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**ROLE OF BUILDING INFORMATION MODELING IN  
IMPROVING BUILDING DESIGN PROCESS IN ETHIOPIA  
The case of Addis Ababa.**

**Master's Program Thesis**

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This thesis is submitted to the Addis Ababa institute of Technology (AAiT) and to the School of Graduate Studies of Addis Ababa University in the Partial fulfillment of the requirements for the degree of Masters of Science in Construction Technology and Management.

**Title of Thesis: ROLE OF BUILDING INFORMATION MODELING IN IMPROVING BUILDING DESIGN PROCESS IN ETHIOPIA, The Case of Addis Ababa.**

Addis Ababa

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May, 2016

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## DECLARATION

I, the undersigned, declare that this thesis is my own and original work and has not been presented a degree in any other University, and that all sources of material used for the thesis has been duly acknowledged, following the scientific guidelines of the institute.

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## CONFIRMATION

This thesis has been submitted for examination with my approval as an Institute's advisor.

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## LISTS OF ACRONYMS

<b>A.A</b>	Addis Ababa
<b>AAiT</b>	Addis Ababa institute of Technology
<b>AAU</b>	Addis Ababa University
<b>AISC</b>	(American Institute of Steel Construction)-
<b>AWCI</b>	Association of the wall and ceiling industry
<b>BDE</b>	Building Design Enterprise
<b>BIM</b>	Building information modeling
<b>BOQ</b>	Bill of Quantity
<b>BREEAM</b>	Building Research Establishment for Environment Assessment Method
<b>CAD</b>	Computer Aided Design
<b>DGNB</b>	German Sustainable Building Council
<b>EiABC</b>	Ethiopian institute of Architecture, Building Construction and City Development
<b>FCI.</b>	Facility Condition Index
<b>FGD</b>	Focus Group Discussion
<b>GSA</b>	US General Service Administration [
<b>IFCs</b>	Industry Foundation Classes
<b>II</b>	Informal Interview
<b>LCCA</b>	life-cycle costing analysis
<b>NGOs</b>	Non-Governmental Organizations
<b>NIST r</b>	US National Institute of Standards and Technology
<b>PPAR</b>	practicing professional architect
<b>RFIs</b>	Requests for Information
<b>RFIs</b>	Requests for information
<b>VDC</b>	Virtual Design and Construction

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## ABSTRACT

Ethiopia is under a major and fast transformation on the subject of building construction. The country is now building grand projects in areas like, housings, higher education, health buildings and many more. This fast building construction industry faces many challenges, one of these challenges being the gap in building design process management basically caused by incomplete design and less integrated design management. The international practice, moved from the conventional to the integrated design modality, with the latest intervention of Building Information Modeling (BIM). There are a few attempts in Ethiopia, even though it is at its infant stage. This study focuses on reviewing the existing design management with in Addis Ababa; tries to identify the major gaps, problems and challenge and sees how such BIM can improve the situation in design related problems. To conduct this research, two methods are used, survey and case study. Questioner and interview for the survey having eleven G-I consultants used as a population taking two as samples and two governmental university projects as a case study.

The gaps identified in this research are to follow: - Most of the designers in the case area, are currently implementing the conventional designing approach, resulting in substandard property, fragmented building design process, errors and omissions in paper communication resenting in project period delays being the major gap, additional financial expense and reduction of quality are also take major portion, resulting undesirable friction between involved parties. The documents are fragmented and take longer time to prepare. The project going over budget, extended period and lesser quality are problems caused by the poor building design management. The major challenges of the building design process are very low project fee, no permanent staff, incomplete design with fewer details, limitation on accessing licensed software, expensive and unaffordable database infrastructure and lack of adequate training centers are also partly concluded as challenges. The majorities of the professionals in Ethiopia have at list the basic understanding of the significance and the advantages of BIM or used BIM application; this shows a promising future.

As a recommendation, BIM should be included in Ethiopian Building coed of standard; as fundamental tool for designing, design evaluation, project monitoring and follow-up and design documentation. Standard minimum professional fee should be set; banks should support the professionals by loan system so that they can adopt BIM; regulatory body, client, professionals should set integrated design management platform environment.

**Key words:** *building construction, design challenges, integrated design process, building information modeling [BIM], Design modality and sustainability*

## CHAPTER I: INTRODUCTION

To quote technology industry analyst Jerry Laiserin,

“The real promise of BIM lies in its application across the entire project team, especially in the area of improved building performance.”

The two types of human settlements: urban and rural settlements. In earlier times rural settlement was incomparably dominant but, in the course of times the urban increases and the rural decreases especially after industrial revolution that started in England. Thus, more densely populated industrial cities were created due to migration from rural to urban to work in the industries. Along with this urbanization process many new buildings were designed and built together with its growing problems, like continuous increasing of cost of construction materials, high energy requirement for the production and installation of construction materials, shortage of places to live, work and entertain and expensive occupancy...etc. These problems still exist and are given serious attention in most of the areas. Addis Ababa as one of these urban area, who faces multiple challenges, of which is building design process management. The city government of Addis Ababa is trying to solve this problem in different mechanism.

Another issue that is currently concerning the construction industry including these urban areas is the subject of sustainability. Sustainability is a concept that started in 1960s from concerns to environmental pollution and shaped into a wider scope in the last four decades. Facts from different studies indicate that the earth is highly affected and is being affected by human action raising concern to mitigate and if possible to reverse this situation. Thus, the issue of sustainability has gained a worldwide acceptance and is linked to almost all kinds of development activities making it the main stream development paradigm where nations are shaping their policies and strategies towards it.

Shelter or in general building is one of the basic human needs. Like any investment, building construction industry demands labor, capital and technology. It produces a physical asset, thus construction industry is really one of the forefront development concerns or issues. As it is said above today all development activity is expected to be in alignment with sustainability meaning our construction industry needs to be sustainable transforming development. Integrated design process-building information modeling [BIM] modality has been used by the developed world, for more efficiency and sustainable output.

## 1.1 BACKGROUND OF THE STUDY

Since the discovery and implementation, Building Information Modeling (BIM) has been one best way to construct a building virtually, and to the detail. BIM is not just the latest release of CAD software; it is an entirely new way of looking at the design and construction of a building.

Many consultants in the world are now days upgrading to BIM as the solution to most, if not all, construction industry ills, solving both design and construction problems while also providing a complete as-built 3-D building model as a property management facility upon completion of the project.

Those who have already taken the BIM jump, whether architects or contractors, report that they already see significant benefits, and savings, with BIM technology and processes; a reported reduction to near zero job RFIs (Requests for Information) and in-the-field change orders speaks for itself.

During the BIM-design phase you can not only attach and place the materials that will make up the finished structure, including concrete slabs, re-bar, steel structure, wall and ceiling components, HVAC, plumbing and electrical, but you can also test all such parts for conflicts ash detection. To ensure everything will come together seamlessly. This makes thing to be very efficient, as one don't have to wait till later to test it on the field.

It is also very possible to use this 3-D building model to analyze the designed building's energy efficiency by running "what if" scenarios to determine the best of several potential solutions. In addition, depending on the detail of the model, you can automatically take off all items contained in the model and can easily quantify that way produce an impressively precise estimate.

The software and database management technology exist today to accomplish exactly this. What has yet to be realized and bought in to by a large majority of our industry, however, is the degree of collaboration and coordination between the various construction disciplines that BIM calls for.

Not only the owners and architects, but engineers, contractors and, ideally, subcontractors as well, need to be involved in the project from the outset; in other words, during the design of the building. This, of course, invariably means some form of design-build rather than the currently prevailing design-bid-build process.

Those who claim that BIM has yet to enter prime time also have a point that there are still many issues to be resolved; chief among them being the question of interoperability among various BIM software, the learning curve involved in implementing BIM, and the necessary paradigm shift in how buildings are designed and constructed.

Opinions notwithstanding, BIM is moving forward. Several high-visibility projects, such as the Freedom Tower in New York City, are BIM-designed and constructed. While it may still be on the horizon for most of AWCI's membership, BIM is approaching rapidly.

To date, BIM has offered only glimpses of what 3-D modeling, and the requisite team spirit to make it work, are capable of. As more government agencies specify BIM in their contracts, as more benefits surface, and as more owners see and share higher profits, BIM will find full traction and will reshape the industry. It is not a question of if, it is a question of when.

The contractor or subcontractor who gears up now or at the least fully informs him or herself about what BIM can do for his or her company, or how a BIM enabled company might better serve the industry will soon be in high demand. Those who feel that the boat is doing just fine and should not be rocked may find themselves scrambling for BIM tools and rushing into perhaps risky choices once BIM becomes a general requirement, be it for economic, green or other reasons.

The important thing to be realized is that BIM, at heart, is not just software but a “human activity that ultimately involves broad process changes in construction.”

Although the concepts and methodologies we now understand as Building Information Modeling date back as far as 30 years and then primarily within the manufacturing and aerospace industries, BIM as a design and construction term was introduced about 15 years ago to set the then emerging, information-rich, architectural computer-3-D modeling apart from traditional, and mainly paper-based, 2-D design and drawing.

BIM aimed to designate both a software approach and a method of designing and constructing a building by the use of highly coordinated and internally consistent computable information about the building; all the way from conceptual design, through construction, to post construction and asset management.

A correctly assembled BIM is a reliable, digital, three dimensional, “virtual” representation of the project to be built, for use in design decision making, in construction document production, in

construction scheduling and planning, in performance predictions and in cost estimates. Keep in mind that, as with all other computer based applications, the quality of the output is always limited by, and does reflect, the quality of the input.

With what in essence is a three dimensional representation of a centralized database containing all items that will comprise the actual building including their location, dimension, relation to other items, composition, cost, as well as their ordering or manufacturing details. The owner, architect, engineer, contractor, subcontractor and manufacturer have a clear view of the project as a whole, in one up-to-date and integrated digital environment.

The model, again assuming all input is correct, will provide the builder an easily assimilated view of the entire picture, its interrelations, and of any positional conflicts and problems. And most importantly, it will also provide the information and the understanding necessary to resolve positional conflicts and other issues during the design phase, rather than later the on construction phase.

These potential benefits notwithstanding, many organizations are still taking a wait-and-see attitude about BIM, waiting for the proverbial jury to return.

Needless to say, for BIM software vendors, the jury is back, and has been for a while: BIM is the answer.

The consensus among those who have actually used BIM is that, BIM saves both time and money, sees fewer conflicts and design errors along with a drastic reduction in RFIs and change orders and improves productivity.

BIM is used not only for drawings but also, it contains an information and data that are imbedded in building. The components and elements used to draw the building contain a prior information in their database or their library.

The 3-D images of that BIM produce are no longer only surfaces and shapes. BIM conceptually coordinates objects as it is to be constructed.

They are objects with content. As an example; the wall contains studs at indicated intervals; it contains wallboard of a certain thickness. The concrete slab contains rebar to increase tensile strength. The windows are well

If all database fields (parameters) pertaining to a given object are correctly populated, and it is easy to find out everything need to know about any given item, including, among other things, its position and relation to other items, its R-value, its manufacturer, its cost, its place of manufacture, its use of recycled material, and its delivery time even its installation instructions.

Easy to look at a true (meaning all pertinent information is accurately entered) BIM rendering and know as much about what you are looking at as if the building is seen as the real thing, in real time. And easy to understand the BIM 3-D model so much better than a 2-D drawing, because one can see it as it is supposed to look.

Of the many strengths of BIM, the crucial is that, BIM truly facilitates communication and understanding among the different stakeholders. BIM facilitates communication between the owner and the designer and between the designer and the contractor, who now sees how it all goes together, and who can be assured through clash detection that there will be no conflicts; and between the contractor and the subcontractor, who also gains a much better understanding of what, exactly, is to be done from the clear visual that BIM offers.

## 1.2 STATEMENT OF THE PROBLEM

Nowadays, there are many improvements in constructing sustainable buildings. Many initiatives and experiments have been taken in order to make buildings to be built sustainable and durable. This concept is poorly applied on the currently being built buildings in Ethiopia particularly in Addis Ababa mainly because of lack of awareness among the professionals and high infrastructure establishment cost.

It has also become very common to observe construction projects going over budget and extended period. One major problem for this is incomplete drawing from the consultant; an additional problem on top of this is that, those incomplete architectural and engineering drawings are not coherent.

According to Addis Ababa housing agency 70% of the project in Ethiopia goes over budget and time and of those 55% is caused because of incomplete drawings.

Taking the example of Construction Design S. Co, the two projects out of three go over schedule, over budget and ends up creating pressure on the client.

The working drawings might differ from the architectural drawings; the architectural drawing might not be consistent with the structural design and drawings, and vice versa. The authority that is responsible for the checking of the drawings and the coherence approves the drawings because of lack of proper tool of checking. Then when the Client proceeds to the construction, those differences force the Client to pay more than expected, directly or indirectly without getting the project with in the expected project completion period.

Looking at the current practice in Ethiopia, the consultant outsources the different engineering design services resulting in designs that do not correlate or sometimes design that even conflict with each other. This weak system is also promoting freelancers, which are not bounded by the national taxation system, and lack accountability in terms of the outcome.

Because the design is not made centrally, the architectural and different engineering outputs lack relationship, resulting in cost and time over run, so, the modification and wrongly implemented constructions are on the cost of the client.

## **1.3. OBJECTIVE**

### **1.3.1 GENERAL OBJECTIVE**

- ❖ To identify advantages and challenges of applying BIM for Ethiopian design process management.

### **1.3.2 SPECIFIC OBJECTIVES**

Within the above broad objective, this study has the following specific objectives:

- ❖ To find the gaps in building design process management in Ethiopia at inception (planning) and design Stage.
- ❖ To find out the key problems and challenges that building design process management faces.
- ❖ To figure out possible draw backs on implementation of BIM in Ethiopia.
- ❖ To study, if BIM can be applied sustainably to improve building design process management in Ethiopia.

## **1.5. SCOPE AND LIMITATION OF RESEARCH**

### **1.5.1. SCOPE OF THE RESEARCH**

The main scope of the study is to contextualize BIM as a sustainable way of building designing process management system in Ethiopia and evaluate it based on international framework.

This research is limited to Addis Ababa where over 80% of consultants for architectural and engineering design reside. It is also limited to consultancy offices with category I /One/; this is because most bids for public grand project by the private and governmental agencies are carried out for consultancy office category I /one/. And also the capital for running the office is above  $2 \times 10^5$  ETB which can undertake projects over  $200 \times 10^6$  ETB.

### **1.6. SIGNIFICANCE OF RESEARCH**

The Ethiopian government allocated 178.6 billion Birr for the 2007 Ethiopian Fiscal Year Federal budget. It has an increase of 15.3 percent from the previous year budget. From the allocated budget for infrastructure which goes directly in the pocket of infrastructure and construction industry which covers over 70% of the overall allocated budget. 5-8% is used for building out of the total budget allocated for infrastructure, including housing, higher education buildings, health buildings and many more. Unless this money is managed properly the country will definitely loss. And will be difficult to fulfill the five year /GTP/ Growth and Transformation Program goals. Even in Addis Ababa substantial numbers of buildings are being built and/or under construction. [ (The World Bank Group, 2016)]

Prioritizing problems on the construction design service management and to propose an alternative and sustainable building design modality will improve the quality and also improve unintended money and time loss during design, planning and on construction phase.

Reducing back and forth route on design and drawing between professionals, granting coordination, consistency and correlation speeds up design process procedure.

If the design is to be made centrally, where all the architectural and different engineering out puts are made to a certain relationship, then that is one sustainable way of reduction of cost and time, whereby, the client spent for frequent revisions.

The ultimate aim of a research is to reduce project cost by 20% and cut project period extension caused by improper design and/or drawings; this way, to contribute in some way to the existing knowledge we have in the field of Architecture and construction management industry.

This research is important because this is a relatively a new idea that could potentially fill the gap in between sustainable design management system. And more importantly it tries to answer what the difference between the trend of building and designing in Addis Ababa and the advanced contemporary technology of designing.

This research paper will have its own significance as an academic input, social transformation, economic development and technological improvement. The outcome of the research depends on the facts collected from up dated resources and current situations. This in turn will add to reliability of the information gathered.

Academically this paper can be used as pioneering ground to professionals and other individuals whom in the future may establish too deeply conduct further researches related to the topic.

## **CHAPTER II: METHODOLOGY**

Research Methodology is the path to find answers to research objectives. It is a practical step through which a researcher must pass in his/her research journey in order to find answers to his/her research questions.

### **2.1 TYPES OF RESEARCH**

This research consists of both descriptive and explanatory research types. Descriptive research type tries to describe a certain problem, phenomenon, or a situation systematically to simply to provide information about the living condition. Whereas explanatory type of research is used to explain the how and why there is an existence relationship / interdependence between two or more aspects of a situation. The Mixed types of quantitative and qualitative approaches were used under the two structures of inquiry modes:

To conduct this research, two methods are used, survey and case study. Questionnaires and interview for the survey having eleven G-I consultants as a population taking two as samples and two governmental university projects as a case study. Archival document review is done on these two projects, AXUM UNIVERSITY LIBRARY and DEBRE-MARKOS STAFF LOUNGE designed by Construction Design S. Co. The reviewed document was re-checked and triangulated through an interview and site visit.

### **2.2 TYPES OF DATA & MATERIALS**

For this research both primary and secondary data sources are used to filter out the major problems and challenges that the building design industry faces.

#### **2.2.1 PRIMARY DATA**

These include case study's architectural and engineering drawings, archival documents, site visit, personal observation; interviews, small focus group discussion and questionnaires are this research's as a primary data source.

#### **.2.2.2 SECONDARY DATA**

These include literatures in the fields of BIM, and other collateral data that were of great help to this research. Also include Architectural and engineering drawings, maps showing infrastructure distribution.

## **2.3 DATA SOURCES AND COLLECTION TECHNIQUES**

The research relied on the data collected from questionnaire, case study, related literature reviews, site visits and observations, sample survey. Since the concept of BIM is relatively new to the study area, it was necessary to rely upon internet search on legitimate web sites. Few experts' discussion consisting of fellow colleagues that had worked on the title of BIM was of great help to understanding the issue at hand.

### **2.3.1 PRIMERY DATA SOURCE AND COLLECTION TECHNIQUES**

Concerned government officials, Owners and managers, consultants, contractors and professionals and Personal observation and experiences were the main sources of the primary data. The following data collection methods were used to collect these primary data:

#### **1. CASE STUDY**

Two higher education projects design and archival document review is done, AXUM UNIVERSITY LIBRARY and DEBRE-MARKOS STAFF LOUNGE designed by Construction Design S. Co. project's architectural, structural, electrical sanitary and BOQ; drawings and documents were compared with one another and tried to find the difference between them. And tried to find the project delay, additional cost and loss of quality it incurred.

#### **2. INTERVIEWS**

Drawings and archive documents were re-checked and triangulated through an independent interviews with involved professionals, project's design head and project architect Mr. Neway Semunigus [ArchEng MSC], structural designer Mr. Milkiyas Mezegebeziker [ST Eng. BSc], Electrical designer Mr. Elyas Tesfaye [EL Eng. Bsc.], Sanitary designer Mr. Leulseged Ali [Water supply and environmental Eng. BSc.], Mechanical designer Mr. Miteku Negash [Mech Eng. BSc.] and Mr. Quantity surveyor Iman Abdulaziz [Adv. Diploma].

Small focus group discussion was conducted with, researcher and instructor on BIM Mr. Denamo Addissie [PHD candidate], Cad and Visual Informatics Expert and instructor at EiABC Mr. Yele Bedada [Arch BSC], PPAR and Design team Leader ETG consult Mr. Megersa Biyena [Arch BSC] and PPAR and Design team Leader Construction Design S. Co Mr. Neway Semunigus [ArchEng MSC].

### **3. PHYSICAL OBSERVATION METHOD**

Own direct observation is used through taking photographs of the case study aided with field notes and sketches.

### **4. CONTACT METHOD**

An informal Interview was used for gathering descriptive information from representatives' of, owners, construction managers, Consultants, contractors, resident engineers and on site experts.

### **5. SURVEY METHOD**

Both direct and indirect approach questions were used with the aid of Structured Surveys (using predefined lists of questions in which all respondents were asked in the same way) and Unstructured Surveys (by probing the respondents and guide the interview according to their answers).

### **6. SAMPLE SIZE AND SAMPLING TECHNIQUES**

Random sampling was used to select different stakeholders with different scale. There are 11 consultants in Addis Ababa currently registered from category 1/one/ which we considered here as a total population.[ (Ministry of Urban Development Housing and Construction, 2013)]

The sampling size selected will be governed by representative samples of consultants that are selected to study the existing contextual frame work. Further criterion for selection of consultants is: Consultants that have worked for at list 15/fifteen/ governmental projects and 15/fifteen/ privately owned project for the last five years, out of which a total of six [two from category 1] will be selected by means of a lottery.

To evaluate the building design process management in Ethiopia from inception to design, anonyms check list will be distributed among consultancy offices, to check if they fallow any international frame work and service modality to find out problems facing building design process management a questionnaire is distributed among the selected consultant.

With the requirements set above, two representative consultants and two governmental projects will be selected and distribute 75# questioners with a 20% unreturn rate.

After data collection it will be organized and analyzed by using double data entry system.

Then the evaluation process undergoes and findings will be drawn from the process followed by conclusion. Based on the final outcome a possible recommendation will be prepared. The research report will be written meanwhile.

### **2.3.2 SECONDARY DATA SOURCE AND COLLECTION TECHNIQUES**

The main sources used to collect the secondary data were both hard and Softcopies which include: Published books and journals; unpublished norms and standards, reports, brochures from internet, libraries and office stacks;

The secondary data were collected through reading and note taking; scanning and photocopying books, journals, reports and maps; browsing and extracting through trusted websites.

### **2.4 DATA ANALYSIS AND INTERPRETATION TECHNIQUES**

Software such as Microsoft office Word, Microsoft office Excel was used to write texts, create tables and graphs. These softwares are also used to analyze and present the surveyed data from questionnaires and interviews.

To organize the data different possible techniques is used not forgetting editing and description. Editing is the first step where unnecessary information is cut out and the remaining is sorted. Also, for any kind of data that needs conformation from the source officially it was sent for confirmation. In the description stage all kinds of sorted data is reviewed and additional descriptions and explanations of data is undertaken as required. The descriptions could are textual, graphs, numeric findings...

In addition to the search for the fact contained in the data the analysis of the organized data aimed at preparing the data for a direct uses in the evaluation process. Here again different techniques are used based on the data type like brainstorming, asking questions, making comparison (quantitative or conceptual comparison) and arithmetic analysis.

## **2.5 PRESENTATION TECHNIQUES**

Illustrations that were easily understood and could be translated were used to present the analyzed data, results and proposals. Charts, tables, maps, contextual drawings are self-explanatory and used in such a way that they could explain a certain relationship among issues.

## **2.6 OUTPUTS AND REPORTS**

This research paper contains remedial solutions for possible problems that revealed through the research process. The solutions are design modifications which are shown by illustrating the existing buildings supporting with graphs and charts.

This paper is reported in both hardcopy and Soft copy for Addis Ababa University, Addis Ababa Institute of Technology (AAiT) and Post Graduate Program Office.

## **CHAPTER III: LITERATURE REVIEW**

This chapter discusses the results gained through different methods predefined under the methodology of the study to answer the objectives stated to be attained in this thesis paper. The result includes: gaps identified in conventional design process, integrated design process, design process frame work, BIM application, its major drawbacks and challenges in Ethiopian context.

The conceptual framework aims at implementing sustainability principles in the building design industry. The proposed framework based on the sustainable triple bottom line principle, includes resource conservation, cost efficiency and design for human adaptation. Following thorough this literature review, each principle involving strategies and methods to be applied during the life cycle of building design is explained and a few case studies are presented for clarity on the methods. The framework will allow design teams to have an appropriate balance between economic, social and environmental issues, changing the way design practitioners think about the information they use when assessing building projects.

The Integrated Design Process (IDP) describes a more holistic approach to building design that has been developed on the basis of experience gained. Resulting in very high levels of performance, and its technical requirements cover energy performance, environmental impacts, indoor environment, functionality and a range of other related parameters. The performance goals of the program led its managers to believe that the incremental costs for design and construction would be substantial, and provision was made for support of incremental costs in both the design and construction phase.

### **3.1 THE CONVENTIONAL DESIGN PROCESS**

In order to understand what the IDP is, it is useful to first characterize the more conventional design process. The process often begins with the architect and the client agreeing on a design concept, consisting of a general massing scheme, orientation, fenestration and, usually, the general exterior appearance as determined by these characteristics as well as by basic materials. The mechanical and electrical engineers then design and suggest appropriate systems.

Although this is vastly oversimplified, such a process is one that is followed by the large majority of general-purpose design firms, and it generally limits the achievable performance to conventional levels. The traditional design process has a mainly linear structure due to the successive contributions of the members of the design team. There is a limited possibility of optimization during the traditional process, while optimization in the later stages of the process is often troublesome or even impossible. For example, little advantage may be taken of passive solar potential; there may be excessive exposure to high solar gain during the summer, and poor day lighting and discomfort for the occupants. All these potential outcomes reflect a design process that appears to be quick and simple, but actual results are often high operating costs and an interior environment that is sub-standard; and these factors in turn may greatly reduce the long-term rental or asset value of a property. Since the conventional design process usually does not involve computer simulations of predicted energy performance, the resulting poor performance and high operating costs will most often come as a surprise to the owners, operators or users. If the engineers involved in such a process are clever, they may suggest advanced, high-performance heating, cooling and lighting systems, but their inclusion at a late stage in the design process will result in only marginal performance increases, combined with considerable capital cost increases. The underlying cause is that the introduction of high-performance systems late in the design process cannot overcome the handicaps imposed by initial incompatible or otherwise poor design decisions.

### **3.1.1 GAPES IN THE CONVENTIONAL DESIGN PROCESS**

Currently, the facility delivery process remains fragmented, and it depends on paper-based modes of communication. Errors and omissions in paper documents often cause unanticipated field costs, delays, and eventual lawsuits between the various parties in a project team. These problems cause friction, financial expense, and delays. Efforts to address such problems have included: alternative organizational structures such as the design-build method; the use of real-time technology, such as project Web sites for sharing plans and documents; and the implementation of 3D CAD tools. Though these methods have improved the timely exchange of information, they have done little to reduce the severity and frequency of conflicts caused by paper documents or their electronic equivalents.

One of the most common problems associated with 2D-based communication during the design phase is the considerable time and expense required to generate critical assessment information

about a proposed design, including cost estimates, energy-use analysis, structural details, and so forth. These analyses are normally done last, when it is already too late to make important changes. Because these iterative improvements do not happen during the design phase, value engineering must then be undertaken to address discrepancies, which often results in compromises to the original design

It is not easy to manage a team involving such a large number of people and documents, regardless of any contractual approach taken.

### 3.2 THE INTEGRATED DESIGN PROCESS

The Integrated Design Process has impacts on the design team that differentiate it from a conventional design process in several respects. The client takes a more active role than usual; the architect becomes a team leader rather than the sole form-giver; and the structural, mechanical and electrical engineers take on active roles at early design stages. The team always includes an energy specialist and, in some cases, an independent Design Facilitator.

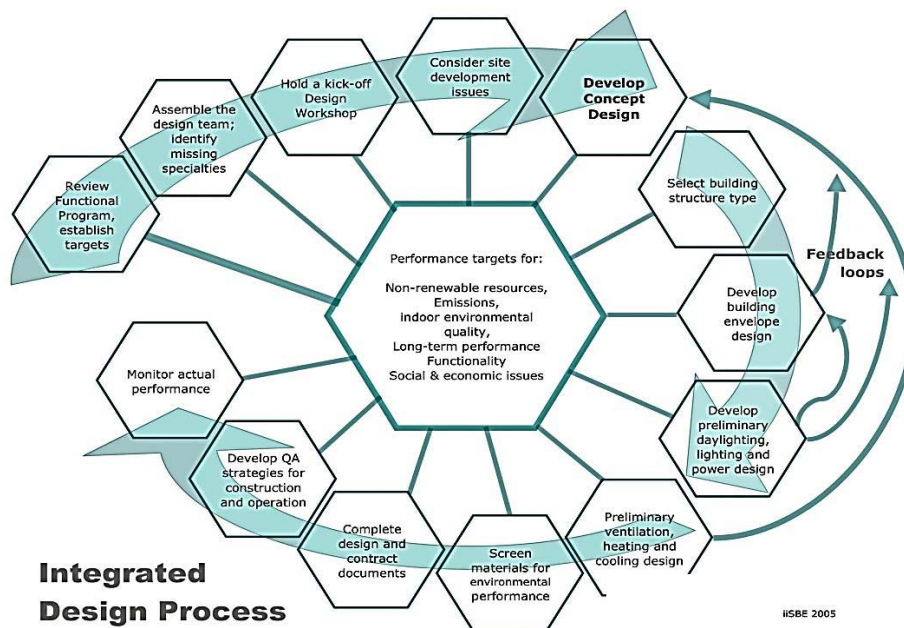


Figure 1, Integrated Design Process

The IDP process contains no elements that are radically new, but integrates well-proven approaches into a systematic total process. The skills and experience of mechanical and electrical engineers, and those of more specialized consultants, can be integrated at the concept design level from the very beginning of the design process. When carried out in a spirit of co-operation among key actors, this results in a design that is highly efficient with minimal, and sometimes zero, incremental capital costs, along with reduced long-term operating and maintenance costs. The benefits of the IDP process are not limited to the improvement of environmental performance. Experience shows that the open inter-disciplinary discussion and synergistic approach will often lead to improvements in the functional program, in the selection of structural systems and in architectural expression.

The IDP process is based on the well-proven observation that changes and improvements in any design process are relatively easy to make at the beginning of the process, but become increasingly difficult and disruptive as the process unfolds. Although this may seem obvious, it is a fact that most clients and designers have not followed up on the implications. As well, the existence of a defined roadmap gives credence and form to the process, making it easier to promote and implement.

Typical IDP elements include the following:

- Inter-disciplinary work between architects, engineers, costing specialists, operations people and other relevant actors right from the beginning of the design process;
- Discussion of the relative importance of various performance issues and the establishment of a consensus on this matter between client and designers;
- Budget restrictions applied at the whole-building level, with no strict separation of budgets for individual building systems, such as HVAC or the building structure. This reflects the experience that extra expenditures for one system, e.g. for sun shading devices, may reduce costs in another systems, e.g, capital and operating costs for a cooling system;
- Addition of a specialist in the field of energy engineering and energy simulation;

- Testing of various design assumptions through the use of energy simulations throughout the process, to provide relatively objective information on this key aspect of performance;
- Addition of subject specialists (e.g. for day lighting, thermal storage, comfort, materials selection etc.) for short consultations with the design team;
- Clear articulation of performance targets and strategies, to be updated throughout the process by the design team; and
- In some cases, a Design Facilitator is added to the team to raise performance issues throughout the process and ensure specialist inputs as required.

Based on experience in Europe and North America, an IDP is especially characterized by a series of design loops per stage of the design process, separated by transitions with decisions about milestones. In each of the design loops the design team members relevant for that stage participate in the process.

The design process itself emphasizes the following broad sequence.

1. Establish performance targets for a broad range of parameters, and develop preliminary strategies to achieve these targets. This sounds obvious, but in the context of an integrated design team approach it can bring engineering skills and perspectives to bear at the concept design stage, thereby helping the owner and architect to avoid committing to a sub-optimal design solution.
2. Repeat the process to produce at least two, and preferably three, concept design alternatives, using energy simulations as a test of progress, and then select the most promising of these for further development.
3. Integrate the product with related engineering disciplines.

The process diagram and the outline of IDP steps shown in figure 1 and 2, give some idea of how IDP may be applied to a typical design project.

### 3.2.1 THE INTEGRATED DESIGN PROCESS (IDP) A METHOD FOR DESIGNING ARCHITECTURE

In the following section the various phases of a design project, will be described to give an insight into the phases of the Integrated Design Process.

Designing a building is a very complex process. Therefore the Integrated Design Process is combining knowledge from architecture and engineering in order to solve often very complicated problems connected to the design of buildings. The integrated design process (IDP) [ (Knudstrup M., 2004)] works with the architecture, the design, functional aspects, energy consumption, indoor environment, technology, and construction. A process which can be done by an architect or an engineer but because of the many parameters and the trans- disciplinary approach it would be easier to overcome the many aspects in a team consisting of people with different competences, if it is a larger project.

#### The phases of the Integrated Design Process

The design process is a very complex process, so figure 2 is a simplification of the process. However it illustrates the various phases in the process. It is also here very important to be aware that the process is an iterative process.

The Phases are:

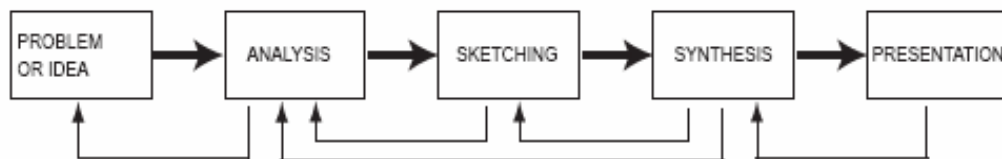


Figure 2, The phases of the Integrated Design Process

The Analysis Phase encompass an analysis of all the information that has to be procured before the designer of the building is ready to begin the sketching process, e.g. information about the site, municipality plans and local plans the architecture of the neighborhood, topography, vegetation, sun, light and shadow, predominant wind direction, access to and size of the area and neighboring buildings. Furthermore, it is important to be aware of special qualities of the area and the sense of the place; genius loci.

Through the analysis phase detailed information is procured about the user's demands for space, functionality, logistics as well as criteria for architectural qualities are discussed etc. The user or the building owner goes in as a very important sparring partner for the elaboration of a room program and logistic needs, the architecture demands and a chart of functions and a company concept which can lend inspiration to the design of the building. It is also here decided if the new building is going to have an iconic character at the site or in the urban landscape. Here it is also very important to decide principles for especially targets for energy use; heating, cooling, ventilation, lighting and indoor environmental quality as thermal comfort, air quality, acoustics, lighting quality, of the new building as well as criteria for application of passive technologies as natural ventilation, day lighting, passive heating, passive cooling. These criteria should be developed considering the local climatic conditions and the local energy distribution facilities.

At the end of the analysis phase a statement of aims and a programme for the building is set up including a list of design criteria, target values.

repeatedly make an estimate of how his or her choices regarding the form of the building, the plans, the room programme, the orientation of the building, the construction and the climate screen influence the energy consumption of the building in terms of heating, cooling, ventilation and daylight – and how these choices inspire each other. Typically the different solutions have different strength and weaknesses when the fulfillment of the different design criteria and target values is evaluated. In this phase the designer makes a lot of sketches to solve the various problems in order to optimize the final and best solution that hopefully will appear in the next closely connected phase, the synthesis phase.

The Synthesis Phase is the phase where the new building finds its final form, and where the demands in the aims and programme are met. Here the designer reaches a point in the design process where all parameters considered in the sketching phase flow together or interact – architecture, plans, the visual impact, functionality, company profile, aesthetics, the space design, working environment, room programme, principles of construction, energy solutions and targets and indoor environment technology form a synthesis. In the synthesis phase the various elements used in the project should be optimized, and the building performance is documented by detailed calculation models.

In this way the project reaches a phase where every item, one might say “falls into place”, and other possible qualities may even be added.

The project finds its final form and expression, and a new building with – hopefully good – architecture, architectural volumes, aesthetic, and visual impacts, functional and technical solutions and qualities have been created.

The Presentation Phase is the final phase, which includes the presentation of the project. The project is presented in such a way that all qualities are shown and it is clearly pointed out how the aims, design criteria and target values of the project have been fulfilled for the new building owner. The presentation to the client will consist of a report a cardboard model and IT-visualization.

### The Interaction of the parameters in the IDP

The complexity of the IDP springs from the interaction between the different tools and products of the process. This was analyzed and described in the theoretical master project “The Integrated Design Process Focused on Sustainability and Method” [ (Hansen, Madsen, & Madsen, 2003)]. Discussed here is an example of how the tools and products interact when sketching on the climate screen.

Numerous illustrations indicate the number of iterations one has to make whenever a decision is made regarding the design of the climate screen. Different illustrations were made for each parameter found in the Integrated Design

Process when applied to sustainable architecture thereby illustrating the complexity of the design process and simultaneously providing a comprehensive view of the parameters involved in the IDP up to the end of the synthesis phase.

The parameters which influence the design of the climate screen, while other parameters are the parameters which are influenced by the design of the climate screen. The project tried to describe which consequences the interactions could have and how it could happen. Furthermore specifications of the technical methods were provided based on material from the technical courses held by polytechnics. This master project provided the theoretical background for the virtual design project which will be presented later in this paper.

### 3.2.2 OTHER METHODS FOR ENVIRONMENTAL ARCHITECTURE

Sustainable Architecture has been of interest to architects and engineers for many years. The interest in climatic architecture can be traced back to Vitruvius' in the 1st century BC in his "Ten Books on Architecture" [ (Morgan, 1914)].

In the 20<sup>th</sup> century the interest in green, sustainable, bioclimatic and environmental architecture increased as a result of climatic changes, increased consumption and energy-crises. People like Victor Olgay, Leslie Martin, Wolfgang Feist, Ken Yeang, Renzo Piano and Norman Forster and others showed interesting results in form of methodologies and sustainable architecture.

The different methodologies and approaches each have their way of creating sustainable architecture some of these will shortly be introduced in the following.

"Design with climate – a bioclimatic approach to architectural regionalism"

In 1964 Victor Olgay published a book entitled "Design with Climate – a bioclimatic approach to architectural regionalism". The method he presented here has been an inspiration to many of the methods developed and used today. "The process of building a climate-balanced house can be divided into four steps, of which the last is the architectural expression. Architectural expression must be preceded by study of the variables in climate, biology, and technology" [ (Olgay, 1964.)]

The method focuses primarily on the climate and physiology, and not as much on the resources used in the building process. This is probably due to the fact that this method was developed prior to the energy crises in 1973 and 1979. Therefore it deals with the needs which were present at the time; comfort in relation to climate. It also focuses on the cultural influences on the site, which is very much a part of the rationalistic tradition; in fact Olgay was the first person to use regionalism in relation to climate [ (Morgan, 1914)]. This method differs from the traditional way of thinking architecture as he begins with climatic and comfort considerations and then later deals with the architectural expression. This also differs from the IDP, where the brief and architectural analyses are made in the initial stage of the analysis phase.

The parameters used in Olgay's approach are similar to some of the parameters used in the IDP. Olgay is therefore interesting in relation to the IDP, as he is regarded as a source of inspiration.

The Malaysian architect Ken Yeang has been engaged in bioclimatic design in connection with Skyscrapers since 1981. Working in Malaysia presents him with climatic problems, as he works in a tropical climate with small changes in temperature and a large cooling-load due to high external temperatures and a humid climate. To develop his designs Yeang insists on doing research to update his knowledge during every project thereby improving the architecture. Over time he, thus, integrates more and more sustainable measures in his architecture, which also enables him to reflect on the effectiveness of his solutions. He calls this method RD+D (Research Design and Development). The application of this method has over the years resulted in the development of more and more sustainable principles used in his buildings. [ (Yeang, 2014)]. “At the heart of the principles are the first and dominant concerns of energy reduction and buildings as open systems – interactive inside and outside in response to the seasons. In essence the fundamental propositions are very simple, but the overall, global effect of their consequences represents an optimistic and progressive vanguard of potential that is crucial to the effort Design with Climate]. “The overall arrangement abandons traditional geometry and responds to the dynamics of climate, sun path, wind direction and the issue of lifestyle: openness – including breezeways, verandah ways, transitional spaces that relate to the society they serve” [ (Yeang, 2014)]. Malaysia used to be a British colony until 1957 and therefore there was no vernacular architectural tradition when Yeang began his career. The architectural tradition in Malaysia was up until then influenced by a European tradition. Thus Yeang has tried to establish an architectural tradition based on the Malaysian culture and climate throughout his work. [ (Yeang, 2014)].

Yeang's approach to sustainable architecture is interesting because of the principles he uses, as these are similar to the tools used in the IDP. His approach is not as process oriented as the IDP but the fact that he uses the RD+D method indicates that he uses a process, with an analysis of research material, an implementation phase and an evaluation phase.

“The Selective Environment – An approach to environmentally responsive architecture”

The Selective Environment presents a terminology developed at the Martin Centre at Cambridge University,

“Selective design, as opposed to exclusive design, aims to exploit the climatic conditions to maintain comfort, minimizing the need for artificial control reliant on the consumption of energy. This manipulation of climate, to filter selectively positive characteristics of the environment, is achieved through architecture. A building's form is probably the most significant consideration

with respect to the selective potential of a design. Solar gains, daylight and natural ventilation are three aspects where climate can provide useful support to minimize the use of energy for heating, electric lighting and fan power respectively. The degree to which a building can be selective is dependent on the very first strategic considerations in its design.”[ (Morgan, 1914).

“In its original definition, the characteristics of a ‘selective’ building were defined by the following parameters: initial environment; built form; orientation; fenestration; and energy sources.

In adapting these principles to the global context, these may be redefined. The primary aim remains the same: to seek to achieve the maximum use of ambient energy sources in the creation of internal environments that are, as far as possible, naturally sustained, and in which comfort conditions are related to the climate of the location. It is also assumed that there will be spatial and temporal environmental diversity and that the operation of control systems will be primarily in the hands of the buildings’ occupants.”[ (Morgan, 1914).

If this method is compared to the IDP we find that the methods use many of the same parameters in the design process. The main difference between the two methods seems to be:

The Selective Environment is a development of the LT-method [ (Woodward, 1997,)], which can be regarded as an engineer method, thus, the development of The Selective Environment has gone from an engineer method towards an architectural method.

The IDP started as an architectural method adapting to an engineering method.

The end results of the two methods have many of the same basic parameters and goals, but the development of the two originates from two different approaches to science, i.e. the qualitative and the quantitative.

“Passive House”

The idea of the passive house was suggested by Professor Bo Anderson in 1987. Since then it has been developed further by Dr. Wolfgang Feist. The European countries each have their standards for sustainable buildings. Amongst these standards the passive house concept is regarded as one of the more successful approaches, which is why many countries are now looking towards Germany to learn how to achieve similar results.

The heating load must not exceed 15 kWh pr. m<sup>2</sup> pr. year. In order to achieve this, the following guidelines can be applied:

Passive House is mostly applied to dwellings, more specific single-family houses and low-rise apartment buildings, which is why the principles for the concept are few and simple to apply. The principles do not set any demands or present any method on how to ensure architectural quality in the buildings, and it could therefore be regarded as an engineer method as opposed to the IDP which represents an integration of both engineering and architectural principles. Even so the parameters applied in this method are relevant for the development of sustainable projects.

Let us return to the challenge of the work with-in the Integrated Design Process where a lot of parameters from architecture and engineering are combined and taken in. It is obvious that the IDP leads to other solutions – other types of buildings and new designs – when the technical disciplines are included in the design process. On the sketching level the projects become better defined than they use to be in the more “artistic” architectural setting, as the indoor environmental conditions and the energy frame of the building are clarified. This clarification is also important for the comfort, and for a good working environment for the coming users. From an economic point of view the operating costs can be kept to a minimum when the climate screen of the building is optimized, thus, saving energy for cooling and heating, and the passive ventilation principles employed also reduce energy expenses.

### **3.2.3 VIRTUAL DESIGN PROJECT**

The IDP was tested in a virtual design project entitled “Citylife” [ (Hansen, Madsen, & Madsen, 2003)]. The result was a master plan for an eight acre plot, from the master plan a building unit was selected for detailing. The aim of the project was to achieve a sustainable development on an industrial area of the harbour front in Aalborg/Noerresundby. The old industry of this city area was closing and the focus of the project was what to do with the devastated site that could reintroduce prosperity in the city area.

The following parameters from the IDP were used in the project: Analysis phase:

- Site analysis (history, architecture, genius loci, green structures, infrastructure, functions in the area, age of inhabitants etc.)
- Comfort analysis (based on CR 1752)
- Climate analysis (Solar calculations of altitude and azimuth, temperatures, rainfall, humidity, Wind roses etc.)
- Analysis of the legislative demands (Building codes and municipality documents)

Sketching phase:

- Site plan
- Solar studies of site plan in a computer programme (Bsim2002), to investigate shadows from buildings.
- Green roofs
- Green corridors
- Consideration of daylight levels in the middle buildings and the risk of glare.
- Optimization of U-values (Insulation thickness)
- Calculation of the heating and cooling load
- Ventilation strategies (Natural ventilation, Placement of windows)
- Atriums in relation to entrance area in the dwellings
- Open floor plans
- Construction system (stability)
- Physical models
- Virtual models

Synthesis phase:

- Ventilation strategies (Natural ventilation, Placement of windows)
- Calculation of the heating and cooling load
- Choice of internal materials based on room acoustic calculations in the office area
- Choice of materials based on LCA profiles
- Calculation of a structural detail (The four story corbel towards the inlet)
- Calculation of minimal ventilation rate and the opening area of the windows to ensure this.
- Physical models

The different parameters were integrated in the design process at different stages as tools instead of obstacles. The green area of the site was very important in the project such as the new standards which were suggested for the sociality of the inhabitants in the new area.

The parameters became a natural part of the project and some of them merged. The design of the facades and the floor plan were influenced by the strategy for the ventilation and daylight considerations and the placement of the different stores in the office area were decided based on the penetration of daylight and the risk of glare, in order to be able to avoid shading on the facades. Just as the design of the site plan was influenced by the site analysis, the green corridor, the simulation of light and shadow in a computer model.

The site plan and the scale and expression of the building were also greatly influenced by physical models which laid the foundation for the computer simulations.

The master plan was inspired by the urban structure in the area, and therefore consisted of two types of building structures; long rectangular buildings towards the waterfront and u-shaped building blocks facing the city. A large green area was placed between the two building types. The green area was developed as a continuation and an enlargement of the green corridors on the site and the functions envisioned for this area were those of an interactive city park with different types of leisure activities.

The functions in the buildings on the site were a spa, an arcade, a gym, small shops, a restaurant, business centers with new innovative working environments and dwellings.

The project presents a new way of living in the city, as the project group wanted to go against the antisocial development of the urban inhabitants. The green area was therefore an area for both the inhabitants of the buildings on the site and in the area, just as the entrance areas to the dwellings were made as unofficial meeting points in the building in order to enable closer relations between the inhabitants.

The project resulted in a master plan and a building design with environmental considerations incorporated into the master plan and in the choice of materials, ventilation systems, daylight strategies and heating and cooling strategies in the building. The aim of the project was to revitalize the area into an urban breathing space which could reunite the inhabitants of the area and create prosperity in a shrinking city area.

### 3.2.4 SUSTAINABLE IDP

One of the interesting lessons in using IDP is that, unlike many other design support methods or systems, it is applicable to a wide range of situations and building types. Thus, even though IDP was developed for a few building types and assumed new construction, the approach has now been applied to a wide variety of building types and to renovation projects.

We foresee a wide application of the IDP around the world. A generic international version has been developed within Task 23, a working group of the International Energy Agency. What is needed now are the resources to develop supporting software and to develop an educational campaign for international use, especially to developing countries. [Chuck Eastman, 2011]

IDP is used as a tool for resource optimization, cost reduction and enhance cost effectively and allows a sustainable, fast and easy adoptable design.

#### A. PROPOSED PRINCIPLES FOR SUSTAINABLE BUILDING DEVELOPMENT

“Economy: Good project management is a vital overarching aspect in delivering sustainable projects, both in the short and long term” [ (Halliday, 2008.)].

**Using Resources Effectively:** Buildings should not use a disproportionate amount of resources, including money, energy, water, materials and land during construction, use or disposal.

**Supporting Communities:** Projects should clearly identify and seek to meet the real needs, requirements and aspirations of communities and stakeholders while involving them in key decisions.

**Creating Healthy Environments:** Projects should enhance living, leisure and work environments; and not endanger the health of the builders, users, or others, through exposure to pollutants or other toxic materials.

**Enhancing Biodiversity:** Projects should not use materials from threatened species or environments and should seek to improve natural habitats where possible through appropriate planting and water use and avoidance of chemicals.

**Minimizing Pollution:** Projects should create minimum dependence on polluting materials, treatments, fuels, management practices, energy and transport.

Profitability and competitiveness, customers and clients satisfaction and best value, respect and treat stakeholders fairly, requiring well-structured and well-coordinated information flow among key professionals, working in team can be a major solution.

Minimization of resource consumption, maximization of resources reuse, use of renewable and recyclable resources, protection of the natural environment, create a healthy and non-toxic environment, and pursue quality in creating the built environment.

In general, there is a consensus that the breadth of the principle of sustainable building mirrors those of sustainable development, which is about synergistic relationships between key professionals in economic, social and environmental aspects of sustainability. Each of these three pillars (and their related principles) is over-arched by a set of process-orientated principles, including:

1. The undertaking of assessments prior to the commencement of proposed activities assists in the integration of information relating to social, economic, biophysical and technical aspects of the decision making process;
2. The involvement of key stakeholders in the decision making process;
3. The promotion of interdisciplinary and multi-stakeholder relations (between the public and private sectors, contractors, consultants, nongovernmental) should take place in a participatory, interactive and consensual manner;
4. The recognition of the complexity of the sustainability concept in order to make sure that alternative courses of action are compared. This is so that the project objectives and the stakeholders are satisfied with the final action implemented;
5. The use of a life cycle framework recognizes the need to consider all the principles of sustainable construction at each stage of a project's development (i.e., from the planning to the decommissioning of projects);
6. The use of a system's approach acknowledges the interconnections between the economics and environment. A system's approach is also referred to as an integrated (design) process;
7. That care should be taken when faced with uncertainty;
8. Compliance with relevant legislation and regulations;

9. The establishment of a voluntary commitment to continual improvement of (sustainable) performance;
10. The management of activities through the setting of targets, monitoring, evaluation, feedback and self-regulation of progress. This iterative process can be used to improve implementation in order to support a continuous learning process; and
11. The identification of synergies between the professionals.

These principles will form a framework for achieving sustainable design that includes an environmental assessment during the planning and design stages of building projects, and the implementation of sustainable practices. It will be used to guide the process of construction at all levels and within all disciplines. From them, it is possible to extrapolate an endless series of project- or discipline-specific principles and guidelines, which can assure that decisions taken follow the road of sustainable development.

Building construction practitioners worldwide are beginning to appreciate sustainability and acknowledge the advantages of implementing sustainable principles in building projects. For example, the concept of sustainable building costs lower than conventional method and saves energy as demonstrated by Hydes and Creech [ (Hydes & Creech, 2000)]. This was further supported by Pettifer [ (Pettifer, 2004.)], who added that sustainable buildings will contribute positively to better quality of life, work efficiency and healthy work environment. Pettifer [ (Pettifer, 2004.)] explored the business benefits of sustainability and concluded that the benefits are diverse and potentially very significant.

## **B. SUSTAINABLE IMPLEMENTATION:**

In order to achieve a sustainable future in the building industry, [ (Asif, Muneer, & Kelly, 2007,)] suggest adoption of multi-disciplinary approach covering a number of features such as: energy saving, improved use of materials, material waste minimization, pollution and emissions control etc. There are many ways in which the current nature of building activity can be controlled and improved to make it less damaging, without reducing the useful output of building activities. To create a competitive advantage using environment-friendly construction practices, the whole life-cycle of buildings should, therefore, be the context under which these practices are carried out. A review of literature has identified three general objectives which should shape the framework for implementing sustainable building design and construction (Figure 3), while keeping in mind

the principles of sustainability issues (social, environmental and economic) identified previously. [ (Eziyi O.I & Dominic E.A, 2011.)] These objectives are:

1. Resource optimization
2. Cost efficiency and
3. Design for Human adaptation

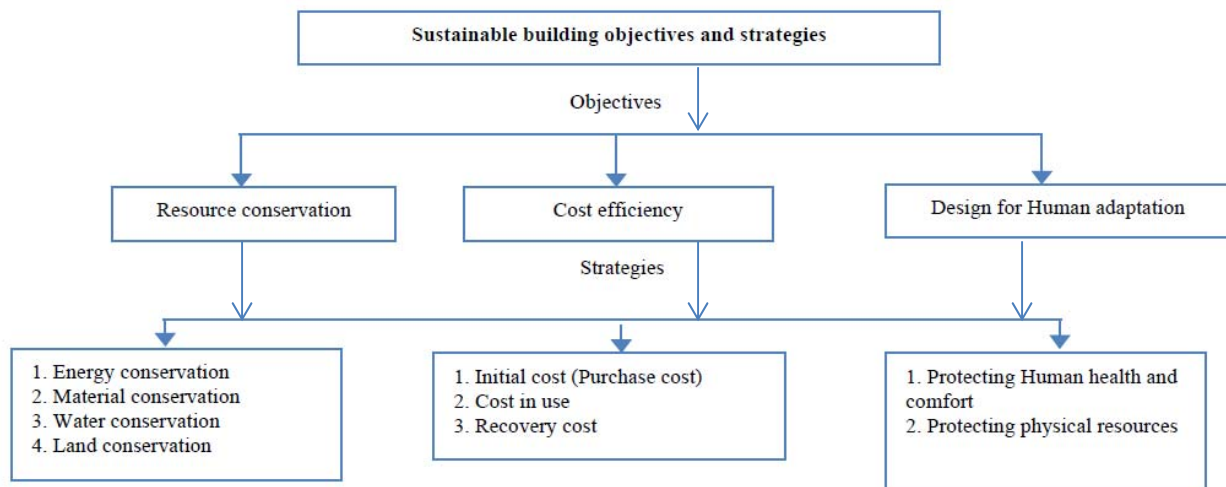


Figure 3, Framework for implementing sustainability in building construction. (Wei Wu, 2015)

From the above fig 3, protecting physical resources should be included under resource conservation not under design for human adaptation.

### a. Objective 1: Resource optimization

“Resource optimization” means achieving more with less. It is the management of the human use of natural resources to provide the maximum benefit to current generations while maintaining capacity to meet the needs of future generations [ (Wilson, Uncapher, McManigal, Lovins, Cureton, & Browning, 1998.)]. The concept has become a major issue in debates about sustainable development. [ (Halliday, 2008.)] Halliday observe that certain resources are becoming extremely rare and the use of remaining stocks should be treated cautiously. The author called for the substitution of rare material with less rare or renewable materials.

Bold statements about the need for radical improvements in the use of materials and energy resources have achieved recognition in policy circles. The argument is that productivity improvement is necessary to minimize impacts on the capacity of natural systems to assimilate waste materials and energy. The building industry is a major consumer of natural resources, and

therefore many of the initiatives pursued in order to create ecology sustaining buildings are focusing on increasing the efficiency of resource use. He stated that the ways in which these efficiencies are sought are varied. He cited examples ranging from the principles of solar passive design which aim to reduce the consumption of non-renewable resources, the consumption of energy production, life cycle design and design for construction. Methods for minimizing material wastage during building construction process and providing opportunities for recycling and reuse of building material also contribute to improving resource consumption efficiency. Calls to be resource efficient have been born from concern for increasing depletion of non-renewable natural resources. Since the non-renewable resources that play major role in a construction project are energy, water, material and land, the conservation of these non-renewable resources has vital importance for a sustainable future. Resource conservation yields specific design strategies and methods.

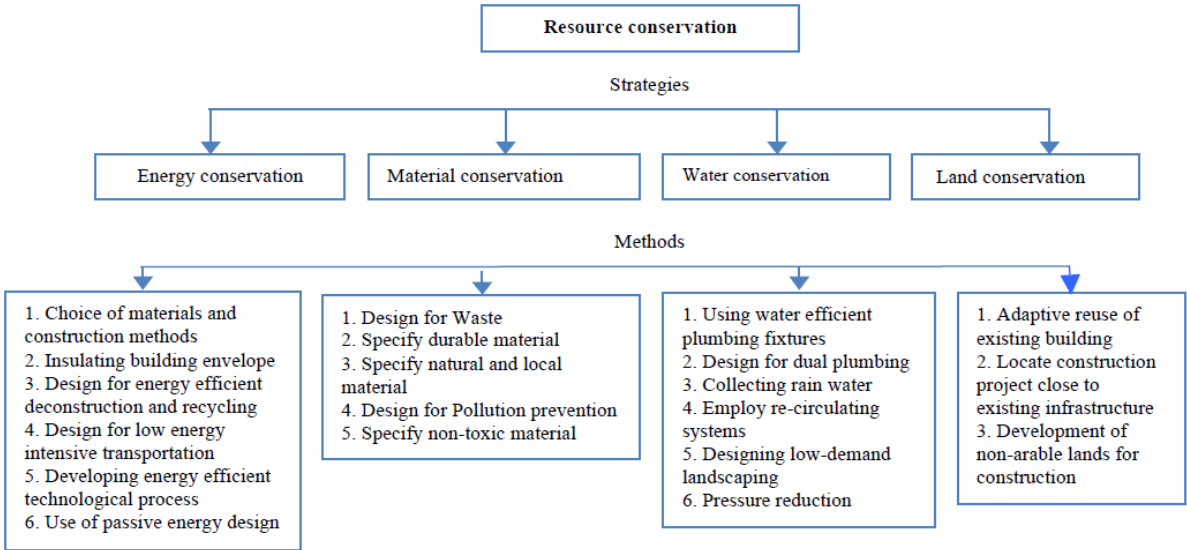


Figure 4, Strategies and Methods to achieve resource conservation. (Wei Wu, 2015)

- Materials Conservation.** Extraction and consumption of natural resources as building materials or as raw materials for production of building materials and building materials production itself in implementing construction works has a direct impact on natural biodiversity due to the fragmentation of natural areas and ecosystems caused by construction activities. In particular, large amount of minerals resources are consumed in the built environment and most of these mineral resources are non-renewable. Therefore, it is important to reduce the use of non-renewable materials. According to Abeyesundara, (Abeyesundara, 2010) this should be incorporated for consideration at the project initiative and design phases, where the selection of materials is very important and the choice should be based on the materials' environmental impacts. At the

construction and deconstruction phases, various methods can also be used for reducing the impacts of materials consumption on the natural environment. The subsection discusses some of the methods to be considered in achieve material efficiency in construction.

- **Design for Waste Minimization.** The construction industry is one of the major waste generators, which causes several environmental, social and economic problems. Waste takes the form of spent or unwanted materials generated from construction and demolition processes. Prevention and reduction of waste in the construction of housing can save considerable amounts of non-renewable resources. An increasing body of scholarly work, notably that produced by has demonstrated that the building designers have an important role to play in construction waste minimization and reduction. Waste minimization should be addressed as part of the project sustainability agenda throughout the design process by the application of the three key designing out waste principles namely: Reducing and recovering construction waste; Reuse and Recycling and the storage and disposal of construction waste.
- **Reducing and Recovering Construction Waste:** According to Esin and Cosgun [ (Esin & Cosgun, 2007,)], the most effective measure of reducing the environmental impact of construction waste is by primarily preventing its generation and reducing it as much as possible. This will reduce reuse, recycling and disposal needs thus providing economic benefits. An analysis has shown that recovery reduces the amount of waste and Green House Gas (GHG) emissions, saves energy, and reduces the use of raw materials [ (Pimenteira, Carpio, Rosa, & Tolmansquim, 2005,)]. Recovery of useful energy and materials from wastes has also been emphasized as one of the most important environmentally friendly practices for achieving energy savings to alleviate the pressing energy situations.
- **Reuse and Recycling:** Recycling products reduce general environmental impacts, particularly the use of resources and waste creation. The importance of alternatives (such as recycling and reuse) for re-entering construction materials and components in the production chain has been already presented in the literature. The reuse of building materials is an alternative for the reduction of construction and demolition waste (CDW) when renovating and demolishing buildings, by performing building deconstruction, which enables the recovery of building parts as functional components

such as bricks, windows, tiles, differently from traditional demolitions in which parts are transformed back into raw materials to processing. Designers should assess whether any existing buildings on site could be partly or completely refurbished to meet the project's needs; carrying out a pre-demolition audit of buildings that are being demolished to discover whether any materials or components can be reused. Designers should also assess whether deconstruction and flexibility can be considered, or is a priority.

- **The Storage and Disposal Of Construction Waste:** In situations where construction waste could not be prevented and recovered, they need to be stored in an appropriate manner and kept under control. Non-hazardous construction debris and construction debris classified as special waste are landfilled in either municipal solid waste (MSW) landfills or in landfills that only accept construction debris. Around the world, decisions on the types of waste acceptable at landfills were entirely based on site-specific risk assessment. Licenses controlled the quantities and types of waste to be accepted and often, in the case of hazardous waste, specified maximum loading rates for particular wastes or components substances. Designers need to be aware and take into consideration policies and guidelines for material storage and disposal at the design stage of construction project.
- **Specify durable materials.** Defined durability as an indicator which informs of the extent to which a material maintains its original requirements over time. The sustainability of a building can be enhanced by increasing the durability of its materials, and a material, component or system may be considered durable when its useful service life (performance) is fairly comparable to the time required for related impacts on the environment to be absorbed by the ecosystem. [ (Markarian, 2005,)] Materials with a longer life relative to other materials designed for the same purpose need to be replaced less often. This reduces the natural resources required for manufacturing and the amount of money spent on installation and the associated labor. The greater the material durability, the lower the time and resources required to maintain it. Durable materials that require less frequent replacement will require fewer raw materials and will produce less landfill waste over the building's lifetime.
- **Specify Natural and Local Materials.** Natural materials are generally lower in embodied energy and toxicity than man-made materials. They require less processing and are less damaging to the environment. Many, like wood, are theoretically

renewable. the products become more sustainable. The use of building material sourced locally can help lessen the environmental burdens, shortens transport distances, thus reducing air pollution produced by vehicles. Often, local materials are better suited to climatic conditions, and these purchases support area economies. For instance, the decorative use of marble quarried halfway around the world is not a sustainable choice. Steel, when required for structural strength and durability, is a justifiable use of a material that is generally manufactured some distance from the building site.

- **Design for Pollution prevention.** Pollution prevention measures taken during the manufacturing and construction process can contribute significantly to environmental sustainability. [ (Kibert, 2008.)], suggest selecting materials manufactured by environmentally responsible companies encourages their efforts at pollution prevention. Although these products may have an initially higher “off-the-shelf” price, choosing products that generate higher levels of pollution exploits the environment. Pollution comes in form of air, water and soil. However, emissions to soil are hardly discussed in any LCA literature, and the data available are very limited. In the construction industry, soil pollution is mainly a problem at the construction site. It may also be a problem in the extraction of some minerals, when the waste is deposited, especially hazardous waste. This wastewater is often released directly into streams and can contain toxic substances. The means of transport is also important. Emissions from road, air and rail transport are a major cause of photochemical smog, of which the main components are carbon monoxide, nitrogen oxides, hydrocarbons and ozone released by the action of sunlight on organic compounds in the lower atmosphere.
- **Specify Non-Toxic or Less-Toxic Materials.** Non- or less-toxic materials are less hazardous to construction workers and building’s occupants. Many materials adversely affect indoor air quality and expose occupants to health hazards. Some construction materials, such as adhesives, paints, sealants, cleaners, and other common products contain volatile organic compounds (VOCs) and emit dangerous fumes for only a short time during and after installation; others can contribute to air quality problems throughout a building’s life. By using building materials with lower or non-existent levels of toxic substances, environmental health problems can be avoided and the need for air scrubbers reduced.

## b. Cost Efficiency

Construction clients are demanding assurance of their buildings' long-term economic performance and costs. In addition, the construction project supply chain of developers, suppliers, manufacturers, design and construction teams are under increasing pressure from clients to minimize total project cost and consider how much a building will cost over its life cycle and how successfully it will continue to meet occupier's requirements. Buildings represent a large and long-lasting investment in financial terms as well as in other resources [ (Oberg, 2005.)]. Improvements of cost effectiveness of buildings is consequently of common interest for the owner, the user and society.

The concept of sustainability as applied to the construction of buildings is intended to promote the utmost efficiency and to reduce financial costs. There is considerable evidence to suggest that many organizations, in both the private and public sectors, make decisions about building related investment based on estimates of the initial construction cost, with little or no consideration for costs relating to operation and maintenance throughout the life of the building [ (Woodward, 1997,)]. Design decisions require choice of construction structure, building materials and building installations which are often accompanied by errors in investment through an inadequate economic control of decisions. Sharply rising energy costs have highlighted the opportunity for overall savings in the life of a building that can be achieved by investing in more energy efficient solutions initially. Savings on other operating and maintenance costs can also be considered.

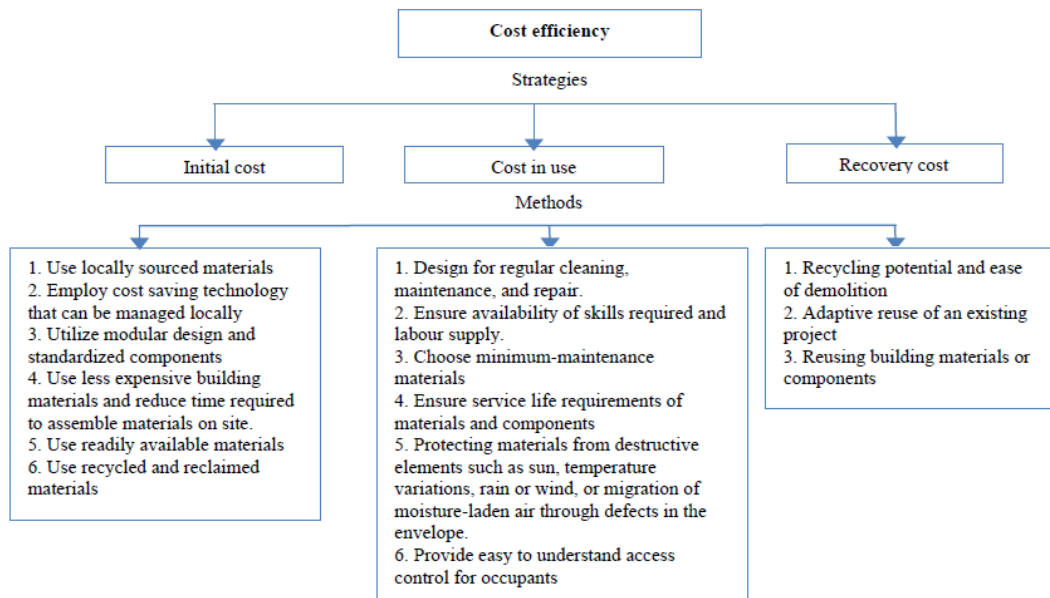


Figure 5, Strategies and Methods to achieve cost efficiency. (Wei Wu, 2015)

The concept of life-cycle costing analysis (LCCA) will play significant roles in the economics of a building project. Life cycle cost analysis (LCCA) is an economic assessment approach that is able to predict the costs of a building from its operation, maintenance, and replacement until the end of its life-time.

The effective implementation of life-cycle costing involves utilizing a thoughtful, comprehensive design along with construction practices with selected environmental considerations. Life cycle cost (LCC) is therefore an important tool for achieving cost efficiency in construction projects. This paper has identified three principal life cycles cost to be considered at the outset of a construction project. The initial cost, the cost in use and the recovery cost.

- Initial Cost: Also referred to as the acquisition cost or the development cost, the initial cost covers the entire cost of creating, or remodeling, the building, such as cost of land/building acquisition costs, professional consultants fee, the cost of the materials that compromise the completed building, and the cost of putting it all together. When planning the acquisition of a major asset, [ (Emmitt & Yeomans, 2008.)] observed that organizations spend considerable time and effort in making an economic evaluation of the initial cost. For many clients, this is their primary and often only concern. Cost reductions may be possible by selecting less expensive building materials and reducing the amount of time required to assemble them on site, but this assumes that these costs can be discovered. Other methods associated with initial cost reduction in building include the following:
  - The design should optimize the use of locally-available materials. In most cases, locally manufactured products are cheaper than their imported counterparts since their transport costs are not as huge and they do not come with import duty.
  - Use of cost saving construction technology such as the use of masonry stone for building foundation instead of reinforced concrete saves a lot of cost. This method is only suitable for low-rise buildings such as bungalows. For high-rise structures, careful structural design can be utilized so as to have the most optimum foundation design type to ensure less material is excavated.
  - Identify opportunities to minimize initial construction costs, through use of modular designs and
  - Standardized components where these are compatible with high quality, distinctive architecture that is appropriate to its context. For instance, a standardized plan with uniform office sizes provides an organizational framework that can be reconfigured as

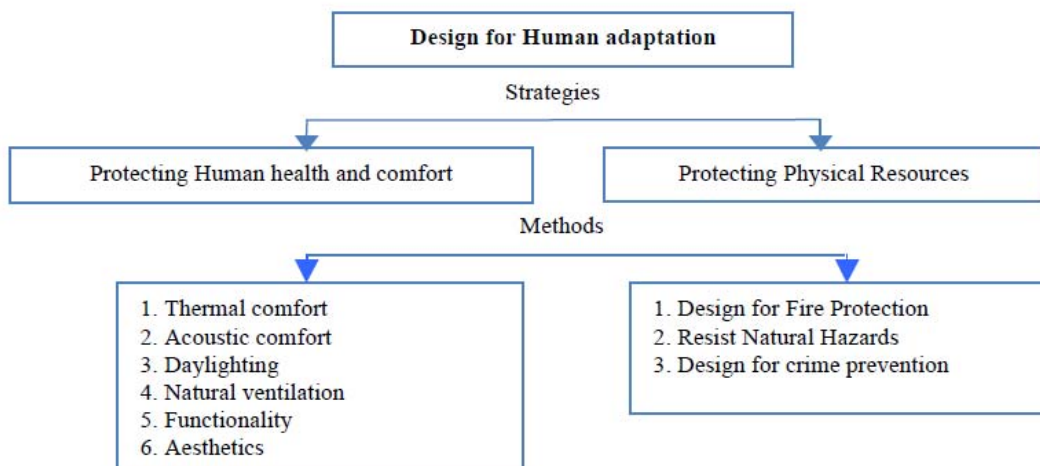
required, even the company changes. The design should also support technological changes.

- Using recycled and reclaimed materials. On site reuse and reprocessing of construction, demolition and excavation materials; and importing recovered and recycled materials in the place of more costly primary material can significantly reduce overall project cost. For examples, using products with a high recycled content, such as recycled asphalt or cement replacement in concrete products can save project cost by at least 3% [ (Innes, 2004.)] without significant investment outlay.

### c. Design for Human Adaptation

One of the main purposes of a sustainable building is to provide healthy and comfortable environments for human activities. A building must accommodate the activities it is built for and provide floor-space, room volume, shelter, light and amenities for working, living, learning, curing, processing etc. Furthermore, the building must supply a healthy and comfortable indoor climate to the people using it. In meeting these basic requirements, the building should not cause harm to its occupants or the environment and must, for example, be structurally stable and fire safe. Sustainable development requires that the building does not cause unnecessary load or risk to the environment, for example in the form of energy use. To promote and enhance human adaptation the

Figure 6, Strategies and Methods to achieve human adaptation. (Wei Wu, 2015)



### 3.3 BUILDING INFORMATION MODELING (BIM) CONCEPTS

“There is no consensus on the definition of sustainable design. However, the common interpretation of sustainability within the construction industry is the provision of building that use less virgin material and energy, and produce less pollution and waste.” (Zimmermann, et al., 2005; Szokolay, 2004).

'Building Information Modeling [BIM] is a Virtual design and construction tool. **Virtual Design and Construction** (VDC) is the management of integrated multi-disciplinary performance models of design-construction projects, including the product (i.e., facilities), work processes and organization of the design - construction - operation team in order to support explicit and public business objectives.

The theoretical basis of VDC includes:

- Engineering modeling methods: product, organization, process
- Analysis methods - Model-based design: including quantities, schedule, cost, 4D interactions and process risks, these are termed Building Information Modeling (BIM) tools
- Visualization methods
- Business metrics - within Business analytics - and a focus on strategic management
- Economic impact analysis, i.e., models of both the cost and value of capital investments

The concept of BIM has existed since the 1970s.

The term 'building model' (in the sense of BIM as used today) was first used in a 1986 paper by Robert Aish- then at GMW Computers Ltd, developer of RUCAPS software - referring to the software's use at London's Heathrow Airport. The term 'Building Information Model' first appeared in a 1992 paper by G.A. van Nederveen and F. P. Tolman.

However, the terms 'Building Information Model' and 'Building Information Modeling' (including the acronym "BIM") did not become popularly used until some 10 years later. In 2002, Autodesk released a white paper entitled "Building Information Modeling," and other software vendors also started to assert their involvement in the field. By hosting contributions from Autodesk, Bentley Systems and Graphisoft, plus other industry observers, in 2003, Jerry Laiserin helped popularize and standardize the term as a common name for the digital representation of the building process. Facilitating exchange and interoperability of information in digital format had previously

been offered under differing terminology by Graphisoft as "Virtual Building", Bentley Systems as "Integrated Project Models", and by Autodesk or Vectorworks as "Building Information Modeling". As Graphisoft had been developing such solutions for longer than its competitors, Laiserin regarded its ArchiCAD as then "one of the most mature BIM solutions on the market" but also highlighted the pioneering role of applications such as RUCAPS, Sonata and Reflex. Following its launch in 1987, ArchiCAD became regarded by some as the first implementation of BIM, as it was the first CAD product on a personal computer able to create both 2D and 3D geometry, as well as the first commercial BIM product for personal computers.

Building information modeling is strategy for the application of information technology to the building industry. Building information modeling solutions have three characteristics:

- (1) They create and operate on digital databases for collaboration.
- (2) They manage change throughout those databases so that a change to any part of the database is coordinated in all other parts.
- (3) They capture and preserve information for reuse by additional industry-specific applications.

The application of building information modeling solutions results in higher quality work, greater speed and productivity, and lower costs for building industry professionals in the design, construction, and operation of buildings.

This paper discusses how the use of information technology in the industry has led to the idea of building information modeling and the characteristics and benefits of building information modeling solutions.

## **DEFINITION**

Different definitions have been given for BIM. The term BIM is commonly used as a generic term encompassing a wide and expanding cluster of concepts. Fundamentally, the building information model is a coordinated and consistent data store to which information and knowledge generation procedures – advanced or simple – can be applied depending on specific requirements. The satisfaction of the specific requirements may be contingent upon restructuring of business processes and relationships, and some requirements may as yet be outside of the current capacity and capability of either the technology or human resources, but these are temporary, solvable constraints [ (Vanessa Quirk, 2012.)].

The (U.S. General Services Administration, 2007 )defined Building Information Modeling and

Building Information Model as follows:

“Building Information Modeling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views appropriate to various users’ needs can be extracted and analyzed to generate feedback and improvement of the facility design”.

BIM consists of information representing the entire structure and the complete set of design documents stored in an integrated database. All the information is parametric and thereby interconnected. Any changes to an object within the model automatically affect the related assemblies and constructions, because the model contains the necessary relational information. This is quite unlike the 2D building representation of conventional CAD-based drawings.

For these reasons, BIM has already begun changing how designers collaborate with consultants and builders, and it also has the capability to guide the industry towards the production of buildings meeting sustainable development goals.

The integration of BIM during the design stages enables more rational design decisions to be made due to the increased quality, speed and availability of design data. BIM is an excellent tool for achieving a higher triple bottom line, with environmental, social and economic factors all standing to benefit from a more streamlined design process.

The US National Building Information Model Standard Project Committee has the following definition:

“Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition”. [ (Nationalbimstandard.org., 2014)]

Traditional building design was largely reliant upon two-dimensional technical drawings (plans, elevations, sections, etc.). Building information modeling extends this beyond 3D, augmenting

the three primary spatial dimensions (width, height and depth) with time as the fourth dimension (4D) and cost as the fifth (5D). BIM therefore covers more than just geometry. It also covers spatial relationships, light analysis, geographic information, and quantities and properties of building components.

BIM involves representing a design as combinations of "objects" – vague and undefined, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. BIM design tools allow extraction of different views from a building model for drawing production and other uses. These different views are automatically consistent, being based on a single definition of each object instance (Eastman/ Chuck, 2009) BIM software also defines objects parametrically; that is, the objects are defined as parameters and relations to other objects, so that if a related object is amended, dependent ones will automatically also change. .[ (Eastman/ Chuck, 2009)] Each model element can carry attributes for selecting and ordering them automatically, providing cost estimates as well as material tracking and ordering. .[ (Eastman/ Chuck, 2009)]

For the professionals involved in a project, BIM enables a virtual information model to be handed from the design team (architects, landscape architects, surveyors, civil, structural and building services engineers, etc.) to the main contractor and subcontractors and then on to the owner/operator; each professional adds discipline-specific data to the single shared model. This reduces information losses that traditionally occurred when a new team takes 'ownership' of the project, and provides more extensive information to owners of complex structures.

## **4D BIM**

4D BIM, an acronym for 4D Building Information Modeling and a term widely used in the CAD industry, refers to the intelligent linking of individual 3D CAD components or assemblies with time- or schedule-related information. The use of the term 4D is intended to refer to the fourth dimension: time, i.e. 4D is 3D plus schedule (time) (Eastman, Tieholz, Sacks, & Liston, 2011). The construction of the 4D models enables the various participants (from architects, designers, contractors to clients) of a construction project, to visualize the entire duration of a series of events and display the progress of construction activities through the lifetime of the project. This BIM-centric approach towards project management technique has a very high potential to improve the project management and delivery of construction project, of any size or complexity.

In 1998, Sir John Egan, in his report Rethinking Construction, argued that certain principles and

management techniques could successfully cross-over from other industries like manufacturing to serve the project delivery demands of the construction industry. The Egan Report cited "Technology as a Tool":

"One area in which we know new technology to be a very useful tool is in the design of buildings and their components, and in the exchange of design information throughout the construction team. There are enormous benefits to be gained, in terms of eliminating waste and rework for example, from using modern CAD technology to prototype buildings and by rapidly exchanging information on design changes. Redesign should take place on computer, not on the construction site." (U.S. General Services Administration, 2007 )

4D BIM adds a new dimension (time) to 3D CAD or solid modeling, it enables a sequence of events to be depicted visually on a time line that has been populated by a 3D model (augmenting traditional Gantt charts and Critical Path (CPM) schedules often used in project management). Construction sequences can be reviewed as a series of problems using 4D BIM, enabling users to explore options, manage solutions and optimize results. It enables construction product development, collaborative and transparent project implementation, partnering with the supply chain and production of components, and is in keeping with Egan's vision: "sustained improvement should then be delivered through use of techniques for eliminating waste and increasing value for the customer."

As an advanced construction management technique, it is increasingly used by project delivery teams working on larger projects. For example, it is used in the construction of projects including tall buildings, bridges, highways, tunnels, university campuses and hospital complexes, luxury residential, residential and infrastructure such as courthouses, levee systems, hydro-electric power generation stations, mining and industrial process facilities. 4D BIM has traditionally been used for higher end projects due to the associated costs, but technologies are now emerging that allows the process to be used by laymen or to drive processes such as manufacture.

## **5D BIM**

5D BIM, an acronym for 5D Building Information Modeling, is a term used in the CAD and construction industries, and refers to the intelligent linking of individual 3D CAD components or assemblies with schedule (time - 4D BIM) constraints and then with cost-related information.

The creation of 5D models enables the various participants (from architects, designers, contractors to owners) of a construction project to visualize the progress of construction activities and its related costs over time. This BIM-centric project management technique has potential to improve management and delivery of projects of any size or complexity. (Aish, 1975.)

## **THE ROAD TO BUILDING INFORMATION MODELING**

In the early 1980s architects began using PC-based CAD. The familiar layer metaphor that originated with pin-bar drafting was easily adapted to the layer-based CAD systems of the day, and within a few years a large percentage of construction documents and shop drawings were plotted from computers rather than being manually drafted on drawing boards.

Slowly technology began to affect the process. DWG files were exchanged with consultants instead of physical underlay drawings. Beyond simple graphics these files communicated information about a building through their layer structure; a rectangle on one layer represented a concrete column, but on another layer a tile pattern on the floor. Electronic file formats originally designed to store only graphics and drive plotters now directly conveyed information about the building that would not appear in the plotted version of the file. The use of CAD files was evolving toward communicating information about a building in ways that a plotted drawing could not.

This evolution continued with the introduction of object-oriented CAD in the early 1990s. Data “objects” in these systems—doors, walls, windows, roofs—stored non graphical data about a building in a logical structure together with the building graphics. These systems often supported geometrical modeling of the building in three dimensions, thereby automating many of the laborious drafting tasks like laying out building section drawing and generating schedules. Forward-thinking design firms adopted these tools, realizing that the data in the object-oriented CAD files, if carefully structured and managed, could be used to automate certain documentation tasks like schedules and room numbering.

A parallel development in the 1990s was the increasing use of the Internet for sharing data digitally. Suddenly information could not be effectively communicated unless it was represented digitally. CAD files that had been exchanged on floppy disks within the design team appeared instead on Internet FTP sites, on web pages, and attached to emails. The same forward-thinking design firms who were adopting object-oriented CAD into their practices began sharing and delivering their documents to clients digitally and began investigating web-based project

management and collaboration services. But object-oriented CAD systems remain rooted to building graphics, built on graphics-based CAD foundations, and as a result are not fully optimized for creating and managing information about a building. Other industries, such as Manufacturing, have realized great benefit from no graphical, parametric information technology tools. Another generation of software solutions, designed with current technology and purpose-built, is required to fully realize the benefits information technology can bring to the building industry. This next generation of information-centric software provides building information modeling in place of building graphic modeling.

By storing and managing building information as databases, building information modeling solutions can capture, manage, and present data in ways that are appropriate for the building team member using that data. Because the information is stored as a database, changes in that data that so frequently occur during design can be logically propagated and managed by the software throughout the project life cycle.

Building information modeling solutions add the management of relationships between building components beyond the object-level information in object-oriented CAD solutions. This allows information about design intent to be captured in the design process. The building information model contains not only a list of building components and locations but also the relationships that are intended between those objects. For example, that a door should be 3 feet from a window or the eaves of the roof should overhang the exterior wall by 550 mm. Or that three beams should be spaced equally across a structural bay or that the slope of an excavation should be maintained at a certain angle. These relationships, implicitly understood by the designer, become explicit when the building is described in a building information modeler.

Further, these relationships can be inferred by the building information modeler as the user works, or explicitly entered as work progresses. These relationships then allow for changes to the building information model to be managed by the software consistent with the design principles and intent for the project. The richness of the relationships embedded within building components themselves, as well as those embedded in the overall model, makes reuse of the data in other applications even more powerful and the design process significantly more efficient.

## **THE CHARACTERISTICS OF BUILDING INFORMATION MODELING**

Building information modeling solutions create and operate on digital databases for collaboration, manage change throughout those databases so that a change to any part of the database is coordinated in all other parts, and capture and preserve information for reuse by additional industry-specific applications.

### **DIGITAL DATABASES**

Building information modeling solutions create and operate on digital databases for collaboration. The building industry has traditionally illustrated building projects through drawings and added information over those illustrations via notes and specifications. CAD technology automated that process, and object-oriented CAD extended the idea of adding information to illustrations and graphics into software. The result of earlier manual drafting, graphics CAD systems, and object-oriented CAD systems were identical: the creation of graphic abstractions of the intended building design.

The principles of building information modeling turn this relationship around. Building information modeling applications start with the idea of capturing and managing information about the building, and then present that information back as conventional illustrations or in any other appropriate way. A building information model captures building information at the moment of creation, stores and manages it in a building information database, and makes it available for use and reuse at every other point in the project. Drawings become a view into the database that describes the building itself.

In a building information modeler, the building information is stored in a database instead of in a format (such as a drawing file or spreadsheet) predicated on a presentation format. The building information modeler then presents information from the database for editing and reviews in presentation formats that are appropriate and customary for the particular user.

Although each professional working on the building project views the building information in the way he or she expects to see it, these presentations of the information drawings, schedules, cost estimates, other conventional presentations of the building information are all views into the same information model. While each discipline interacts with familiar and customary views of the information, the building information modeler assures that changes made in any of these views is reflected in all other presentations.

Building information models organize collaboration by the building team through digital databases. The building information model can be distributed to individual team members working on a network or sharing files through project collaboration tools. Team members work independently on local data sets while the building information modeling solution manages changes to the model from each of these local databases in a central shared location. Team members can compare their work to concurrent work by other team members and dynamically reserve and release portions of the database for use over the network. A record of these interactions who changed what, and when is available for review, and a history of all changes made by all team members can be preserved in the building information model for as long as this information is useful. Changes can be selectively rolled back to support investigations of options or changes in design direction.

## **CHANGE MANAGEMENT**

Building information modeling solutions manage iterative change through a building's design, construction, and operation. A change to any part of the database is coordinated in all other parts.

The process of building design and documentation is iterative. The understanding of a design problem develops during the design process. In addition to the refinements typical to any design process, a new insight into the design problem may lead the design team to discover that the solution could be quite different, and possibly better. At that point another iteration occurs that may reconsider earlier assumptions. Managing this iterative change is an inherent part of the design process. Technology tools and work processes that do not allow the design to be refined and reconsidered in an iterative way as the project develops discourage the best possible solutions to the design problem. Building information modeling solutions, because of the management of relationships within the data and change to that data, are ideal for this approach. And using building information modeling tools results in the highest quality project for the owner and the best possible work by the team.

Maintaining an internally consistent representation of the building as a database improves drawing coordination and reduces errors in the documents to the benefit of all building team members. Time that would otherwise be spent in manual document checking and coordination can be invested instead in the real work of making the building project better. The resulting documents are of higher quality, and thus the costs of changes and coordination are reduced.

Building information modeling tools enable the design, construction, and occupancy of the building to proceed with less friction and fewer difficulties than conventional tools.

Estimating, procurement, and construction are also iterative processes of definition and elaboration. Specific materials and products are selected from among the range of possibilities that meet the project specification. Selection, refinements, and substitutions may result in changes to some aspects of the design. Ambiguities in the design documents are resolved between the design and construction teams before construction. The construction and design teams consider changes to improve constructability and value for the client. Each of these decisions requires evaluation and that new information be captured to support later evaluations as well as operation and management of the building. Building information modeling solutions capture and manage this information and make it available to support the collaborative process.

The operation of buildings after completion is also an iterative process that is well supported by building information modeling solutions. The first occupancy of a building the end of the conventional design and construction cycle is just the beginning of the life and use of the structure. The evolving occupancy of the building together with the maintenance requirements of the building materials, assemblies, and systems result in changes throughout the life of the building. Building information modeling supports the building life cycle with solutions for the design and documentation of the continuing maintenance, renovation, and renewal of the building itself within the building information model.

## **RECYCLE OF INFORMATION**

Building information modeling solutions capture and preserve information for reuse by additional industry-specific applications. Successful information technology solutions outside the building industry are based on one primary principle: Data is captured once, as close to its point of origin as possible, and stored in a way that it is always easily available and can be presented in context whenever required. A simple example is a personal financial management package that captures information from your checkbook register as you write checks and make deposits, stores and manages that information for a variety of purposes, and presents it back as your income tax return in one case and a statement of net worth in another. Building information modeling accomplishes the same thing for the building industry.

The moment that an architect sketches the outline of a building on a site survey, data is created.

The general size of the building footprint is now known. General program requirements and planning ratios can be applied to deduce the overall building configuration. Similarly, when an architect is working out the building plan, data is being created that can be re-presented in interior elevations, sections, and schedules. Conventional tools require all this data to be rederived at the point in the project where the information about building size or sections and schedules is required. Building information modeling tools capture this data at the moment it is created, store it, and make it available for re-presentation as information in other documents and artifacts as needed.

A construction cost estimator traces over a drawing on a digitizing tablet to derive quantities for a cost estimate or bid or to measure that drawing manually. The construction project manager in the same company traces over these same drawings to develop plans for construction sequencing and phasing. Using building information modeling, instead of tracing over the plans for the quantities, the estimator and the design team can interact with the building information model. Or, if the project team is not ready for that level of collaboration, the estimator can trace over digital plans in software, constructing a building information model in about the same amount of time required for the manual tracing. Now this data is captured in the building information model itself and can be re-presented as a phasing and sequencing plan.

The use of scheduled data in a building information model is for inventory management in a retail operation. As the display unit layout is planned for a store in a building information model, the possible configurations and capacity for each unit are captured and reported back later in a schedule for inventory calculations, and the inventory schedule information can be linked to a procurement system to coordinate the management of inventory with the capacity of the store. The building information model data extends to the support of the store operations.

Recycle of building information leads to connections from Autodesk's current solutions to other applications for energy analysis, structural analysis, cost reporting, facility management, and many others. The persistence of the building information model through the building design, procurement, construction, and operation supports the management of workflow and process around this information.

### 3.3.1 THE BENEFITS OF BUILDING INFORMATION MODELING

The application of building information modeling solutions results in higher quality work, greater speed and productivity, and lower costs for building industry professionals in the design, construction, and operation of buildings.

#### **HIGHER QUALITY**

Building information modeling solutions allow exploration and changes to the project at any time in the design or documentation process without encumbering the design team with laborious recoordination tasks. They also return more time for design and solving real architectural problems to the design team by minimizing coordination time and manual checking. By sharing common building information modeling tools, more experienced team members' work together concurrently with the production members of the project team through all phases of the project, providing close control over technical and detailed decisions about the execution of the design. In construction the consequences of proposed or procured products can be studied and understood easily. The builder can quickly and easily prepare plans showing site utilization or renovation phasing for the owner, communicating and minimizing the impact of construction operations on the owner's operations and personnel. The building owner uses building information models to improve quality in the management of the building. The building information model provides a digital record of building renovations and improves move planning and management.

#### **GREATER SPEED**

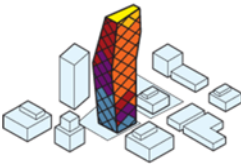
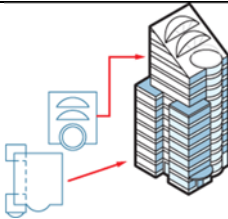
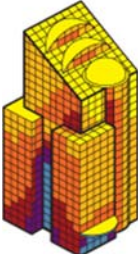

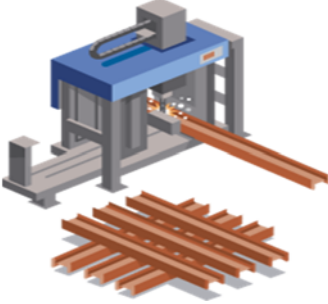
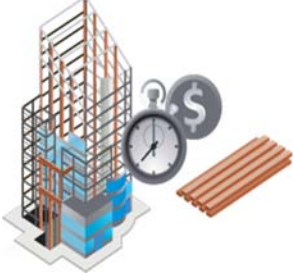
With building information modeling solutions the design and documentation of the building can be done concurrently instead of serially. Design thinking is captured at the point of creation and embedded in the documentation as the work proceeds. All deliverables for the design team schedules, color-filled diagrams, drawings are created dynamically while the design work is being done. When a change is made, all the consequences of that change are automatically coordinated through the project. All of this allows the design team to deliver better work faster. The production of key project deliverables, like visualizations and regulatory approval documents, requires less time and effort by the design team, so the project can move ahead faster. In construction the builder can use the building information model (or create one) to




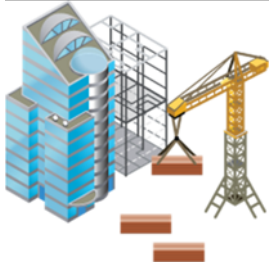


accelerate the quantification of the building for estimating and value engineering purposes. This same model is then reused for revised estimates and construction planning. Building information modeling accelerates the adaptation of standard building prototypes to site conditions for businesses such as retail that require similar buildings in many different locations.

## **LOWER COST**

Using building information modeling, design teams get more work done with fewer people. A smaller design team means lower costs and less chance for miscommunication. Because the documents are coordinated by the computer and therefore can be more complete, the cost of changes and coordination in construction administration is reduced. Floor area-based (square-foot) budgeting and cost estimating is easier with a building information model, and cost information is available earlier and can be updated more frequently than with conventional tools. Changes late in the design process to reduce construction costs are difficult, inefficient, and expensive for the design team. With better cost information available from a building information model these kinds of changes are less likely.

In construction, less time and money are spent in process and administration because document quality is higher and construction planning is better. More of the owner's construction dollar goes into the building instead of administration and overhead in design and construction. The building information model is also used to access and manage physical information about the building such as finishes, tenant or department assignments, and furniture and equipment inventory, as well as financially important data regarding leasable areas and rental income or departmental cost allocations. Access to this information improves both revenue and cost management in the operation of the building.

no	Benefits	Illustration
	Conceptual Design	
	Detailed Design	
	Sustainability Analysis	
	design and construction Documentation	
	Mass and custom fabrication	
	Construction 4D/5D	

<p>Construction Logistics</p>	
<p>Operation and Maintenance</p>	
<p>Demolition</p>	
<p>Renovation</p>	
<p>Programming</p>	
<p>Visualize and simulation</p>	

In 1998, John Elkington introduced the idea of "the triple bottom line" (Figure 7): economic, social and environmental considerations in the report "Cannibals and Forks. "

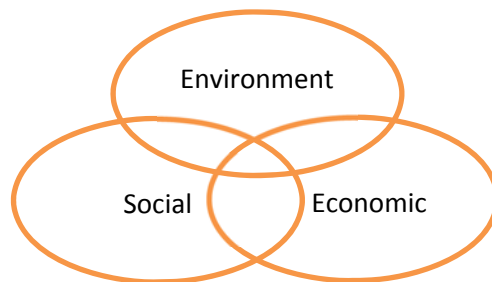


Figure 7, Triple bottom line

Sustainable construction may be described as follows:

- Environmental sustainability – building, up keeping and managing buildings and infrastructure with efficient use of natural resources and minimize the impact on environment.
- Social sustainability – nurturing social cohesion and provision of safe and healthy environment not only to the users, but those working on construction sites and day to day management of buildings and infrastructure.
- Economic sustainability – building cost-effectively while functionally meeting users' requirements, keeping operating costs low, extending the service life of building and infrastructure.
- Buildings are responsible for nearly a quarter of some countries' energy consumption (Cosgrove, 2006). Energy, water and materials are expected to become more expensive as resources dwindle, population and demand grow, and fuel prices increase. There is a growing movement to reduce greenhouse gas emissions and improve the resource efficiency of buildings through better design, construction methods, use of more environmentally preferred materials, and higher-performing building services systems.

Sustainability is usually one of the design objectives identified by a client for a building design project. The design of sustainable buildings requires a more collaborative approach than conventional methods allow. Design of sustainable building and infrastructure calls for a shift from the conventional design process to an innovative ICT based and integrated design process. The conventional design process has a mainly linear structure due to the successive contributions of the members of the design team. There is a limited possibility of optimization

during the traditional process, while optimization in the later stages of the process is often troublesome or even impossible. Since the conventional design process usually does not involve computer simulations of predicted energy performance, the resulting poor performance and high operating costs will most often come as a surprise to the owners, operators or users.

The nature of the conventional design process and the cash flow of fees is also currently frontend loaded which discourages the design team's involvement in the later construction, commissioning, post-occupancy and feedback stages of construction.

Based on experience in Europe and North America, an IDP is especially characterized by a series of design loops per stage of the design process, separated by transitions with decisions about milestones. In each of the design loops the design team members relevant for that stage participate in the process.

## **BIM, IDP AND SUSTAINABLE DESIGN**

As the significance of BIM has become increasingly appreciated, more activity in the building industry has focused on BIM and sustainable design strategies.

Building Information Modeling (BIM) is ideally suited to the delivery of information enabling improved design and building performance. Two major beneficial features of BIM in relation to sustainable building design are those of Integrated Project Delivery (IPD) and Design Optimization.

Traditionally CAD-based design requires a great deal of human intervention and the whole process is time-consuming and costly. However, with BIM, designers can optimize the building design efficiently in the very early stages of the whole process and produce a better solution.

### **3.10.4 SUMMARY OF BIM FOR SUSTAINABLE DESIGN**

Below are outlined benefits of IDP and BIM towards sustainable building and infrastructure design:

- Environmental aspect. The contributions of BIM to integrated project delivery and design optimization are well recognized as significant in reducing the use of materials and energy. Purpose-built BIM solutions and integrated analysis tools can be applied to the assessment of building performance and the selection of solutions which can best reduce consumption of resources such as energy, water and materials. Wastage due to inefficiencies or mistakes in the project delivery process can also be reduced.

- Social aspect. Integrated Project Delivery (IPD) reduces the risk in a construction project by improving communication and collaboration between team members. IPD also improves safety by anticipating problems earlier in the planning stage, e.g. the function of clash detection by combining architectural and MEP models in Navisworks. The quality of the design and construction of the built product can also be improved to provide a better living environment. Furthermore, the growing popularity of BIM will likely lead to an increased number of innovative jobs opportunities via professional BIM consultancy.
- Economic aspect. As discussed above, IPD can improve communication and collaboration as well as anticipate problems earlier. This reduces undesirable wastage due to improved construction management and thus reduces project cost. Moreover, BIM helps to optimize the design, reducing capital and lifetime costs through improved material and energy efficiency.

BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. It has been defined as “the act of creating an electronic model of a facility for the purpose of visualization, engineering analysis, conflict analysis, code criteria checking, cost engineering, as-built product, budgeting and many other purposes.”

**Table 1, BIM Uses Purposes and Objectives**

BIM Use Purpose	BIM Use Objective	Synonyms
<b>Gather</b>	<b>to collect or organize facility information</b>	administer, collect, manage, acquire
Capture	to represent or preserve the current status of the facility and facility elements	collect
Quantify	to express or measure the amount of a facility element	quantity takeoff
Monitor	to collect information regarding the performance of facility elements and systems	observe, measure
Qualify	to characterize or identify facility elements' status	follow, track, identify
<b>Generate</b>	<b>to create or author information about the facility</b>	create, author, model
Prescribe	to determine the need for and select specific facility elements	program, specify
Arrange	to determine location and placement of facility elements	configure, lay out, locate, place
Size	to determine the magnitude and scale of facility elements	scale, engineer
<b>Analyze</b>	<b>to examine elements of the facility to gain a better understanding of it</b>	examine, evaluate
Coordinate	to ensure the efficiency and harmony of the relationship of facility elements	detect, avoid
Forecast	to predict the future performance of the facility and facility elements	simulate, predict
Validate	to check or prove accuracy of facility information and that is logical and reasonable	check, confirm
<b>Communicate</b>	<b>to present information about a facility in a method in which it can be shared or exchanged</b>	exchange
Visualize	to form a realistic representation of a facility or facility elements	review
Transform	to modify information and translate it to be received by another process	translate
Draw	to make a symbolic representation of the facility and facility elements	draft, annotate, detail
Document	to create a record of facility information including the information necessary to precisely specify facility elements	specify, submit, schedule, report.
<b>Realize</b>	<b>to make or control a physical element using facility information</b>	implement, perform, execute,
Fabricate	to use facility information to manufacture the elements of a facility	manufacture
Assemble	to use facility information to bring together the separate elements of a facility	prefabricate
Control	to use facility information to physically manipulate the operation of executing equipment	manipulate
Regulate	to use facility information to inform the operation of a facility element	direct

### 3.3.2 BIM SOFTWARES

The first software tools developed for modelling buildings emerged in the late 1970s and early 1980s, and included workstation products such as Chuck Eastman's Building Description System and GLIDE, RUCAPS, Sonata and Reflex. The early applications, and the hardware needed to run them, were expensive, which limited widespread adoption. ArchiCAD's Radar CH, released in 1984 was the first modelling software made available on a personal computer.

Due to the complexity of gathering all the relevant information when working with BIM on a building project some companies have developed software designed specifically to work in a BIM framework. These packages (e.g.: Bentley AECOsim Building Designer, ArchiCAD, Tekla Structures, Autodesk Revit, Synchro PRO, VectorWorks) differ from architectural drafting tools such as AutoCAD by allowing the addition of further information (time, cost, manufacturers' details, sustainability and maintenance information, etc.) to the building model.

### NON-PROPRIETARY OR OPEN BIM STANDARDS

BIM is often associated with Industry Foundation Classes (IFCs) and aecXML – data structures for representing information. IFCs have been developed by buildingSMART (the former International Alliance for Interoperability), as a neutral, non-proprietary or open standard for sharing BIM data among different software applications (some proprietary data structures have been developed by CAD vendors incorporating BIM into their software).

Poor software interoperability has long been regarded as an obstacle to industry efficiency in general and to BIM adoption in particular. In August 2004 a US National Institute of Standards and Technology (NIST) report conservatively estimated that \$15.8 billion was lost annually by the U.S. capital facilities industry due to inadequate interoperability arising from "the highly fragmented nature of the industry, the industry's continued paper based business practices, a lack of standardization, and inconsistent technology adoption among stakeholders".

An early example of a nationally approved BIM standard is the approved CIS/2 standard, a non-proprietary standard with its roots in the UK.

There have been attempts at creating a BIM for older, pre-existing facilities. They generally reference key metrics such as the Facility Condition Index (FCI). The validity of these models will need to be monitored over time, because trying to model a building constructed in, say 1927, requires numerous assumptions about design standards, building codes, construction methods, materials, etc., and therefore is far more complex than building a BIM at time of initial design.

### 3.3.3 CONTEXTUAL REVIEW

Achieving sustainable building and infrastructure entails concerted considerations all the way from inception to demolition stages. In contrary to the fact that the issue of sustainability is in vogue, its implementation especially in the construction industry of developing countries including Ethiopia is still at its infancy.

Investment in infrastructure in developing countries is essential for poverty reduction ( (Bisrat kifle, 2008)) and it positively and significantly correlates with economic growth. According to the World Bank report there is a huge gap in infrastructure provision which is estimated at \$1 trillion in low-and middle-income countries, and the demand continues to grow as countries develop. Infrastructure access gap looms large in the developing world where an estimated 748 million people live without access to safe water, 1.2 billion without electricity, 1 billion people live more than two kilometers away from an all-weather road, 2.5 billion without sanitation, and more than 1 billion without access to telephone services ( (The World Bank Group, 2016)). This signifies the need for more investment in building and economic infrastructure in Ethiopia within the coming years. However, lessons from other developing and developed countries shows that these huge investment needs to be coupled with aspects of sustainable design and construction considerations which in turn necessitates a shift from the traditional to a modern design approach.

In the traditional design and delivery approach where sustainability is not adequately considered, resulting building and infrastructure become fragmented that are highly unsustainable and vulnerable ( (Autodesk, 2002.)). Due to presence of huge input and complex process in sustainable building and infrastructure design and delivery, the need for innovative information based intervention like BIM (Building Information Modeling) and IDP is inevitable.

While IPD and BIM are being implemented in the construction industry of the developed world, their application in the developing countries, especially in the area of buildings and infrastructure is very much limited. Therefore, there is a need to assess the current practices and formulate interventions to pave a way for its implementation in Developing countries including Ethiopia.

## CHAPTER IV: DATA ANALYSIS AND FINDINGS


This chapter will first compare the building design process management according to the criteria described under methodology. The analysis of the design process assessed will be done simultaneously in order to make the comparison easier. Then in the second part of the chapter the analysis is conducted in relation with the research question in continuative order; the gap in Ethiopian building design process, the problems and challenges during building construction design services and potential of BIM in solving the problems and narrowing the gap. Then the gaps between the findings and the BIM will be addressed.

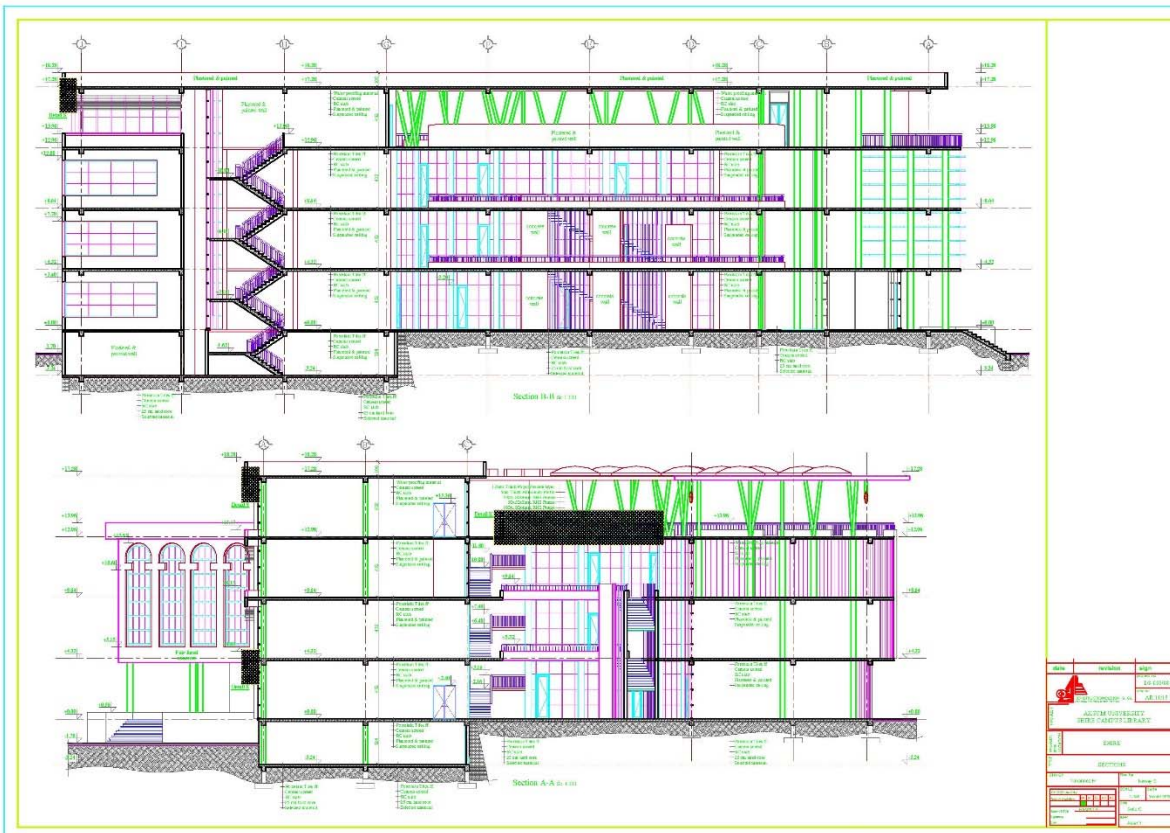
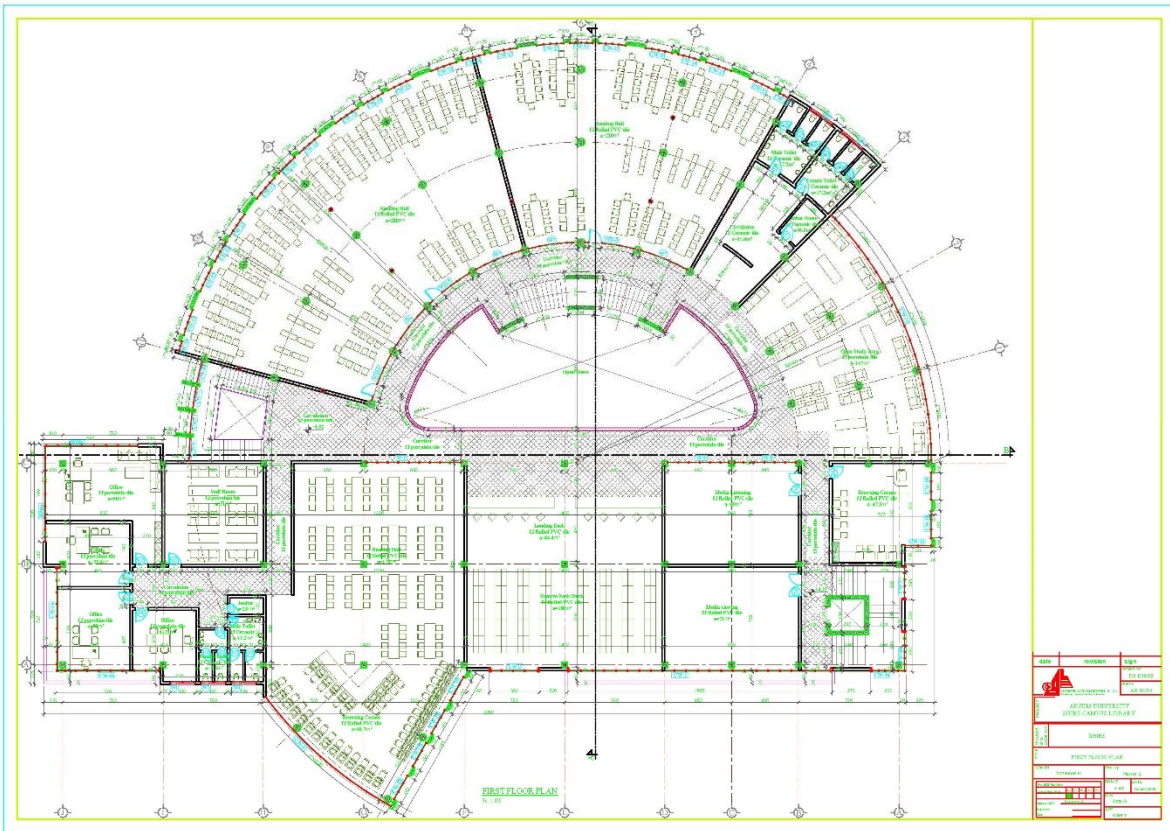
### 4.1 GENERAL DESCRIPTION

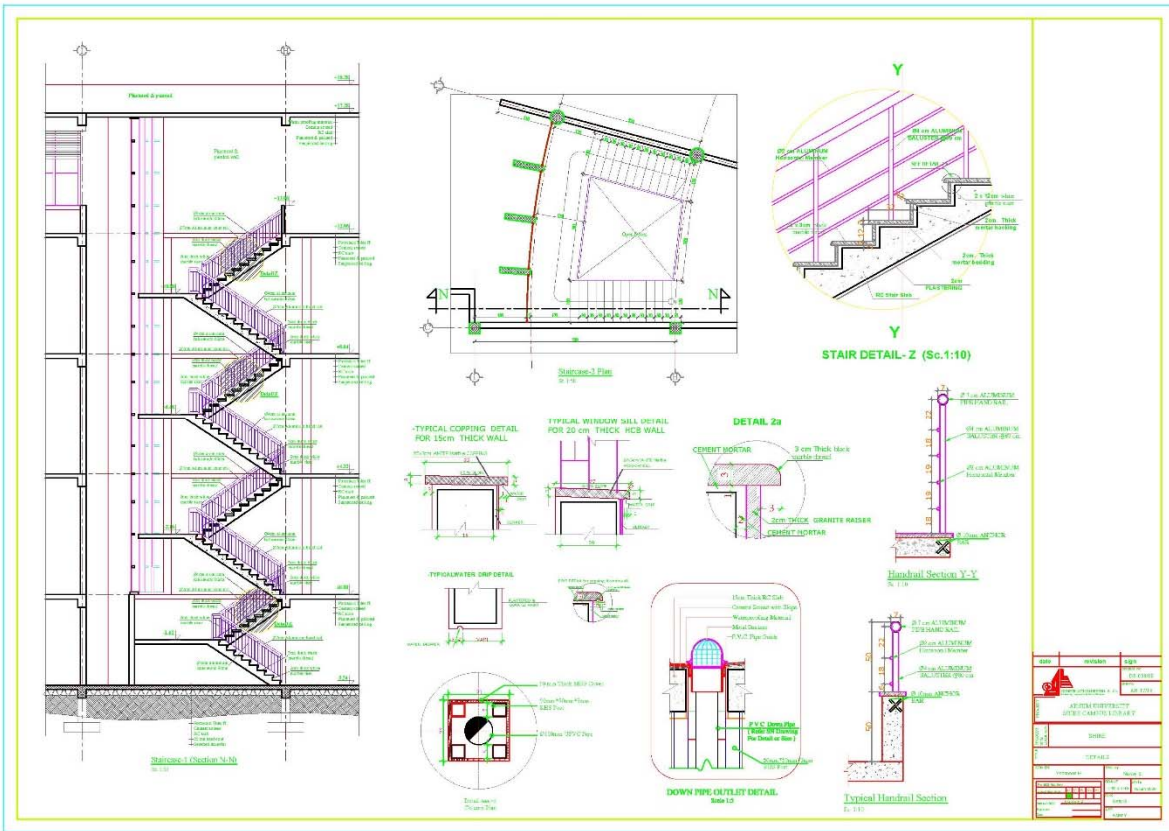
The data used for this research is questioner and document review crosschecked with an interview. Of the distributed questioners 88% were returned and analyzed. The data calmed from client was 19%, from consultant was 41%, and from contractor was 15%. Consultants selected and fulfilling the sampling size indicated on the methodology are; Consultant's target case was the Former BDE /Building Design Enterprise/, Construction Design S. Co. And ETG Designers and Consultants P.L.C (category I architects and engineers consultancy firm).

Two governmental university projects, **AXUM UNIVERSITY LIBRARY** and **DEBRE-MARKOS STAFF LOUNGE** designed by Construction Design S. Co are reviewed.

#### AXUM UNIVERSITY LIBRARY

<p><b>PROJECT AREA</b>-61Mx26M</p> <p><b>PROJECT COST</b>-110Million ETB</p> <p><b>CLIENT</b>- Axum University</p> <p><b>CONSULTANT</b>- Construction Design S. Co</p> <p><b>PROJECT PROGRESS</b>-70%</p> <p>See annex 2</p>	 <p>The image displays a collection of architectural renderings for the Aksum University Library. At the top is a large, wide-angle rendering of the building's exterior, featuring a modern design with a curved facade and large glass windows. Below this are several smaller, circular and rectangular renderings showing different perspectives of the building, including interior views of the library's structure and exterior details. The text 'AKSUM UNIVERSITY LIBRARY' and 'DESIGNED BY : NEWAY S.' is visible at the bottom of the main rendering.</p>
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## DEBREMARKOS UNIVERSITY STAFF LOUNGE

**PROJECT AREA-40Mx40M**

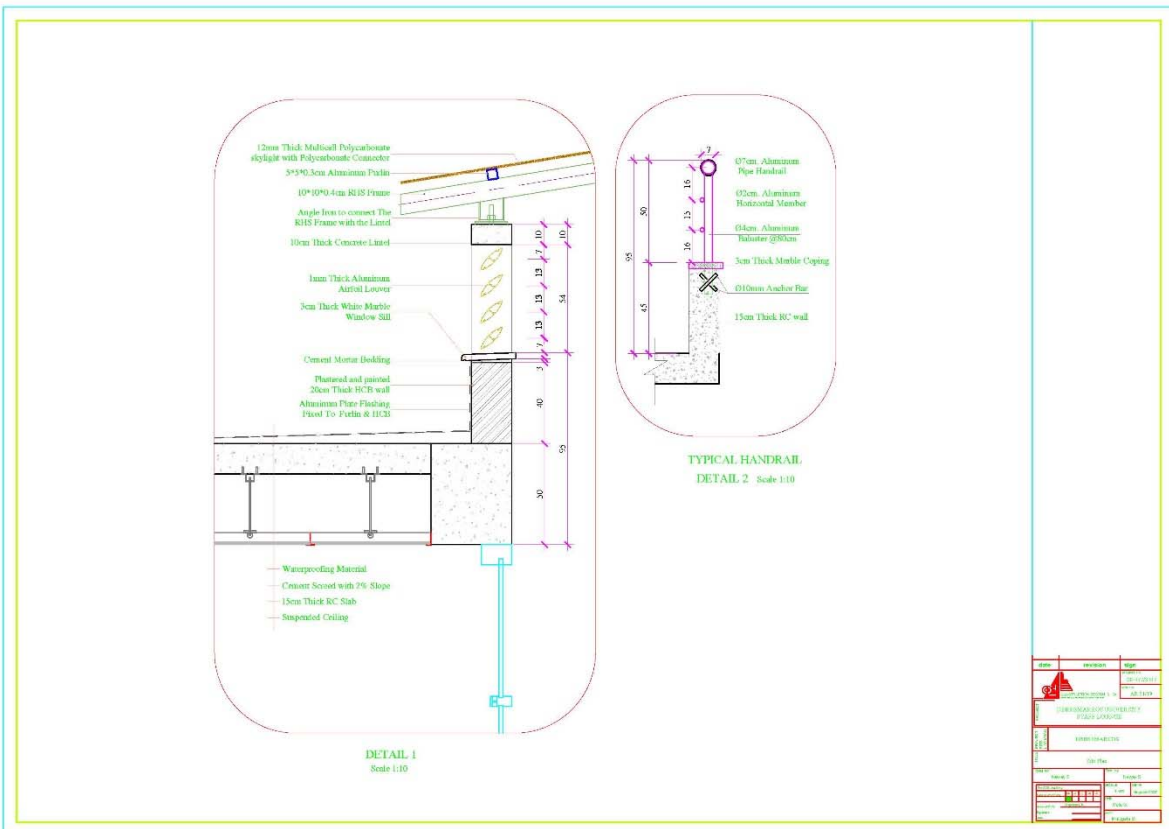
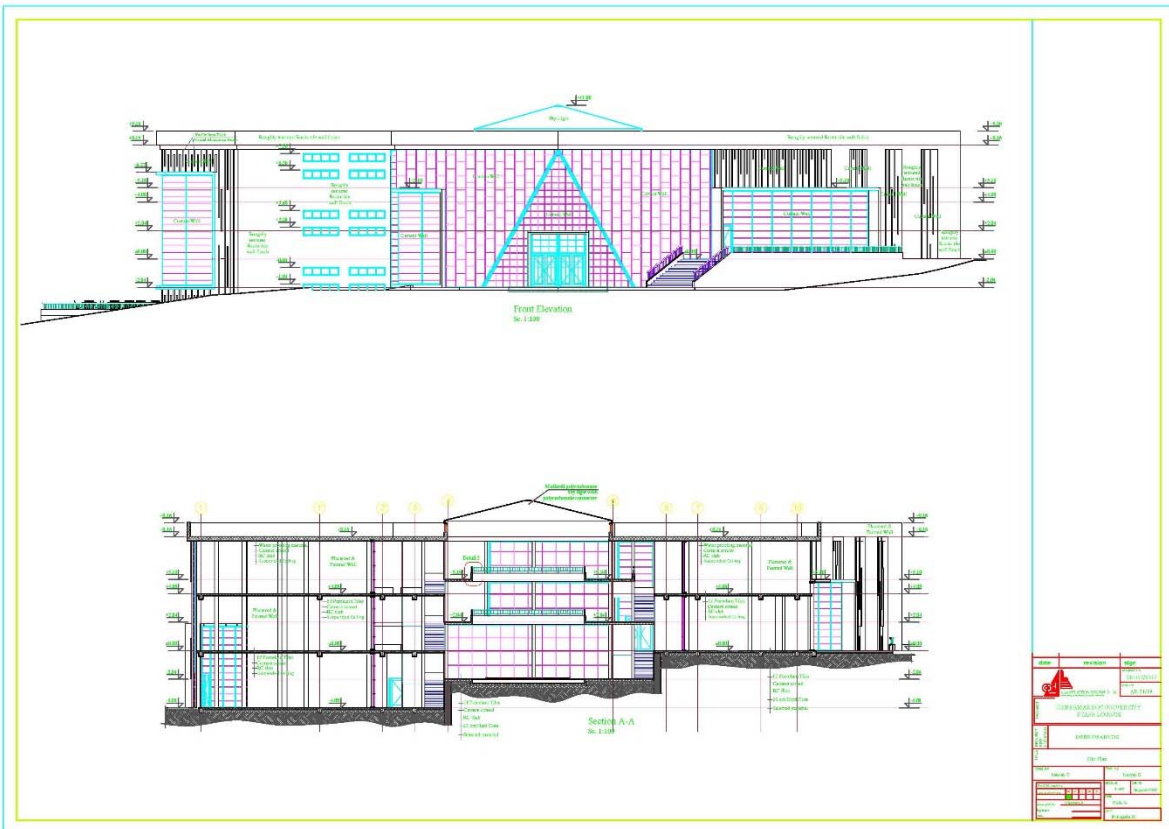
**PROJECT COST-50Million  
ETB**

**CLIENT- Debre-Markos  
University**

**CONSULTANT-  
Construction Design S. Co**  
**PROJECT PROGRESS-12%**  
See annex 1







## General Project description

Projects Status	Design Process Missing
Project modality – Linear/ successive design process	Integrated design process
Conceptual design addressed- General massing scheme, Orientation, openings arrangement, general exterior appearance, , 3D visualization and Animatin	basic materials, construction process structural principles,
Computer Software used- AutoCad, Archicad, Exce, SAP,	Integrated design Tolls
value engineering-	Architectural science analysis Environmental impact analysis energy-use analysis structural details analysis, Material use analysis, cost estimates
final design documents- Construction working drawing, Window + door schedule	Room schedule, basic materials specification construction process recommendation Detail quantity specification
modes of communication- paper-based	Automated

Note: all graphs in this chapter are indicated in percent (out of 100%).

### 4.2 GAPS IN CONSTRUCTION DESIGN PROCESS MANAGEMENT PRACTICE

The first research question to be addressed was, “What are the gaps in construction design process management practice and its impact in Ethiopia?”

Below is the set of findings related to the Ethiopian design process that were asked to find the gap to be identified.

100% of the respondents responded “yes” by assuring that the Ethiopian design process begins with the architect. Even though the consultant provides a conceptual design with an alternative or more than one scenarios and the client confirmation is recommended approach, identified gaps are indicated on the graphs below.

## Design Concept Address

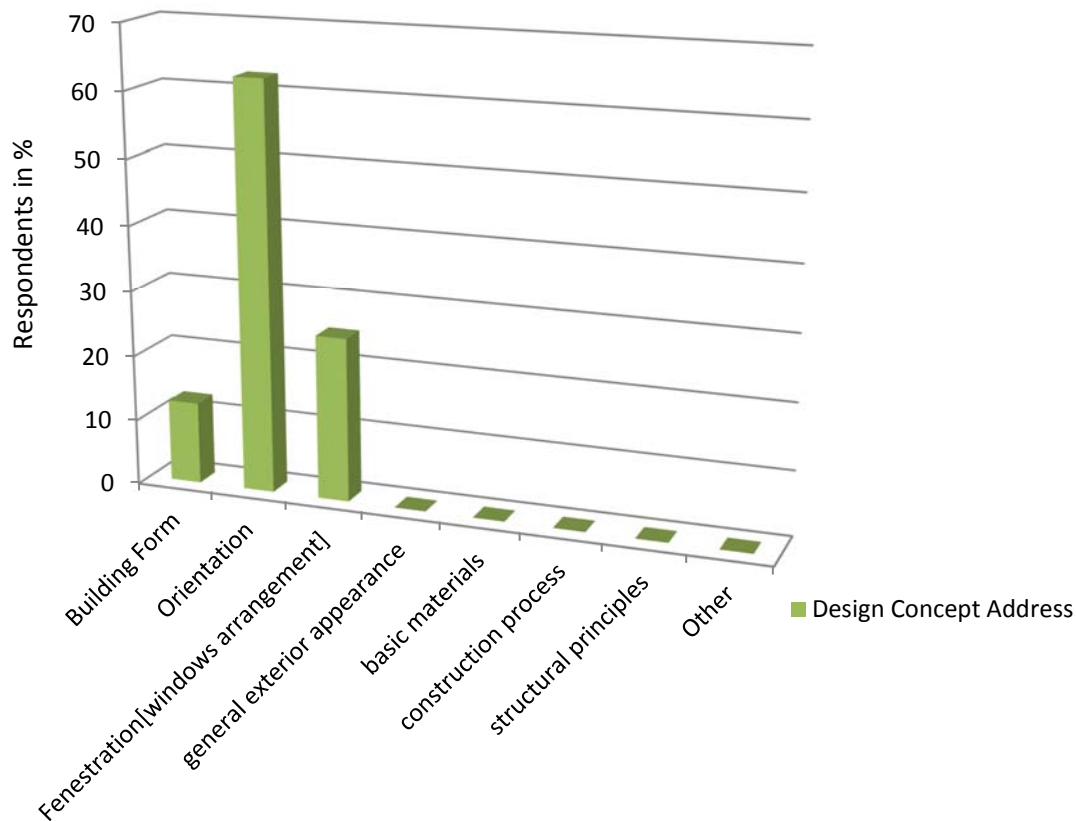


Figure 8, Design Concept Address

As it is backed in the literature review, Ethiopia, Addis Ababa embraces the conventional design process; as the design begins with the architect and the client agreeing on the concept. And, it is also missing all the important and key features.

From the graph, Figure 8, we can see that, on the conceptual design, general massing skims (Building form) are only 12.5%, this indicates that it is conceptualized way less than the required even less than average. Basic things like the building materials, construction process and structure principle are ignored from the beginning by local building designers and consultants.

## Plan at the conceptual stage

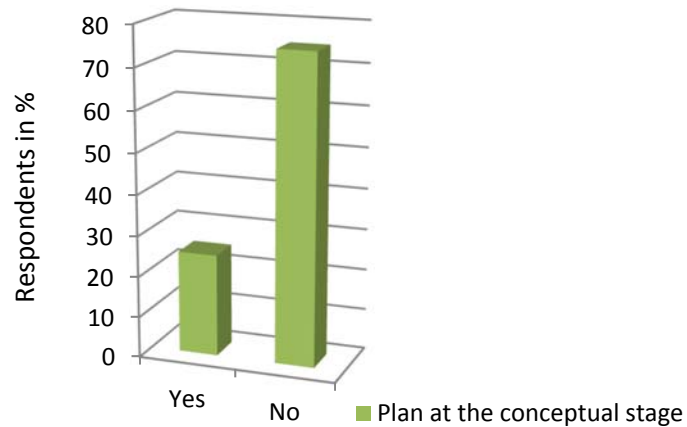


Figure 9: plan at the Conceptual Stage

Planning from starting from the conceptual stage is a critical aspect in the building industry. But here we can see that the planning stage is not properly addressed, as the majority of the respondents did not give attention for this important stage.

Even looking to the perspective to those who responded yes shows that it needs further improvement, as it is indicated by the graph, Figure10, below,

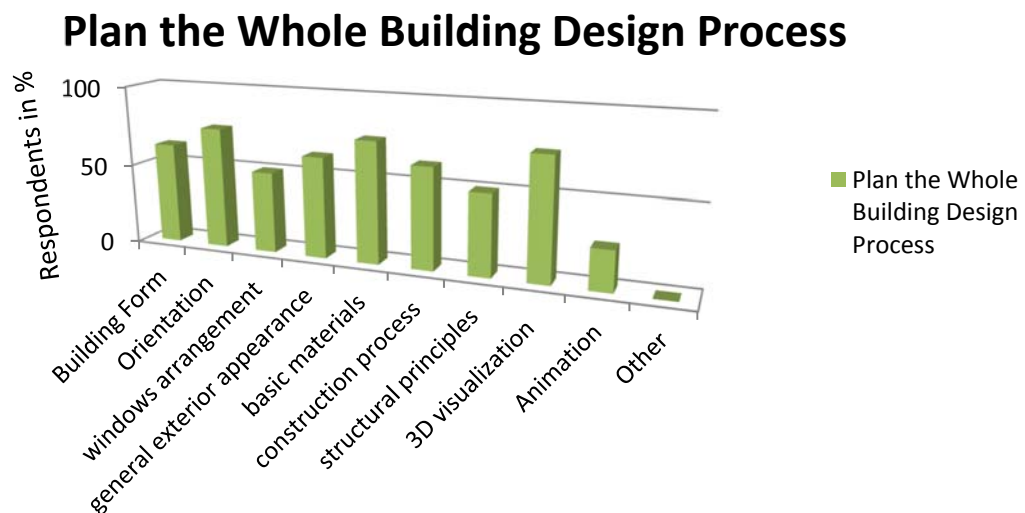


Figure 10: Plan the Whole Building Design Process

Looking to the design process, most of the designers in the case area, are currently implementing the linier/successive designing approach, as they all think that is quick and simple, it does not require computer simulation, it requires less operational cost and paper based communication.

### Design Process to Follow

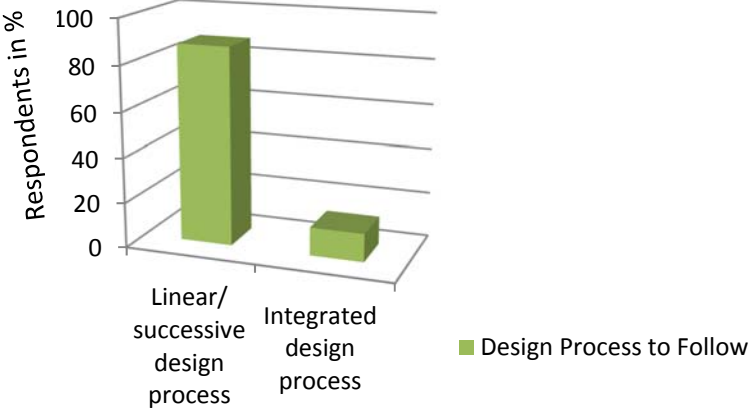


Figure 11: Design Process to Follow

The respondents agree that linier/successive designing approach has gaps, in resulting substandard property, fragmented facility delivery process, errors and omissions in paper communication do occur.

### Effects of Errors and Omissions

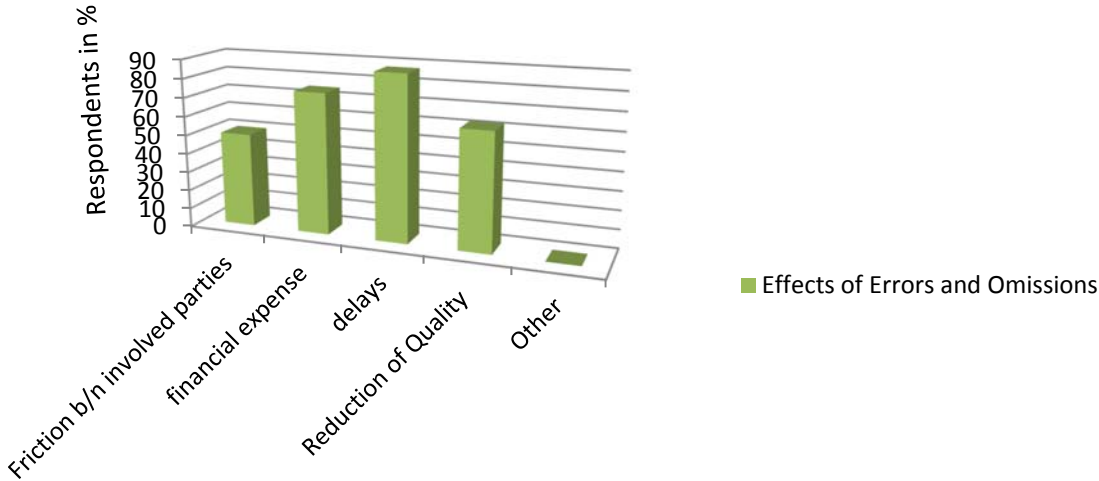


Figure 12: Effects of Errors and Omissions

This indicates that the integrated design process requires high operational cost; the sustainable implementation of this kind of process has an additional expense on the side of the designer which is not proportion to the low design fee.

### High Operational Costs

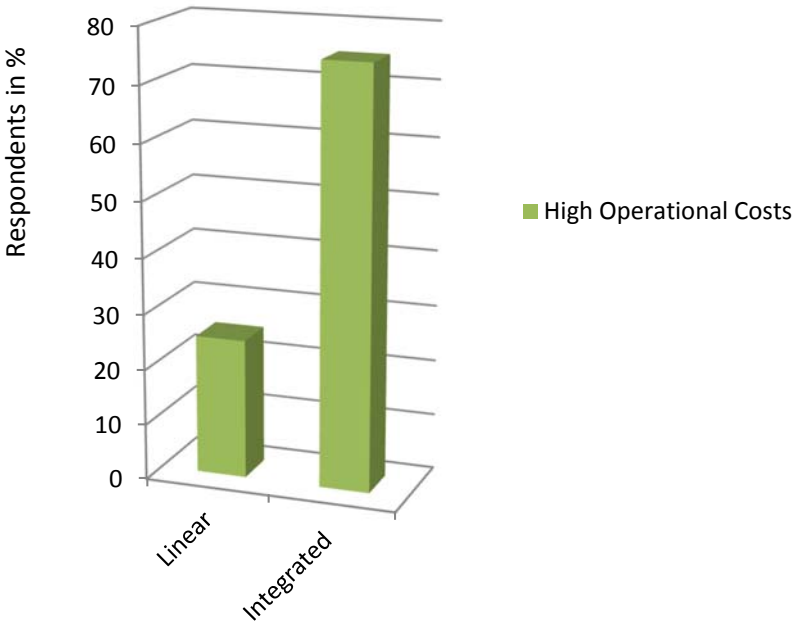
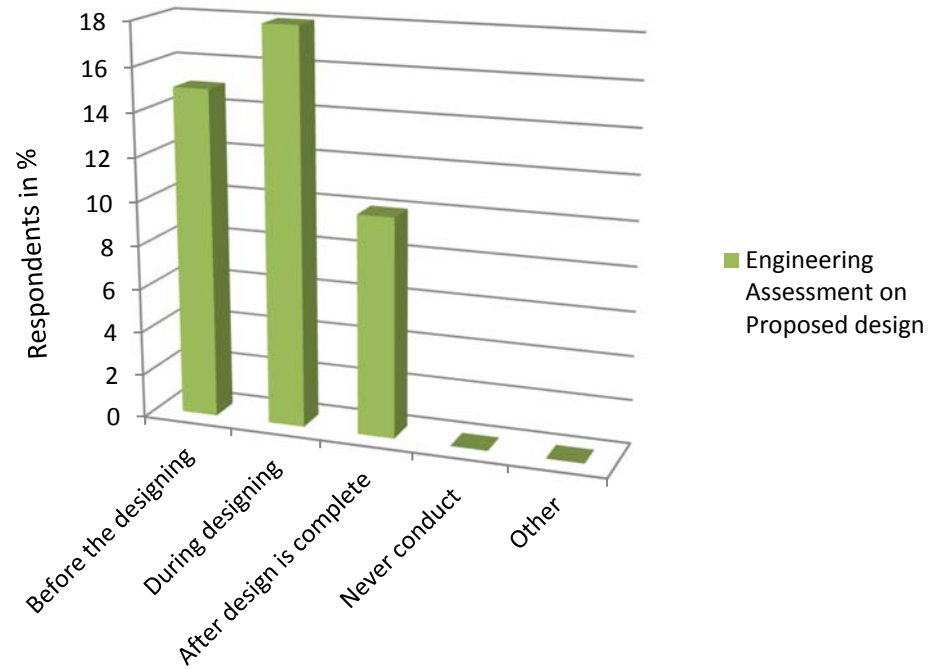


Figure 13:High Operational Costs

Paper based documents result in omission of information and document errors indicated in the graph, Figure12, above, illustrates that delays being the major gap, additional financial expense and reduction of quality are also take major portion with average friction between involved parties

and all the stakeholders, including client, consultant, contractor and government.

## Engineering Assessment on Proposed design



**Figure 14: Engineering Assessment on Proposed design**

Engineering or critical assessment along the design process is given a very little attention even less than 20%. This also shows that the design process is not as per the standard design framework that stated in the literature review of this research paper.

Even though the documents are fragmented and take longer time to prepare, the final design document includes most of the standard criteria for such design stage.

## Final Design Documents

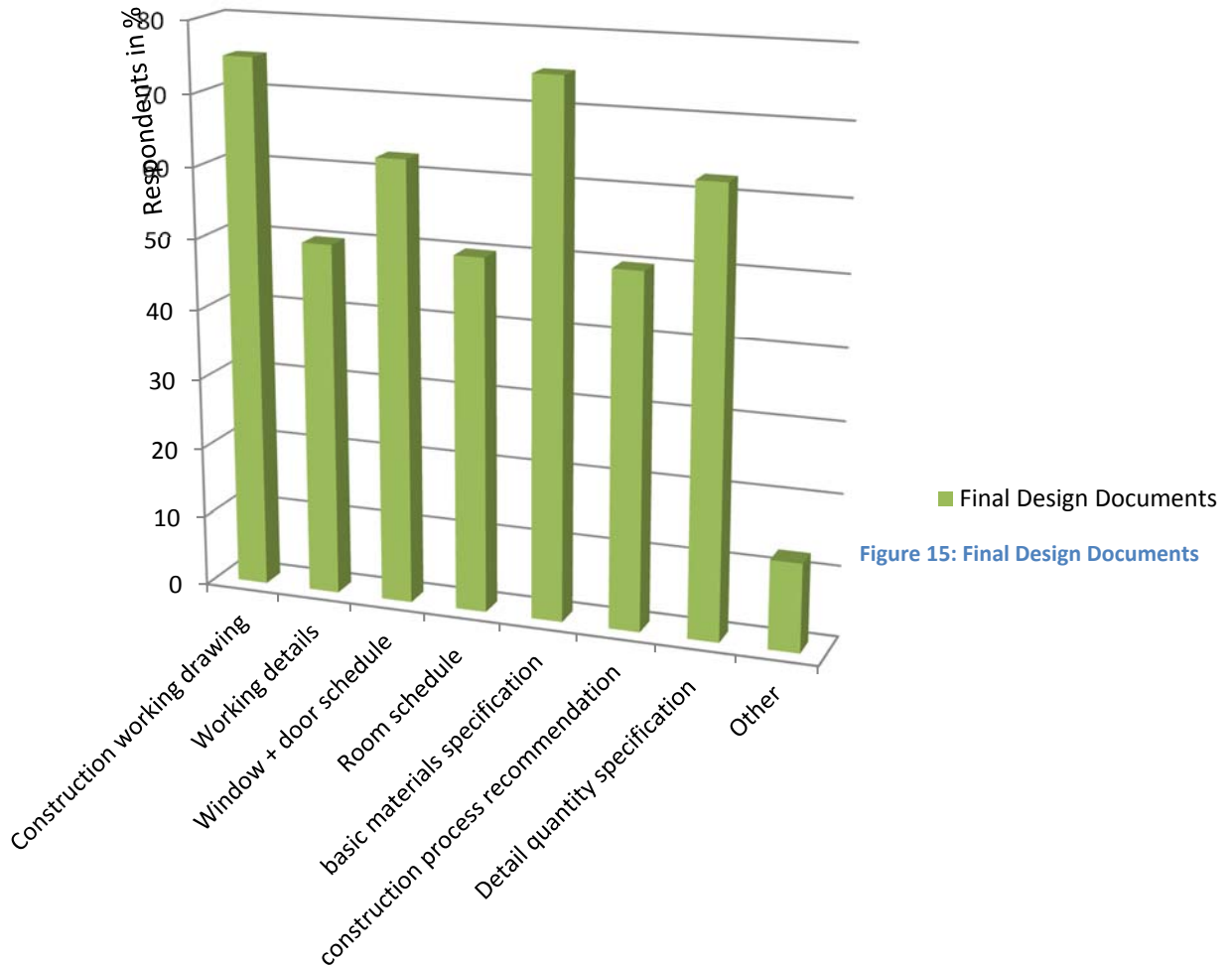


Figure 15: Final Design Documents

### 4.3 PROBLEMS AND CHALLENGES OF BUILDING CONSTRUCTION DESIGN SERVICES

In this sub chapter, the major challenges of the building design process are analyzed. Very low project fee resulting in reduced capacity to have permanent staff and limitation on accessing licensed software are placed as the leading challenges. Expensive and unaffordable database infrastructure and lack of adequate training centers are also partly mentioned as challenges.

## Problems and Challenges

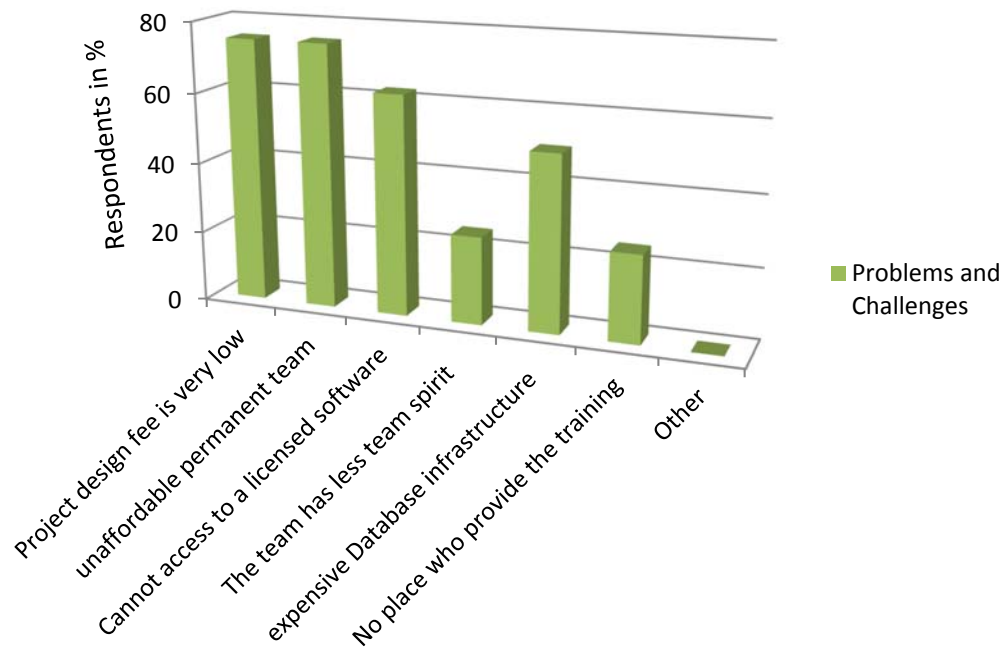
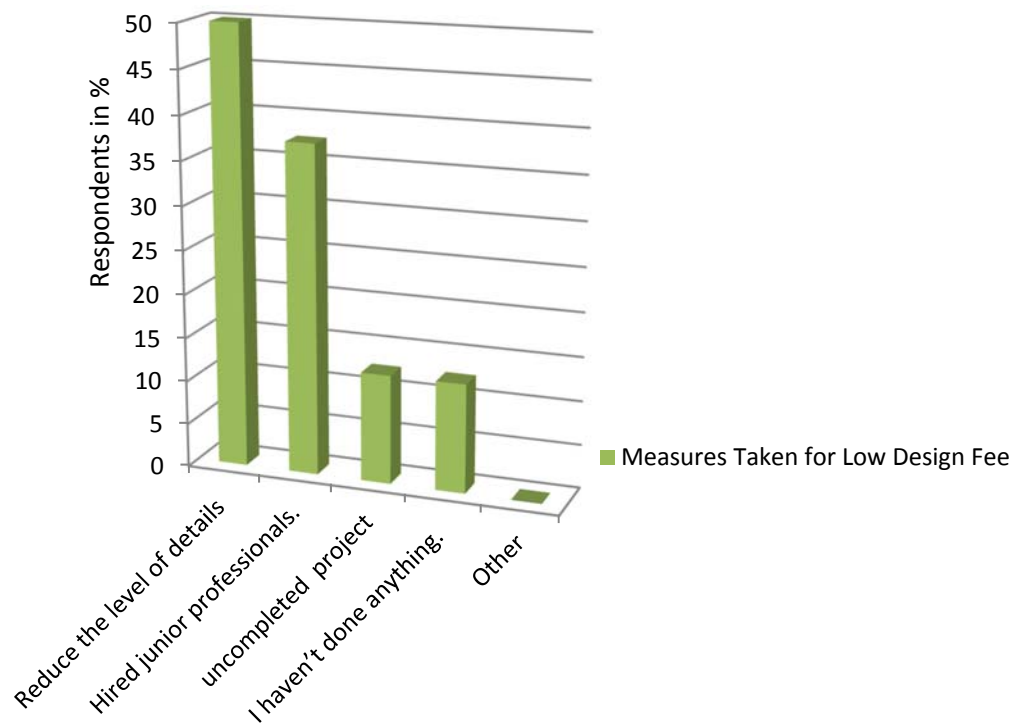


Figure 16: Problems and Challenges

As expressed on the graph, Figure17, below, the majority agrees that the basic challenge is to be inefficient design fee. This results in handing over substandard products, uncompleted design with fewer details, and allocating less experienced professionals for the project; in order to minimize design process cost.

The majority, 87.5% were affected by it. The remaining has done nothing to this challenge. As indicated, it is insufficient for covering basic expenses like, very low that it wouldn't cover for purchasing licensed software/ researches, and data-base infrastructure development.

## Measures Taken for Low Design Fee



**Figure 17: Measures Taken for Low Design Fee**

Looking at the consequence of low design/professionals fee is the reduction of the detail design making and this is done by appointing junior professionals taking the highest factor, handing over incomplete design comes on the next rank. It is clear that this has a great impact on the design quality as well.

# Reduce the level of details for the design

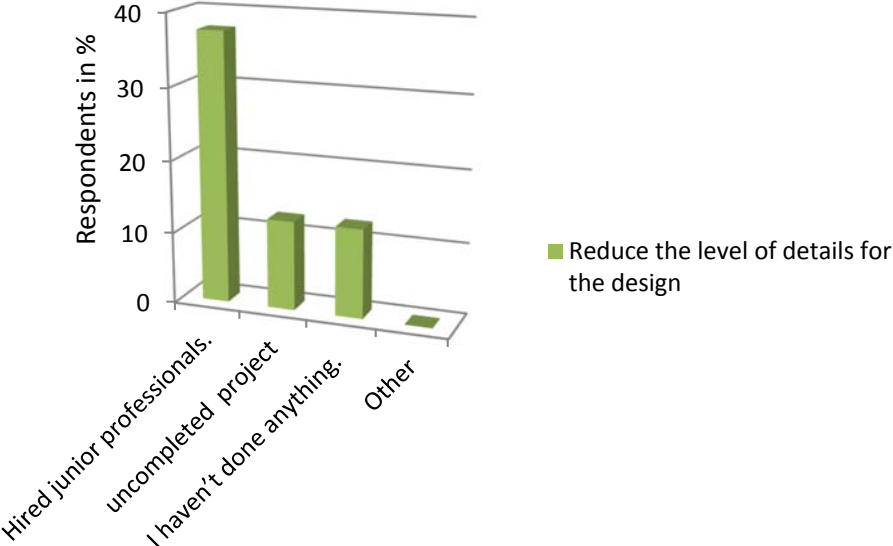


Figure 18: Reduce the level of details for the design

# Can Not Afford Permanent Team

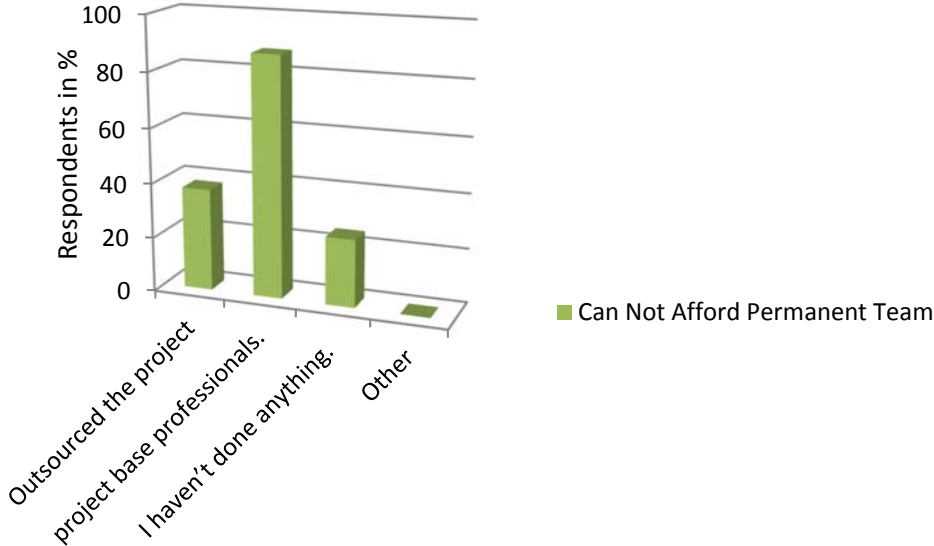


Figure 19: Can Not Afford Permanent Team

One other challenge caused by low design fee is, the designers were unable to purchase licensed software. This forced them to use cracked version of the software with all the limitations, use open software that are equivalent, if found.

As seen on the graph, Figure 20, below, the majority use cracked version, literature indicates that the cracked version cannot operate as the brand ones. While cracking some features might not operate, or even if it does it comes with limitations.

### Can Not Afford licensed software

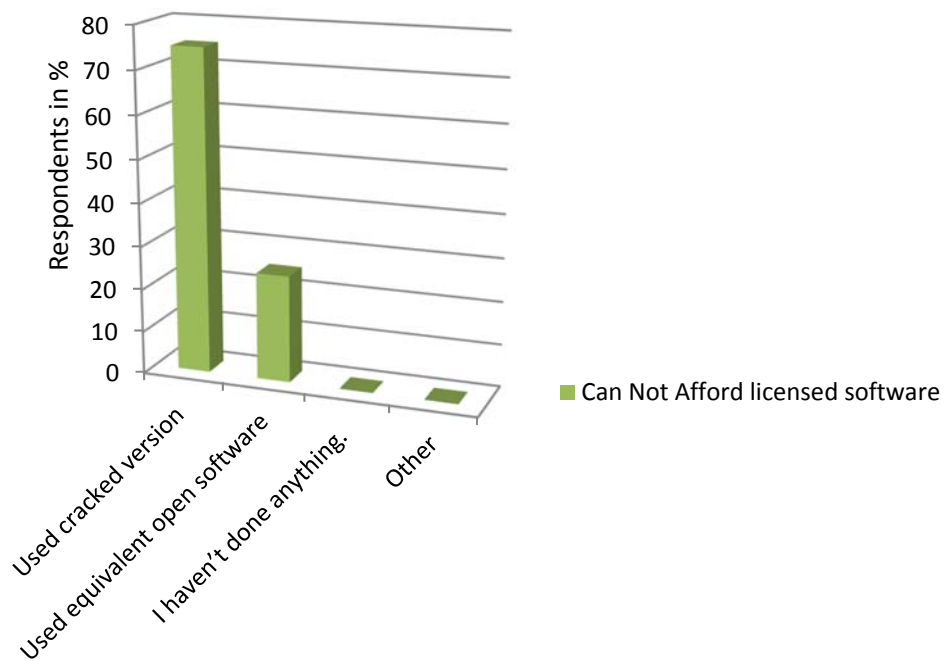


Figure 20: Can Not Afford licensed software

The project going over budget, extended period and lesser quality are also mentioned as a problem caused by the poor building design management, low design fee, inability to have a permanent team, limitation in having licensed software, higher cost in establishing data base infrastructure.

## Projects Go Over Budget

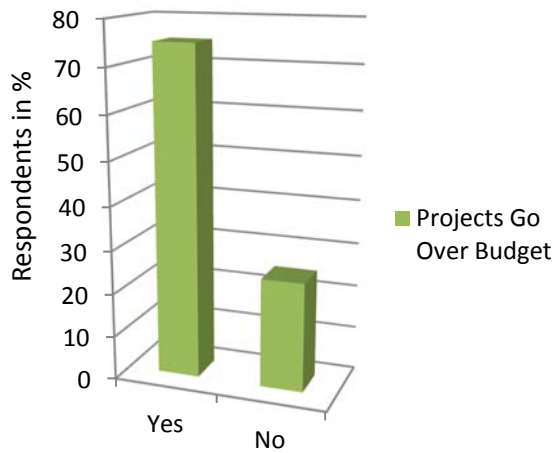


Figure 21: Projects Go Over Budget

## Projects Budget Negatively Altered

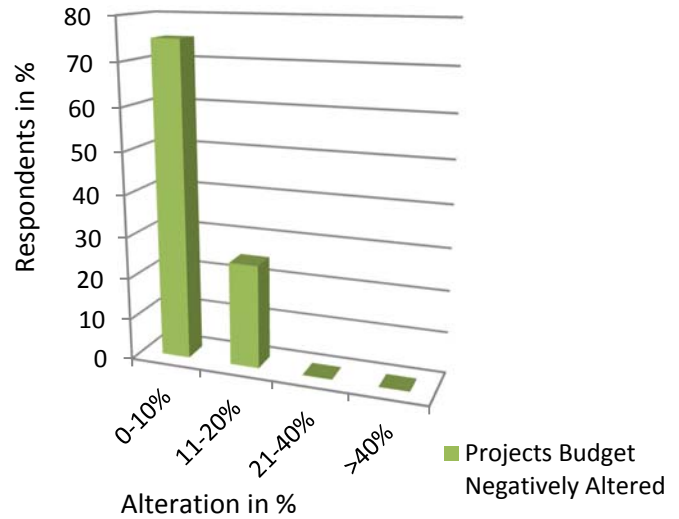


Figure 22: Projects Budget Alteration

## Projects Go Over Schedule

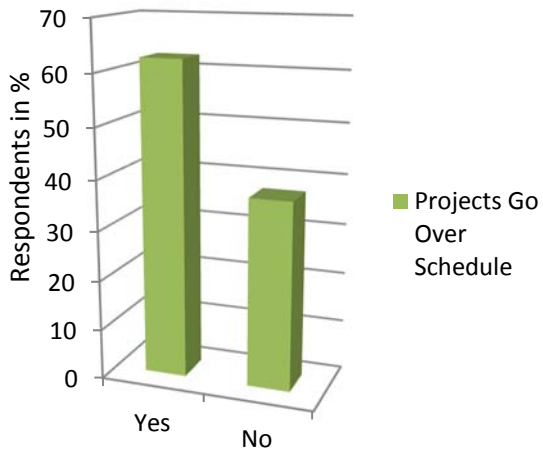


Figure 23: Projects Go Over Schedule

## Projects Schedule Negatively Altered

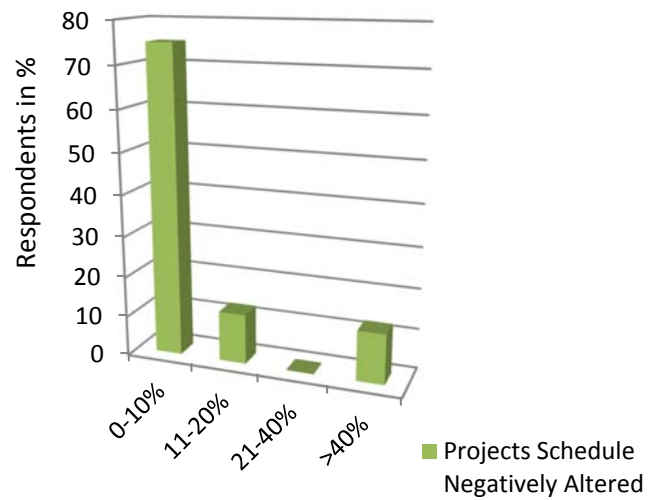
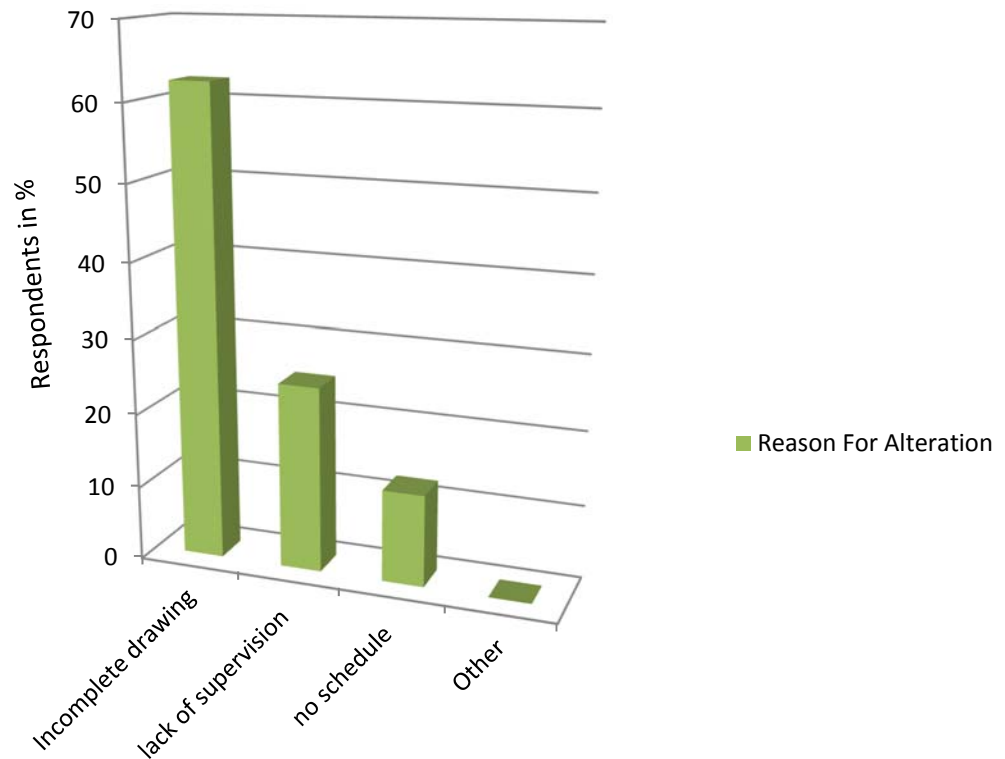


Figure 24: Projects Schedule Alteration

## Reason For Alteration



**Figure 25: Reason For Alteration**

As showed on the graph above, incomplete drawing covers major Cause for alteration of cost, quality and completion period.

### **4.4 CAN BIM Fill THE GAPS AND SOLVE THE PROBLEM?**

Generally in this chapter, the capacity of BIM in solving the problems indicated in 4.3 will be analyzed. 1<sup>st</sup> the general awareness of the professionals were studied and then the significance of BIM as per the professionals perspective, and finally what is analyzed is the benefit acknowledged by those local professionals who used it.

Form the analyzed data, it is understandable that the majority of the professionals has at list has used BIM application; they rated the significance in encouraging way. This is a good sign for future adoption of BIM based applications.

The affordability factor has been stated as major purpose for those who haven't used BIM. But this is a good sigh as most of them are aware of the significance and the advantages. And seen is the limitation in financial capacity, as this limitation can be improved with the general growth of the country.

### BIM knowhow In the Case Area

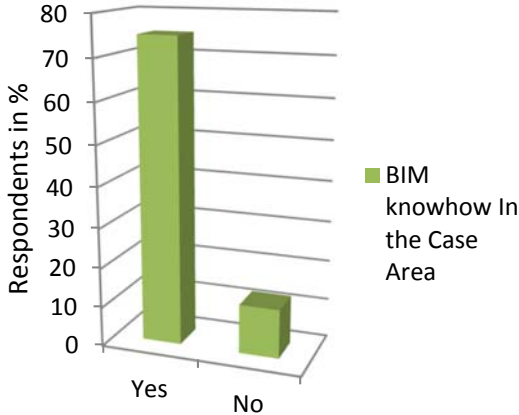


Figure 26: BIM knowhow In the Case Area

### BIM significance In the Case Area

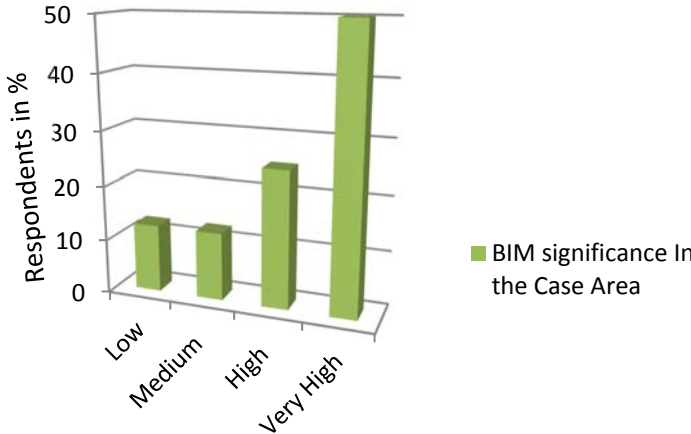


Figure 27: BIM significance In the Case Area

The above graph, fig 26, shows respondents basic knowhow regarding BIM. Fig 27, shows the 50% of respondents agree that BIM is significant for the case area. And its advantages and uses have been rated on the graph below.

## BIM's Advantages

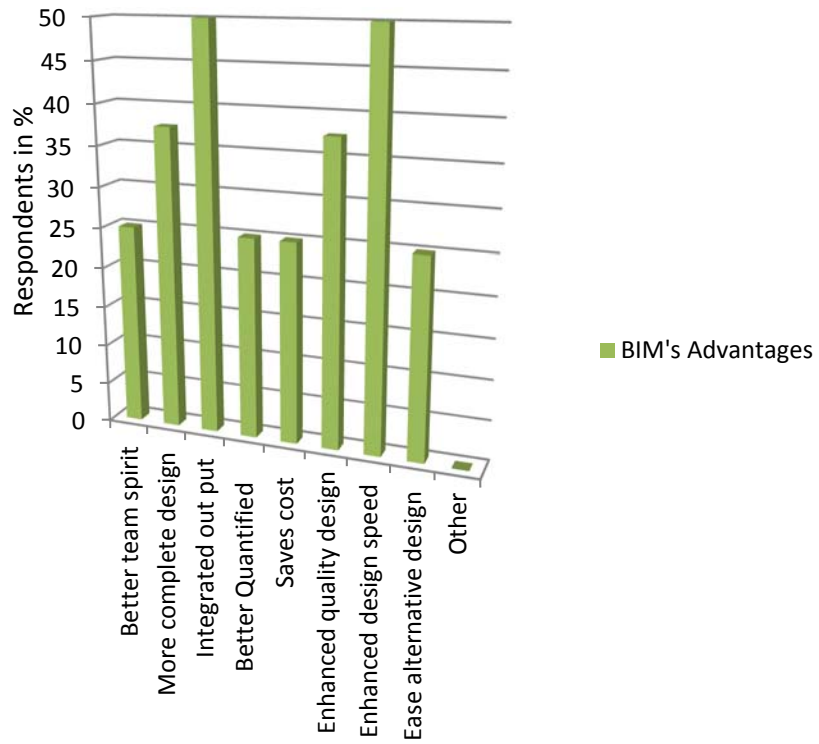


Figure 28: BIM's Advantages

## BIM Stage Used

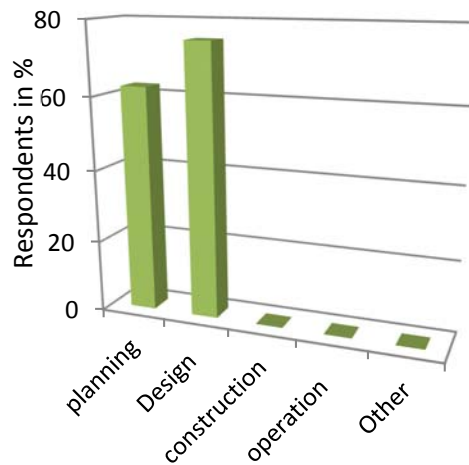
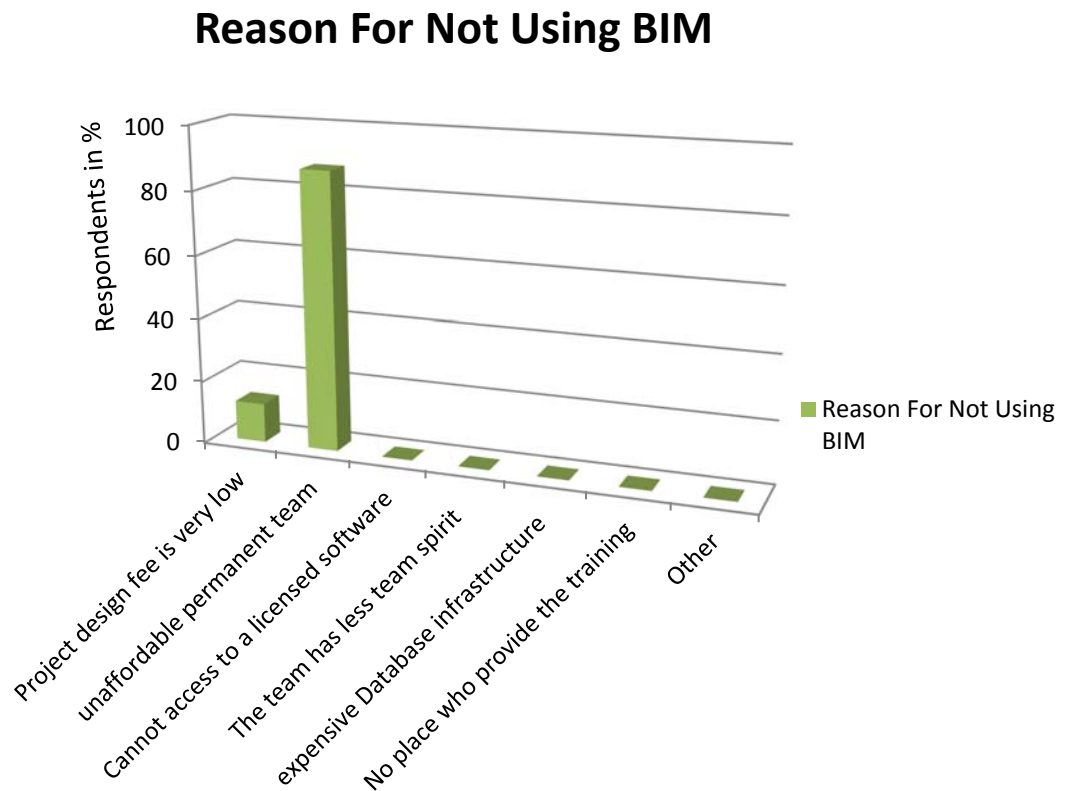


Figure 29: BIM Stage Used

The graph, Figure29, indicated above shows that there is particular works needs to be done on building planning, construction and operational stage.

The graph, Figure30, indicates why professionals in the case area are not able to use BIM. By considering the project fee being very low, expensive to have permanent team, unable to access licensed softwares, less team spirit, establishing database infrastructure is very expensive, unable to find a place to receive training.



The above graph shows, the majority of the Respondents agree that the major reason for not using BIM is, not able to afford permanent working team, as per BIM requirement.

**Figure 30: Reason For Not Using BIM**

## 4.5 RESEARCH FINDINGS

This chapter discusses the summarized findings gained through the methods predefined under the methodology and gives an answer for the objectives stated in this thesis paper. The findings are extracted from the general information from the respondents, case study and interview. Below is the list of findings:-

- Design process is not as per the standard design frame work
- Most consultants/designers do not provide design alternative to the client.
- Designers in the case area, are currently following the conventional designing approach
- Conventional design approach documents are fragmented and take longer time to prepare.
- Conventional design /Paper based approach result in omission of information and document errors.
- Engineering or critical assessment on the design process is given a very little attention
- projects go over budget, extended period and lesser quality caused by the poor building design management
- Low design fee is the root problem identified poor building design management
- Low design/professionals fee resulted in reduction of the details, limitation in having licensed software forced the experts to use cracked version, higher cost in establishing data base infrastructure.
- the majority of the professionals has at list the basic knowhow on BIM application; they rated the significance in encouraging way

- 

#### **4.6 POSSIBLE REMEDIAL SOLUTIONS**

This chapter discusses the obtained results in detail by comparing with the existing facts and forwards possible onsite sanitation options for each problem so far discussed.

##### **POSSIBLE REMEDIAL SOLUTION FOR BETTER ADOPTING BIM**

- BIM should be included in Ethiopian Building code as one of the integrated design modality for all stakeholders, as an integral design approach.
- Increase/ set standard minimum professional fee.
- Banks should support the professionals by loan system so that they can adopt BIM.
- Promote the client to pay an adequate amount.
- Consultant should set integrated design management platform environment.
- The consultant should be part of the whole construction process as a supervisor.
- The client and the consultants need to start collaborating with contractors at the initial stage.

## **CHAPTER V: CONCLUSION and RECOMMENDATION**

### **6.1 CONCLUSION**

We can conclude that, the lack of proper attention of the planning stage is found to be the major gaps in building design process management in Ethiopia. Furthermore, it misses basic considerations like the selection of building material, construction process, structural principles, proper integrated design management system as a process and lack of sufficient detail drawings as an output.

Very low project fee, limitation on accessing licensed software, expensive and unaffordable database infrastructure requirement and lack of adequate training centers are determined as key challenges that building design process management faces. Most projects in the case area run over budget, over the expected time limit and lower quality resulting from poor design process management are seen as a key problems.

Lacks of training centers, trained professionals with BIM tools and difficulty to access licensed software are the major drawbacks to implement BIM in Ethiopia.

Advantages of applying BIM for Ethiopian design process management, is that it reduces unforeseen cost and project delay resulting from fragmented design document preparation modality. BIM gives a better integrated output and with an enhanced design speed. A promising side of it is that, a majority of these research area professionals have at list the basic knowhow about BIM application.

## **6.2 RECOMMENDATION**

### **COLLABORATION WITH OWNERS OF BUILDINGS, DESIGNERS, THE BUILDING CODE & GOVERNMENT**

#### **Regulatory-Body and Employers**

During the drafting and implementation of the building codes of Ethiopia, Addis Ababa can enforce laws and regulations in promoting sustainability issues that could improve the situations in the studied areas.

The adaptation of BIM, looking from the bigger perspective, the city can save tremendous capital. Even though the initial establishment cost is high the sustainability point of view, it is a solution which bring all stakeholders to one arrangement.

From our culture and from experience, has a tendency to follow the rules once set, than to think and who what is batter and important. So, ministry of works and Construction should grant BIM as a mandatory tool to be adopted. The government should draft a strategy for bank loan system for the professionals to establish the infrastructure and software licensing.

Looking at the common trend, which is checking the summited final document in fragmented manner, needs to be changed to coin a system where a group of interdisciplinary professionals review the submitted data in an integrated manner. Regarding Work ethics of designers, training needs to be delivered by government to reduce ethical misconducts like, reducing cost by appointing nonprofessional or less experienced professionals to reduce cost.

#### **Professionals**

Professional association needs to set a standard minimum fee that can allow the professional to set up basic infrastructure and deliver quality product. As indicated in the finding, insufficient design fee is the basic problem faced by the professionals. Resulting in many sub-standard output. So solving rout problem should be addressed by the professional associations.

#### **Educational institutions**

Give attention and Integrated BIM as one of the curricula activity

#### **The Client**

Clients are the crucial stakeholder in implementing the proposed remedial solutions. But, if the owners are not aware of the consequences of such avoidable expenses, they may not be willing to cooperate.

Pay adequate amount for the design so that they can save more money at latter stage of construction.

### **Consultant**

Designers (Architects, Urban planners, Engineers and contractors) environmentalists and analysts should design sustainable building and should create eco-friendly environment using an integrated design platform like BIM. In addition, they should aware their clients about the benefits of such buildings. The government should encourage those clients and designers to apply the principles of sustainability by giving them awards and promoting their works. The government can also support importers, small and micro enterprises in importing or producing energy and cost efficient items for buildings' facilities. Requesting for relational fee that can allow the consultant grow and become competitive with in the industry.

The consultant should be part of the whole construction process. A consultant should supervise the building one designed. Submitting final document and not following the construction process is an outdated and wrong system. Adopt a batter environment for professionals that can promote team work and integrated design management. Establish small scale data base or a small scale network to start with.

Start collaborating with contractors at the planning and designing stage, this could be advantage for identifying problems at earl stage and designing in collaboration.

### **Contractor**

Awareness needs to be created, that BIM can also be used at construction stage. It can be used to monitor the progress and progress analysis, scheduling, report production, and communication tools.

## REFERENCES

- Abeyesundara, N. (2010). Sustainable Non-Metallic Building Materials. Journal: Sustainability 2010, P.400-427.
- Aish, R. (1975.). Building Modelling: The Key to Integrated Construction CAD. Journal: CIB 5th International Symposium on the Use of Computers for Environmental Engineering related to Building,, P.52-60.
- Asif, M., Muneer, T., & Kelly, R. (2007,). Life cycle assessment:-A case study of a dwelling home. Scotland.: AK Press.
- Autodesk. (2002.). Autodesk Building Information Modeling. San Rafael, California: Autodesk Inventor Publisher.
- Bisrat kifle. (2008). public housing: the condominium approach,. Addis Ababa, Ethiopia: Addis Ababa University, Msc thesis.
- Eastman, C., Tiecholz, P., Sacks, R., & Liston, K. (2011). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors (2nd ed.). New Jersey: Hoboken, John Wiley & Sons, Inc.
- Eastman/ Chuck. (2009). What is BIM? New Jersey: Hoboken, John Wiley & Sons, Inc.
- Emmitt, S., & Yeomans, D. (2008.). Specifying Buildings: A Design Management Perspective, 2nd. Amsterdam, The Netherlands: John Benjamins Publishing.
- Esin, T., & Cosgun, N. (2007,). A study conducted to reduce construction waste generation. Turkey.: Feza Publications.
- Eziyi O.I & Dominic E.A. (2011.). Framework For Evaluating The Sustainability Of Public Housing. Journal of Sustainable Development and Environmental Protection Vol.1 No.3, 24-39.
- Halliday, S. (2008.). Sustainable Construction. UK,: Butterworth Heinemann P.C.
- Hansen, L., Madsen, M., & Madsen, S. (2003). The Integrated Design Process Focused on Sustainability and Method. Stanford: Stanford University Press (SUP).
- Hydes, K., & Creech, L. (2000). Reducing mechanical equipment cost: The economics of green design. US: Keen Engineering Co. Ltd.
- Innes, S. (2004.). Developing Tools for Designing Out Waste Pre-Site and Onsite. London, UK,: New Civil Engineer Publishing.
- Kibert, C. (2008.). Sustainable Construction: Green Building Design and Delivery, 2nd ed. NJ, USA: John Wiley and Sons, Inc.
- Knudstrup M. (2004). Integrated Design Process in Problem-Based Learning: Integrated Design Process in PBL,. Aalborg: Aalborg University Press.
- Markarian, J. (2005,). Wood-plastic composites: Current trends in materials and processing. US: Thomas Publishing.
- Ministry of Urban Development Housing and Construction. (2013, June 30). Ministry of Urban Development,Housing and Construction. Retrieved May 04, 2014, from Ministry of

Urban Development, Housing and Construction:

<http://www.mwud.gov.et/web/construction-professionals-registration-service1>

- Morgan, M. H. (1914). *Vitruvius, Ten Books on Architecture*. Cambridge: Harvard University Press.
- Nationalbimstandard.org. (2014, October 17). The National BIM Standard-United States - . Retrieved May 04, 2015, from National BIM Standard - United States: <https://www.nationalbimstandard.org/>
- Oberg, M. (2005.). *Integrated Life Cycle Design—Applied to Concrete Multidwelling Buildings*. Lund, Sweden: Lund University, Division of Building Materials.
- Olgay, L. (1964.). *Design with Climate*. Princeton: Princeton University Press.
- Pettifer, G. G. (2004.). *Case Study in Commercial Green Construction*. London, UK: LEED Publishing Co., Ltd. .
- Pimenteira, C., Carpio, L., Rosa, L., & Tolmansquim, M. (2005,). *Solid wastes integrated managemen*. Rio de Janeiro:: Brazilian publishing service companie.
- The World Bank Group. (2016, Jan 15). The World Bank. Retrieved june 01, 2016, from The World Bank/ Countries/ Ethiopia /publication: <http://www.worldbank.org/en/country/ethiopia/publication/ethiopia-great-run-growth-acceleration-how-to-pace-it>
- U.S. General Services Administration. (2007 ). *BIM Guide* . Washington,: U.S. General Services Administration.
- Vanessa Quirk. (2012.). *Brief History of BIM*. Journal: Archdaily, Detroit Publishing co., P. 95-99.
- Wei Wu, R. R. (2015). *BIM Execution Planning in Green Building Projects*. Journal of Management in Engineering, 31-35.
- Wilson, A., Uncapher, J., McManigal, L., Lovins, H., Cureton, M., & Browning, W. (1998.). *Green Development: Integrating Ecology and Real Estate*. New York, US: John Wiley and Sons, Inc.
- Woodward, D. (1997,). *Life cycle costing—Theory, information acquisition and application*. Great Britain: Elsewer Science Ltd and IPMA.
- Yeang, Y. (2014). *Sustainable Buildings Principles, Bioclimatic Architecture*. Journal: 30Th International Plea Conference, 6-9.

# ANNEXES 1:- RESEARCH INSTRUMENTS

## 2.1 QUESTIONNAIRES

This questionnaire is prepared by Belay Getachew, Addis Ababa University the department of Construction technology management second year Masters Program student, who currently is working on the topic Role of Building Information Modeling in Improving Building Design process in Ethiopia, The case of Addis Ababa.

This questionnaire is prepared for information gathering purpose and any form of support is greatly appreciated.

### **1. What should a standard design address? [major variable]**

#### **CONCEPTUAL STAGE**

Does the process often begin with the architect?

Yes

No

Do you allow the client to agreeing on a design concept?

Yes

No

How many concept /scenarios do you provide the client?

One

Two

three

More than three

If yes which concept does it address?

General massing scheme

Orientation

Fenestration

general exterior appearance

basic materials

construction process  
structural principles  
Other

If other, Please specify?

---

### **PLANNING STAGE**

Do you plan the whole design to construction process?

Yes

No

If yes please select those you plan?

General massing scheme  
Orientation  
Fenestration[windows arrangement]  
general exterior appearance  
basic materials  
construction process  
structural principles  
3D visualization  
Animation  
Other

If other, Please specify?

---

Which design process do you follow?

Linear/ successive design process  
Integrated design process  
Other

If other, Please specify?

---

Which design process appears to be quick and simple?

Linear/ successive design process

Integrated design process

Other

If other, Please specify why?

---

Which design process requires high operational costs?

Linear/ successive design process

Integrated design process

Other

If other, Please specify how?

---

Which design process results in sub-standard property?

Linear/ successive design process

Integrated design process

Other

Please specify why?

---

Which design process does not involve computer simulations?

Linear/ successive design process

Integrated design process

Other

Please specify why?

---

What is/are the advantages of computer simulation?

Analyzes predicted energy performance

High performance

Reduce operational cost

Other

Please specify why?

---

Is the facility delivery process remains fragmented?

Yes

No

Do you follow paper-based modes of communication or computer equivalents?

Yes

No

How often errors and omissions in paper documents do occurs?

Very often

often

Sometimes

never

Other

If other, Please specify?

---

If yes, what are its consequences?

Friction between involved parties

financial expense

delays

Reduction of Quality

Other

If other, Please specify?

---

Do you conduct value engineering/ critical assessment information about a proposed design

Yes

No

If yes, when do you conduct value engineering/ critical assessment information about a proposed design?

Before the designing

During designing

After design is complete

Never conduct

Other

If other, Please specify?

---

If yes, which part of value engineering do you conduct?

<input type="checkbox"/>	Architectural science analysis
<input type="checkbox"/>	Environmental impact analysis
<input type="checkbox"/>	energy-use analysis
<input type="checkbox"/>	structural details analysis
<input type="checkbox"/>	Material use analysis
<input type="checkbox"/>	cost estimates
<input type="checkbox"/>	Other

If other, Please specify?

---

### **FINAL DESIGN**

Which document does your final design includes?

<input type="checkbox"/>	Construction working drawing
<input type="checkbox"/>	Working details
<input type="checkbox"/>	Window + door schedule
<input type="checkbox"/>	Room schedule
<input type="checkbox"/>	basic materials specification
<input type="checkbox"/>	construction process recommendation
<input type="checkbox"/>	Detail quantity specification
<input type="checkbox"/>	Other

If other, Please specify?

---

## **2. WHAT ARE THE PROBLEMS AND CHALLENGES? [major variables]**

What are the problems and challenges?


- Project design fee is very low
- Cannot afford to have a permanent team to work on a project
- Cannot access to a licensed software
- The team has less team spirit
- Database infrastructure is expensive and not affordable
- No place who provide the training
- Other

If other, Please specify?

---

If, Project design fee is very low, what measures did you take?


- Reduce the level of details for the design
- Hired junior professionals.
- Submitted the project before completion
- I haven't done anything.
- Other

If other, Please specify?

---

If, Cannot afford to have a permanent team to work on a project, what measures did you take?


- Outsourced the project
- I have professionals on project base.
- I haven't done anything.
- Other

If other, Please specify?

---

If, Cannot access to a licensed software, what measures did you take?


- Used cracked version of the software
- Used equivalent open software
- I do not use software.
- Other

If other, Please specify?

---

If, the team has less team spirit, what measures did you take?

- Tried to give incentives and bonuses
- Provided them with the required education and skill
- Have regular motivational meeting
- I haven't done anything.
- Other

If other, Please specify?

---

Did your projects go over budget?

Yes

No

If yes, please rate the alteration?

0-

10%

11-

20%

21-

40%

>41%

If yes, what is the reason for?

- Incomplete drawing
- Ware not involved for the supervision
- Client's uncontrolled involvement in the project
- Other

If other, Please specify?

---

Did your projects go over schedule?

Yes

No

If yes, please rate the alteration?

0-

10%

11-

20%

21-

40%

>41%

If

yes, what is the reason for?

- Incomplete drawing
- Ware not involved for the supervision
- There were no schedule at the first place

Other

If other, Please specify?

---

Does your team have a good collaboration?

Yes

No

If other, Please specify?

---

### **3. HOW CAN IT HELP? [MAJOR VARIABLE]**

Have you used building information modeling [BIM] before?

Yes

No

If yes, how do you rate the significance?

For

0-  
25%

26-  
50%

51-  
75%

>75%

which construction stage have you used it?

planning

Design

construction

operation

Other

If other, Please specify?

---

If planning, for which part did it help?

Existing condition modeling

Cost estimation

Phase planning

Site analysis

Programing and analysis

Other

If other, Please specify?

---

If design, for which part did it help?


- Design reviews
- Code validation
- LEED evaluation
- Eng. analysis
- Mechanical analysis
- Science analysis
- Structural analysis
- Energy analysis
- Design authoring
- 3D animation/ visualization
- Other

If other, Please specify?

---

If construction, For which part did it help?


- 3D animation
- 3D controlled planning
- Digital Fabrication
- Construction system design
- Site utilization planning
- Site Logistics Planning
- Record model
- Other

If other, Please specify?

---

If operation, For which part did it help?


- Record model
- Disaster planning
- Space management
- Space tracking
- Asset management
- Building system analysis
- Maintenance scheduling
- Other

If other, Please specify?

---

If no, please specify the reason for not using BIM?


- Project design fee is very low
- Cannot afford to have a permanent team to work on a project
- Cannot access to a licensed software
- The team has less team spirit
- Database infrastructure is expensive and not affordable
- No place who provide the training
- Other

If other, Please specify?

---

Did your try to have an integrated designing process approach?

Yes

No

If yes, how did it help you in design?


- Batter team spirit
- More complete design
- More integrated/ coordinated out put
- Batter quantified
- Abele to save cost
- Able to produce batter quality design
- Enhanced design speed
- Easy alternative design production
- Other

If other, Please specify?

---

If no, why not?


- Lack of skill
- Network administration problem
- Lack of team spirit
- Reduce design production speed
- It's not flexible
- Need high speed computers
- Unable to access licensed software
- The cracked software have limitations
- I cannot afford it
- Other

If other, Please specify?

---

Do you think it you can afford to install a database/ networking for the designing team?

Yes

No

What do you say is the greater challenge in adopting BIM for Ethiopian building industry?

---

Do you know any Training center in Addis who can provide BIM training?

Yes

No

Do you know where you can gate the licensed Program/software? Licensing

Yes

No

## 2.2:- INTERVIEW QUESTIONS FOR CONSTRUCTION DESIGN S. CO.

This questionnaire is prepared by Belay Getachew, Addis Ababa University the department of Construction technology management second year Masters Program student, who currently is working on the topic Role of Building Information Modeling in Improving Building Design process in Ethiopia, the case of Addis Ababa.

This Interview questions are prepared for information gathering purpose and any form of support is greatly appreciated.

Date / /

1. Full name
2. Position within the company?
3. How many Projects does the company undertake per year?
4. How much is the company's annual turnover?
5. What are the biggest projects undertaken by the company for the last five years?
6. What are the major design challenges in undertaking those projects, regarding cost, quality and time?
7. How do you integrate the different design works, like AR, St, EI, Sn, ELM?
8. Did you use licensed softwares?
  - a. If yes, how do you get it?
  - b. If yes, what softwares?
  - c. If no why not?
9. Does your design process management have a direct implication on cost, time and quality?

- a. If yes, what kind, positive or negative implication?
  - i. If positive, how did you achieve that?
  - ii. If negative, how did you encounter it?

## **ANNEXES 2:- DATA SOURCES FOR TWO CASE STUDY PROJECTS**

**01:-AXUM UNIVERSITY LIBRARY and**

**02:-DEBRE-MARKOS STAFF LOUNGE**

%