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Application of BIM in Nepal

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The purpose of this Bachelor's thesis was to identify the reasons of the low level of BIM technology development in Nepal and to determine the best applications of BIM technology in Nepalese AEC industries.

To understand the lack of BIM technology usages in Nepal, first, its origin and development history were studied and then its advantages and disadvantages were analysed. Then current situation of BIM technology in Nepalese AEC industries were analysed. Once the current situation of Nepalese AEC industries in regard of BIM was understood, how BIM was used to form innovative and effective solutions of AEC industries throughout the world was studied. After that the possible applications of BIM technology in the context of Nepal and the ability to meet these applications among limitation and disadvantages were verified.

Affordable Housing, Government Tenders, Heritage Buildings, Earthquake Resistance Buildings and Hydropower were identified as best applications of BIM for Nepal. Various cases of BIM application in these fields throughout the world were presented and their results were discussed. This thesis would be useful for AEC firms looking to provide innovative solutions using BIM models.

Keywords	building information modelling, BIM obstacles, BIM application, BIM technology, heritage BIM

Contents

List of Abbreviations

2D	Two Dimensional.
3D	Three Dimensional.
AEC	Architecture, Engineering and Construction.
BIM	Building Information Modelling.
CAD	Computer Aided Design.
CFD	Computational Fluid Dynamics.
FEA	Finite Element Analysis.
UAV	Unmanned Aerial Vehicles

1 Introduction

Building Information Modelling (BIM) is the process of generating and managing building data during its life cycle. Typically, this process uses three-dimensional, real-time, dynamic building modelling software that covers geometry, spatial relationships, geographic information, quantities and various other properties of an object to facilitate building design process [1]. BIM is changing the way Architecture, Engineering, and Construction (AEC) sectors are working and providing new processes for design solutions and construction collaboration [2]. Compared with traditional methods, BIM provides one solution that makes material quantity takeoff and cost estimate easier, faster, cheaper and more accurate. By using BIM tools and processes instead of CAD systems, numerous benefits can be achieved like material takeoffs, calculations, and measurements can be generated, revised and updated directly from the underlying models, which potentially saves time, cost and labour efforts, and facilitates the ease for collaboration and cooperation between various participants during material procurement processes. BIM integrated with ecommerce software applications provides potential benefits of streamlining the workflow of material quantity takeoffs, estimating, bidding and procurement stages of the preconstruction interactions among various construction participants. [3.] BIM also facilitates a variety of related material procurement activities including material specifications, design to digital fabrication, and quality inspection. However, very few efforts have been directed to the application of BIM in construction material procurement. Limited commercial BIM software, integrated with ecommerce software systems for material quantity takeoff, cost estimate or procurement, has been designed or developed by construction software vendors. [4.]

In Nepal, however, it seems that BIM technology has not flourished. Perhaps there are various problems and a lack of infrastructural development have stopped BIM from being widely used. It is possible that many areas of BIM application and usages are still left undiscovered. The market of innovative solutions that can be provided with the use of BIM technology is still untouched. The use of BIM has been limited to functionality of using 3D models for visualization. The round o'clock of BIM implementation from design through construction to operation and demolition are yet not practiced. BIM as a collaborative tool is seldom utilized.

1.1 Statement of Problem

AEC industries of world have greatly benefited from technological development of the last few decades. Many problems existent in AEC industries for hundreds of years have been solved and new possibilities have been identified. However, this is not the case of Nepali AEC industries. Surely Nepal too has benefited from these technological advancements, but the country is nowhere near the advancements made by the rest of the world. State of the art technologies like BIM still awaits to be used in its full extent. Technologies like these, when used properly, can provide major benefits not only for the industry but for the whole country.

In developing countries like Nepal, the problem is further amplified by a lack of technological infrastructure. The use of traditional constructional practices have limited any progress in modern construction techniques like modular construction. BIM aims to solve the problems by providing a means of proper communication between a client and contractor, simple design environment and database of information vital for constructional and operational purposes.

1.2 Objective

The main objective of this final year project is to identify areas of application for BIM in Nepal. To achieve an overall objective of work, this study will focus to answer out following research questions.

- How BIM is currently being used in the Nepali housing sector?
- What benefits can BIM offer to the Nepali AEC industry?
- What are the challenges in the adoption of BIM technology in Nepal?
- How to apply BIM to solve problems in the Nepali AEC industry?

2 Building Information Modelling

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

> *Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition*. [97.]

Building Information Modelling (BIM) technology is a process of compiling information of a building in such a way that the construction of objects, as well as possible changes over time, along with their characteristics, are presented in one place. In practice, BIM technology is used to create 3D models of buildings with the help of parametric objects that contain both graphical and non-graphical information necessary during a construction project lifecycle. The process incorporates both all stages of production and all life stages of a building, including data collection, design works, construction, equipment's operation, repair works and demolition. The information is generally sub-modelled into architectural, construction, economic and technological sub-models. [5.]

A BIM model contains geometric information of a building, as well as information about many other factors, such as the site, building materials, quality, cost quantity estimate, construction sequence, and schedule. The model is sometimes also referred to as a 4D model as the construction activities can be linked to the building components to simulate the construction activities virtually. BIM is a tool that enables the visualisation of a complete aspect of designing, constructing, operating, maintaining and renovating a building structure even before it is constructed. The BIM tool is useful for every stakeholder in a construction project and has various benefits. For example, developers can use BIM to track the progress, estimate the costs, and change orders, to name a few. Designers can use BIM to develop a functional building model, a constructor can use the model to extract constructional information. End user clients can use BIM models to verify that the building under construction meets their requirements. Clients can also use the as-built model later, after the construction for a smooth operation of the building. [6;7;8.]

2.1 History

The very early idea of BIM dates back to the 1960's. Though necessary technological advancements were still not made at that point, the very first concepts of BIM started surfacing in 1975, Charles Eastman laid the very first foundation of modern BIM technology in his paper "The Use of Computers Instead of Drawings in Building Design" [9]. Many industries moved towards object oriented parametric modelling by building sophisticated analysis tools, but the construction sector remained chained to 2D drafting only for quite some time [10, 11]. Some construction projects from the early 21st century started using BIM in engineering projects and saw the perceived benefits of BIM [9]. After that, research has been conducted to get BIM full featured. Various capabilities, such as design, planning, visualisation, data management, cost allocation, and data management, were developed and added [12]. After that, more complex features, like analysis, scheduling, and progress tracking, were added [13]. Currently, BIM utilisation is considered to be matured for design and construction activities, and the focus has shifted to its rapid utilisation in the operational phases, such as maintenance, renovation, and demolition [12, 13].

The earliest BIM tool to be used was RADAR CH released in 1984. This tool, later renamed to ArchiCAD in 1987, is still a popular BIM framework and is one of longest marketed BIM products. In 1988, Pro/Engineer, the first BIM software to provide parametric modelling, was released. Autodesk, which was hugely popular for its CAD tools, also got involved in BIM by purchasing Revit in 2002. Under Autodesk, Revit has become so popular that Revit nowadays is synonymous with BIM itself. [9.]

2.2 Advantages of BIM

BIM technology has lately revolutionized building industries. Many organisations have migrated from CAD to BIM solutions during the decade. Many countries now have mandated BIM in construction projects in some form. Some of the benefits provided by BIM technology are

- improved communication and teamwork
- cost assessment based on model
- change management
- project visualisation during planning stage
- effective clash detection and collaboration
- lower expenses and risks
- superior sequencing and scheduling
- improved work safety
- site safety. [8, 14.]

Modern BIM tools allow better teamwork, work breakdown, work allocation and assignment, distribution, sectioning and reporting of design and construction activities. This is virtually impossible with paper-based drawings. Modern BIM tools have a better project framework that allows for task assignment, issue tracking, cost tracking, material and budget estimation. Communication and teamwork also improve as all the stakeholders refer to a single source of information. This makes a traditional workflow process immensely more convenient. Changes can be easily tracked, supervised and approved by a project manager. [15.]

Not only in construction projects, but in any project, cost assessment and cost tracking play a vital role in outcome of project. BIM tools allow budget planning and expense tracking system. The budget plans are far more accurate than ones done by traditional methods. This is because a BIM model contains a detailed model of what is going to be built. It has accurate information on the material required, as well as time allocation. Cost information required to procure materials, as well as resource cost to build the component can be linked with BIM elements. With this information, the budget estimation becomes very precise and accurate, which is hard to beat with any other tools. Furthermore, if there is a cost overrun due to some unforeseen circumstances, the cost estimate updates itself to accommodate the required changes. This will also happen when design changes, project timeline changes or on any other changes. [16.]

Another great benefit of using BIM tools is that they make it easy to track changes. Changes are made included in the model instantaneously. One can also go through the changes to see what changes have been made. This allows for a side-by-side comparison of design before and after a change. BIM tools can also implement a hierarchical change monitoring system where the project administrator needs to approve every design change made by designers. When changes are made to a BIM model, all parties are instantly notified of the changes and their effects. This change tracking system becomes extremely useful when working with large projects. Additionally, as changes can be reviewed almost instantly on a single platform, it removes all hassles and paperwork in changing orders. [17.]

The BIM model is constructed during the planning period, well before any onsite construction work. Thus, it allows the stakeholders to visualize the whole construction process beforehand. It provides for a way to identify problems and weak spots very early in a project. As a virtual model is constructed, every aspect of the engineering model can be analysed. If there are specific needs and functions in the building, like in airports and malls, these requirements can be simulated and verified before actual work. This is one of the most valuable advantages of BIM tools: to get to see what is being built without actually building it on site. The virtual model contains all specific data to provide reliable information. The model can be tested for structural design, and application failures, and enormous amount of both time and money can be saved. [18.]

Clash detection and collaboration are another advantage of BIM tools. They allow different partners to get involved in the same set of models. Designers can immediately see the effects of their changes. Engineers can then analyse the design immediately after the changes are made. BIM also prevents any clashing between two parties by providing the same set of information. BIM also acts as a platform for sharing information and vision. Clash detection provides an opportunity for the stakeholders to see how different design discipline models fit with each other. Automated clash checking during the design phases for clashes between the plans of different disciplines help in removing potential clashes which would have a major impact during the construction time. Moreover, the information content and its validation support construction related activities like procurement. [19, 20.]

The fact that one can easily verify a BIM model for architectural, structural, functional and operational failure before a single brick in laid lowers the risk of the whole project. The non-occurrence of any faults and problems during the construction phase also means that the expenses of the project do not rise. A BIM model also provides a mean to optimize the whole project in terms of cost, tie or resources. [21.]

BIM tools shine when it comes to construction management. They provide a way to overview the whole construction process in a sequential order. That really helps in project manager adopt a superior project schedule. BIM provide a tine series of a project construction overview, which is phenomenal in providing extremely useful insights needed for project scheduling. This feature also allows for test sequencing of construction work. The ability to view the time series of a construction process really helps a project manager to test different sequencing and scheduling methods. Due to this, the project manager can easily implement an optimized schedule that meets the project criteria. [22.]

BIM tools allow architects and engineers to focus on what is important. They can now concentrate on design and test while getting rid of repetitive and mundane tasks like structural analysis, dimension, and operational tests since they are automated. Such automation allows engineers and architects to focus on the actual work to be done since they already know how the parts of the building go together in the design phase, which can increase the project productivity. [23; 24.]

This might be one of the most underrated benefits of BIM technology. Due to BIM, constructional failures are down to unbelievable figures. This reduces site related accidents and mishaps by a very large margin and hence creates a secure development site. The fact that the construction process is very efficiently scheduled means that there is also a very low risk of faulty conditions due to the schedule. Efficient scheduling ensures that work is done in a proper order and safely executed. [25.]

BIM eliminates many unnecessary aspects of construction and automates most of the remaining. As a result, projects are now completed faster than ever. During the design phase, the processes of design changes, verification and analysis are automated. During construction scheduling, processes like cost tracking and progress tracking are automated to a level. Furthermore, operation facilities are monitored, and maintenance is scheduled. The overall effect of this automation results in a decrease of the project duration. [26.]

2.3 Disadvantages of BIM

Although BIM technology is full of wonderful features and promises, it is far from perfect. Many times, BIM technology causes headaches which otherwise would have been nonexistent. Some major drawbacks of using BIM technology are:

- complexity
- cost
- conflict of interest
- incompability with partners. [27, 28.]

BIM technology is constantly developed and changing day to day. The constant additions of features make BIM hard to implement. Also, as this technology is quite new, there are not many experts in the field. New users of BIM technology find it quite hard to even started. Once the basics are mastered, the advanced features are even harder. Also, as BIM contains information from various sectors such as engineering, marketing, and operation, it is quite easy to get things mixed up. [29.]

Furthermore, BIM costs money and time to implement at the beginning. BIM software is very expensive. It takes years to develop the software and even after that, the software needs constant updates and addition of features. Therefore, the software costs thousands of dollars. In addition, the software is not enough; one needs people with knowledge of BIM to use the software. These BIM experts are not cheap either. [30, 31.]

Although BIM can be extremely helpful to solve conflicts of interest among different members in most of cases, sometimes it becomes a source of such conflicts. As BIM is a central database of all information, conflicts arise when information gets mixed up. Conflicts also arise when some users of BIM do not have clear idea of project. [32.]

BIM technology is still new and is far from being fully adopted. There is a high probability that not all the designers or stakeholders use BIM. This creates difficulties between partners working together as some may use BIM and some may have no knowledge about BIM. [31.]

Apart from these most common disadvantages, BIM technology has also many other problems, depending mostly on how BIM is being implemented. BIM sometimes causes the exact problems that it aims to solve. However, BIM technology overshadows its shortcomings by its feature and its promises to revolutionize the building industries. [11.]

2.4 BIM Methodology

There may be a standard schedule for BIM technology to implement, but it varies from company to company. However, there are certain process that always need to be carried out no matter how the technology is implemented, and which software is used [33].

Figure 1. BIM possibilities in different phases [34].

A list of the phases of the life cycle of a construction project lifecycle are categorized under three BIM applications and possibilities that are described below and shown in figure 1 above.

2.4.1 Design

Design is the very first phase of a BIM implementation in a project. At this phase, a detailed design of a project is created by understanding the needs of the client [8]. The aspects of BIM utilisation during the design phase, the requirement phase, conceptual design, detailed design, analysis and documentation, are discussed below.

Requirement phase

In the first step of the requirement capture phase, it is important to understand the client's demands and needs in order to progressively plan for the different possibilities of using BIM for it to have a positive impact throughout the project process. This phase, basically, focuses on gathering information about client needs, about the location and its zoning guidelines, as well as about possibilities of what can be built, and the process required for actions related with design and construction. BIM execution plan is normally started in this stage where vital information like BIM goals, processes, stakeholder information, roles and responsibilities, and project execution processes are outlined. This step is further attributed to the creation of a program required for the project. This includes a program formulation, for example, about different types of space requirements and type of building or construction. [35, 36.]

Conceptual Design

At the conceptual design stage, the very first sketch of projects are drawn. Ideas are constantly communicated to different stakeholders and changed according to their inputs, based on the project delivery method and taking the Integrated Project Delivery method for BIM into consideration. A conceptual design and its alternatives are prepared by the designers at this phase, and further developed after the approval of a selected conceptual design. [37.]

Detailed Design

At the detailed design stage, every partner has a clear idea of project. So, engineers and architects create a detailed design of the building. The design is created on BIM software and consists of 2D and 3D drawings. All information collected beforehand is used to enhance the design. At the end of this stage, there is a working BIM model that can be used for different applications. [38, 39.]

Analysis

During the various design phases, different types of analysis are performed according to the requirements of the project. For example, architects can create a visual study of daylighting based on the orientation of the building, optimize both the building material usage and its impact on the carbon footprint. Structural engineers can perform different structural analysis, like a structural stability analysis, load distribution analysis and an analysis of its impact on the structures. HVAC engineers can, similarly, during the design phases simulate building performance analyses, heating and ventilation requirements and so on. [40, 41.]

Documentation

At the documentation stage, a comprehensive documentation of a feasible design is created. BIM-based modelling processes support automated documentation. During the model creation processes, various interlinked documents are generated and updated automatically with minimal effort. The linked documents support various workflows and processes, and significantly reduces the amount of time required during the documentation phase. Design changes that happen during the design processes are well supported with the automatic update of the documents. The documents are used for the rest of the actions that are to be performed. These documents usually contain drawings and specifications, construction schedules, economic analyses, technical analyses and many other pieces of information that are required for the construction and operation of a project. [42, 43.]

2.4.2 Building

The next step after design is the actual building process. Building construction is a very challenging process. BIM technology helps building construction by properly analysing pre-constructed studies. These studies help to get more accurate estimate on construction schedule. BIM also helps in visualizing building through different construction phases.

Fabrication

At the fabrication stage, various prerequisites for the construction process are manufactured. The beams, truss and different other steel parts of the building are fabricated. At this stage, BIM provides information regarding quantities, sizes, quality and other relevant information required for the fabrication. After the fabrication, BIM informs all stakeholders about updates of status. The next process in the building phase of the life cycle is the actual construction. [44,45.]

Construction

The construction phase is very complicated in nature because of, among others, the involvement of multiple small and medium enterprises as subcontractors, the involvement of both skilled and unskilled laborer, and a wide range of building materials. Thus, the construction processes and activities need a careful planning and scheduling of tasks, materials, machines and people. Preliminary information required for such planning and management is extracted from various BIM models and planned accordingly. Virtual simulation possibilities and different systems integrated models provide the possibility to look into how different components fit with each other, providing a better understanding of the systems. [46, 47.]

Construction logistics

A crucial and laborious process during building construction is the logistics management. BIM technology helps here by providing a method to control the whole process of logistics management. One can manage vendor/suppliers, plan consumption, track consumption of different materials quite easily, as well as manage the inventory of different materials and equipment that are kept stocked. [48.]

2.4.3 Operation

At the operation stage of a building, maintenance and renovation of the building are taken care of. The interior designs and colouring according to the clients' desire can be done in this phase.

Operation and Maintenance

BIM tools also helps in the operation and maintenance of a building after the construction process is complete. A BIM tool can help in planning the operation process of the building. A BIM tool contains actual information of how the building is constructed, including all information about spaces, and elements that constitute different segments and parts of the building. This helps in effectively utilising those parts by simulating different scenarios in BIM. The elements can also be scheduled and tracked for maintenance in BIM. [49.]

Renovation

As BIM contains information about a building and about how it was built, one can easily use it to plan and execute renovations in buildings. The proposed changes can first be planned and designed in a BIM tool to check whether they are actually feasible. After the design is finalized, the actual renovation process can be tracked with BIM. After the renovation is complete, the BIM model is updated to accommodate the changes. [50.]

3 BIM technology in Nepal

BIM is still in incubation in Nepal, but that does not mean that it is nonexistent. BIM is beginning to gain popularity in the housing sector, but it is seriously limited to the design aspect. Nepalese architectural firms have used BIM tools to visualize building design before construction, as well as for structural analysis. As the design firm and the construction firm are usually different companies in most cases of Nepal, the BIM model is never passed to the construction phase. Operation, maintenance and renovation are carried out according to the documents. Some engineering firms that provide both design and construction services are also only use BIM for the design phase. [51, 52.]

However, the involvement of international AEC companies in large projects has ensured that certain projects do use BIM to a greater extent. Many large transports, hydropower, airport and stadium projects use BIM. Projects dating back to late 90’s have been found to implement BIM. In most of these projects, as there is a local partner for the project completion, the technological transfer will hopefully increase the adoption of BIM by Nepalese firms. [53.]

3.1 Current Scenario of BIM in Nepal

A recent study shows that BIM is used to any scope by only 23.25% of the construction firms in Nepal. The study was conducted among sixty-eight construction companies currently operating in Nepal. [54.]

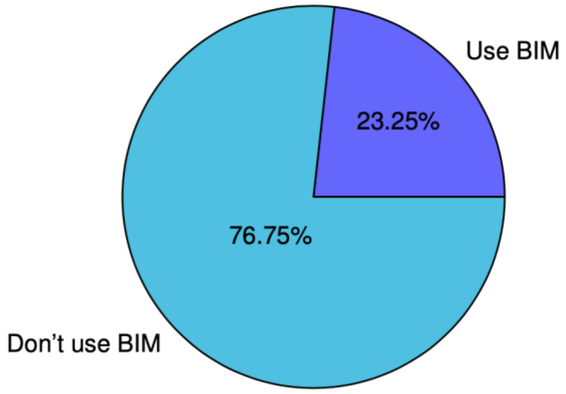

Figure 2. BIM usage among AEC industry in Nepal [54].

Among the firms using BIM tools, 81.25% were using Autodesk Revit as their BIM software, while the remaining 18.75% all used Graphisoft ArchiCAD as their prime software. Among the firms using BIM were all limited to using BIM only in the design phase only. BIM was non-existent in construction, operation, maintenance and renovation phases, as seen in figure 2. [54.]

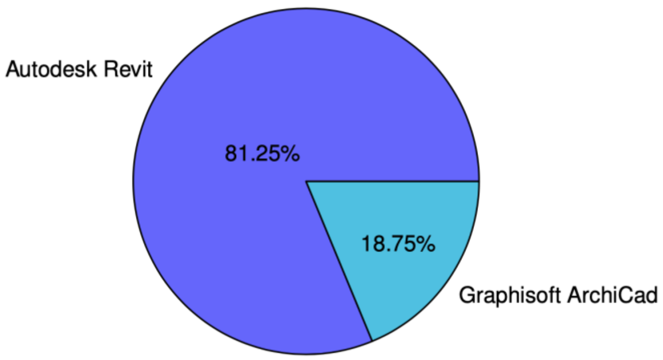

Figure 3. BIM software share in Nepal [54].

The data presented in figure 3 shows that the usage of BIM is greatly limited in Nepal. The AEC industries have relied upon traditional 2D based design methodology and traditional construction management processes. BIM as a complete solution to building construction has never been practiced. Some housing companies use BIM tools to create 3D models of buildings, but they are incomplete. [55, 56.]

3.2 Challenges for BIM in Nepal

Building Information Modelling is a continuously evolving technology, which is facing problems in adoption. This is because of the continually changing modern design requirements and the sustainability of technology in itself. The rapid development of new technology, multiple competitors, higher costs, less Custer demands, lower technical background, and limited software knowledge are only some barriers against the adoption of BIM in Nepal. Clients' expectations of visibility of design works as represented by modal works, where contractual implication does not let complete design are also problems in BIM. [57.]

Business goals, work processes and information technologies are tightly coupled. Changes in business goals require changes in work processes which can be achieved through the use of information technology. But in Nepal, the organizational structure of the AEC companies has not changed much to accommodate Information Technology and computer aided designs. Similarly, Nepal's transnational business processes have not evolved much to automate extraction of business data from computers Model. Another major challenge identified is knowledge transfer. Knowledge transfers are largely affected by a lack of understandings of the knowledge transfer and the interrelationship of both firm skills and procedures. Furthermore, there are not enough preexisting transfer mechanism and manpower. [58.]

On a study on AEC industry, it was established that although BIM technology has benefited the profession, practical issues have limited the implementation [59]. An inefficiency in properly utilizing new technology, a lack of resources in a company to invest in new technology, the cost and time of implementation, slow software learning curves, and high initial investment required are among the factors that limit companies from properly utilising BIM tools. The profitability of a company is highly affected by these factors. Therefore, companies are reluctant to migrate. Another aspect of difficult implementation arises un managing the risk and liabilities through BIM tools. Additionally, financial disincentives, high equipment cost, inadequate technology transfer, inadequate basic and industrial R & D, adversarial relationships, poor leadership, inflexible building codes and standards and construction based initial costs also become important factors. [30, 60.]

Another research done into the BIM process itself points out that the BIM tools in question themselves seriously implicates the adoption. Performance barriers of software, ability of software to handle complex requirements, integration of models to multiple sources, speed and drawing extractions all act as barriers against the adoption of BIM in an organisation. Other inherent problems in the adoption of BIM include a lack of mutual recognition of the need for innovation, insufficient technical capabilities and lack of skills, reluctance to change, inexperienced team members, lack of training, weak commitment and support by the administration , inadequate resources, deficiency in integration and collaboration, poor learning environment, lack of incentives and the difficulty to comply with the existing regulations and established standards. [61.]

A list of challenges that are major barriers against using BIM in Nepal are

- high software cost
- high setup cost
- lack of skilled manpower
- absence of supporting technology
- lack of interest in clients [62].

BIM tools and software's are expensive. Nepal is a small market for AEC industries, most companies do not have enough revenue to justify the purchase of such expensive tools and software. Companies who, however, buy such tools cannot offer competitive prices to get enough costumers. [63.]

Apart from the cost of software, the use of BIM tools incurs other indirect costs that form a fairly big sum. Running such software requires high end computers, skilled employees and much more. As BIM is more inclined towards automation it requires other supportive tools and equipment which are also expensive to fully function. [62, 63.]

Another key barrier against BIM implementation is the lack of manpower. There are not enough people that properly understand the concepts of BIM to fully implement it. Additionally, the steep learning curve of BIM software means that training new people to use BIM is also a time and resource consuming process. BIM tools are sophisticated and incorporate lots of different areas of the AEC industries. Using all those features require people that are seriously skilled in BIM. [64.]

BIM technology is a highly advanced, integrated tool, which requires many supportive technologies and equipment to be in place. As Nepal is lagging in technological development, this becomes a major obstacle in adopting BIM. [65.]

For BIM to be fully functional, it needs to be operated and used by the clients of a project too. But at the present state of Nepal, house buyers do not have enough knowledge about BIM to use it effectively. In addition, the clients are reluctant to learn and use BIM tools. This is a major problem in the adoption of BIM as it is quite difficult to solve immediately. [62, 66.]

3.3 Application of BIM in Nepal

BIM is a very promising tool in the AEC industry. It has shown its potential to solve many existing problems in the field. The AEC industry of Nepal has lacked technological advancements made by other AEC industries around the globe. BIM is one of such technological advancements that has ´not been used to its potential by Nepal’s AEC industry yet. [65.]

Throughout the world BIM has been used to solve various problems in design, construction and operation phases of projects. Application-specific problems are solved easily by using BIM. In sectors from housing, to commercial complex to airports and power stations, BIM has been able to provide solutions. In the housing sector, BIM has been used to design for example energy efficient buildings, smart homes, affordable homes, and space efficient homes. In other fields BIM is mainly used to solve structural and architectural problems. [67, 68.]

3.3.1 Affordable Housing

Affordable housing, as defined by the U.S. Department of Housing and Urban Development (HUD), states that a household is not to pay in excess of 30% of its annual income for housing expenses [69]. The margin of 30% of annual income is set because paying more than this will result in cost burden affecting money left for food, clothes and other basic needs. Thus, for housing to be deemed affordable, its monthly costs, including rental fees and utilities, should be less than 30% of the monthly family income.

One of the major applications of BIM lies in the Nepali housing market. Traditionally, houses were built without any proper design and planning. The experience of a construction worker was the key in building houses that are good. Nowadays, 2D drawings of buildings are created and verified before construction, in most cases. Some handful of people also build 3D models. The problem with this type of working process is that one cannot truly experience the building before its construction. Also, it becomes very difficult to renovate and modify buildings after construction. BIM excels in these scenarios as it allows the users to visualize and have the living experience of a building before it is constructed. Customers can review 3D models to get proper understanding of the building being constructed [70, 71]. BIM also enables for designers to share and show their ideas more clearly to the costumers. The customers can visually compare different options available without the actual process of building construction. The customers can also get a time, budget and benefits comparison of the different options. Changes made according to costumer requests can be quickly visualized too. As the costumers get involved in each decision of the design and construction process, they gain confidence over the organisation. This results in happy costumers of the AEC industry. Furthermore, with an average annual income just above $3,000, affordable design becomes very important. Affordable building designs are made on renting mode of ownership and are more suitable for city areas where people mostly rent their dwellings. [72, 73.]

Table 1. Housing topology in Nepal [74].

Type	Description	Composition
Permanent	Burnt brick with cement mortar or concrete blocks	27%
Semi-permanent	Stone, soil, sunburnt brick	51%
Temporary	Wood or bamboo reinforced walls with mud plaster	22%

The construction industry contributed to 10% of the National GDP of Nepal in 2018. About 30% of the construction income is estimated to originate from the housing sector. And even though table 1 above shows housing units in Nepal are not up to par standards. Apart from the advantages mentioned above, BIM has much more to offer to the housing sector. BIM models can be used to verify that the built housing units comply with the regulations. BIM models can also be used to check if the structural design of a building meets the guidelines issued for an earthquake resistant building. In apartment and bid housing building designs, BIM models can be used to simulate people flow, which helps in optimizing the entry and exit systems. [75.]

Table 2. Cost savings on Alley Flat Initiative [76].

Serial Number	Sector	Saving
1	Design Time	2%
2	Construction Time	10%
3	Material Cost	6%
4	Energy Cost (per month)	16%

According to a result published in 2010 for the alley flat initiative of Austin, Texas, BIM was extensively used to design and develop affordable buildings, can be seen in table 2. These buildings were able to save 10% in construction time and 6% in material cost. The utility expenses were brought down by careful design of the building, allowing for an extensive use of natural energy. The energy expenses alone were reduced by 16%. [76.]

Table 3. Cost savings on Ahmadabad housing [77].

Serial Number	Sector	Saving
1	Design Time	7%
2	Construction Time	4%
3	Material Cost	8%
4	Energy Cost (per month)	23%

A project of similar nature but in a lesser scale was carried out in Ahmadabad India as in table 3. The results found were similar except for the design time. Design times increased by 7% on the BIM models of the project. This might be due to technical difficulties faced because of lack of expertise, or simply because designing low-cost energy efficient building was a difficult task. The savings made on construction materials were 8%, while the energy cost was reduced by 23%. [77.]

3.3.2 Government Tenders

Another important application of BIM in Nepal is in government projects. Government projects of Nepal have been plagued by delays, poor quality, budget overruns and many other problems. Currently, consultants only provide 2D drawings to contractors for construction work. By applying BIM in this process, these problems can be eliminated completely. 3D information models of BIM tools provide very advanced tools for quantity and cost estimation. This helps in solving problems of budget overruns. The sequencing and scheduling features of BIM helps to properly plan the construction process, which greatly reduces delays in project. In addition, the use of BIM models ensures that the consultant and contractor work more closely together. This ensures that the whole knowledge of a consultant about the design is transferred to the contractor. Furthermore, by using BIM tools the whole process of construction verification is automated and now consumes less time. BIM tools also ensures that government officials and regulatory bodies can remain updated about the progress of a project all the time. BIM tools also allow for keeping track of transactions between various parties. This makes corruption much harder. [78, 79.]

According to Marzia Bolpagni, the possibilities of implementing BIM on public procurement are discussed. In the design-bid-build process, Bolpagni states that BIM models have the best methods of describing the client's requirement. If BIM is an official tender document, the client is responsible for its content and the design team must check its quality before delivery to the bidders. Thus, the contractors do not have to check and eventually correct the models themselves anymore. Additionally, the complexity of a project is clearer for the bidder. In addition, BIM models contains data that can be extracted and consulted. For a case, bidder can extract a bill of materials and prepare cost estimate faster and more accurately. Even doing so, the final estimate would be low due to the optimisation carried out within BIM for material. For this reason, the final offers will be more reliable and the gap between the tender price and the final one will be reduced. The quantity takeoffs can also be used also to generate a time schedule and a draft of the supply chain management, if requested in tendering. Thanks to an easier way to calculate quantities the bidder can save money and prepare a more convenient offer. [80.]

In case of bid for design, BIM models can be useful for both the client and designer. Clients can fill a requirement on a BIM tool that ensures that enough information to develop the design is acquired. In paper-based system this process is tedious as the information provided by the client may not always be enough. Furthermore, taking advantage of the collaborative tools of BIM, clients can track the progress of work. And thanks to the 3D modelling process, the design can be easily visualized and checked for compliance. The model can also be automatically analysed and checked for structural compliance. [81.]

3.3.3 Heritage Buildings

Nepal is culturally rich country. Many different cultures have their own traditional building design methods. These architectural masterpieces of different cultures are mostly visible in Durbar and Mandirs, but they are getting extinct day by day due to a lack interest from people towards their culture. These cultural heritages are a living proof of complex architectural practices of the previous generations. The designs embedded are masterpieces of their own. Skills needed to build such buildings without any machines and computers are lost today. However, BIM can help preventing these designs from getting extinct. Throughout the world, BIM has also been used to construct models of pre-existing buildings to help in operational problems and renovation. BIM can be used to capture and preserve the architectural details of such existing buildings. This will help in preserving Nepal's cultural heritage and renovating them in upcoming years. The model can also play an instrumental role in teaching new generations about traditional building designs. The BIM models can also be used to construct new buildings with traditional designs. [82, 83.]

This aspect of BIM is now developed under Heritage Building Information Modelling (H-BIM). H-BIM can be used to record such features as the geometry, materials, textures, and relationships between features of a historical monument [84]. In recent years, a lot of work has been done in the HBIM sector. The case study made by Arayici, describes how Manchester city hall has been refurbished using BIM modelling [85]. Table 4 below has enlisted many such applied cases of H-BIM throughout world. As of 2017 there have been more than 100 HBIM case studies which have been done either to understand the heritage, preserve it or for reconstruction [86]. Table 4 below shows just how diversified the application of BIM to heritage sites could be.

Table 4. Number of published H-BIM case studies and their purpose by 2017 [86].

Serial Number	Purpose	Number of cases
1	Testing BIM for heritage	15
2	Planned conservation/FM	19
3	Archaeological/architectural studies	12
4	Restoration project	12
5	Representing historical stages	9
6	Valorisation of heritage	14
7	Energy/wind/sunshine analysis	7
8	Degradation analysis	6
9	Structural analysis	6
10	Virtual reality	2
11	3D printing	2

BIM models of pre constructed buildings are generated mostly by using digital photogrammetry with laser scanning method. Lately this method has been used in conjunction with UAV’s to capture images from different viewpoints and triangulate depth. LIDAR and camera fitted within UAV’s provide images with all necessary information for modern software tools to convert the information into a 3D model. These 3D models are then converted into BIM models. These models preserve all available architectural detail. [87.]

Many such heritage buildings exist in Nepal, and most of them are inside the Kathmandu valley. Many of them were destroyed in the earthquake of 2015, including world heritage sites like Basantapur Durbar square, Bhaktapur Durbar square and Patan Durbar square. The reconstruction process was very difficult as materials and skills used to make the buildings did not exist today. With BIM models it would have been much easier to reconstruct and repair such damaged heritage. Apart from renovation, such BIM models when constructed could be used for virtual tourism, which is another emerging and interesting application of BIM models. Furthermore, these heritage buildings attract a lot of tourists and the models could be utilized to formulate an operational plan to manage visitors. [88, 89.]

3.3.4 Earthquake Resistant Building

Nepal lies among one of most susceptible countries for earthquake. These events of devastating magnitude have affected the country many times in the past. The earthquakes of 1934 and 2015 ¨killed tens of thousands of people and damaged buildings in even greater amounts, in many hundred thousand. Scientific researches have, furthermore, shown that these earthquakes will not be the last ones either. The number of buildings destroyed in the earthquakes of 2015 is shown in the table 5 below, according to the functions of the buildings. [90.]

Table 5. Destruction data of Nepal earthquake 2015 [90].

Serial Number	Building Type	Number
1	Government	6,400
2	Health	960
3	School	8,500
4	Private	600,000
5	Partially Damaged	285,000

For a building to be earthquake resistive, it needs to follow the building acts, laws and criteria. A catalogue for construction has been published by the Department of Urban Development and Building Construction (DUDBC) to every construction sector in order to spread the knowledge of seismic vibration, the damage that it can cause, and about preventive measures. Attention was paid to houses in cities and villages. DUDBC have decided to divide the building materials into four categories: stone and mud mortar masonry, brick and mud mortar masonry, stone and cement mortar masonry and brick and cement mortar masonry. [91.]

Although BIM cannot eliminate earthquakes, it can surely help containing the damage done by one. Incorporating BIM in early design phases can ensure that all earthquake resistant building criteria are met. BIM can also be used to design and test newer earthquake resistive techniques. [92.]

3.3.5 Hydropower

BIM has become even more common in the design, construction, and management in the construction field, and recently BIM has attracted some attention from the hydro power sector. There are some examples of hydropower projects that have adopted BIM. Some examples are the construction of the Guanyinyan Hydropower Station on Jinsha River, China, the Smisto Hydropower Project, Norway and the Keselstraße Hydroelectric Power Station, Kempten, Germany. BIM technologies can be used throughout the hydropower project. The process starts at site information modelling by collecting detailed information about the geographical information about the site. From there the project migrates to facility information modelling where the designs of buildings and facilities to be built are designed, including head works, tunnels, buildings, and dams. Next step would be design validation, where tools like FEA and CFD are used to analyse and validate the design parameters. After this, the project moves to construction and then operations. [93.]

Hydro power in Nepal has great potential and it is one of the growing fields. Nepal's theoretical capacity for producing power from hydropower projects is around 80,000 MW. However, as at 2014, installed capacity is only around 700 MW of electricity, despite the fact that the demand is over 1,000 MW. Thus, Nepal remains one of the lowest energy consuming countries in the world. The demand for electricity is increasing at 7–9% per year, and according to the forecast from Nepal Electricity Authority, the demand for electricity will reach 3,600 MW by 2027. To deal with the shortage of electricity in Nepal, IBN and other government agencies have stepped forward to implement mega hydropower projects. In September 2014, Nepal signed its first Project Development Agreement (PDA, concession agreement) with a private developer, GMR LTD, to develop the Upper Karnali Hydropower Project, a 900 MW project. IBN has also signed another PDA with SJVNL, an Indian governmental entity, for the development of the 900

MW Arun III. The combined cost of these two projects exceeds USD 2.5 billion. In addition, Nepal has signed the Power Trade Agreement (PTA) with India, paving the way for a free flow of electricity as a commodity across the border. [94.]

BIM is already used in various hydropower projects. Some examples are the construction of the Guanyinyan Hydropower Station on Jinsha River, China, the Smisto Hydropower Project, Norway and the Keselstraße Hydroelectric Power Station, Kempten, Germany [93]. In the work of Zhang S., Pan F., Wang C., Sun Y., and Wang H., BIM is used as a tool for collaboration [95]. This work is by far the most extensive work done on BIM in the hydropower sector. Zhang S., Pan F., Wang C., Sun Y., and Wang H. have developed a web based digital collaboration tool based on BIM models, as collaboration with all stakeholders is a major issue on such large EPC projects. The Keselstraße Hydro-electric Power Station has a different story of BIM usage. The Keselstraße Hydroelectric Power Station had a unique problem, it had to be harmonious with nearby protected buildings. This was a major issue as conventional hydro power design is more focused on structural capacity than architectural elegance. Here, BIM was used to design an architectural masterpiece element with a dynamic and elegant shape that immediately catches the eye in the new central on the river Iller in Kempten. The "shell" of the sculptural form, almost 100 meters long, brings to mind many associations of ideas: from whales to ships, to smooth stones. The plant replaces a building from the 1950s and supplies energy to around 4,000 households, with a capacity estimated at around 14 gigawatts per year. [96.]

4 Discussion and Conclusion

4.1 Discussion

At the present, Nepal is lagging behind other countries in adopting BIM technology. Developed countries which have mandated the use of BIM in construction projects have used BIM to its full potential. The lag in adoption is mainly due to the technological gap between Nepal and the developed countries. Developed countries like the UK have used BIM to introduce newer, more efficient and faster construction methods like modular construction, components and assembly-based construction, and automation, but the Nepalese limited AEC industries who have been using BIM are also limited to the design of buildings.

On the other hand, the gap is not that large. As BIM is a relatively new technology constantly evolving, it is not impossible to catch up with the world. To do so, Nepal needs to address the problems that affect the BIM implementation in the first place. Problems like high initial setup and software costs should be solved by the government at a national level. This can be done by subsidizing or mandating the use of BIM. However, other problems are more related to multiple issues than a single one. All other problems seem to have their root cause in the lack of technological infrastructure in the country. Skilled manpower on BIM tools can only be available if there is enough technical infrastructure to support BIM usage. On the other hand, clients can only get any idea and interest in BIM with gradual progression.

Based on the findings of the thesis, it can be said that adopting BIM in the housing market could revolutionize the current housing market of Nepal. It could help solving existing problems of the housing sector as well as bring some additional benefits. BIM provides a better platform to get connected with clients and house buyers right from the design process. This, in turn, helps in gaining confidence of the buyers as they feel involved. It also helps in raising the living experience of the buyers as they get to put their preference right from the design phase. Additionally, BIM can improve work efficiency, assist in faster project completion, support safe and efficient construction work and guarantee an easy handover of a project. Information available in BIM models becomes useful in knowledge transfer from a contractor to clients.

The study also showed that adopting BIM in designing earthquake resistant buildings can help build safer buildings. In an earthquake prone country like Nepal, this would surely reduce the fatalities in case of such events. The government could also use BIM models to verify the design of buildings against the regulations. BIM tools could implement various building design methods, as well as aid in developing new ones through the process of simulation. Building models built in BIM tools can be analysed for structural failures before construction, as well as tested for response with seismic shocks. This helps in ensuring compatibility of a building prior construction.

BIM in the field of heritage building offers something different. In all other cases, BIM offers state-of-the-art features and problem solving of modern rapid construction. But when it comes to heritage buildings, BIM models can be utilized as a means of preserving ancient architectural masterpieces, and the skills used to make these which may otherwise be lost. In addition to preserving old heritage, the models also become useful in case of renovation and operation. Another application that has arisen in this sector with the advancement of VR technology is of Virtual Turism. Here, people sitting far away in their homes can enjoy travelling through these heritage sites with the use of VR and BIM models. Lastly, BIM models of heritage buildings can be used to teach younger generations about the glorious work of their ancestors.

As discussed in chapter 3.3.2 above, Government tenders in Nepal have long been plagued by delays and bad workmanship. The adoption of BIM models could have the biggest impact here. The current governmental procedure only allows for the transfer of 2D drawings from consultant to contractor. Such documents cannot encompass all information collected and utilized by the consultant. As a result, contractors can have a hard time performing the work up to specification. In later stages, the consultant has a difficult time while auditing the work done by the contractor as, again, knowledge about construction is not shared. As a collaborative tool, BIM can excel in this aspect by providing a platform for sharing and searching information.

With lots of different hydro power projects launching every year, hydro power is clearly one of most busy sectors in Nepal, as shown above in chapter 3.3.5. Unlike the types of projects discussed above where BIM offers a clear advantage, there is no advantages offered by BIM in this sector. BIM is required in hydro power projects because of the sheer amount of work to be done and the complexity of the projects. These projects would be nearly impossible to complete if done otherwise.

4.2 Conclusion

Currently, the use of BIM technology in Nepal is seriously limited. However, this can be changed. With effective planning and execution by the government and some enthusiasm from the private sector, the scenario could be different in no time. Especially in the housing sector the adoption of BIM would be a somewhat simple and straight forward process, compared to many other uses of BIM. Skills in the use of BIM tools can be developed quickly with practice. As shown in the thesis, the advantages brought by BIM technology are second to none. With the whole world welcoming and adopting BIM, it is now Nepal's turn to do so. BIM tools have solved centuries old construction problems. As shown in the chapters above, BIM, as a computer based modern tool, is highly automated and only requires minimum effort to function once the usages are mastered. The BIM tools have allowed many developed countries to adopt modern, better, faster, automated construction process. In addition, BIM as a database of information has helped solving problems in the effective utilisation and operation of a building, maintenance scheduling, renovation and many more. The BIM technology has evolved constantly and new features are added almost daily. BIM is a technology of the future and, thus, it is future proof to invest and adopt in BIM technology now.

The application of BIM technology is only limited by our imagination. With the technology behind these tools improving, newer and more innovative applications of BIM are emerging. This thesis has identified five application areas for BIM which offer most for Nepal: housing, hydro power, heritage buildings, earthquake resistant buildings and government tenders. These sectors contribute most to the construction activities within Nepal. For these sectors, advantages offered by BIM tools outweigh the drawbacks by a clear margin.

References

1 Castro-Lacouture, D.; Medaglia, A.L. & Skibniewski, M. 2007. Supply chain optimisation tool for purchasing decisions in B2B construction marketplaces. Automation in construction, 2007 Aug 1, Vol. 16 Iss. 5, pp. 569-575.

2 Grilo, A. & Jardim-Goncalves, R. 2010. Value proposition on interoperability of BIM and collaborative working environments. Automation in construction, 2010 Aug 1, Vol. 19 Iss. 5, pp. 522-530.

3 Holness, GV. 2008. Improving energy efficiency in existing buildings. ASHRAE Journal, 2008 Jan 1, Vol. 50 Iss. 1, pp. 12-21.

4 Grilo, A.; Zutshi, A. & Jardim-Goncalves, R. 2011. Business Interoperability in the context of BIM-based projects. CIB W78 2011: 28th International Conference, 2011.

5 Milyutina, MA. 2018. Introduction of building information modelling (BIM) technologies in construction. InJournal of Physics: Conference Series 2018 May, Vol. 1015, Vol. 4, pp. 420-438.

6 Azhar, S. 2011. Building information modeling (BIM): trends, benefits, risks, and challenges for the AEC industry. Leadership and management in engineering, Vol. 11 Iss. 3, pp. 241-252.

7 Goubau, T. 2016. What is BIM? What are its benefits to the construction industry? Online. LetsBuild. <https://www.letsbuild.com/blog/what-is -bim-what-are-its-benifits-to-the-construction-industry>. Accessed 12 September 2020.

8 Kjartansdóttir, I.B.; Mordue, S.; Nowak, P.; Philp, D. & Snæbjörnsson, J.T. 2017. Building Information Modelling-BIM. Warsaw: Civil engineering faculty of Warsaw university of technology.

9 Eastman, CM. 1975. The use of computers instead of drawings in building design. AIA Journal, 1975 March, Vol. 63 Iss. 3, pp. 46-50.

10 Aram, S.; Eastman, C. & Sacks, R. 2013. Requirements for BIM platforms in the concrete reinforcement supply chain. Automation in construction, 2013 Nov 1, Vol. 35, pp. 1-7.

11 Gray, M.; Gray, J.; Teo, M.; Chi, S. & Cheung, Y. K. F. 2013. Building information modelling: an international survey. In Manley, K; Hampson, K & Kajewski, S (Eds.) Proceedings of the 19th International COB World Building Congress, Brisbane 2013: Construction and Society. Queensland University of Technology, Australia, pp. 1-14.

12 Penttilä, H.; Rajala, M. & Freese, S. 2007. Building information modelling of modern historic buildings. Online.

<http://papers.cumincad.org/data/works/att/ecaade2007_124.content.pdf>. Accessed 12 Sep 2020.

13 Becerik-Gerber, B.; Jazizadeh, F.; Li, N. & Calis, G. 2012. Application areas and data requirements for BIM-enabled facilities management. Journal of construction engineering and management, 2012 Mar 1, Vol. 138 Iss. 3, pp. 431–442.

14 Diaz, P. M. 2016. Analysis of benefits, advantages and challenges of building information modelling in construction industry. Journal of Advances in Civil Engineering, Vol. *2* Iss. 2, pp. 1-11.

15 Mohandes, S. R. & Omrany, H. 2015. Building information modeling in construction industry. Teknol Journal, p. 78.

16 Thurairajah, N. & Goucher, D. 2013. Advantages and challenges of using BIM: A cost consultant’s perspective. In: 49th ASC Annual International Conference, 10th - 13th April 2013, San Luis Obispo, USA.

17 Volk, R.; Stengel, J. & Schultmann, F. 2014. Building Information Modeling (BIM) for existing buildings-Literature review and future needs. Automation in construction, Vol. 38, pp. 109-127.

18 Borrmann, A.; König, M.; Koch, C. & Beetz, J. 2018. Building information modeling: Why? What? How? In: Building Information Modeling, pp. 1-24. E-book. Springer Nature.

19 Seo, J. H.; Lee, B. R.; Kim, J. H. & Kim, J. J. 2012. Collaborative process to facilitate BIM-based clash detection tasks for enhancing constructability. Journal of the Korea Institute of Building Construction, Vol. 12 Iss. 3, pp. 299-314.

20 Akponeware, A. O. & Adamu, Z. A. 2017. Clash detection or clash avoidance? An investigation into coordination problems in 3D BIM. Buildings, Vol. *7* Iss. 3, p. 75.

21 Ginzburg, A. 2016. Sustainable building life cycle design. MATEC Web of Conferences, Vol. 73, p. 201.

22 Fernandes, R. P. L. 2013. Advantages and Disadvantages of BIM Platforms on Construction Site. Master’s Thesis, Universidade do Porto.

23 Moreno, C.; Olbina, S. & Issa, R. R. 2019. BIM use by architecture, engineering, and construction (AEC) industry in educational facility projects. Advances in Civil Engineering, 2019.

24 Onur, A. Z. & Nouban, F. 2019. BIM Software in the Architectural Presentation And Design Of Buildings: State-Of-The-Art. International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol. 8, p. 10.

25 Deng, L.; Zhong, M.; Liao, L.; Peng, L. & Lai, S. 2019. Research on Safety Management Application of Dangerous Sources in Engineering Construction Based on BIM Technology. Advances in Civil Engineering, 2019.

26 Lin, Y. C. 2015. Use of BIM approach to enhance construction interface management: a case study. Journal of Civil Engineering and Management, Vol. 21 Iss. 2, pp. 201-217.

27 Diaz, P. M. 2016. Analysis of benefits, advantages and challenges of building information modelling in construction industry. Journal of Advances in Civil Engineering, Vol. 2 Iss. 2, pp. 1-11.

28 AUEssays. 2018. Bulding Information Modelling Pros and Cons. Online. <https://www.auessays.com/essays/construction/bulding-information-modelling-pros-and-cons.php?vref=1>. Acessed on 12 Sep 2020.

29 Migilinskas, D.; Popov, V.; Juocevicius, V. & Ustinovichius, L. 2013. The benefits, obstacles and problems of practical BIM implementation. Procedia Engineering, Vol. 57, pp. 767-774.

30 Tulenheimo, R. 2015. “Challenges of Implementing New Technologies in the World of BIM.” 8th Nordic Conference on Construction Economics and Organization. Procedia Economics and Finance, Vol. 21, pp. 469–477.

31 Hardi, J. & Pittard, S. 2015. If BIM is the solution, what is the problem? A review of the benefits, challenges and key drivers in BIM implementation within the UK construction industry. Journal of Building Survey, Appraisal & Valuation, Vol. 3 Iss. 4, pp. 366-373.

32 Criminale, A. & Langar, S. 2017. Challenges with BIM implementation: a review of literature. In Proceedings of 53rd Associated School of Construction International Conference, Seattle, WA, April, pp. 5-8.

33 Rivera, M. L.; Vielma, J. C.; Herrera, R. F. & Carvallo, J. 2019. Methodology for Building Information Modeling (BIM) Implementation in Structural Engineering Companies (SECs). Advances in Civil Engineering, 2019.

34 Cherkaou,i H. 2017. Recognizing BIM roles in a project cycle. Letsbuild formerly GenieBelt and Aproplan. Online. LetsBuild. <https://www.letsbuild.com/blog/recognising-bim-roles-project-cycle>. Accessed 5 Jan 2020.

35 Kasim, N.; Zainal Abidin, N. A.; Zainal, R.; Sarpin, N.; Abd Rahim, M. H. I. & Saikah, M. 2017. Best practices of Building Information Modelling (BIM) implementation in design phase for construction project. In IOP Conference Series: Materials Science and Engineering, p. 271.

36 Munoz-La Rivera, F.; Vielma, J. C.; Herrera, R. F. & Carvallo, J. 2019. Methodology for Building Information Modeling (BIM) Implementation in Structural Engineering Companies (SECs). Advances in Civil Engineering, 2019.

37 Çavuşoğlu, Ö. H. 2015. The Position of BIM Tools in Conceptual Design Phase: Parametric Design and Energy Modeling Capabilities. BIM - Early Design, Vol. 1, p. 2.

38 Azhar, S.; Hein, M. & Sketo, B. 2008. Building information modeling (BIM): benefits, risks and challenges. In Proceedings of the 44th ASC Annual Conference, pp. 2-5.

39 BIM Essential Guide for Architectural Consultant. 2013. Singapore: Building and Construction Authority.

40 Lee, M.; Lee, D.; Kim, T. & Lee, U. K. 2020. Practical Analysis of BIM Tasks for Modular Construction Projects in South Korea. Sustainability, Vol. 12 Iss. 17, p. 690.

41 Azhar, S.; Carlton, W. A.; Olsen, D. & Ahmad, I. 2011. Building information modeling for sustainable design and LEED® rating analysis. Automation in construction, Vol. 20 Iss. 2, pp. 217-224.

42 Afsari, K. 2012. Building Information Modelling in concept design stage Doctoral dissertation, Tese de Mestrado, University Salford Manchester, School of the Built Environment, Manchester, UK.

43 Fürstenberg, D. & Lædre, O. 2019. Application of BIM Design Manuals: A Case Study. Proc. 27th Annual Conference of the International. Group for Lean Construction (IGLC), Pasquire C. and Hamzeh F.R. (ed.), Dublin, Ireland, pp. 145-156.

44 Ham, N. & Lee, S. 2019. Project Benefits of Digital Fabrication in Irregular-Shaped Buildings. Advances in Civil Engineering, 2019.

45 Hamid, M.; Tolba, O. & El Antably, A. 2018. BIM semantics for digital fabrication: A knowledge-based approach. Automatiin in Construction, 2018, Vol. 91, pp. 62–82.

46 Talebi, S. 2014. Exploring advantages and challenges of adaptation and implementation of BIM in project life cycle. 2nd BIM International Conference on Challenges to Overcome, BIMForum Portugal.

47 Xu, X.; Ma, L. & Ding, L. 2014. A framework for BIM-enabled life-cycle information management of construction project. International Journal of Advanced Robotic Systems, Vol. 11 Iss. 8, pp. 126.

48 Hedborg Bengtsson, S. 2019. Coordinated construction logistics: an innovation perspective. Construction Management and Economics, Vol. 37 Iss. 5, pp. 294-307.

49 Sinopoli, J. 2010. Design, Construction, and Renovations. Smart Building Systems for Architects, Owners and Builders. Oxford: Butterworth-Heinemann.

50 Häkkinen, T.; Ruuska, A.; Vares, S.; Pulakka, S.; Kouhia, I. & Holopainen, R. 2012. Methods and concepts for sustainable renovation of buildings. Espoo: VTT Technical Research Centre of Finland.

51 Ismail, N. A. A.; Chiozzi, M. & Drogemuller, R. 2017. An overview of BIM uptake in Asian developing countries. AIP Publishing LLC, Vol. 1903, Vol. 1, p. 80008.

52 Gurung Naren. 2020. BIM for Infrastructure in Developing Countries. Bachelor's Thesis. Metropolia University of Applied Sciences Theseus.

53 Phuyal, S. 2017. Perspective in using Building Information Modeling Technology in Nepal", International Journal of Emerging Technologies and Innovative Research, Vol. 4 Iss. 3, pp. 35-39.

54 Shrestha, A.; Bishwokarma, R.; Chapagain, A.; Banjara, S.; Aryal, S.; Mali, B.; Thapa, R.; Bista, D.; Hayes, B.P.; Papadakis, A. & Korba, P. 2019. Peer-to-Peer Energy Trading in Micro/Mini-Grids for local Energy Communities. A review and case study of Nepal, IEEE Vol.12 Iss. 7, pp. 131911-131928.

55 Parajuli, Y. K.; Bothara, J. K.; Dixit, A. M.; Pradhan, J. P. & Sharpe, R. D. 2000. Nepal Building Code-Need, Development Philosophy and Means of Implementation. 12th World Conference on Earthquake Engineering, Auckland, New Zealand, January.

56 Moreno, C.; Olbina, S. & Issa, R. R. 2019. BIM use by architecture, engineering, and construction (AEC) industry in educational facility projects. Advances in Civil Engineering, p. 201.

57 Whyte, J. 2010. Information Management and its Impact on Project Management, Oxford Handbook on the Management of Projects. Oxford, Oxford University Press.

58 Shabanesfahani, A. & Tabrizi, F. 2012. Barriers of Systemic Innovation to Increase Productivity of Engineering and Construction Industries of the World.

59 Cory, C. & Bozell, D. 2001. 3D Modelling for the Architectural Engineering and Construction Industry. Online. Purdue University. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.195.8406&rep=rep1&type=pdf>. Accessed 15 May 2020.

60 Nepal, M. P.; Jupp, J. R. & Aibinu, A. A. 2014. Evaluations of BIM: frameworks and perspectives. Computing in Civil and Building Engineering, 2014, pp. 769-776.

61 Shabanesfahani A. & Tabrizi F. 2010. Next Wave of Digital Innovation: Opportunities and Challenges. Report on the Research Workshop: Digital Challenges in Innovation Research.

62 Basnet, B. 2018. A short description of BIM use in Nepalese Architecural Engineering and Construction (ACE) industry. Online. Nepal BIM Forum. <https://nbimf.com/a-short-description-of-bim-use-in-nepalese-architectural-engineering-and-construction-aec-industry/>. Accessed 20 Sep 2020.

63 Karki, M. 2019. BIM adoptation in Nepal. Online. Nepal BIM Forum <https://nbimf.com/bim-adoption-in-nepal-part-1/>. Accessed 20 Sep 2020.

64 Pretti, S. M. & Vieira, D. R. 2016. Implementation of a BIM solution in a small construction company. The Journal of Modern Project Management, Vol. 3, p. 3.

65 Abbasnejad, B.; Nepal, M. P.; Ahankoob, A.; Nasirian, A. & Drogemuller, R. 2020. Building Information Modelling (BIM) adoption and implementation enablers in AEC firms: a systematic literature review. Architectural Engineering and Design Management, pp. 1-23.

66 Park, K. S. & Kim, K. P. 2014. Essential BIM input data study for housing refurbishment: homeowners' preferences in the UK. Buildings, Vol. 4 Iss. 3, pp. 467-487.

67 Ahmad, T. & Thaheem, M. J. 2017. Developing a residential building-related social sustainability assessment framework and its implications for BIM. Sustainable Cities and Society, Vol. 28, pp. 1-15.

68 Dainty, A.; Leiringer, R.; Fernie, S. & Harty, C. 2017. BIM and the small construction firm: a critical perspective. Building research and information, Vol. 45 Iss 6, pp. 696-709.

69 Housing Communities. 2020. Affordable Housing. Online. U.S. Department of Housing and Urban Development. <https://www.hud.gov/program_offices/comm_planning/affordablehousing/>. Accessed 12 February 2020.

70 Wilkinson, S. J. & Jupp, J. R. 2016. Exploring the value of BIM for corporate real estate. Journal of Corporate Real Estate, Vol. 18, pp. 4.

71 El Yamani, S.; Hajji, R. & Ettarid, M. 2019. Building Information Modeling Potential for an enhanced real estate valuation approach based on the hedonic method. WIT: Transactions on the Built Environment, Vol. 192, p. 12.

72 Wilkinson, S. 2015. Turning data into value. Property Journal, 32.

73 Munir, M.; Kiviniemi, A. & Jones, S. W. 2019. Business value of integrated BIM-based asset management. Engineering, Construction and Architectural Management. Vol. 26 Iss. 6, pp. 1171-1191.

74 Nepal Urban Housing Sector Profile. 2010. Online. United Nations Human Settlements Programme. <https://www.alnap.org/system/files/content/resource/files/main/nepal-urban-housing-sector-profile.pdf >. Accessed 21 Aug 2020.

75 Bakrania, S. 2015. Urbanisation and urban growth in Nepal. Governance. Social Development, Humanitarian Response and Conflict (GSDRC), Applied Knowledge Services of University of Birmingham, Birmingham, UK.

76 Moore S.A. 2015. Adapting building information modelling (BIM) for affordable and sustainable housing. Master's Thesis. University of Texas, Austin.

77 Dowhower J.F. 2010. Adapting building information modelling (BIM) for affordable and sustainable housing. Master's Thesis. University of Texas, Austin.

78 Saka, A. B.; Chan, D. W. & Siu, F. M. 2020. Drivers of Sustainable Adoption of Building Information Modelling (BIM) in the Nigerian Construction Small and Medium-Sized Enterprises (SMEs). Sustainability, Vol. 12 Iss. 9, p. 3710.

79 Dahal, S. 2019. BIM Based Design of Hydropower in Nepal: Lower Piluwa Small Hydropower Project. Bachelor's Thesis. Metropolia University of Applied Sciences. Theseus.

80 Bolpagni, M. 2013. The implementation of BIM within the public procurement: a model-based approach for the construction industry. Online. VTT. <http://www.vtt.fi/publications/index.jsp>. Accessed 18 February 2020.

81 Smith, D. K. & Tardif, M. 2009. Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers. Hoboken, New Jersey: John Wiley & Sons.

82 Fai, S.; Graham, K.; Duckworth, T.; Wood, N. & Attar, R. 2011. Building information modelling and heritage documentation. In proceedings of the 23rd international symposium, international scientific committee for documentation of cultural heritage (CIPA), Prague, Czech Republic, pp. 12-16.

83 López, F. J.; Lerones, P. M.; Llamas, J.; Gómez-García-Bermejo, J. & Zalama, E. 2018. A review of heritage building information modeling (H-BIM). Multimodal Technologies and Interaction, Vol. 2 Iss. 2, p. 21.

84 Stober D.; Žarnic´ R.; Penava D.; Podmanicki M.T. & Virgej-Đuraševic´ R. 2018. Application of HBIM as a research tool for historical building assessment. Civil engineering journal, 2018 Jul 30, Vol. 4 Iss. 7, pp. 1565-1574.

85 Arayici Y. 2017. 15 HBIM, a case study perspective for building performance. Heritage Building Information Modelling. 218.

86 Ewart I.J. & Zuecco V. 2019. Heritage building information modelling (HBIM): A review of published case studies. Advances in informatics and computing in civil and construction engineering, 2019, pp. 35-41. Springer, Cham.

87 Lu, N. & Korman, T. 2010. Implementation of building information modeling (BIM) in modular construction: Benefits and challenges. Construction Research Congress 2010: Innovation for Reshaping Construction Practice, pp. 1136-1145.

88 Pradhan, P. 2018. Structural BIM Application: Implementation of Tekla Structures in Nepal. Bachelor's Thesis. Metropolia University of Applied Sciences. Theseus.

89 Dhonju, H.K.; Xiao, W.; Sarhosis, V.; Mills, J.P.; Wilkinson, S.; Wang, Z.; Thapa, L. & Panday, U.S. 2017. Feasibility study of low-cost image-based heritage documentation in Nepal. International archives of the photogrammetry, remote sensing and spatial information sciences, Vol. 42, pp. 237-242.

90 NRA, N. 2015. Design catalogue for reconstruction of earthquake resistant houses. Nepal Government, Department of Urban Development and Building Construction, Kathmandu: Ministry of Urban Development.

91 Khan, M.A. 2013. Earthquake-Resistant Structures: Design, Build, and Retrofit. Structural effects of seismic events. Oxford: Elsevier.

92 Alirezaei, M.; Noori, M.; Tatari, O.; Mackie, K. R. & Elgamal, A. 2016. BIM-based damage estimation of buildings under earthquake loading condition. Procedia Engineering, Vol. 145, pp. 1051-1058.

93 Huang J. 2016. Thinking Inside of the Box: Using Autodesk BIM Technology for Hydropower Projects. Online. Autodesk University. <https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/auonline/autodesk-university/forge-content/au-class-urn-adsk-content-content-4e4bec27-4113-4762-9b69-447184f62694.html>. Accessed 20 Sep 2020.

94 Federation of Nepalese Chambers of Commerce and Industry. 2017. Online. Energy/Hydropower. <http://fncci.org/energyhydropower-150.html>. Accessed 16 March 2020.

95 Zhang S.; Pan F.; Wang C.; Sun Y. & Wang H. 2017. BIM-based collaboration platform for the management of EPC projects in hydropower engineering. Journal of Construction Engineering and Management, Vol. 143 Iss. 12, pp. 4017-4087.

96 BIM for renewable energy: the shell Keselstraße hydropower plant. 2018. Online. BIM Community. <https://www.bimcommunity.com/experiences/load/149/from:%20bim-for-renewable-energy-the-shell-of-the-keselstrasze-hydropower-plant.>. Accessed 15 March 2020.

97 National BIM Standard-United States. 2015. Online. National Institute of Building Sciences. <https://www.nationalbimstandard.org/files/NBIMS-US_FactSheet_2015.pdf>. Accessed 25 June 2020.