Effectiveness of Integrated BIM analysis in Small Dams.

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LIST OF ABBREVIATIONS

2D	2-Dimensional
3D	3-Dimensional
AEC	Architectural, EngineerConstruction
AIA	American Institute of Architects
BIM	Building Information Modeling
CAD	Computer Aided Design
CI	Construction Industry
CM	Construction Management
FM	Facility Management

Abstract

Small dams play a vital role in the development of every country and regions with water resource challenges. They have many benefits such as water storage and supply, flood control, energy generation etc. Despite of having potential in all provinces, currently Pakistan has approximately 150 small dams however according to the estimates, Pakistan needs approximately 750 more small dams to fulfill it water requirements.

Without following the principles, the guidelines of construction management, effective designing and execution of a project becomes difficult. Designing of a construction project using conventional methods and techniques often leads to clashes between different stake holders thus resulting in delays in the project completion as well as an increase in cost. BIM (Building Information Modelling) has the solution to all these problems.it can not only model, collaborate and visualize but detect the clashes and produces reliable platform for resolution of these clashes.

This Project is aimed to analyze and validate the effectiveness of integrated BIM in construction of small dams. The overarching goal is to enhance the efficiency, sustainability and economic viability of constructing small dams. Besides, changing the orthodox nature of construction, this study would help in providing guidelines for practical implementation of integrated BIM in construction of small dams in Pakistan.

1.1 SCOPE

The scope of this research is to modernize the way small dams are built.the research will be conducted through a literature review of existing studies and case study of different projects to determine the effectiveness of BIM in constructions of small dams by providing a framework for the practical implementation of BIM in the construction of small dams.

1.2 BACKGROUND

Small dams play a vital role in the development of every country and regions with water resource challenges. Small dams serve various purposes and offer several advantages, particularly in rural and semi-arid regions. Some of the advantages and uses of small dams are:

1. Water Storage: Small dams are primarily built to store water. They can help in capturing and retaining rainwater runoff, which can be used for various purposes, including agriculture, drinking water supply, and livestock.

2. Irrigation: One of the primary uses of small dams is for irrigation purposes. They can provide a reliable source of water for crop cultivation, helping to increase agricultural productivity and food security in areas with erratic rainfall.

3. Drinking Water Supply: Small dams can serve as a source of clean drinking water for local communities, especially in areas where access to safe drinking water is limited.

4. Livestock Watering: They provide water for livestock, improving animal health and increasing the productivity of livestock farming.

5. Flood Control: Small dams can help mitigate the impact of flash floods by temporarily holding excess rainwater and releasing it gradually, reducing downstream flooding.

6. Aquaculture: Some small dams are used for fish farming or aquaculture. They provide a controlled environment for fish breeding and can contribute to local food production.

7. Hydropower Generation: While small dams may not generate large amounts of electricity, they can be used to harness hydropower for small-scale energy needs in rural areas.

8. Erosion Control: Small dams can help prevent soil erosion by reducing the speed of flowing water and trapping sediment. This can improve soil quality and protect downstream areas from siltation.

9. Recreation: Small dams can create recreational opportunities for local communities, such as fishing, boating, and swimming.

10. Drought Resilience: They can act as a buffer against drought by providing a reserve of water during dry periods, ensuring a more stable water supply for agriculture and other needs.

11. Biodiversity Conservation: Well-designed small dams can create wetland habitats that support a variety of wildlife and plant species, contributing to biodiversity conservation.

12. Rural Development: The construction and maintenance of small dams can create employment opportunities in rural areas, stimulating economic development.

13. Groundwater Recharge: When excess surface water is allowed to infiltrate into the ground behind a small dam, it can help recharge local aquifers, improving long-term groundwater availability.

It's important to note that the construction and management of small dams should be done with careful consideration of environmental, social, and safety factors. Proper planning, engineering, and monitoring are essential to ensure that the benefits of small dams are realized without causing negative impacts on ecosystems or communities.

1.3 PROBLEM STATEMENT

Despite conducting multiple feasibility studies and having potential in all provinces the construction of small dams have not been possible in Pakistan, mostly because of the use of conventional methods and techniques of management, which as a result causes clashes among various stakeholders and budget overruns. Currently Pakistan has approximately 150 small dams however according to the estimates, Pakistan needs approximately 750 more small dams to fulfill it water requirements.

1.4 OBJECTIVES

This project aims to modernize the construction of small dams in Pakistan by utilizing, analyzing and validating the effectiveness of integrated BIM, which already has the solution to all these problems. The overarching goal is to enhance the efficiency, sustainability and economic viability of constructing small dams. It will be achieved through following objectives:

- Development of virtual architectural and structural models of a dam using Autodesk Revit.
- Rendering of the developed 3D models
- Detection and removal of clashes between the developed models
- 4D scheduling using Primavera P6 and linking it with 3D model for 4D simulation
- Carrying out quantity takeoff and cost estimation (5D modelling)by using Autodesk Navisworks.

LITERATURE REVIEW

2.1 BIM tecnology's critical role in assesing cost for complex dam projects

The use of Building Information Modeling (BIM) technology and BIM software principles can be highly advantageous in estimating the costs of complex dam construction projects. The key findings and work outcomes of this research include:

1. Beneficial Use of BIM: The research indicates that the utilization of BIM technology and principles is significantly beneficial, practical, and helpful in estimating the budget of construction projects, particularly for large-scale dam projects such as the one studied in Iraq. BIM can help streamline the estimation process and improve its accuracy.

2. Time and Cost Savings: Evaluating the cost of dam construction projects using BIM can lead to considerable savings in terms of time, effort, and budget. Dams are known for their complexity, lengthy construction periods, and challenging management, making the traditional estimation process time-consuming and costly. BIM can expedite the estimation process and help in optimizing resource allocation.

3. Reduction of Human Errors: BIM techniques are found to significantly reduce human errors in cost calculations. This is crucial, especially in large-scale dam construction, where precision is essential. The use of BIM technology can lead to more accurate cost evaluations, ultimately contributing to better project management and financial control.

In summary, this research emphasizes the advantages of employing BIM technology and software principles in the estimation of dam construction costs. It highlights the potential for time and cost savings, increased accuracy, and reduced human errors. These findings can be valuable for project managers, engineers, and stakeholders involved in complex construction projects, particularly large-scale dams, where precision and efficient cost estimation are critical for project success (Hussein Hasan, S. Naimi1, M.M. Hameed, 2022).

2.2 BIM Adoption Benefits

BIM is the new recognized ICT for integrated project documentation and information hence minimizing the data conflicts and better productivity in CI. (Bryde *et al*, 2013) carried out the analytical study on twenty (20) projects to sort out the benefits of BIM and formulated the following: control or reduction in cost and time, coordination improvement, collaboration and communication improvement and quality control. Furthermore, many researchers addressed the potentials of BIM for explicating financial and ecological implications simultaneously at early design stage (Z. Ma *et al*., 2012 & J. Basbagill *et al*., 2013). Current benefits of BIM as per United Kingdom (UK) government report (2012) are; about thirty eight (38) percent reduction in total construction project cost and nineteen (19) percent to forty (40) percent cost saving is expected from the design stage alone. BIM survey report (2013) states that the current BIM adoption rate in

UK construction sector is thirty nine (39) percent.

Stanford University Center for Integrated Facilities Engineering (CIFE) identified the few noteworthy benefits based on thirty two (32) major projects using BIM (CIFE, 2007):

- Up to forty (40) percent elimination of unnecessary work and unbudgeted change
- Cost estimation accuracy within three (3) percent
- Up to eighty (80) percent time saving in creation of cost estimate
- Up to ten (10) percent contract value saving due to clash detection
- Up to seven (7) percent reduction in construction time

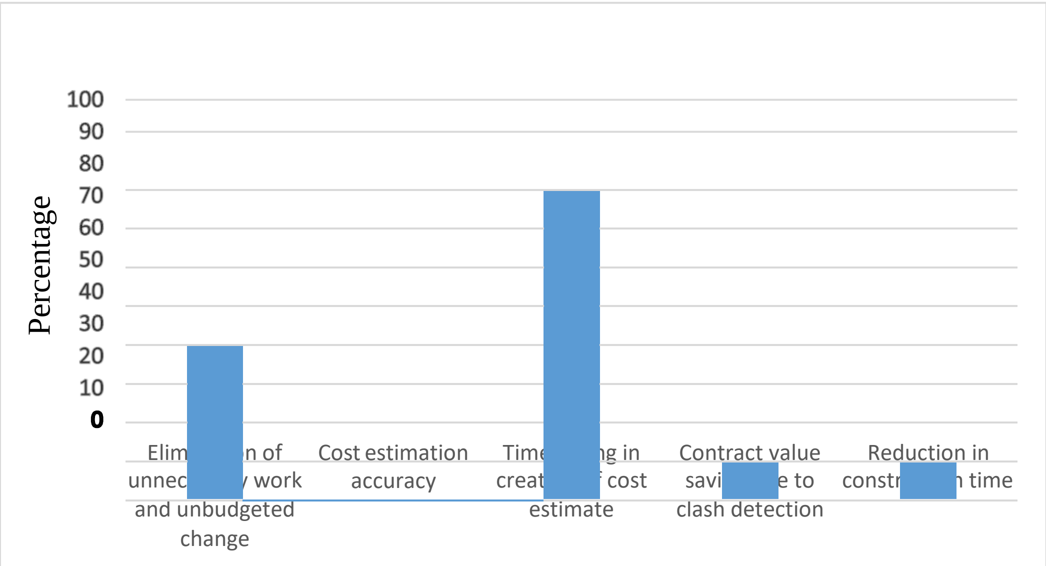


Figure 2.3: Benefits of BIM (CIFE, 2007)

BIM benefits from earlier conceptual stages through design, construction, life cycle operation and maintenance are greatly recognized for all the three stakeholders i.e. owner, consultant and contractor.

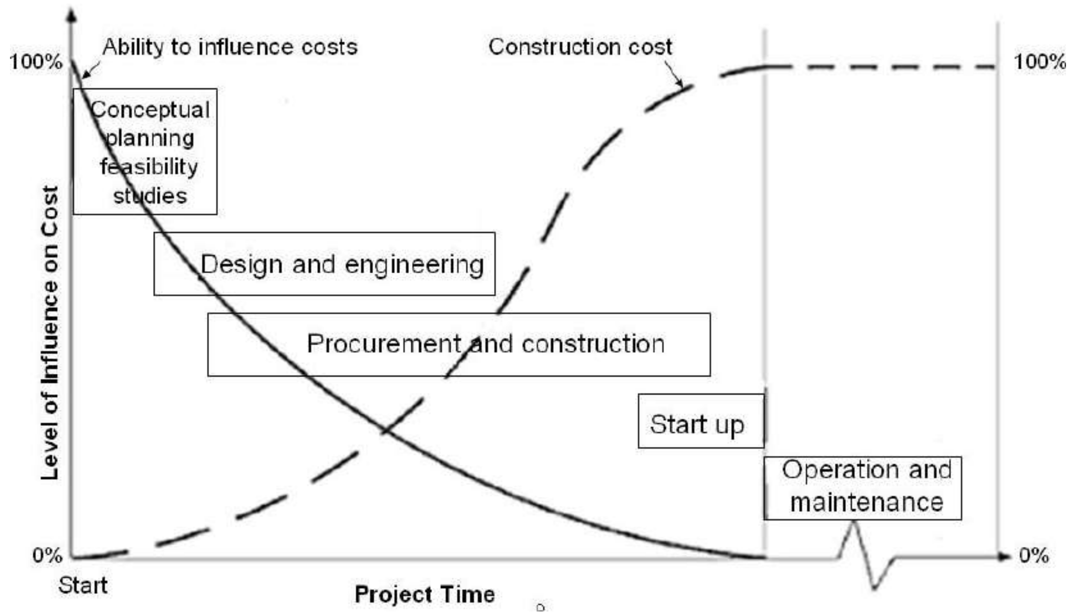


Figure 2.4: Project life cycle - ability to influence cost (Eastman, 2008)

2.2.1 Accurate 3D Visualization of Design

Parametrically accurate and consistent 3D model can be designed directly in BIM software which can be used for visualization at any stage of project. Earlier visualization of project is very important to owner, who is the main stake holder and whose money is involved in all stages of construction. By 3D model visualization he can actually see the final product which is going to be handed over to him. By 3D visualization he can make changes if he wants to do, in earlier stages of design, results in less change orders which ultimately save unbudgeted cost and time. 3D model visualization gives a very little room for any kind of misinterpretation by the stakeholders involved in the project and it also helps them to re-align their expectations (Salazar *et al*., 2006).

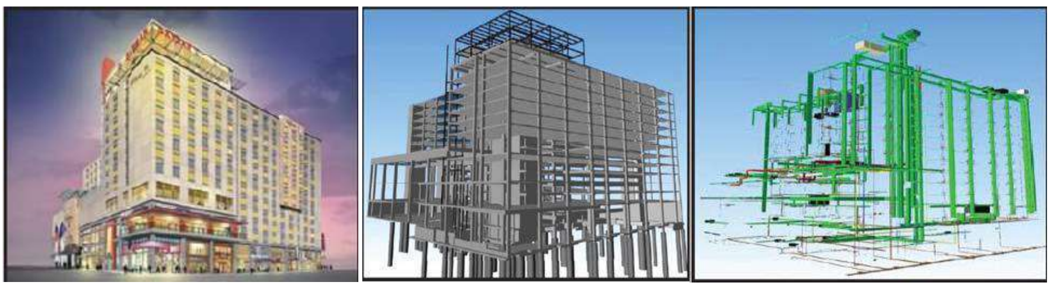


Figure 2.5: Architectural, structural and plumbing models of BIM

2.2.2 Interoperability: Collaboration across Multiple Disciplines and Organizations

BIM facilitates the simultaneous working of different design disciplines. For working in a team BIM have the ability to work on a single model saved as central model and the working models assigned to team members connected to the server. Any work done in working model is automatically updated to central model and at the end of the day one can extract the central model containing all the work. BIM allows the collaborations of coordinated models which shortens the design time and greatly reduces the design errors. As contractors and consultants work on the same model and this model plays a mediating role between the two and designers can act more rapidly on engineering problems faced by contractors and vice versa. Construction organizations are able to more clearly formulate their knowledge of construction problems and ask changes to the model that otherwise would have had to be worked out in the field during construction or later 'with a hammer' (Taylor and Levitt, 2007). BIM gives the solution to minimize the disputes between the design and construction phase by providing a single digital environment in which both designer and contractor working their own way round. Computer model containing the rich information data of project can be handled from one contractor to the other in contracting out regimes.

In common situation, an architect would extract information from the model such as HVAC pressure, wind direction, lighting analysis, and emergence under emergency situations, structural performance and budgetary feasibility, specialized skills and information would no longer be required for data input and result interpreting creating a closer linkage between design process and analysis (Autodesk, 2003).

2.2.3 Clash Detection and Minimizing Conflicts

Clash detection is significant tool of BIM which can reduce the project time and cost efficiently. As coordination between designer and contractor enhanced which lead to less chances of errors results in reduction of legal disputes and a smoother process for whole project team. Major hard and clearance clashes can be detected and highlighted by integrated all the key models together and checked for multisystem interfaces. Major and minor internal conflicts between the structural and MEP design systems can be detected and rectified at early design stages before field construction which can be a difficult challenge at construction phase. The solution can then be checked to ensure that it resolves the problem and to determine if it creates other, unintended, consequences (Ashcroft, 2006).

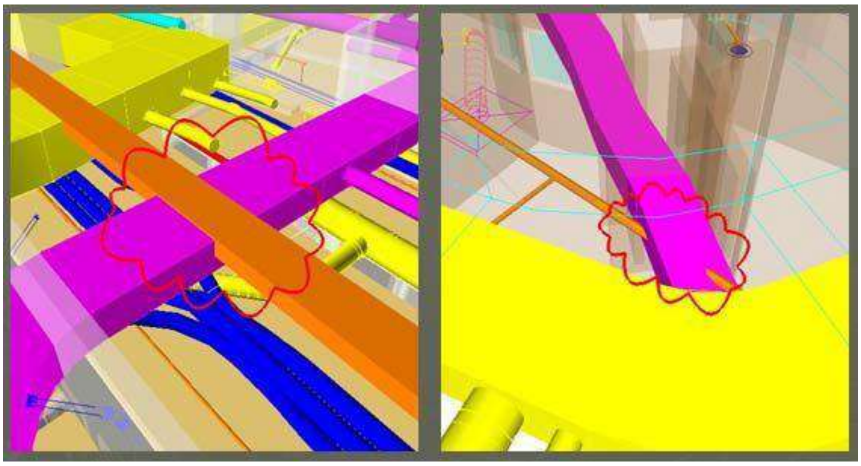


Figure 2.6: An illustration of clash detection via BIM

2.2.4 Quantities and Cost Estimation

BIM technology can be used to extract the Bill of Quantities (BOQs) at any stage of design. Quantities can be automatically take off in BIM software tools by using simple commands and used for cost estimation in design stages. BIM allows the automatically updating of quantities once change is made in model. As the design progress more detail quantities are generated and can be used for more detailed and accurate cost estimates. As stated earlier, up to eighty (80) percent cost saving can be achieved by using BIM technology. Final cost estimate with in the accuracy of three (3) percent, can be prepared based on quantities for all objects contained in the model at final design stage. This helps in making better decisions regarding cost and financial approaches to the project by using BIM technology rather than paper work.

2.2.5 Energy Efficient and Sustainable Design

BIM allows one step ahead green building design by linking the created model to energy analysis tools for evaluation of energy. The capability to link the building model with various analysis tools can give more opportunities to increase the building's energy performance. Solar study carried at early design stages helps in elimination of modifications at construction stage and improves building quality. Lightning analysis can be done for energy efficient design and efficiently save the lightning cost by reducing electricity load.

2.2.6 Construction Sequence and Planning

4D scheduling and sequencing in BIM allows the simulation whole construction process by linking the 3D objects in the design model with a construction plan. The simulation is done in a manner to show what building and construction site would look like at a particular point in time and provides considerable insight how the building will be constructed day by day and reveals the potential problems during construction related to cast and crew, equipment, safety problems and so forth. This type of simulation cannot be done with ordinary 2D and 3D software or paper work. Moreover temporary construction objects like cranes, scaffoldings etc. can be linked with the schedule activities and can be reflected in simulation.

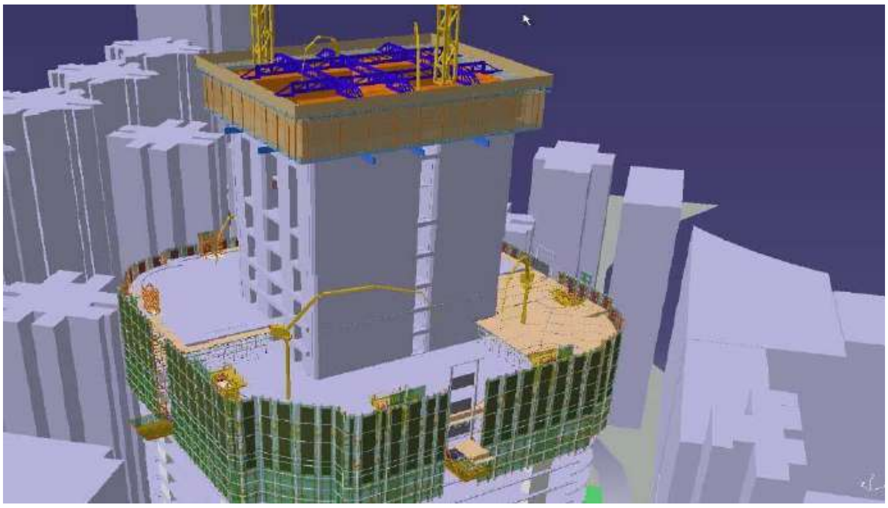


Figure 2.7: Construction sequencing model

2.2.7 Procurement of Materials

BIM can be used to design different kind of models shaped for product vendors and contractors. The quantities, specifications and properties provided for all materials and objects contained in complete building models can be used to procure materials from subcontractors and contractors. The major part of complete data that is included in BIM model comes from fabricators, subcontractors, suppliers and vendors. The accuracy of the data acquired from the data is the same as the accuracy provided in making the model. Since the BIM model contains all the vital details of every element in the construction, this facilitates off-site prefabrication.

2.3 BIM Adoption Barriers and Challenges

BIM is a thriving technology in AEC industry ready to bring huge change in whole construction process. As CI is very resilient to changes and very slow in adoption of any new technology. Initially BIM was not adopted by CI at a rate at which it was expected though now a days it is increasing exponentially. Barriers to the adoption of BIM can be categorize as business and legal issues, technical issues and organizational issues.

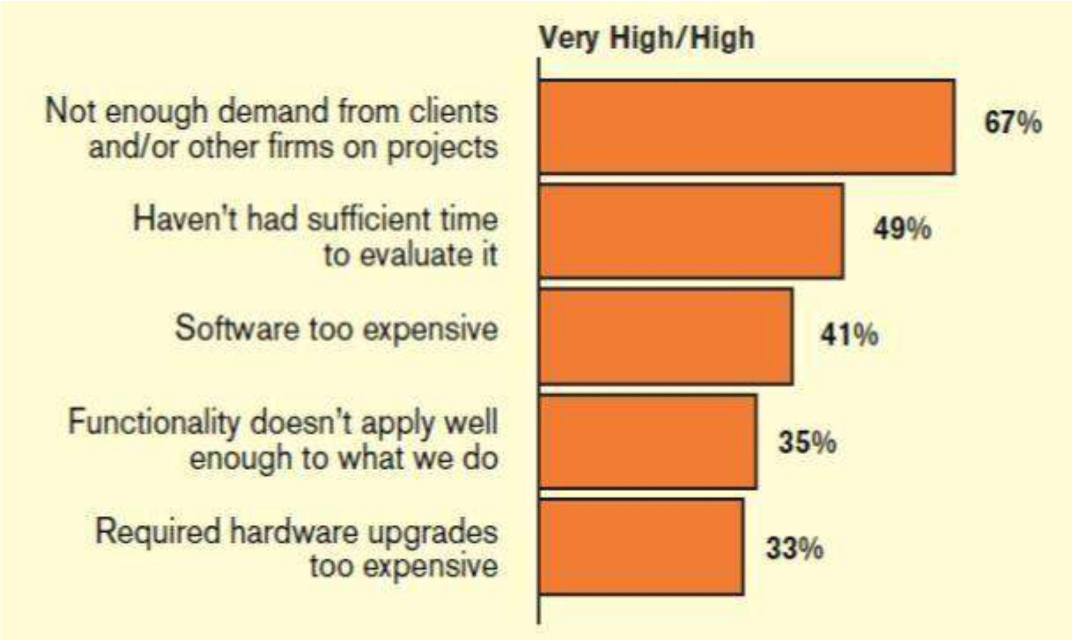


Figure 2.8: Most important obstacles to BIM adoption

2.3.1 Business and Legal Issues

2.3.1.1 Data ownership and risk liability

Due to single complex project file, the legal issues involved with BIM and between working organizations are; who owns the multiple design, fabrication and datasets?, who financially support them?, and who is legally responsible for a faulty design?. The legal issues associated to BIM are identified by Ashcroft (2006) are risk allocation, standard of care, privacy and third party reliance, economic loss doctrine, who is the designer?, Intellectual Property (IP), etc.

As BIM typically involves various architects and design professionals who contribute their expertise and IP to the creation of rich data model. This raises the question of ownership of the IP of model. Other issue is the risk and liability, who is responsible for any defect in the model and failure. As architects creating the seeds for whole BIM model, so Frazer (2006) evokes that it is possible to hold the architects responsible for any defect in the model as architects have IP rights.

Architects have shown reluctance in sharing their models due to risk and liability concerns. This made some contractors to develop their own construction phase models (Batcheler and Howell, 2005). At later stages if there is any model that turns out to be defective, all the professionals would blame the original creator of work. This leads to unusual scenario that the architect initially creates the model would receive immediate benefits but greater risk and liability (Ashcroft, 2006).

2.3.1.2 Data privacy and contractual issues

As a single BIM model is a data rich database which leads to the issues of data privacy and secrets. The problem is also recognized by Drogemuller *et al*. (2006) who states that an auxiliary issue is the ability of firms in construction and FM to manage the shared data and databases. As the data in BIM model relates to the numerous parties involved in its development so contract must address the risk related to the databases in BIM model (CURT, 2006).

Ashcroft (2006) argues that these new approaches will have to be developed to support the collaborative process within a system able to maintain design integrity and discipline.

2.3.1.3 Lack of standards and high cost

BIM standards are in stage of development and no particular standards were defined. So lack of standards lead to ambiguities and legal issues but now people are working and some standard sets are defined and available to cover the issue raised in CI. Professional groups like American Institute of Architects (AIA) and Associated General Contractors are establishing new standard guidelines for contractual forms and language. Also the lack of client demand or market demand due to ignorance and low knowledge of technology and its benefits.

People in industry are not trained as professionals of BIM. If an organization tries to adopt the BIM technology they certainly have to train their employs and also have to buy the BIM software tools and highly efficient computer systems. All these approaches lead to high initial cost and investment. The process to obtain a high level of knowledge and expertise of this software is often very difficult and prohibitively expensive (Bazjanac, 2004).

2.3.2 Technical Barriers

2.3.2.1 Interoperability

In BIM technology a shared building model is intensively used in all construction phases. As a base for whole construction process and collaboration, a set of coordinated building models is used during the process of design, construction and fabrication processes. In order to make a BIM project successful immense inter organizational coordination is needed. Taylor and Levitt (2007) identified the same problem and states that for all construction firms it is important to implement 3D CAD and to adopt and work with same software tools or at least the same standards.

In CI the software vendors launch new and different innovative software tools in order to compete in industry. This make different design and construction firms to work with different software. Once the organizations using BIM, they have to coordinate because of using a single electronic design file throughout the construction process and this collaboration demands the same software by a single vendor or same standard software by any other vendor otherwise the whole structure of collaboration will fail. Files produced in one software format may not be able to open in other software tool which will lead to the failure and delay at any stage of construction. File converter software tools are available in market but actual file is viable to corruption or loss of any crucial data during conversion. So it is important for participating firms and organizations to switch to the same software before working on a project using BIM. Each organization should have the specialized software to perform BIM functionalities because inconsistent adoption pattern will lead to budgetary problems for participating organizations (London and Bavinton,2006).

2.3.3 Organizational Barriers

2.3.3.1 Lack of initiative and training

Lack of initiative and training can be named as socio-technical issue related to the introduction of BIM. Taylor and Levitt (2007) also recognized this problem and stated that there is a little work in the way of providing guidance to the organizations, working in collaboration, about how to implement the BIM which requires a change in whole process.

Also there is no implication of BIM in educational community which results in untrained staff and graduates. Less or no knowledge about the BIM and cost associated with training is also a major factor.

2.3.3.2 Resistance of AEC industry to change

CI is very resistant and slow to accept any change. It has been number of years people are preparing 2D drawings, manually and by using CAD programs, and working with it. They have their own expertise in this regard and they think they can easily learn and adopt current technologies while learning of new technology is very difficult and hectic work. Most of them are of opinion that if they are good with already available technologies and working satisfactorily then there is no need to learn and implement new technology. Due to these skill issues they are reluctant to any change in industry. For implementation of BIM organizations have to recruit trained and professional personal or existing staff have to be trained to the appropriate level which results in more cost. Construction firms will only able to successfully implement 3D CAD after they obtain sufficient training (Taylor and Levitt, 2007).

3 Research Methodology

3.1 Topic Selection

The topic selected for our final year project is “Effectiveness of 5D BIM analysis in small dams". This study concentrated on the implementation of BIM on a dam project to get better results than the traditional practices. This topic is selected due to research advancement and potential benefits of BIM for the construction industry.

3.2 Data Collection

2D AutoCAD drawings of dams` will be collected including structural, architectural, electrical and plumbing drawings. Project activities sequencing, and duration will be obtained from the site supervisor. The rest of the information regarding the project will be collected with the help of project advisor.

3.3 3D Modelling and Clash Detection

After acquiring the data, 2D drawings will be imported from AutoCAD to Autodesk Revit. 3D architectural model will be prepared first, followed by the structure, plumbing and electrical models. Clashes will be then detected and removed using Autodesk Navisworks. As expertise will be lacking for the use of software programs, tutorials will be gathered from Autodesk site to acquire the mandatory skills for software running.

3.4 Scheduling (4D), 4D Simulation and Cost Estimation (5D)

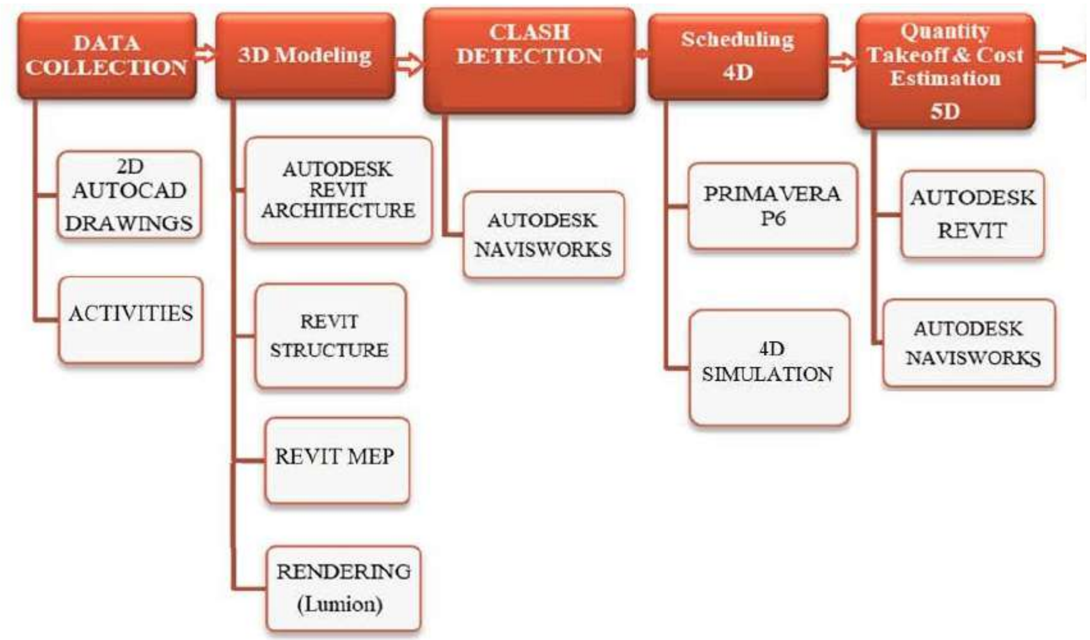
4D modeling will be then carried out on Primavera P6 which included forming the Work Breakdown Structure and assigning the duration to each activity. Then a Gantt chart will be generated. Activities will be then scheduled to get a clear picture of how much activities have been completed. For 4D simulation Navisworks Timeliner module of Autodesk Navisworks will be used, all the activities in the scheduler will be imported to Navisworks. Then the 3D objects will be linked to the activities by selecting the objects in the " Selection Tree " window. After linking all the objects the simulation will be reviewed in the " Simulation " tab of Timeliner.

After the scheduling and 4D simulation part cost and quantity takeoff (5D modeling) will be estimated using Autodesk Navisworks and Autodesk Revit, and then overall cost of the project will be manipulated.

3.5 BIM 360 Glue

BIM 360 is an online cloud for managing information to key stakeholders related to the project. The understudy building project will be managed and coordinated through this advanced tool.

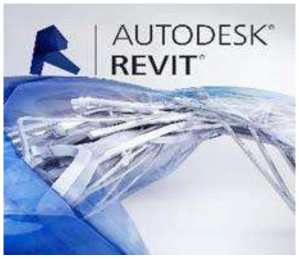
3.6 Flow Chart of the Project



3.7 Software to be Used

- Autodesk AutoCAD

- Autodesk Revit



- Primavera P6
- Autodesk Navisworks
- Lumion 8