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ARTICLE

A Study of Prospective Barriers, Benefits and Measures for Building Information Modeling (BIM) Adoption in Nepalese AEC Industry

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ABSTRACT

The construction industry needs modern construction methodology and technology to improve sustainability and production performance. Building Information Modelling (BIM) technology supports improving the quality of products by reducing design and construction defects, risks to the health and safety of workers, and reduce overall project cost and delivery time. The BIM has capabilities, but it is still undiscovered and unable to exploit the full scale of its benefits in the Architectural Engineering and Construction (AEC) industry. There is a trend to adopt the BIM level 1, which is limited to 2D and only in a few cases 3D models uses in the design and construction of residential and commercial buildings, particularly in Nepal. Hence, this paper focuses on providing insight into the BIM benefits and identifies the potential barriers while adopting BIM Level 3 in Nepal. This was accomplished by developing a 4DBIM model of a multi-story residential building in Nepal and conducting the industry survey via focus group with the AEC professionals based on the developed 4DBIM model. A comprehensive literature review was conducted and presented the findings of the BIM benefits and barriers while adopting BIM. The study found that commercial and governmental projects can immediately be adopted BIM technology. It is concluded that the unavailability of skilled BIM users and the lack of proper policies for BIM adoption are key barriers in Nepal. Hence, the new policy is required to achieve and exploit the full scale of the BIM benefits and improve the project delivery in terms of quality, cost and time including the health and safety of workers and the sustainability of the AEC industry.

Keywords: BIM adoption; Barriers; Benefits; Clash detection; 2D and 3D models; 4DBIM

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1. Introduction

Time and cost overrun are two major problems facing the Nepalese AEC industry due to the lack of awareness, poor project management and lack the new and evolving technology like BIM and modern methodology like offsite and modular construction. The poor analysis and management of the risks from the initiation stage to the design, construction, and operation stage of the project cause additional challenges to project delay and cost overrun [1]. The Nepalese construction industry is still following traditional methods of construction practices. Static shows more than 74% of Nepalese AEC professionals do not use any type of software for cost and project management in hydropower construction projects [2]. Currently, construction project faces a higher variation order due to changes in the design, scope, and unsystematic estimate of quantities and poor surveying reports [3]. Nepalese consulting firms only use 2D or sometimes 3D drawings at BIM level 1 and mainly used traditional tools for quantity take-off and cost estimating. Implementing BIM in building and infrastructure projects in Nepal will improve the project performance from the design stage to the construction or operation of the project [4]. This will help to reduce the sum of the above problems at a certain level by exploiting the benefits of BIM technology.

The status of BIM adoption in Nepal is relatively low. Lack of research on BIM and its further dimensions, and very few AEC professionals are aware of BIM benefits and, and its implementation is relatively low. The status of BIM implementation and its barriers and recommended 4DBIM models to calibrate actual benefits that BIM would yield in the Nepalese AEC industry [5]. The Nepalese AEC industry has not implemented the BIM concept in construction projects. Only 23.53% of the AEC firms were implementing BIM to level 1. The current AEC industry of Nepal is only using BIM for 3D visualization, and there is no trend toward incorporating BIM into the construction process [6].

The above studies support that the AEC industry in Nepal has a low level of BIM applications and the the awareness of its benefits. The past research has presented the findings of BIM benefits without conducting any experiments with a 4DBIM model in a real case study project in Nepal. Hence, the study attempts to explore the 4DBIM benefits and the problems while adopting in the AEC industry by developing a 4DBIM model using a real-life case study of a residential building. The paper explores the potential BIM benefits, challenges of BIM adoption, and further examines various aspects of 4DBIM applications in Nepal.

2. Literature review

2.1 Current research

BIM is defined as a technology that allows different professionals to generate, exchange, and see other designers' project information which integrates the data into a single database and is not limited to 3D models and relates the building productivity process throughout its life span [7,8]. A BIM model can be used for various pre-defined purposes known as use cases [7]. BIM provides a shared knowledge resource platform that enables collaborative work relating to the project with different stakeholders by data interoperating using several BIM applications or software [9].

The traditional construction sector focuses on the critical path approach and bars charts from examining the project timelines [10]. Modern practices adopt the novel concept of 4DBIM, which can simplify and solve various construction issues such as inconsistencies in schedule degree of detail, missing actions, schedule logic, and time and space conflicts. The 4DBIM model is the composition of a 3D drawing model and additional time information. It stores basic information such as building components and materials, stories, grids, and elevation. The fourth-dimension model drafts additional dimensional information known as scheduling data or time elements [11]. It has reduced the issue of misunderstanding caused by a lack of visualisation in traditional building sequence scheduling [8]. The actual project duration can be easily projected by formulating the various schedules of the task into the system [12].

2.2 Benefits of 4DBIM

A 4DBIM model was developed to visualize and analyze the actual construction in a residential building and supply essential information at every stage of the construction [13]. The 4DBIM-based simulation can help to minimise errors in construction activities, rework, solve delay problems, maintain quality, and reduce cost overruns [14]. The 4DBIM is ideal for poor project performance, which is generally related to time [15]. It was found that 4D can solve data-related inconsistency problems through visualisation and sharing the daily 4DBIM at an accurate time and take precise decisions based on communication and collaboration [15]. The 4DBIM modelling used for a visual planning method in a 70-story high-rise building for crane operation, locating building structure and materials at different construction levels, monitoring construction activities with site safety and labour safety, and revealed that the project could save significant cost and time [16].

In addition to the above, the 4DBIM is beneficial in planning by making planners think about broad project concepts, project reliability through collaboration and motivation to team members, actual project progress measurement, and identifying and guiding the various risks in the project [17]. The 4DBIM improves site planning and scheduling optimization, encourages seamless coordination between architects, contractors, and on-site teams, maintains better preparedness in terms of the next steps during each construction stage, improves information sharing related to timeline expectations, reduces costly delays, and improves safety and efficiency by documenting an entire plan with specific details [18]. The 4D model enables engineers to see planning data, eliminating the need for conceptualisation, and quickly comprehending timetable issues [19]. It can help with early conflict identification by monitoring site status information in real time and displaying the effect of changes throughout the life cycle [20]. The 4DBIM benefits are summarized in **Table 1**.

Table 1. Summary of 4DBIM benefits.

Authors	**4DBIM benefits**
[21]	Visualization for communication and analysis
	Reducing delays and schedules issues
[22]	Ensures planning efficiency
	Control over project execution
[23]	Connection of 4D model with 2D
	Minimization of errors and rework in design and construction
	control over schedule, quality, and cost
[15]	Solution for information delay
	Visualization of real-time information to enhance data consistency
	Promotion of communication and collaboration among participants
[16]	Optimization of the construction workflow
	Monitoring the site safety requirements
[17]	Increment in planning efficiency
	Evaluation of planned and actual construction progress
[18]	Avoiding the construction delays
	Sufficient information to eliminate the re-scheduling issues
	Environmental assessment
[19]	Identification of errors in the construction schedule
	Reduction of cost and duration

2.3 4DBIM adoption level

The BIM adoption in developed countries like the U.K., U.S., China is higher than in developing countries [24]. The adoption of 4DBIM in the U.K. while planning the construction project is 51.5% [25]. However, overall, BIM awareness and adoption level is entirely satisfactory in the UK. It is found that 73% of the industry is aware of and using BIM in a recent survey, with just 1% unaware of it [26]. A survey data of six continents for 4DBIM adoption was conducted and found that North America had 54.5%, Europe had 57.1%, and Asia had an 18.9% rate of adoption [27]. However, the Australian 4DBIM adoption level in their AEC sector is low [28]. It was found that the 4DBIM adoption in the Indian construction industry is only 24% because of low awareness levels. A study in Asian developing countries found that BIM adoption is low whereas China is in the top position in adopting the 4DBIM with higher awareness of BIM designs, but Pakistan is at the bottom of the BIM adoption level [30].

2.4 Barriers in 4DBIM adoption

The process of defining the barriers to BIM adoption is the first step to BIM promotion [31]. Several studies have identified the possible obstacles to 4D implementation depending on several authors and country contexts. This paper has attempted to point out some of the barriers that might be the same condition in Nepal's AEC industry.

- *Lack of 4DBIM Expertise:* The 4DBIM model requires various software, so it becomes necessary to be an expert on it to implement them professionally [8,9]. 4D Planning will only be successful if planners/contractors understand BIM technology and have suitable experience in construction practices [25].
- *Lack of interest of client due to time and cost:* A pilot study suggests that the client also seems dissatisfied with the time consumed during the preparation of the design and the cost of the design for 4DBIM in the Brazilian context [24]. The design cost of the 4DBIM design model is comparatively expensive due to software and hardware access costs.
- *Incompetent government supervision:* Past literature supporting government policies and regulations have successfully accelerated BIM adoption [8]. For example, the UK has mandated the BIM adoption for the AEC industry. Building SMART is the organisation for standardising BIM in the Australian industry. The US AEC industry has remarkable integrity with the construction industry and software developers. It is necessary to get high-level support to implement the 4DBIM in the construction industry [32].
- *Resistance to change:* The traditional method dominates the project delivery system [33]. The lack of interest in changing the way of work is one barrier to adopting 4DBIM [34].

3. Research methodology

3.1 Adopted methodology

The study adopted a qualitative research methodology. Qualitative research is a set of techniques to understand better a phenomenon based on real-world issues or learning [35]. A focus group interview to gain the views of different stakeholders involved in construction waste management through BIM [36]. The study focuses on identifying the potential BIM benefits and challenges by developing a 4DBIM model and conducting an industry survey via a focus group study with construction professionals using the developed 4DBIM model. The primary purpose of creating a 4DBIM model is to provide insight into BIM tools and their functionality, linked with their overall importance to the construction industry. Previously, the project was designed using level 1 BIM, which is confined to 2D design, and eventually developed into a 4DBIM model containing architectural and structural models with the detection of clashes in the design and adding time evolve a construction simulation. After model development, the study progressed to a focus group study where the 4DBIM model is discussed with the different AEC professionals in a virtual interview. The outcomes from the focus group study are organized into a thematic analysis which synthesizes the raw data of the discussion into elegant themes and sub-themes.

3.2 Development of 4DBIM model

This research's first focused on creating a 4DBIM model (see **Figure 1**) using ASTA PPBIM (ASTA Powerproject BIM) planning tool. The building selected for this case study is a residential building that was designed to use for both residential and commercial purposes. Initially, a 2D AutoCAD file shows the commercial building's detailed site plan, floor plan, and structural details (see **Figure 2**). The floor area of the building within which it is 2500 sq. ft., with four stories. The building is provided with strap footing on its foundations with different column sizes starting from 16" × 16". The plinth beam and foundation beam are provided with a size of 9" × 9", the floor beams are 9" × 14", and the second beam is 9" × 12". The walls in the foundation and floor are brick, with varying thicknesses. The outer wall is 9", and the inner wall is 4", varying as per design. The double L-shaped stairs are designed for access from floor to floor.

3.3 Steps of 4DBIM model procedure

The following procedures and steps are involved while creating a 4DBIM model of a residential building.

Step1: Initial Project Information

The model development starts with collecting initial information about the building, which helps to study the building structure and basic project visualisation. Initially, we have the level 1 adopted BIM file limited to a 2D AutoCAD file having all the details specified: The floor plans, section, elevation, door and window sizes, and structural drawing. For the 4DBIM model, this study has targeted developing a 3D architectural and structural model to detect clashes in the design and add time information to the different activities of the project. After finalising the activities and sequencing them practically, a 4D simulation video is required to visualise the building construction in real time. The project has a deadline of 73 weeks with a proper analysis of risk due to the client's financial burden. So, the project has the overall scope of the architectural model, structural model, clash detection, and 4D simulation with the timeline.

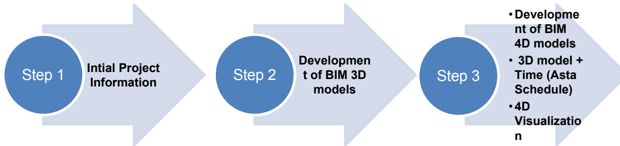

Figure 1. Key steps for 4D model development and key inputs.

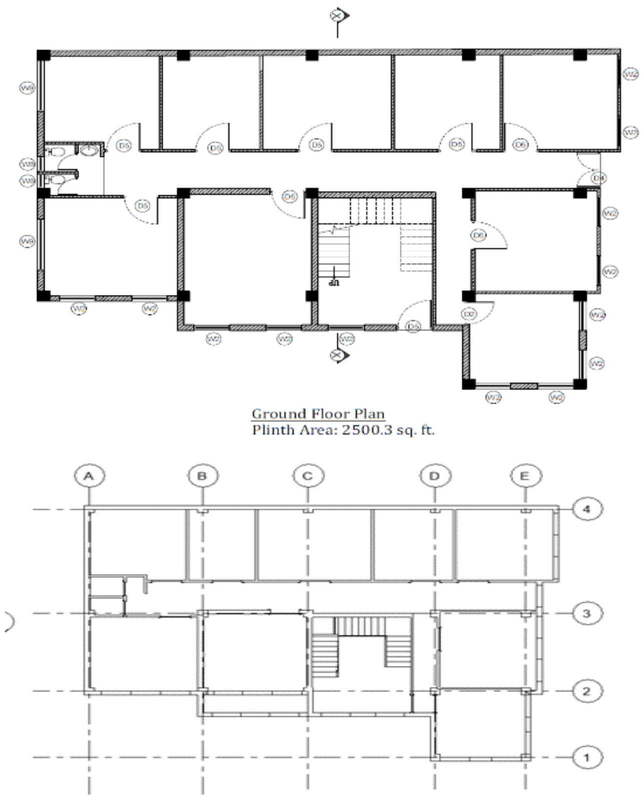

Figure 2. AutoCAD 2D architectural floor plan and structural 2D grid plan.

Step2: Development of BIM 3D model

Due to its IFC file format export feature for generating a 3D model, Autodesk Revit is ideal for the case study. Based on the level 1 BIM 2D AutoCAD, an initial layout in Revit was created, maintaining the original architectural design. In addition, the templates help in defining each floor level, elevations, the section in the design, and the family library would provide a variety of options for materials for building components needed for construction. Autodesk Navisworks would detect the clashes in the Revit design. The files supported on Navisworks are either IFC or NWC format exported from Revit design. The BIM 3D model comprises architectural and structural models. This study is limited to only two models: a) architectural and b) structural models, though the MEP model would add more detail.

A) Architectural Model

It is critical to have an extensive library of families because they make up much of the model's functional components. Serial numbers, precise weights, dimensions, and other non-graphical data are stored in families. It is required to have a template and a family library in Autodesk Revit before beginning a project. The template specifies how floor plans, sections, and elevation are represented in the design. Standard templates in the software are accessible; however, many applications have unique requirements. It becomes more accessible and quicker to draw a proposed 3D architectural model (see **Figure 3**) with family libraries and templates.

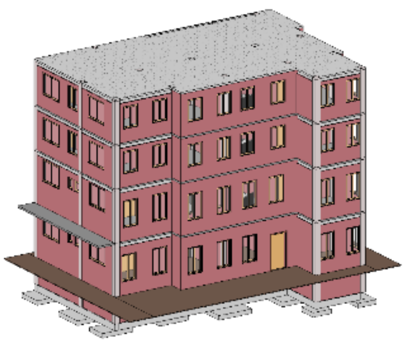

Figure 3. Revit architectural model.

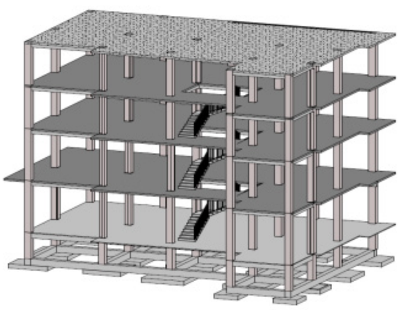

Figure 4. Revit 3D structural model.

B) Structural Model

With the 3D structural model of Revit, it is possible to visualise the structural part of the building in Revit. **Figure 4** shows the structural model of the commercial building. In this model, we can focus on the structural members of the model. The central structural units are the foundation, strap beam, plinth beams, columns, slabs, and floor beams.

Clash detection

Autodesk Navisworks performs the clash detection functionality in this model. In a building project model, clash detection aids in effectively discovering, inspecting, and reporting interference. One of the most important advantages of BIM is the capacity to detect "clashes" early in the project, when they are significantly easier, cheaper, and less time-consuming to resolve. **Figure 5** shows clashes between structural (Beam) and architectural components (wall) and it is detected a total 467 clashes.

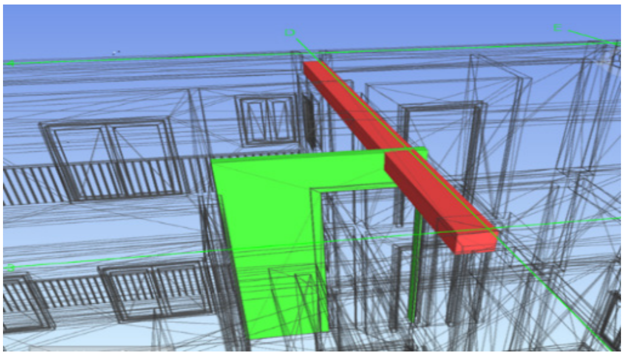

Figure 5. Clash on beam and wall.

Step 3: Development of 4DBIM model

Illingworth (2017) defined a project schedule as the arrangement of activities or resources in a sequential and managed way to execute or implement those activities so that the project manager can identify the critical or non-critical path. The various activities were listed and sequenced on a practical basis. Based on the experience and judgment of the planned activities, milestones are set to track the project's progress and priorities. Each activity's duration is provided and linked with suitable links. The exported IFC format file from Revit opened in the ASTA Powerproject as shown in **Figures 6 and 7**.

The imported BIM model into the ASTA Powerproject is checked with all the information provided on the Revit. Now the 3D model components are individually linked with the related task. For example, the wall components of the building in the 3D model connect to the construction wall activity on the timeline. The completion of linking each task with their completion time would be enough to get the critical path. The critical path depicts the project activities in a graphical format, which aids in evaluating parallel activities, creating a delay control strategy, and exercising judgment. We can also determine the most critical work in our project. It aids in comparing planned and completed tasks. As a result, it provides a map of the project at the planning stage, indicating where to begin and what decisions must be made [28]. A two-week delay in the strap beam would extend the project by three weeks. Here, the case study has compared the actual progress to the planned progress as shown in **Figure 8**.

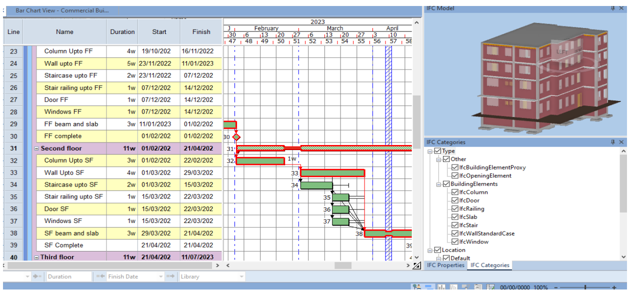

Figure 6. Project scheduling on ASTA Powerproject.

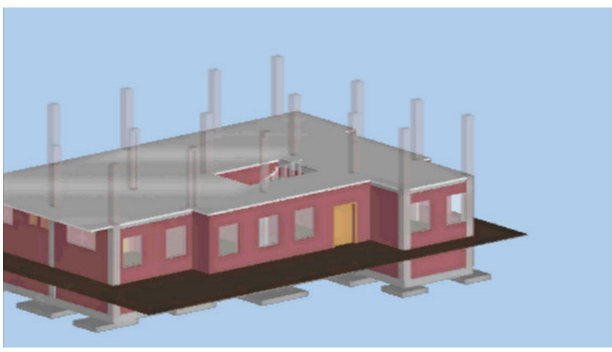

Figure 7. 4DBIM model on ASTA Powerproject.

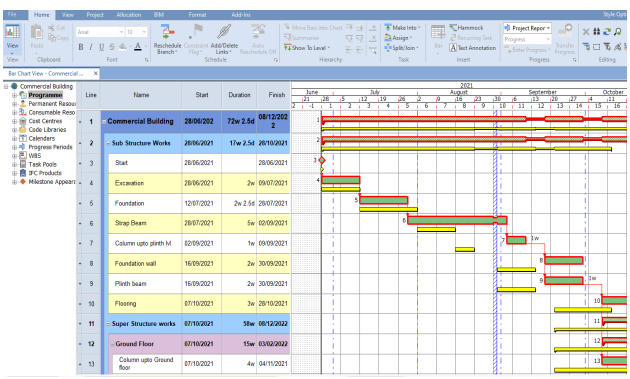

Figure 8. Project Tracking timeline.

4. Data collection and analysis

4.1 Research data collection

The study presents the qualitative data analysis of the viewpoints of key stakeholders of the AEC industry in Nepal about the challenges, applications, and benefits of 4DBIM. The data were collected via focus group interviews by running the demonstration of the developed 4DBIM simulation model to the different AEC professionals in Nepal. The professionals having experience of a minimum of five years in the design and construction sectors were targeted in the focus group interview. The participants are from the diverse professions of the industry from architectural, civil engineering, and contractor backgrounds. The interview was conducted online through social conferencing media like zoom and team.

It is found that 12 focus group interviews and a minimum of 3 focus group interviews are enough to get a saturated form data set [37]. It also argued that three focus group interviews should include enough data to notify the saturation [38]. Thus, this study has included three focus group interviews to validate the number of focus groups. The interview is recorded and saved in audio and video format considering ethical points. The main advantage of recording the discussion is that it helps to validate the research data [39].

4.2 Research data analysis

This section presents the systematic thematic analysis of the data gathered via the focus group interview according to the process outlined by Braun and Clarke [40].

Phase 1: Familiarization with data

All three focus group interviews lasted 2-3 hours and discussed ten qualitative questionnaires based on the case study and interrelating those benefits in Nepal's AEC industry. After performing the focus group interviews, the interpretative meaning of the interview is written. The initial codes with the transcript are studied to become familiar with the data obtained from the interviews.

Phase 2: Generating initial codes

Codes highlight a component of the data that the analyst finds noteworthy. They relate to the most fundamental segment, or part, of the information that may appraise meaningfully about the phenomenon [40]. The codes are generated manually based on an interpreted transcript. The study interviewed the architect, engineer, and contractor, and based on the answers presented and mapped the initial code onto the diagram as shown in **Figure 9**. The mind map diagram is shown below, which helps this study develop the initial regulations.

Figure 9. Mind map diagram for initial codes.

Phase 3: Searching for themes

The themes in the thematic analysis are one of the threads that combine all the codes and provide the generalized meaning. The formation of themes in this study requires further development of sub-themes. The results are generated based on the participant's perspective. **Table 2** shows the sub-themes and themes developed from the initial data analysis.

Phase 4: Reviewing themes

In this section of thematic analysis, the data review and refining are carried out (Braun and Clarke, 2006). The generation of themes as shown in **Table**

3 is based on refining the participants' ideas presented in the interview. Here, these two and "Project tracking as one of the benefits of 4DBIM" correlate with the same meaning to the planning procedures in 4DBIM and the sub-themes (integrated 3D models and schedules, 4D simulated video, project tracking, and project scheduling). So, these themes are merged into one theme.

Phase 5: Defining and naming themes

The generated nine themes as shown in **Table 3** from the codes help to analyse the sub-themes. This section provides the integrated meaning for the themes, and readers can identify what the theme is about [40]. These elegant themes in this study are in terms of the benefits, application, and barriers of 4DBIM in Nepal. So, providing the same category with the themes would define the overall objective. The category of 4DBIM benefits in Nepal has three themes: introducing a collaborative concept, being more efficient in planning than other traditional methods, and minimising time, cost, and waste of materials. Similarly, the application has two themes (suitability in residential housing and demand in government or international projects). Lastly, it identifies the barriers to 4DBIM in Nepal: Demand for government or international projects, the concept of design and construction, procurement system and contractor perspective, expertise on 4DBIM, and government policy.

Table 2. Sub-theme and themes development.

Category	Themes	Sub-Themes
4DBIM Benefit in Nepal	Introduces collaborative concept	Cloud-based working environment
		Early clash detection
		Integrated design
		Design and Build concept
	Efficient planning than other Traditional methods	Integrated 3D models and schedules
		4D simulated video
		Project schedules
		Project tracking
	Minimizing time, cost, and waste of materials	Early clash detection
		On-time delivery
		4D visualization
Application of 4DBIM in Nepal	Suitability in Residential housing	High design cost
		Benefit analysis
	Demand in government or commercial building projects	Detailed design
		Few firms are aware and implemented.
Barriers of 4DBIM in Nepal	Concept on design and construction	Municipal pass
		The architectural and structural requirements only.
		Competitive market
	Procurement system and contractor perspective	Petty contracts
		Fragmented works
		Multiple projects at the same time
	Expertise in 4DBIM	Training
		Availability of software
		Investment
	Government Policy	Standard BIM regulations
		BIM awareness

Table 3. Themes occurrence.

S.N.	Themes	Focus Group interview
1	Introduces collaborative concept	2,3
2	Efficient planning than other Traditional methods	1,2,3
3	Minimizing time, cost, and waste of materials	1,3
4	Suitability in Residential housing	3
5	Demand in government or commercial building projects	1,2,3
6	Concept on design and Construction	1,3
7	Procurement system and contractor perspective	3
8	Expertise in 4DBIM	2
9	Government Policy	1,2

Phase 6: Producing the report

The thematic analysis is adopted in this study to demonstrate data from the focus group interview. The overall procedures need to be written into the paper to validate and analyse the relative findings from the thematic analysis [40]. In summary, initially, the codes are generated from the interpretative transcript of the interview. The codes are divided and grouped into sub-themes that provide meaning to the codes. The sub-themes are categorised into themes that build a concrete sense in this study and align with to research objective. Thus, the themes are classified into three main findings of this study.

5. Results and discussions

Each category's results and themes are briefly discussed with the interview participants. The focus group discussion results offer the 4DBIM advantage in the Nepalese AEC industry and its implications and implementation obstacles.

5.1 4DBIM benefits in Nepal

In the focus group interview discussion, the participants presented their views and shared their experiences on the AEC industry's current scenario in Nepal. From the interview, it has been found that the industry needs some novel concepts that can solve the various issues in design and construction. For example, the issues in design and construction are the time overrun issues while running the project, better visualisation of the project, efficient designing tools, prediction of the impacts of the risk involved, communication gaps between the project stakeholders, and the management of project implementation.

Introduces the collaborative concept

Mostly, the architects in the interview felt that 4DBIM helps to collaborate while planning the projects. The design needs to be changed many times, which is one of the challenging parts of designing. Within the "Cloud-based working environment", various personnel can work on the same file, reducing design errors and immediately detecting and rectifying mistakes. The participants have mentioned that "early clash detection" also involves the collaborative concept by identifying the clashes and dividing them into different respective team members, which can lessen the work overload for one member. All participants have agreed that most of the AEC firms perform the non-collaborative design of the project. One of the participants in interview 3 mentioned that the architect designed the project in AutoCAD 2D; the structural engineer would design the structural part; there is very slight communication between the architect and engineer. So, these situations create a demand for "integrated design". In addition, the concept of "design and build" is gaining popularity to fill the communication gap between designers and contractors.

Efficient planning than other traditional methods

This result is based on the 4DBIM model presented in this study. The project offers the benefit of scheduling and planning in 4DBIM. Among the ten participants, eight participants confirmed that the 4DBIM provides better construction planning by showing "4D simulation video", "project schedules", and "project tracking". The video can give visualisation to non-technical people and detect errors in planning. The "project schedules" with milestones and work breakdown structures provide the proper sequence for the activities. The linking nodes help to figure out critical activities. Mostly the participants from engineers and contractors have appreciated "project tracking" on model presentation since it can measure the delivery of the project to the planned in terms of duration and completion time. Usually, there is a practice of scheduling the project activities using Excel or MS Project. All participants agreed that integrating the 3D model and linking those models to the schedules is a new concept in Nepal. The client was pre-informed that the project completion can be two weeks from the actual estimated completion due to his financial risk.

Minimizing time, cost, and waste of materials

From a profit point of view, one of the participating contractors thinks that "on-time delivery" will significantly reduce the material storage space, waste, and cost of the materials. "Early detection of clashes" provides the detection of errors so that the project in execution can omit those errors by resolving those clashes in design. Participants have shared their experience of the errors in design and the results on performance. All the participants agreed that early clash detection would help to minimise the materials' time, cost, and waste. The time-based simulation of 4DBIM modelling would create a virtual construction scenario where the designers, engineers, and contractors can understand the construction and construction sequence.

5.2 Applications of 4DBIM in Nepal

The focus group interview participants cited areas that the 4DBIM should focus on in its application. Based on the types of projects, this category results from the discussion that a 4DBIM is feasible. The lower-level application to a higher level is mapped while constructing the questionnaires and preparing for the interview. Throughout this study, most participants have highlighted its application to residential and high-budget projects.

Suitability in residential housing

Using 4DBIM for residential design and construction projects in Nepal is challenging. According to the participants, the preliminary design cost of residential housing will be relatively higher. The clients do not want to spend much money. The 4DBIM technology requires considerable time and resources throughout the design phase. After implementing 4DBIM, the designer would expect more in return. The participants felt that only a small number of residential dwellings have detailed designs. Simple residential homes rarely plan for MEP designs because the clients do not want to spend additional money on the project. Most participants felt that adopting 4DBIM in residential structures would be exceedingly challenging. Some participants suggested that "benefit analysis" could be an excellent way to change people's minds about the unique notion of BIM. Most interview participants agreed that Sketchup is easier to use than Revit. Almost every client nowadays wants to see their project in a 3D model.

Demand in government or commercial building projects

The participants have experienced 4D or 5D BIM design demands in government projects. These projects usually demand "detailed design" and are complex. Most of the participants have agreed on high-budget projects that are the most suitable for adopting 4DBIM in Nepal. In addition, internationally funded projects even require proper BIM implementation projects. One of the participants shared the requirement for BIM adoption in the JICA projects to reconstruct the school projects.

5.3 Barriers to the adoption of 4DBIM in Nepal

Professionals were asked to comment on and confirm the relevance of the 4DBIM and its barriers to adoption. The responses from the participants have developed themes relating to the potential barriers to adoption. The following four themes help to identify the challenges of 4DBIM in the Nepalese AEC industry.

Concept of design and construction

Participants agree that "municipality pass" requirements do not demand the 3D or schedules/plan. The primary focus concerns the structural and architectural plans of the building. They confirm that only AutoCAD 2D showing the minimal structural requirements, plans, sections, elevations, and site plan is enough for a simple housing project. Participants have agreed that most building projects do not proceed beyond the "architectural and structural requirements". The "competitive market" of the AEC industry is another factor in the hindrance of 4DBIM adoption. The clients seek an economical design of the building. But to adopt the 4DBIM, there should be a minimum requirement policy for BIM adoption, so that the competitive industry can provide better business value to BIM innovative firms. Before implementing the 4DBIM concept on the projects, the feasibility of the competitive market is the primary consideration for all participants.

Procurement system and contractor perspective

The "petty contracts" are the fragmented contracts from the main contract. Those contractors, primarily from small firms, are unaware of the present construction changes, and it is tough to change the working mentality of the most experienced contractors. Thus, this could hinder the adoption of novel technology in construction. If the design is based on 4DBIM, it is difficult to trace the work in execution. To trace the progress and implement the 4DBIM on the project while construction requires more human resources and costs to adopt.

Expertise in 4DBIM

Many architects, engineers, and contractors are not aware of the benefits of 4DBIM in Nepal. Those who are aware of them lack access to the relevant software. The purchase of the software is not that much easier because many of the banking systems in Nepal do not offer direct international transactions. Participants agreed that many professional firms use cracked software versions to design AEC projects. In contrast, advanced software like Autodesk Navisworks and Revit requires payment to use professionally. Training is one of the essential requirements in getting expertise in any software, but in the case of Nepal, it seems lacking due to difficulty in accessing the software. When users do not use that software, they cannot quickly adapt to professional careers. The other issue with adoption is that the return on investment is not satisfactory for the novel tools.

Government policy

The government has provided guidelines and specific codes to follow in Nepal while designing and constructing buildings. However, a lack of the strategy supplied by government guidelines for BIM requirements on construction projects. The participants have proposed that government support with robust policies and procedures can better implement BIM technology like the literature cited by different countries where BIM adoption has gained insight due to government guidance. The government can implement the pilot projects to show the 4DBIM concept from design till the closure of the project. Based on this demonstration, awareness will arise in the Nepalese AEC sector.

6. Conclusions and recommendations

The current construction practices in Nepal have severe issues with cost, time, and quality. Various research and practical life experiments have shown that 4DBIM can deal with these issues. This study has also shown that the adoption of 4DBIM is essential in the Nepalese AEC sector and noted the scope of implementation and barriers to implementing it in the Nepalese construction industry. This paper reported the findings of a 4DBIM simulation, which was demonstrated with a case study project of a residential building in Nepal. The first part of the study has developed a 4DBIM model and extracted the technical requirements and information for the project. Professional interviews were conducted within a focus group to evaluate the developed model and present the findings from the study.

6.1 Conclusions

The high design cost of the 4DBIM is the critical problem with its adoption in residential housing.

Government and commercial projects have some immediate relevance in Nepal since these projects have full support from the government with funding to invest in novel technologies. Most construction and consultancy firms adopt the traditional design and planning which are the initial barriers to 4DBIM adoption in Nepal. The lack of expertise in 4DBIM and the easy availability of splintered software are severe obstacles to its adoption. It is concluded that strong government support is needed to adopt the BIM concept at level 3 in the AEC industry in Nepal because the change is not easy and requires various policies to be changed and educating the AEC stakeholders about the BIM technology. Due to the competitive market in the AEC sector and initial investment cost in technology, small private firms cannot quickly adopt the BIM. The BIM requires comparatively high initial investment; hence, government pilot projects are the best way to demonstrate the BIM potential in Nepal.

6.2 Recommendation: Future study and limitations

In future work, the integration of 4DBIM with energy analysis could be an exciting topic in the case of Nepal. The baseline model and the actual 4DBIM model are yet to be compared with the cost, time, and human resources. The location of the observer and the accurate model have impacted the 4DBIM modelling. Despite these limitations, this study has attempted to provide an actual case study of a Nepalese residential building initially designed on AutoCAD 2D.

Conflict of Interest

There is no conflict of interest.

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