in any manufacture, construction, services or wherever a dollar is spent. (5)

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(1) The Hong Kong Institute of Value Management. (2004). The Value Manager (ISSN J,029-(J982). Hong Kong: The official publication of Hong Kong Institute of VM.

(2) Ibid.

(3) Zimmerman, L,, &Hart, G. (1982) Value engineering: A practical approach for owners, designers and contractors. New York: Van Nostrand Reinhold.

(4) Elsanabary, M.'(2004) Application of construction management in irrigation projects Utilizing VE techniques. Master, thesis, Suez Canal University. P8.

(5) Miles, L. (1961) Techniques of value analysis and engineering. New York: McGraw-Hill.

Value Analysis is an organized creative approach to the identification of unnecessary costs i.e. costs which provide neither quality, nor use, nor life, nor appearance, nor customer features. (1)

Definition by: Gargari et al (1998):

Value Engineering is a proven management technique used to identify alternative design approaches for satisfying the requirements of the project while lowering costs and ensuring technical competence in performance. (2)

Definition by: The US Department of Transportation (DOT):

Value Engineering is an organized effort to analyze the function of systems, equipments, facilities, services and supplies for the purpose of achieving the essential function at the lowest life-cycle cost consistent with required performance, reliability, quality and safety. (3)

Definition by: Dell'laola:

Value Engineering is a creative, organized approach whose objective is to optimize cost and/or performance of a facility or system. It can also be defined as a systematic approach for obtaining optimum value for every dollar spent by removing unnecessary costs without affecting the value of a facility or system. (4)

Definition by: Albenaa magazine:

A systematic team work technology, an overall evaluating study for a project according to consecutive steps in order to raise the function performance and control total costs for construction and maintenance. Therefore, value engineering is an applying and using the design team talents (architects, civil, electrical and mechanical engineers) in a way which guarantees the best benefit of their experience at the right time. (5)

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(1) Kelly, J. (2002) Best value in construction. London: RJCS foundation science LTD. P78.

(2) Elsanabary, M. (2004) Application of construction management in irrigation projects Utilizing VE techniques. Master thesis, Suez Canal University. P9.

(3) The Hong Kong Institute of Value Management, (2004). The Value Manager (ISSN 1029-0982). Hong Kong: The official publication of Hong Kong Institute of VM.

(4) Dell'Isola, A. (1982) Value engineering in the construction industry. New York: Van Nostrand Reinhold.

(5) Almadi. M. (2002, May). Military experiment with value engineering. Albenaa,P78.

1.2 VE Standard Sheets:

Value Engineering Recommendation

Project: VE Rec. No.

Item:

Original Design

Proposed Design

Advantages & Disadvantages

Discussion

Life Cycle Cost Summary

	Initial	Annual O&M
Original		
Proposed		
Savings		
PW Annual Savings at (Factor)		
Total Savings (Initial + PW Annual)		

(1) AUC, PRMG Course 099, Value Analysis Lecture material (2011)

Value Engineering Recommendation

Project: VE Rec. No.

Item:

Original Design

Proposed Design

Ibid.

Cost Worksheet

Project: VE Rec. No.

Item:

Original Design

	Unit	Quantity	Unit Cost	Total

Total Cost

Proposed Design

	Unit	Quantity	Unit Cost	Total

Total Cost

Potential Savings

Potential Savings

Ibid.

1.3 VE Techniques:

While VE is studying the function and the cost worth these functions, the pioneers develop several techniques in order to break down each function analyzing it carefully and estimating the cost of each discipline aiming to control the cost. These techniques could be used together or separately in evaluation, realizing cost saving and the adding value.

The study will briefly illustrate the VE techniques defining and explaining each.

1.3.1 Modeling Technique

Preparing a cost model from a detailed estimate is a common practice in value engineering construction work. Costs are the foundation of value analysis. The cost model is a tool that assembles and breaks down total facility costs into more functional units that can be quick analyzed. Once a model is prepared, other benefits shall be included:

- Increasing cost visibility, enabling one to see the high cost areas.
- Helping to identify VE potential.
- Providing a baseline reference for use in comparing alternatives

1.3.1.1 Making models

All models generically represent a work breakdown structure in which each part works in relationship with the other parts, or through levels of indenture. These relationships are illustrated in Figure 1.1. "Work Breakdown Structure".

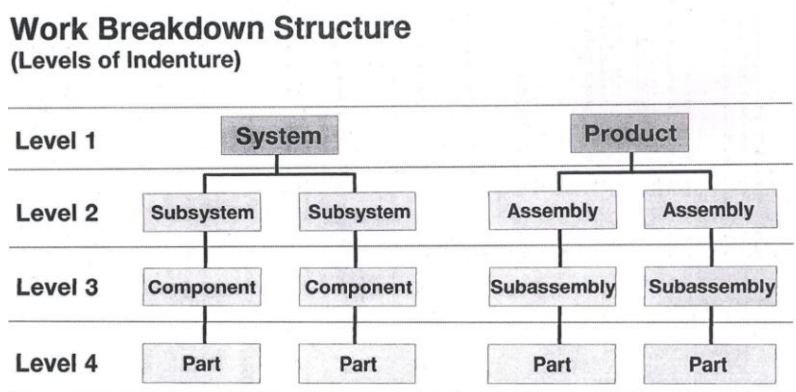

Figure 1.1: Work Breakdown Structure[1]

(2) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997, P. 34

Models for any subject matter can be developed by obtaining cost or other recourse information at the first level of indenture, then logically breaking down that information to subsequent levels. Some of the rules for making models as following:

- Work from the top down.
- Identify cost centers at each level of indenture.
- Organize the model so items above depend on items listed below.
- Make the total cost of items equal to the sum of each level.

1.3.1.2 Construction cost models

The most common work breakdown structure for a construction cost model of a building is based on the uniform system. Uniformat for buildings has become a standard in the construction industry because it is based on a building systems level of detail rather than on a trade breakdown.

The cost model includes a basic target costs together with the actual estimated costs. The model blocks are adjusted for each facility to better reflect the functional areas involved and the estimating data. The target cost costs are developed based on the VE team experience with similar buildings, cost files on similar buildings, or previous study results. These costs represent the minimum cost possible for each block of the cost model, and become cost targets to compare with actual costs from the project estimate. Where the largest differences occur, the area is isolated for study.

1.3.1.3 Types of models

Although cost is the most common, it is not the only resource to which VE applies. Certainly, cost is not the lull measure of value. Other resources that represent value to an owner are space, time, utilities, labor, quality of materials, and aesthetics. When resources other than costs are imported, models can be generated to assist in optimizing the impact of these resources on the project.

When resources other than costs are important, models can be generated to assist in optimizing the impact of these resources. The following are examples of models that can address space, energy, life cycle costs, and quality.

a) Space models

Preparation of space model is highly recommended when a VE study is being performed at programming or conceptual stage of facility design. In the early project phase, all one knows about the project, or all one can measure the area of various types of functional space. In this case, worth was established by the owner as the programmed amount of space. Worth of space functions can also be established through historical data, space performance standards, and elimination of secondary function space.

A function analysis of space performed for a new sports stadium is illustrated in Figure 1.2 it was prepared at the concept stage of design, where the resource used was measured in square meters. The value index can be determined for each function because the units of measurement for cost and worth are the same.

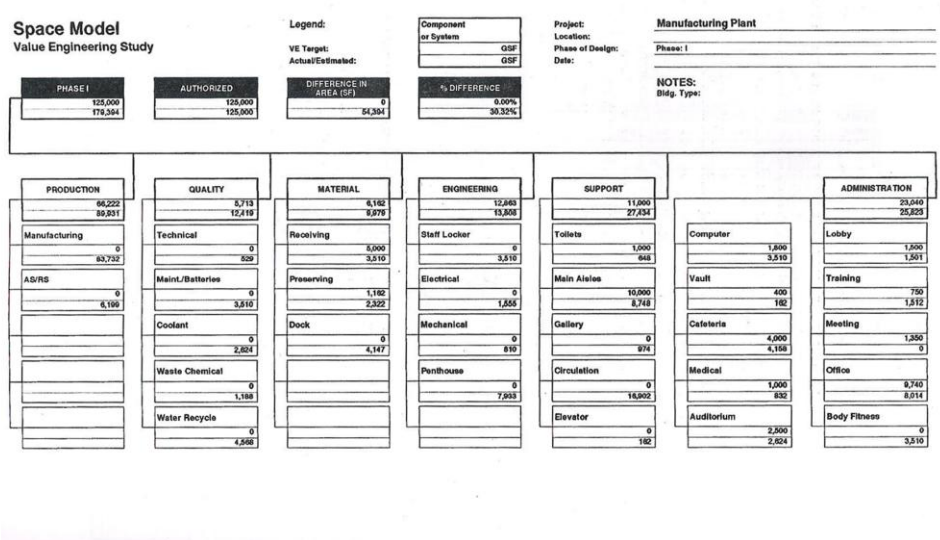

Figure 1.2: Space Model [(1)]

b) Energy Model

Another resource that can be modeled is energy. One of the features of the energy model is the need to show the operating hours per year for the various type of space as well as the unit rate: KW/hr or K.W/SF. Figure 1.3 illustrates an energy model for a shopping center project based on Kilowatt-hours per year (KWh/yr). Worth is determined by asking "what is it?" about potential of the function, changes to operating hours, use of utilization rates for energy efficiency, reductions in square footage of change in system types, and elimination of energy sources.

(1) ibid P. 44

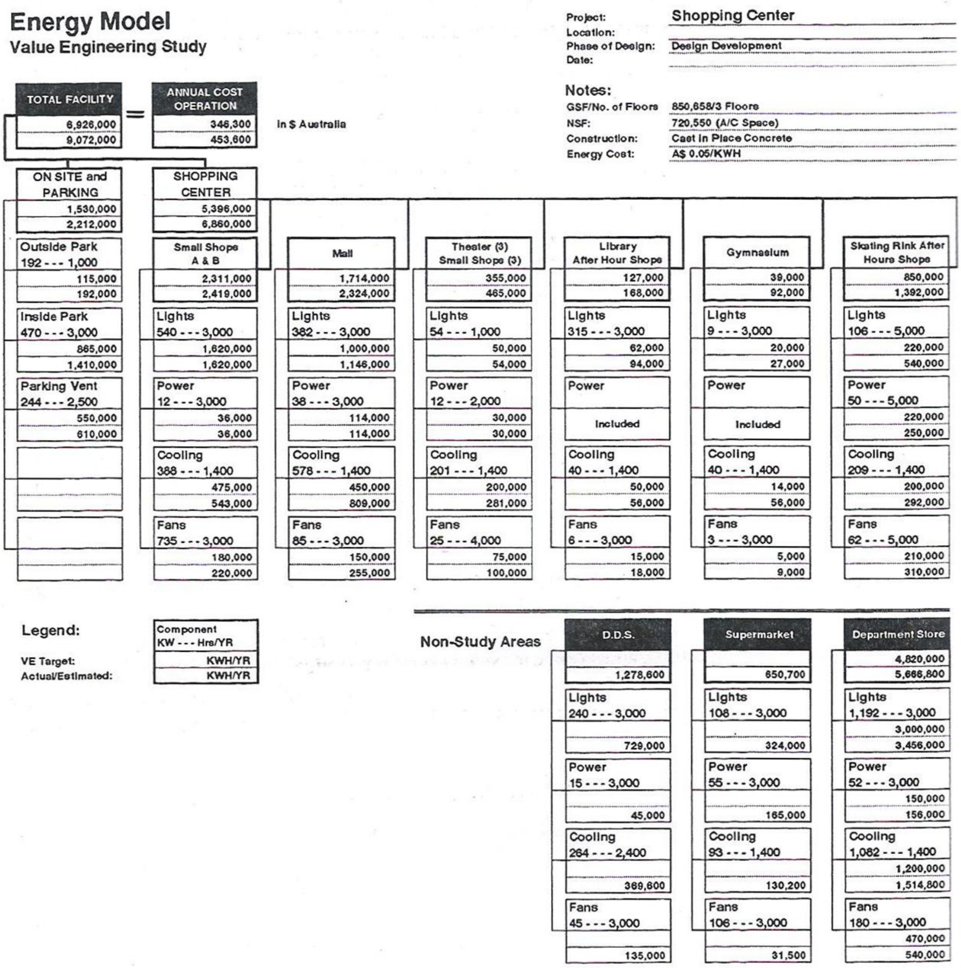

Figure 1.3:Energy Model(1)

(1) ibid P. 48

c) Life cycle cost model

The LCC model is the ultimate indicator of value to client. It encompasses both initial costs and running costs. The LCC model considers optimum value because it takes into account all probable cost over the life of the facility. The LCC model can be based on either the annualized cost or the present worth approach, where, all costs shown in the model can be equivalent annual or present worth cost. More discussion was in chapter one in the section of Life Cycle Costing Technique.

d) Quality model

The quality model illustrated in Figure 1.4 provides a through definition of the owner's project performance expectations. These expectations must result in a consistent definition and understanding between the owner and the design team. This consistency helps to ensure that original owner expectations in terms of functional performance are indeed met when the project is delivered and the facility is operating. The quality model defines the overall expectation of the project representatives regarding project goals, image concerns, design criteria, and performance standards.

The information is established from an interactive Quality Model Workshop at the concept stage, in which owner representatives of facility are polled for their concerns and opinions regarding their desired, minimum, balanced, or maximum response.

The quality model then serves as the foundation for the VE application. Attitudes and expectations regarding operational and technical performance, which having been clearly defined, understood, and documented, and become the yardstick by which decisions are made as design proceeds, the quality model is used to ensure that VE design alternatives are consistent with original owner expectations. During the early design phase, the VE team explores a number of alternatives that seek to optimize owner expectation. These alternatives are then reviewed in the workshop session. During the workshop, the owner and design team compare the alternatives with the quality model. The alternative that most closely matches the owner's functional performance needs is selected for further development.

The number of participants in the Quality Model Workshop should represent live points of view: financial, users, facility operations, design, and construction. The objective is to determine and document through group dynamics a consensus directive that will guide all subsequent decision making in the development of the design. The Quality Model Diagram along with narrative records the relative choices of importance between the twelve major planning elements as illustrated in figure 1.4. Those items of greatest concern are indicated on the outer edges of the diagram, those of less concern toward the center.

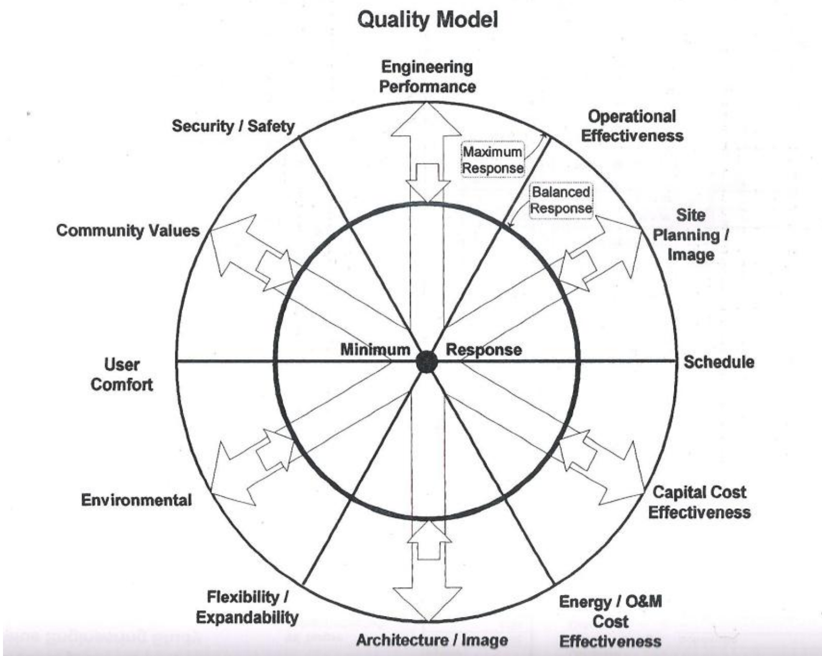

Figure 1.4: Quality Model [(1)]

1.3.2 Function Analysis Technique

1.3.2.1 Definition

Function is defined as the specific purpose or intended use for an item or design. It is that characteristic which makes it work, sell, produce, revenue, or meets mandatory owner/user requirements.

1.3.2.2 Determine function

The function of *any* item, component, or design is defined literally by two words: active "verb" and measurable "noun". The verb should answer the question "What does it do?" while the "noun" answers the question "What does it do it to?". Consider the following examples:

e) Active verb with measurable noun:

- Support weight
- Transmit load
- Enclose space
- Conduct current
- Condition space
- Protect people

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1982, P.54

- Reduce sound
- Reduce losses foiled heat
- Exclude

f) Verb with non-measurable noun:

- Provide beauty
- Beautifies design
- Attract users
- Identify item
- Improve appearance
- Enhance product
- Satisfy owner.

A measurable noun together with a verb provides a description of a work function. They establish quantitative statements. While the verb and non-measurable noun are classified as sales/sell or aesthetic functions. They establish qualitative statements.

1.3.2.3 Classify function

After identifying and describing functions of an item using a verb and a noun, it requires classification of each function as basic or secondary. The purpose is to simplify design, operation, plan, or schedule to make the item less expensive.

Basic function: is the purpose of performance feature(s), which must be attained if an item or design is to work or meet the owner's needed requirements. An item may possess more than one basic function depending on the owner's needs. The basic function should answer the question "What must it do?"

Secondary function: is any characteristic of an item which is not essential to the user for the desired application of the item and does not contribute directly to the accomplishment of basic function. It has a zero use value. It should answer the question "What else does it do?"

Required secondary function: is considered where secondary functions are essential to the performance of the basic function or required by codes, (i.e. they have value).

After determine of the cost/worth of the Basic and required secondary functions, the value engineering will attempt to eliminate or reduce as many secondary functions as possible, and reduce the cost of performing the basic functions whenever feasible. (Figure 2-11) is the functional analysis of the exterior skin system, where the analysis result (cost/worth) ratio = 239.

1.3.2.4 Function Analysis System Technique (FAST)

FAST involves a function block diagram based on answers to what is the problem? Why is a solution necessary? How can the solution be accomplished? The result is a hierarchy of functions showing logical why/I low relationships that provides an analysis of functions to achieve an objective or an end result. FAST diagram procedures are illustrated in Figure 1.5.

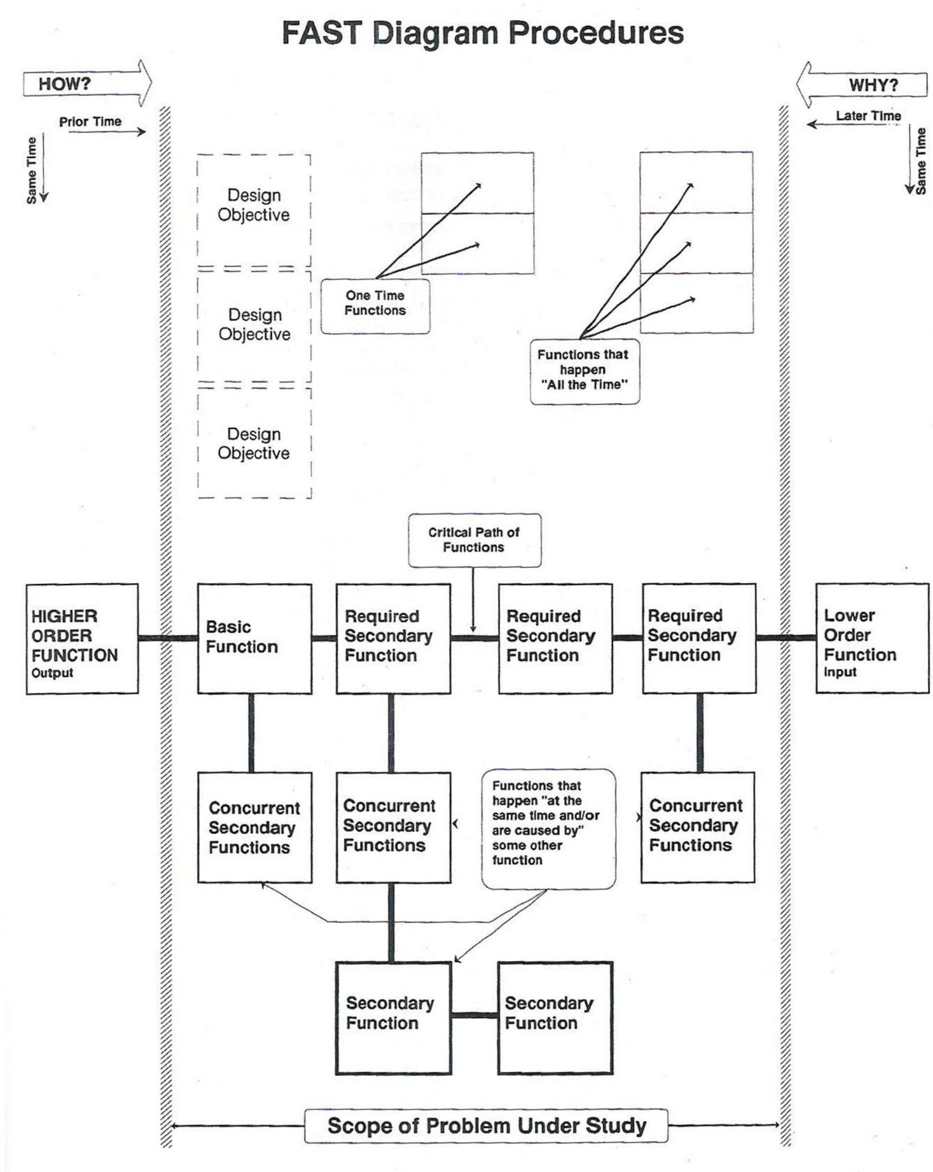

Figure 1.5: FAST diagram [(1)]

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1982, P.75

1.3.3 Delphi Technique [1]

The technique is used to identify areas of potential cost savings and design alternatives at early design in the absence of good cost data.

1.3.3.1Definition and application

Delphi is characterized as a method of obtaining general agreement from a group of qualified individuals as a whole, where they first identifying, and then evaluating the outcome.

The group might consist of project managers, designers, maintenance and operations personnel, cost estimators, marketing sales (owners), and value engineers.

1.3.3.2 Implementations

- Delphi is used in VE for:
- Selecting & evaluating project areas for study.
- Putting together a cost or energy model.
- Identifying the pros and cons with alternatives.
- Developing cost relationships in complex facilities.

1.3.3.3 Delphi technique methodology

Delphi technique consists of several cycles.

In the first cycle, the group revises the project and selects the potential project saving areas for detailed study using the functional analysis.

In the second cycle, each participant individually suggests alternatives for the selected potential savings areas.

Then, the group assembles to discuss the suggested alternatives.

At the end of this cycle, the alternatives are refined to select specific alternatives for more cycles, and so on until reaching a complete agreement.

The degree of confidence of the results greatly improved with number of Delphi cycles.

The final step of Delphi involves group recommendations towards the project selection areas, proposed alternatives, and target savings for the project under study.

(1) Prof Mohamed Askar, Training Course in VE Techniques, Cairo University, April 2005.

1.3.4 Weighted Evaluation Technique [1]

1.3.4.1 Definition

sIt is an organized process with which optimum solutions are .selected in areas involved several criteria. Since cost is not only the evaluation factor for the alternatives generated by VE study, human factors such as comfort, appearance, performance, safety, ...etc. should also he evaluated by such a technique.

1.3.4.2 The Weighted Evaluation Form

The evaluation form has been divided into two processes:

a. The criteria weighted process, where

1. Important criteria are isolate.
2. Their importance and relative weights are established.

b. The analysis matrix, where

1. Each alternative is listed and ranked against each criteria.
2. The rank and weight of each criteria are multiplied and totaled.
3. The alternates are then scored for recommended implementation.

1.3.4.3 The Weighted Evaluation Methodology

Step (1) - Criteria weighted process:

- List and assign a letter to the important criteria for the particular project or area. Only those criteria which have significant impact in comparing alternates should be listed. In addition, criteria should be unique and not overlapped by other criteria of similar properties.
- Compare criteria to one another and establish the degree of importance for each criteria relative to the others. The degree are ranked as slight (or equal), minor, medium, and major preference (difference in important).
- After the favored criteria and their relative importance are determined, enter both the letter of favored criteria and the number of the established difference into the criteria scoring matrix in the appropriate weights of importance of each criteria.
- When a decision of importance cannot be made between two criteria, the two criteria can be indicated as equal by using both letters in scoring the matrix and by scoring each at one point.
- Calculate the raw score for each criteria by adding the numbers of the relative degrees of importance, both horizontally and vertically, for this criteria (key letter) in the criteria scoring matrix.

(1) Alphonse Dell'Isola, Value Engineering in the construction industry, New York: Van Nostrand Reinhold Co., 1982, P.131-133

- Standardize the weighted evaluation process by converting the row scores to scale of Zero (0) to ten (10) under the weight column, ten being the criteria receiving the highest row score.
- Review the total process before using the criteria and weights developed. The weights developed may be too bunched or too far apart, which are not representative of actual conditions.

Step (2) Using the Analysis Matrix:

- The input data consist of the criteria and weights taken from the criteria weighting process and the alternatives developed up to this point.
- List the alternatives in the left-hand column.
- Evaluate each alternative against each criteria and rank it
- a.) Excellent = 5
- b.) Very good = 4
- c.) Good =3
- d.) Fair = 2
- e.) Poor = 1
- Multiply the rank of the upper half blocks with the weight of each criteria to determine the weighted factors, and enter the weighted factors in lower half blocks.
- Add all the weighted factors in the evaluation.
- The alternatives can then be ranked for selection, the one having the highest total isolated as the top selection.

1.4 Life Cycle Cost Categories

Initial Expenses

Initial Investment Cost (one time start-up costs)

Construction Management

Land Acquisition

Site Investigation

Design Services

Construction

Equipment

Technology

Indirect/Administration

Art

Contingency

Future Expenses

Operation Cost (annual costs)

Heating Fuel

Electricity

Water and Sewer

Garbage Disposal

Custodial

Grounds

Lease

Insurance

Maintenance and Repair Cost (scheduled & unscheduled upkeep costs)

Site Improvements

Site Utilities

Foundation/Substructure

Superstructure

Exterior Wall Systems

Exterior Windows

Exterior Doors

Roof Systems

Interior Partitions

Interior Doors

Interior Floor Finishes

Interior Wall Finishes

Interior Ceiling Finishes

Maintenance and Repair Cost (cont.)

Interior Specialties

Conveyance Systems

Plumbing Piping

Plumbing Fixtures

Fire Protection Systems

HVAC Distribution

HVAC Equipment

HVAC Controls

Electrical Service/Generation

Electrical Distribution

Electrical Lighting

Special Electrical Systems

Equipment & Furnishings

Replacement Cost (scheduled replacement of building systems or components)

Site Improvements

Site Utilities

Foundation/Substructure

Superstructure

Exterior Wall Systems

Exterior Windows

Exterior Doors

Roof Systems

Interior Partitions

Interior Doors

Interior Floor Finishes

Interior Wall Finishes

Interior Ceiling Finishes

Interior Specialties

Conveyance Systems

Plumbing Piping

Plumbing Fixtures

Fire Protection Systems

HVAC Distribution

HVAC Equipment

HVAC Controls

Electrical Service/Generation

Electrical Distribution

Electrical Lighting

Special Electrical Systems

Replacement Cost (cont.)

Equipment & Furnishings

Residual Value (value of facility at end of study period)

Site Improvements

Site Utilities

Foundation/Substructure

Superstructure

Exterior Wall Systems

Exterior Windows

Exterior Doors

Roof Systems

Interior Partitions

Interior Doors

Interior Floor Finishes

Interior Wall Finishes

Interior Ceiling Finishes

Interior Specialties

Conveyance Systems

Plumbing Piping

Plumbing Fixtures

Fire Protection Systems

HVAC Distribution

HVAC Equipment

HVAC Controls

Electrical Service/Generation

Electrical Distribution

Electrical Lighting

Special Electrical Systems

Equipment & Furnishings

References

English References

Books:

- Anil Kumar Mukhopadhyaya, Value Engineering Mastermind- From concept to VE certification, 2001.
- Alphonse Dell'Isola, Life cycle costing for facilities, New York: Construction Publisher & Consultant, 2003.
- Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1982.
- Alphonse Dell'Isola, Value Engineering in the construction industry, 3rd edition, New York: Van Nostrand Reinhold Co., 1997.
- Andrew Harrison, Eric Loe & James Read, Intelligent Buildings in Soth East Asia, London: E & FN spons, 1998.
- Albert Ting & Wai Lok Shan, Intelligent Building Systems, USA, 1999.
- Connaughton, J. & Green, S., Value Management in Construction: a client's guide, London: Construction Industry research and Information Association, 1996.
- Edward Heller. Value Management: Value and Cost Reduction, London: Addison-Wesley Publishing co., 1971.
- Prowler, D. Whole Building Design. Washington, DC: National Institute of Building Sciences, Steven Winter associated, Inc. 2007.
- Sieglinde K. Fuller & Stephen R. Petersen, Life Cycle Costing Manual for the Federal Energy Management Program.
- Shengwei Wang, Intelligent Buildings and Building Automation, USA: Spon Press, 2010.
- Thomas King, Principles of Value Analysis/Engineering, Dallas: Society of American Value Engineers, 1979.
- Michael Wigginton and Jude Harris, Intelligent Skins, London, 2002.
- Kelly, J. Best Value in Construction, London: RICS foundation science LTD, 2002.
- Larry W. Zimmerman & Glen D. Hart. VE: A practical Approach for Owners, Designers and Contractors, New York, Van Nostrand Reinhold Co., 1982.

- Younker Del L. Value Engineering, Analysis and Methodology. New York: Marcel Dekker, Inc. 2001.

Standards:

- Life Cycle Cost Analysis Handbook, State of Alaska, Education support services/ facilities, 1999. SAVE International, Value standard and body of knowledge, 2007.
- SAVE International, Value standard and body of knowledge, 2007.
- Value Engineering Hand Book, Institute for Defense Analysis, Virginia, USA, 2006.
- Wikipedia, the free Encyclopedia

Internet Sites:

- www.automatedbuildings.com
- www.intelligent-building-dictionary.com
- www.value-eng.com
- www.red-bag.com/jcms/index.php/general-procedures.
- www.alyousefi.com
- www.acec-co.org
- www.amigoreader.com/book
- www.boma.org
- www.energydesignersources.com
- www.misronet.com/valueeng.htm
- www.uk.sagepub.com/books
- www.valuefoundation.org/index.htm
- www.ve.ida.org
- www.vecourse.com/index.html
- www.wbdg.org/resources/lcca.php
- www.wendt.library.wisc.edu
- www.wikipedia.com

Training Courses:

- AUC, PRMG 099: Value Analysis, Prof. Tarek Sakr, December 2010.
- Prof Mohamed Askar, Training Course in VE Techniques, Cairo University, April 2005.

Research Papers:

- Alsheash, S. (1993) Why some managers think in VE as a CR. In proceedings of the 1993 International Conference of the SAVE, Florida, 1993.
- Michael Dell'Isola, Value Engineering application using UNIFORMAT II, SAVE conference 1998.
- Abdulmohsen Al-Hammad & Mohammad A. Hassanian, Value Engineering in the Assessment of Exterior Building Wall Systems. Journal of architectural Engineering, 1996.

Thesis:

- Amr Hassan M. Hassan, "The Impact of the VE on the Decision Making and the Development of the Construction Industry" M.Sc Thesis, Faculty of Engineering, Architectural Department, Ain Shams University, 2010.
- Ahmed Abd El Aziz Waseef, "Value Engineering as an Approach for Designing the Public Buildings in Egypt" M.Sc Thesis, Faculty of Engineering, Architectural Department, Suez Canal University, 2008.

Arabic References: المراجع العربية

- الصادق محمد حلاوة، " الثورة التكنولوجية وانعكاسها على آليات المبانى الذكية دراسة خاصة لموقف مصر من ثورة المعلومات فى الألفية الثالثة"، "، رسالة ماجستير، كلية الهندسة جامعة القاهرة، 2004.
- م. عبد العزيز اليوسفي، ادارة القيمة- المفهوم و الأسلوب، 2000.
- هبة محمد جمعة، "هندسة القيمة و التصميم المعماري"، رسالة ماجستير، كلية الهندسة جامعة القاهرة، 2010.

جامعة عين شمس
كلية الهندسة
قسم الهندسة المعمارية

تكامل الهندسة القيمية في تصميم المباني الذكية

رسالة مقدمة الى كلية الهندسة – جامعة عين شمس
كجزء من متطلبات الحصول على درجة الماجستير في الهندسة المعمارية

إعداد
م/ أرميا إيليا نصحي
بكالوريوس الهندسة المعمارية – جامعة عين شمس 2004

تحت إشراف

الأستاذ الدكتور / حنان مصطفي كمال صبري
أستاذ العمارة - كلية الهندسة - جامعة عين شمس

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القـــــاهرة ، مصــــر
2012

جامعة عين شمس
كلية الهندسة
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تكامل الهندسة القيمية في تصميم المباني الذكية

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المقدمة

إن التطور السريع المتلاحق لثورة المعلومات والتكنولوجيا يؤثر تأثيراً ملحوظاً على الحياة اليومية فى كافة جوانبها، وكان لهذه الثورة تأثيرها الواضح على نظم الإنشاء ومواد البناء الذى نتج عنهما تحول فى المبانى من مبانى تقليدية إلى مبانى ذكية .

المباني الذكية لها أسس ومبادئ ترتبط إرتباطاً وثيقا بنظم إدارة المبني التي تمـد المبنـي بالحيوية و الفعالية والتحكم في حركاتها الآلية بغرض دعم وظائفه وأنشطته. بجانب ضروره المحافظة على الطاقة و توجيهها ناحية الاستفادة من مصادر الطاقة المتجدده، حققت المباني الذكية هذه التوجيهات من خلال أنظمتها الذكية، مع الأخذ في الاعتبار التكلفة الباهظه لهذا النوع من المباني نظراً للتقنيات و الأنظمه الحديثة المستخدمه بها و التى تهدف للتوفير على المدى البعيد.

يوجد اهتمام في الأونة الاخيرة بعلم ادارة المشروعات بما يسمي بالهندسة القيمية، فهى عملية فريدة و ثورة شاملة تسعى للتقليل من التكلفة الكلية للمبني مع الحفاظ علي جودة و أداء الوظيفة على أكمل وجه، ويمكن تطبيق مفهوم الهندسة القيمية في شتي المجالات باستراتيجيات تمكنها من احداث تغيرات ملحوظة في مختلف مراحل المشروع بدءً من مرحلة التصميم حتى الصيانة والتشغيل، و ذلك لان منهجية الهندسة القيمية لا تتضمن فقط التكلفة المبدئية للمشروع بل بالأكثر التكلفة الكلية للمبنى على مدى عمره الافتراضي. إن كلاً من المباني الذكية و الهندسة القيمية يهدفان لتحسين كفاءة و أداء المبنى مع الاهتمام بتكلفته الكلية على مدى عمره الافتراضي.

تناولت الابحاث السابقة الهندسة القيمية في مجال التصميم و التنفيذ للمشروعات، كما تناولت أبحاث أخرى المباني الذكية بمختلف عناصرها المعمارية وتقنياتها و أنظمتها، أمـا هذا البحث فبمثابة حلقة الوصل، فيتناول فكر و منهجية الهندسة القيمية للاستفادة منها فى تصميم المبانى الذكية بتكلفة مرضية للمستثمر.

مشكـــــل البحث

لا يوجد ربط واضح بين استراتيجيات الهندسة القيمية والفكر التصميمى للمبانى الذكية فى حين اتفقا كليهما فى رفع كفاءة المبنى والتقليل من التكلفة الكلية.

هدف البحث

يهدف البحث إلى تحديد العناصر المعمارية التى تحقق التكامل بين مفهوم الهندسة القيمية فى تصميم المبانى الذكية.

ويتحقق هذا الهدف من خلال الأهداف فى الثانوية الآتية:

- التعريف باستراتيجيات الهندسة القيمية ومجالات تطبيقها.
- تحديد الأسس والمعايير الخاصة بحسابات التكلفة الكلية للمبنى.
- دراسة المعايير التصميمية للمبانى الذكية من منظور إقتصادى.
- دراسة تحليلية لأربعة أمثلة تطبيقية بهدف معرفة الآتى:
  - معرفة اساليب تطبيق الهندسة القيمية ودراسة نتائجها فى تحسين التكلفة الكلية للمبنى.
  - تحديد الأسلوب والنتائج لتطبيق الهندسة القيمية فى التكلفة الكلية للمبنى.
  - معرفة النتائج المترتبة غلى تطبيق التقنيات الذكية على التكلفة الكلية للمبانى الذكية.
- استنتاج العلاقة لتكامل الهندسة القيمية مفهوم المبانى الذكية.

مجال ومحددات البحث

- **مجال البحث:**

1. دراسة العناصر المعمارية التى تحقق تكامل الهندسة القيمية فى المبانى الذكية.
2. دراسة وتحليل عينات الدراسة للمبانى الذكية حيث يتوفر العديد من السمات والأنظمة الذكية ولكن تم تطبيق و دراسة الهندسة القيمية علي عناصر الواجهات فقط.

- **محددات البحث:**

1. تختص الدراسة بمراحل التصميم فقط وليس اثناء أو بعد التنفيذ.
2. لا يؤخذ فى الإعتبار الوظيفة او استخدام لعينات الدراسة و لكن تم التركيز على المباني العامة.

فرضيـــة البحث

يفترض البحث أن إقتراح قائمة مرجعية للهندسة القيمية في تصميم المبانى الذكية سيرفع من قيمة المبنى وأدائه مع تحسين التكلفة الكلية للمبنى.

منهجية البحث

تعتمد الدراسة على أساليب منهج البحث العلمى لتحقيق أهداف الدراسة وإثبات فرضية البحث. ويعتمد ذلك على ثلاثة مداخل:

المدخل النظرى:

يستخدم فى دراسة الهندسة القيمية وتعريفها وشرحها وتوضيح المراحل الختلفة لدراستها واستراتيجيتها ومجال تطبيقها وكذلك دراسة التكلفة الكلية للمبانى وطرق حسابها وتطبيقاتها وعلاقتها بالهندسة القيمية كما يستخدم هذا المدخل فى دراسة المبانى الذكية وسماتها ومعاييرها التصميمية وذلك من منظور اقتصادى.

المدخل التحليلى:

يستخدم هذا المدخل فى تحليل مجموعتين من الامثلة كالتالي :

– أمثلة لمباني قامت بتطبيق الهندسة القيمية في المراحل الأولية لتصميمها وذلك بغرض دراسة وتحليل النتائج المترتبة على تطبيق الهندسة القيمية في تاثيرها على التكلفة الكلية للمبنى.

– أمثلة محلية لمباني ذكية وتقيمهم طبقا لمعايير تصميم المبانى الذكية , وتطبق منهجية الهندسة القيمية باقتراح بدائل ذكية للعناصر المعمارية بالواجهات ودراستها وتحليلها وذلك بغرض معرفة تأثيرها على التكلفة الكلية للمبنى

المدخل الاستنباطي:

يستخدم هذا المدخل لربط النتائج المستخلصة من تحليل الأمثلة السابقة للوصول الى النتائج واقتراح قائمة مرجعية لتكامل الهندسة القيميه فى المبانى الذكية

محتويات البحث

الباب الأول : الهندسة القيمية والتكلفة الكلية للمبنى

هذا الباب يقوم بدراسة الهندسة القيمية وتعريفها وتحديد أهدافها وطرق تطبيقها واستراجياتها كما يتناول الباب دراسة تفصيلية لأحد تقنيات الهندسة القيمية وهى تقنية حساب التكلفة الكلية للمبنى خلال عمره الافتراضي كذلك طريقة حسابها ومنهجيتها .

الباب الثاني : المنظور الإقتصادي للمبانى الذكية

هذا الباب يقوم بدراسة المباني الذكية وتطورها تاريخياً وتعريفها وتحليل العناصر المكونة لها ومعايير تصميم المبنى الذكى ومدى احتياج السوق لهذه النوعية من المباني مع ذكر أسباب ارتفاع التكلفة المبدئية للمبنى الذكي وانخفاض التكلفة الكلية على مدى عمره الافتراضي , وفى نهاية هذا الباب يتم تنظيم المعلومات الخاصة بعناصر المبنى الذكى عن طريق جدول يحتوى على جميع هذه العناصر

الباب الثالث : أمثلة لتطبيقات الهندسة القيمية

هذا الباب يقوم بعرض وتحليل لمستندات دراسة الهندسة القيميه لمشروعيين بهدف عرض طرق تطبيق تقنيات الهندسة القيمية مع التركيز على العناصر المعمارية التى أثرت دراستها على التكلفة الكلية للمشروع وينتهى هذا الباب بتحليل مقارن للمثالين

الباب الرابع : دراسة حالة – تطبيقات الهندسة القيمية للمبانى الذكية

هذا الباب يقوم بدراسة تحليلية لأمثلة محليه لمباني ذكية فى مصر وتقنيتها بناء على المعايير التصميمية للمبانى الذكية وعمل دراسة قيمية للعناصر المعمارية للواجهات مع دراسة مدى تاثير إستخدام التقنيات الذكية على التكلفة المبدئية والكلية للمبنى

النتائج والتوصيات :

هذا الباب يعرض النتائج التى تم استنباطها من الدراسة النظرية والتحليليه السابقه وعمل مقترح لـــ " قائمة مرجعية لتكامل الهندسة القيمية في المبانى الذكية " كما يقترح بعض التوصيات للأبحاث المستقبلية فى هذا المجال.