Using BIM for Sustainable Design and Construction Management

Master thesis

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Topic: "Using BIM for Sustainable Design and Construction Management"

Summary

This research will discuss the use of BIM for Sustainable Design and Construction Management which combines both Building Information Modeling (BIM) and concepts on Sustainable Design and Construction Management process to increase the advantages.

In reality, sustainable design and construction control technique is almost nearly as same as new production beginning from idea, feasibility, programming, initial research, making plans, initial and investigation layout, production, handing over, operation, and ending with demolition or maintenance of the construction. However, in the protection process preliminary investigation is the most crucial component due to fact that different essential parts are designed according to this part. Usually research procedure is completed with a purpose to acquire the required documentation for the final purposes. But for sustainable layout there are a few elements that during the design stages we should take them in to account which include electricity efficiency, environmental issues and etc.

BIM is a widespread system for reconnaissance of tasks' traits earlier the production. The usage of BIM assists proprietors, engineers, architects and contractors to generate a common platform to explore all the components, test the characteristics and overall performance for the alternation and correction before the construction.

Introduction

By means of growing the value of energy concerning finance and environmental price, consequently gave a motivate and argumentum to this enterprise to searching out sustainable constructing device's and equipment along with BIM with minimum effect on surroundings resource and construction field, sincerely in a few nations became a rule and is kind of building code for architects and architects to take gain of BIM for electricity requirement in their design building manner to have sustainable constructing.

In traditional strategies for planning in creation CAD turned into used, however to have sustainable design is required to have potentially made selection before pre-construction tiers, however in vintage approach there weren't such tools to make selection regarding energy evaluation and overall performance, it is placed after architectural layout plans immediately is going for next step production documents, there was a lacking factor in that procedure the combination of design and constructions tactics. As a result of that we'd have inadequate method in the manner of taking impact on a beyond method, so that it will attain a high overall performance building in earlier than creation stage, we need to a great volume information thorough information of a topic or subjects of building materials, feature of technical component, through BIM allow us to access to multi concerning subject information just in via one model. It's an extensive possibility to have some kind benchmark and measures for sustainable overall performance and evaluation with the aid of using BIM via design procedure.

Sustainable layout became most objective in production enterprise than ever, however by way of the use of BIM became simpler concerning simulation and constructing analysis even for electricity overall performance analysis, energy performance evaluation. Through the usage of BIM tools, software program permits architects and engineers to have perception digital version of building performance in preconstruction levels. power efficiency designing and building aid efficiency in a few countries is obligatory specifically in locations that strength is highly-priced, as a result constantly proprietors searching out kind of layout that is more price powerful for operation as an instance the buildings which have green certificate like LEED has cost for rent and in marketplace due to the fact operation value in less and building fee is growing due to LEED. The nearly software program of analysis is quite complicated that's why to require specific kind of schooling in any other case may want to pass off that sustainable analysis modified to unsustainable evaluation, sustainable evaluation equipment furnishes get entry to large records and records in this because has the functionality to be rapid and with excessive accuracy to evaluation. That's why most creation industries searching out the best way to mix the BIM generation with sustainable evaluation and design gear to improve comparing and integrate numerous alternatives for comparison at the identical time in this situation might plenty simpler to discover the great design selection.

Basically, the most important gain of BIM for sustainable analysis is to provide a version in three-D geometric to evaluation and evaluation the vital standards of building inclusive of daytime, thermal, airflow, and many others. Definitely, sustainable design analysis based on lots of factors for as a substitute power saving, water saving, materials, and so forth. This factors have encouraged in the course of design process by means of architects' engineers of structural, mechanical a majority of these come in one virtual three-D model and could analysis it for specific conditions in just one version and this way make it easy for design crew to comprehend to have sustainable analysis and optimize the time and much less paintings through analysis manner and have higher result in line with the favorer of inhabitants and their wishes and be extra performance.

Objective

The goals of this take a look at are to analyze and find out the blessings of the usage of BIM building statistics Modeling at hand over the initiatives regarding Sustainable design and construction management even as by using the use of BIM tools to enhance area control and sustainability, primary cause turned into to discover and emphasize the possibilities points and make them more clear for customers to rising up the cost of Sustainable design and creation management in actual system.

Methodology

There are massive limitations concerning studies goal fulfilment. The largest cause of this methodology intend to proven the studies method which trying to satisfy the sophisticated research on boundaries which apposite to the transport system for sustainably layout and construction management, however, comparison specific solutions and locate gain and disadvantage of each and to utilizing the strategies has been taken to account at some stages in studies particularly by going through distinct case take a look at for one-of-a-kind advocate as a way to explore nice tips for penetrating via the sustainable design and production market.

The expression of Sustainability in construction field can be described as innovation and reliable management for building up a sufficient and non-sick environment respecting resource efficiency, healthy and ecological aspects:

- Resource efficiency concept in all aspects
- Improvement in Energy efficiency also reducing greenhouse gas (GHG)
- Impediment of pollution such as indoor air quality controlling
- Adaptability with surrounding environment
- Systematic and combine different approaches and ideas for better environment management model.

Questions to be answered for this research are:

1. What is the benefits of using BIM for Sustainable Design and Construction Management?
2. How Building Information Modeling can help in Support of Sustainable Design and Construction?
3. What type of barriers will we encounter while using BIM for Sustainable Design and Construction Management?
4. What type of software might be needed in this process?
5. Does BIM help us more than other methods in sustainable design and construction, if yes, how?

Timescales

Date	Planned schedule
24th April, 2017	Submission of the conceptual formulation
30th May, 2017	Start reading the literature
2nd September, 2017	Surveying data (first draft)
1st November, 2017	Collecting data
15th January, 2018	Data analysis (second draft)
15th May, 2018	(final draft)

Resources

Using different software for getting the best result in my thesis. After collecting information by surveying the construction industries, I will ask some companies which I asked my questions related to my thesis before to continue my research there…

Helsinki Metropolia University of Applied Sciences

Jalal Hamidi - ConREM 2016

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Supervisor's signature

Student's signature

Abstract

In recent years, there has been a growing trend in the construction industry, which has had a profound impact on the use of more detailed data on construction design. The use of these detailed data is required in the design of construction details before the overall design process. Building information modelling has emerged as a building design process to meet this need. This research discussed the use of BIM for Sustainable Design and Construction Management which combines both Building Information Modelling and concepts on Sustainable Design and Construction Management process in order to increase the advantages. To achieve this purpose, a questionnaire was designed based on the PMBOOK standard, which has 6 sections, these sections are completed by 44 experts. Risks in this questionnaire were as threats that increases the time and cost of the project. The main criteria are as follows: technical and technological, easier access to information and required materials, construction, economic and financial, administrative and organizational, socio-cultural. The result showed that the lack of structure and performance of the project team, along with the definition of BIM and its output measurements is the most influential factor that needs to be addressed.

Keywords: Building Information Modelling, Sustainable Design, Construction Management, BIM.

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List of Abbreviations

3D	3-Dimensional
AHP	Analytical Hierarchy Process
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Method
CAD	Computer-Aided Design
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CI	Consistency Index
ELECTRE	ELimination Et Choix Traduisant la REalité
FAHP	Fuzzy Analytical Hierarchy Process
FM	Facility Management
GIS	Geographic Information System
GPS	Global Positioning System
ICT	Information and Communication Technology
IPD	Integrated Project Delivery
I.R	Inconsistency Ratio
LEED	Leadership in Energy and Environmental Design
LOD	Level Of Detail
MADM	Multiple Attribute Decision Making
MCDM	Multiple Criteria Decision Making
RFID	Radio Frequency Identification
SAW	Simple Additive Weighted
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
UNSCO	United Nations Special Coordinator for the Middle East Peace Process
WSV	Weighted Sum Vector

List of Symbols

j	Number of sub-questions in the questionnaire
S_i^2	Sub-test variance
S^2	Total test variance
n	sample size
N	size of the society
Z	The normal variable value of the standard unit
P	The value of the attribute rate in the community
q	Percentage of people who do not have that attribute in society
d	The allowed error value

Chapter One

1 Introduction

1.1 Background of the Study

Building information modelling (BIM) is a kind of process which used of a software for creating a virtual model of a building space and in fact, it is a visual display from the main database included some data in the field of construction and also about spaces of a building. This main file recognized as a model which can be applied by users and its geometry is updated with all planes, sections, views and three-dimensional images. The tools for building data modelling such as Revit, ArchiCAD, Navisworks are a subset of parametric software in which some multi-dimensional or mathematical variables which called parameter that used for different purposes and features like space numbering and components geometry. There is much parametrical software which used for some forms derived from complex curved surfaces or patterns, but their main difference with building information modelling is in the information. In BIM, each wall, door, window and even fix instruments have their last information about features, place and specification size (Krygiel & Nies, 2008). The building informational modelling defined by international standards as a digital representation of the physical and functional characteristics of the components that make up the basis for decision making (Mekawy, 2013), BIM recognized by the parametrical software and included parametrical components which display structural elements (Azhar, 2011). These components include geometric or non-geometric features with functional, topological or conceptual information (Holness, 2008).

In recent decades, there has been an increasing tendency in the construction industry to the use of building information modelling due to the great benefits and resource storage during the design, planning and construction of new buildings (Holness, 2008). The development of 3D modelling in the 1970s began in many industries. While many industries developed their analytical tools and parametrical modelling based on BIM ideas (The construction section is limited to the use of two-dimensional maps) (Mekawy, 2013). The building informational modelling was introduced in early 2000 in pilot projects to support architectural and engineering designs (Stadel, et al., 2011). Subsequently, major research focused on improving and developing early planning and design, identifying errors, illustrating, quantifying, costing and managing data

(Mekawy, 2013). Using special design tools, architects and engineers turned to basic functions such as energy analysis, structural analysis, following of scheduling and workshop safety.

1.2 Statement of the Problem

The BIM application focuses on pre-design, plan, construction, and integrated management of construction and infrastructure projects, while recent research has focused more on the maintenance of the life cycle of the project and, in fact, on the late stages of the lifecycle rather than on initial stages (Autodesk, 2011). Buildings and structures are different according to the type of use (commercial, residential, infrastructure, health care), (based on age) new, in use, old (and in terms of ownership), personal, collaborative, and academic. These different frameworks have an effect on the use of BIM, level of detail (LoD), and support functions with respect to design, construction, maintenance and with taking into account the requirements of the stakeholders.

According to the recent studies, BIM is appropriate for big and complicated buildings and are used in commercial, residential, treatment, educational projects and another kind of buildings (Youngsoo. & Mihoo, 2011). Since building information model counted as a tool for accurate data management throughout the life cycle of the project, it is very proper to support the information in the maintenance process of the building (Mekawy, 2013).

1.3 The Objective of the Study

The aim of the present study is to analyze and find out the advantages of using BIM building statistics Modelling at hand over the plans regarding Sustainable design and construction management even by the application of BIM tools to enhance area control and sustainability.

1.4 The Significance of the Study

In the building information modelling, a virtual multi-dimensional model simulated from the building's geography, geographic information, analysis of consumption energy, properties of materials and other building elements, and the way they communicate logically together are made via collecting and processing information by software. Features of the virtual model of a building before its actual construction provides a method of performance to examine its feasibility in the real world with the ability to remove any defects during this process, which allows for the adoption of desirable, optimal and reliable decision making in sustainable design in minimizing environmental damage, providing proper resource management and building compatibility with nature. As it is deduced from the definition of the sustainable design, in fact, the modelling is an engineering method in analyzing data in the field of different building industry such as using proper and recyclable materials in constructing, assigning the best position and how to use of sustainable energy such as solar energy, wind, …etc. the correct resources management and eventually they are adopting with the environment will be included in this area which in the field of using of them in construing, while bringing the least damage to the environment, provide the required technical and engineering needs at minimum cost from the recurrent resources (Middlebrooks, 2006).

General knowledge of misusing effects of buildings and infrastructure on the environment increased the need to accept the sustainable designs with the help of construction industry professionals. In fact, the sustainable design is a considerable process that within the industry formwork helps to change a process which needs a continuous workflow with a greater amount of information that obtained at the beginning of the design. Since building modelling creates an interconnected design workflow, in which the design and analysis are interrelated, and software also facilitates this change. As software applications become more popular in modelling the building and in the construction industry, the designs and precious structural results are sustainable and predictable, as it leads to cost-effective design and delivery of solid buildings and natural resources protective and reduces carbon track in our construction environment (Middlebrooks, 2006).

1.5 Research Questions

Questions to be answered for this research are:

1. What are the benefits of using BIM for Sustainable Design and Construction Management?

2. How can Building Information Modelling help in Support of Sustainable Design and Construction?
3. What type of barriers will we encounter while using BIM for Sustainable Design and Construction Management?
4. What type of software might be needed in this process?
5. How much does it cost to implement BIM for sustainable design?
6. Does BIM help us more than other methods of sustainable design and construction, if yes, how?

Change in one question: At one of the consultation session in August with Professor Bunte as my first supervisor, we have decided to delete the question number five (How much does it cost to implement BIM for sustainable design?) because it is far from our objectives which we are talking about in this thesis and it needs different effort in comparison with the current research.

1.6 Definition of Key Terms

1.6.1 Building Information Modelling (BIM)

Building information modelling is used as a method for project and construction management. The use of this method has led to the implementation of construction projects and the ability to predict results more efficiently and improvement. At the same time, building modelling improves interaction and collaboration between members of the team, resulting in increased efficiency, cost-effectiveness, better management of time and more efficient customer relationships. However, along with the benefits of using this method, legal issues such as information ownership and risk management should be considered. These issues are explained in the agreement between the parties (Azhar, et al., 2007).

1.6.2 Sustainable Design

Sustainable design was used at the early 1970s in the field of environment and development. In fact, sustainable design is a process that will provide a desirable future for human societies in which life situation and resources usage meets human requirements with no harm to integration, beauty and stability of critical systems (Rahbarian Yazdi, et al., 2016).

1.6.3 Construction Management

Construction management might be regarded as well-designed and extensively confirmed for building cost management (Barrie & Paulson, 1984). Efficient, constantly control is the main demand for following and managing expenses, time, and quality on a building plan. Project monitoring makes sure of development by measuring real accomplishment of work and contrasting it to the planned activity.

Chapter Two

2 Review of the Related Literature

2.1 Introduction

Global awareness of buildings effect and in frustration on environment increases needs to focus on construction designs based on the sustainable development. In this process, the sustainable design is the most important issue. The building information modelling is an effective tool in this process which caused many proper analyses done for better design and correctly form a relationship between analyzing and design process. Designs based on this method make the work more accurate and at the same time compatible with the environment. Reducing cost related to health promotion in the building is also counted as another effect of using this method (Middlebrooks, 2006). Many comparative graphs in the field of sustainability made to help designers in using international guidelines. In these graphs, designers get some information about designing obligations based on sustainable development in countries and different areas. At the same time, Logic of the principles of the sustainable design process can be chosen an implant according to needs. Designing sustainable buildings is dependent on considering all aspects of life, which should use this information from the design stage to the construction stage, consequently, the important feature of sustainable buildings is for adopting with the needs of contemporary people. However, unlike the emphasis on the durability of sustainable buildings on theoretical foundations, in practice, the recommendations have not paid much attention to this issue. Also, there has been criticism about the sustainability of a building and the impact of sustainable designing. For instance, a 20-year-old high-performance building may have a lower sustainability rating than other buildings with lower productivity and a lifespan of 100 years. Ultimately, the concept of building sustainability can go beyond environmental issues and include other issues such as quality of life, employment conditions, dependency on foreign goods, and compliance with historical and cultural considerations (Patrick Bynum, Raja, et al., 2013).

2.2 Building Information Modelling (BIM)

Building Information Modelling (BIM) is originally an advanced method for building designing and management of planning and construction which become feasible by advancement in the technology based on computer modelling (Langdon, 2012). Generally, building information modelling (BIM) by taking advantage of technological capability of computer modelling has succeeded to display improved method for the construction designing and management of this designing and construction, along with the process which, is digital display of project information, that can to be stored and to be accessible easily by the whole people that, are sharing this project. Furthermore, building information modelling (BIM), is a three-dimensional model based on the construction components which in it the properties and behaviour of every part or section have implemented on it. The general purpose of building information modelling (BIM) is an exhibition of a common database and intelligent information which can be built up in serial and integrated, by the whole members of the designing team, and to the utmost to be used by the customer and operator on the throughout life of project (Holness, 2006).

This program additionally can to be analyzed and studied for using of its data in decision-making and for improvement of the construction process (AGC, 2005). As well-integrated building information Modelling is one great step to forward and for altering of designing teams, capabilities and the process of construction in the way of production and exchange of information on the common models of computerized ones and constructional projects. Certainly, this order can bring much more benefits, and among all the ideal concordance on the designing and subsiding of planning and likewise the orders of construction of some usage advantages of building information modelling (BIM) which can easily rest into our hands as ripped fruit. It is possible for us to generate a free and concord designing without any contrast along with the ability of construction data display in the three-dimensional model. In the other word, this program is the first-rate method of visual, for making impressive connection and formation of teamwork among the project’s interested people and customers in particular. Simply speaking, this means that we can find out the costumer’s designs more plainly and to expand the construction planning very energetically in a short time, and all of these are for this purpose that, we long for, to construct one common understanding, speedily due to subtler planning. The building information modelling (BIM) can be amplified with the production of some of the programs of four-dimensional simulation (Al Ahbabi, 2014).

The BIM can be defined as this: providing or digital displaying of the BIM characteristics, and the national committee of the US building Information modelling is a good and common information resource including information data which supposed to supply the BIM functional and physical base of a building or a reliable model for making decisions throughout the project life cycle and from the initial stages of conceptualization to the degradation stages of the various project partners in different stages of the BIM life cycle can be referred and cited to it. The main formula is for supporting and reflecting the role of participants in the project. From another insight the BIM building for entering, extraction, promotion and changing information or data in model of modelling technology via computer and management or producing building information or set of other BIM process (information model) or related to it for manufacturing or communicating and models analysis of object-oriented building which means the building components including some information which its qualifier indicates them (Lahdou & Zetterman, 2011). Auto-desk is a big and great developer of drawing or modelling software which used for creating and managing infrastructure and construction projects, economic insight and faster with less impact on the environment. Not only the BIM is not a software but also represents both software and process, honestly, the BIM is used for smart and 3D models but also it can make some significant changes to the workflow and project delivery process (Hardin & McCool, 2015). In addition, it has 3D physical nature, an array of information related to actives and some different BIM duties in manufacturing management. This information is for the entire life cycle of the project and can be included the subject following below the first steps till the end of its project (Salazar, et al., 2006).

- Stage of justification study till its conceptual design
- First and second stage of studies
- Logistic / supplies
- Creating / setting
- Installing
- Operation period and even the end of the project

Therefore if we want to describe the BIM so briefly as a short sentence it is included a producing process and building information management during its life cycle.

2.3 Design Position within Building Information Modelling

The BIM is as the main core in building products and other factors related to it such as architects, civil engineers, structures, mechanical and electrical systems, designers, design executers and finally owners as marginal elements. the users of it will be considered as they have a regular and correlation relationship with it (Ding, et al., 2014). A BIM model, in addition, to create a digital communication between various design elements, it enables the virtual design for all stakeholders to be explored in a variety of design scenarios. In this system, the three-dimensional and sometimes four-dimensional modern construction a building is as a central or main core which implements independently and other objects or components related to building such as celling, windows or doors or stair steps are as some elements depend on a building and in following its central core play their own roles. On the other side, with using this new technology. the building defined as a sum of objects with having three-dimensional capabilities. Therefore, all of this information related to a building saved as a central core which allows connecting all of the dimensions and the components of a building together. The BIM is a building project with executes a construction project in a virtual environment. with BIM technology an accurate and virtual model of a building made digitally. Information technology capabilities in digital architecture: One of the benefits of rapid information technology growing is the development of systems that can measure, evaluate and respond to changes around us. This ability to control changing has led to a change in the physical environment around us, especially the buildings in which we live or work such as smart growth building widespread changes means some buildings with communicational systems and information technology combined these facilities together to make a comfortable and integrated system with high security and benefits (as economical aspect) and eventually low cost (Ding, et al., 2014).

2.4 The Building with Digital Architecture

At the International Symposium on Architecture in 1985 (Toronto) stated that a digital building is a mixture of innovations (whether it be technological innovations or not) along with an unmanageable management that given with having these characteristics many spent investment will be returned. With this definition, the necessary for innovation and using technology reminded this subject. One of the main proposes of digital architecture is to construct many buildings that return investment and spent money on construction. Other main proposes of this matter is to fewer costs (efficiency and utility) by controller systems which should be considered. A building with using modern technology can make this kind of facility to control components and different equipment as automatically. With this definition can be shown that transferring information between controller components and controlled components in some buildings are digital (Wong & Li, 2005).

The BIM and in digital design: The process of developing and producing a computer model for simulating planning, design, construction and execution of operations is the modelling of BIM building information. A gained model by BIM is a digital data-rich, object-oriented, intelligent, and parametric model which each of its visualizations and data is tailored to meet the diverse needs of specialized users. In such a way that the user can extract and process their views and data from the BIM model and thus obtain information that is relevant for decision making and promotion for the process of providing and reviewing the facilities. The BIM and all information relevant to building included many physical features and acting to its guidelines and information related to project life cycle which makes them a series of intelligent objects, for example, an air conditioner in the BIM model has data about the amount of blasting, and the maintenance process, airflow velocity, and cleaning needs. A BIM defines and determinates the geometry of the building, spatial communication, geographic information, the amount and characteristics of building execution, cost estimates, inventory requirements and project tables. Also, this model can indicate the whole building lifecycle consequently amount and other material features can be extracted easily and simple from the BIM model and Similarly, its range and the various parts of the work can be easily re-categorized and redefined. Systems and arrangements can be indicated on a scale in association with a whole or a group of building facilities and similarly, manufacturing documents such as drawings, datasheets, pre-designed processes, and other specifications can easily be linked to each other. The requirement to follow-up by the design team is essential in order to obtain sufficient information for appropriate decision making. For example, an open-plan design provides the ability to present a plan with the maximum use of daylight. On the other phrase, the provided plan at a BIM system given to all and different dimension in a design will be considered and It is able to even consider the reflection of sunlight on a building and thus show the maximum power of the building in utilizing light and energy of the sun. Different design options in a BIM model grantee different visualization moods and time or cost quality and analyzing or design quality and energy analyzing at a building so, therefore, can be prepared these issues for a design any time you want. The BIM with digital design and providing the possibility of development or studying other design by designers in all designing steps caused to optimize the design process why not a designer can make some changes to the design of the building by reviewing different options in designing at the same time and in a single–model (Energy, 2003).

An analysis of the energy used in the design strategy of a building which is essential for implementing and consideration of measures to reduce energy consumption. Energy analytical programs are available for many years, but due to lack of adequate and accurate facilities, these software applications are rarely used in designs. Therefore, many companies use external resources such as fossil fuels in order to supply energy (in terms of time and cost), and as a result, functional energy data of the building are available only at fixed points of the project but with using and helping of the BIM software, the BIM now uses better and more accurate design information to complete the analysis, and this analysis is done at a regular interval by the designers (Energy, 2003).

The possible integration options relevant to various design options in this regard included architectural, instrumental, mechanical, electrical, etc. In a building, it is also a feature of this technology that uses engineering analytical systems these enters are able to consider different and effective options on a design because there will be considerable cost savings. The BIM application framework is based on three sections: the project management domain, stakeholders, and the design and construction phases. The BIM application is for cost management from the perspective of other stakeholders, in this case, the owner, contractor and supervisor of the owner's representatives. The BIM application area is designed to evaluate design during planning, mapping and design with other stakeholders. This matrix structure can provide an understanding of the information and location of access to them. In this framework, the BIM application in the building industry can have 6 different stages based on project management tasks that will be beneficial for the stakeholders (Energy, 2003).

2.5 CAD Design Inputs: Maintaining Original CAD Files is Very Important

The simultaneity of the BIM and CAD starting points is considered as the most accurate and effective technique to carry out it. CAD reference files can be displayed in the BIM model and placed in the appropriate layer and the visibility of the system can be provided. Designing and maintaining a complete BIM implementation plan, and incorporating it in the provision of all building information models for projects, is critical to maximizing the utility of this tool because it maintains conventional standards and facilities applying and developing the model through Multiple sides. Therefore, we can provide a framework for applying a seven-stage modelling of information. This process consists of a preliminary data analysis and a data gathering step for designing the basic model, which comes to be designed and executed after five replicated steps. This framework is designed to match the model with flexibility so as to meet the changing needs of building operational groups (McArthur, 2015). The processes used in repetitions of the model, which have been fully implemented so far, successfully overcome the previous challenges. Moreover, the format of data entry (RRDS format) facilitates energy sustainability and allows for an assessment of energy promotion before completing the perfect building model. This will enable the application of BIM models in an efficient and up-to-date manner to enhance sustainability.

2.6 Differences Between Autocad and BIM Maps

Moving from the current state of the preparation and modelling of building maps in AutoCAD software to the point where the maps are prepared and designed in Building Information Modelling (BIM) applications is not just a change, but also revolutionary transformation because of the fundamental differences in the mechanism of these two techniques. For example, the current building maps are two-dimensional maps, so contractors are constantly having difficulty understanding the three-dimensional demands of architects on a two-dimensional map which is time-consuming and costly to solve. In BIM maps, the designs are three-dimensional, thus eliminating any misunderstanding of the requirements of consultants by the contractors. In BIM, a change is automatically affecting all maps and any spatial overlapping due to the different definition of elements in the system is alerted. This allows us to make sure of the accuracy of the maps to the extent that it can provide us with pre-fabrication in many parts. In AutoCAD mapping, to make changes, each map must be updated and no alert is given because of spatial overlapping. Another difference is in the modelling of building information. The databases that exist in BIM applications are building information. Each component in the BIM model contains a variety of information on the procurement of materials, the price and location of their purchase, and how they are installed and implemented, as well as their maintenance requirements (Matta, 2005).

2.7 The Literature of Building Information Modelling

In this section, a brief review in the field of this current study has been provided about the information modelling system and understanding its positive or negative effects or its impact on improving industry productivity. The three-dimensional and four-dimensional BIM modelling and with establishing a relationship between structural engineer and architect of the CAD process altered by changing the two-dimensional modelling, the overall design process of the building. Not only this subject has altered design and visualization of buildings, but also it caused some changing in designer and architectural thinking and even his visualization of the pure and impersonal design of buildings has led to their meaningful simulation (Smyth, 2005). The building information modelling for designing an optimal and sustainable performance of building projects have been altered the construction industry more than 14 years such as increasing production and productivity, in frustration sustainability, quality, reduction of recycling and repeating costs in building industry. The creation of this industry has emerged through effective collaboration and communication between stakeholders in projects and with the use of this new technology. This significant strategy in the building industry is being tracked especially in EU and American countries with increasing and growing popularity, it is being pursued and continues to survive (McCullough, et al., 2005). On the other side, The BIM introduced as an elixir for tackling interdisciplinary inefficiencies in construction projects by some main activists in constructing industry.it is also a movement, dynamic, developing this idea or a tendency which is causing to increase the designer and architect requirements they have to be more careful in preparing information for building data modelling. Furthermore, a created design of a building by information modelling system has a significant advantage in the field of helping to the project management which made by design engineers and project executives and to BIM building can be presented this significant advantage as following below (Kymmell, 2007).

2.8 Benefits of BIM

1- Helps the client to test project feasibility

The first benefit of BIM is in the project feasibility phase where the client needs to estimate the time and cost of the project to know if the project is affordable. Due to the high precision required in the estimation of materials, time, labour force and machinery, BIM can provide a near realistic estimate of the time and cost of carrying out a project (Abbasnejad, 2013).

2- Joint with Integrated Project Delivery method

When Integrated Project Delivery (IPD) is used for the project, the BIM is introduced to the project team from the very beginning and will help improve the understanding of the needs of all stakeholders involved in the project implementation. The principles of BIM and IPD are to ensure the integrity and effective collaboration in all stages of design/build (Handler, 2010).

3- More realistic and faster visualization of the project

Since the design is modelled in a parametric and three-dimensional fashion, and according to the advantages of BIM applications mentioned above, the built models have high similarity to the real buildings. Also, its accurate estimates can speed up the evaluations of designers from different concepts. With the appropriate assessments of different initial designs and ideas, the best possible idea consistent with all the desired aspects can be selected and also the selected idea can be improved with the necessary changes (Karimi Aflak, 2013).

4- Modifying errors at the initial levels and preventing the occurrence of a problem

The BIM, by finding overlapping or non-compliance in the plan, prevents the non-buildability of building plans informed by consultants to the contractors. This advantage also has other benefits such as reduced construction time (finishing work at the scheduled time) and reduced production costs. In addition, in most cases, at the end of the works which need changes in the plans, there are disputes and quarrels between consultants and contractors; preventing the creation of map change needs also prevents these quarrels (Eastman, et al., 2009).

5- *Improving the quality of construction by contemplating several design aspects*

In designing by BIM applications, all working groups including architects, structural engineers, mechanical engineers, facilities, etc., are present and express the idea of raising the quality of the project. By integrating all the ideas, the constructed building will have a good performance in terms of all aspects of creative, structural, functional, lighting, energy, operation and etc (Azhar, et al., 2007).

6- *Better evaluation and control of costs during design and implementation*

BIM tools can accurately estimate the cost of the project by estimating the exact amount of consumed materials, the required machinery, and the amount of labour (in projects that do not have complexity), along with entering the market-based unit prices into the application. They can also, by applying the changes at the same time, change the price. In addition, by adding a time and cost dimension and having a five-dimensional model, the cost curve can be plotted with greater precision throughout the life cycle of the project in order to know what costs we have to pay each week. This helps in a better financial planning for the project (IMS, 2011).

7- *Improving the energy efficiency of buildings to become sustainable buildings*

Energy costs during the construction are the biggest costs that are imposed on a building (Faraji & Golabchi, 2009). Therefore, it is imperative that, for new constructions, the topic of energy and sustainable building be considered as design priorities. BIM applications with the ability to link with energy analysis tools can positively perform energy control and compliance with its rules, in order to control and remind the needs, imperfections and the essential requirements for achieving these goals at the beginning.

8- *More benefit from industrial construction (prefabrication)*

One of the most important advantages of using BIM technique is to achieve the lowest error rate and the highest accuracy in providing "workshop maps". This advantage from another perspective brings about a great benefit: "industrial and prefabricated building construction". By knowing the most precise dimensions and properties of building materials and components, they can be produced at the factory and installed at the building site, and not worried that, for example, the length of a beam was 2 cm shorter than the required size (Khanzode & Reed, 2005). Pre-fabrication, has a number of advantages such as reducing construction time due to mass production of the plant, reducing waste of materials and manufacturing costs, the use of pre-assembled components and weight reduction of building structures, higher resistance of the building system and thinning of the sections (Sharif, 2011).

9- Planning the equipping of the workshop

Workshop planning is one of the major issues related to project management, which will have a significant impact on the overall success of the project. With the assistance of BIM, the project manager and contractors can decide about examining the existing auxiliary equipment and offers of access routes, procedures for discharging the workshop in case of danger and safety issues, planning for digging and sparkling, positioning of cranes and forklifts, determining the location of materials and so on. To do this, there are a number of scenarios and if one of them confirms, the contractor will inform the results to project stakeholders and, if necessary, the neighbours of the project (Karimi Aflak, 2013).

2.9 BIM Applications

2.9.1 Recording and Evaluating Existing Assets of the Construction Unit

The application of the BIM for the recording and evaluation of project assets can help the employer manage costs in the life cycle of the project. If the information about assets enters in BIM, decisions about the work business and employer management will be easier to identify and the owner or employer works more efficiently (Marzouk & Abdelaty, 2012).

2.9.2 The Application of Product Changes

If the BIM combines and analyzes the architectural design with financial factors and return on capital, the employer can timely see the effects and benefits of changes in the initial design on the investment benefit (Marzouk & Abdelaty, 2012).

2.9.3 Design, Evaluation, Tender

The BIM can allow the employer to coordinate the designs made by companies and design firms with security, fire, lighting, energy issues, construction and coordination costs and to approve or reject it. After this, the employer can act confidently in a tender process that is accurate and clear (Marzouk & Abdelaty, 2012).

2.9.4 Examination and Admission of Work by BIM

The BIM can adapt materials to the design and evaluate its durability and analyze the contradictions. BIM can detect the distortion of the design of the project and what is created in the reality by its analysis. Use of three-dimensional BIM, or four-dimensional (3-dimensional plus time) and five-dimensional (3-dimensions plus time and cost) (for communicating with government investment institutions and any other party involved in the project) such as insurance and so on. It can reduce the errors and differences between them and prevent time loss (Lowe & Muncey, 2009).

2.9.5 BIM Compatibility with the GIS System

Whether people at home or in the community can use real-world methods to control their capital is another issue that is seen in the BIM. To use capital information, which will later assist in the marketing and collective use of capital and to a large extent to emergency responses, the BIM model will work with the GIS system and will provide the most optimal locations for deploying labor and stockpile equipment for project manager and designer group (Thompson & Miner, 2007).

2.9.6 Management and Maintenance of Capital

BIM includes all information required for use, maintenance, and adjustment to a project handbook, and can simultaneously provide full initial information for large changes, refinements, development, reconstruction, or destruction, and it can also simulate based on the interactive synchronization between the BIM and the training and penetration of all systems (including daily operations and exit from emergency situations), which is subject to the integrity and convergence of information units and alarm for insecure situations (Marzouk & Abdelaty, 2012).

2.9.7 Destruction Stage

The BIM has a function to simulate destruction. We cannot definitely say that our intended building will fall down after several times unsuccessful destructions. Or to be sure of it, how much of the explosives are used and in which places. If we use BIM, these problems will not happen. With the help of the BIM, it is possible to determine precisely the location of the explosives, the number of explosives can be found, and consequently, we can predict the results of the simulation of destruction correctly (Matta, 2005).

2.9.8 Design with The Program

In addition to analyzing shape, form and space; BIM can analyze energy consumption and construction costs, which makes it possible to create a more scientific program and lead to more scientific decision making (Matta, 2005).

2.9.9 Construction Design

All types of sectional plans, views, and structural reports can be obtained from the BIM model (Matta, 2005).

2.9.10 Change in Design Orientation Towards Leading Design

Today, 57% of designers work to produce building maps. BIM can help designers return to their original mission, which is merely design, with less energy to produce maps (LeBlanc, 2010).

2.9.11 Management of Construction Unit

The quantities and sizes of all details of parts and components can be obtained with the BIM model, the amount of all kind of materials can be calculated and evidence can be provided for the purchase and receive of materials (LeBlanc, 2010).

2.9.12 Location and Construction Site

Integrating and combining BIM with RFID[1] and GPS[2] technologies can help to find the optimal location of the various factors and equipment of the site, including cranes and warehouses, and so on. BIM technology requires more and more precise programming in the construction phase, such as various activities sequences, the logical order of the site, the location of cranes, cost changes, critical project path and critical points of the project. Therefore, the feasibility of the project, safety issues and other details are easily viewed and analyzed and the best and most suitable construction program is selected (Xie, et al., 2010).

2.10 Sustainable Design

These days, water crisis, soil pollution, noise pollution and other various environmental challenges counted as the main and serious crisis in the world that engineers have played important roles in this situation. In order to step forward in sustainable development way, many manufacturing industry expertise should focus on the environmental bad situation in our country to build a better future. Since, the importance of this issue is clear that based on the statistics of some advanced countries, the building industry uses almost 40% of extraction resources and 11% electricity and 11% drinking water and produced nearly 40-54% garbage. Near to 44%

[1] Radio Frequency Identification
[2] Global Positioning System

costs related to energy in developed countries (and in the field of manufacturing or process after manufacturing. Manufacturing from the aspect of greenhouse gas industry has the first rank and green buildings are a flagship of sustainable development and a balance between environmental, economic and social health issues. Green building than to industrial buildings was made over past three decades and it has less effect on the environment today's the industry language has been changed and it is used of the sustainable term for green place instead. The sustainable design is better than the green one because of sustainability which included more effects while the green one has only an effect on the environment, given two issues, three principles, for instance, people, the earth, social or economic boom this subject has the role of centralization (Krygiel & Nies, 2008).

Sustainable design as one of the different types of designing ways include some products which made by only renewable resources. Additionally, for some items or products which prepared in the sustainable design area, there is no harm to the environment during manufacturing time or serious usage. Often, these products designed to make a close relationship between the user and his natural environment. The sustainable design is called a kind of designing which has a friendly environment feature. But before we deal with sustainability issues, we have to provide some explanation about some abbreviations such as *Green* or *Sustainability*.

The Green Sustainable is an action which can be less harmful to natural resources during the manufacturing process, before and after it. In addition, during this process, materials must be useful and have a long span life, and can be reversible to the natural cycle.

Things with long span life are useful and they are the biggest obstacle to wastage and this is better than reusing or recycling them and here the concept of sustainability included: a kind of attempt to combine developing concepts in the field of environmental issues besides economic and social subjects. Therefore, this sustainability has more effects while the Green one included the effects on the natural environment. In this regard, the global commission of development and environment was established in 1983 by United Nations General Assembly and with attending 22 members from different countries (Rahbarian Yazdi, et al., 2016).

In 1987, The Brundtland commission (in UN) with the motto (our common future) defined the sustainable development as follow: removing requirements for a current generation without taking a risk for future generations to remove their own requirements (Krygiel & Nies, 2008).

The sustainable design is the result of architectural thoughtful collaboration with electrical and structural engineering in addition to some common design factors such as beauty, fit, texture, shadow, light and other facilities which should be considered in the design of buildings. The design group should notice to long-term environmental and economic and human factors and some initial principles as follows: (Migilinskas, et al., 2013)

Energy resource management, this kind of management is considerable from 2 aspects:

- Design for returning to the life cycle
- Design for human

Each of them has its own particular strategies. Knowing and studying these schemes, makes the designer and architecture understand from their environment that they should design it. A design of the building should consider the future because it is not always feasible but can be designed a building with opened-channels to the future to accept of unexpected and new technologies on the other side it should be tolerable against any environmental changes in the future. The building industry and of course the design of house and buildings have already become an abolished and hard attempting tasks and it is arriving at 11 centuries which everything in this field will be considered by a biologist and scientists or architectures and engineers not only on an empty paper but also on advanced computers and all of these conceptions can be sought in a sustainable design (Luo & Wu, 2015).

2.11 History and Approach to The Sustainable Design in The World

The sustainable design in the field of environment and development was used at the early 1970s and the root of this term also refers to the ecological development approach that has been incorporated into the World Conservation Strategy. However, its formation related to the establishment of the global independent commission in the field of environment and development and providing a report about sustainable development principles. During the 90s, several seminars performed by UNSCO[1] in order to achieve to the sustainable development and based on the contents of table 1 (about the history of the meetings of international organizations with the theme of sustainable development), the first global approaches started from 70s in the world (Mark Saunders, 2009).

Table 1- The History of the Meetings of International Organizations with the Theme of Sustainable Development [2]

Theme	Date	Expresser	Place	Explanation
The first ideas about sustainability issues	1887-1947	Aldo-Leo Pold	US	How much can the environment tolerate the effect of today's human lives and stay stable?
The first conference about the international environment	1972	United-Nations	Stockholm	The UN-conference statement in the field of human-environment - Stockholm statement with formation Rome conference Simultaneously and a report about (Economic Growth Constraints)
Sustainable development term	1987	UN	Bruntland	The report of the UN Global commission of development and environment (our common future)
Statement	1992	UN	Rio de Janeiro	Land meeting Frist document: Rio statement (27 principles) Second document: Agenda 21
Statement	1997	UN	kyoto	Kyoto contract Reduction of greenhouse Gaz emission
Statement	2002	UN	Johannesburg	Statement by the World Summit on Sustainable Development - Developing practical solutions for implementing sustainable development projects
Statement	2012	UN	Rio de Janeiro	Rio statement+20 (the future we want)

[1] United Nations Special Coordinator for the Middle East Peace Process
[2] Own search

2.12 Reasons of Sustainable Development Approach

Following a good definition of sustainability, now let us talk about its importance. There are three principles of sustainable design: people, the earth planet, economic development, considering human nature, everyone tends to value one of these three principles more than the other two. But as better as we can make a balance between these three principles, we will get a better and more logical solution (Patrick Bynum, Raja, et al., 2013).

The earth planet	People	Economic development

Figure 1- The Earth Planet, People, Economic Development [1]

Considering the growing threat of global warming, many of construction industry sections started paying attention to the need to some structures from the aspect of crater energy, although some efforts have been made to reduce energy use and carbon emissions by buildings, these efforts are still needed to maximize their potential in creating a new generation of high-performance green buildings. On a global scale, investment in sustainable development is essential to reduce the global warming potential in the construction environment. This important aspect will promote sustainable development in communities by correct applications of innovative design methods, construction and building operations. Using sustainable methods and techniques during a period of time, there will be a significant change which results in reducing environmental impacts not only within the construction environment but also on a larger environmental scale (Patrick Bynum, Raja, et al., 2013).

2.13 Sustainable Development Approach in Construction Industry

The environmental effect of building design, construction and construction industry is too much, almost 40% of total and global Co_2 emissions are related to buildings. In 2006, only the commercial building department in the USA, made more than 1 billion tons Co_2 and an increase of over 30% compared to 1990. Every day 5 billion Gallon drinking water used for toilets syphon. The earth ecological changes of the land from

[1] (Patrick Bynum, Raja, et al., 2013)

the natural state changes the diverse biological habitats to adverse environmental conditions that are free of any biodiversity. The high impact of the building environment requires measures to reduce the effect of harmful gases. Actions taken in the field of green buildings can reduce or remove these harmful and negative ecological effects as considerably while it can maintain the comfort of users (Patrick Bynum, Raja, et al., 2013).

2.14 Efficiency Factors of Sustainable Design in Building Industry

2.14.1 Geographic Recognitions

- **Climate recognition**: include the main realization related to the sun, wind, humidity, temperature, psychometric diagram and other plant and animal species and etc.
- **Location**: knowing the latitude and longitude of the project location is simple but it is very important and efficient for finding the rest of the project climate information.
- **Sun**: the solar information included 2 primary items: the main angle of the sun for the area and data of the number of rays of the sun for that area.
- **Culture recognition**: a culture should be recognized in 2 levels: social culture and culture of employer organizations.
- **Less need to consume resources**: in green structural industry, there is a common phrase related to this matter: The greenest building is a building which has never built and which means if there is no need to build a structure, do not build it.
- **Space**: the first question is: Does the employer need this space? This question should be asked in the whole scale of the project and each of its sections so that each section can be adequately dimensioned.
- **Materials**: What resources and materials are you using? And how can you gain the most efficiency from the lowest resources? (Krygiel & Nies, 2008)
- **Energy**: many systems of a building describes how to use energy. For example: if you add numbers of windows to the southern view of a building, in fact, you allow more natural light to enter to the building and consequently, more solar

heat is allowed to enter the building which it increases requirements to more air conditioning. Energy models of factors such as desired air conditioning, number of inhabitants and level of their activities, instruments, combine shadow of the sun and other factors to predict building energy demand. With adjusting purposes and reviewing more designing options related to this project, reduction and optimization can be implemented for loading energy (Krygiel & Nies, 2008).

- **Optimization:** can be observed in 3 initial areas: Lighting, heating and air conditioning, and electricity. By examining the use of energy in these three areas, a designer can explore some options for fewer energy needs (Patrick Bynum, Raja, et al., 2013). (figure 2)

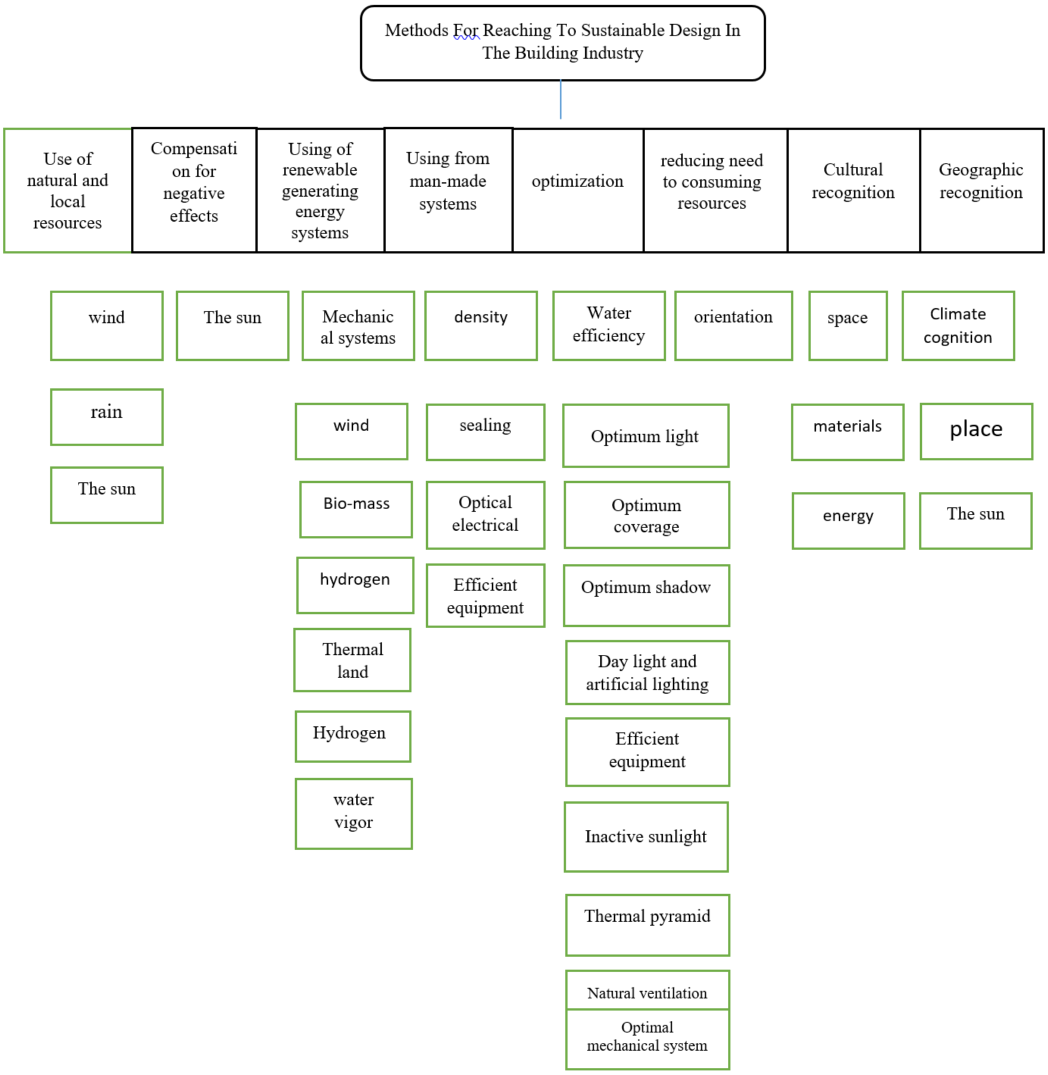


Figure 2- Methods for Reaching to Sustainable Design in the Building Industry [1]

[1] (Patrick Bynum, Raja, et al., 2013)

2.14.2 Optimization Construction

With careful examination and based on the analysis of collected data related to an important indicator of energy consumption, can optimize and reduce the building requirement to energy with different methods. There are twelve common indicators for energy saving as below:

- **The direction of building and building density**: an appropriate building direction and density allow accessing a good daylight for total residents, while the building coverage also provides a protective layer that is optimized for thermal and comfort performance. Among many design considerations, accumulation counted as one of the decisive factors (figure 3) but one of the initial concern is to select a proper mass and correct direction for a building to help reduce the energy needs of the building while simultaneously providing users with convenience (Mekawy, 2013).

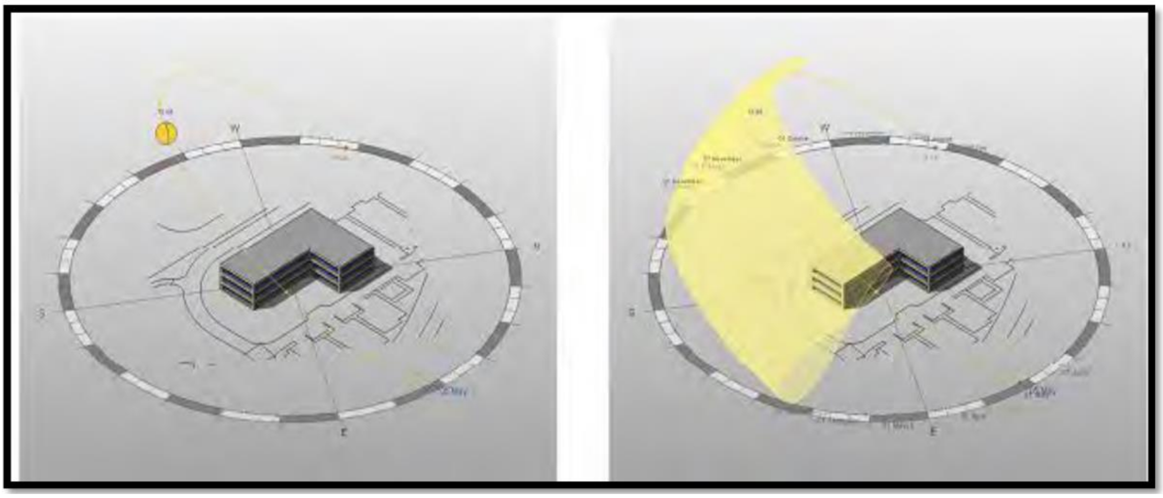


Figure 3- The Effect of Building Orientation and Sun Movement [1]

- **Optimized light**: daylight can prepare using natural light for initial lighting for the inner building. This issue reduces the requirement to artificial light at the space. Therefore, it heats the inner building and reduces using energy. In fact, natural light is a free light resource with high quality and efficiency. An effective daily lighting design relies strongly on the proper orientation of the building and accumulation (Mekawy, 2013).

[1] (Autodesk, 2011)

- **Water efficiency**: water is one of the most important resources for us. As our population grows, the available amount of water is limited, so it increases the requirement for water. Developing and reinforcing different technologies allow us not only reduce our consuming water but also make sure this vital fluid is used effectively for instance:
    - **Selecting effective equipment**: Some effective systems and equipment found for optimal use of water in the market for instance: toilets with 2 syphons.
    - **Collecting rainwater**: In fact, rainwater can be reused with little energy and simple filtering systems for irrigation purposes. It can also be reused for toilet syphon.
    - **Reusing household wastewater**: Household wastewater is shower water (bath), sinks and air conditioners (cooler) and sinks for dishwashing and etc., modifying and reusing this water can be an important strategy to reduce using water. (Mekawy, 2013)

2.14.3 Local and Free Resources

Using local and free resources or natural resources such as wind, water, energy, sun (Patrick Bynum, Raja, et al., 2013).

- **Effective use of man-made construction systems**: mechanical systems, plumbing (using water in a closed system) electrical light and efficient equipment (Patrick Bynum, Raja, et al., 2013).
- **Use of renewable energy systems**: seven renewable energy resources have been recognized such as the sun, wind, biomass, hydrogen, thermal land, ocean, water vigour (Krygiel & Nies, 2008).
- **Compensation for negative effects**: Most of the energy effects lie in design work. All of this hidden energy can be converted into carbon dioxide unit equivalent that you can compensate it with supportive plans of pollutants reduction (Krygiel & Nies, 2008).

2.15 Evaluation of the Sustainability and Durability of Buildings Based on BIM

In order to build a sustainable building, the problem of the energy consumption has always been a concerning issue for customers and designers. In this regard, the UK's national regulations on energy performance and carbon influence have led to greater coordination of building information in order to emit carbon dioxide. Therefore, customers and industry need to work together to design programs to make it possible to decrease the amount of carbon dioxide emission and entering it into the buildings. Building information modelling can play an important role, in addition to its ability to create greater convergence in the supply chain of the building. Designers usually do an investigation on energy consumption and carbon production to find out how much energy the building consumes, how much carbon dioxide emissions are projected, and whether or not the building will have an efficiency criterion. Building information modelling is applied for energy analysis, but it is mainly practical at the designing stage.

Nevertheless, for the post-residential stage, not only a proper and systematic methodology is required to control the behaviour of the building but also a critical decision is needed to ensure that an energy criterion of a precision design has been implemented in practice. Using a BIM-based perceptual model that can improve the post-residency assessment process. And meet the industry's requirements for durable buildings. One of the applications of building information modelling is to increase sustainability, (Motawaa & Carterb, 2013). According to the conducted study, construction operations allocate 40 per cent of global energy and carbon dioxide emissions. Therefore, sustainability in general, and energy efficiency, in particular, have become the main criterion for building function. And numerous programs have been applied such as being a pioneer in environmental energy and designing, environmental assessment methodology in construction research, SBTool, CASBEE[1] and the green world to approve buildings in terms of durability and durability. In England, environmental regulations for buildings have been reviewed three times over the past decade.

On the other hand, implicit implications of sustainability and durability related to the construction financial interests are also considered. Old designs of constructions and

[1] Comprehensive Assessment System for Built Environment Efficiency

operative stages have been influenced by sustainability, and especially energy consumption. Several approaches and technologies have been designed to ensure that energy saving and carbon dioxide emissions can be achieved through a sustainable design and a more optimized use of energy. On the other hand, achieving the goal of carbon dioxide emissions requires a better control of building function and the sharing of accurate information among shareholders. Among applied technologies, BIM can be referred to model energy consumption, heating flow, lighting patterns, and other sustainability and durability measures (Monirabbas, et al., 2015).

2.16 Selection of Produces Compatible with Environment Based on Modelling Data of Building Information

One of the most important uses of the BIM is the use of a backup system of decision making that makes it possible to optimize the environmental performance of the building through the process of choosing construction products compatible with the environment. Moreover, it identifies the components of the proposed system, which is realized with the technologies and available resources and shows the areas in which there is a need for development (Adamus, 2014). Three types of data modelling systems can be used to evaluate buildings from the standpoint of sustainability: BREEAM[1], LEED[2] and OPEN HOUSE.

In the LEED and BREEAM systems, the assessment methodology used does not allow to estimate how the difference between the environmental characteristics of the product and the materials influence on the final grade of the building. The Open House Methodology, which assumes some implicit implications, provides an opportunity to evaluate the impact of manufacturing and selection of materials on the ultimate degree of the building. However, this score is shown in points, not by a degree on a scale, so it is difficult to estimate the market value of improving the evaluation score. According to the facts, the evaluation methodology of Open House building as one of the methods of building information modelling seems to be the best, but it is still not an ideal solution. Priorities concerned to the costs and environmental performance of possible solutions should be received directly from the decision maker and should enable him to

[1] Building Research Establishment Environmental Assessment Method
[2] Leadership in Energy and Environmental Design

determine the extent of this benchmark in terms of interactions. The process of selecting construction materials is a difficult problem to increase the sustainability of buildings. There is no software to back up it comprehensively. Designing such a tool obtained from the data of the building information modelling will help a more successful decision-making based on knowledge. The use of BIM systems will facilitate the presentation of comprehensive information for the ones who choose creative and compatible materials with the environment (Monirabbas, et al., 2015).

2.17 Challenges of Using the Building Information Modelling in Sustainable Architecture

Four major challenges need to be removed in order to use the appropriate BIM to increase sustainability:

1. To identify the critical information needed to be aware of operational decisions.
2. Significant efforts and actions to design and modify current BIM models for buildings.
3. To manage the information transferring between simultaneous operations and monitoring systems and the BIM model.
4. To control the instability based on incomplete documentation of the building.

Researches show that BIM can be used for the most challenging construction projects and effectively improve its sustainability (McArthur, 2015).

To reduce the challenges of using BIM, the following is presented below.

Data Collection of the site: Creating RRDS and its application for collecting the data of the site allows for each group's population to be replicated quickly in the model. Combining with the general or main lines for each room is very valuable for geometric modelling and data allocation, but less efficient.

2.18 Application of Building Information Modelling in Sustainable Design

Building information modelling involves ICT[1] frameworks and technologies that can support beneficiaries' engagement, in the life cycle of projects by equipping, importing, extracting, updating or modifying information in the BIM model. BIM applications can provide more practical data and information to visualize and simulate the requirements than traditional ones. In fact, BIM changes the way of the constructed environment works. BIM studies have basically changed from the functions for storing, communicating and exchanging project-based information to analyze all of the information, data, and knowledge relevant to the life cycle of a project that is in the interest of all beneficiaries (Monirabbas, et al., 2015).

For example, to apply sustainability characteristics, a designing tool with the help of the computer is used to model the building, then the design data enters into the energy simulation tool to analyze the building's performance. Energy simulation packages such as pass energy, ecothek and IES virtual environment pays attention to the features of building design such as thermal insulation, climate reaction, glass, shadow, lighting, air compression, mechanical air conditioning, construction dynamics and thermal mass. Moreover, local climate data and desirability rate are taken into account when calculating the thermal load. The simulation engine of these packages functions based on thermodynamics considering the assumptions of annually and hourly thermal load production in the manuals graphically. In the case of any undesirable result, designers can modify design features such as window size and building direction, and examine the impact on thermal loads and energy consumption (Monirabbas, et al., 2015).

The main problem of current activities upon the coherence between these packages to avoid the entry of multiple data, as well as the examination of changes in building characteristics throughout its lifecycle is with the operational and protective activities. The data collections for analyzing energy consumption in buildings is quite complex and includes external environment data, building configuration, load equipment, mechanical lighting systems, and air distribution.

[1] Information and Communication Technology

So coherent simulation tools must be applied to predict properly the correct use of energy (Motawaa & Carterb, 2013). Designing of modelling tool of green building that combines the design model and simulation can analyze multidisciplinary information resulting in improving the analysis and decreasing control errors and information processing. The intelligent information created by the BIM model can analyze the energy of the whole building, and perform simulation and illustration of the outward. This will give the designer a direct reflection to test the design in order to improve the performance of the building throughout its life cycle. Typically, the BIM model of the building involves design features, type of building, construction materials, system types, room types, project locations, etc., which can be transformed into building simulation tools. The usual output of simulation tools includes warm/energy analysis, lighting and shadow analysis, acoustics and value/cost analysis. The data transferred from the BIM application can be formatted using IFC, aecXML, or gbXML. These are schemes designed to ensure the consonant exchange of data and to operate among different BIM applications, including the ones using to control the energy consumption such as geometric modelling, HVAC[1] design, energy analysis and equipment management (Motawaa & Carterb, 2013).

2.19 Current Problems of Using BIM for Sustainability

There are still problems with using BIM for sustainable design. For example, applying BIM for energy analysis today is based on estimated values for loads, airflow and heat transmission for simulation, which may lead to inappropriate estimates. In a sample of the building of the University Gold lead in the United States, the Ecotock Autodesk program showed a thermal load of all basic evaluations less than actual and showed brightness levels in assessments equal to 98% and more than real values. So this problem can be solved using real data derived from buildings. This is the approach taken for this research during the operational phase by integrating BIM models with building management systems that use sensor devices to obtain real data. Another problem is to circulate the data between the BIM models and the energy analysis tool. While project data can be easily transmitted from the BIM model to the energy consumption tool via IFC and gbXML, this process still has problems in the other

[1] Heating, Ventilation, and Air Conditioning

direction if there is a need to modify the building model to achieve better building performance. Manual configuration is still required in some cases. Therefore, further development is still necessary to use BIM so as to make it more durable and sustainable (Motawaa & Carterb, 2013).

2.20 Management of Resources

2.20.1 Management of Unrenewable Resources

Given the developing process, some unrenewable resources such as fossil fuels faced with serious energy crisis during past years and optimal usage from this type of vital resources increased. Because this type of energy given to the current and available resources will be finished in the future and in order to reach other available resources should follow from some serious activities.

2.20.2 Management of Renewable Resources

The best type of energy resource which can be focused on it for a sustainable design included some resources that are able to put in natural and returnable cycles. In this kind of resources management which always attempted to keep a balance between produced effects and environment around for making a kind of relationship between these subjects in a returnable cycle, in this design used of some available and natural resources such as wind, sun, rain and we will always have more economic project (Krygiel & Nies, 2008).

2.20.3 Designing with Returnable Features to Life Cycle

The plan emphasizes the adoption of a way to recycle and reuse existing resources. In fact, at this stage, the designer of his own mind must realize that the resources used in the design can return to the main cycle of nature after the stage of decline and dislocation which means our resources turned from one and useful shape to another shape but again after this changing they are efficient and reusable.

2.21 Time Schedule and Sequence of Construction Operations with the Help of the 4-D Model

Planning and scheduling of construction operations are one of the most important aspects of construction management. These efforts continue during the construction process and are constantly monitored so that the project does not exit from the right path. By adding scheduling data to the 3D building information model, the fourth dimension means time is added to it. The fourth dimension of the model helps stakeholders of the project to be able to visualize the timetable and actually understand how much the proper sequence of construction operations is effective in the success of the project. A four-dimensional timetable is a powerful tool for staging, coordinating the scheduled operations with subcontractors, designers, employers, and other project stakeholders. Determining the BIM timetable schedule will optimize the sequence of building operations and managing project logistics (Karimi Aflak, 2013).

2.22 Effective Communication Between Different Project Stakeholders

Due to the type of collaboration and the integrated implementation of the work that starts from the design stage, all stakeholders, including the various engineering and workgroups that are responsible for the implementation of different parts of the project, from the very first stage of design, they will go through the process of progress and will announce and apply their comments and requests at the same stage. In addition, by creating a single database for the project, stakeholders will be more likely to be able to access their relevant and required information. All of these factors make the relationship between stakeholders more effective than before and see its positive effects on the working relationship and the outcome of the project (Karimi Aflak, 2013).

2.22.1 Ease of Use and Facility Management

With the help of the BIM, the end users of the building can see the final product of the design phase and, as far as possible, announce their opinions for the better use of the building, but pass this step and reach to the exploitation phase. The facility management (FM) of the building, having a proper database of how to build and how all parts and equipment work, manufacturers and supporters of parts and equipment, etc. can do their best. Exploitation in buildings built with BIM will be much simpler and more desirable (Hammond, 2007).

2.22.2 Ownership and Legal Rights of Information in BIM

The first legal risk is to determine ownership of BIM data and how to protect it against copyright law and other laws. For example, if an employer has paid for a design, he will be the owner; on the other hand, if the team members have entered their proprietary information for use in the project, they should regularly support this information, so there is no simple answer to the ownership of this data. This means that a unique response will be found in each project, depending on the circumstances and the needs of the internal stakeholders. The effort is to prevent people from being discouraged from using BIM and taking advantage of its potential benefits by creating appropriate solutions (Thompson, 2001).

When other project team members, other than employer, designer and contractor, contribute to the production and provision of information, issues such as the issuance of permissions for use and ownership occurs. For example, often, vendors of materials and equipment, along with their products, offer plans for using those products, hoping to help them sell their goods more easily. This method can help sell their products, but instead, if the vendor design is provided by an unlicensed designer, there will be problems with licensing (Thompson & Miner, 2007).

2.22.3 Responsibility for The Correctness of Input Information and Necessary Controls

Another important issue to be addressed is who controls the entry of data to this system, and who is responsible for data integrity? Accepting responsibility at BIM and ensuring their integrity is a very high risk. The application of complex compensation by BIM users and the provision of limited warranties and disclaimers by designers are among the essential requirements for negotiation that must be resolved before using the BIM. In addition, more time is needed to import information into this model, which is a new cost in the design and management process of the project. So, before using BIM technology, we must not only identify the risks and risks but also have to calculate the costs and pay for it (Thompson, 2001).

The concept of integration in BIM makes the level of responsibility of various people involved in the project unclear and increases its risks. Consider a scenario in which the employer and owner of the BIM request explanation about a design mistake. The architect, engineer, and other people are looking at each other and trying to figure out who was responsible for the mistake. In this case, if there is no agreement, all the faults cannot be attributed to the leader of the group and the project manager, and on the other hand, it is hard to prove who is responsible for it (Eastman, et al., 2009).

As in the BIM, the dimensions of time and cost are layered, the responsibility for an appropriate technology to deal with different applications creates another problem. Many sophisticated construction teams need to use subcontractors to provide a timetable in detail, along with the cost of each part of the work prior to the start of the project. The main contractor then collects the information in different sections and provides a comprehensively detailed timetable along with the cost of each section of the entire project. Subsequently, subcontractors use the same program and by integrating their information, information integration is created. In cases where data is incomplete or various timing and costing programs are provided, a member of the team -usually the main contractor or project manager- must approve and update the program. The generated program can be a BIM model or another program integrated with the 3D model. It should be noted that the responsibility for the correctness and coordination of the time and cost schedule data should be seen in the contracts. Now often these project management tools and 3D models are rapidly developing (Eastman, et al., 2009).

2.22.4 The Lack of Clarity of the Work Area of Individuals

Doing tasks in a collaborative and integrative way increases the knowledge of each workgroup over its general work, but it can also be a major problem, and it is the interference and lack of clarity of the work areas of individuals and different groups. In the past centuries, we have seen that a leader who was the architect of the project, did all the design work, took over the project and accepted its management. While, all the honours of the project attributed to him, and in return, he was responsible for everything. With the complexity and enlargement of the projects, specialized teams were created to facilitate work and increase efficiencies, with some in the field of aesthetics and standardization and design team. Others worked and studied on the correct implementation and created the implementation team, and finally, for the proper business communication between the two groups of management teams (whether the employer or his agent) were formed (Bodaghi, et al., 2015).

Over time, the need for a proper understanding between the two groups of the design and implementation has led to the two-factor approaches for employers, and now, considering the BIM discussion, and in particular using the IPD method, the practical integrity of all the groups is raised. Certainly, the use of these methods and the integrated work was on the basis of the advantages of its benefits over its difficulties, but it cannot be concealed that the scope of work of individuals and teams is more and more dampened, and the drawing of the matrices of work and responsibility in such cases becomes difficult. When several groups need to collaborate with each other, the input information of each group will affect the work of other groups, and any mistakes in the chain will spread to other groups. Therefore, after the occurrence of any defect, it is unlikely that the first mistake would be due to the misinformation of the other group (Bodaghi, et al., 2015).

2.23 Overview of the Related Literature

(Morlhon, et al., 2014) examined the way of success and the underlying factors in the building information modelling system, and concluded that in order to improve the implementation of such systems, different levels of maturity should be considered in order to be able to provide basic performance patterns.

(Hyojoo, et al., 2015), in their research investigated the factors affecting the acceptance and proper use of the building information model system, and showed that among the various factors, the most important of them were management support, custom production, adaptation to needs, and applicable software.

(Dongping, et al., 2015) explored the importance and necessity of using the building modelling information system in China and concluded that the success of using such systems is primarily dependent on the project itself, and secondly, the support of the owner or applicant, the availability and the type of software in China has also greatly contributed to the success of this system.

Two colleagues in 2014 have reviewed the BIM's performance in construction projects. Various types of building performance assessment designs have been presented to measure BIM use capacity in companies. These scales have been designed instead of measuring the organization's performance in the use of BIM. Contrary to the assessment, which is mainly based on adherence to the use of the BIM in an organization, the measurement criteria, is more interested in comparing the performance of a BIM organization with its industry counterparts. Based on large data collected from the BIMCS database, an overview of the current state of the BIM industry can be obtained, and ultimately a protocol for BIM performance can be based on a better knowledge discovery process. In addition, BIM data helps private companies improve their performance in using BIM considering their industry competitors.

(Liang, et al., 2016) examined the development of a multi-purpose evolutionary BIM model. Evolving BIM models have been created by showing the various stages of making information modelling and providing a roadmap to these stages. However, existing models are not capable of detecting and measuring BIM in different analysis units, including individual projects, companies, or generally the construction industry. The purpose of this research was to develop a multi-purpose BIM evolution model. A repeated method for identifying domains, sub-domains and sections that are organized in a hierarchical structure to form an evolutionary BIM model.

(Lee, et al., 2016) reviewed the comparison of BIM acceptance between Korea and the United States. Comprehensive research on data standards and exchanges in the architecture, engineering, construction and management of facilities over the past several years has been carried out. The growing popularity of building information modelling technology strongly believes that it can help to share and reuse information throughout the life cycle of a project. Although many researchers and experts agree on the potential and BIM benefits to construction, BIM has been accepted in the United States prior to Korea, and It is expected to have more BIM and to be considered positive for using a BIM for a longer period of operation. This means that the mechanism for achieving BIM acceptance in Korea is different from the mechanism in the United States. Therefore, the BIM acceptance model of Korea was compared with the United States using structural equation modelling. Based on this, a questionnaire was developed for workers in construction agencies (such as contractors, architects, building managers, engineers and facility managers) in Korea and the United States. A total of 164 questionnaires were completed. Structural equations modelling was done to test the hypotheses using existing commercial software. The results of this study could serve as a basis for research looking for an organizational context for BIM's greater acceptance in the construction industry. Comparison of the mechanism and its results will then be developed as a guide for developing an appropriate adoption strategy for Korea.

(Lu, et al., 2013) reviewed the general model for measuring BIM benefits as a learning tool in construction work. Over the past years, people's understanding of building information modelling in the architecture, engineering, and construction industry have been significantly improved. Building information modelling can be a virtual design and construction environment, a communication tool for stakeholders, a lifelong information model, or a learning environment that can be used at universities. Building information modelling can also be used as a learning tool that can familiarize project teams with the environment before it starts working. However, little effort has been made to measure the benefits of this type of model. The purpose of this empirical research is about the benefits of BIM as a learning tool in real construction tasks. This model can be used to encourage potential users of BIM by demonstrating empirical evidence of the benefits of BIM. It is also hoped that the model will be able to join the coordinated efforts to boost BIM's value in the construction industry.

(Yih, et al., 2017) reviewed the primary framework of the contract for active BIM projects. Building information modelling has entered into another stage of evolution, especially in countries such as Taiwan, the Republic of China, which are actively using the BIM. Effective management in BIM is increasingly an architectural, engineering, construction, and operation feature that establishes two objectives of this study:

(1) identifying the potential legal aspects that should be addressed in the BIM active projects;

(2) determining the requirements for the contract required in the BIM.

36 valid and completed questionnaires were analyzed. The results show that 21 related contracts that could potentially be used in BIM contracts. After a complete analytical discussion, these provisions of the contract then developed in the framework of the contract. While in the future, a solution for robust contractor mechanism for active projects with BIM will be provided, this research will provide sufficient knowledge to manage the BIM-based contract.

(Siebelink, et al., 2018) examined the development and testing of tools for assessing BIM analysis of the sector in the Dutch construction industry. The purpose of this study was to examine the realization of the building information modelling in the Dutch construction industry using a BIM developed tool that can be used in various fields of the construction industry. BIM models are currently focusing on technical aspects and are often developed for specific disciplines. This paper first presents the development of a model that allows feasibility of both the technological and organizational aspects of the BIM and allows comparing all disciplines in the supply chain of construction. Second, the ability to use the BIM model was examined by interviewing 53 Dutch companies in various fields in the construction industry. Based on these findings, priorities have been identified to enable the process of implementation of the BIM, which can be incorporated into industry or section policies.

(Park, et al., 2017) have studied the web-based visualized database for BIM. Four-Dimensional modelling of the building is a powerful tool for visualizing and communicating construction plans and milestones. The potential use of BIM has been shared to support daily construction operations and monitoring and tracking. Using the web technologies advancements and database, this paper provides a support visualization method of database and web that allows real-time data sharing in BIM every day. A central database structure, consisting of a method for determining and updating an automated BIM visualization, is designed to facilitate the daily BIM display of D4. The newly created method is shown through the implementation of a real project of the construction project. The results indicated that this method resolves information delays and issues related to D-BIM4 file-based disorientation to provide real-time sharing and daily visualization of D-BIM4.

Chapter Three

3 Methodology

3.1 Introduction

This chapter is divided into two sections. At first, the method used in this research and its advantages and disadvantages are investigated and then multi-criteria decision-making methods are introduced and the proposed method to select the most appropriate factor is suggested. The aim of the present study was to analyze and find out the advantages of using BIM building statistics modelling at hand over the plans regarding sustainable design and construction management even by the application of BIM tools to enhance area control and sustainability.

3.2 Research Methodology

The aim of conducting any research is to identify and recognize unknowns and figuring out about these unknown issues. Therefore, the research method is to use a special way and technique to provide more relevant and appropriate information about the subject and identify the relevant factors and causes (Deng, 1999).

The research methods are divided in various ways, the most common of which are as follows:

1) Historical Method

2) Empirical Method

3) Descriptive Method

According to the nature of this study, a descriptive method has been used in this study which will be further discussed.

3.2.1 Historical Method

Historical research is an activity for understanding past realities and one of the most difficult types of research. This research interprets and evaluates events in the past. In this method, the purpose is to identify the past events in order to better understand the existing situation. In other methods, such as descriptive or empirical evidence, the researcher can choose the sample of a case study with his model, but in historical research, he only has to examine information and documents remained from past (Monirabbas, et al., 2015).

3.2.2 Empirical Method

Empirical or experimental research is one of the most accurate and effective research methods used to test hypotheses. The purpose of this study is to investigate the effects of stimuli, methods or specific environmental conditions on a subject's group. The characteristics of the empirical method are that while manipulating or intervening variables (manipulation or intervention) and controlling the conditions, the results are observed for the group selected by randomization.

In this research, researchers place one or more groups as experimental groups under specific circumstances (independent variables) in order to identify the cause and effect relationships of them and compares the results (dependent variable) with the group or witness groups that have been subjected to such conditions. Investigating the effects of two different teaching methods (independent variable) on academic achievement (dependent variable) of university students using empirical and witness groups, and examining the effects of a drug training program are examples of empirical research.

When the choice of experienced individuals is not possible randomly, or it is impossible to completely manipulate or interfere with independent variables, Quasi-experimental research is used. Often, research on humans that are done experimentally is usually quasi-experimental. (Faraji & Golabchi, 2009)

3.2.3 Descriptive Method

Descriptive research consists of a set of methods which aim to describe the investigated conditions or phenomena. Conducting the descriptive research can only be used to understand the existing conditions or to be involved in the process of decision-making. On opposite to historical studies, descriptive studies investigate the present time issues.

This type of research deals with the description and interpretation of existing conditions and relationships. This kind of research studies the current state of the phenomenon or subject, and it involves different types.

Descriptive research can be divided into the following categories: (Vahidnia, et al., 2009)

1) Estimation Research: Describes the position of a phenomenon at a time. This method does not propose any hypothesis. It does not study the relationship of variables and does not recommend for subsequent actions, but merely describes the existing situation. For example, it describes the progress of students in terms of educational objectives at a given time or a general census to determine the population status of the country.

2) Evaluation Research: This method focuses on evaluating the social benefits, the desirability or effectiveness of a process, product, or program, and takes into account the application of its findings. This type of research is often accompanied by recommendations for constructive actions and is not intended to find general rules that can be extended to other situations. For example: Assessing the effectiveness of university education programs, the implementation of the basic sciences program, to what extent practice the competencies that the university planning committee has formulated, or are the facilities of a given library appropriate?

3) Follow-Up Study: It can be considered as one of the types of evaluation research. This type of research examines individuals after completing a course of treatment or a course of study. The purpose of this study is to determine the impact of the institute or a specific course on individuals. This type of study can provide useful information on the training or work of institutions so that changes can be made to the programs. For example: Studying success in a job or success in finding university graduate jobs or assessment of the outcomes of in-service training for faculty members of universities in education.

4) Case Study: A deep and extensive study of one case in a given time. In this way, a person from a family, a group, or a studying university is carefully and comprehensively studied. The purpose of the study is to identify all relevant variables. The best example, in this case, is medical study or psychoanalysis on a person. This method can serve as a ground for future extensive studies.

5) Evolutionary (Developmental) Research: Includes having accurate information in the fields of programs development and the development and progress of individuals. This type of study examines the extent of changes and patterns of programs or the growth of individuals over time, and may be carried out in two ways: longitudinal (continuous) and latitudinal (cross-sectional).

6) Correlations Study: One of the most commonly used methods in descriptive research, it examines the relationship between two variables. Correlation can be used in studies designed to formulate a hypothesis or to test it. The correlation coefficient is used to calculate the correlation between the two variables, because the variables of the research may be of different measurement scales (nominal, rank, distance, relative). Therefore, correlation coefficients are used to calculate the relationship between the two variables. The correlation coefficient is changeable between +1 + 1.

7) Post-Action Research: This type of research examines the causes and effects of relationships by examining the existing implications. If the research question arises when the value of an independent variable is already known and naturally determined, then such a research is called post-action research. The researcher begins by observing and verifying the variable or dependent variables in order to reach the variable or independent variables. It actually starts with the effect to look for the cause. Examining the causes of suicide, the causes of driving accidents or the causes of divorce are examples of post-action research. It should be noted that some scholars separate this research from a descriptive one and categorize it in a separate classification of the same name.

8) Survey Research: Considering the issue that the field study and case study has been used in this research, further explanation is given in this regard.

3.2.4 Survey Research

This method involves collecting information directly from a group of individuals. A sample of surveying studies are usually large (from 100 to 250 million people). By this method, different information can be obtained, which consists of three types: information about facts, beliefs and behaviours, the reality is a phenomenon or feature that can be observed and includes variables such as age, gender, income, and years of study. In general, the facts include everything that can be addressed. Belief is the expression of a response of feeling or a deliberate behaviour. Believes can be measured objectively but cannot be addressed. Behaviour involves action taken by the individual.

Surveying research examines a limited number of variables. The Callous Institute uses this method to examine people's opinions in politics and business. Researchers in economics, anthropology, psychology, health, and education use this method. Survey research, in contrast to historical research, deals with phenomena that are occurring in the present.

In economic and social studies, when it is not possible to examine all subjects or issues, the research is conducted through sampling, which means that a number is selected of the total population and the result of the study is generalized. The survey can be considered as one of the social research methods.

In which study subjects respond to questions about the research subject either through questionnaires provided to them or through oral interviews. Therefore, the survey method is a quantitative method not qualitative. According to some sociologists, the survey is the best method of sociological research. (Lin, et al., 2007)

3.2.4.1 Flexibility and Multi-Purposes

Survey research can be designed to measure simple issues as natural or population characteristics of the respondents, or the complexities, attitudes, tastes or lifestyle patterns. The survey may involve only one or a small aspect of the attitude or position of the respondents, or they may include dozens or even hundreds of questions about almost every aspect of the life of the respondents. Surveys can be designed in such a way that record the personal story of the respondents and their goals and expectations for the future or for all times (Lin, et al., 2007).

3.2.4.2 Expertise and Efficiency

In examining a survey, three questions are instantaneously addressed:

- ✓ How much does this survey cost?
- ✓ How long does it take?
- ✓ How many people will get information of?

At first, one cannot accurately answer these questions. A lot of detail is needed because survey research is not uniform. This is an important advantage of survey researches because they can usually be done according to the customer's order due to the feature of being suitable for the needs and the budgets of those who want information. Since survey research uses sampling, very large population data can be obtained from a relatively small sample of people.

One of the functions of survey research is to describe the units of research. For example, if we want to measure how people vote for a group, we need to consider each individual's opinion about the election. The survey researcher attempts to explain phenomena by comparing the items. For example, if people are divided into two groups of traditional and progressivism in terms of political orientation, the survey researcher tries to know what differences have the progressivist in terms of traits or other variables with traditionalists, and whether these differences have category origin? Thus, the purpose of the survey research is to achieve a complete inference by comparing the different features of the items. (Lin, et al., 2007)

3.2.4.3 Advantages of the Survey Research

The survey research is the best current method for social researchers that are interested in gathering the main data for describing a huge population that directly cannot be observed. With accurate possible sampling, we are able to prepare a group of respondents that their characteristics will be a reflector for larger population characteristics and standard accurate questionnaires provide some data which are so similar to data obtained by respondents.

Surveys are flexible and it can be asked many questions about a certain case and make significant flexibility in analyzing its data. It may provide an opportunity to a researcher for using his own real observations for an operational definition. The survey research has some advantages which included:

- Low cost

- Amount of data
- And the amount of gathered data

Standardizing gathered data can be considered as one of the strong points of the survey research.

3.2.4.4 Disadvantages of the Survey Research

The survey method addresses only certain aspects of an individual’s beliefs and practices and does not take into account the context in which these beliefs and practices take place. Using the survey method requires more caution in all stages of the work such as the exact writing of the questionnaire, the complete observation of the sampling plan, extraction and accurate interpretation of data. The smallest error in each of these cases will lead to incorrect results. Survey studies provide the possibility of conditional predictions and provide the identification of the most probable solution in a variety of ways, which are available for solving future problems, so it is not definitive.

On the other hand, the survey method cannot find the causality between the phenomena, because it shows only the correlation between the two phenomena. Correlation is not the reason for causation. For example, in the high correlation between two phenomena A and B, various states may exist between them, such as A is cause of B, B is cause of A, or the third phenomenon is the cause of two phenomena A and B. Other states are possible that shows non-causality of correlation between variables (Lin, et al., 2007).

3.2.4.5 Tools for Collecting Data in Survey Research

One of the most important parts in each research work is data collection. Observations, interview, the questionnaire can be used as some useful tools for gathering data in survey researches.

The steps to perform an ordinary survey are as follows:

1) Problem design
2) Review theoretical literature

- Review the theoretical literature of research
- Review the historical literature of the research subject
- Review the related literature
- Providing theoretical and operational definitions
- Extract theoretical model
- State of the Problem and hypotheses

3) Design of survey methodology
    - Specify sample size
    - Sampling
    - Completing questionnaire
    - Reliability and validity

4) Research findings

5) Summary and Conclusion

3.3 Integrated Project Delivery (IPD)

Integrated Project Delivery (IPD) is a project delivery approach that combines elements, systems, economic structure, and procedures into a process that exploits collectively the talents and insights of all project factors to optimize project outcomes, enhance the value of business for the employer, reducing wastages and increasing efficiency throughout all phases of design, construction, and operation.

IPD principles can be used in a variety of contractual layouts. Also, IPD members may include factors that are more than three common factors for the employer, consultant and contractor. The point in all aspects of the IPD is the effective collaboration between the employer and the original designer and the main contractor from design to delivery. (Handler, 2010)

Preparing an Integrated Project should be based on the following factors:

A. The structure and function of the project team

A.1 Formation of the Team

A.1.1 Main Members

A.1.2 Key Supporting Factors

A.2 Project Decisions

A.3 Team Communications

A.4 Building Information Modeling

A.5 Share sensitive, Proprietary or Confidential Information

A.6 Service Compensation

A.7 Dismissal and Employment

A.8 Resolving Differences between Team Members

B. Defining Roles, Responsibilities and Range of Services

B.1 Range of Services

B.1.1 Designer

B.1.2 Producer

B.1.3 Employer

B.2 Multifaceted Tasks

C. Define and Measure Project Outputs

C.1 Objectives and Standards

C.2 Project Cost

C.3 Project Schedule

C.4 Project Quality

C.5 Efficiency Operation

C.6 Sustainable Development

D. Legal Considerations

D.1 Non-Standard Contracts

D.2 License and Professional Responsibility

D.3 Insurance

D.4 Formation of Company

D.5 Joint Responsibility and Profit Partnership

3.4 Multiple Criteria Decision-Making Methods

In today's world, most of the issues that are presented to managers for decision making are diverse and formulated in several ways. In other words, most managerial decisions are influenced by a variety of quantitative and qualitative factors, which often conflict with each other and they try to choose the best options among several options. Mistakes and inaccuracies in decision making involve a payment for errors. The greater the power and authority of management, the higher the cost of the wrong decision (Vahidnia, et al., 2009).

Normally, the solution of the multi-criteria decision-making problem is complex and it is not easily feasible, especially most of the criteria are in conflict with each other. The increasing desirability of one can reduce desirability for the other. For this reason, methods have been developed under the name of multi-criteria decision making, and especially multi-index decision-making that helps to solve these problems (Vahidnia, et al., 2009). Multi-index methods have different techniques in different stages of decision making. In these methods, several options are compared on the basis of several different criteria; then best option or arrangement of the suitable options are chosen. MADM's methods based on mathematical reasoning determine the best decision-making option among the available options with their prioritization.

Because of each of these methods deals with modelling and problem solving with their specific assumptions and approaches, therefore, in different situations, each one has a set of different answers. Furthermore, one of the basic assumptions is the validity of the weights associated with the indicators used in the techniques. In a general view, methods used to determine weight are objective and subjective methods. Certainly changes in the results of calculating the weights will affect the performance of the techniques used in achieving the superior option; therefore, in such a situation, the existence of an empirical or scientific criterion that can validate the resulting weights and the difficulty of the answers obtained from the implementation of these techniques are more important than ever. In this regard, in previous investigations, criteria such as statistical correlation of options rank, consensus, and others have been discussed (Vahidnia, et al., 2009).

Many of the decisions are so complex that the analyst is different from the one who makes the final decision. In spite of the widespread application of multi-criteria decision making in the real world, this approach also has its own limitations and challenges. This is analytic who determine which method to be used (to determine the weight or evaluation of options), or in which position to use only part of the method (Lee, et al., 2008).

Today, multi-index decision-making methods are widely used in a variety of fields. The reason for this issue is the ability and capability of these methods in modelling real issues and their simplicity and understandability for most users. Although the techniques and methods of planning and decision making provide an optimal answer, under certain conditions and assumptions, they have this capability. These types of techniques require precise and definite information. In real issues, it is not possible to provide this information, or in the case of providing them, it requires a high cost. On the other hand, it is not possible to consider all dimensions and aspects of the problem in these methods (Lee, et al., 2008).

But in modelling, the aspects of the problem are taken into consideration, which is quantitative and their measurement and evaluation are cost effective. Therefore, in general, many of the qualitative variables and conditions cannot be applied in modelling. Therefore, since multi-index decision-making methods, and at the top of them, the Analytical Hierarchy Process (AHP) method is able to take into account the quantitative and qualitative variables of the problem simultaneously, has been widely used and expanded.

3.4.1 Choosing the Right Method

Decision making "is one of the most important and basic tasks of management, and the realization of organizational goals depends on its quality. As Herbert Simon states, one of the experts in the field of decision-making, ‘‘Decision making is the essence of management‘‘.

The decision process can be displayed as follows:

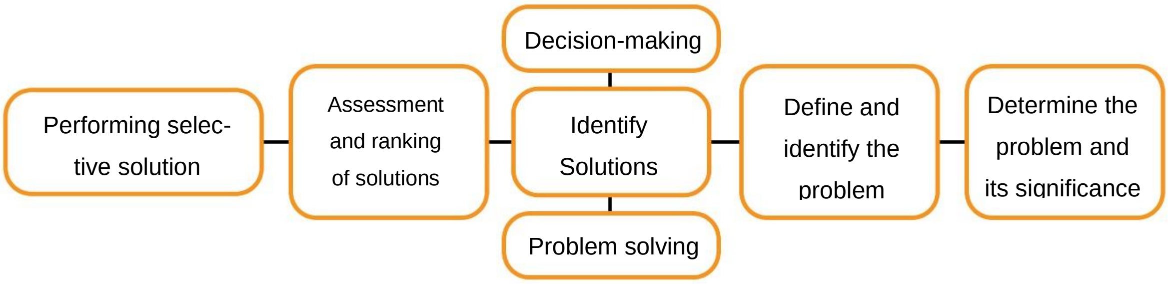


Figure 4- Decision-Making Process

To select the appropriate decision-making method, a few related studies will be presented.

Procedures for selecting the appropriate Multiple Criteria Decision Making (MCDM) technique was presented by people like Ozemoy. (Ozemoy, 1992)

These procedures are mainly based on inputs required by the techniques (the variety and manner of information that the decision maker should provide). But these procedures were used as a means to remove techniques, rather than to select the appropriate technique. (Ozemoy, 1987)

Denpontin and his colleagues provided a comprehensive list of different methods but they concluded that the implementation of these methods in the form of a general framework is difficult because decision-making studies are very diverse in terms of quality, quantity, and accuracy of information. Many scholars have emphasized the reliability of the method as the main criterion for choosing the method. From their point of view, reliability shows that the applied method chooses the option that correctly reflects the decision maker's values. (Denpontin, et al., 1983)

However, there are no objective and absolute standards for determining the validity of the methodology because the decision making studies have shown that the relationship between the effectiveness of the decisions made and the amount of information provided is in the up-side-down of U.

A research named the application and comparison of multi-criteria decision-making techniques in the ranking of countries based on the amount of human development is conducted by Sultan Panah and colleagues. In this research, entropy and AHP techniques were used to obtain the coefficient of the importance of human resource forming indicators (HDI) and SAW[1] and TOPSIS[2] techniques as well as numerical taxonomy analysis are used as a substitute for the simple mean method for ranking Countries based on human development rate. The results of this study showed that all the methods used to rank countries can be applied. Obviously, none of these methods will have the same results in determining the ranking of countries. Therefore, according to the degree of accuracy required, it seems that based on the nature of the TOPSIS method, which would rank based on the relative closeness to the ideal answer and avoid the anti-ideal answer. The results of this method when the coefficient of the importance of the indicators is calculated by the AHP method is closer to reality. In addition, given that in multi-index decision-making models, apart from the features of the methods, other factors cannot be mentioned for the appropriateness of the method, the use of the mixed method, which has a certain characteristic of all methods, will be more protective.

In a study conducted in the form of a dissertation titled "Reviewing the Performance of the Most Used Multi-index Decision-Making Techniques Using the Optimization Approach" by Yousefi, among the methods of AHP, TOPSIS, ELECTRE[3] And SAW, it has been shown that the AHP technique has the most similarity in terms of average rank to optimal response in comparison with other ranking techniques, indicating that this technique will be better than other ranking techniques. Finally, it has been shown that among the studied methods, the behaviour of the SAW and TOPSIS techniques is very consistent, but their deviation from the AHP is very high.

Another study also found that the entropy method had no good stability for weight evaluation, and, in addition to its deep effects on the achieved ratings, it does not fit into the decision maker's internal demands.

3.4.2 Analytical Hierarchy Process Model (AHP)

The AHP method for complex and phased problems is proposed by a researcher named Thomas Al-Saati in the 1970s (Deng, 1999).

[1] Simple Additive Weighted
[2] Technique for Order Preference by Similarity to Ideal Solution
[3] ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality)

Analytical hierarchy process is one of the most comprehensive systems designed for decision making with multiple criteria because this technique allows formulation of the problem in a hierarchical manner, and also the possibility of considering different quantitative and qualitative criteria in the problem, this process interferes with different options in decision making and allows for sensitivity analysis on criteria and sub-criteria, in addition, it is based on pair comparison that facilitates judgment and computation, furthermore, it shows the degree of compatibility and the incompatibility which is one of the advantages of this technique in multi-criteria decision making.

The type of paired comparison between the criteria and the sub-criteria is linear. For example, if the preference of element A on element B is always equal to n, the preference of element B on element A will always be equal to 1/n, while at the different levels of element A, the element B desirability is undergoing changes. In this research, we have tried to make a more accurate comparison of criteria and sub-criteria based on desirability theory which is one of the most applied theories in microeconomics, and the relative weight of each criterion with the utilization of the desirability function is obtained between the two criteria (Dodge, 2006).

In decision-making science, where choosing a solution from existing solutions or prioritizing solutions is matter, lately, the methods of decision-making with MADM "multi-dimensional" indices have been developed. Analysis hierarchical process (AHP) has been used more than other methods in management science. The analysis hierarchical process is one of the most popular multi-purpose decision-making techniques. The hierarchical analysis process reflects the natural behaviour and human thinking. This technique examines complex issues based on their interactions and turns them into a simple way to solve them.

Analysis of the hierarchical process can be used when decision-making is faced with several competing choices and decision criteria. The proposed criteria can be quantitative and qualitative. The basis of this decision-making method lies in paired comparisons. The decision maker begins the decision with the process of providing the hierarchical tree. The tree of the decision hierarchy shows the comparison of the factors and the evaluated compete options in the decision. Then a set of paired comparisons is performed. These comparisons show the weight of each of the factors in line with the competing options evaluated in the decision. Finally, the logic of the analytical hierarchy process combines matrices from paired comparisons to make the optimal decision. (Ozemoy, 1992)

3.4.2.1 Principles of Analytical Hierarchy Process

Thomas Al-Saati (founder of this method) outlines the following four principles as the principles of the analytical hierarchy process and has based all the calculations, laws and regulations on these principles. These principles include:

Inverse condition: If the preferences of ''A'' element on ''B'' element is equal to ''n'', then the preferences of ''B'' element on ''A'' element is equal to ''1/n''.

The principle of homogeneity: Element ''A'' with element ''B'' must be homogeneous and comparable. In other words, the element A's superiority over element ''B'' cannot be infinite or zero.

Dependency: Each hierarchical element can be depended on its higher level element and can linearly maintain this dependence to the highest level.

Expectations: Whenever a change occurs in projects hierarchically, the evaluation process should be redefined.

3.4.2.2 Model of Analysis Hierarchical Process

Applying this method requires four main steps: (Vahidnia, et al., 2009)

A) Modelling

In this step, the problem and purpose of decision making are presented in a hierarchical manner from the decision elements that are relevant to each other. Decision elements include "decision-making indices" and "decision options". The analysis hierarchical process requires breaking a problem with several indicators into a hierarchy of levels. The top level represents the main goal of the decision-making process. The second level represents the major indicators "that may be broken down to sub-indicators and more detailed at the next level." The final level provides the options for the decision.

B) Preference Judgments (paired comparisons)

Making a comparison between different decision-making options, based on each indicator and judgment on the importance of the decision index by making a paired comparison, after designing the hierarchy of decision problem, the decision maker should make a set of matrices which numerically measures the importance or relative importance of indicators related to each other and each decision option measured by the indicators relative to other options. This is accomplished by making two-by-two comparisons between decision elements (paired comparisons) and by assigning numerical scores that indicate the priority or importance of the two elements of the decision.

In order to do this, it is usually used to compare options with the ‘’i-th’’ indexes to ‘’j’’ indexes or options. The below table shows how the indices are evaluated relative to each other.

Table 2- Evaluation of Indices Relative to Each Other[1]

Preferred -Value	***Status of comparing (i) to (j)***	***Explanation***
1	Equal importance	The ‘’i-th’’ index or option has equal importance to ‘’j’’ index or option or has no preference to each other
3	Relatively more important	The ‘’i-th’’ index or option is little more important than ‘’j’’ index or option
5	More important	The ‘’i-th’’ index or option is more important than ‘’j’’ index or option
7	Much more important	The ‘’i-th’’ index or option has more preference to ‘’j’’ index or option
9	Very important	The ‘’i-th’’ index or option is absolutely more important than ‘’j’’ index or option and is not comparable to ‘’j’’
2,4,6,8		The mean values show between the preferred values, for example, 8, representing greater importance than 7 and lower than 9

C) Computing the Relative Weights

Determining the weight of "decision elements" to each other through a set of numerical calculations. The next step in the hierarchical analysis process is to perform the com-

[1] (Vahidnia, et al., 2009)

putations necessary to determine the priority of each decision element using the information of the paired comparison matrices. The summary of mathematical operations at this stage is as follows.

The sum of the numbers of each column is computed from the paired comparison matrix, then we divide each column element into the sum of the numbers of that column. The new matrix obtained is called the " normalized comparison matrix ".

We compute the average of the numbers of each row from the normalized comparison matrix. This provides the means of the relative weight of the decision elements with the matrix rows.

D) The Integration of Relative Weights

In order to rank the decision options, at this stage, we must multiply the relative weight of each element in the weight of the higher elements in order to obtain the final weight. By doing this for each option, the amount of final weight is obtained.

3.4.2.3 Compatibility in Judgments

Almost all calculations of the analytical hierarchical process are based on the initial judgment of the decision maker, which appears in the form of a paired comparison matrix, and any mistakes and incompatibilities in comparison and determining the importance of the options and indices distort the final result obtained from the calculations. The incompatibility rate that we'll be familiar with its calculation in the next process, is a tool that identifies compatibility and shows how far you can rely on the priorities obtained from the comparisons. For example, if option A is more important than option B (preferred value 5) and B is relatively more important (preferred value 3) then it should be expected that A is much more important (preferred value of 7 or more) or if the value of preferred A to 2 is B, and B to 3 is C, then the value of A to C should be the preferred value of 4. Perhaps the comparison of the two options is simple, but when the number of comparisons increases, it is not easy to ensure comparability, and this trust must be achieved using the compatibility rate. Experience has shown that if the incompatibility rate is less than 10/0, the comparative compatibility is acceptable and otherwise the comparisons should be revised (Deng, 1999). The following steps are used to calculate the incompatibility rate:

Step 1. Calculating the total weight vector: multiply the matrix of the paired comparisons in the vector of the "relative weight" column. The new vector you get is called the total weight vector.

Step 2. Calculating the compatibility vector: Divide the total weight vector elements into relative priority vector. The achieved vector is called the compatibility vector.

Step 3. Obtaining λmax, it gives the mean of the compatibility vector elements of λmax.

Step 4. Calculating the compatibility index

(3-1) $$CI = \frac{\lambda_{\max} - n}{n-1}$$

n is the number of factors in the problem.

3.4.2.4 Fuzzy Analysis Hierarchy

In fuzzy theory, unlike traditional methods, the boundaries of collections are not explicit and clear, and the basis of judgments is words like less or more. In other words, fuzzy systems are based on approximate modelling and reasoning that are in line with the nature of human systems (organizations). In this type of reasoning, the states of zero and one express the boundaries of reasoning. An approximate reasoning is a type that is neither completely accurate nor like guessing, completely inaccurate (Deng, 1999).

Modelling uncertainty in decision-making issues is done by fuzzy theories. In the fuzzy method, the inadequacies and limitations of classical multi-criteria decision-making (zero and one) methods lead to the emergence of a fuzzy method, fuzzy logic is a new worldview that is highly adaptable to the needs of today's complex world and makes the world as it is (wang & Yoon, 1981).

Fuzzy AHP method considers uncertainty in judgments. In this way, overcoming ambiguities in the linguistic variables of triangular fuzzy numbers are used in paired comparisons, resulting in more accurate outcomes (Ozemoy, 1992).

The methodology of the FAHP is based on the concept of the fuzzy set theory proposed by Professor Lotfizadeh in 1965. The fuzzy analytical hierarchy process (FAHP) extends the "hourly" AHP's through its combination with the fuzzy set theory. In fuzzy

AHP, after creating a hierarchical structure for a problem to be solved, the fuzzy relative scales are used to indicate the relative importance of the factors corresponding to the criteria.

Therefore, a fuzzy judgment matrix is constructed, the final points of the options are represented by fuzzy numbers, and the optimal option is obtained through the fuzzy number rankings using certain algebraic operators (Lee, et al., 2008).

Based on the development analysis methodology, when the decision maker faces an uncertain and complex problem and states its comparative judgments as non-deterministic ratios such as "approximately twice more important" and "between two and four times less important", the standard AHP steps and Particularly, the special vector prioritization approach cannot be considered as proper procedures. In 1996, a Chinese researcher named Yong Chang presented the developmental analysis approach. In this methodology, due to the simplicity of computation, the triangular fuzzy numbers are used in all elements in the matrix of judgment and the weight vectors of this method in most investigations.

Suppose $\tilde{A} = \{\tilde{M}_{ij}\}$ is a fuzzy pairwise matrix which is defined as:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{M}_{12} & \dots & \tilde{M}_{1n} \\ \tilde{M}_{21} & 1 & \dots & \tilde{M}_{2n} \\ . & . & . & . \\ . & . & . & . \\ \tilde{M}_{n1} & \tilde{M}_{n2} & \dots & 1 \end{bmatrix} \qquad (3\text{-}2)$$

Then, $\tilde{M}_{ji} = 1 / \tilde{M}_{ij}$ relationship will be established.

Now, for solving a model using the FAHP method, in each of the rows of the paired comparison matrix, the value of S_k which is a triangular fuzzy number is computed as follows:

$$S_k = \sum_{j=1}^{n} M_{kj} * \left[\sum_{i=1}^{m} \sum_{j=1}^{n} M_{ij} \right]^{-1} \qquad (3\text{-}3)$$

In which k represents the row number and, respectively, indicate options and indicators.

In this method, after the calculations of the S_k, their great degree to each other should be achieved. In general, if M_1 and M_2 are two triangular fuzzy numbers, M_1 to M_2 a great degree is defined as:

(3-4)

$$\begin{cases} V(M_1 \geq M_2) = 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots M_1 \geq M_2 \\ V(M_1 \geq M_2) = hgt(M_1 \cap M_2) \end{cases}$$

And otherwise we have:

(3-5)

$$hgt(M_1 \cap M_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)}$$

To calculate the weight of the indices in the paired comparison matrix, we perform as the following:

(3-6)

$$W'(X_i) = \min\{V(S_i \geq S_k)\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots k = 1,2,\ldots\ldots,n, k \neq i$$

Therefore, the weight vector of the indices will be as follows:

(3-7) $$W' = [W'(X_1), W'(X_2), \ldots., W'(X_n)]^t$$

That is the same fuzzy AHP abnormal coefficient vector. Indices normalized weights are obtained according to this relationship $W_i = \frac{W'_i}{\sum W'_i}$ (Lund Research Ltd, 2014).

Now, the question is that how we can *determine the compatibility rate* in *the fuzzy analytical hierarchy process?*

To measure the degree of compatibility of the fuzzy judgment matrix, an index can be optimally defined as below after determining the non-fuzzy Crisp priority vector:

(3-8)

$$\widetilde{A} = \begin{bmatrix} 1 & \frac{w_1}{w_2} \cdots\cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 \cdots\cdots & \frac{w_2}{w_n} \\ . & . & . \\ . & . & . \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & 1 \end{bmatrix}$$

In which, $\widetilde{A}$ is the paired fuzzy comparison matrix, W_1 is the weight of factor 1, W_2 is the weight of factor 2, w is the weight of n factor.

Assume that a fuzzy judgment matrix is constructed as $\widetilde{A} = \{\widetilde{a}_{ij}\}$ in which the triangular fuzzy number $\widetilde{a}_{ij}$ is expressed as (l_{ij}, m_{ij}, u_{ij}). for Crisp weight vector $W = (W_1, W_2, ..., W_n)^T$ you can define $\mu_{ij}\left(\frac{W_i^*}{W_j^*}\right)$ as the following function:

(3-9)

$$\gamma = \exp\left\{-\max_{ij}\left\langle \mu_{ij}\left(\frac{w_i^*}{w_j^*}\right) \middle| i, j = 1,2,....,n, i \neq j \right\rangle\right\}$$

$$\mu_{ij}\left(\frac{w_i^*}{w_j^*}\right) = \begin{bmatrix} \frac{m_{ij} - (w_i / w_j)}{m_{ij} - l_{ij}}, \dots\dots\dots 0 < \frac{w_i}{w_j} \le m_{ij} \\ \frac{(w_i / w_j) - m_{ij}}{u_{ij} - m_{ij}}, \dots\dots\dots \frac{w_i}{w_j} > m_{ij} \end{bmatrix}$$

(3-10)

Value γ is always between zero and one. If its value is larger than $e^{-1} = 0.3679$. then all true inequalities rates of $l_{ij} \le \frac{W_i^*}{W_j^*} \le u_{ij}$ are satisfied, and the fuzzy judgment matrix will be well adapted. If γ is equal to one, it indicates that the fuzzy judgment matrix is fully compatible. As a result, the fuzzy judgment matrix is more compatible with one larger γ (Lund Research Ltd, 2014).

Chapter Four

4 Case Study Review and Survey Analysis

4.1 Introduction

In the previous chapter, the research methodology of fuzzy hierarchy analysis and the method of calculating the compatibility rate was discussed. In this chapter, the questionnaire, the way of answering it, statistical tests, gender, education, the number of respondents and the results of the questionnaire are discussed.

4.2 Questionnaire

To the purpose of using BIM for sustainable design and construction management, a questionnaire as shown in Figure 5 is designed with 6 main criteria and 24 sub-criteria based on technical, economic, social indicators and etc. which are shown in Figure 6 and 7. The full version of the questionnaire is presented in the appendix.

1. Technical and technological C1
    - Insufficient studies and local information on land and work conditions A1
    - Inappropriate design and design information in the correct estimation of cost, time and resources A2
    - Limited access to projects materials A3
    - The lack of standard information in relevant organizations A4

2. Easier access to information and required materials C2
    - Lack of resources (land, materials, and workers) A1
    - Lack of technical specialists in technical and workshop sensitive systems A2
    - A commitment to do things that the executor or the employer or the supervisor does not have a background of doing the same issues A3
    - Working in the border, deprived, or fighting areas, because of the probability of the existence of explosives and the subsequent risks resulted from it A4

3. Construction C3
    - Low Efficiency and productivity and time delay A1
    - The lack of knowledge and proficiency of the contractor increases the cost A2
    - Working with unskilled employers, financially and managerially weak, prolonging the performance time and completion of projects for rational and irrational reasons A3
    - Weather conditions A4

4. Economic and Financial C4

- The lack of cooperation of financial institutions in the payment of facilities to employers A1
- Performing fixed and non-moderated works in areas with high and unpredictable inflation A2
- Material price fluctuations due to the economic conditions of the country, region and world A3
- Not having scale Inflation for costs and analyzing the cost of completion of projects A4

Figure 5- Part of Designed Questionnaire[1]

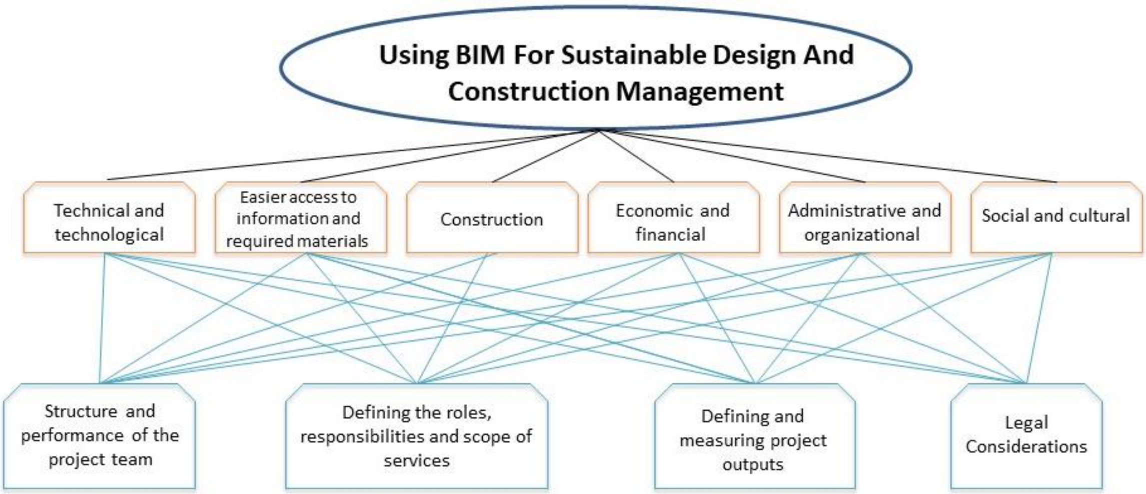


Figure 6- Analytical Hierarchy Model with Main Criteria and Solutions[2]

[1] Own work
[2] Own work

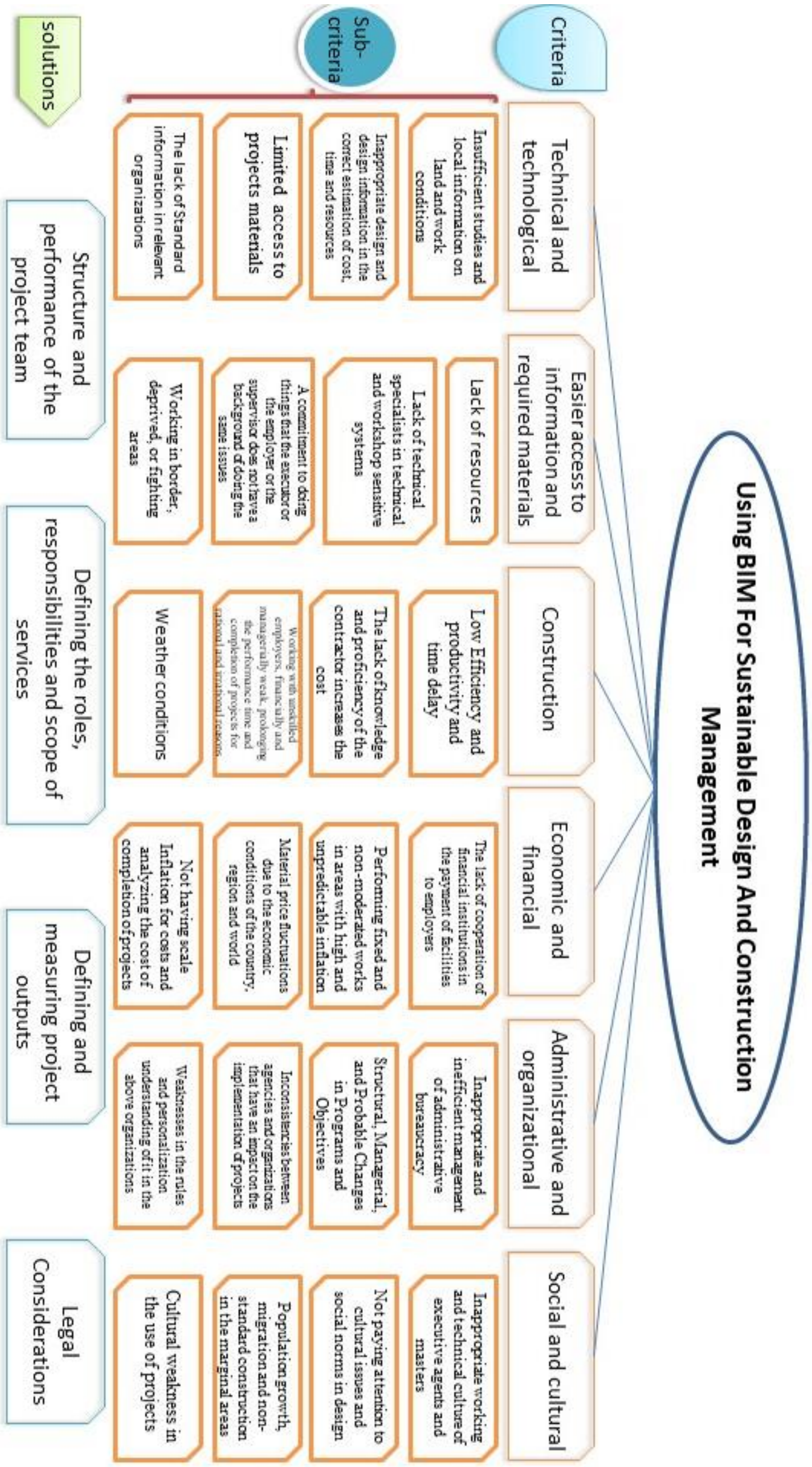


Figure 7- Analytical Hierarchy Model with the Main Criteria, Sub-Criteria and Solutions[1]

[1] Own work

One of the widely used instruments for measuring the reliability is the Cronbach's alpha method, its formula is as follows.

(4-1)

$$r_a = \frac{j}{j-1}\left(1 - \frac{\sum s_i^2}{s^2}\right)$$

In the above formula:

j = Number of sub-questions in the questionnaire or test

S_i^2 = Sub-test variance

S^2 =Total test variance

The statistical population of the research includes all experts. In this research, the Cochran formula has been used to determine the sample size, if the term "limited society" cannot be ignored, the formula is as follow:

(4-2) where:

$$n = \frac{N \times Z_{\alpha/2}^2 p(1-p)}{d^2(N-1) + Z_{\alpha/2}^2 P(1-P)}$$

n: sample size

N: size of the society

Z: The normal variable value of the standard unit, which at 95% confidence level is 1.96.

P: The value of the attribute rate in the community. If it is not available, it can be 0.5. In this case, the amount of the variance reaches its maximum value.

q: Percentage of people who do not have that attribute in society (q = 1-p).

d: the allowed error value equal to 0.05.

Considering that the designed questionnaire was completed by 44 people, the sample size was determined by Cochran method is 39.57 with a 5% error rate. The observed skewness value is 0.156 and is in the range (-2, 2). In other words, in terms of tilt, the questionnaire is normal and the distribution is symmetric. Its elongation is 0.694 and is in the range of (-2, 2). This indicates that the variable distribution has a normal elongation and the questionnaire has passed the normal test successfully.

Table 3- Normality Test of the Questionnaire[1]

Kurtosis		Skewness	
Std. Error	Statistic	Std. Error	**Statistic**
0.466	0.694	0.297	**0.156**

Table 3 shows the reliability sub-test of the statistical summary.

Table 4- The Reliability Sub-Test of the Statistical Summary[2]

Cases	N	%
Valid	24	100.0
Excluded	0	0
Total	24	100.0

In Table 4, the number of acceptable questionnaires and the number of excluded items in terms of the studied item sub-test have been determined.

In Table 5, Cronbach's alpha is shown and the value is 0.992, which is obtained after standardization as 0.993.

The questionnaire used for hierarchical analysis and multi-criteria decision making is called, ‘‘Certified Questionnaire‘‘. The characteristics of respondents to the questionnaire were specified by three criteria: age, education, gender. In general, 44 respondents answered the questionnaire. Among the respondents, 27 have a bachelor's degree, 10 have a master degree and 7 Ph. D degrees. The average age of respondents was 55 years. Figure 8 shows the number of respondents in the diagram.

[1] Own work
[2] Own work

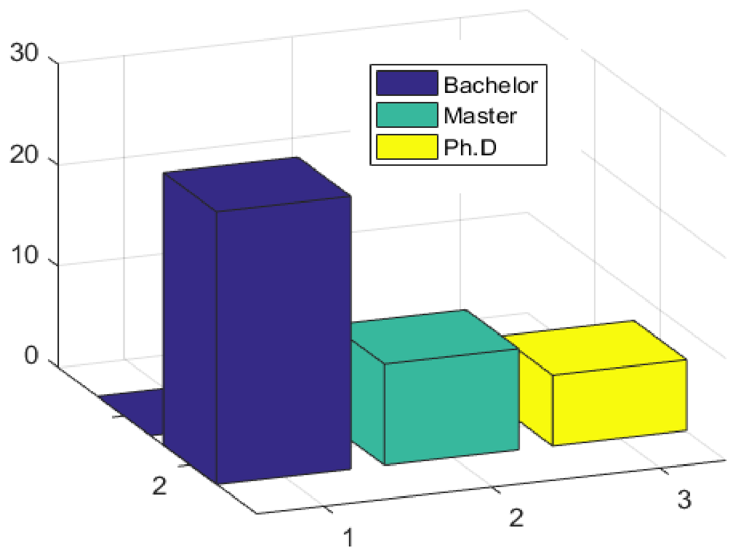


Figure 8- Questionnaire's Respondent Educational Level[1]

Among the respondents, 9 were female 35 were male. Figure 9 shows the number in the diagram.

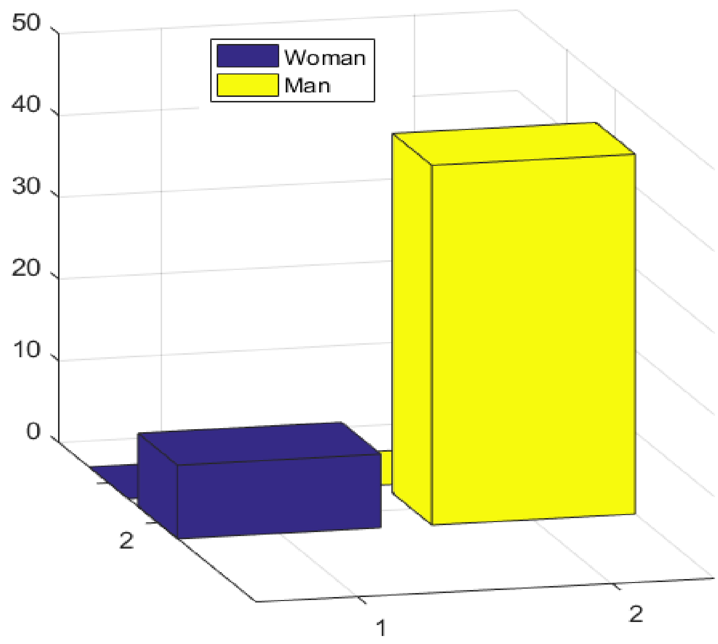


Figure 9- The Gender of the Respondents to the Questionnaire

The normal distribution of the questionnaire is presented in Figure 10.

[1] Own work

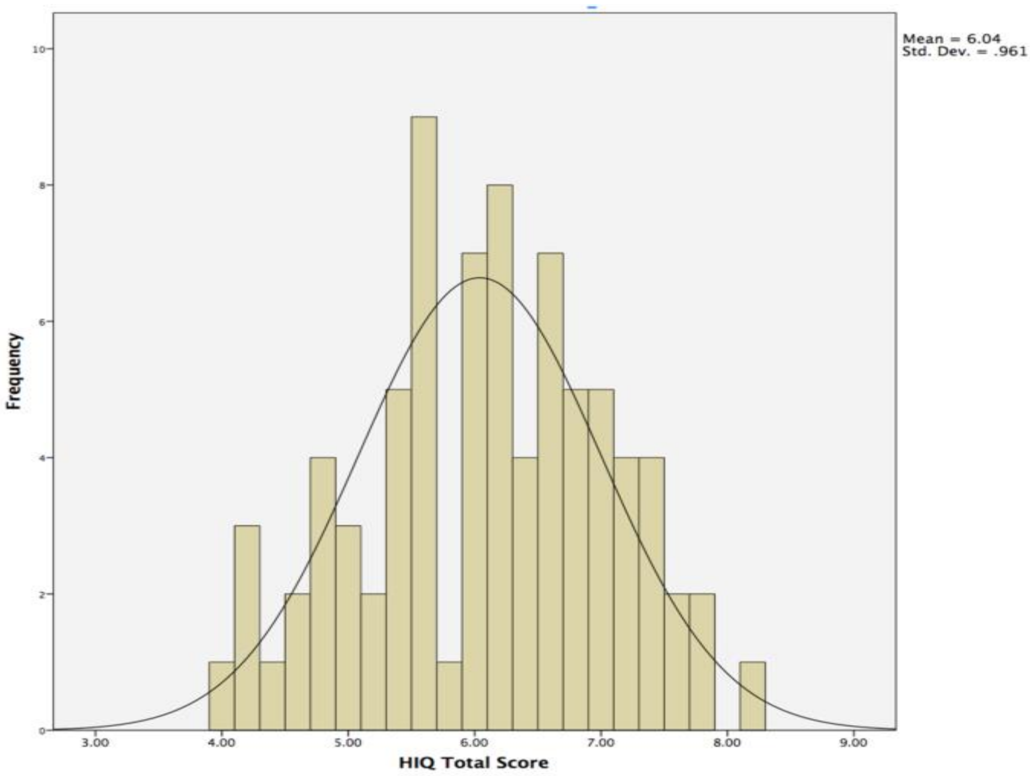


Figure 10- Normal Distribution of the Questionnaire[1]

4.3 The Study Area of This Case Study

A developing country is a country with relatively low standards of living, an undeveloped industrial basis and a low human development index. This term is different from the previous expressions made on this subject, including the term "cold war", which defines the Third World and brings to the mind a secondary meaning that is negative.

Another synonym for the term "Developing Country" is the less developed country or the less economically developed country.

The less economically developed country is a term used by new geographers to describe countries that are more precisely classified as developing countries, with the characteristic that they are economically less developed, and usually, have the most solidarity with other factors as low human development.

International development requires a new structure (both physical and organizational) and a kind of distance from low added value sectors such as agriculture and natural

[1] Own work

resource extraction. In this comparison, developing countries usually have systems based on spontaneous economic growth in the third segment and fourth section of industry and high standards of living.

The use of the term "developing country" for all the less developed countries can be considered inappropriate: a number of poor countries are not improving their economic conditions (as the term refers), but have experienced long periods of economic decline.

Countries that have more advanced economies among developing nations, but are not yet fully integrated with the signs of a developed country, are classified as a newly industrialized country. (Figure 11)

Figure 11- Developing Countries[1]

In this thesis, the use of BIM for sustainable design and construction management has been investigated. The PMBOOK-based questionnaire has 6 sections as follows:

1. Technical and technological

2. Easier access to information and required materials

3. Construction

4. Economic and Financial

5. Administrative and organizational

6. Socio-cultural

[1] https://www.slideshare.net/graceedward/demographic-attributes-of-developed-developing-and-3rd-world-countries [Accessed in 12.07.2018].

Each section is divided into several sub-sections as follows:

1. Technical and technological

- Insufficient studies and local information on land and work conditions
- Inappropriate design and design information in the correct estimation of cost, time and resources
- Limited access to projects materials and the lack of standard materials
- The lack of standard information in relevant organizations

2. Easier access to information and required materials

- Lack of resources (land, materials, and workers)
- Lack of technical specialists in technical and workshop sensitive systems
- A commitment to do things that the executor or the employer or the supervisor does not have a background of doing the same issues
- Working in the border, deprived, or fighting areas, because of the probability of the existence of explosives and the subsequent risks resulted from it

3. Construction

- Low efficiency and productivity and time delay
- The lack of knowledge and proficiency of the contractor increases the cost
- Working with unskilled employers, financially and managerially weak, prolonging the performance time and completion of projects for rational and irrational reasons
- Weather conditions

4. Economic and Financial

- The lack of cooperation of financial institutions in the payment of facilities to employers
- Performing fixed and non-moderated works in areas with high and unpredictable inflation

- Material price fluctuations due to the economic conditions of the country, region and world
- Not having scale inflation for costs and analyzing the cost of completion of projects

5. Administrative and organizational

- Inappropriate and inefficient management of the administrative bureaucracy
- Structural, managerial, and probable changes in programs and objectives
- Inconsistencies between agencies and organizations that have an impact on the implementation of projects
- Weaknesses in the rules and personalization understanding of it in the above organizations

6. Socio-cultural

- Inappropriate working and technical culture of executive agents and masters
- Not paying attention to cultural issues and social norms in design
- Population growth, migration and non-standard construction in the marginal areas
- Cultural weakness in the use of projects

Solutions provided based on Integrated Project Delivery (IPD) are as follows:

- Structure and performance of the project team
- Defining the roles, responsibilities and scope of services
- Defining and measuring project outputs
- Legal considerations

4.4 Analysis of the Results

A paired comparison of options is used to prepare an expert questionnaire. An expert questionnaire is prepared for each level of the hierarchy. For scoring, Al-Saati nine-grade scale is used as Table 5.

Table 5- Al-Saati Nine-Grade Scale for Scoring[1]

Preferred Value	Status of comparing i to j	Explanation
1	Equal importance	the i-th index or option has equal importance to j-index or option or has no preference to each other
3	Relatively more important	the i-th index or option is little more important than j-index or option
5	More important	the i-th index or option is more important than j-index or option
7	Much more important	the i-th index or option has more preference to j-index or option
9	Very important	the i-th index or option is absolutely more important than j-index or option and is not comparable to j
2,4,6,8	mean	the mean values show between the preferred values, for example, 8, representing greater importance than 7 and lower than 9

Coding process has been done in the Matlab software for analytical hierarchy. Figure 12 and 13 show the writing of code for hierarchical analysis.

[1] (Vahidnia, et al., 2009)

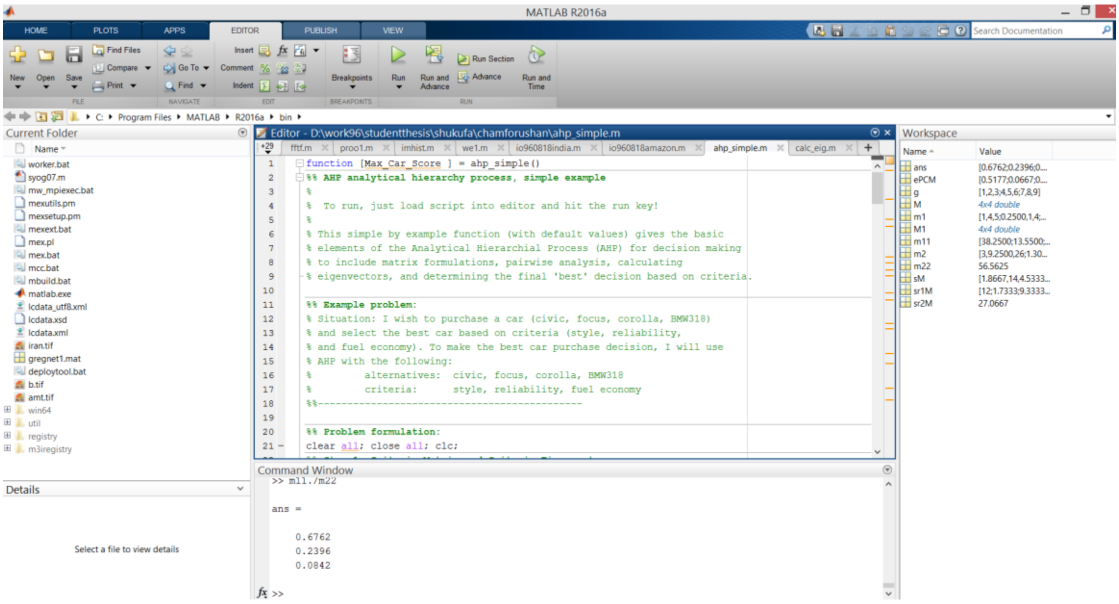


Figure 12- Written Code for Hierarchical Analysis[1]

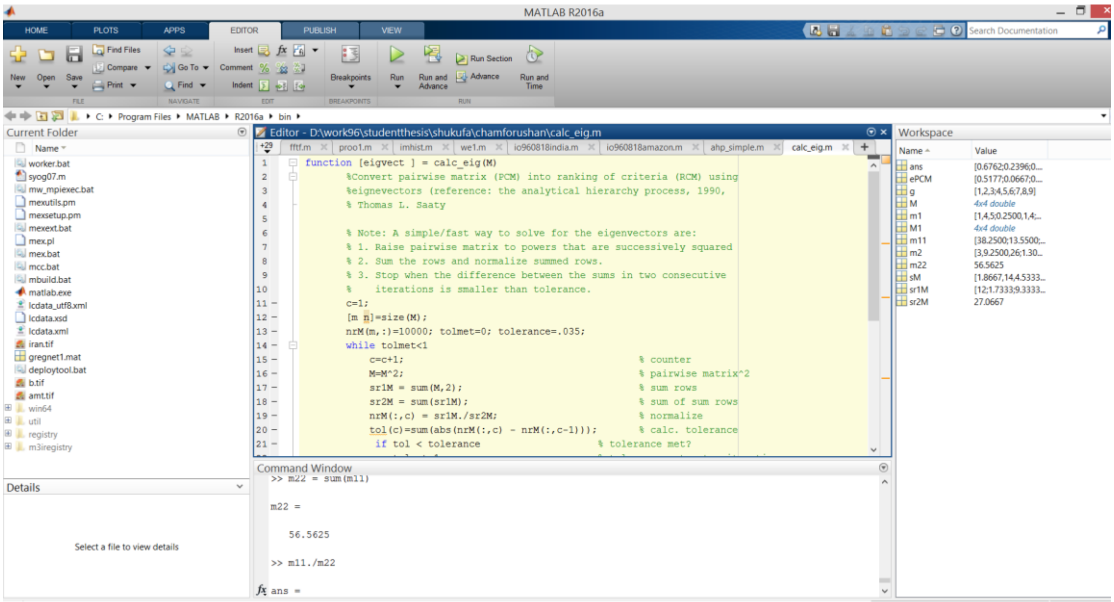


Figure 13- Continue of Written Code for Hierarchical Analysis[2]

The writing of weight matrices in the MATLAB software is shown in Figure 14.

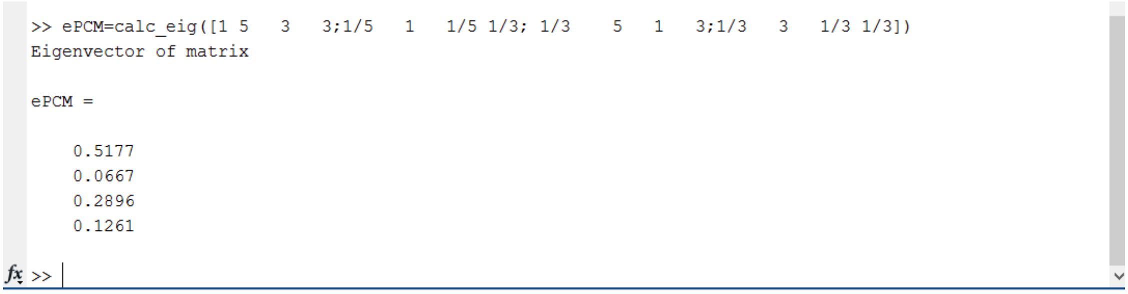
```
fx >> ePCM=calc_eig([1 5   3   3;1/5   1   1/5 1/3; 1/3    5   1   3;1/3   3   1/3 1\3])
```

Figure 14- The Writing of Weight Matrices in the MATLAB Software[3]

---

[1] Own work
[2] Own work
[3] Own work

The calculation of the specific vector value of the output of each matrix is shown in Figure 15.



```
>> ePCM=calc_eig([1 5   3   3;1/5   1   1/5 1/3; 1/3    5   1   3;1/3   3   1/3 1/3])
Eigenvector of matrix

ePCM =

    0.5177
    0.0667
    0.2896
    0.1261

>>
```

Figure 15- The Calculation of the Specific Vector Value of the Output of Each Matrix[1]

To calculate the special vector in the weight matrix, we perform as follows:

1. The weight matrix is multiplied by itself

2. The elements of each row are summed up and assigned to a variable such as “a“

3. The elements of the matrix “a“ are summed up and assigned to a variable “b“

4. Each of the elements of “a“ is divided by “b“ and a special vector is obtained.

For the weight matrix, the following operations are performed:

Step 1:

$$\begin{bmatrix} 1 & 4 & 5 \\ 1/4 & 1 & 4 \\ 1/5 & 1/4 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 4 & 5 \\ 1/4 & 1 & 4 \\ 1/5 & 1/4 & 1 \end{bmatrix} = \begin{bmatrix} 3 & 9.25 & 26 \\ 1.3 & 3 & 9.25 \\ 0.46 & 1.3 & 13 \end{bmatrix}$$

Step 2:

$$\begin{bmatrix} 3 & 9.25 & 26 \\ 1.3 & 3 & 9.25 \\ 0.46 & 1.3 & 13 \end{bmatrix} = \begin{bmatrix} 38.25 \\ 13.55 \\ 4.76 \end{bmatrix} = a$$

Step 3:

$$[55.65] = b$$

Step 4:

$$a/b = \begin{bmatrix} 0.67 \\ 0.24 \\ 0.84 \end{bmatrix}$$

[1] Own work

Determine the weight of the criteria:

The first level of hierarchy consisted of the main criteria. Also paired comparisons are converted into a fuzzy triangle. The first questionnaire examines the priority of each of the main criteria by paired comparison of the main criteria based on the goal. Therefore, we must compare the criteria on a two-way basis. The result of the questionnaire for the weight of the criteria is presented in Table 6.

Table 6- Paired Scale Between Criteria[1]

	Technical and technological	Easier access to information and required materials	Construction	Economic and Financial	Administrative and organizational	Socio-cultural	Weight
Technical and technological	(1,1,1)	(1,3,5)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(3,5,7)	0.098
Easier access to information and required materials		(1,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/5,1/3,1)	(1,3,5)	0.072
Construction			(1,1,1)	(1/7,1/5,1/3)	(1,3,5)	(3,5,7)	0.25
Economic and financial				(1,1,1)	(1,3,5)	(3,5,7)	0.34
Administrative and organizational					(1,1,1)	(3,5,7)	0.23
Socio-cultural						(1,1,1)	0

[1] Own work

In this matrix, the inconsistency of 0.097 is acceptable and there is no need to revise judgments.

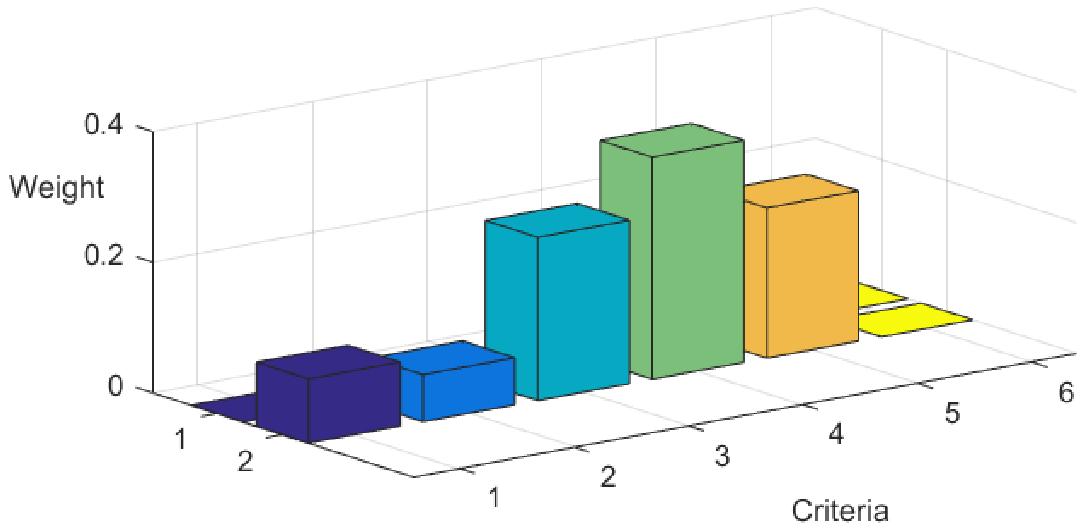


Figure 16- The weight of Each Criterion[1]

According to Figure 16 and Table 6, the priority of the criteria is as follows:

1. Economic and financial

2. Construction

3. Administrative and organizational

4. Easier access to information and required materials

5. Technical and technological

6. Social and cultural

7. Figure 16 shows the weight of each criterion. In this figure, the order from 1 to 6 is technical and technological criteria, Easier access to information and required materials, construction, economic and financial, administrative and organizational, social and cultural, with the highest weight of economic and financial criteria and the lowest weight of social and cultural criterion.

We consider the criteria in the order of C1 to C6 and the sub-criteria as A1 to A4.

---

[1] Own work

The paired scale matrix of options is based on C1 criterion in Table 7.

Table 7- Paired Scale Matrix of Options Based on C1 Criterion[1]

	A1	A2	A3	A4	Weight
A1	(1,1,1)	(1,3,5)	(1,3,5)	(5,7,9)	0.39
A2		(1,1,1)	(3,5,7)	(5,7,9)	0.47
A3			(1,1,1)	(1,3,5)	0.12
A4				(1,1,1)	0

In this matrix, the inconsistency of 0.092 is acceptable and there is no need to revise judgments.

Figure 17 shows the weight value of the options based on C1 criterion. In this figure, the order from 1 to 4 is insufficient studies and local information on land and work conditions, inappropriate design and design information in the correct estimation of cost, time and resources, limited access to projects materials, the lack of standard materials required with the highest weight belongs to the inappropriate design and design information in the correct estimation of cost, time and resources and the lowest weight criterion is the lack of standard materials required.

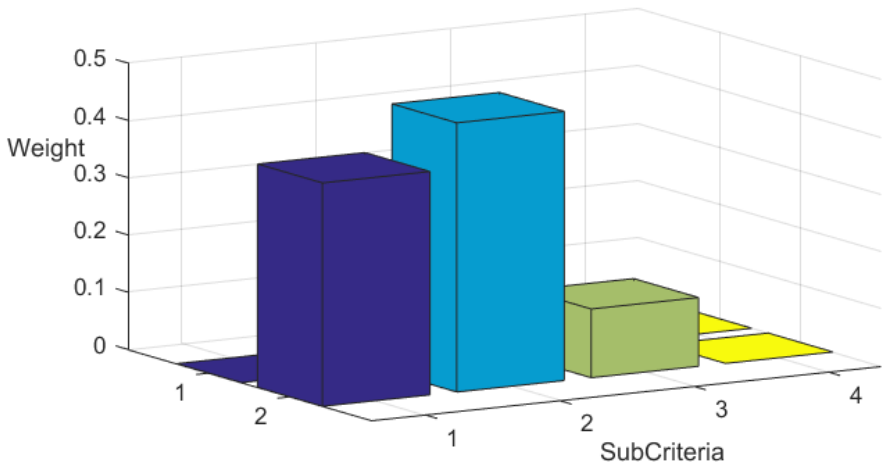


Figure 17- Weight of Each Sub-Criterion Based on the C1 Criterion[2]

[1] Own work
[2] Own work

The paired scale matrix of options based on C2 criterion is shown in Table 8.

Table 8- Paired Scale Matrix of Options Based on C2 Criterion[1]

	A1	A2	A3	A4	Weight
A1	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1,3,5)	0.24
A2		(1,1,1)	(1,3,5)	(3,5,7)	0.30
A3			(1,1,1)	(1,3,5)	0.24
A4				(1,1,1)	0.20

In this matrix, the inconsistency of 0.094 is acceptable and there is no need to revise judgments.

Figure 18 shows the weight value of the paired scale of the options based on C2 criterion. The order from 1 to 4 criteria is the lack of resources (land, materials and workers), lack of technical specialists in technical and workshop sensitive systems, a commitment to do things that the executor or the employer or the supervisor does not have a background of doing the same issues, working in border, deprived, or fighting areas, because of the probability of the existence of explosives and the subsequent risks resulted from it, with the highest weight belongs to the criterion of lack of technical specialists in technical and workshop sensitive systems, and the lowest weight for working in border, deprived, or fighting areas, because of the probability of the existence of explosives and the subsequent risks resulted from it.

[1] Own work

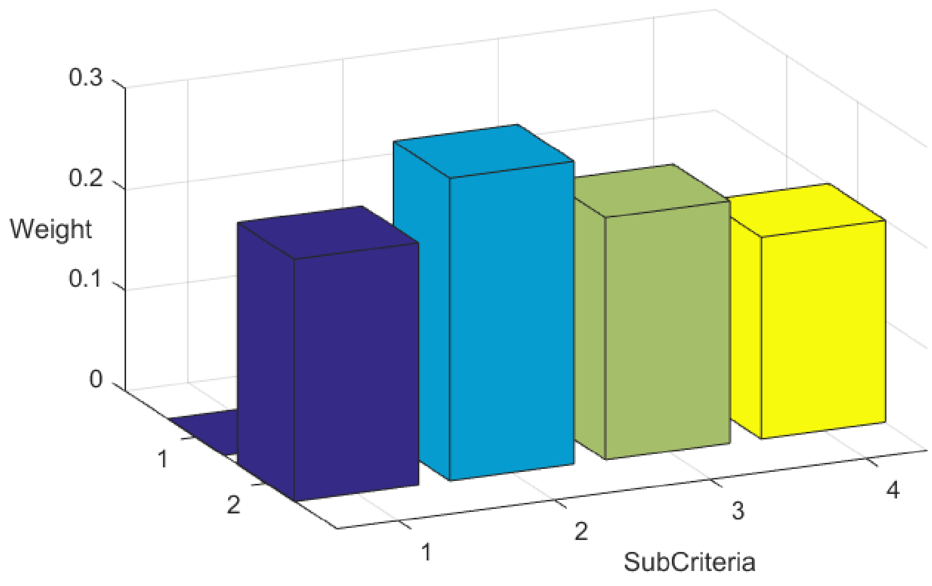


Figure 18- Weight of Each Sub-Criterion Based on Criterion C2[1]

The paired scale matrix of options is presented based on criterion C3 in Table 9.

Table 9- Paired Scale Matrix of Options Based on C3 Criterion[2]

	A1	A2	A3	A4	Weight
A1	(1,1,1)	(1,3,5)	(3,5,7)	(1,3,5)	0.14
A2		(1,1,1)	(1,3,5)	(1,3,5)	0.4
A3			(1,1,1)	(1,3,5)	0.2
A4				(1,1,1)	0.16

In this matrix, the inconsistency of 0.097 is acceptable and there is no need to revise judgments.

Figure 19 shows the paired scale value of options based on C3 criterion. The order from, 1 to 4 criteria is low efficiency and productivity, the lack of knowledge and proficiency of the contractor, working with unskilled employers, financially and managerially weak, prolonging the performance time and completion of projects for rational and irrational reasons and weather conditions, with the highest weight belongs

[1] Own work
[2] Own work

to the lack of knowledge and proficiency of the contractor and the lowest criterion for weather conditions.

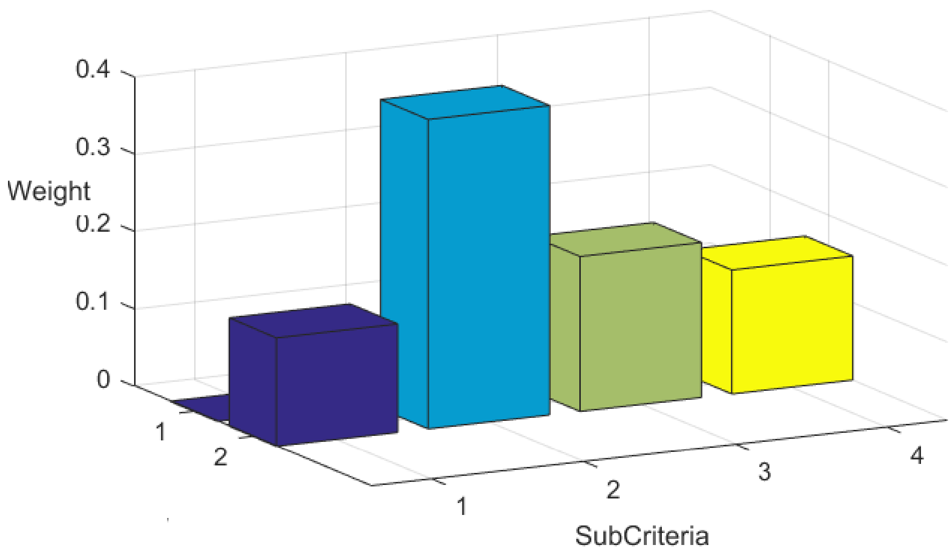


Figure 19- Weight of Each Sub-Criterion Based on C3 Criterion[1]

The paired scale matrix of options is presented based on C4 criterion in Table 10.

Table 10- Paired Scale Matrix of Options Based on C4 Criterion[2]

	A1	A2	A3	A4	Weight
A1	(1,1,1)	(5,7,9)	(3,5,7)	(3,5,7)	0.68
A2		(1,1,1)	(1/7,1/5,1/3)	(1,3,5)	0
A3			(1,1,1)	(1,3,5)	0.23
A4				(1,1,1)	0.07

In this matrix, the inconsistency of 0.091 is acceptable and there is no need to revise judgments.

Figure 20 shows the paired scale matrix of options based on C4 criterion. In this figure, the order from 1 to 4 criteria is the lack of cooperation of financial institutions in the

[1] Own work
[2] Own work

payment of facilities to employers, performing fixed and non-moderated works in areas with high and unpredictable inflation, material price fluctuations due to the economic conditions of the country, region and world, not having scale Inflation for costs and analyzing the cost of completion of projects, with the highest weight belongs to the lack of cooperation of financial institutions in the payment of facilities to employers and the lowest weight for not having scale Inflation for costs and analyzing the cost of completion of projects.

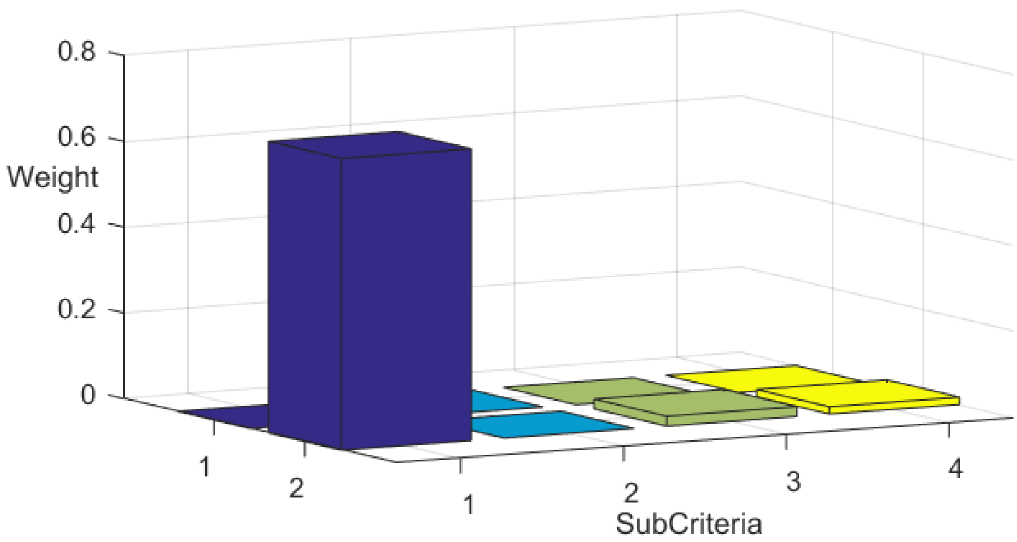


Figure 20- The Weight of Each Sub-Criterion Based on the C4 Criterion[1]

The paired scale matrix of options is presented based on C5 criterion in Table 11.

Table 11- Paired Scale Matrix of Options Based on C5 Criterion[2]

	A1	A2	A3	A4	Weight
A1	(1,1,1)	(1/5,1/3,1)	(1/7,1/5,1/3)	(3,5,7)	0.23
A2		(1,1,1)	(1/7,1/5,1/3)	(1,3,5)	0.07
A3			(1,1,1)	(5,7,9)	0.5
A4				(1,1,1)	0.2

[1] Own work
[2] Own work

In this matrix, the inconsistency of 0.095 is acceptable and there is no need to revise judgments.

Figure 21 shows the paired scale matrix of options based on C5 criterion. In this figure, the order from 1 to 4 criteria is inappropriate and inefficient management of administrative bureaucracy, structural, managerial, and probable changes in programs and objectives, inconsistencies between agencies and organizations that have an impact on the implementation of projects, weaknesses in the rules and personalization understanding of it in the above organizations, with the highest weight belongs to the criteria of inconsistencies between agencies and organizations that have an impact on the implementation of projects, and the lowest weight criterion for structural, managerial, and probable changes in programs and objectives.

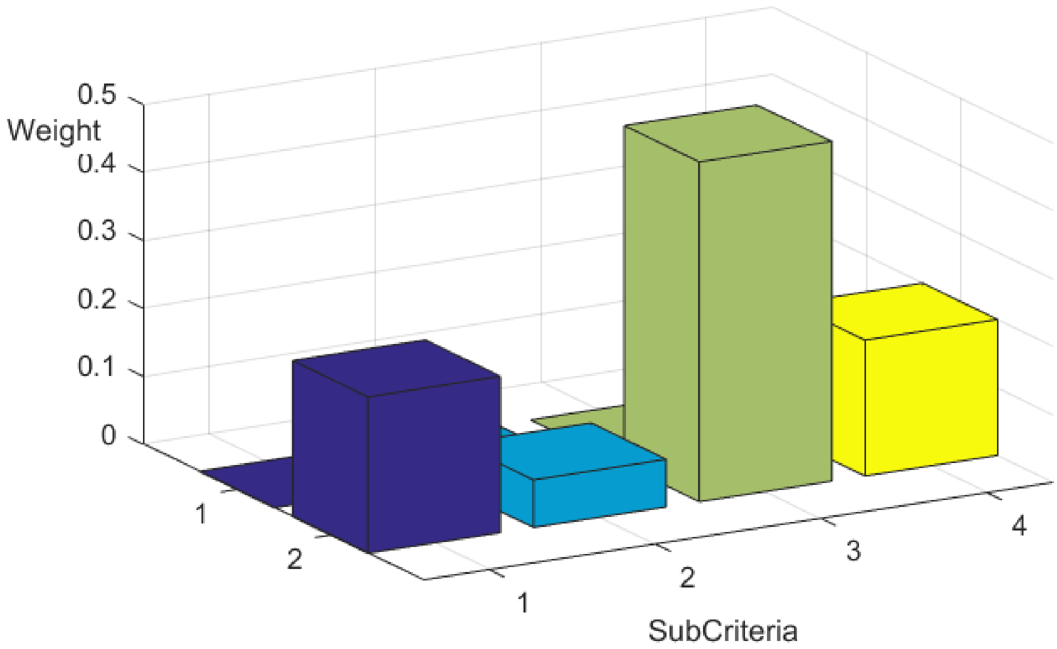


Figure 21- The Weight of Each Sub-Criterion Based on the C5 Criterion[1]

The paired scale matrix of options is presented based on C6 criterion in Table 12.

[1] Own work

Table 12- Paired Scale Matrix of Options Based on C6 Criterion[1]

	A1	A2	A3	A4	Weight
A1	(1,1,1)	(1/5,1/3,1)	(3,5,7)	(3,5,7)	0.37
A2		(1,1,1)	(1,3,5)	(1,3,5)	0.24
A3			(1,1,1)	(1,3,5)	0.18
A4				(1,1,1)	0.18

In this matrix, the inconsistency of 0.091 is acceptable and there is no need to revise judgments.

Figure 22 shows the paired scale matrix of the options based on C6 criterion. In this figure, the order from 1 to 4 criteria is inappropriate working and technical culture of executive agents and masters, not paying attention to cultural issues and social norms in design, population growth, migration and non-standard construction in marginal areas and cultural weakness in the use of projects, with the highest weight belongs to inappropriate working and technical culture of executive agents and masters and the lowest weight to population growth, migration and non-standard construction in the marginal areas and cultural weakness in the use of projects.

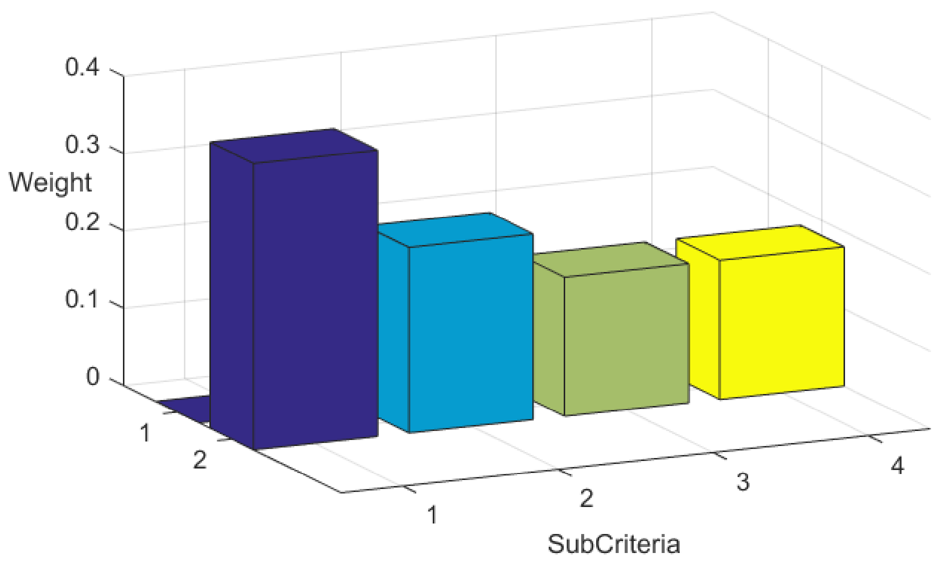


Figure 22- Weight of each sub-criterion based on C6 criterion[2]

[1] Own work
[2] Own work

The weight of each option is presented based on the criterion in Table 13.

Table 13- Weight of Each Option Based on Criteria[1]

	C1	C2	C3	C4	C5	C6	Score
S1	0.39	0.24	0.14	0.68	0.23	0.37	0.37
S2	0.47	0.30	0.4	0	0.07	0.24	0.18
S3	0.12	0.24	0.2	0.23	0.5	0.18	0.27
S4	0	0.20	0.16	0.07	0.2	0.18	0.12

Figure 23 shows the weight of each option based on criteria. In this figure, the order from 1 to 4 is cost estimation solutions, the provision of necessary equipment, the conduct of local environmental studies, the provision of safety and required forces, following the necessary bureaucracy in the relevant in the hierarchy process and the suspension of the project.

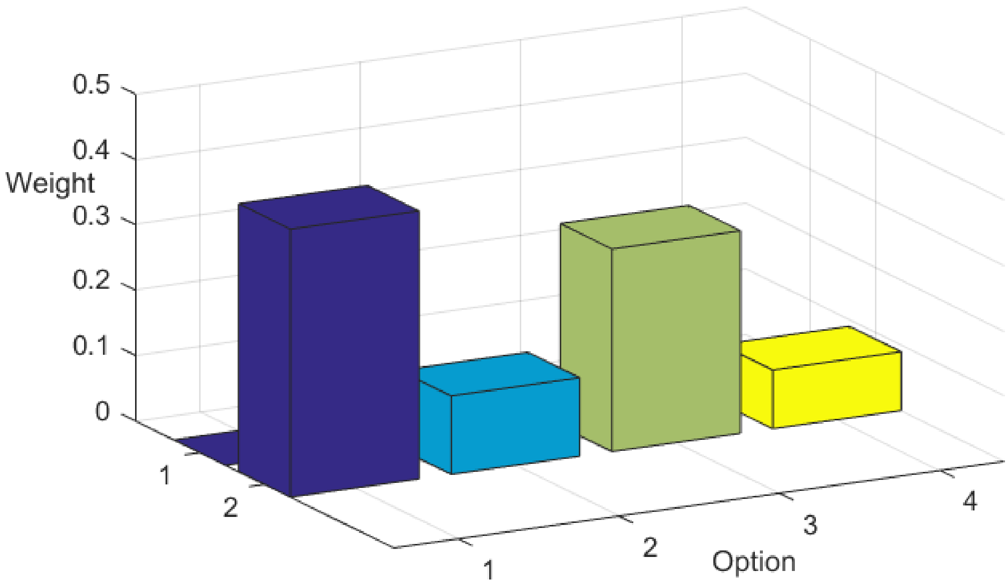


Figure 23- Weight of Each Solution Based on Criteria[2]

[1] Own work
[2] Own work

4.5 Conclusion of the Case Study

Solutions provided based on IPD and according to the fuzzy AHP ranking which is shown in Figure 23, are as follows:

S1>S3>S2>S4

Prioritization provided by hierarchical analysis is as follows:

1- Structure and performance of the project team S1

2- Defining and measuring project outputs S3

3- Defining the roles, responsibilities and scope of services S2

4- Legal Considerations S4

Chapter Five

5 Conclusion and Recommendations

5.1 Introduction

In recent years, there has been a growing trend in the construction industry, which has had a profound impact on the use of more detailed data on construction design. The use of these detailed data is required in the design of construction details before the overall design process. Building information modelling (modelling of building data) has emerged as a building design process to meet this need.

Building information modelling has revolutionized the construction industry for more than 20 years for the design and optimal and sustainable implementation of construction projects and increasing the production, productivity, infrastructure sustainability, quality, reduction of recycling and recurring costs has emerged in this industry. This important strategy is being followed and continued to grow in popularity in the construction industry, especially in the European and American countries.

5.2 Conclusion

In this thesis, the use of BIM for sustainable design and construction management has been investigated in developing countries. The questionnaire is based on the PMBOOK standard, which has 6 sections, these sections are as follow and completed by 44 experts. Risks in this questionnaire were a threat that increases the time and cost of the project. The main criteria are as follows:

1- Technical and technological
2- Easier access to information and required materials
3- Construction
4- Economic and Financial
5- Administrative and organizational
6- Socio-cultural

Considering the issue that in developing countries economic and financial factors are one of the main parameters affecting the whole country, the high weight of this criterion is expected to be 34%. In the prioritization, the second criterion of construction is weighted at 25%, the third criterion of administrative and organization is 23%, and in the fourth level, easier access to information and materials needed is 9% and in the fifth level technical and technological is 7%, and at the 6th level of social and cultural with 0%.

The used questionnaire for hierarchical analysis and multi-criteria decision making is called ‘‘Certified Questionnaire‘‘. The characteristics of respondents to the questionnaire were specified by three criteria: age, education, gender. In general, 44 respondents answered the questionnaire. Among the respondents, 27 were bachelor's degree, 10 respondents were master degree and 7 respondents were PhD degrees. The average age of respondents was 55 years old. Among the respondents, 9 respondents were female and 35 were male.

According to the experts' opinion, for each of the main sections, the following solutions are presented:

- Structure and performance of the project team S1
- Defining the roles, responsibilities and scope of services S2
- Defining and measuring project outputs S3
- Legal considerations S4

Solutions provided based on IPD and according to the fuzzy AHP ranking are as follows:

S1>S3>S2>S4

Prioritization provided by hierarchical analysis is as follows:

1. Structure and performance of the project team S1
2. Defining and measuring project outputs S3
3. Defining the roles, responsibilities and scope of services S2
4. Legal considerations S4

The first two solutions are 64% and the last two are 36%, reflecting the focus of the problems on the first two solutions. The result shows that the lack of structure and performance of the project team, along with the definition of BIM and its output measurements, is the most influential factor that needs to be addressed.

The framework provided to use the BIM for sustainable design and construction management is such that it can be used for any project and area. In the first step, the BIM implementation problems are identified and, in the next step, based on the opinion of the experts‘ solutions are provided on the IPD-based.

5.3 Suggestions

• Using methods to reduce project time, such as artificial intelligence, by entering time and cost of the project with regard to the progress of the project at a later time, presents the time and cost with high precision.

• Modern management of metropolises construction projects with intelligent CBR systems, this type of system is based on learning and training, and the time and cost of estimation depending on the weight to each previous stage are made as more to less.

• An investigation of optimal BIM implementation in developing countries based on meta-algorithms.

Appendix A

Questionnaire

Dear Respondent

This research tries to respond to the use of BIM for sustainable design and construction management. Hope with your cooperation, we achieve this matter. Therefore, you are requested to honestly answer the questions by spending your precious time. It should be noted that the questionnaire information will only be used for the purposes of the research and there is no need to mention your name in the questionnaire. Thank you very much for your sincere cooperation.

Please complete the following items before answering the questionnaire.

Personal Information:

Age: 30-40 ☐ 40-50 ☐ 50-60 ☐
Sex: Male ☐ Female ☐
Degree of Education: Bachelor Degree ☐ Master Degree ☐ Ph.D. ☐

Each section is divided into several sub-sections with a specified code as follows.

1. Technical and technological C1

- Insufficient studies and local information on land and work conditions A1
- Inappropriate design and design information in the correct estimation of cost, time and resources A2
- Limited access to projects materials A3
- The lack of Standard information in relevant organizations A4

2. Easier access to information and required materials C2

- Lack of resources (land, materials, and workers) A1
- Lack of technical specialists in technical and workshop sensitive systems A2
- A commitment to doing things that the executor or the employer or the supervisor does not have a background of doing the same issues A3

• Working in the border, deprived, or fighting areas, because of the probability of the existence of explosives and the subsequent risks resulted from it A4

3. Construction C3

• Low Efficiency and productivity and time delay A1

• The lack of knowledge and proficiency of the contractor increases the cost A2

• Working with unskilled employers, financially and managerially weak, prolonging the performance time and completion of projects for rational and irrational reasons A3

• Weather conditions A4

4. Economic and financial C4

• The lack of cooperation of financial institutions in the payment of facilities to employers A1

• Performing fixed and non-moderated works in areas with high and unpredictable inflation A2

• Material price fluctuations due to the economic conditions of the country, region and world A3

• Not having scale Inflation for costs and analyzing the cost of completion of projects A4

5. Administrative and organizational C5

• Inappropriate and inefficient management of administrative bureaucracy A1

• Structural, Managerial, and Probable Changes in Programs and Objectives A2

• Inconsistencies between agencies and organizations that have an impact on the implementation of projects A3

• Weaknesses in the rules and personalization understanding of it in the above organizations A4

6. Socio-cultural C6

• Inappropriate working and technical culture of executive agents and masters A1

• Not paying attention to cultural issues and social norms in design A2

• Population growth, migration and non-standard construction in the marginal areas A3

• Cultural weakness in the use of projects A4

Solutions provided based on Integrated Project Delivery (IPD) are as follows:

• Structure and performance of the project team S1

• Defining the roles, responsibilities and scope of services S2

• Defining and measuring project outputs S3

• Legal Considerations S4

The paired scale between criteria

	Technical and technological	**Easier access to information and required materials**	**Construction**	**Economic and financial**	**Administrative and organizational**	**Social and cultural**
Technical and technological	1	3	1/5	1/3	1/5	5
Easier access to information and required materials		1	1/5	1/5	1/3	3
Construction			1	1/5	3	5
Economic and financial				1	3	5
Administrative and organizational					1	1
Social and cultural						1

Paired scale matrix of options based on C1 criterion

	A1	A2	A3	A4
A1	1	3	3	7
A2		1	5	7
A3			1	3
A4				1

Paired scale matrix of options based on C2 criterion

	A1	A2	A3	A4
A1	1	1/3	1/3	3
A2		1	3	5
A3			1	3
A4				1

Paired scale matrix of options based on C3 criterion

	A1	A2	A3	A4
A1	1	3	5	3
A2		1	3	3
A3			1	3
A4				1

Paired scale matrix of options based on C4 criterion

	A1	A2	A3	A4
A1	1	7	5	7
A2		1	1/5	3
A3			1	3
A4				1

Paired scale matrix of options based on C5 criterion

	A1	A2	A3	A4
A1	1	1/3	1/5	5
A2		1	1/5	3
A3			1	7
A4				1

Paired scale matrix of options based on C6 criterion

	A1	A2	A3	A4
A1	1	1/3	5	5
A2		1	3	3
A3			1	3
A4				1

Paired Scales Matrix of Solutions

	S1	S2	S3	S4
S1	1	1/3	5	5
S2		1	3	3
S3			1	3
S4				1

Appendix B

MATLAB Code

The written code to calculate hierarchical analysis in MATLAB software is presented below.

```
function [eigvect ] = calc_eig(M)
%       Convert pairwise matrix (PCM) into the ranking of criteria (RCM) using
%       eignevectors (reference: the analytical hierarchy process, 1990,
 %       Thomas L. Saaty
Note: A simple/fast way to solve for the eigenvectors are:
1% Raise pairwise matrix to powers that are successively squared
2% Sum the rows and normalize summed rows.
3% Stop when the difference between the sums in two consecutive
% iterations are smaller than tolerance.
    c=1;
    [m n]= size(M);
    nrM(m,:)=10000; tolmet=0; tolerance=.035;
    while tolmet<1
      c=c+1;                          % counter
      M=M^2;                          % pairwise matrix^2
      sr1M = sum(M,2);                % sum rows
      sr2M = sum(sr1M);               % sum of sum rows
      nrM(:,c) = sr1M./sr2M;          % normalize
      tol(c)=sum(abs(nrM(:,c) - nrM(:,c-1)));      % calc. tolerance
       if tol < tolerance             % tolerance met?
         tolmet=1;                    % tolerance met, stop iterations
```

```
            elseif sum(sum(M))>=10e30
               tolmet=1;                    % tolerance unlikely, stop iterations
            end
        end
        disp('Eigenvector of matrix');
        eigvect = nrM(:,end); % eigenvector of PCM
    end
 %%sub-function to normalize a vector (0-1)
    function [normvect ] = calc_norm(M)
        sM = sum(M);
        normvect = M./sM;
        disp('Normalized matrix');
    end
function [Max_Car_Score ] = ahp_simple()
 %%AHP analytical hierarchy process, simple example
%
  %To run, just load script into editor and hit the run key!
%
 %This simple by example function (with default values) gives the basic
 %elements of the Analytical Hierarchial Process (AHP) for decision making
 %to include matrix formulations, pairwise analysis, calculating
 %eigenvectors, and determining the final 'best' decision based on criteria.
 %%Example problem:
 %Situation: I wish to purchase a car (civic, focus, corolla, BMW318)
 %and select the best car based on criteria (style, reliability,
 %and fuel economy). To make the best car purchase decision, I will use
```

```
 %AHP with the following:
        %alternatives:  civic, focus, corolla, BMW318
        %criteria:      style, reliability, fuel economy
------------------------------------------%%
 %%Problem formulation:
clear all; close all; clc;
 %%Step 1: Criteria Matrix and Criteria Eigenvector
 %
 %Since this part is subjective, I give reliability, style and fuel economy
 %importance. Thus I will rank these as follows (subjective qualitative):
 %Reliability (R) is 2 time as important as style (S)
 %Style (S) is 3 times as important as fuel economy (FE)
 %Reliability (R) is 4 times as important as fuel economy (FE)
 %Using Scale:
%-1 equal, 3-moderate, 5-strong, 7-very strong, 9-extreme
disp('Criteria Pairwise Comparison Matrix PCM');
 %pairwise comparison of each criteria to each criteria
 %denoted as the matrix PCM
     %(S)   (R)  (FE)
PCM= [ 1/1   1/2   3/1; ...   % (S-style)
) % ….; 1.4, 1.2, 1.1 R-reliability
) % [1.1   4.1    3.1 FE-fuel economy)
%        ePCM=eig(PCM)
  ePCM=calc_eig(PCM)
%%
%% Step 2: Alternatives Matrix and Alternatives Eigenvectors
```

```
% Alternative Ranking (Car to Car on Style, Reliability, and Fuel)
% Compaire each car to each car denoted as the alternatives
% (civic, focus, corolla, BMW318)
 %In the terms of style, reliability, and fuel economy using
 %pairwise comparison for qualitative and normalization for quantitative
 %
   %example of the style comparison
                  % civic       focus        corolla        BMW318
 %civic              1/1        1/4          4/1           1/6
 %focus               4/1        1/1          4/1           1/4
 %corolla             1/4        1/4          1/1           1/5
 %BMW318               6/1        4/1          5/1           1/1
 %%Compare Style:
disp('Style Comparison: Alternatives Qualitative Pairwise');
ACM_St = [ 1/1 1/4 4/1 1/6; ...
…; 4.1    1.4   1.1    1.4
….; 5.1   1.1   4.1    4.1
1.1     1.5     1.4    1.6
eACM_St = calc_eig(ACM_St) % calculate eigenvector on qualitative matrix
%%
 %%Compare Reliability:
disp('Reliability Comparison: Alternatives Qualitative Pairwise');
ACM_Re = [ 1/1 2/1 5/1 1/1; ...
…; 1.2   1.3   1.1 2.1
…; 4.1    1.1    3.1     5.1
1.1         1.4     2.1     1.1
```

```
eACM_Re = calc_eig(ACM_Re) % calculate eigenvector on qualitative matrix
 %%
 %%Compare Fuel Economy:
disp('Fuel Economy Comparision: Alternatives Quantitative (MPG)');
 %given MPG data for each vehicle, create a fuel economy matrix
  %MPG matrix
 cv = 34;  % civic
 sa = 27;   % focus
 es = 24;   % corolla
 cl = 28;   % BMW318
ACM_Fe = [ cv; ...
            sa; ...
            es; ...
            cl]
eACM_Fe  = calc_norm(ACM_Fe)  % normalize quantitative type data
 %%
 disp('Hit space key to continue to winner of benefits')
       pause ()
       clc;
%% Step 3:  Calculate Final Answer and Determine winner
 % construc a matrix of eigenvectors calculated above for each criteria
 % eigenvectors: Style   Reliability   Fuel-econ
 eM        =   [eACM_St   eACM_Re     eACM_Fe];

 % multiply eigenvector matrix by eigenvector of criteria to obtain
```

```
 % scores for each car based on criteria and car-to-car comparisons
 disp('Scores for: civic, focus, corolla, BMW318')
 Car_Scores = eM * ePCM
 %Best Car as a factor of benefits (criteria)
 disp('Winning Car based on benefits, BMW318')
 Max_Car_benefits = max(Car_Scores)
 disp('Hit space key to continue to calculate in costs')
        pause()
        clc;
 %% Step 4: Costs versus benefits
% now we consider costs
  benefits = Car_Scores;
%  Costs Matrix
 cv = 16;   % civic
 fo = 13;   % focus
 co = 15;   % corolla
 bm = 40;   % BMW318
costs = [ cv; ...
         fo;   ...
         co; ...
         bm]
ncosts = calc_norm(costs); %normalize costs
 disp('Benefits to cost ratio');
 benefits_cost_ratio=benefits./ncosts
disp('If costs are considered, then winner is focus')
 %%sub-function on calculating eigenvectors
```

```
function [eigvect ] = calc_eig(M)
%       Convert pairwise matrix (PCM) into the ranking of criteria (RCM) using
%       eignevectors (reference: the analytical hierarchy process, 1990,
%       Thomas L. Saaty
    % Note: A simple/fast way to solve for the eigenvectors are:
    % 1. Raise pairwise matrix to powers that are successively squared
    % 2. Sum the rows and normalize summed rows.
        c=c+1;                                   % counter
        M=M^2;                                   % pairwise matrix^2
        sr1M = sum(M,2);                         % sum rows
        sr2M = sum(sr1M);                        % sum of sum rows
        nrM(:,c) = sr1M./sr2M;                   % normalize
        tol(c)=sum(abs(nrM(:,c) - nrM(:,c-1)));       % calc. tolerance
         if tol < tolerance                 % tolerance met?
            tolmet=1;                       % tolerance met, stop iterations
         elseif sum(sum(M))>=10e30
             tolmet=1;                      % tolerance unlikely, stop iterations
         end
    end
    disp('Eigenvector of matrix');
    eigvect = nrM(:,end); % eigenvector of PCM
end
%%sub-function to normalize a vector (0-1)
function [normvect ] = calc_norm(M)
    sM = sum(M);
    normvect = M./sM;
```

```
        disp('Normalized matrix');
    end
end
```

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