

**ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL & ENVIRONMENTAL ENGINEERING**



**Design Management Using Building Information
Modeling:
In Case of Projects in Addis Ababa**

by
Betelhem Tesfaye Adinew
GSR/7271/10

A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements of the Degree of Master of Science in Civil Engineering in Construction Technology and Management

Advisor:
ABRAHAM ASSEFA TSEHAYAE (PhD)

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Betelhem Tesfaye Adinew- GSR/7271/10

Approved by the Board of Examiners

Abraham Assefa Tsehayae (PhD)
ADVISOR

SIGNATURE

DATE

Abebe Dinku (Prof- Dr-Ing)
INTERNAL EXAMINER

SIGNATURE

DATE

Eng. Yibeltal Zewdu
EXTERNAL EXAMINER

SIGNATURE

DATE

COMMITTEE CHAIRPERSON

SIGNATURE

DATE

DECLARATION

I certify that this research work titled “*Design Management Using BIM: Case of Projects in Addis Ababa*” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources, it has been properly acknowledged/referred.

BETELHEM TESFAYE | GSR/7271/10

ABSTRACT

Design is a major part of a building project which must be planned and managed carefully. Design management aims to improve the design quality by creating managerial techniques. Poor design management contribute to poor design quality, less integration, poor communication, and frequent reworks. This impact will propagate throughout the project life cycle.

Building information modeling is a methodology that provide integrated platform for designing which enable the multi-disciplinary working under a collaborative environment. BIM also known as a revolution in industry, many countries have adopted BIM based design process by understanding its benefits. This research objectives accordingly were focused on design management using BIM and assess the conventional design management practice of category one consultant within Addis Ababa.

To achieve the above objectives the research design employed questionnaire survey and case study research which is descriptive type in nature. ICT park design project and ZIAS consulting firms' projects are the case studies taken as a baseline to describe design management using BIM. Case studies were analyzed using structured interviews and document review. To assess the design management practice of category one consultant, questionnaire survey was also used as data collection tool.

The major finding of this research is that even if BIM is not fully implemented in both case studies, design management process has been improved through better communication and collaboration, visualization, design coordination and included constructability and maintainability concepts have been observed from the case studies. In the meanwhile, both case studies have been confronted with infrastructure, software interoperability, lack of expertise in the field and process-based challenges. Besides that, the research also indicated that traditional design management have gaps and challenges in improving the industry. As a result, the research recommends the adoption of BIM as it improves the current design management of consultants in Ethiopia.

Key terms: BIM, Current practice, Design Management, Design proces

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ABBREVIATION

AASHDE	Addis Ababa Savings & Houses Development Enterprise
AEC	Architectural, Engineering and Construction
BEP	BIM execution plan
BIM	Building Information Modeling
BoQ	Bill of Quantity
DM	Design Management
CDE	Common Data Environment
COBie	Construction Operation Building information exchange
ECPMM	Ethiopian construction project management manual
EIR	Employer Information Requirement
ETB	Ethiopian birr
GDP	Growth Domestic Production
GTP	Growth Transformation Plan
IBDE	Integrated Building Design Environment
IFC	Industry Foundation Class
LCC	Life Cycle Cost
MEP	Mechanical, Electrical and Plumbing
MOUC	Ministry of Urban Development and Construction
NBIMS	National BIM Standard
ROI	Return on investment
RII	Relative Importance Index
WIP	Work In progress

1. INTRODUCTION

This chapter provides background of the study and literature review in which previous studies state about the construction industry and its gap which explains the area of the research to set context for the problem at hand and how BIM makes design management improved that led to the researches questions and aims of the study.

1.1 Background of The Study

1.1.1 Construction Industry in General

Construction industry is an important industry worldwide. The construction industry generally defined as a sector of the economy. The Industry is playing an important role in economic growth of a country, but it faces many challenges currently that lead to affect project goal and steady growth of the economy.

Construction is a high hazard industry which comprises a wide range of activities involving plans, design, constructs, alteration, maintains repairs and eventually demolishes of buildings, civil engineering works, mechanical and electrical engineering and other similar works (Hillebrandt, 1984).

Construction is always complex that make industry susceptible to disputes, delays and cost exceeding. The construction industry has characteristics that separately are share by other industries but in combination appear in construction alone (Hillebrandt, 1984).

1.1.2 Ethiopian Construction Industry

The construction sector, which is the second most important sector in the Ethiopian economy in terms of workforce and 9.8 percent of the GDP in 2018, is crucial in ensuring the successful transformation of the economy. Although, internationally construction is a \$1.7 trillion industry, amounting to between 5 and 7 percent of GDP in most countries, during the period of the first Ethiopian Gross Transformation Plan, the construction industry on average grew at 28.7% per annum, pushing its share in GDP from 4% to 9.8% by 2017/18. The Construction industry makes significant contributions to the socio-economic development process of a country. Its importance emanates largely from the

direct and indirect impact it has on all economic activities. It contributes to the national output and stimulates the growth of other sectors through a complex system of linkages. It is noted that about one-tenth of the global economy is dedicated to constructing and operating homes and offices. (EEA 2008)

EEA (ibid) the construction industry has been registering rapid performance in recent years but it has not been weighed comparatively to understand the problems and make policy recommendations. In Ethiopia there are huge infrastructure expansions, high rise building constructions and high development of urban centers. However, there is lack of series historical data on the industry.

1.1.3 Design Management and BIM

Consultant firms, being the key stakeholders of the construction design industry, are the primary agents for meeting the design demands made upon the industry. These firms in general, are project-based organizations which are mainly devoted in production of design and supervising projects. This output of design passes through sequential processes and needs to be managed and controlled. The discipline called design management plays a significant role in handling these processes. Design Management is an emergent professional discipline which separates the management function of a project's design phase from the design function. It is becoming increasingly important in modern construction projects (Gray and Hughes 2001). A simplified definition is to say that design management is about managing people and information (Emmitt and Ruikar 2013).

BIM is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. The use of BIM goes beyond the planning and design phase of the project, being extended throughout the building life cycle of several infrastructures (water, wastewater, electricity, gas, waste, roads, bridges, ports, houses, apartments, schools, hospitals, shops, offices, factories, warehouses, prisons, etc.) (Algan.T, Zeeshan.A, Chuxiong.J, 2016). The AEC (Architectural, Engineering and Construction) industry is adapting to increased demands for the use of BIM during the design and construction phase of construction projects. Building owners, private and public are increasingly requiring that BIM is used on their projects as the method has proven to have

a positive impact on the construction process in many aspects e.g. clash detection, better visualization, energy analysis or its effect on buildings LCC (Life Cycle Cost) which improved the traditional design management. This study will elaborate the current practice of design management and design management using BIM in case of pilot projects and other BIM based design projects in Addis Ababa.

1.2 Problem Statement

There are several defining features of the design process that have been noted that interact and make it difficult to manage. Primarily, the process is iterative and poorly defined which can be attributed to two key factors; first, it requires the production of incomplete outputs to develop understanding of both design problems and alternative solutions secondly, this is undertaken by a diverse team (e.g. Architects, Clients, Mechanical, Civil, Structural, Electrical, Environmental and Process Engineers, Quantity Surveyors, Estimators and Planners) representing different disciplines, educational backgrounds and goals. As a result, the process is one of significant co-ordination, negotiation, agreement, and compromise often under uncertainty and time-pressure to achieve success and failing to manage might lead to expected quality defects. (Pocock et al. 2006; Wong et al. 2007).

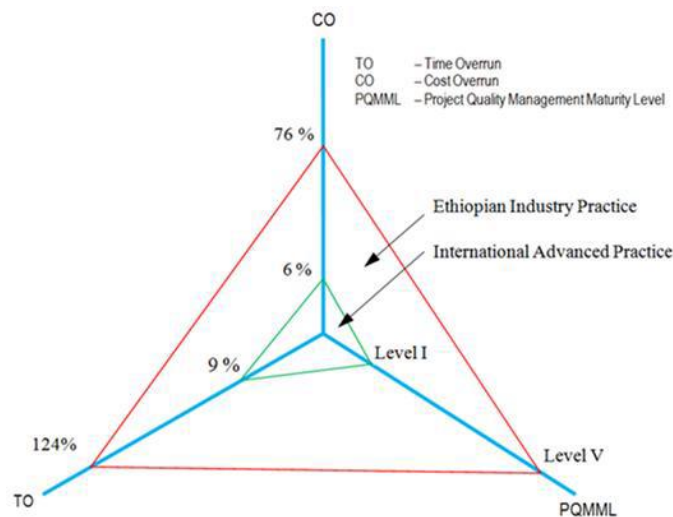


Figure 1-1 Comparison of Performances with the International Good Practices (Asmerom Taddese 2016)

The above figure is based on Material Project Information obtained from Construction Sector Transparency Initiative (CoST-Ethiopia), in 2016 the World Bank Governance Global Practice (GGP) Ethiopia Country Office (CO) has undertaken evidence based

analytical work on the performance of construction contracts in a more quantitative ways with the identified gaps compared to global good practice in the industry such as, for example, the UK practice, is schematically exhibited in. The difference shows the gap between the construction industry of the Country and the good practice (Asmerom Taddese 2016).

Reasons for cost and time overruns of projects are attributed to design incompleteness, design changes, scope changes, changes in volume of work, poor initial estimation of completion time, force majeure and other reasons. As can be noted from this Study, most of the reasons arise at earlier stages of the project cycle (gaps in strategic project planning and preparation) thus showing more serious gaps related to project feasibility/planning, design and tender documents Equally important gap is associated with ineffective contracts implementation management that includes risks management and performance monitoring practices (Asmerom Taddese 2016).

Recent studies imply that BIM application have great influence in design management. BIM is a technology, and not a specific program, that offers an integrated platform to improve design, increase the speed of delivery for design and construction, and provide a flow of information without breaks. Nevertheless, due to the technological maturity and interoperability issues, industrial culture change requirements, lack of BIM standards, and training and education needs, there is a common consensus that BIM is currently still immature for its full adoption over the construction life-cycle in the AEC industry (Zhiliang et al., 2011; Wong & Fan, 2013; Xu et al., 2014). Having mentioned this, the AEC industry throughout the world still tends to adopt the BIM technology including Ethiopia.

According to GTPII, by introducing construction project implementation techniques and tools (kaizen, integrated project management and information system), it is planned to bring about a significant shift in technological transfer and utilization. During the planning period, BIM stated as a revolutionary tool(F.D.R.E 2016). Therefore, there is a need to develop a research-based analysis on the design management practice of the BIM based project, and, it's necessary to document the key challenges and barrier and the key lesson learned during the projects for the future studies and works.

1.3 Research Questions

The following research questions will be formulated:

1. What are the existing building construction project design management practices and its challenges of category one consultant?
2. How does BIM manage design and the design process?
3. What are the key challenges faced and key lesson learned during the design management practice of BIM based projects in Addis Ababa?

1.4 Objective of the Study

1.4.1 General Objective

The final goal of this study is to assess the current practice of design management and to show the design process and management using BIM by taking ICT park project and ZIAS consultant office as case study.

1.4.2 Specific Objectives

The objectives of this study are:

1. To asses of the current design management practices and challenges of selected category one consultant in Addis Ababa.
2. To identify the design process and management using BIM
3. To illustrate the key challenges faced and key lesson learned during the design management practice using BIM
4. To forward recommendations based on the result of the research

1.5 Significance of the Study

This study assesses the current design management practice and its drawback and limitations of level one consultant. This study also presents the design management and process using BIM in case of BIM based project in Ababa . Furthermore, this study will demonstrate the mechanism, challenges and key lesson learned in BIM based design management of the case studies. Since its new technology and no further research has been done in this area, it is anticipated that it will entice interested researchers to undertake further research works on the issue.

1.6 Scope of the Research

This research targeted to assess the current design management practice of level one consultant in Addis Ababa. This study includes case study of design management using BIM on ICT park pilot project and ZIAS consultant office.

This research is limited to

- assess Category I building consultants in Addis Ababa.
- The research only investigated BIM with respect to design stage due to data unavailability at construction stage and so on.

2. LITERATURE REVIEW

2.1 Design Management

2.1.1 Project life cycle

Every project, not just those in the construction industry, goes through a series of identifiable phases, wherein it is ‘born’, it matures, it carries through to old age and it ‘expires’. In construction projects, there are six identified phases, each with its own purposes and characteristics. First, the owner must make certain pre-project decisions. Then the planning and design of the project is carried out. Next, the contractor is selected, after which the contractor mobilizes in order to carry out the field operations. The field work that the lay person often considers to be ‘construction’ can be considered a separate phase. Lastly, the project must be terminated and ended; because these activities are distinct from the installation work, we separate them into a distinct, final phase (Bennett 2003).

The results of each stage influence later stages, and it may be necessary to involve the professionals and specialists who undertook earlier stages to explain or review their decisions. Again, the way the professionals and specialists are employed should be decided in principle during the strategy stage.

2.1.2 Design phase

The design process passes through five phases before its completion. These are schematic design, design development, construction documents, bidding/negotiation, and contract administration. Among these phases, the first three are essential for developing an effective client-architect relationship. Bidding/negotiation and contract administration phases are beyond the actual design stage of a building. They focus at the construction and realization of a building and so that they do not much affect the client-architect relationship of a building design.

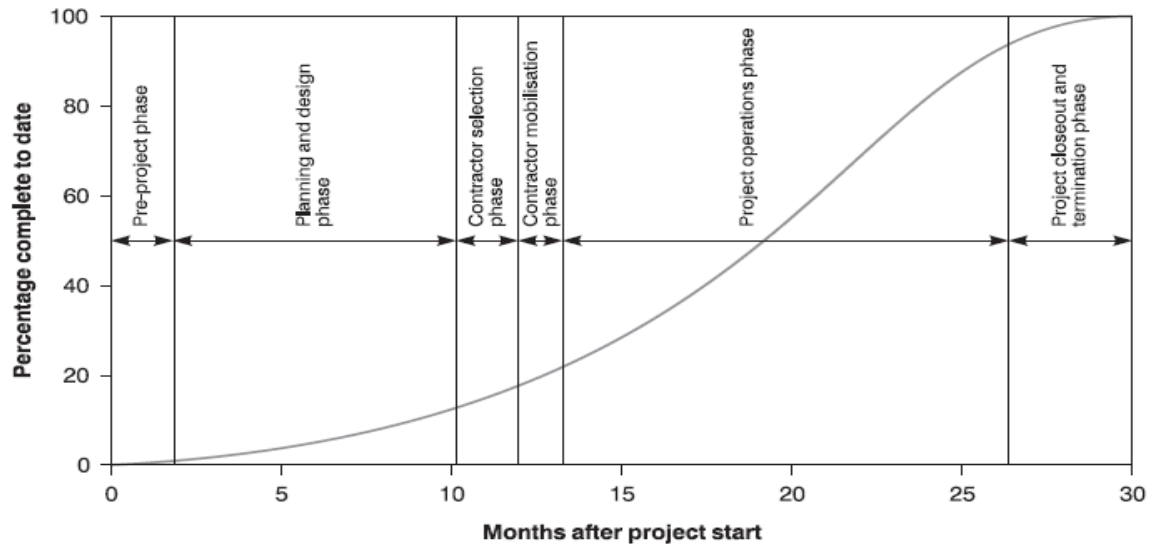


Figure 2-1 Typical construction project life cycle. (Bennett 2003)

The schematic design phase establishes the general scope, conceptual design, and relationships among components of the building. The primary objective is to arrive at a clearly defined, feasible concept while exploring the most promising alternative design solutions. The architect prepares a series of rough plans, known as schematics, which show the general arrangement of rooms and of the building. Models and/or illustrations are prepared to help visualize the project as necessary (figure 2.2). Upon the owner's approval of the schematic design, the project proceeds to the design development phase. In this phase, the architect expands upon the approved schematic design studies to develop more detailed drawings that illustrate other aspects of the proposed design. For Example, floor plans show all the rooms in the correct size and shape. Outline specifications are prepared listing the major materials and room finishes (figure 2.2). The architect both verifies that the design complies with building codes and works with engineers to design the structural, mechanical, and electrical systems. The project proceeds to the next phase when the owner approves the design development documents. Once the owner has approved the design development phase, the architect then prepares detailed working drawings and specifications or contract documents. The contractor will then use the architect's drawings to establish actual construction costs and build the project. These drawings and specifications become part of the construction contract.

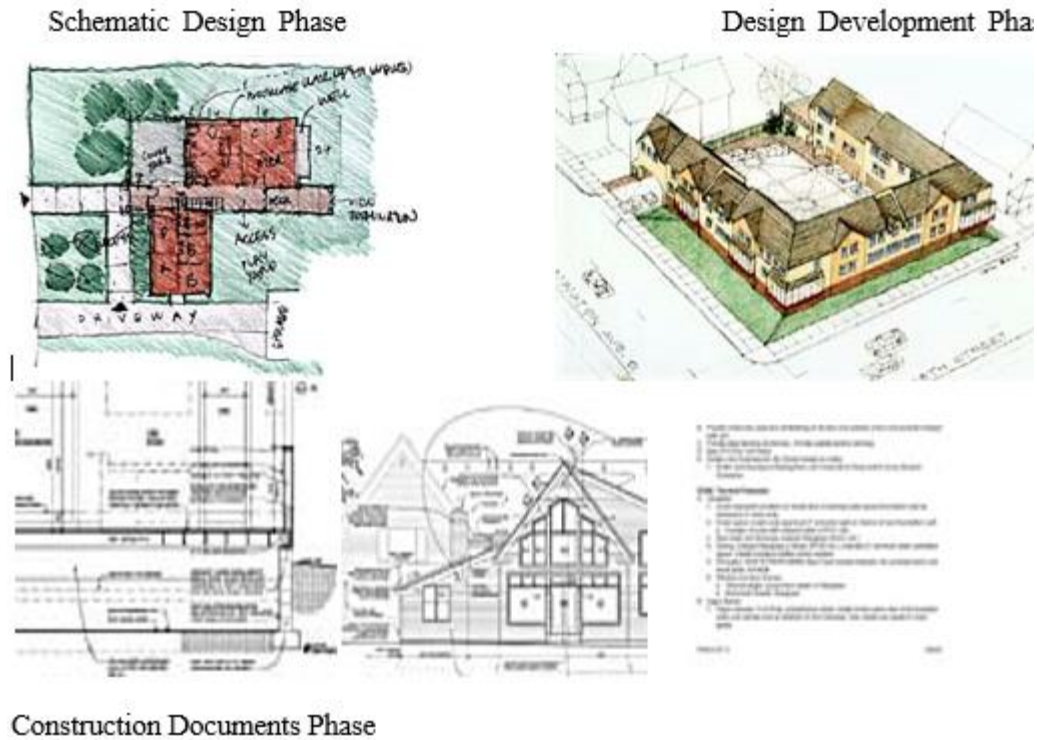


Figure 2-2 Design Phases (Levin and Charles 2006)

2.1.3 Design Process

Traditional design process: can be understood as a linear process, but sequential work routines may be unable to support any adequate design optimization efforts during individual decoupled phases, which of course leads to higher expenditure. Although there are many exceptions, we can refer to a "traditional" design process as one consisting of the following features:(Azhar.S 2011)

Integrated Design process: is a procedure considering and optimizing the building as an entire system including its technical equipment and surroundings and for the whole lifespan. This can be reached when all actors of the project cooperate across disciplines and agree on far-reaching decisions jointly from the beginning. The integrated design process emphasizes the iteration of design concepts early in the process, by a coordinated team of specialists.

Table 2-1 *Integrated Design Process versus Conventional Design Process (Azlan and Cheong 2013)*

Integrated Design Process		Conventional Design Process
Inclusive from the outset	VS	Involves team members only when essential
Front-loaded — time and energy invested early	VS	Less time, energy, and collaboration exhibited in early stages
Decisions influenced by broad team	VS	More decisions made by fewer people
Iterative process	VS	Linear process
Whole-systems thinking	VS	Systems often considered in isolation
Allows for full optimization	VS	Limited to constrained optimization
Seeks synergies	VS	Diminished opportunity for synergies
Life-cycle costing	VS	Emphasis on up-front costs
Process continues through post-occupancy	VS	Typically finished when construction is complete

2.1.4 Design Management Practice

Design is the process of creating a solution to a project brief and then preparing instructions allowing that solution to be constructed. In order that project budgets can be satisfied, programmes achieved, and designs properly coordinated and communicated, the design process needs to be planned and controlled. Problems can occur where there is missing information, poorly communicated information, inconsistencies between documentation, poor resource allocation, poor decision making due to inadequate information, and so on. These difficulties have become more prevalent as building have become more technical, the range of product and material has increased, standards and regulation have become stricter, and there are a greater number of specialist designers, particularly in the early stages of the design process (Lesley and David 2011).

Design management endeavors to establish managerial practices focused on improving the design process, thus creating opportunities for the development of high-quality innovative products through effective processes. Even though excellence in management is not considered a substitute for high quality creativity and innovation, it can represent the difference between success and failure in multidimensional and complex project environments (Cooper and Press 1995).

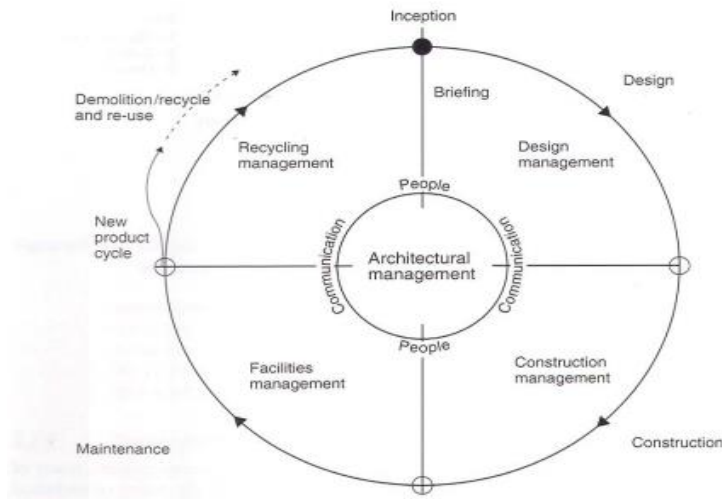


Figure 2-3 Architectural design management within the project framework (S. Emmitt 2002)

Collaborative working is establishing collaborative practices is of particular importance on building design and construction projects, as they are likely to involve bringing together large number of diverse disciplines, many of whom will not have worked together before. They are also likely to involve the co-ordination and integration of a great deal of complex information, procedures and systems. Design managers initially emerged in contractor organizations as they started undertaking a portion of design, which involved their specialist sub.(Tilley 1997)

2.1.4.1 Managing the Design Team

A. Effective communication

This exchange process is difficult to plan and follow up, and equally difficult to foresee interdependencies that each exchange might have. (Azlan and Cheong 2013) argue that “coordination needs to be performed by a designer”.

The way we communicate is therefore important. (Otter and Emmitt 2008) Describe the two ways of communicating, i.e. asynchronous and synchronous. Synchronous communication is described as an information flow between two or more directly using hearing, sight and talking (e.g. meetings, telephone etc.). Asynchronous communication is a remote flow of information, which is not directly in time (e.g. emails, drawings, models). The more complex processes are, the higher need is for synchronous communication.(Flager, et al. 2009) have shown that as much as 58% of the time is spent

in managing the information in the design phase. With a more effective information management, some of this time can be reduced and used in more value creating activities.

B. Collaboration

Establishing collaborative practices is of importance on building design and construction projects, as they are likely to involve bringing together large number of diverse disciplines, many of whom will not have worked together before. They are also likely to involve the co-ordination and integration of a great deal of complex information, procedures and systems.

This has become increasingly true as project structures have evolved from straight-forward client - consultant - contractor relationships to more integrated structures with complex financing arrangements, early engagement of the supply chain and the introduction of subcontractor and supplier design.(Gray and Hughes 2001)

2.1.4.2 Managing information (Design: A Process of Information Management)

A. Co-ordination of information and approval of inputs

The current situation over responsibility and liability for design makes the task of producing a set of coordinated information complex. Despite the basic assumption that all design is the architect's responsibility, the complexity of modern construction technology has led to an increased dependence on specialists at both the design and construction stages. (Cooper and Press 1995)As a result, the client will often give authority to an architect to delegate specified parts of the design to others, and it may even be implied from the circumstances of the case. In recommending the appointment of a specialist, architects owe their clients the normal duty to use reasonable care and professional skill. Although they may not automatically be directly responsible for the defaults of the people they recommend, their overall obligation to co-ordinate the design will render them at least partially liable for all design defects.(Gray and Hughes 2001)

B. Information recording and controlling

Each organization must keep a precise record of the information it generates, its current status, the distribution and, where appropriate, the stage it has reached in the approval system. For simple projects and small offices, a paper-based record system will suffice, however, on large projects a computer database is desirable.

2.1.4.3 Evaluation of Information

The independent review of the content of the design (to ensure that it is competent, gives value for money, and will provide long-term satisfaction in use) is a requirement of modern design and must be approached in an orderly way. This chapter includes descriptions of some of the reviews that should be undertaken formally during each stage of design.

A. Design reviews

The convention of many design teams is to hold an internal ‘crit’ session of the design at key stages, such as initial concept and scheme design. These are critical reviews involving people both working on the project and from other projects. The object is to view the developing design, to share the ideas evolving within it, and to receive alternative views in order to improve the design(Gray and Hughes 2001).

The review process is divided into categories, which, depending upon the stage, can be interpreted as appropriate.

Items pertaining to customer needs and satisfaction include the following.

- Comparison of client needs with standard or innovative technical specifications for materials, products or processes.
- Validation of the design by building product or element prototype tests.
- The capacity of the designed building to perform under expected conditions of use and environment.
- Consideration of unintended uses or misuses by potential users.
- Building safety and environmental compatibility.
- Compliance with building regulations, planning regulations, health and safety law, national and international standards, and designer’s corporate practices.
- Comparisons with other practices’ comparable building designs.

- Comparisons with own similar designs, especially analysis of own and other practices 'external problem history to avoid repeating past problems.

The following items pertain to product specification and in-service requirements (these relate to the engineering and specifying stages and, if carried out in full, should assist in the prevention of errors).

- Reliability, serviceability and maintainability of the building structure, fabric and services components.
- Permissible assembly tolerances and comparison with process (material/methods of assembly) capabilities.
- Buildability; ease of assembly, storage needs, component life and disposability.
- Aesthetic specifications and acceptance criteria.
- Failure modes and effects, and fault analysis.
- Ability to diagnose and correct problems.
- Labelling, warnings, identification, and traceability requirements of building components or elements.

Items pertaining to process specification and in-service requirements include the following.

- Buildability of the detail building design, including special process needs, mechanization and
- Automation of deinstallation building components.
- Capability to inspect and test including special test requirements.
- Specification of building materials and components, including approved supplies and suppliers.
- The safe execution of building operations, especially operative safety and working conditions.

B. Constructability and maintainability

❖ Constructability

(Gray and Hughes 2001) Argues the site production activity is dependent on the detail of the design. The increasing use of design by works contractors is one way of obtaining simple, easy to build details because contractors can apply their production experience to

the details that they propose. As long as the bid documents and the process of detail design are open enough to allow for adjustment of the details, then a buildable design will emerge. However, if the detailing cannot be left to a works contractor to make a full trade-off between production, cost, time and quality, then it will be necessary for the design team as a whole to consider constructability as an integral part of their activity.

While the design of simple-to-construct details and connections should be the task of all designers, the complexity of construction operations is difficult to determine without extensive site experience. There is a need to prepare a constructability checklist that gives a guide to the steps in the evaluation process and the strategic issues to be considered in each step. (Ehsan 2014) Most benefit is gained if the constructability evaluation is undertaken at the earliest opportunity, perhaps as a contribution to the concept stage.

Experience has shown that the essence of the constructability decisions, taken in any earlier strategic analyses, must be maintained throughout the detail design. For example, pre-cast concrete cladding panels can be an economic form of cladding, but their cost will rise dramatically if a large number of different panels are needed. Even small variations in basic dimensions, the insertion of windows, or the addition of decoration will rapidly increase the number of 'specials'. Much of this kind of detailing is added during the detail design process, and can rapidly destroy the economies of prefabrication implicit within the initial strategic decision. (Gray and Hughes 2001)

Previous studies have shown that improved constructability can lead to savings in both cost and time, as well as significant improvements in quality and safety, which are keys for the successful delivery of the projects ((Trigunarsyah 2004a); (Ugwu, Anumba and Thorpeb (2004).) The concept of constructability integrates construction knowledge, experience, and skills into the early planning and design phases targeting a more constructible project, which improves the efficiency of actions and leads to fewer problems during field works and better teamwork throughout the project ((Fischer and Tatum 1997); (Trigunarsyah 2004a)). Such integration provides a clearer view of construction phase for project planners and designers. This is more critical in infrastructure projects because there are more complexities in the construction of infrastructure projects compared with smaller constructions, and these complexities often remain hidden even for the most professional

planning and design teams. This can put the project in danger in terms of being on-time and within budget for successful delivery.

To achieve the optimum benefits, it is essential to consider constructability at an early stage of the Project because the ability to influence the project cost diminishes as the project progresses in time (Griffith and Sidwell 1995). A construction-directed design is more likely to consider the concerns of all stakeholders. It can influence the overall cost of projects much more than late action (see Figure 2.4). The Business Roundtable (1982) stated that the advantages obtained from a good constructability are about 10 to 20 times of the costs spent for it.

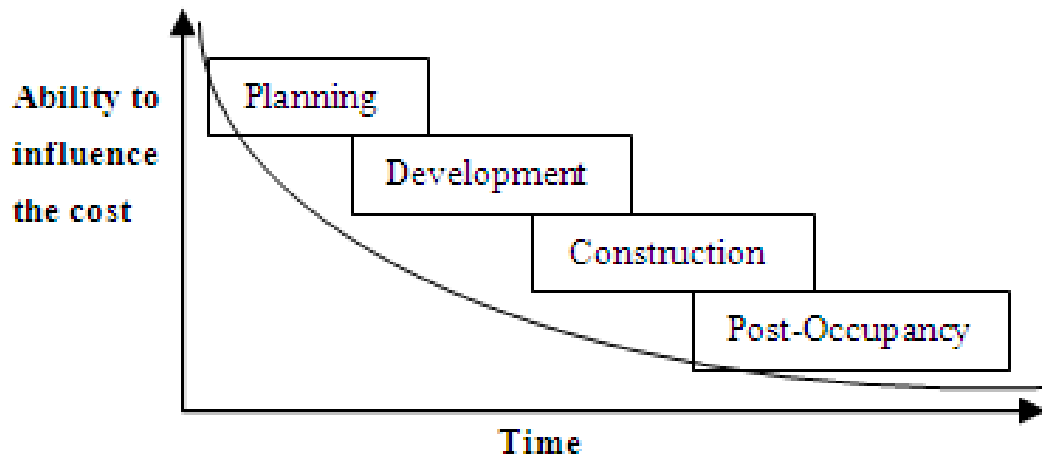


Figure 2-4 Cost influence curve (Griffith and Sidwell 1995).

❖ Maintainability

The design should allow the maintenance of the building to be carried out in a safe and reasonable way. In the UK, this is a legal requirement, imposing obligations on clients, designers and builders. The design review is undertaken to ensure that all parts of the building that will need to be maintained during its life can be accessed safely and with the least disruption to the users. (Gray and Hughes 2001)

The first issue is to examine each component and assembly, determine its design life, and then examine the details to ensure that the design life will not be reduced through poor attention to detail. This analysis will make many assumptions about the way that the building will be maintained. These should be recorded to form the basis of the maintenance

manual for the building and they need to be incorporated into the Health and Safety File. There is another legal issue concerning safe access for maintenance. The Health and Safety at Work Act 1974 places an onus on the employer for the safety of maintenance workers, i.e., the owner or occupier of the building is responsible for the safety of any employee in the building. This includes visiting maintenance workers (Stavely, 1991).

C. Safety consideration

In operations that involve complex processes, dangerous substances, and potential safety risks, there is a need for a review of the design by those who are to operate the building and its processes. This needs to be done in increasing detail as the design progresses. However, it must not be left too late as major changes during the construction stage will lead to delays and major cost increases. In the process industries, considerable effort is put into this review, with scale models of the plant used to test both process and escape procedures.

D. Life cycle cost analysis

It was not until the early 1960 that it became common practice to set up formal procedures to plan and control the capital cost of construction work as an integral part of the design process. The methods that were employed enabled informed choices to be made regarding the cost of alternative design solutions (at both outline and detailed levels) and their effect on the cost of the development. Within a comparatively short time, the success of these procedures has led to attempts to bring the longer term running and replacement costs into the calculations. By the end of the 1980s the term 'costs in use' was current but was soon superseded by the more self-explanatory title 'life cycle costing' (Fuller., 2010).

The basis of life cycle costing involves putting the estimated capital, maintenance, operating and replacement costs into a comparable form and bringing them together into a single figure which allows for the fact that these items of expenditure will take place at different stages within the time-scale. There are many techniques for doing this.

Strictly speaking, life cycle costing is concerned only with the costs of an asset. However, if there are any benefits that can be expressed in monetary terms then they should also be considered, as otherwise only a partial picture of the cost-effectiveness of the asset will

emerge. If this is done, then the exercise is more properly termed investment appraisal, although it is considered as part of the field of life cycle costing.

These techniques enable straightforward comparisons to be made so that the most cost-effective approach can be chosen as the solution to the problem. Almost any form of a tangible asset, ranging from a simple floor covering to A fleet of nuclear submarines is, in theory, agreeable to this treatment.

Life cycle costing has gained favor as an idea. It is inherently more sensible to look at the total cost consequences, rather than just capital costs, when looking at the choice between alternatives. To be considered: access for inspection, external maintenance, and services maintenance (lee, 2002).

2.1.4.4 The Design Manager

Design managers initially emerged in contractor organizations as they started undertaking a portion of design, which involved their specialist sub-contractors. The design manager has an enabling and coordinating role but is not acting as a designer themselves. The role should not be confused with the lead designer, who heads the decision making and co-ordination of the actual design, or with the lead consultant, who directs the work of the entire consultant team.

The main tasks of the design manager are to:

- Establish a platform for good communication and collaboration between relevant parties and thereby an effective flow of design and production information.
- De-risk design problems by finding solutions before they materialize.
- Contribute to planning and co-ordination in a way that adds value to the processes.
- Prepare, manage and secure all-party ownership of an integrated design programme.

This requires a great deal of experience, and it is important that design managers are good forward planners, capable of managing project timescales, and with the requisite knowledge for ensuring the design process is in accordance with current legislation, standards and codes of practice.

As design managers are utilized by the construction industry in projects where they are responsible for design and construction then one would expect them to take on functions required to better integrate design and construction and as such overcome some of the above issues. Design managers may integrate the design and construction processes and as such may provide training in new project delivery methods. They may ensure timely interaction between designers and constructors including preparing them for ambiguity; last minute information, and changes. Design managers may devise new methods which compensate for unavailable design information, for example flexible estimating, scheduling and construction methods. They would need to ensure the construction is not deficient no matter how the design is delivered. It would be their responsibility to solve design and construction problems by participation rather than arbitration. Things such as making allowances for design trials during construction may be permitted by this new relationship(Lesley and David 2011).

2.1.4.5 The client engagement

In the context of this literature, the client is defined as an individual, a group of people or organizations that contract the construction of facilities for their own use or for the use of a third party. They are expected to be the “brain” behind the project and the steering force of processes for achieving results. The effectiveness of briefing by the client and the subsequent management of the relationship between the client and the design team have been spotted as one of the major factors that help to achieve a good design. It is important for the client to have a continuous participation and interaction with the design team as the design develops and there is the need for a level of trust of the designer by the client(Felix Atsrin,Joseph Ignatius Teye Buertey,Kwasi Boateng 2015).The role of the client in the design process is of much importance since the initial briefing is what informs the design. For this reason, The Latham Report 2008 expressed the need for government to be influential in improving clients’ knowledge and practice of how to brief designers.

There is always a difference between the requirements of the client and the possible solutions considering the technical and regulatory limitations. This becomes more complex when the client is not well informed on the range of options coupled with designers not

actually understanding what the clients want. In most cases the client has very little idea of what he wants (Lawson 1994).

The client needs to remain involved to a varying degree throughout the process. As the design consultants are appointed and responsibility is delegated to them, so the client should normally expect less involvement with the project. This will vary with the type of project, the procurement approach, and the client's organization. The client's involvement is at its highest during the briefing, concept, feasibility and scheme design stages and will normally reduce during the detail design and construction stage. Detailed involvement with the building itself will increase again towards the end of the construction stage, as the client begins to consider the occupation of the building. At each stage the client must make positive decisions and commitments: the design and construction teams need this certainty if they are to deliver a satisfactory project (Gray and Hughes 2001).

2.1.5 Challenges and limitation of conventional design management practice

Considerable advances have been made in DM, but there are still few examples of total success (Gray and Hughes 2001). Current practice is characterized by poor communication, lack of adequate documentation, deficient or missing input information, poor information management, unbalanced resource allocation, lack of coordination between disciplines and erratic decision making (Austin et al 1994; Cornick 1990). This in part can be attributed to the complex and challenging nature of the design process. However, many current approaches are inappropriate for managing the design process. For example, the design process is typically unstructured which leads to insufficient understanding of the design process between parties (Karhu and Lahdenpera 1999) and is a barrier to people working effectively together (Taylor 1993). The following outline the key problems and causes of poor DM practice.

A. Design planning

An effective and workable design programme is essential to improve co-ordination between disciplines and exert managerial control over the design process. Yet it is usually programmed to achieve the required timings of information release to contractors, followed by the preceding procurement activities and finally the design (Austin, et al. 1998). This low priority of design in project planning is attributed to construction accounting for most

of the project costs. However, there is now an increasing recognition that construction efficiency and costs are heavily dependent on the quality of the design solution and information (Austin, et al. 1998) and therefore the quality of the design programme. Yet, little effort is given to planning the design in detail in the belief that it is not possible for such a creative and iterative process (Cole, 1993) - a situation perpetuated by a lack of understanding of design information flow, dependency and availability of suitable planning techniques (Austin, et al. 1998)).

Poor understanding of information flow and dependency exists because each discipline does not understand how their work contributes to the whole building design process, causing a fragmented approach to planning (Newton, Hedges 1996). Therefore, the identification and co-ordination of cross-disciplinary information, essential for a fully integrated design, is left to the expertise of the design planner or project manager (Baldwin et al, 1994) who lack a full understanding of the processes of design (Hedges et al, 1993; Saxon, 1998). This results in a poor-quality design programme with implications for the co-ordination of design disciplines and general process control.

Another facet of poor design planning practice is that resource allocation is often unbalanced (Cornick 1991, Austin et al 1994, Kostelac et al 1997). This initially can cause delays (Koskela et al 1997b; Love et al, 2000) but can also escalate into further problems. To retrieve delays, new designers are usually recruited, introducing additional delay, as they become familiar with project characteristics, requirements and history. This may in turn increase design error and subsequent time-consuming rework (Love et al, 2000).

B. Integration of design and construction

A construction project involves a large group of people with different skills, knowledge and interests working together for a short period and then separating upon completion of the project. This creates problems in organizing both the design and construction processes, due to the large number of interfaces and communication difficulties (Kagioglou et al, 1998). However, integration during the design phase is crucial to project success. It prevents problems in subsequent phases, it is necessary for the development of suitable design solutions (Mitropoulos and Tatum, 2000) and ultimately to achieve client satisfaction (Ferguson and Teicholz, 1992). Therefore, while the integration of design and

construction is vital to project success – it is also a fundamental weakness in the industry (Egan 1998).

C. Information management

The principal design activity of any project is the processing of information (Baldwin et al, 1994), yet in the construction industry this is poorly performed (Latham 1994). Current management of design information is predominantly through schedules programmed to achieve the required timings of information release to contractors (Austin et al, 1998). Yet it does not consider the internal logic of the design process – such poor planning practice is a factor in poor information management (Formoso et al, 1998). As a result, the timing of information transfer is not properly controlled; designers do not have the right information at the right time and are overloaded with unnecessary information (Huovila 1997). This creates the risk of failure of design tasks, deficient analysis and wrong decisions with potential for waste in the process due to rework (Huovila et al, 1997). Furthermore, the erratic delivery of information and unpredictable completion of prerequisite work can quickly result in the abandonment of design planning (Koskela et al, 1997), therefore perpetuating a cycle likely to create further difficulties. As such information management is another issue vital to project success where the industry performs poorly.

D. Design Changes

Design changes are a significant problem in the construction industry. They have large administration costs (Machowski and Dale, 1995), account for 40-50% of a designer's total work hours (Koskela, 1992) and even in well-managed projects can cost between 5 and 15% of total construction costs (Morris et al, 1999; CIDA, 1994; Burati et al, 1992). Love et al (2000) highlight that such costs could be even higher as they do not represent the latent and indirect costs and disruption caused by schedule delays, litigation costs and other intangible aspects such as buildability (Kagioglou et al, 1998). However, evidence suggests that even for successful, well-managed projects carried out by industry leaders, around two-thirds of design changes by cost are avoidable (Morris et al, 1999). This is a significant potential for improvement – so why is controlling change such a problem?

Newton and Hedges (1996) observe that traditional DM techniques cannot predict the effect of change on the design programme and fees. As such, it is difficult to determine all the possible change paths and to select which one of them is the best to follow (Mokhtar et al, 2000). Thus, if current tools cannot determine the full impact of design changes and human judgement is unable to account for the myriad interactions that jointly determine its outcome (Richardson, 1991; Sterman, 1992) then many design changes are being made without full exposure to all potential impacts. Such an inability to predict the impact of changes must be considered a barrier to effectively controlling design changes and therefore managing the design process. As such, if changes can be better controlled then there is more chance of project success.

In general, the management of design is problematic due to the following design problems:

- Poor briefing and communication;
- Inadequacies in the technical knowledge of designers;
- Lack of confidence in preplanning for design work;
- Lack of adequate documentation;
- Deficient or missing input information;
- Unbalanced resource allocation;
- Lack of coordination between disciplines;
- Erratic decision making;
- Lack of effective planning and control to minimize the effects of complexity and Uncertainty.

(Ballard and Koskela (1998) and Tzortzopoulos and Formoso (1999) While sites can operate on a definition of quality as conformance to requirements, design must produce those requirements from identification of client needs! Many design decisions are reciprocally independent, making the management of workflow among the various specialists important and difficult. Early design stages are notoriously hard to evaluate and against progress milestones. In general, the design phase, being one of the early phases of the project life cycle is found to be a major source of problems for the subsequent phases, even to the extent of undermining systematic management during construction (Ballard &Koskela, 1998).

2.1.6 Poor design management impacts to construction stage

Building design is an iterative process in which designers identify problems, exchange information and ideas implement the ideas and solve the problems. In order to improve design management, it is important to optimize the design process, particularly in the earlier conceptual and preliminary design phases (Tilley, 2005; Reifi& Emmitt, 2013). It is frequently emphasized that there is no infallibly correct design process, and the design process be a continuous negotiation between problems and solutions. Since design problems defy comprehensive description and offer an inexhaustible number of solutions, the design process cannot have a finite and identifiable end (Lawson, 1997). In practice however, design durations and budgets are limited, so it is necessary to control the design process. Construction design has an iterative form with a multitude of interdependencies and therefore, it needs mutual adjustments between all participants, and coordination among the project stakeholders is a key factor that influences its outcome (Kalsaas& Sacks, 2011).

Poor communication, lack of adequate documentation, deficient or missing input information, unbalanced resource allocation, lack of coordination between disciplines, and erratic decision making have been pointed out as the main problems in design management (Tzortzopoulos and Formoso, 1999). Poor management of design can cause document deficiencies and reworks (Tilley, 2005; Reifi& Emmitt, 2013), project cost overruns and reduced productivity (Baldwin et al., 1999). The design phase is also a major source of problem for the subsequent phases, undermining the systematic management of construction projects (Koskela et al., 2002) and preventing many projects from fully realizing their value potentials (Hamzeh et al., 2009; Hansen & Olsson, 2011). A better management of design can improve constructability, and eventually bring about tangible benefits in terms of time, cost, quality and safety when designers are directly involved in implementing the constructability measures (Pocock et al. 2006; Wong et al. 2007).

2.1.7 Economic and Social Benefits of Effective Design Management Process

The benefits of properly managed designed process cannot be overemphasized. Some of the benefits are:

- It reduces the total duration for the design process

- It enhances coordination and reduces conflicts and disagreement between the stakeholders and the design team
- It enhances proper scope planning, scope definition and scope control
- It results in a reduction in change orders during project execution
- Reduces the risk of schedule overruns during project execution
- It enhances a clear prediction of the project cost ahead of time and reduces the challenges of cost overrun
- It produces higher stakeholder satisfaction during the project execution and after completion
- Enhance effective project risk management and risk control
- Enables the development of a complete work break down structure and hence deliverables
- It enables a comprehensive quality management plan to be put in place for the construction process
- It enhances effective project procurement process and integration management

2.2 Building Information Model

2.2.1 General

2.2.1.1 What is building information modeling (BIM)

BIM is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations. BIM is a strategic enabler for improving decision making for both buildings and public infrastructure assets across the whole lifecycle. It applies to new build projects; and crucially, BIM supports the renovation, refurbishment and maintenance of the built environment of the largest share of the sector.

2.2.1.2. Key Considerations When Moving to BIM

Some people mistakenly think of BIM as just a new variety of software. BIM is a process that relies on information rich models to help owners and AEC service providers to more efficiently plan, design, construct, and manage building and infrastructure projects. Implementing BIM will impact your business and your processes, as well as your technology toolset. As you move to BIM you should be aware of how your organization's

business, processes, and technology might change, so you can better position your firm to reap the benefits of BIM (van Nederveen , et. Al. 1992).

2.2.1.3 Maturity Levels of BIM

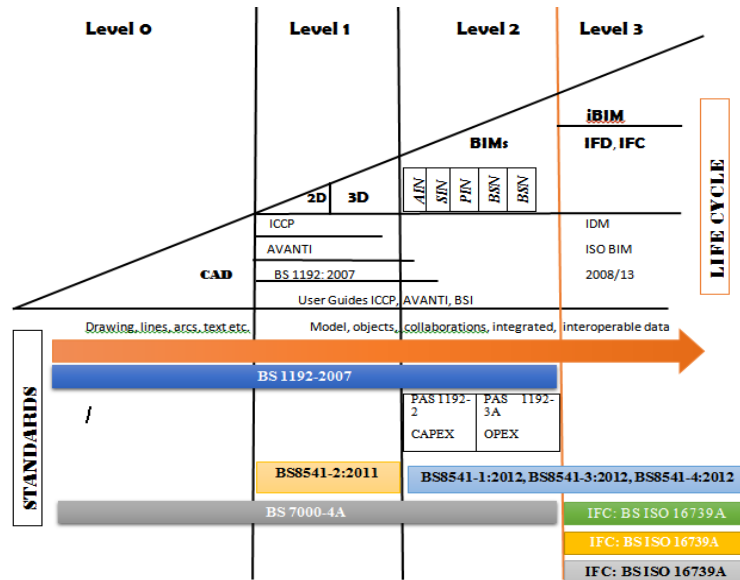


Figure 2-5 BIM maturity level(Sager.U 2014)

BIM Level 0

In its simplest form, level 0 effectively means no collaboration. 2D CAD drafting only is utilized, mainly for Production Information (RIBA 2013). Output and distribution are via paper or electronic prints, or a mixture of both. Most of the industry is already well ahead of this now.

BIM Level 1

This is the level at which many organizations are currently operating. This level is a combination of 3D used for conceptual work, followed by 2D for the drafting of approval documentation. CAD standards are managed to BS 1192:2007, and the digital/electronic distribution of data among the stakeholders is carried out from a common data environment (CDE) that is generally managed by the contractor. Models are not shared between project team members(RIBA 2013).

BIM Level 2

This is distinguished by collaborative working all parties use their own 3D CAD models, but not necessarily working on a single, shared model. The collaboration comes in the form of how the information is exchanged between different parties and is the primary difference between Level 1 and 2. The design information is shared among various parties with ease due to the use of a common file format which enables any organization to be able to combine that data with their own in order to make a federated BIM model, and to carry out interrogative checks on it. Hence any CAD software that each party uses must be capable of exporting to one of the industry-accepted common file formats such as Industry Foundation Class (IFC) or Construction Operations Building Information Exchange (COBIE). This is the method of working that has been set as a minimum target by the UK government for all work on public-sector work, by 2016.

2.2.2 Elements of BIM

Building Information Modeling refers to a collaborative method of working which is based on the generation and exchange of data and information between the various project parties. For effective functioning, BIM requires integration of the following five elements: **Processes, Policies, People, Information and Technologies**

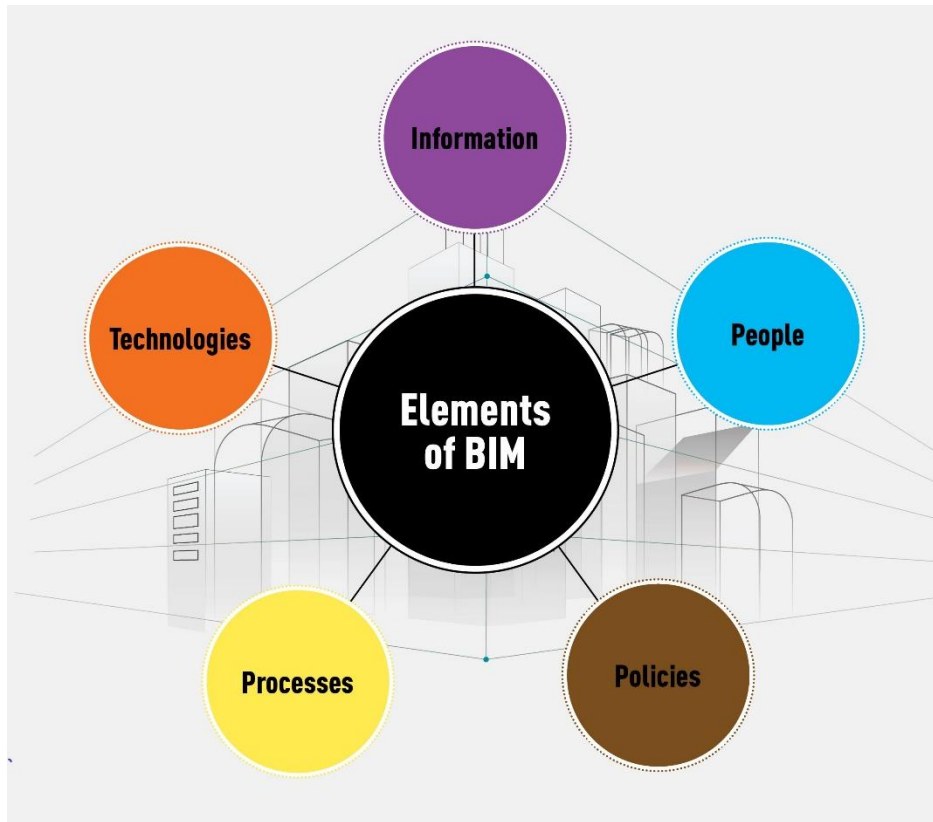


Figure 2-6 Elements of BIM(BIM Academy 2017)

Processes Forms allude to the particular arrange of work exercises with a starting, conclusion, and a clear recognizable proof of the inputs and output of each stage

Policies allude to the standards and rules to direct the decision-making prepare process. Policies are framed to create guidelines and best practices to minimize disputes between the parties involved.

People make the difference and therefore are the most important. Effective management by people can only lead to successful BIM. Important people in Building Information Modeling usually include BIM director, BIM manager, BIM consultant, BIM technologist. (Abas.E and Jonathan 2013)

Information: There are two types of information: models and documents. **Models** are digital data that are the representation, reproduction, or simplified version of an object, road, bridge, building etc. They are stored in a file format and can be exchanged and shared to support the decision-making process for the construction of the infrastructure, buildings etc. Documents are the digital version of papers, drawings, prints, images and video.

Technologies refer to the software and hardware tools used to manage the various stages of the Building Information Modeling process (Azhar.S 2011).

2.2.3 BIM based design process

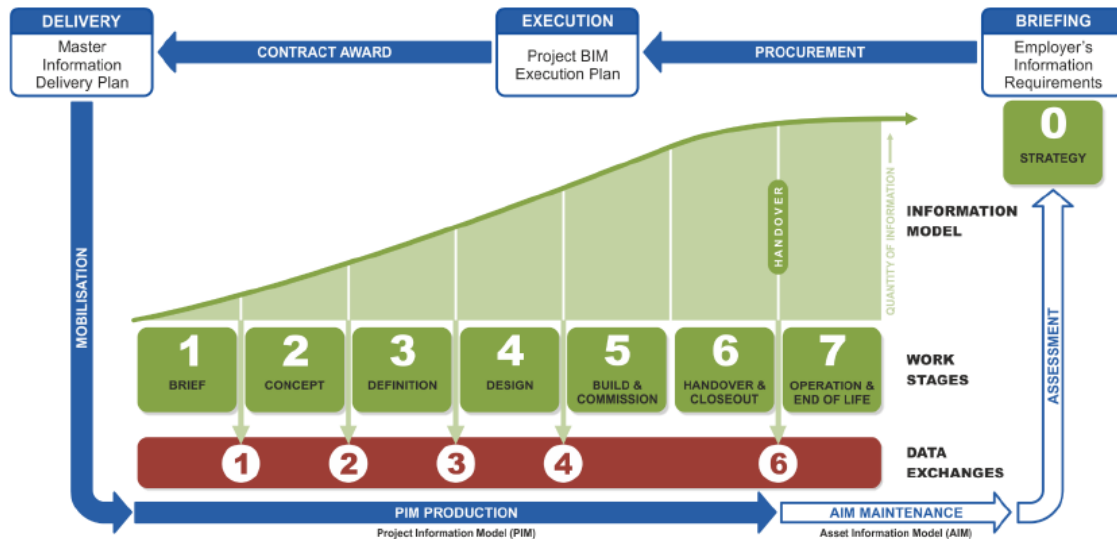


Figure 2-7 BIM based design process (BIM Academy 2017)

A. Project design brief

At the project design brief start with client preparing EIR. The EIR is a key document for Level 2 BIM. The document is compiled by or on behalf of the client and is issued at tender stage, its intention is to define the client's requirements, and how the project model and information is to be delivered in relation to a number of standards, namely PAS1192 .

A set of Employer's Information Requirements is intended to be part of the wider tender document set for the procurement of the Design Team and the Constructor.

The main purpose of an EIR is to document the information requirements and also to establish the information management requirements. The type of information that is typically included in an EIR document. (BIM Academy 2017)

- Project brief
- Objectives
- Client aspirations
- Required data drops
- BIM Execution Plan requirements
- Agreed Common Data Environment (CDE) and its management
- Information Manager and responsibilities

B. Project execution plan

Then respond with their outline BIM Execution Plan (BEP). Essentially the BEP demonstrates how, if successful, the bidders will deliver and manage this digital information throughout the project.

Typical issues that are covered in a BEP would include Project Information, as well as Project Objectives and Management which are really concerned with how and what you are going to provide the client and confirms that your sub-contractors can also perform regarding digital information. In the Technical & Procedural section you will explain technical details, for example the software expertise, and project specific BIM content.

C. Developing design

At this stage the designers are developing model information in accordance with the BEP requirements. For certain components the level of detail may be high whereas the level of information low and for other elements vice versa. It is important to remember when modelling objects that they should be modelled with enough detail and information to fit their purpose per the BEP.

It is easy to over model objects and saturate them with un-necessary high levels of detail and information which serves no purpose but to slow down model use.

Any number of 3D modelling products could be used to produce the discipline specific models, here are just a few of them.

Designers will always prefer the product that suits their own work processes and internal requirements, this isn't a problem at all, the products ability to create a suitable exchange format as described in the project documents is what is important. The ability to communicate as defined in the EIR and BEP is vital, not what you use.

The architect develops the concept model for internal use and provides this information to the other discipline specific design team members. They each begin to develop their own internally hosted models based on the BEP requirements. The project BEP reflects the unique project stakeholders and their diverse software preferences, this will vary with each project.

The structural engineer develops the model for design coordination and a number of other purposes, such as performing structural analysis and design options. This is sometimes referred to as value engineering, in essence trying to find the optimal design for the structure in terms of structural efficiency, cost, construction time and a host of other criteria.

At the same time the building services team are creating mechanical, electrical and plumbing models. They too are performing analysis and design calculations on the systems to be installed.

D. Model Transmittal and Publish to Shared Folder

These models are shared at regular intervals by the team and it is important that prior to issuing them each model author performs a check on the model's content for validity and reliability. Prudent authors will always check their work prior to issuing to another party.

Whilst a number of file types exist, for practical purposes we will exchange and share models with the design team using our native 3D modelling software format. The files should be placed in the agreed location; mostly in Shared folder. This allows us to link these different models together for the purposes of undertaking a design review meeting.

E. Design Review

During this definition stage the design team will regularly undertake a design review to ensure design intent is being understood and wherever possible potential issues are reported for resolution amongst the team.

Here again the format these design review meetings takes may vary enormously depending upon the level of BIM sophistication amongst the stakeholders, they type of contract and the BEP requirements for data transfer.

It could be that model federation software is utilized, standard exchange formats such as IFC are adopted or native file formats are exchanged. File types could include RVT, NWD or IFC. Any design issues are allocated to the relevant designers for resolution and model revision (BIM Academy 2017).

F. Model Federation and Clash Detection

In this session we will consider model federation, the act of bringing together a number of discipline specific models often produced from different file formats. This is normally performed by the client's representative, the Information Manager or BIM Manager, and it is from this federated or aggregated model that tasks such as clash detection are performed.

Clash Detection refers to the automated or semi-automated procedures for identifying design errors in 3D models, where objects either occupy the same space (a hard clash) or are too close as to violate spatial constraints (a soft clash or clearance clash). Time-based clashes are either hard or soft clashes involving temporary objects competing for the same space at the same time.

There are many BIM Software Tools that allow a combination of automated geometry-, semantic-, and rule-based clash analysis for identifying clashes.

Clash Detection consists of processing, coordination, and tracking activities leading to the resolution of detected conflicts, whether visually or automatically identified. When successfully conducted, Clash Detection offers the following main benefits:(BIM Dictionary 2019)

- Improved project coordination and quality;
- Reduction of workplace conflicts;
- Acceleration of the design and delivery processes; and
- Cost reduction through productivity increases

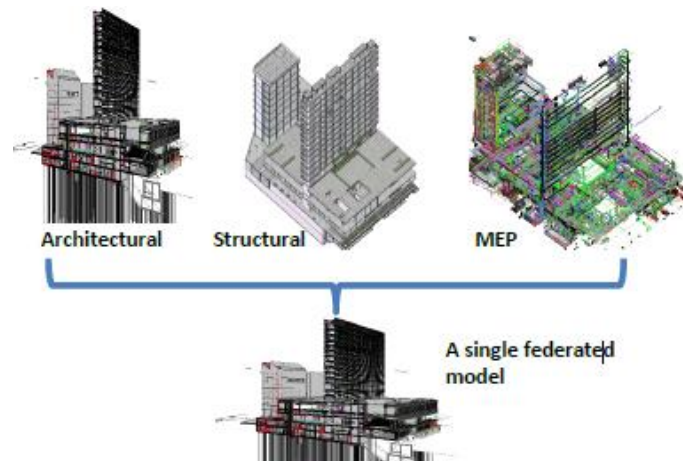


Figure 2-8 *Model Federation (BIM Academy 2017)*

G. Model renderings

Model rendering are being created from concept modelling to handover, and they serve a broad range of requirements. In their earliest form as simple concept models they allow clients to identify with the project. As the scheme develops so too does the model and its usage, from urban planning to landscaping to the motion of people and traffic.

H. Time as 4D in Building Information Modelling

Time is a very unique non-material element in construction projects that can be represented in various perspectives, including time-space conflicts and construction schedule visualization. Attempts at incorporating time as additional information to evaluate and analyze different forms of project sequences comes in the form of 4D Computer Aided Design (CAD) (Algan.T, Zeeshan.A, Chuxiong.J, 2016).

Models and construction sequencing are not only used at the construction stage; stakeholders are increasingly preparing models for alternate initial engagements. For example, to meet planning requirements and engage with non-technical individuals during public consultations. At bid stage it is very powerful to be able to provide the client peace of mind that you have a clear understanding of what the design intention is, and more importantly that you can demonstrate how you are going to build the project.

4D is widely understood to represent the combination of 3D elements with time, in essence it could be considered to be the Model plus the Programme. Using the 3D models and

allocating the construction programme to the objects creates 4D planning, where visually it is far easier to notice potential errors in the construction programme. This is far easier than reading through drawings and Gantt charts. In the image above model objects have been grouped into selection sets.

Model data can be imported into a quantity take-off (QTO) product such as Navisworks, to first derive material quantities, this detailed information may have a direct effect on the overall programme, for example a large volume of concrete may require additional time to pour, or additional joints which would result in additional tasks being created. The updated programme is then transferred back for visual scheduling of the new tasks (BIM Academy 2017).

Information on tasks and programmes can be used for a multitude of other planning requirements. For example, to show temporary works, transport access and egress, ancillary construction logistics such as scaffold and crane placement, delivery and storage of components and materials, temporary offices, and many more.

I. Cost as 5D in Building Information Modelling

Cost estimation is very significant for decision making as inaccurate estimation may lead to disastrous cost overrun and project delay. Early project estimation represents a major factor in business unit decisions and often becomes the basis for a project's ultimate funding. In spite of great importance given to cost estimation, it is neither simple nor straightforward due to deficiency of information in the early stages of the project (Sheng 2016).

The ability to derive material quantities at the earliest stages of a project is extremely beneficial for those tasked with producing cost estimation, or for comparison with the design brief.

The topic of quantity take-off often leads to some interesting conversations regarding model accuracy, level of information, and trust in the fidelity of the model contents. In this module we will consider this in more detail, and we'll use Navisworks to perform a material quantity take-off of the model objects.

A real strength of using the model to perform a material take-off is the ability to quickly perform this on the federated model, often comprising of a number of models originating from different authoring programmes (BIM Academy 2017).

2.2.4. BIM based design management

The construction industry is widely being criticized as a fragmented industry. There are mounting calls for the industry to change. The espoused change calls for collaboration as well as embracing innovation in the process of design, construction and across the supply chain. Innovation and the application of emerging technologies are enablers for integrating the processes 'integrating the team' such as building information modeling (BIM). There was a general agreement about design team was responsible for design management in their organization. There is a perception that the design manager and the client are the catalyst for advancing innovation. The current state of industry in terms of incorporating BIM technologies is posing a challenge as well as providing an opportunity for accomplishment. BIM technologies provide a new paradigm shift in the way buildings are designed, constructed and maintained. This paradigm shift calls for rethinking the curriculum for educating building professionals, collectively (Abas.E and Jonathan 2013).

BIM has been increasingly used in the building industry with many well documented benefits such as reduction in project costs, savings in project durations, improvements in project communication, coordination and project quality (Azhar.S 2011). Improved multi-disciplinary coordination, communication and shared understating among the design team and stakeholders are some of the most underlined benefits of BIM adoption in the design phase (Korman et al., 2012).

Similarly, BIM is a comprehensive information management tool capable of simulating the design and construction method alternatives rather than merely a 3D graphic representation of the design intent. Going beyond 3D models, BIM allows designers to choose the best design solution by enabling virtual visits inside a facility, simulating various design alternatives with their possible effects on the project. Thus, BIM facilitates the communication of objectives, problems and changes in design. The use of BIM also provides a means to increase the overall design quality by automatically detecting and solving the conflicts and clashes between different disciplines with fewer coordination

related errors (Khanzode et al., 2008). Popov et al. (2006) demonstrated that BIM supports a management environment in which designers can effectively share information; avoid data loss, miscommunication, and translation errors for a higher quality design process. Along with better value capturing, the BIM capabilities of generating rapid design alternatives, project drawings, quantity take-offs and presenting a synchronous design platform among different disciplines also facilitate the reduction of non-value adding design activities and design lead-times in the AEC industry (Sacks & Barak, 2008; Flager et al., 2009).

Due to the technological maturity and interoperability issues, industrial culture change requirements, lack of BIM standards, and training and education needs, there is a common consensus that BIM is currently still immature for its full adoption over the construction lifecycle in the AEC industry (Zhiliang et al., 2011).

Yung et al. (2014) reported a BIM based case study in China. It was found that the use of BIM might not save the overall design time as 2D design is still extensively involved mainly because it is required to submit 2D project documentation for regulatory approvals but it is still difficult for BIM software applications to automatically generate 2D shop drawings in accordance with the industry specifications in China (Ding et al, 2012). However, BIM could still save the costs of manual mechanical, electrical and plumbing (MEP) coordination and potentially improve the design quality by reducing the number of change orders (Yung et al., 2014).

2.2.4.1 Interoperability

The first value level of BIM interoperability is **communication**. In this level, the main concern is with the use of 3D modeling. This relates to interoperability in the sense that 3D visualization allows much better understanding, henceforth, better communication of the design. The second level is called **coordination**. In this level, clash detection, overlap avoidance, etc. are expected. After this, full 3D BIM is expected on the third level, also known as **cooperation**. This means that there should be supply chain visibility, construction and energy simulations, cost prediction, etc. This level is focused on obtaining advantages by sharing work among agents. The next level, **collaboration**, assumes BIM collaborative environments. And the fifth and final level, channel, expects an automatized environment

permeated in the whole process, including production. The group known as Building SMART seeks to create solutions for BIM interoperability, and created the IFC (Industry Foundation Classes). IFC is an open format for BIM platforms.

Building information modelling is expected to play an important part on interoperability for the AEC industry according to the views in the literature. However, the specialists see further need for development for interoperability to reach a level where BIM is implemented and working fully (or at least with most agents connected). The specialists perceived that BIM is not regularly used in the AEC industry yet, especially on the data (format) and business (share) concerns. This means that further study on interoperability concerns will be needed, with a special focus on how to improve IFC files, in order to improve interoperability in data, which showed the least developed of all four concerns. In order to improve data interoperability through IFC, the special aspects of the AEC industry must not be taken for granted in the development of the systems and their ability to generate IFC files. A special attention must be given to materials, geometrical characteristics and detailing to improve IFC interoperability in cast-in-place concrete structures (sumedha.k 2012).

2.2.4.2 Communication and Coordination with BIM

There are various ways of communicating and collaborating with BIM. To prepare this Collaboration, BIM objectives can be shared through e.g. guidelines and protocols, secondly, actors can work together online in a shared environment, and using virtual reality to show images to clients or end users (Cavka, Straub and Pourier 2017). Communication of BIM requirements and project outcome can be done via BIM standards, BIM policy, BIM guidelines, BIM protocols or BIM execution plans. The difference between e.g. standards and protocols is that: standards state the required outcome of the project, and protocols include information about how to achieve this outcome (Cavka et al, 2017). A recent view on BIM is that of a 'boundary object': a virtual, physical or electronic object, which carries information. Different actors can have different interpretations of boundary objects, which create the need for someone that creates shared meaning. This person can also be called a boundary broker or boundary spanner. The boundary broker is a person who can mediate in projects because other actors have much trust in him/her, and who

translates the meaning of the boundary object amongst the others (Papadonikolaki and Van Oel 2018).

In the lifecycle of a building, many actors, interfaces and knowledge are involved. The extensive length of this lifecycle makes that integration and communication have importance for a long period long time. In the design phase, it is determined how practical and usable the building is (Huang, Yien, Chen, Su & Lin, 2017). During the operation phase, which is the longest phase of the life cycle, interaction exists between professionals, stakeholders, facilities and management activities. It also involves space planning, scheduling, repairing and emergency managing (Peng, Lin, Zhang, & Hu, 2017).

BIM can further be used to exchange information from the design and construction phase to the operation and maintenance phase. These big amounts of data can be managed by BIM platforms to improve interoperability, for better facility management. Some challenges or improvements considering this use of BIM are the large amount of data that must be processed, as well as the fact that managers need professional knowledge to access the information. Also, inaccurate data, e.g. through erroneous manual input, possibly hampers management. Because manual checks are nearly impossible, (Peng, Lin, Zhang and Hu 2017) propose algorithms for data management, which provide the opportunity to extract data from the design and construction phase, and to share this information between stakeholders in a shared platform. They discuss improvement of their system: a further optimization of the algorithms, integration of Internet of Things, and professional training of e.g. data analysts with AEC knowledge. Furthermore, discipline and accuracy in databases should be improved and missing data should be reduced to optimize the platform.

– **Introducing the CDE (common data environment)**

Common Data Environment (CDE) refers to a single source where project information is stored. The CDE enables the collection, management, and dissemination of all relevant project documents among the multidisciplinary teams in an orderly process. A CDE may refer to a project server, an extra-net, a file-based retrieval system or any other suitable file repository or toolset. CDE have a folder structure containing WIP (work in progress), shared publish and archive. CDE could be cloud based or server-based data exchange for

a multi-disciplinary team in order to extract information or share information using a single resource.

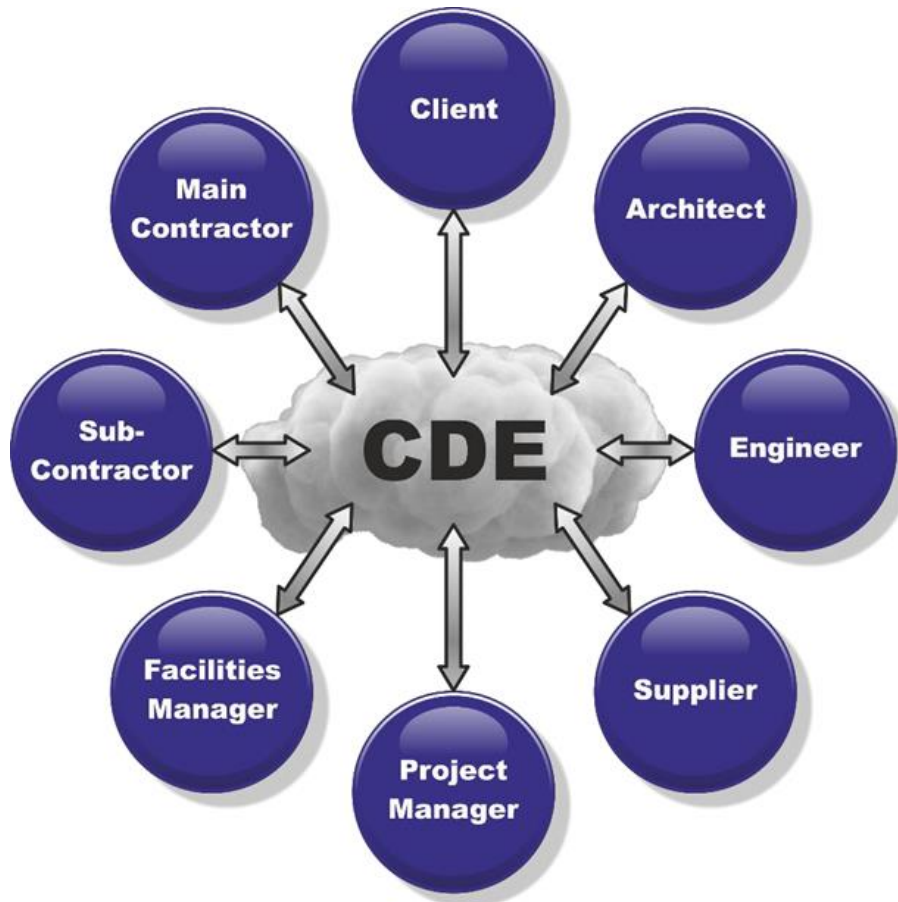


Figure 2-9 Common data environment (BIM Academy 2017)

BIM information is passed through the 4 areas where the information is:

1. authored, checked, reviewed and approved for use outside of the authoring team (Work in Progress (WIP) area)
2. shared with other disciplines to use as reference material for their own design development and authorized to publish (Shared area)
3. published (in non-changeable formats) for use by the total project team (Published / Issued area)
4. stored and maintained for knowledge, regulatory and legal requirements (Archive area)

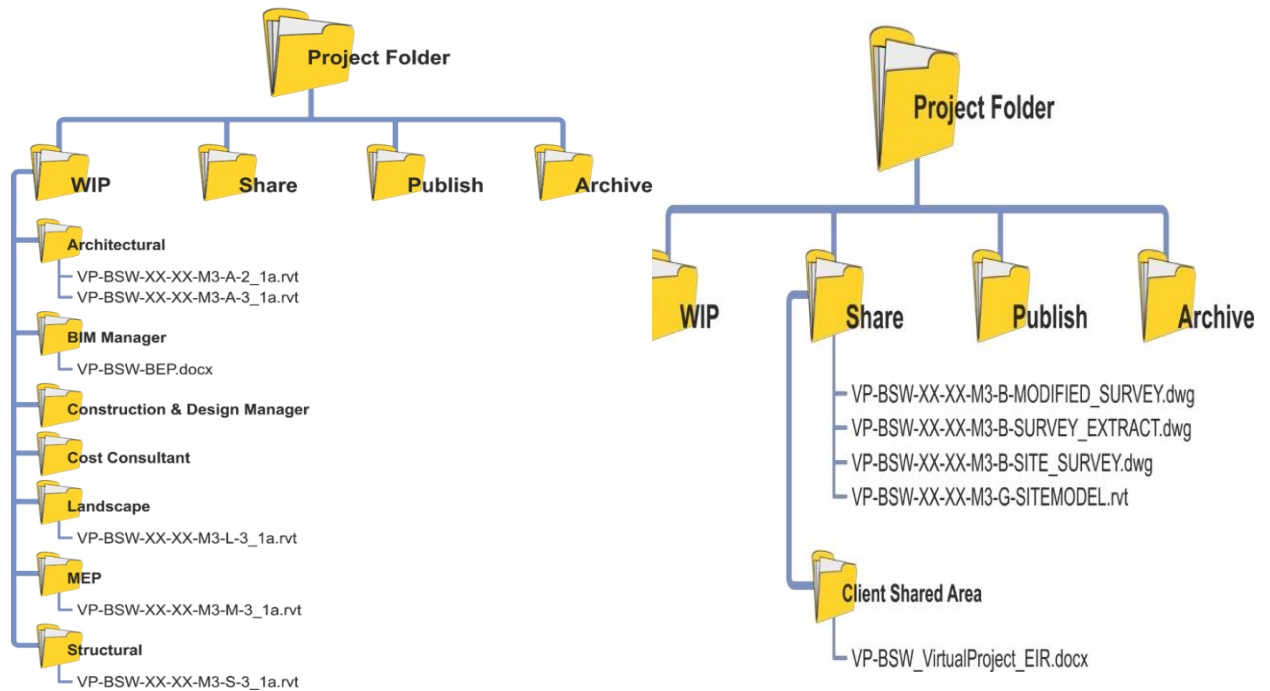


Figure 2-10 common data environment folder structure (BIM Academy 2017)

2.2.4.3 Integration of information using BIM

Building Information Modeling (BIM) is one of the most important supporting factors for a successful integrated design. BIM makes it possible to integrate information from the project participants of different disciplines which traditionally work in different phases of the building process (Rizal Sebastian & Willem Haak 2013).

BIM application to support integrated design, much can be learned from FP6 European research project ‘Open Information Environment for Knowledge-Based Collaborative Processes throughout the Lifecycle of a Building (InPro)’. On average, by the time when 1% of the project costs are spent, roughly 70% of the life-cycle cost of the building has been committed. Therefore, InPro develops a conceptual framework for collaborative decision making by the clients and project participants based on open information environment during the early design phase. The use of BIM offers the opportunity to carry out a performance-based design through which information on the future building performance is considered in design decision making ([InPro 2009]). InPro project BIM consists of three main aspects, namely: 3D visualization, specifications, and cost estimates. Each decision is taken after verifying the design based on the requirements and

performance analysis. In the decision-making process, ideas are translated into concepts, then elaborated in proposals, then approved as results (Huang, Yien, Chen, Su& Lin, 2017).

2.2.4.4 Design changes using BIM

Owner-generated design changes are common in building projects and can be problematic for cost-related and legal reasons. Understanding the ripple effect of contemplated design changes is critical in making rational decisions about whether to proceed with these changes. A BIM-based visualization model was thus developed to overcome the difficulties associated with the timely recognition of design changes and their ripple effect. (Algan.T, Zeeshan.A, Chuxiong.J, 2016)

The proposed model applies a pair comparison methodology at the component level between as-planned and as-changed BIM models to identify each design change and its ripple effect in a structured report. The methodology was implemented and validated through a project example showing how the full effects of a proposed change will affect a project. The proposed model provides owners with a novel method for obtaining the information needed to make enlightened decisions in order to identify beneficial design changes for their projects. This will be of great benefit to owners and designers for all types of building projects (Huang, Yien, Chen, Su& Lin, 2017).

The main BIM platform of the proposed model was implemented with Autodesk Revit Architecture 2014, which allows for the auto-adjustment of building components affected by design changes. However, the software is unable to detect and visualize the ripple effect of the design changes; therefore, Revit Application Programming Interface (API) was used to develop an addon in C# that can automatically detect and quantify changes, as well as analyze the ripple effect of the design change on other components of the model. The Revit add-on, named Check

Change provides the user with a 3D BIM visualization of the requested design change and its ripple effects on the project's architectural and non-architectural components. In addition, the proposed model provides the user with a detailed report on all the changed components and their ripple effect. The proposed model consists of three main modules: data acquisition, data analysis, and reporting and highlighting. The data acquisition module

provides the input of the Check Change add-on, which are the as-planned and as-changed BIM models.(Azhar.S 2011)

- **Data Acquisition**

The generated BIM models feed the developed Check Change add-on by providing data such as component specification, family type, assembly code, assembly description, and unique ID.

The family represents the main description of objects, such as wall, door, window, column, etc., and the type represents a specific kind of a family object, such as a 450 mm round column, or a 600 mm rectangular column. The assembly code represents a type of component, and the unique ID represents the individual component.

The proposed model then exports and stores all the components of the generated as-changed and as-planned BIM models to a central database, including all the above-mentioned component characteristics. The user opens the two BIM models in Revit and selects the as-planned BIM model as the base model, and the other model is automatically saved in the system as the as-changed model. The user can alter the as-changed model even after opening it in the interface, but the system does not allow any changes to the as-planned base model.

- **Data Analysis**

The proposed model then uses the data captured in the generated central database to identify the differences between the two BIM models' components by running a component-by component comparison based on their unique IDs. The proposed model starts matching similar IDs and compares the component characteristics to find differences.

The result provides a list of components that are added to, deleted from, or modified in the as-changed BIM model. The list of changed components is then used to identify the cause-and effect relationship between the changed components, and the proposed model generates a room-grouping command for this, which adds a new attribute to the Revit components. This command is based on the proposed micro-level WBS, which groups the project's floor, area by area, and gives the same ID to components that are in the same area as in the as-changed model.

The group ID helps the proposed model run the ripple effect analysis for each changed component of the as-changed model. Upon grouping all the components of the as-changed model, the user selects the main changed components in the as-changed or as-planned model's architectural system based on the owner's requested design changes. The system then considers the selected components as the main source of the change and lists the rest of the impacted components that belong to the same group with the connections to the main source of changes. All the changed components detected by the system connected to the main source of change are considered the ripple effect of that change. Thus, the proposed model conducts a ripple effect analysis on two levels: components that the main source of change is connected to (same group ID) or surrounded by (different group ID). As a result, the proposed model provides the user with the change's path, indicating the main source of the change and its effects.

- **Reporting and Highlighting**

The proposed model provides the result of the change's ripple effect analysis in two different modes. The first provides an analysis of the change's ripple effect in report format, in the Revit interface. In the report, the user can see the main source of the change along with the list of impacted components. The report consists of two parts, the as-planned model and the as-changed model, each of which provides the component's specifications and physical information such as length, height, weight, material, and location. Also, the report for both as-changed and as-planned BIM models provides the type of building system for each component, change type (modification, addition, and deletion), component ID, and location of components. Moreover, the report shows the component's virtual information such as family type, assembly code, and assembly description. Reporting the information of as-planned and as-changed BIM models side-by-side eases the understanding of the nature and scope of the introduced change. In the second mode a color code is used to visualize the result of the ripple effect analysis, highlighting the types of changes with a different color in both BIM models: red for deletion, green for addition, and yellow for modification. In other words, the newly added component is green in the as-changed BIM model, deleted components are red in the as-planned model, and the modified components are yellow in both the as-planned and as-changed BIM models. To find the

cause-and-effect relationship, the user first selects a component as main source of the change and the ripple effect is highlighted in the BIM as-changed model. The proposed model links the report and the BIM model, matching the component's unique ID generated in Revit for each element. The user can then select a component in the model and get the component's data in the report, and vice versa.

2.2.4.5 Evaluation and management of information

In trying to propose new technologies and frameworks for information management, researchers have found that information management and exchange within construction typically still takes place manually, with individuals or organizations reformatting and manually distributing information (Dawood et al. 2002), normally on a document level (Anumba et al. 2008). This leads to wasted time and cost through data loss when information is exchanged or converted, inefficiencies through rework, further wasted time spent identifying the useful information in a document (Anumba et al. 2008), and the late, incomplete, uncoordinated and/or inappropriate exchange of information. The fragmented nature of the construction industry frequently leads to incompatibilities in semantics, process and software between collaborating organizations (clients, designers, contractors, suppliers, and so on), amplifying the waste mentioned above (Anumba et al. 2008, Abukhder and Munns 2005).

Taken cumulatively, it is therefore clear that the key requirement in any improved information management system is the co-ordination of information exchange. Dawood et al. (2002) discuss the challenges involved in creating a system that will 'meet the different views and needs of the multiple professional disciplines involved in the construction process'. BIM is well positioned to meet these needs in construction. Sacks et al (2010) have identified the synergies between the principles of BIM and lean construction and observed that information can be managed according to lean principles. However little work is published specifically on measuring information flows through BIM to evaluate its impact on the challenge of information exchange and co-ordination.

2.2.4.6 Validation and verification of design (constructability)

A. Constructability

Construction interfaces had been identified as a big issue during the construction phase because interfaces may affect the project implementation. Entity interface problem usually refers to not good design efforts. And not good designs also may result in constructability problems such as labors do works difficultly in a too small space. Construction Industries Research and Information Association (CIRIA) define the constructability: the design efforts can be used in the construction phase, and let contractors implement activities easily and smoothly (CIRIA 1983). Based on this definition, the designer must understand construction, but the designer common lacks the construction experience. Therefore, if contractors want to implement activities well, they need to identify the potential problems from initial designs before the construction. Even though there are no problems may be found, this process still needed to be worked.

- **The application of BIM in constructability analysis**

The construction project implementation depends on the quality of designs so designers should concern the integration of different systems such as structure and HVAC system. The interface problems that affect constructability should be eliminated as possible before the construction, reducing the chance of reworks or activity cannot be constructed because space is not enough.

The steps of model review relating to constructability are developed in this process. It is very important for the construction. If serious problems are not found in the step, the performance of BIM application will be low. Thus, senior engineers with construction experience must join to assist constructability identification. The common encountered construction problems can be classed into three types, including space, measurement, and clash. The following sections describe three issues separately and develop the BIM procedure to address them.

- **Space Review**

The net space for use inside the building is reviewed whether the spatial allocation is available such as the distance between TV and sofa, and the traditional way is to integrate both of engineering drawings related to architecture, structure, and interior decoration. The problems, however, are detected during the integration of these engineering drawings, including the inconsistency drawing versions, complicated lines and notations maybe

overlap in one integrated CAD drawing, it's difficult to review net elevations, and so on. Therefore, BIM provides a high-performance solution for reviewing the integrated design content

- **Measurement Review**

In the design process, the plan drawing of a building is first accomplished, and the elevation and section drawing are then also produced. The draftsman needs to annotate the measurement in these drawings for showing the relationships of building objects in the space. For example, when the designer changes the stair step number of a stair, the designer must attend to consider the clear height for user climbing. If the draftsman cannot handle the relationships among plan, elevation, and section, the errors of measurement annotation will make the problems after the construction, such as a clear height of a stair is not enough at the staircase for user climbing. To improve this problem, the BIM technology is utilized. A procedure for users checks the design about measurement that indicates the relationship between building objects. Utilizing BIM technology, checking measurement design is easier than before. Also, designers enable to ensure the consistency of the design through BIM because of it is database. When a designer moves one object or change the properties of one object in the plan view, all drawings of this object included will change at the same time. Moreover, the measurement annotations are also changed if you had been assigned the annotation to this object. Also, designers can check these changes immediately through using two views in one window; Synchronization function is the best advantage for designers. However, by apply BIM to implement design works, the measurement check will be easier for users.

- **Clash Detection**

The activity of the constructability checking is always implemented by manpower. This is the traditional way for constructability review. However, conflict problems will occur based on this situation. The engineer checks and reviews the engineering drawing, which integrate structure, architecture, and MEP, to detect the clashes and inconsistent building objects by 2D CAD. It is too difficult for engineers. Even the senior and experienced engineer still cannot find out all clashes from 2D CAD because this integrated drawing is serious complexity. However, BIM solution provides a chance to detect and

review conflicts easily for engineers. During modeling BIM model, the modeler can utilize the clash detection function to find out the potential conflicts. The system will create the clash detection report and then engineers can check these found potential conflicts and to eliminate them. Based on 3D model review, the clash detection is easier than before, and the consistency can be ensured due to the core of BIM is database when any object is moved, deleted, or changed. Consequently, the application of the BIM technology can enhance the quality of the construction because engineers can detect conflicts and other construction problems such as construction space is not enough as early as possible. (Hui-Hsuan, et al. 2013)

2.2.5 BIM based design Versus Traditional design

Case 1: Based on (Wang 2014) he takes two similar buildings were selected for investigation in the project as initiated by the client. The comparative data below was recorded based on reports generated from the project. The first comparative result was the duration required to develop the completed design model. The traditional design method required to spend an additional four weeks compared to the BIM-based design collaboration as shown in Table 2-1. This result was contributed significantly due to less rework and effective communication in the BIM approach.

Table 2-2 Comparative analysis on duration (Wang 2014)

Week (W)	W1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12
Traditional design method												
BIM-based collaborative design												

Apart from that, after the design completed, the performance analysis was carried out to determine number of errors from both designs. Table 2-2 shows a total of 392 errors were reported in the traditional design method; whereas only 143 errors were identified from the BIM approach. The clashes were the main source of errors for both designs, especially, the clashes between MEP and structure. The results also revealed that personal errors were

obvious especially in MEP design. Nevertheless, the BIM approach performed effectively to reduce the clashes involved.

Table 2-3 comparative analysis of traditional design versus BIM based design (Wang 2014)

Comparative analysis	Traditional design method	BIM-based collaborative design
Architecture design errors	23	15
Structure design error	34	29
MEP design errors	40	34
clashes between architecture and structure	16	4
clashes between MEP and structure	224	45
clashes between MEP and architecture	55	16
Total	392	143

Traditional design method relies on the completed designs from various parties to identify and solve the clashes in the final design. On the other hand, the BIM approach can coordinate and make good the clashes during the design development process. Figure 2.12 illustrates the details of the clashes that were identified along the process development. The analysis also revealed that most of the clashes were identified and solved in Week 5.

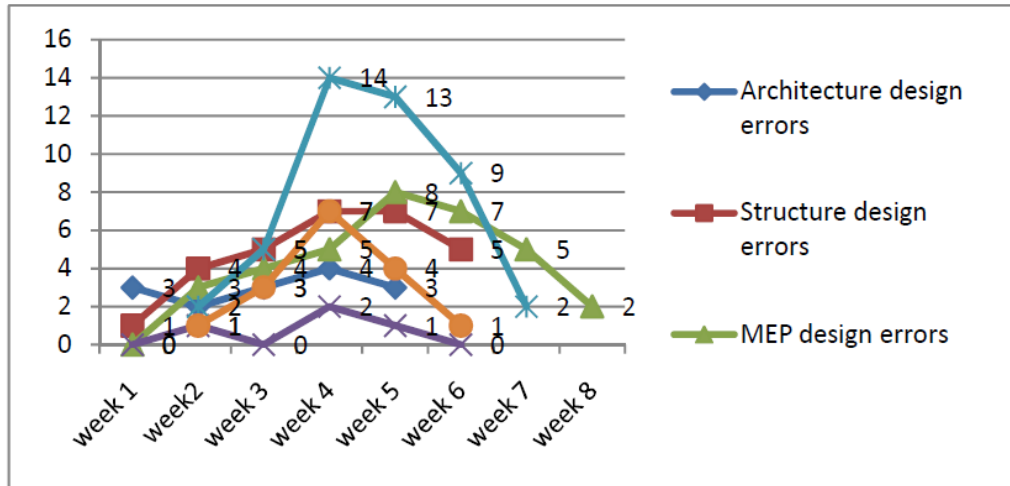


Figure 2-11 Number of clashes during the BIM design development (Wang 2014)

The case study was analyzed and explained the improvements in terms of duration and design performance by incorporating the BIM technology in addressing the design collaboration for a complex building. The BIM has significantly shortened the duration for the whole design development over 30% compared to the traditional design approach. It is also able to resolve the clashes during the design process. There were some clashes identified in the BIM approach due to coordination problems. This limitation should be addressed by having a more optimized and collaborative platform using a real-time BIM model in the future.

Case 2: In a study of BIM adoption in India, Yan and Damian (2008), identified a strong acceptance potential for BIM. BIM, with its limited use in construction companies in India reveals its potential in communicating and integrating information across the different trades resulting in smoother and efficient work processes and better decisions. The efficiency of BIM in comparison to Auto CAD in Indian industry is depicted in the Table 2-4 (Yan and Damian, 2008).

Table 2-4: Efficiency difference between CAD and BIM, Source ((Yan and Damian, 2008).

The Efficiency Difference Between CAD and BIM Applications for Particular Project in Different Phases				
Task	CAD (Hours)	BIM (Hours)	Hours Saved	Time Savings
Schematic	190	100	90	53%
Design Development	436	220	216	50%
Construction Documents	1023	815	208	20%
Checking and Coordination	175	16	159	91%
Totals	1824	1141	683	

2.2.6. BIM Implementation

BIM caused a revolution in construction industry (Jones, 2008). “Just as CAD (Computer-Aided Design) improved upon hand drafting, BIM is improving upon CAD. The difference is that BIM involves so many more project participants than just the architect” (Weygant, 2011).

2.2.6.1 International implementation of BIM

In the following are presented some countries in which BIM is already implemented and being the analysis more developed in the countries that have been leading the adaptation to BIM in the construction industry:

Table 2-5 BIM adaptations practice in the world

Australia	Not mandatory for projects, nevertheless, was used for the project of Sydney Opera House
Brazil	Began to be implemented in 2006 in some private initiatives.
	In 2010 ABNT/134 EEC Special Commission to Study the implementation was created

	In 2011 BIM was widespread to public initiatives
Canada	Founded by the end of 2008, the Canada BIM Council for support the adoption of standardizes models in architecture, engineering and construction,
	To manage national wide implementation and introduce good practices and standards.
	Requires the use of BIM in public construction projects;
Germany	Following the examples of some neighboring countries, where the use of BIM is already mandatory, Germany is trying to spread the use of BIM.
	It was previewed for 2014 the publication of a BIM-Guide, that offers recommendations and knowledge for all in Germany that are interested in using the BIM.
	The BIM guide is a non-binding recommendation; it is no mandatory directive to execute construction projects using BIM;
India	BIM is also known as VDC: Virtual Design and Construction.
	It has many qualified, trained and experienced BIM professionals who are implementing this technology in Indian construction projects and assisting teams in the USA, Australia, UK, Middle East, Singapore and North Africa to design and deliver construction projects using BIM;
China	BIM has been included as part of the National 12th Five Year Plan (2011-2015) for Mainland China and is formulating a BIM framework.
	It has been created a partnership between Academy of Building Research Technology and Autodesk for BIM models.
	The Hong Kong Institute of Building Information Modeling (HKIBIM) was established in 2009
	The Hong Kong Housing Authority set a target of full BIM implementation in 2014/2015;
Norway	BIM has been used increasingly since 2000.

	Several large public clients require use of BIM in open formats (IFC) in most or all their projects
	National BIM development is centered on the local organization, building SMART Norway which represents 25% of the Norwegian construction industry. Requires IFC/BIM for new buildings since 2010
Singapore	Determined national wide implementation roadmap in 2011.
	BIM as part of public sector building project procurement (2012).
	BIM introduced for architectural submission (2013)
	Structural and M&E submissions (2014).
	Requires mandatory use of BIM from 2015 onwards
South Korea	In the late 2000s the Korean industry paid attention to BIM
	the Korean government has been gradually increasing the scope of BIM mandated projects;
	In 2012 a detailed report was published on the status of BIM adoption and implementation
United Kingdom	In 2011 the UK government published its BIM strategy.
	The Government requires mandatory use of BIM in public sector (£5 million) from 2016 onwards.
	Their target is to become BIM leader in European region.
USA	The General Services Administration requires mandatory BIM submission for government projects since 2008.
	They are experts in using BIM and are leading BIM practice.
US Army Corps of Engineering	Initial Operating capability: 8 centers of standardization productive in BIM by 2008
	Establish life cycle interoperability: 90% compliant with National BIM Standard (NBIMS) ; all districts productive in NBIMS by 2010
	Full Operating capability: NBIMS used for all projects as part of contract advertisement, award, and submittals by 2012

	Automation of life cycle tasks: Leverage NBIMS data for substantial reductions in cost and time of constructed facilities by 2020
Other Countries	Some European countries (France, Switzerland...) require the use of BIM in public construction projects,
	some of them set up agencies to manage national-wide implementation and introduced good practices and standards

2.2.6.2 BIM implementation in developing countries

A study on the awareness level and usage of design and modeling tools and software was carried out among construction industry practitioners and academicians. Findings of this research can be divided into five parts. First, the results show that AEC industry practitioners are familiar with hand drawing, 2D and 3D design, and their knowledge about 3D design is in satisfactory level, but they do not use this skill in their job. Second, despite introducing two new generations of software (3D CAD and BIM-based) in AEC industry, AutoCAD is still most practical software among respondents. Third, architectural 3D software (e.g. 3Ds Max) are more popular among students, where Architects/Engineers are more interested in 3D CAD software (e.g. AutoCAD 3D). Fourth, level of knowledge about BIM-based software through students is disappointing. Finally, Architects/Engineers used ArchiCAD as BIM-based software which is architectural software.

According to these findings, adopting BIM-based courses among architecture and engineering schools' curricula for students and trainings for AEC industry practitioners is strongly suggested. For this reason, serious efforts are required, especially by engineering schools, to introduce the concept of BIM to engineering students. Future research can be conducted on methods of teaching BIM concept in universities of developing countries and policies for AEC industry to encourage companies for using BIM in their projects (N. Sanei Sistani 2012).

2.2.6.3 BIM implementation in Ethiopia

Even though BIM technology is in its very early stage in Ethiopia, there are some significant moves to bring the technology. The Ethiopian Construction Project Management Institute (ECPMI) is responsible for transferring BIM technology into the

Architecture, Engineering and Construction sector (AEC) from the government side. Implementation strategy for BIM technology in the AEC sector of Ethiopia is also included in the yet not publicized Growth and Transformation Plan-II. There are also few private firms trying to utilize the technology in their respective expertise. (Feleke, 2018, Fitsum, 2018)

An international bid Document has been prepared by ECPMI for supply, installation and training of Building Information Modeling (BIM). The bid aimed at securing hardware, software and BIM experts to train professionals from the AEC industry in Ethiopia (ECPMI, 2016). ECPMI has also conducted its first BIM workshop in Addis Ababa in 2015. In its three days, the workshop focused on introducing BIM to the major players of AEC sector in the country. Private and public consulting firms, construction companies as well as government representatives attended the workshop. (Feleke, 2018) The plan of ECPMI is to bring about BIM technology transfer via giving Training of Trainers (ToT) for selected professionals from the local industry. The trained professionals then in turn train other professionals from the industry. The assumption is that the industry will accept the technology and would in turn have an impact in policy making. (Feleke,2016). Currently ECPMI prepared roadmap and hold different workshops, furthermore the trainers working on their second pilot projects

Ethiopian standard for BIM

- ✓ ES ISO 12911:2018. First edition (20-11-2018). Framework for building information modeling (BIM) guidance (Identical with ISO/TS 12911:2012). ICS:91.010.01.
- ✓ ES ISO 29481-1:2018. First edition (20-11-2018). Building Information Models - Information Delivery Manual - Part 1: Methodology and format. (Identical with ISO 29481-1:2016). ICS:91.010.01.
- ✓ ES ISO 29481-2:2018. First edition (20-11-2018). Building information models - Information delivery manual - Part 2: Interaction framework (Identical with ISO 29481-2:2012). ICS:91.010.01

2.3 Summary of Literature Review

The literature review for this thesis was divided into two basic areas of knowledge whose understanding was deemed to be critical before proceeding further with the research. In the first section, after explaining about design phase and process, design management practice was discussed. Design management practice with regarding to managing team, information management, evaluation of information and client engagement were analyzed. conventional design management challenge such as poor design planning, poor integration of design and construction, lack of discipline coordination analyzed in the case studies. Part of the discussion was also dedicated to explaining poor design management impacts on construction and the economic and social benefits of effective design management.

The second area of discussion was that explaining design management using BIM. Four BIM elements have been discussed by combining (Abas.E and Jonathan 2013) and (Azhar.S 2011) studies, which have been further used in discussion part. Next, from (BIM Academy 2017) the general guideline of BIM based design process and its output were discussed. Furthermore, BIM based design management with respect to communication and collaboration, interoperability, integration of information, evaluation and management of information, and validation and verification of design were discussed by incorporating different literatures.

The final area of knowledge focuses on the comparing and contrasting BIM based design and traditional design by taking (Wang 2014) and (Yan and Damian, 2008) case studies to show how the two methodology differ. The two case studies provide that The traditional design method required to spend more time and accustomed with error and rework compared to the BIM-based design.

2.4 Gap Identified

Through the literature review, the research has identified several gaps which the objectives of this research can address. BIM was introduced in Ethiopia relatively late, and this means there is limited research with takes into account the local context. Therefore, the technology hasn't had enough time to sufficiently mature, and research in general regarding BIM is limited.

Firstly, this research will look into the current status of BIM, specifically through the viewpoint of designers that have implemented BIM in Ethiopia in order to survey their viewpoints, especially in terms of the current state of BIM within the design side of the construction industry. This includes:

- How BIM fits into the current design tradition in Ethiopia;
- The challenges designers face when implementing BIM in their projects; and
- The benefits accrued by designers, when compared to traditional design methods;

Second, by recording the experiences of designers on the ICT Part Project, the specific experiences of the participants in a local project will be available for future users. The project is one of the first to be designed using BIM and this represents an important milestone in the introduction of the technology in Ethiopia.

Finally, this research will contribute to the general body of knowledge and can be used by future researchers as a starting point, and policymakers when formulating future policy, especially with regards to the implementation of BIM in Ethiopia as part of the National Development Plan.

3. RESEARCH METHODOLOGY

Research Methodology is the path to find answers of 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.

3.1 Types of Research

This research follows descriptive type of research. Descriptive research type describes a certain problem, phenomenon, or a situation systematically to simply to provide information about the living condition. 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. Questionnaire were used to survey design management practice of category one consultant and two case studies were used representing BIM based design projects.

3.2 Types of Data & Materials

For this research both primary and secondary data sources were used.

3.2.1 Primary data

These include case study's architectural and engineering drawings, personal observation, notes from the case study, interviews and questionnaires are this research's primary data source.

3.2.2 Secondary data

These include literatures in the fields of BIM that were of great help to the research.

3.3 Research Design

3.3.1 Research process

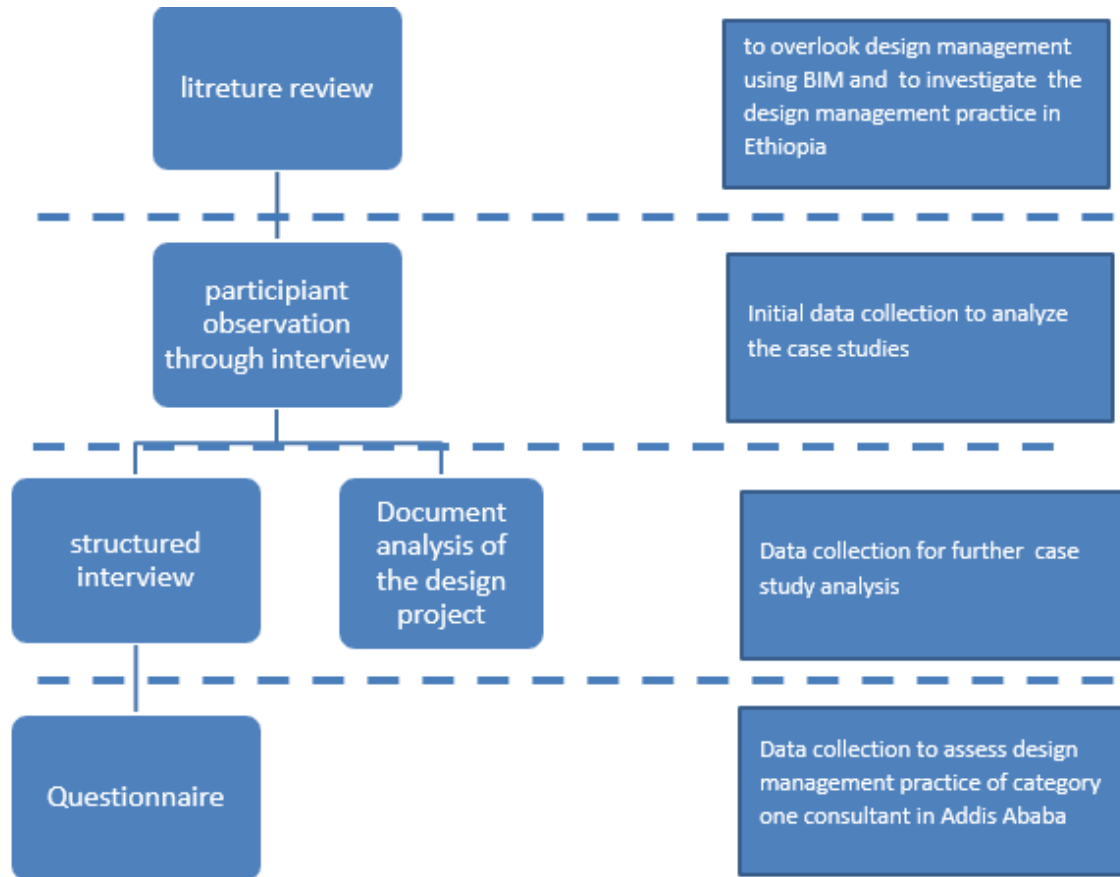


Figure 3-1 Research process

For the comparison of conventional ICT park project and BIM based ICT park project document analysis used as a prime data collection tool. Architectural, structural, MEP and bill of quantity documents of both cases are collected and analyzed.

3.4 Data Sources and Collection Techniques

The research relied on the data collected from questionnaire, case study, related literature reviews, and design document analysis. Since the concept of BIM is relatively new to Ethiopia, it was necessary to rely upon legitimate web sites.

3.4.1 Primary Data Source and Collection Techniques

Category I consultants in Addis Ababa, ICT park project and ZIAS consultant were the main sources of the primary data. The following data collection methods were used to collect these primary data:

A. Questionnaire survey

A questionnaire is sent or given to a respondent for completion and return. A questionnaire was prepared and distributed to correspondences in construction industry. Category I consultants were the targets to distribute the questionnaires. The questionnaire included close ended and open questions.

B. Population of the study

For the purpose of this research category one consultant offices that are engaged in the construction sector used in order to collect the relevant data through questionnaire. A total of 63 actively participate consultant are found in Addis Ababa. Based on the total population of the study representative number of samples will be addressed in order to collect the data from category one consultant offices.

C. Sampling method

In order to achieve the objectives of this study, the total number of category one consultant offices involved in the construction sector were identified using equation 3.1.

$$n = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)} \dots \dots \dots \text{Equation 3.1 sampling method}$$

n is the sample size,

z is the z-score associated with a level of confidence=1.645

p is the sample proportion, expressed as a decimal=50%=0.5

e is the margin of error, expressed as a decimal=10%=0.1

N is the population size=62

$$n = \frac{\frac{1.645^2 \times 0.5(1-0.5)}{0.1^2}}{1 + \left(\frac{1.645^2 \times 0.5(1-0.5)}{0.1^2 62}\right)} = 32.35 \cong 32$$

The total number of category one consultants that were involved in the construction sector of Addis Ababa is 62. So, by using the above formula and taking 10% marginal error the sample size was 32. Thus, according to these 32 category one consultants addressed through questionnaire.

D. Case Study Approach

The case study to be conducted is illustrative case study type. It is primarily descriptive studies. They typically utilize one or two instances of an event to show what a situation is like. Illustrative case studies serve primarily to make the unfamiliar familiar and to give readers a common language about the topic in question. (Bronwyn Becker 2012).

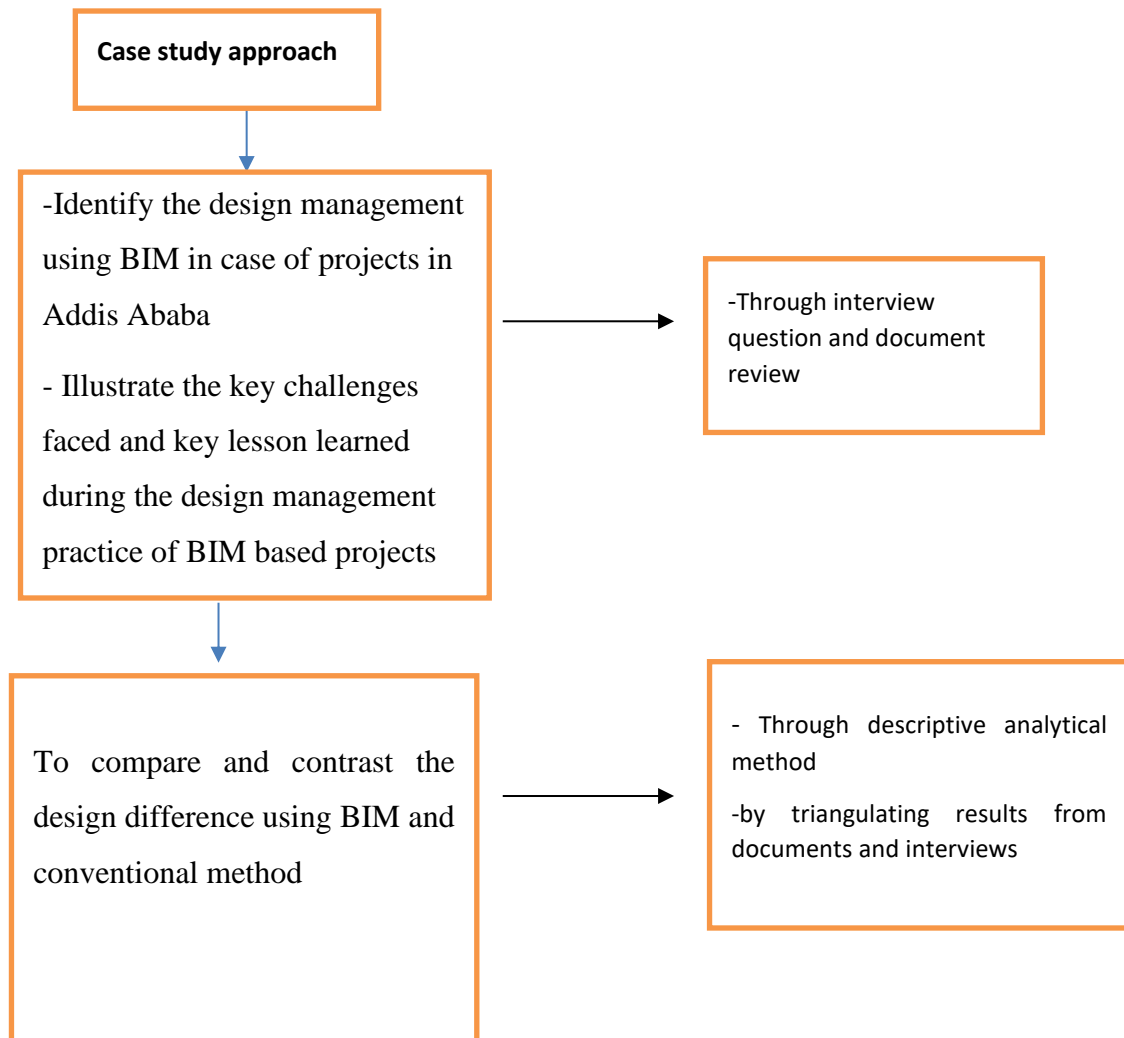


Figure 3-2 case study approach

Purposive sampling is normally used in qualitative studies (Explorable.com, 2015). Etikan, Musa, & Alkassim, (2015) explained in purposive sampling the researcher has something in mind and participants to suit the purpose of the study and each participant will provide unique and rich information. In order to come up with the answer how BIM based design process and management is, case study approach used.

Interviews

15 interviews were conducted to 8 professionals. The interviewees were conducted on the BIM piloting ICT park case project team and the others were from ZIAS consulting office personnel who has participated in modelling of the case project. Interview questions were arranged before interviews to support the goals of the thesis and to give general picture of the project.

Questions were the outline for the interviews but discussions in the interview situations might have expanded to cover also other subjects. After three first interviews the questions were altered to cover the critical subjects related to the thesis. The questions were as follows:

1. How does the design team combination look like?
2. What is your role and responsibility in this project?
3. What is BIM process in your design discipline?
4. How do you manage communication and collaboration using BIM?
5. How do you manage integration of design and information using BIM?
6. What are the methods used to exchange information between stakeholders? And throughout the life cycle?
7. What are the procedures deployed to validate design information?
8. How does BIM based design include the constructability and maintainability concept?
9. How is the collaboration of the client handled in BIM projects?
10. What are the key challenges and lessons learned during the pilot project?

Category of the interviews

The results of the interviews are here collected from different interviews under specific topics as follow.

Table 3-1 Category of interview topics

BIM based design process	BIM based Design management
Discipline design process	Communication and collaboration
Model Quantification	Designs review and integration
Simulation and scheduling	Constructability and maintainability
Encountered benefits	Challenges and lesson learnt

Document Analysis

For the comparison of conventional ICT park project and BIM based ICT park project document analysis used as a key data collection tool. Architectural, structural, MEP and bill of quantity documents of both cases are collected and analyzed.

3.4.2 Data Analysis

After collecting the necessary data different analysis methods were used according to the type of data that were collected. Descriptive method was used to analyze the data and interpret the results in quantitative and qualitative ways. The ideas and opinions gathered from case study interviews were analyzed using descriptive narrations. Data from the questionnaire were analyzed using SPSS and Microsoft excel. The analysis and discussion of the results were carried out using a descriptive research design, including statistical tools such as bar graphs, pie charts, tables and other summary statistics.

3.5 Research Framework

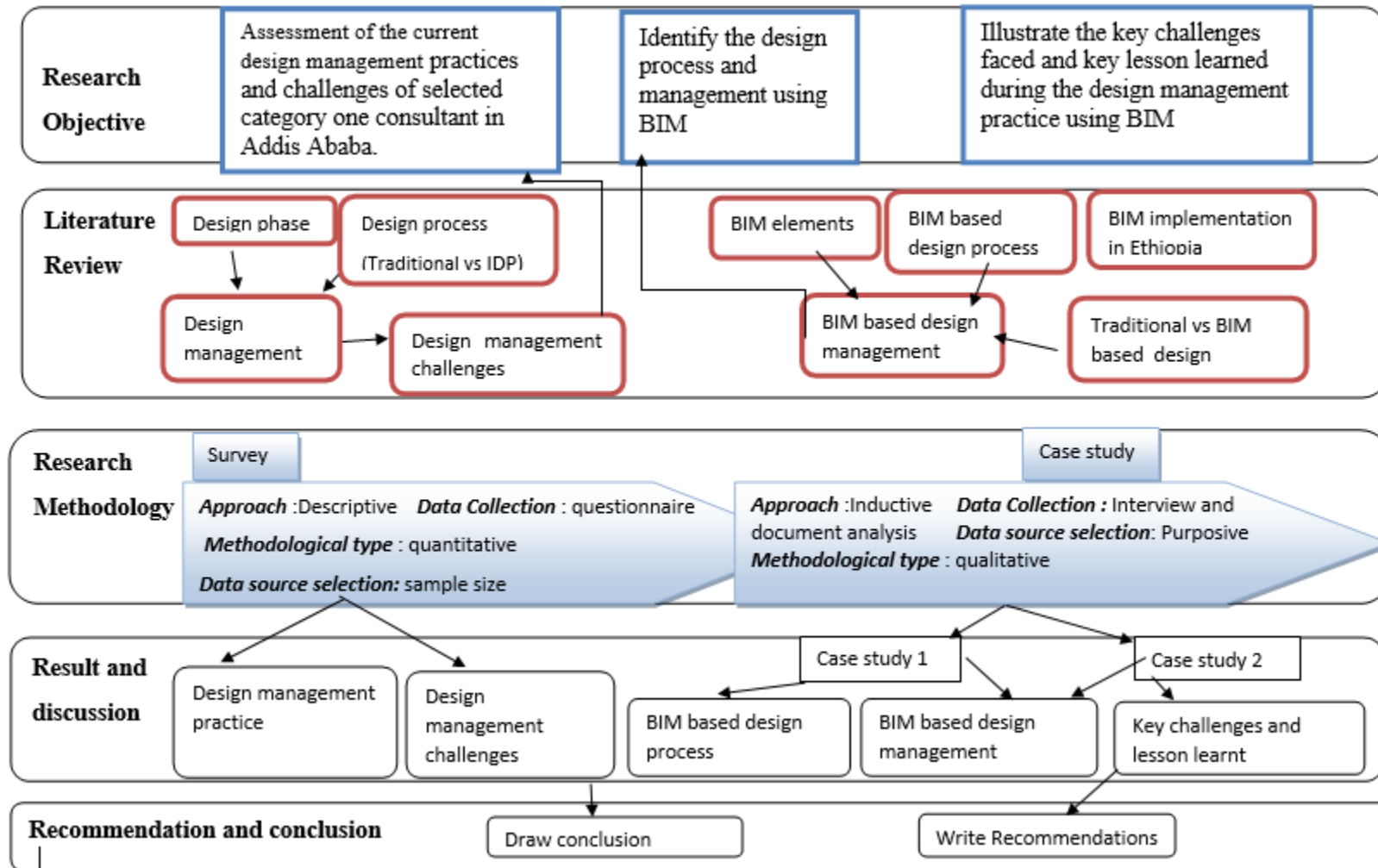


Figure 3-3 Research framework

4. ANALYSIS AND DISCUSSION

4.1 Conventional Design Management Practice

4.1.1 Questionnaire Response Rates

As mentioned in section 3.4.1, the questionnaire form was distributed to 32 class I consultants out of which 25 consultants have returned completed forms, representing a 78.125% response rate.

4.1.2 Respondents Profile

The questionnaire is prepared by targeting design managers of category one consultants in Addis Ababa. Majority of the respondents were professional Architects. Among the 25 respondents; 14 respondents are architects with a title of design manager. Other respondents who have participated on the survey were; structural engineers (4 respondents), civil engineers (4 respondents), Electrical engineers (2 respondents) and one Sanitary engineer.

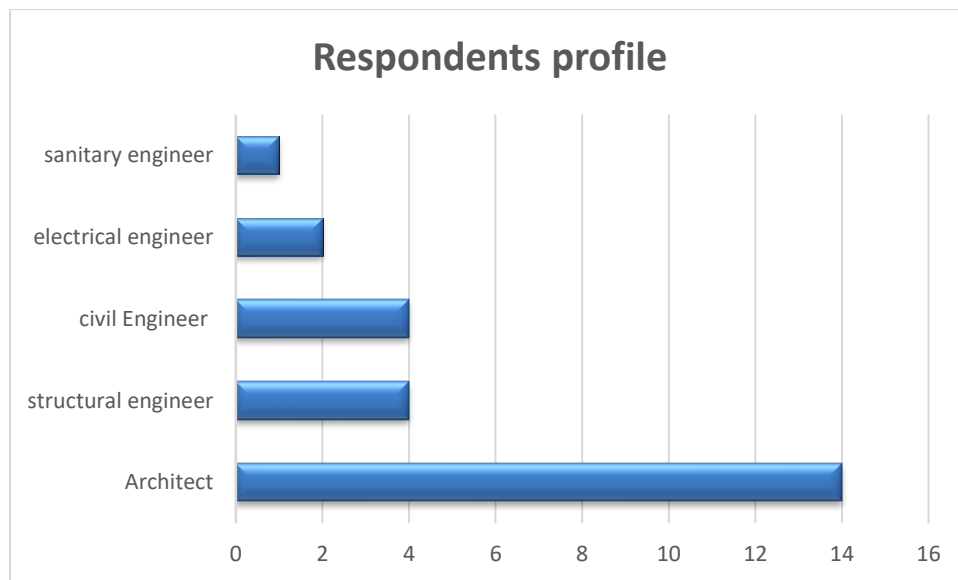


Figure 4-1 Respondents profile (Researcher's own work)

4.1.3 Organization Profile

The average number of design projects executed annually for the majority, 45%, of building category one consultants are more than 20 projects. The survey data was aimed to indicate the work volume of consultant offices.

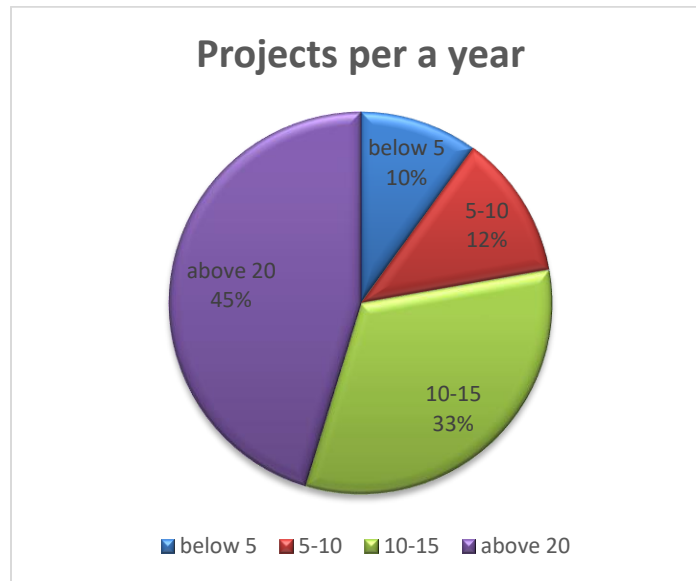


Figure 4-2 projects per a year (Researcher's own work)

4.1.4 Design Process

As presented on the below figure, among the total consultants; 81% of them use linear design process. i.e. a conventional way of design process, which is quick and simple, it does not require computer simulation, it requires less operational cost and paper-based communication.

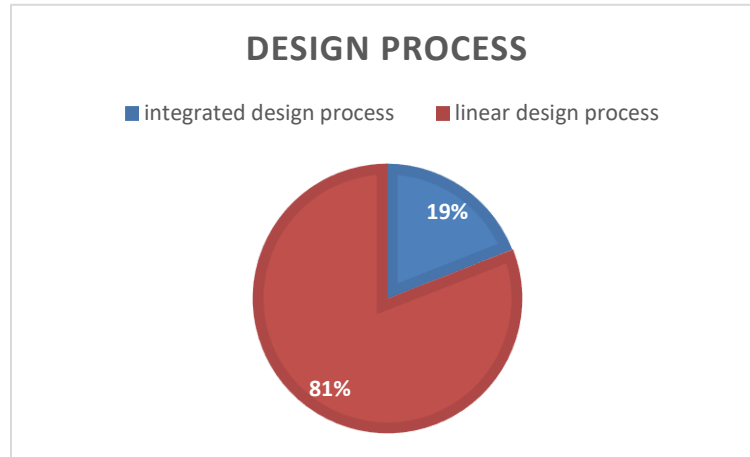


Figure 4-3 Design process (Researcher's own work)

4.1.5 Communication and Collaboration

Interaction among design participants and the client is important. The main purpose in a design phase is exchange of information, exchange of design and transformation of information to ideas and solutions to be presented to others.

A. Client Involvement

Clients should have the key role as initiators of any project. Client involvement in design stage is a very important factor for the success of any building project.

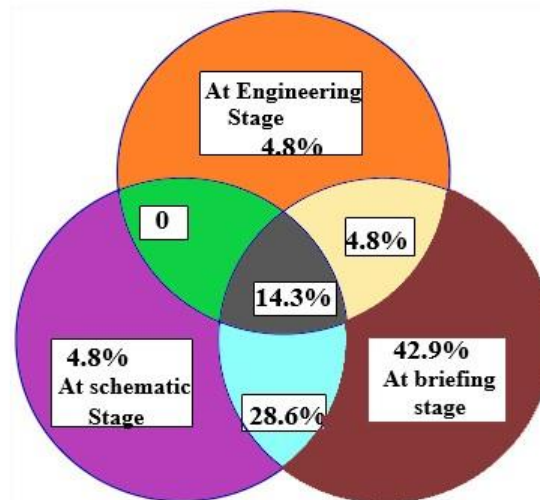


Figure 4-4 Client involvement (Researcher's own work)

The above figure shows the survey result for Client involvement into the design process. Based on the survey, majority of the respondents 42.9 % of the respondent says client involved only at briefing stage, 28.6 % says Client involve only at briefing and schematic stage at their company. 14.3 of the respondents says client involve at all design stages at their company.

The survey finds out that majority the client is only involved at the briefing stage nevertheless Emmitt imply that It is important for the client to have a continuous participation and interaction with the design team as the design develops and there is the need for a level of trust of the designer by the client (Otter and Emmitt 2008).

B. Startup Meeting within the Design Team

A **start-up meeting** is initiated by the client or project manager and differs in purpose from all other forms of project meeting. it is important to identify each key stage in the process, the designers and the personnel in their teams and to introduce them in a positive way to the objectives of the project.

The key stages during the design process when start-up meetings should be held are at the start of briefing, scheme design, and engineering design(Azlan and Cheong 2013).

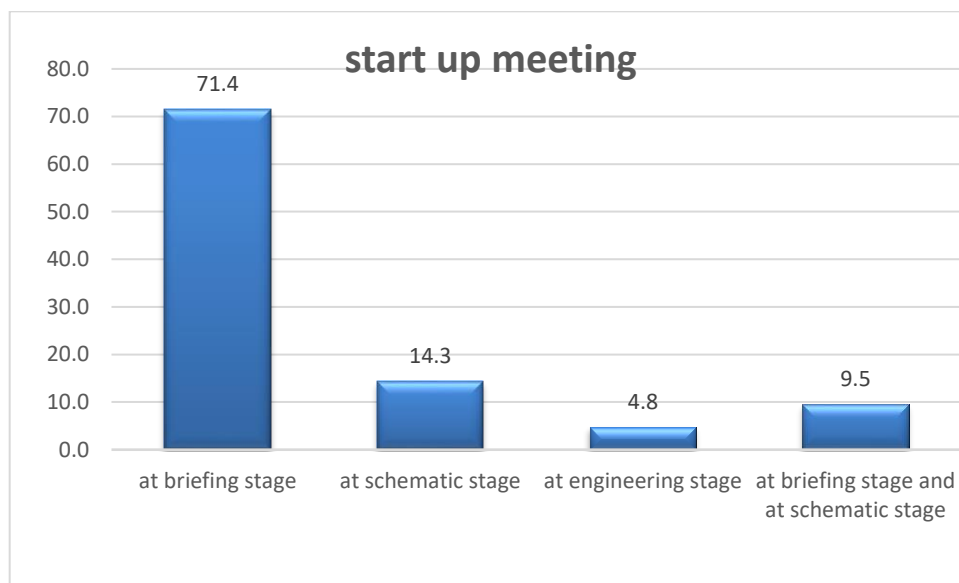


Figure 4-5 start-up meeting (Researcher's own work)

Based on the above figure of questionnaire analysis, consultants that held start up meetings only at briefing stage are 71.4% of the total respondents while consultants that held start

up meetings only at schematic stage are 14.3% of the total respondents. 4.8 % of the Consultants responded to the questionnaire held start up meetings at the engineering stage whereas 9.5% of the total respondents held start up meetings at schematic stage and at briefing stage.

C. Communication Within a Design Team

Communication within the design team is very important. less communication is a result of misinformation and always acquire design rework, low design quality, missed and error of the final design output. As of the conducted survey none of the consultants use a web based/ mobile based communication platform which formally used by all design team. They use a conventional mode of communication which is verbal, paper based and email.

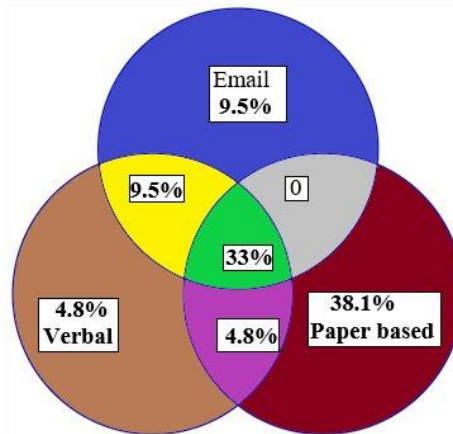


Figure 4-6 Modes of Communication Within the team (Researcher's own work)

Based on the questionnaire analysis, consultants that communicate using “paper based only” have the majority percentage which is 38.1%. The second highest score is the consultant that communicate using all the listed ways which is 33.3%. The third score is consultants’ that communicate using only email and consultants that communicate using email and verbal communication. Respondents also list other type of communication ways like social networks: telegram, Viber, WhatsApp and so on, which is mobile based and very flexible than web-based communication.

Respondents list techniques they use in order to improve the communication and collaboration of the design team at company as follow:

- periodical discussions

- weekly meeting, email and paper communications
- memo sheet to transfer messages and other iso sheet with written formats helps us to communicate formally and to trace back our communication.
- open discussion and critics within a regular meeting schedule
- sharing responsibilities at each level of design team

4.1.6 Information Exchange

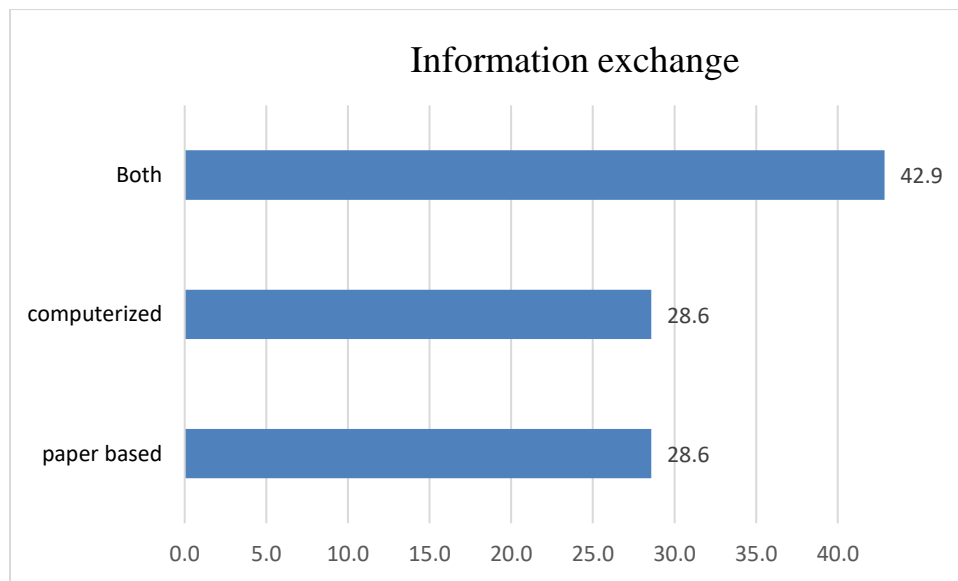


Figure 4-7 Information exchange (Researcher's own work)

As clearly shown on the bar graph; 43% of the consultants used both paper-based and computerized based information exchange mechanism. The other 28% and 29% of the consultants used computerized and paper based respectively. Among the computerized and paper-based data exchange practices the frequency of error occurrence is presented on a bar graph below:

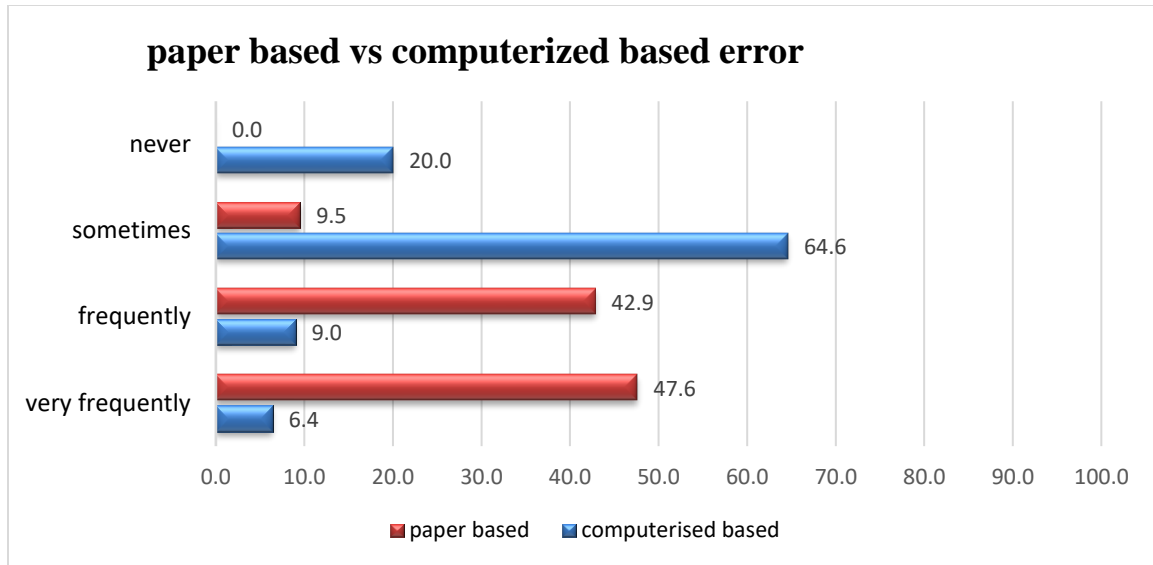


Figure 4-8 paper-based vs computerized based error (Researcher's own work)

According to respondents, paper-based information exchange mechanism encounters frequent error compared to computerized one. The majority of consultants (47.6% and 43%) replied paper-based information exchanging lead to errors very frequently and frequently respectively. In the meantime, 64.6% of the consultants responded as computerized errors sometimes occur.

Respondents list the drawbacks of practicing paper-based data record and information exchange mechanism as follow:

- Design data omission
- Lack of backups
- Limited security
- Time consuming
- Error prone
- Inconsistent layouts

4.1.7 Design Review (coordination) and Validation

A more formal system is that required by ISO 9004(British Standards Institution 1987) which requires that design reviews be carried out at the conclusion of each phase of design development by conducting 'a formal, documented, systematic and critical review' of the design results (Cornick 1990).

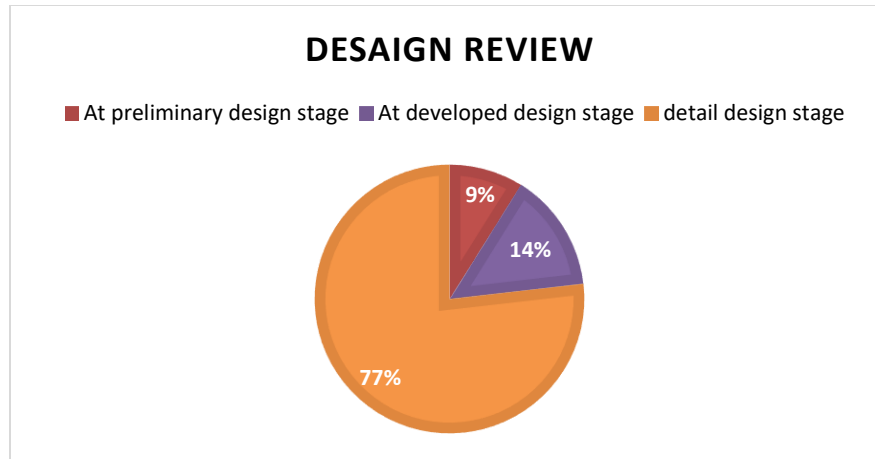


Figure 4-9 Design review (Researcher's own work)

As illustrated on the above bar graph, 77% of the consultant's review design at detail stage. The rest; 14% and 9 % review design at developed design stage and preliminary design stage respectively. Even if the literature implies that design review should be applied at each design stage. Based on the survey most of the consultant's review design at detailed design stage only.

In the qualitative questions of the questionnaire the respondents report on their practice towards design review, evaluation and technique to integrate the different design drawings. The most popular answers are as follows:

- Using design checklists
- Design revision and review accordingly. check the design according the developed templates based on the new Ethiopian building code standard we communicate with the client if the design requires major modification.
- Usually design review happens to be made when difficulties and requests for design clarification arise on construction stage.
- The design team will gather and discuss about all the designs made to finalize the design documents.
- A conventional printout reviews
- Design manager take the design review part and have a meeting with the team fellows afterwards
- Using AutoCAD: by exchanging AutoCAD and checking error to corresponding body

4.1.8 Design Consideration

A. Constructability and Maintainability

Previous studies have shown that improved constructability can lead to savings in both cost and time, as well as significant improvements in quality and safety, which are keys for the successful delivery of the projects, more than 90% of the respondents don't consider constructability and maintainability concept in to the design detail stage due to lack of expertise (construction experts) in their design team. The other respondents answer the question as follow:

- Constructability on the design is considered based on the material availability that is used on the design, local workmanship available on the labor market.
- And maintainability is considered during the design by incorporating service spaces and inspection chambers, so far.
- The material selection and methodology of the construction for the selected materials is given great consideration on the design stage.
- It's not easy to visualize the whole model with the available technology.

One of the reasons for design change orders at construction stage are the design is not constructible, operable or maintainable. If the design considers constructability and maintainability issues starting from the planning stage it is so easy to construct and minimize reworks. Based on the survey the conventional methodology does not enhance constructability and maintainability issues. This will help the client's decision to compare and choose designs iteration.

B. Lifecycle Costing

The basis of life cycle costing involves putting the estimated capital, maintenance, operating and replacement costs into a comparable form and bringing them together into a single figure. This will help the client's decision to compare and choose designs iteration. According to the questionnaire, all the respondents reply they don't consider lifecycle costing at design stage. It considers as a limitation of conventional design process.

C. Health and Safety

According to the qualitative question of the questionnaire survey, all the respondents consider hazardous operations as follow:

- Fire safety standard and open ventilation floor plans

- Environmental safety assessment on feasibility study

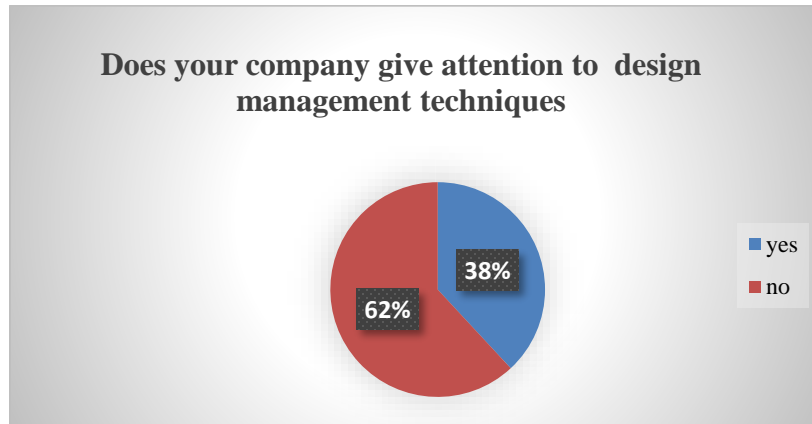


Figure 4-10 Does your company give attention to design management techniques? (Researcher's own work)

- ❖ **As a conclusion 62% of the respondents believe their company don't give enough attention over design management techniques and practices.**

4.1.9 Design Management Challenges

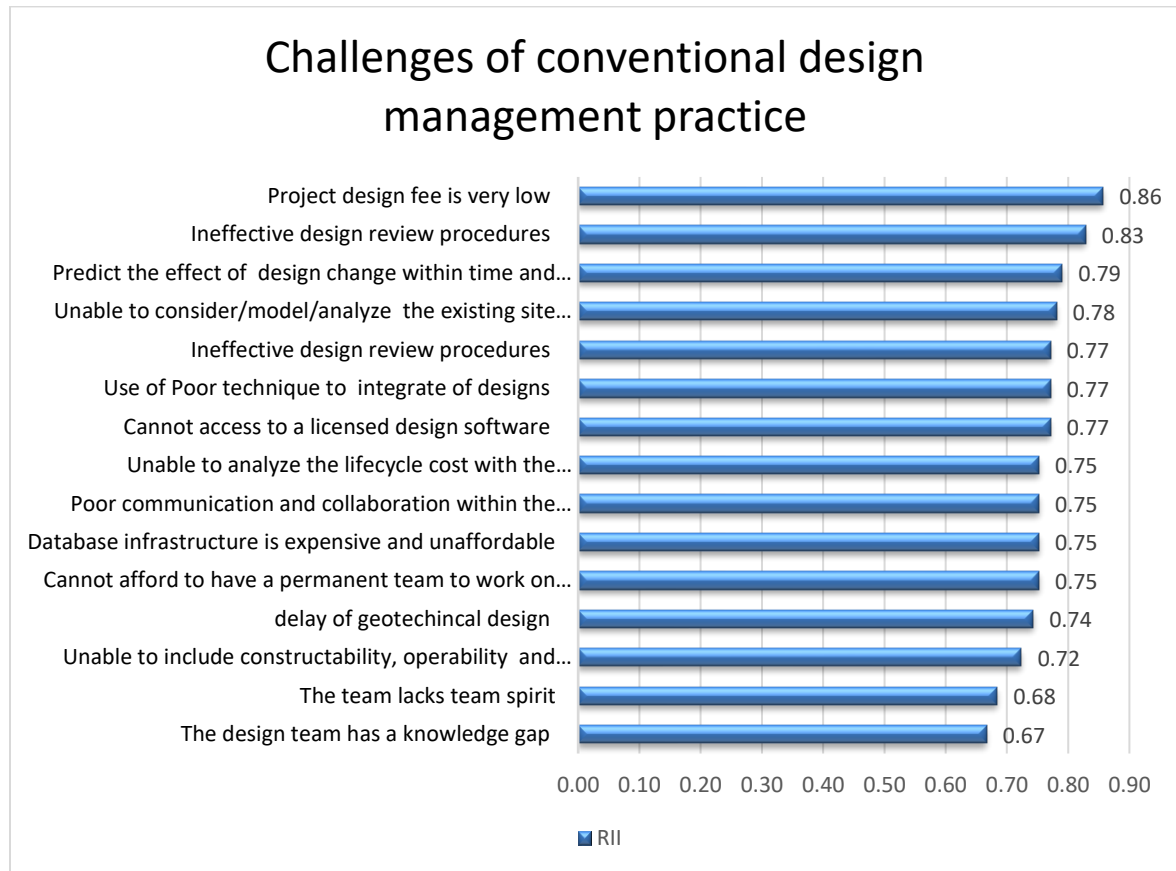


Figure 4-11 Challenges of conventional design management practice (Researcher's own work)

The top 5 challenges of conventional design management techniques ranked based on their RII is presented on table 3-1.

Table 4-1 Challenges of conventional design management (Researcher's own work)

Challenges of conventional design management	RII	Rank
Project design fee is very low	0.86	1
Ineffective design review procedures	0.83	2
Predict the effect of design change within time and Fee	0.79	3
Unable to consider/model/analyze the existing site condition	0.78	4
Use of Poor technique to integrate of designs	0.77	5

Project design fee, ineffective design review procedures, predict the effect of design change within time and fee, unable to consider/model/analyze the existing site condition and use of Poor technique to integrate of designs are the major design management challenges that category one consultant face. In addition to that, the respondents list challenges related to regulatory agencies such as the delay of design confirmation.

From the qualitative survey of the questionnaire here are some points about **how the current challenges and limitations of design management practices can affect the quality of design outputs and the construction stage**

- Ethiopian construction industry is full of complicated problems regarding to integration, flexibility and information in conveniences starting from planning stage up to implementation stage which can be improved by BIM technology.
- Most of problems on site either arise from design problems due to poor planning and coordination of interdisciplinary designer.

Respondents also suggest ways to tackle challenges and limitation of design management

- There should be national standards concerning design management and there should be enough money should be injected in the design budget.
- Early integration of all construction actors even before the conceptual design is approved
- Using advanced technology like BIM
- Maximizing design output and Professional fee
- Through integrated construction information management
- Through training
- By changing the mindset of the design team by using advanced technologies and techniques
- Integrated Building Design Environment (IBDE) Company customized file sharing platforms

4.2 Design Process and Management Using BIM

4.2.1 Case study one: Transforming the Conventional Design Package of B+G+7 ICT Park Building Typology into Integrated using BIM Technology



Figure 4-12 B+G+7 ICT Park Building typology

Project:	B+G+7 ICT Park Building typology
Project type	New
Project category	Institution/Service Buildings
Location	Goro, Addis Ababa
Client	Government
Contractor	Private
Consultant	Private
Method of Project Delivery	DBB

4.2.1.1 Introduction of Case Study

The owner of the project has formally requested government owned consultancy firm to perform a full design review, modeling specification and estimation of these typical typologies which will be implemented in different regions of the country.

The consultant composes a trained team which will include architects, project management professional, structural, MEP –electrical and sanitary engineers with the objective of converting the design done in traditional method to Integrated Design using BIM to review the design. The location where the project constructed is around Goro area, Bole sub city in Addis Ababa city. The piloting of BIM on the stated project has been carried out at the government owned consultancy firm.

Interview participant of the design project and the BIM tool used

BIM compatible Computers and Software applications are used for the whole duration of the BIM design review and modeling.

Table 4-2 Interview Participant of the design project and the BIM tool used

Interview Participant	BIM Profession	BIM tool used
P1	Architectural BIM practitioners	Revit 2018 Architectural
P 2	Structural BIM practitioner	Revit structural and ETABS
P 3	Project management BIM practitioner	Navisworks, MS project and Microsoft excel
P 4	MEP-Electrical BIM practitioner	Revit 2018 Electrical
P 5	MEP-Sanitary BIM practitioner	Revit 2018 Sanitary Designs

4.2.1.2 Design Process of the Pilot project (ICT park project)

What has been the BIM process in your design discipline?

- **Architecture Design Process**

According to the interview with P1, Revit architectural is the only BIM tool set used thought the design. The architect starts the modeling by creating level and grid than by copy monitoring the other disciplines start designing. The architecture is responsible for the level and grid changes. The following are architect roles and responsibilities during the ICT park pilot project

- Grid and levels creations
- Work set creations: Once the architecture finish creating the grid and level, he will drop the file into a local server, then the others share and start to work.
- Modeling Architectural element for the main building and powerhouse building
- Modeling landscaping of the undertaking site

- Family creations, Modeling and setting of Doors, windows, curtain walls, sun breakers
- Family creations, modeling and setting of prefab elements
- Modeling finishing works like plastering, ceiling, floor finish etc.
- Furnishing Architectural
- Model Annotations and dimensionless as required.
- Publishing into server folder

- **Structural Design Process**

Based on the interview with participant 2, Structural team links architectural model as references. By copy monitoring the architectural design, the structural team start design using Revit structural design and check structural analysis using ETABS. Both P1 and P2 imply that there was frequent communication (need to information) happen between Architects and structural designers. Here is the process of structural design of ICT park pilot project:

- Family creations, modeling and placing of prefab elements, cast in place footing and Roof structure
- Work set creations
- Modeling structural Element for the main building and powerhouse building
- Modeling and Rebar detailing for each structural element (After getting the result of structural analysis from ETABS, the team manually place the rebar in Revit software)
- Annotations, dimensioning and publishing,

- **Electrical Design Process**

Based on the interview with P4, The Electrical engineer links the Architectural model for references and start designing right away. Autodesk Revit electrical is the BIM toolset that the electrical engineer used. P4 mentioned that, the MEP team struggled with getting along with architectural and structural design change repetition. It makes the design tiresome from MEP point of view. As of the interview, here is Electrical design process:

- Modeling Electrical fixtures, mechanical equipment, lighting fitting
- Electrical load panel scheduling
- Annotations and publishing

- Revit design input reports
 - **Plumbing design process**

Autodesk Revit was the main tool used by the sanitary team. The Sanitary engineer links the Architectural model for references and start designing. P5 also set challenges the same with p4 adding suggestions which is for the MEP team to start designing after the architectural and structural design team reach the development stage. According to the interview here is the design process of plumbing design:

- Modeling Sanitary fixtures, Mechanical equipment, lighting fitting
- Piping scheduling
- Annotations and publishing
- Sanitary Design report (pipe pressure loss)

- **Project Management**

According to the interview with P3, the first step was importing the Revit model of Architectural, structural, sanitary and electrical to Navisworks manager. P3 highlight that After importing the next step was aggregation of all design together into Navisworks. Linking of Architectural, structural, sanitary and electrical Model for federation (Integration) which enable Compiling and exploring the design Project. For design coordination and integration, the team use the tool clash detection.

- **Model based Material Takeoff – Quantification(5D)**

After the model federation, the Quantification task was done by the project manager of the BIM pilot team. The project management team calculated very rapidly the quantity of all the countable constructing elements. As of the interview with P3, the quantity survey is done by the project management team using Navisworks quantification pane and Revit. P3 further describe that, the team links the model with the quantification pane by simply clicking the counted building element and linking to the quantification pane. The result of quantification can be exported to excel and follow the format of BoQ and manage the data.

Encountered benefits

- The crew can now generate correct and huge counts in a very small quantity of time compared to the time taken traditionally.

- The team can have the self-assurance that their count is correct and meet the design intent and the client's requirement
- There are far fewer manual steps, and therefore far less chance for human error and reduced risk should provide greater cost certainty.
- There is more transparency in the process overall.

Key Challenges

- There was a challenge with items that are not included in the model like formwork.
 - The team gets difficulty when estimating for rebar quantification using Navisworks. As an alternative they use Revit for structure and quantify the amount of rebar according to their rebar size, length and so on.
- **Simulation and the TimeLiner(4D)**

As of the conventional way, BIM based scheduling consists of construction sequence or task includes of a selection of model objects defined with a start and end date, tasks are either manually added directly into the TimeLiner task pane or are imported from external scheduling software like Microsoft project or primavera as links.

The project manager can easily select the task by clicking the model and attach it into the timeliner than assign the sequence time (time, start and end dates), and the task type (construct, demolish, temporarily

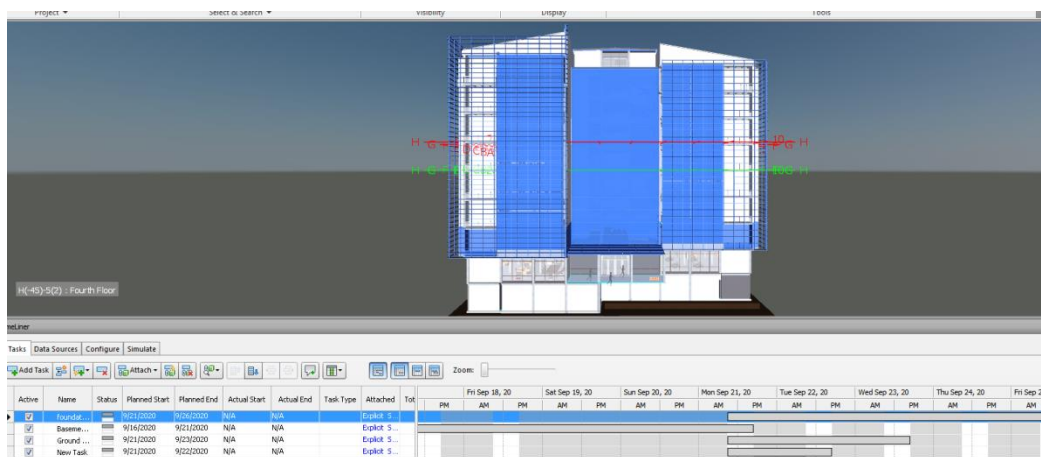


Figure 4-13 Schedule using BIM (From ICT Park design)

➤ Simulation (4D)

P3 explain that tasks are related in the schedule with objects in the model this relationship is used to create a simulation. A 3D model objects links to construction schedule tasks in order to create visual 4D simulations. TimeLiner takes 3D model objects and associates construction tasks (time, start and end dates), in order to create very effective construction sequencing animations, or 4D simulations as they are often called. The project manager can add an optimized location of the crane and that will be included on the simulation part. P1 shared their view that the client benefited from the capability to rapidly examine quite several situations of careful dates towards reliable dates and what if scenarios, all add to improving building team collaboration and better visualization.

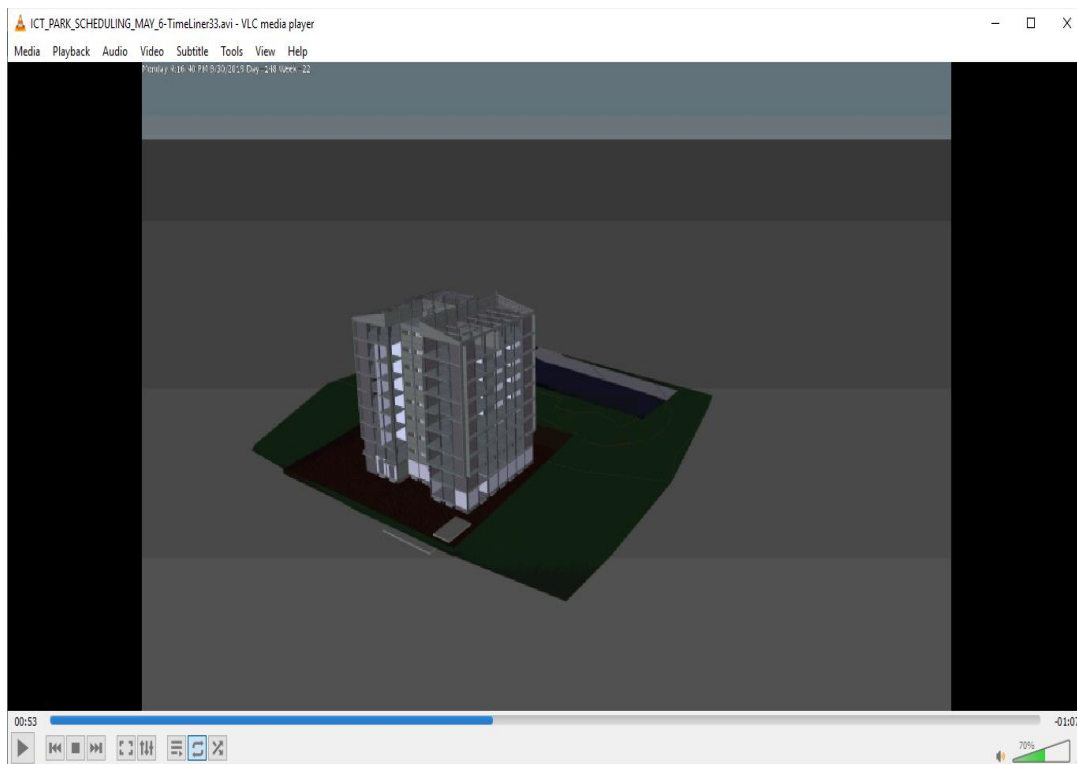


Figure 4-14 Simulation of the pilot project (From ICT Park design)

Encountered benefits

- Better communication within a team about the design output
- The client can easily track the project by visualizing the whole building project using simulation videos
- The ability to produce the construction sequence and visualizing the effects of the schedule on the model helps improve communication

- All the required information was extracted from the model, so it saved time.

Key challenges

- When the team working within the Navisworks scheduling pane, they found out that it has some limitations like it don't show critical path lines
- Besides that, it doesn't show crew task and number of crews too

Design process summary

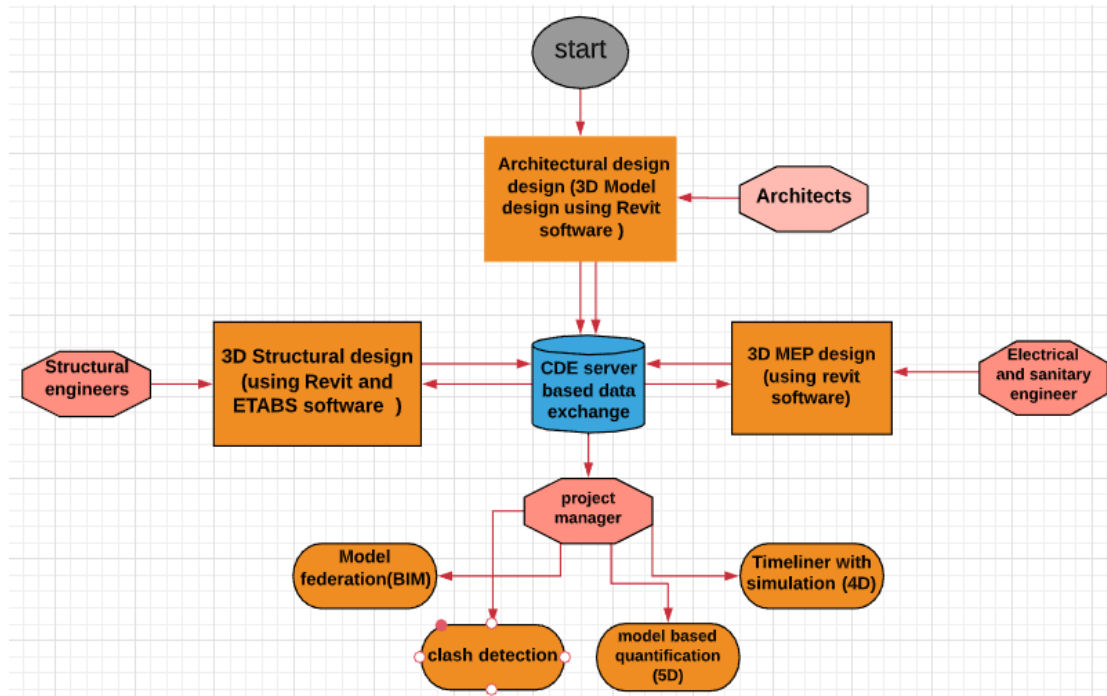


Figure 4-15 ICT Park pilot project Design process using BIM (Researcher's own work)

4.2.1.3 Communication and collaboration

How communication and collaboration managed using BIM?

Design data exchange between the designers of BIM team for ICT park design project was through server-based data exchange and a weekly based meeting further explain, what it means by server-based communication, since the design perform in house or the participants are working in same place server will be provided for interconnecting the participant working on same design. P1 Added that, every discipline saves their design in server so it's available for the participant when its needed. Furthermore, the designers can work on different section of the design for insistence the architecture team can divide the design task and share task so one can work on first floor plan and other on second floor

and so on. When they finish the design, they can synchronize it automatically into one design. If the designer makes a change on his/her design it automatically appears in other design too.

Encountered benefits of server-based communication

The design team experienced a structured data exchange environment and possessed enormous advantages. As of my interview the following are repeatedly advantages of **server-based communication**:

- Shared information from a single unit should result in coordinated data and reduce the time wasted during a conventional way of exchange data.
- Enable to improve collaboration and co-ordination improved outcomes in the idea of using a centralized model.
- Better reliability of data and reduced risk.
- Easy creation and management of information.

Challenges implementing server-based communication within the design team

- The team possesses difficulties in keeping up with updating their work. Each design team has their own internal filing system, their unapproved information, and information would only be visible to the other task team members once it was placed in the Shared folder.

4.2.1.4 Design review and interference management (clash detection)

How integration of design and information is managed using BIM?

A. Model federation

The BIM piloting team use the term model federation, it's the act of bringing together several discipline specific models often produced from Revit file formats. P3 clarified that, it is normally performed by the client's representative, the Information Manager or BIM Manager but in the piloting program the project manager executed the work. From this federated model other actions such as design review, clash detection, 3D Construction 4D and 5D performed.

The piloting team links the design models together using the Navisworks software. This action takes place after the designers finish their task and append it to Navisworks.

The benefits encountered by the team for:

- To review and visualize different model using one tool
- To detect early design coordination problems
- It enhances design change at early stage

B. Clash Detection

After model aggregation, arguably one of the greatest coordination strengths is the software's ability to inspect, identify and then report upon interference or object clashes. Views of clashes can be placed into an html report for circulation and resolution by the necessary team member. The resolution status can be monitored using color coded status updates.

for design review and validating purpose, the piloting team used clash detection. The project manager performs this act.

In order to have useful clash detection results it is important that clearly defined items are selected. The more specific the clash test the more detailed the outcome will be. It indicates by P3 that, every clash meeting the test criteria are illustrated, these can be grouped for like-minded clashes. Each clash can have a viewpoint with red lines added for clarification and comments for action. Other information on the clash is provided such as the clash status, the location of the clash and who is the issue assigned. After the reviewing is done the project manager switches back the design to Revit and assigns the designer to correction.

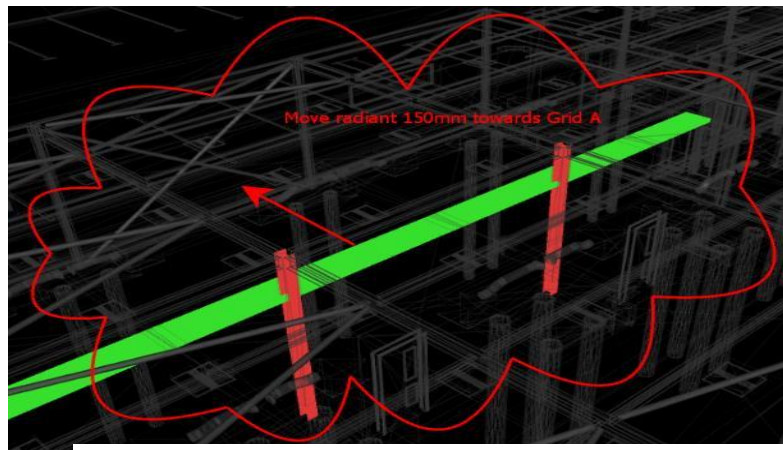


Figure 4-16 Clash detection (From ICT Park design)

P1 emphasize in interview, after finishing the design part all designs export to Navisworks for model review. For design coordination and integration, we use clash detection. We don't take directly the output of clash detection; we survey the output by reviewing the design. As example mechanical duct insulation may double the duct size at construction stage, so we double the size when we design but the clash detection provides it as an error.

The benefits encountered by the team:

- To review and visualize different model using one tool
- To detect early design coordination problems
- *It enhances design change at early stage*

4.2.1.5 Constructability and maintainability

How BIM based design include the constructability and maintainability concept?

The BIM major aim is for virtual design and construction. Based on the interview with architect Dereje, it suggests that the way BIM represents allied with the reality twins as if it represents every detail of the real condition. If the designer feeds every information and planned properly, it's easy for the architect and other disciplines to recognize mistakes that would happen during construction. It's also advisable to include construction manager during design as one part of the design process. If the information about the materials is exchanged in a correct way, it will make it very easy for Maintainability and facility management. P1, P2 and P3 summaries about how BIM based design include the constructability and maintainability concept.

Simulation(4D): The ability to replicate the construction sequence and visualize the effects of the schedule on the model helps improve communication of the actual build itself and helps highlight potential failings in either the constructability of the building or the program scheduling.

Realism/animation: Navisworks is a capable product for its model management or model checker abilities as a BIM tool. The ability to navigate around an aggregated model is fundamental to the product and arguably its greatest asset. Besides the known navigation tools, realism is added which helps to move through the model.

Building information: with BIM, the model contain both geometric information and non-graphic data so all the information about the material(The material type , company

manufactured it,) exchanged from one project stage to another, that will make it easy to maintain since all information about the material are provided in the as built /design model.

4.2.1.6 Conventional Vs BIM based ICT park design comparison

This section analyzes the document that have been collected from the piloting team and a consultant office which design the ICT park project.

Three aspects had been used as comparison between the conventional ICT park design and the BIM based design of ICT park design project.

- Design presentation and visualization
- Quantification
- Design review

1. Design presentation and visualization

Table 4-3 Conventional and BIM based ICT park design outputs

Conventional ICT park design outputs	BIM ICT Project design output
<ul style="list-style-type: none"> • Architectural (AutoCAD file soft copy, Survey data soft copy, BoQ), • Structural (Structural AutoCAD file soft copy and BoQ), • Sanitary (AutoCAD file sanitary design and BoQ), • Electrical (AutoCAD file electrical design), • 3D photo of the building blocks jpg. File format, • prefab reinforcement detail, and • Photo of the prefab detail in jpg file. 	<ul style="list-style-type: none"> • Architectural, structural, and MEP design drawings and 3D models • Time and resource scheduling with 3D simulation • Respective specifications and model-based quantification • Walk through animation • Rendering (for 3D jpg photo)

- The BIM based ICT park project visualization was undeniably easy and very simple. while using BIM tools, it's shown that the architect designs the floor plan and the software generate the elevation drawing and 3D model at one platform as shown on the

- figure below. When we come to the conventional design of ICT park the architect should design all of the drawings one by one on a different platform.
- Construction simulation (simulation 4D) of BIM based ICT park design project contribute a better visualization than the conventional method.

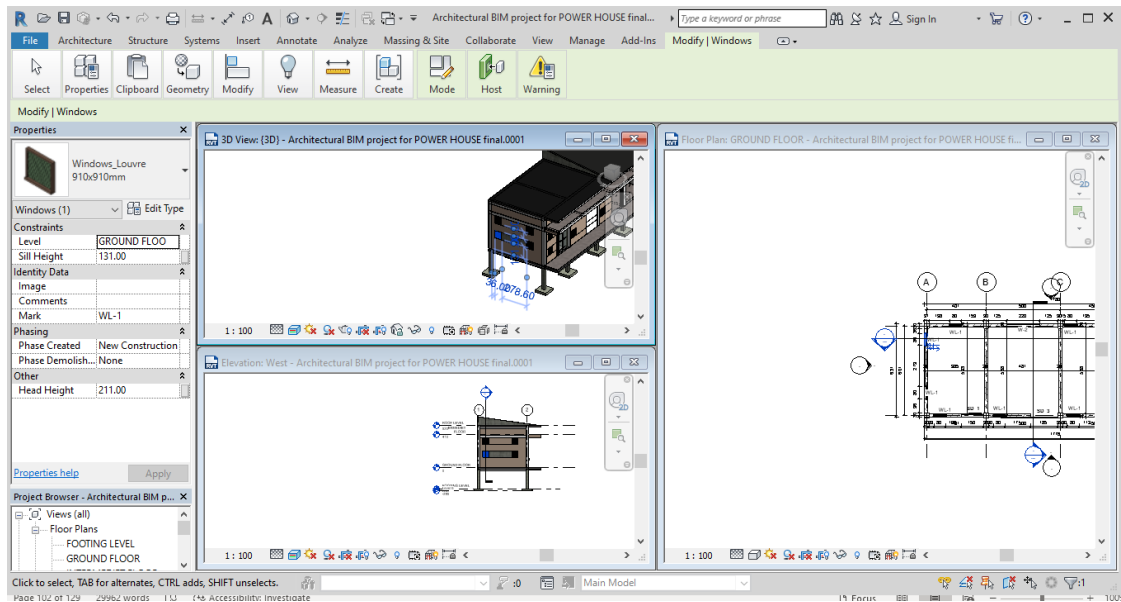


Figure 4-17 ICT project powerhouse architectural design using REVIT (From ICT Park design)

- The piloting of BIM on B+G+7 ICT park has identified the following problems in the original design packages while checking using Visualization tools.
 - Unclear displays of prefab elements (each kind used to be required their own detail and sections drawing)
 - Some elements don't have details e.g. sun breaker, PVC down pipe detail;
 - Room area difference on structural and architectural (e.g. Cantilever wall);
 - Shorten roof structure (overhang length) which instant leakage to the major building in the curtain wall, (the group model the as built roof however recommends extending the roof shape to prevent leakages)

2. Quantification

Quantification result used to determine cost and volume of work. The conventional design of ICT park project used manual way of counting elements of building while using BIM the quantification done using Revit and Navisworks software.

The piloting of BIM on B+G+7 ICT park has identified the following problems in the original design packages while checking the design using clash detection toolset.

Table 4-4 Quantification difference between manual and BIM based ICT park project

Items	Quantification error	Manual quantification	BIM quantification	Difference
Concrete work(m ³)	missed quantified	–	348.85	-348.85
Concrete work(m ²)	Underestimated	400.61	1025	-624.39
	missed quantified	–	1787	-1787
Prefab column (Pcs)	Underestimated	589	596	-7
prefab slab (Pcs)	Underestimated	401	455	-54
Missed quantified pipe fittings	PPR pipe fitting	–	998	-998
	coated PPR fitting	–	45	-45
	UPVC down pipe elbow	–	78	-78
	GSP fitting	–	52	-52
	UPVC pipe Fitting	–	587	-587
Time consumed		10 days (5 professionals)	3 days (two professionals)	7 days saved

- As shown in the above table, the manual quantification encounter error on counting concrete work, prefab elements and pipe fittings. In addition to that , using model-based quantification takes less time with accurate estimation.

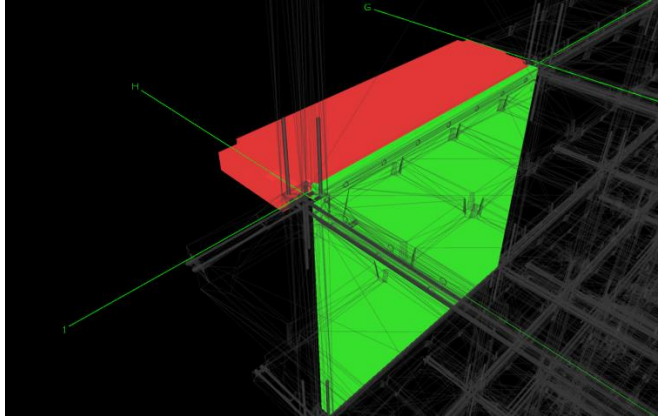
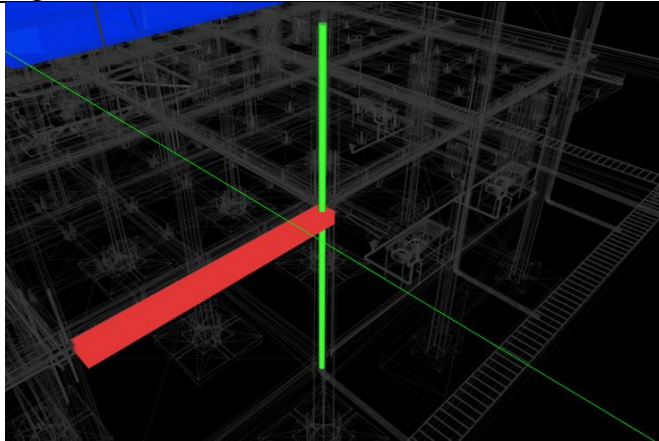
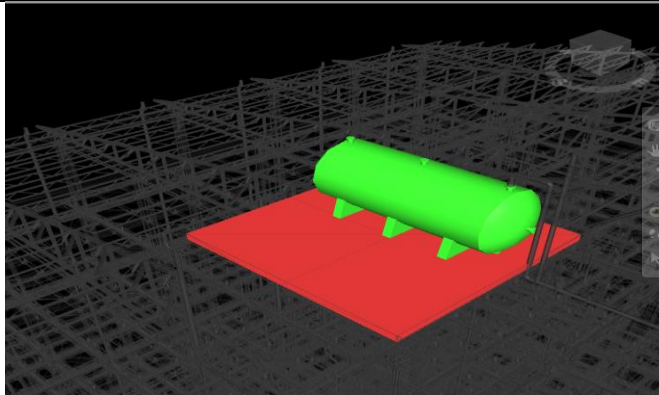
E. Design review

For design review, the conventional ICT park design used AutoCAD print out review which is manually done by the design team. The BIM based ICT park project use clash detection tool (Navisworks) for review.

Clash detection and design review Findings

The piloting of BIM on B+G+7 ICT park has identified the following problems in the original design packages while checking the design using clash detection toolset.

Table 4-5 ICT park design review finding

<p>– During construction between two waffle slab any shear wall cannot pass with their thickness, which leads breakages from prefab and shear wall on the time of installations.</p>		
<p>– Pipe clash with column</p>		
<p>– Missed orientations of water tank on the top of the roof</p>		
<p>– Miss communications</p>	<p>– Miss communications with architectural and structural on shear wall, HCB wall with regard location to and size.</p>	
<p>– Not considering maintainability issue</p>	<p>PVC downpipe locations installed b/n curtain wall and sun breaker which is difficult for maintenance work;</p>	

4.2.2 Case study two: BIM practice in ZIAS Architecture & Engineering PLC.

	<p>Ethiopian public health institute training center (EPHI)</p> <p>Location: Addis Ababa, Ethiopia</p> <p>Project owner: US government</p> <p>Project cost: 6million USD</p>
	<p>ASOY – Classroom Facilities</p> <p>Location: Yaoundé Cameroon</p> <p>Project Owner: America School of Yaoundé</p> <p>Project Cost: 4 Million USD</p>
	<p>Ethiopian Airlines Cargo Terminal, Ethiopia</p> <p>Location: Addis Ababa, Ethiopia</p> <p>Project Owner: Ethiopian Airlines</p> <p>Project Cost: 105 Million Euros</p>

4.3.2.1 Introduction

As of the company profile, ZIAS Architecture & Engineering PLC. was founded in 2006 in New York, USA. Soon after, a regional subsidiary was established in Addis Ababa, Ethiopia to position ZIAS strategically on the African continent. ZIAS was thus able to leverage expertise and resources from both continents to offer superlative A&E services in emerging African markets with rapidly growing economies. In the short time since, ZIAS

has delivered design, construction supervision and contract administration services that have earned it an outstanding reputation in industries such as healthcare, education and aviation among others. Its clients, including the US Government, Government of Ethiopia and other African countries like Mozambique and Cameroon.

ZIAS started BIM Implementation in April 2011. ZIAS use BIM tools to give different services such as :

- Design Analysis and Documentation
- Architectural
- Structural
- Visualization
- MEP
- BOQ
- Fire safety and egress analysis
- Coordination

4.3.2.2 Overview of Design Management in ZIAS Architecture & Engineering PLC

The table below will summarize the structured interview with BIM manager and architect of ZIAS Architecture & Engineering PLC.

Table 4-6 Structured interview of ZIAS professionals

NO	Structured interview topics	ZIAS consulting Architecture & Engineering PLC. (Architectural team leader and BIM manager interview)
1	Use of BIM	All projects done by BIM. Some projects done by BIM starting from the concept stage and some from the detail stage. BIM used mainly for <ul style="list-style-type: none"> -model aggregation -Visualization -Clash detection
2	BIM based design process	Comparing to the international practice ZIAS consulting company does not use BIM guidelines, standards and protocols. The design stage is the same as the conventional one however in BIM. What makes it different is the execution, the focus and the priority. in BIM the designer aggregates the whole project lifecycle at the designing

		<p>stage. After architectural design and structural design finished the design sent to MEP consultants. The company outsourced MEP services for MEP consultants. After they finished the design, they sent it back and the BIM manager integrated the design, quantification, scheduling and simulation using Navisworks as a tool.</p>
4	Communication and collaboration managed using BIM	<p>Design manager collaborates with the design team using email and face to face meetings mostly. Startup meetings include project need, schedule, team tasks and responsibility. There is a meeting every two weeks depending on the project urgency and there is also a fixed meeting which is planned at the initiation stage.</p> <p>Interdisciplinary meetings are also communicated using email and meetings. The BIM manager participated and organized the kickoff meetings.</p> <p>MEP designs are outsourced for MEP consultant offices. The communication was held using email platforms and they also participated in kickoff meetings.</p>
5	Integration of design and information validation	<p>After finishing the design part all designs export to Navisworks for model review. For design coordination and integration, we use the tool clash detection. It's not automated, still it needs human input to clash detect.</p>
6	Design change	<p>-At schematic stage, using the lump sum takeoff method the cost will be provided as a plus or minus percentage for the client to make his decision. After decision making and moving to the next step still the client might come up with the change.</p> <p>-Even if BIM is flexible with change the software is needed to be fully interoperable. As an example, if the client wants to reduce one floor. The architect using Architectural Revit</p>

		<p>design reduces one floor automatically the other designs (structural and MEP) also reduce one floor. For this to be successfully operated the software needs to be compatible. In our case for structural design at first, we use structural Revit. since Revit can't analyze the structure design, they use another software which is ETABS for structural analysis. ETABS and Revit are not compatible so data can't be linked, and we can't use it directly. It makes it over designed. So, it makes the change difficult.</p>
8	Client involvement	Client and client representative involved at every stage of design.
9	Constructability and maintainability concept	<p>- BIM can feed full information of the material what it's made of and important information's that helps facility managers.</p> <p>-BIM is a key for virtual design and construction. It considers such issues by cooperate it at the design stage. it has tools that help visualizing the whole model by aggregate it into one model.</p>
10	key challenges and lesson learnt	<p>-Infrastructure: The MEP team is outsourced from outside. Since a BIM needs a platform to integrate designs under a coordinated environment the ZIAS consultant finds it difficult to coordinate architecture and structural design with MEP designs. The MEP partners sent the design as a file using email but when the design is upgraded the MEP team can't go with the updated designs.</p> <p>As a solution the other countries use cloud-based platforms for professionals that can't work from the same office using server units. When we come here in Ethiopia it's difficult to get a fast internet (40-60 MB/sec) Continuously.</p>

		<p>design is a time taking endeavor but the client doesn't tolerate the amount of time needed to design. Construction should be easy if properly designed.</p> <p>-Change resistance</p> <p>-Software compatibility / and codes</p>
11	Encountered benefits	<p>Information: once feed the information to the software (Revit) at the designing stage. one can use the information from the inception stage to demolish the stage. That help for the decision the stakeholder made and minimize the risk that happens due to poor decision making at construction and operation stage.</p> <p>Interdisciplinary collaboration: designing is the sum up of different disciplines like sanitary, architect, engineer.it will make strong interdisciplinary collaboration .</p> <p>Minimize rework and errors: It minimizes rework and errors so as result it will minimize the time and cost with best quality.</p>
12	Key Drives for implementation BIM	<ul style="list-style-type: none"> - To improve design coordination - To improve design team collaboration

4.2.3 Lesson Learnt From the Case Studies

Described Lesson learnt is one of the objectives and a result of analytics done in this thesis. They represent the things that were performed in the case project and from which other projects can learn. It's is divided to groups: technology, process and people.

Process

Based on interviews with architect Dereje.A working in German BIM consultant office, BIM projects need BIM requirements which start with EIR (employer information

requirement). milestones, naming process, parameters are all defined by client. Then according to the requirement, the consultant prepares a BIM execution plan (BEP). BEP includes every process, feedback to EIR and roles of the designer listed with detail.

- Both case studies don't combine the above process within their projects. BIM standards and guidelines are key solutions for it. The ZIAS consulting projects doesn't prepare EIR and BEP at the start of their project. They only use the BIM concept for design validation that makes it miss the BIM benefits and they are not fully implemented BIM.
- Even if the case studies don't align with the full process, they expose to different practices of a collaborative environment, better visualization, model-based quantification and better communication within a team.
- The other lesson learned from the case studies is due to the Hand-over design from the architects to the structural engineers and then to the MEP team were laggard and involved stress in the iterative design process. The architectural and structural models changed many times due to design modification. As a result, that makes the MEP team tedious to cope up with the change. As architecture design going through changes its advisable to MEP to start designing after the design phase is finished. But till then the MEP can do schematic designs.

Technology

- Regular clash detection and visualizing design in 3D has been proved in the case projects to add value. A single design mistake will propagate throughout the model and affect other work. Visualizing design has caused such design changes that would have not been noticed from 2D drawings. Managing the complex design solution has been much easier and sustainable, particularly because the project is underground level.
- This provides great project insight (visualizations), enhancing its understanding and facilitating the process of solving problems and helping teams communicate more adequately. The ICT park design project using BIM have better design review, accurate quantification and visualization compares to the conventional design.

- Model based quantification is more accurate than the manual work, especially as it saves time and avoid error due to counting. The document analysis section shows that there are quantification errors on the conventional design of ICT park project which ware underestimate the quantities and missed quantify elements.

People

- In the ICT park case project, the missing of mechanical engineer cause an overload over the electrical and sanitary engineers. So, it's advisable to engage the necessary BIM professionals into design project.
- The professionals need

4.2.4. Overall Key challenges with Suggested Solution

This section summarizes the challenges both case studies experience and development suggestions with respect to the challenges. Development suggestions for design management also give solutions for these case projects and for future projects too that were found under the research of the thesis and interviewing professionals who have exposure to international experience.

A. Technology based challenges

➤ Software interoperability issue

In both cases, structural designers encounter software interoperability problems which is structural Revit software do not analyze the structural design. For that matter, they use ETABS structural designing software to analyze and feed the result to Revit structural manually. It's tiresome and takes time for a structural team.

Solution: There is a compatible structural analysis software named Robotic structural analysis software. Robotic analysis software is perfectly compatible with structural Revit software design.

- **Infrastructure** As we seen on the case study analysis infrastructure is one of the challenges both claimed. The main challenges are;
 - Availability of fast internet,
 - Power shortage which affects internet-based software,

- Smaller capacities of computer graphics had the negative overall performance of the computer to process as required accordingly consuming prolonged time to open the models.

B. People-Based Challenges

- **Expertise in the field-** For successful implementation of BIM, people/professionals have the main role. BIM come up with new professional categories like BIM manager, BIM coordinator. As a result, in this case study finding expertise/BIM professional is a main challenge. Since BIM is infant stage in Ethiopia, it's difficult to find BIM professionals in the industry.
- In the case of ICT park project, the absence of mechanical professionals as part of the BIM Team created an additional load on the team members (Sanitary and electrical designers) to work on the fire extinguisher and lift.
- In the case of ZIA consultant, the fact that the MEP designs and models outsourced from other company it makes the interdisciplinary communication and collaboration of architects with MEP and structural designers with MEP affected negatively.
- Using BIM as a tool in some disciplines was on a low level. This caused dormancy in producing good quality models and producing them on time.

Solution:

- Exposing the employees for training, online courses and international practices so they can have the opportunity to develop their knowledge area regarding BIM. BIM should be including in university curriculums so the graduates will be familiar with the concept of BIM
- The design team should be open up for change and using different designing tools as design solutions.

C. Process-Based Challenges

Inspection 4.2.3 mentioned that, ZIAS design process don't align with international practice. The challenge that consults raise is BIM protocol guidelines, EIR, BEP such standards have not been adopted or customized with respect to Ethiopian designing standards.

Solution: Before adopting and going through BIM implementation governmental organization should research whether BIM can elevate the construction industry if it comes as the right approach. The mandated organization should work toward BIM guidelines and standard.

4.2.5 Drawbacks of Design Management using BIM in the Case Studies

Software Interoperability: One of BIM drawbacks is that software interoperability, it leads to favor specific software's companies and that lead to benefited organizations that produce interoperable software. For example, Autodesk company provide software that are interoperable only within software that Autodesk provide. As a result, the interest of the consumer (The designer) will replace with software that can coordinate with BIM toolsets.

BIM setting up cost: Setting up cost include hardware, software and designers training cost. According to Autodesk, one year fully functional Software subscription and designers training for one office cost around ten thousand dollars. Hardware including server cost should be added too. Summing up the implementation costs it might block the small and medium designing offices.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The research aimed to demonstrate the design management practice using BIM in two case studies and assess the conventional design management practice and challenges of category one consultant office. The research list finding /answers for four research questions/Objectives and the result is as follow

1. The research indicates that the current design management practices follow the linear /successive design process which criticize to be error prone and less coordinated. paper based, verbal and email communication ways are the common ways to communicate between the design team. paper based communication is found to be the major ways of communication in category one consultants. It was found that the majority of consultants involve client at briefing stage only, this show the client role in the design process is not significantly considered
2. The current design management practice has limitations on design review for coordination since they use a 2D printed AutoCAD design and check for design clash. That error prone and time taking method found to be a drawback of the conventional way. The current practice also found to be difficult to consider constructability, maintainability and lifecycle cost of the building in depth.
3. Very low project design fee is, ineffective design review procedures, predict the effect of design change within time and Fee, Unable to consider/model/analyze the existing site condition and Use of Poor technique to integrate designs are found to be the key challenges in design management.
4. The research indicates that the design process using BIM follow the integrated design process which described as collaborative environment. The communication and collaboration between the design team during design is said to be live. The research indicates that BIM provides a better collaboration by providing a collaborative environment using server-based communication mode.

5. The research shows that model-based material takeoff has enormous advantage and very fast estimation provides greater cost certainty than manual quantification. The research also shows scheduling and simulation using BIM toolsets have advantages over visualization, communication, and project tracking but still the team fails to show critical path and other information. Furthermore, Design review and interface management is a key benefit of using BIM for having clash detection tools which are still not automated need human input
6. Software interoperability issues, infrastructure, expertise on the field and process-based challenges are found to be the key challenges both case studies imply. From the case study experience the research indicates professionals working from the same space are more advantageous using the benefits of BIM. Furthermore, software interoperability and BIM setting up cost are identified as BIM drawback.

5.2 Recommendations

A. Recommendation For Consultant Office

- BIM is not only about purchasing software and certified BIM professionals. It's also about processes that include BIM guidelines, protocols, standards so it's important to go through the process in order to get the full benefits.
- Consultants should consider carrying out feasibility study and choosing interoperability software before adopting BIM
- BIM concept is against fragmented work methodologies. It's important to engage multi disciplinaries into one collaborative environment for improving communication.
- The role of client is vital for any project success so it's advisable for the consultant office to cooperate and engage clients at every design stage decision.
- It's true BIM have implementation costs but it's advisable to consultants to foresee the enormous benefits and opportunities of BIM rather than avoid it because of the costs

B. Recommendation government bodies

- While Implementing BIM the Ethiopian standard agency should pay extra effort on adopting the BIM standard. It's worthwhile to engage expertise from different professions to consider the situation of Ethiopian construction industry in depth.
- Creating awareness toward BIM by organizing events, seminars and discussion stages besides its important to include an introduction of BIM in the curriculums of undergraduate and graduate courses of engineering departments.
- Motivating consultants that are already engage in implementing BIM will be an eye opener/ inspiration for the other consultants
- BIM institute

C. Recommendation for further studies

- In this thesis, the design management using BIM only focused from a consultant perspective. How Design management affects the construction stage from a contractor perspective should be discovered to show the significance of design sustainability.
- Other research also can determine the ROI (return on investment) of adopting BIM.

- One of the things that the BIM will change is the delivery method. It's important to Government bodies/Institutes to research on delivery methods that can align with BIM process including IPD (integrated project delivery).

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ANNEXES :- RESEARCH INSTRUMENTS

Section 1 : Questionnaires

PART I General information

Please give your response to the following questions by writing your answers in the space provided or by putting “ ” marks at your choice rectangle shown for questions having choice.

1. a. Name of company (Optional) _____

2. Average annual number of projects executed, over the past years.

- Below 5 project 5-10 projects 10-15 projects
 15-20 projects Over 20 projects

4. By which way most of the time design projects awarded at your company?

- Through tendering Through invitation Through Competition

5. What's your profession at the company?

- Architect Structural designer Sanitary engineer
 Electrical engineer Mechanical Other _____
engineer

6. What design process does your company follow?

- Integrated design process Linear/ successive design process
Other _____

PART II Factors for Design Management Practice

1. At planning stage, do you visit the site condition and perform the analysis and modeling with respect to the site condition?

Yes

2. What factors do you include in your site analysis?

3. At what project stage in your company startup meetings held?

At briefing stage At schematic stag At engineering design
stage

4. At which stage the listed stakeholders involve in the meeting?

Stake holders	At briefing stage	At schematic stage	At engineering design stage
client			
Client advisor / representative			
Design team and design manager			
Specialist contractor			

5. What's your mode of communication within the design team in your company?

Verbal paper-based email

Other _____

6. What kind of technique do you use in order to improve the communication and collaboration of the design team at company?

7. What mode of information exchange exists between each design stages?

Paper based computerized

8. If you use paper-based information exchange, how often do errors and omissions occurs?

Very frequently sometin

Frequently Never

9. Do you conduct value engineering for a proposed design?

Yes No

10. If yes, when do you conduct value engineering/ critical assessment about a Proposed design?

At the feasibility stage

During the concept development

After the design is complete

Other _____

11. Does your company consider constructability and maintainability concept during the design stage? If yes, what is your practice and technique on the design projects?

12. How is your company practice towards design review and evaluation? What is your technique to integrate the different design drawings?

13. At what stage of the design process does your company apply the design review?

At conceptual design stage At preliminary detail design stage

At developed design stage At detail design stage

14. Does your company consider health and safety in the design process? If yes, what factors do you consider?

15. Does your company analyze life cycle costing? if yes what method does your company used? _____

16. Do you think your company gives enough attention to design management practices and techniques?

Yes

No

17. In your company, is there any designated design managers?

Yes

No

PART III Challenges of conventional design management practice

Below are lists of **Challenges of conventional design management practice** in building projects. From your experience, please tick the appropriate cell by indicating the level of your agreement based on your experience on the following outline Challenges of design management.

Agreement:

1 - Strongly agree 2 - Agree 3 – Neutral 4 – Disagree 5 – Strongly disagree

	category	Challenges and limitation of current design management practice	Level of agreement				
			5	4	3	2	1
1.	Project related	Project design fee is very low					
2.		Cannot afford to have a permanent team to work on a project					
3.		Cannot access to a licensed design software					
4.		Database infrastructure is expensive and unaffordable					
5.		There is no Ethiopian design management manual to refer					
6.	Design team relate	The team lacks team spirit					
		The design team has a knowledge gap					

		Poor communication and collaboration within the team					
7.	Planning and Design related	Unable to include constructability, operability and maintainability concept in Design project					
		Unable to consider/model/analyze the existing site condition					
		Unable to analyze the lifecycle cost with the available technology					
8.		Use of Poor technique to integrate of designs; architectural, structural, sanitary and electrical designs					
9.		Predict the effect of design change within time and Fee					
10		Ineffective design review procedures					
11		Inadequate control of change					
12	Other						
13							

14. How do you think the challenges and limitation of design management should be tackled?

15. Do you think the current challenges and limitations of design management practices can affect the quality of design outputs and the construction stage?

16. Do you have any recommendation of advanced technology or system to improve the current practice of design management??

Section 2: Case study interview

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

1. Full name ?
2. Position within the company and year of experience ?
3. How many Projects does the company undertake per year?
4. How does the design team combination look like?
5. What is your role and responsibility in this project?
6. What is BIM process in your design discipline?
7. How do you manage communication and collaboration using BIM?
8. How do you manage integration of design and information using BIM?
9. What are the methods used to exchange information between stakeholders? And throughout the life cycle?
10. What are the procedures deployed to validate design information?
11. How does BIM based design include the constructability and maintainability concept?
12. How is the collaboration of the client handled in BIM projects?
13. What are the key challenges and lessons learned during the pilot project?
14. How could the BIM design process be improved?

