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Naren Gurung

BIM for Infrastructure in Developing Countries

Modelling Badigad Khola Bridge

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The aim of this bachelor's thesis was to investigate the possibilities of the implementation of BIM in Architecture, Engineering and Construction (AEC) industry for developing countries.

The thesis first studied literary sources to identify the challenges of BIM implementation in ten developing countries. The practical approach modelled a pre-stressed single box girder bridge with Tekla Structure, utilizing BIM for various tasks. The structural validation and information take-offs were conducted using Solibri model checker. During the modelling process, various benefits such as better visualization and coordination, information modelling process, clash detection, information quantity take-offs were noticed and discussed.

Six obstacles that hinder the utilization of BIM in developing countries were established on the basis of the literary study. Based on this, some recommendations were proposed to raise BIM awareness and encourage BIM implementation in developing countries, such as giving university courses in BIM, consulting clients, and giving organizational support.

The thesis can be used for educational purposes, and as a suggestion for the preliminary process of BIM implementation in developing countries.

Keywords	BIM, construction, maturity levels, Tekla Structure, structural modelling, Solibri model checker, quantity-take offs

Contents

List of Abbreviations

AEC	Architecture, Engineering and Construction
ARTBA	American Road and Transportation Builders Association
BIM	Building Information Modelling
CAD	Computer-Aided Design
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Programme
GNI	Gross National Income
IFC	Industry Foundation Class
ITO	Information Take-offs
LRBP	Local Roads Bridge Programme
MOHURD	Ministry of Housing and Urban-Rural Development
QTO	Quantity-Take offs
SDC	Swiss Agency for Development and Co-operation
SOCSO	Social Security Organization

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1 Introduction

According to the World Bank, economies are categorized into four income groups: low, lower middle, higher middle and high. The countries in the low- and middle-income groups that have a Gross National Income (GNI) per capita below $12,375 are considered developing countries. [1.] The developing countries are far behind the developed countries in the field of innovation and management of technology [2.]

The construction industry is one of the largest sectors of economy that employs 7% of world's working-age population. Around $10 trillion is spent on construction projects globally every year. Figure 1 below compares the global productivity growth of construction industry, manufacturing industry and world total economy. In the time period between 1995 – 2014, the labour productivity growth rate in the construction sector remained a constant 1% a year on average, whereas the productivity growth rate in both the manufacturing sector and total world economy increased significantly to 3.6% and 2.7%, respectively. This difference indicates that the productivity performance of the construction sector is remarkably poor. The reason for this poor performance includes poor project management and execution, poor procurement and supply chain management, and inadequate collaboration between owners, contractors and sub-contractors. Neither has the industry fully embraced the use of new digital technology like BIM (Building Information Modelling) that transforms the way buildings are designed, built and maintained, reducing costs and saving time. [3.]

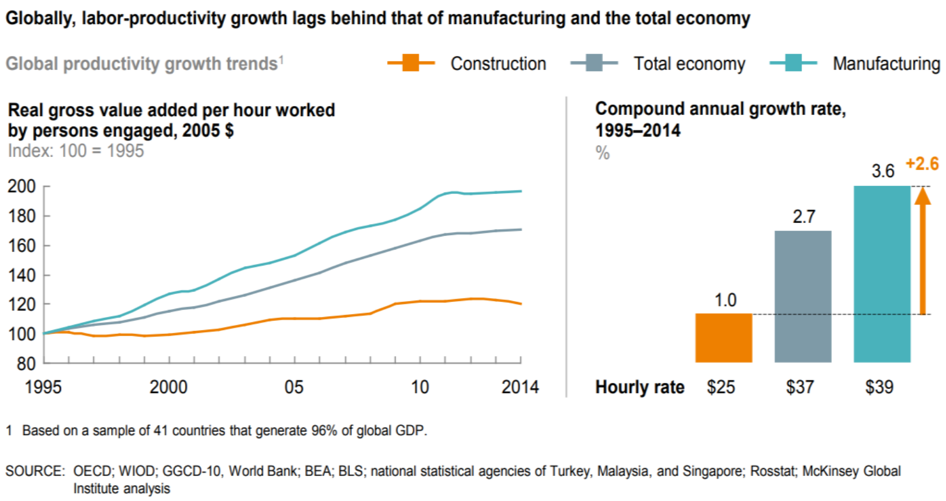


Figure 1. Global labour productivity growth of construction industry [3].

In recent years, the adoption of BIM in industrialized countries like the USA, UK, and some Nordic countries has increased rapidly in the Architecture, Engineering and Construction (AEC) industry to reduce total project cost, increase overall quality and reduce project completion time [4]. Previously, architects, engineers, and contractors used traditional 2D based drawings that show the floor plans, sections, and elevations of a building separately for construction planning, and design [5]. Nowadays, BIM technology allows AEC disciples to visualize and simulate an entire virtual model of a building. Along with 3D visualization and simulation, BIM is also applicable throughout the life cycle of the building from planning to construction to maintenance, covering the sustainability of the project as well. In the developing countries, the use of BIM technology is rare compared to the use in developed countries. [6.]

1.1 Research Methods and Objectives

The goal of this thesis is to raise the awareness about and encourage the implementation of BIM in the construction industry in developing countries. The thesis points out the challenges faced when adopting BIM technology in developing countries, as well as discusses the methods of implementation. The thesis covers both theoretical and practical approaches in implementing BIM processes and applications.

The theoretical approach in the thesis is based on various literary sources that include e-books, journals, videos, and other internet sources. In the practical approach, a bridge model is created using BIM software to show the process, benefits and importance of how BIM application makes the project faster, more accurate and efficient. Tekla Structures software is used to create the 3D model while Solibri Model Checker is used for the structural validation and quantity take-offs (QTO). This thesis focuses on answering the following research questions.

- What are the benefits of BIM application?
- Why is BIM adopted?
- How does the adoption of BIM technology affect a nation’s economy?
- What are the obstacles in implementing BIM technology in developing countries?
- What could be the BIM implementation strategy in developing countries?

1.2 Structure and Limitations

The introduction chapter of the thesis briefly outlines the effects of construction industry on the economy of a country and suggests to the potentials of BIM technology to improve the efficiency of designing and managing construction projects. Chapter 2 reviews the background of BIM, reasons for the adoption of BIM, BIM maturity levels, AEC status in developing countries, obstacles faced while adopting BIM technology and BIM implementation strategy. After the theoretical part, chapter 3 introduces the creation of the structural model of the Badigad river bridge and presents the benefits of the use of BIM in the project. Finally, chapter 4 provides a summary and future improvement suggestions on the thesis topic.

The findings and research are only conducted on a few developing countries which means not all developing countries are studied. The bridge model designed is based on its location in Nepal. The default European standards are used due to the unavailability of working environments following the Nepalese standards in Tekla Structure. Similarly, the study does not cover the analysis of the structure, or its architectural perspective. The research is based on search strings to find the relevant files, databases, and contents. Only articles and websites written in English were used for the research.

The practical case project in the thesis is a bridge recently designed and constructed under Local Roads Bridge Programme (LRBP), in Nepal. LRBP is a joint programme between the Swiss Agency for Development and Co-operation (SDC) and the Government of Nepal that has designed and provided technical assistance for the construction of motorable road bridges in Nepal since 2011. Shakil Manandhar, engineer and deputy team leader of LRBP was approached with the thesis scope. After discussing the subject, it was agreed that a structural model for the case bridge was to be created in order to look into the possible workflow and benefits the model could provide. The final report of the case bridge along with the design documents and drawings are used as a reference for the structural model of the bridge discussed in the thesis.

2 Literature Review

A literature review is conducted to study the advantages that the usage of BIM technology brings to the construction industry in developing countries. The study encompasses the recent situation of the construction industry in developing countries and its challenges and obstacles experienced while adopting BIM technology. With this in mind, the best BIM implementation methods are presented.

2.1 Building Information Modelling

The British National Building Specification (NBS) defines BIM as "*A rich information model, consisting of potentially multiple data sources, elements of which can be shared across all stakeholders and be maintained across the life of a building from inception to recycling" [7.]*

Building Information Modelling is a process of creating information rich models which have versatile uses during design, construction and operation of a building or an infrastructure. BIM is also understood as a single model combined from different design disciplines. The data rich intelligent models have various benefits and are widely used for scheduling (4D BIM), cost estimation (5D BIM), and facility management (6D BIM). The complete single model can store all necessary information and standardized data such as a product's cost, location, service life, carbon impact, maintenance instructions, serial number and warranty details which help facility managers during the lifecycle maintenance and operation of a building. Therefore, BIM is adopted throughout the lifecycle of building or infrastructure projects, from design to operation. In this thesis, a project is divided into preconstruction stage, construction stage and post-construction stage. The specific benefits of BIM at the different stages of the project lifecycle are discussed below.

Preconstruction stage

The preconstruction phase, often known as design phase of the project life cycle involves numerous activities such as planning, design, scheduling and estimating. It is the most crucial phase as several pieces of information need to be collected in advance to set the direction of the project and start the construction. Nowadays, the adoption of BIM has helped in achieving the data and information, transforming paper-based documents to digital-based modelling. [8.]

During the preconstruction stage, BIM technology helps to develop alternative 3D conceptual models, and provides the designer with various types of simulation options. For example, the architect can do energy and lighting simulations to find the best design solution that improves the overall building performance. [9.p.19.] With the traditional Computer-Aided Design (CAD) methods, this type of analysis is time consuming and it is usually carried out in the final design phases when the architectural design and construction documents are produced [10]. Likewise, the automatic Quantity Take-offs (QTO) from the BIM model gives a more reliable cost prediction already in the design phase [11]. This helps the owners to analyse the possible financial risks. Thus, at the pre-construction stage, BIM technology can help in performing a feasibility study of a project, as well as an assessment of future building performance.

The benefits of BIM for a project are numerous. Visual information, or the visualization of the designs is seen as one of the most important outcomes that is there by default. Real time 3D rendering integration in BIM applications provide the owners and other stakeholders with realistic models. Furthermore, the modelling and calculation capabilities help the stakeholders to design and calculate the impacts of design changes. An example of such realistic models is the SaRang Community Church (figure 2) located in Seoul and designed by the Beck Group. The design team created 100 models to achieve a glass curtain wall that would be a smooth curve and saved $1 million on glazing and mullions, as well as 1000 design hours. [12.]

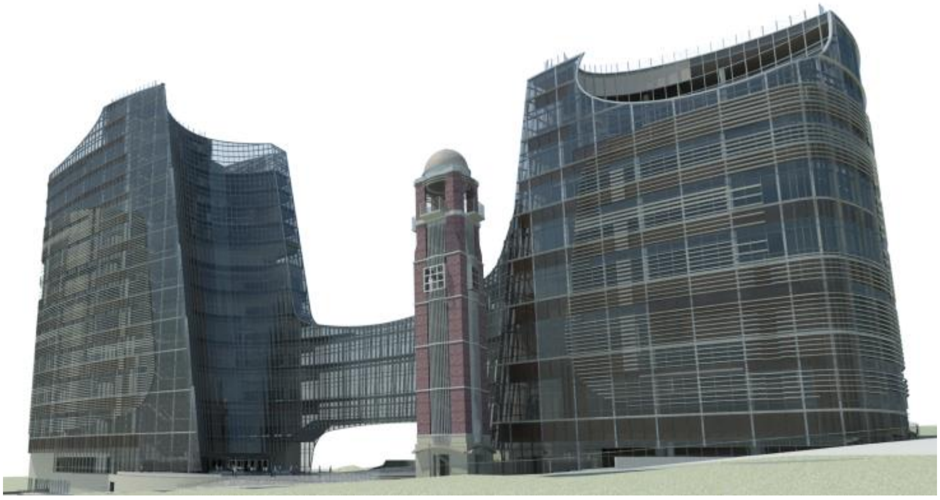


Figure 2. 3D Rendering view of SaRang Community Church [12].

A better visualization of the model gives the project owners an effective decision-making processes, better communications and collaboration with the project team. In addition, with the usage of a BIM model, more accurate and consistent 2D drawings can be produced quickly at any design phase, reducing time consumption and design errors when creating construction drawings for all designers and engineers. [9.p.19.]

Construction Stage

The construction phase means the execution of plans and design which have been proposed previously in the design phase. All construction activities should be shown in the schedule for the project. With the traditional 2D methods, a team of schedulers manually outlines when each component of a construction project should be done or when the next scheduled work should begin. With this method, it is also difficult to update the details of the schedule as the project proceeds. Consequently, the schedule becomes unrealistic. Moreover, when subcontractors and workers are not aware of the schedule, they lack the dedication to complete the given tasks. [13.] As a result, the project delivery time might be delayed, and the costs increased.

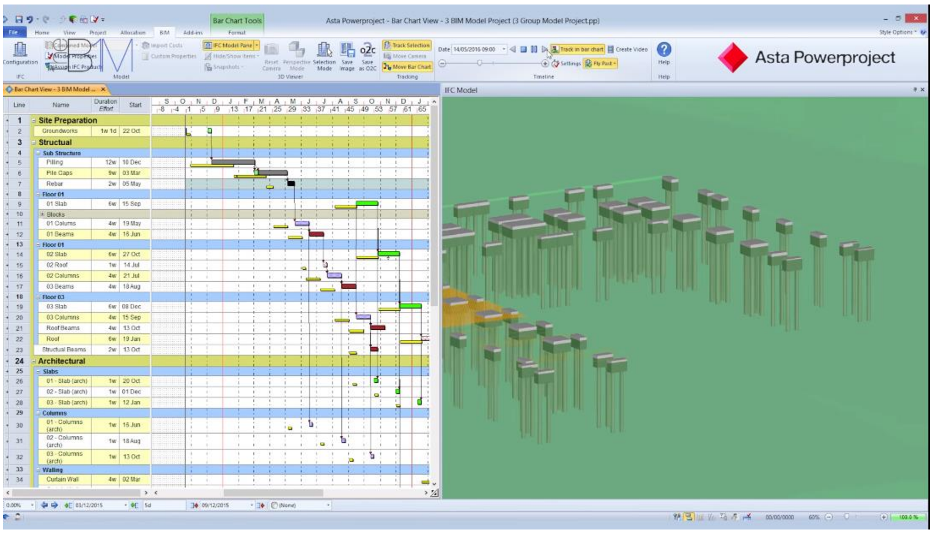


Figure 3. 4D Scheduling of foundation components [14].

Nowadays, it is possible to link a 3D digital model with the scheduling data creating a 4D BIM. 4D BIM modelling shows the sequence of events, such as site logistics and installation phases of building structures, at every stage of the construction process through a visual medium. [15.] Figure 3 demonstrates the scheduling of various foundation components with BIM technology. The virtual simulation of the construction activities helps to point out the logistical issues and scheduling conflicts among multiple trades before the start of the construction project. Furthermore, 4D can also represent the sequence of activities for temporary construction components, such as scaffolding, shoring, and cranes, to help the contractor with safety assessment and constructability issues. [9.p.234.]

In traditional 2D methods, contractors overlay CAD layers to detect potential conflicts which is time consuming, costly and prone to error. BIM technology, on the other hand, has a clash detection feature that helps to detect the design errors and conflicts, thus reducing on-site errors and errors of omission before the construction. [9.p.216]. As the number of mistakes is reduced, redesign work is minimized, and unnecessary extra site visits or meetings are avoided, which ultimately saves time and costs. Not only are costs and time saved, but construction waste in the site is reduced as BIM improves the quality and accuracy of design and construction. Based on a survey of 32 large projects that had adopted BIM technology, the CIFE (Centre for Integrated Facilities Engineering) identified almost 10% savings in the value of contracts through clash detection. [16.]

Post-construction Stage

The aim of the post-construction stage is to improve building management and performance throughout the operation of the facility. At the end of the construction phase, contractors collect, and handover all updated project information, that is as-built BIM models, detailed as-built drawings, warranty information about the building elements, maintenance manuals and many other documents to owners and facility managers. The owners use the project information to get familiar with the technical aspects of the facility, while the facility managers use the information for the life cycle operation and maintenance of the facility. [17.]

In a traditional approach, on-site facility managers depend on paper-based blueprints and their own judgment to locate the components of an electrical system, HVAC system and plumbing pipes which lie invisible below the floor or behind the walls or in the ceilings. This process usually takes enormous amounts of time and money as operators and technicians must go through a great number of documents to locate the positions of components [18.]. On top of that, the project documents provided by contractors are often incomplete from the maintenance viewpoint, leading to inefficient maintenance and operation of systems. In a study by the US National Institute of Standards and Technology, it is reported that an owner suffered the loss of $10.6 billion during the operations and maintenance phase of a facility due to missing information and documents, lengthy information verification and validation processes, and poor business process management. [17.]

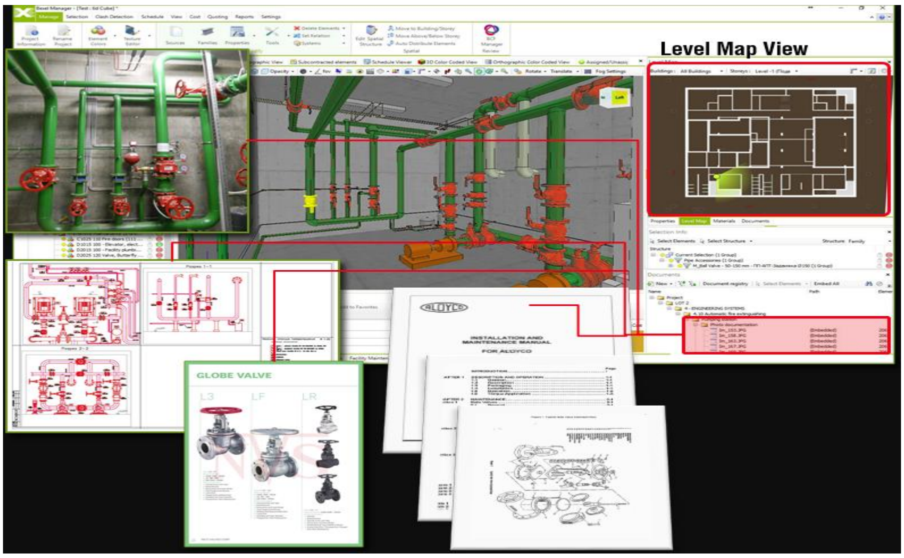


Figure 4. Building equipment’s data information stored digitally using BIM technology [19].

The use of BIM for facility management can solve the problems discussed above, as well as offer a great deal of benefits. BIM has the capability of storing essential data about various parts of the building which are very important for the entire life cycle maintenance and control, as illustrated in figure 4. For example, the use of a 3D BIM model gives a wide range of visualization that helps to detect the exact positions of electrical, plumbing or mechanical components in a facility, together with information like the name, model number, product type, commissioning information, performance data, operation and maintenance manuals of the components. Therefore, a BIM model helps to reduce maintenance costs and time, whereas the guesswork required in traditional methods might result in rework and repair. Furthermore, improved visualization helps managers in different construction activities during renovation, like re-modelling of the building, assessment of construction methods and equipment access check. [17.]

2.2 Construction and Economy

The construction industry in any country plays a vital role in the economic growth of the country. Not only does it drive a nation's economy but, also stimulates other sectors, like education, agriculture, manufacturing, and services, through both backward and forward linkages. For example, with the construction of infrastructure, like roads and bridges, the use of locally produced materials is activated and jobs for the construction and maintenance of infrastructure are created. Furthermore, the movement of goods and people are possible with the help of infrastructure. The developing countries are in dire need of these types of infrastructure. Therefore, the development of the construction industry acts as a driver of economic growth in a developing country. [20.]

According to American Road and Transportation Builders Association (ARTBA), the U.S public and private transportation construction industry contributes about 1.6 % annually to the GDP of the country, which is equivalent to US$254 billion. The industry employs more than 3 million workers every year, which is double the number of employees in commercial banks, real estate, university, or nursing health care facilities. Furthermore, the industry generates direct and indirect wages of around US$155.7 billion annually, resulting each year in state and federal payroll taxes of US$17.5 billion and US$10.9 billion, respectively. [21.]

Despite the importance of the construction industry, there has not been any progress in the construction sector in the developing countries in the last decade. The construction sector in the developing countries has several problems, such as delay in completion of project, construction budget overrun, design changes during construction, poor quality of work, and accidents. [22.] However, the problems can be fought with BIM technology in the AEC industry in the developing countries.

2.3 BIM Implementation Maturity Levels

BIM can be defined differently by different individuals, according to their perception, context, and experience. Some people consider BIM as a data rich 3D modelling technology while others see it an IFC building model. However, Mark Bew and Mervyn Richards developed a widely accepted BIM maturity level scale to establish a common definition in 2008. [23.] The maturity levels help any BIM users to indicate the level they have reached in adopting BIM.

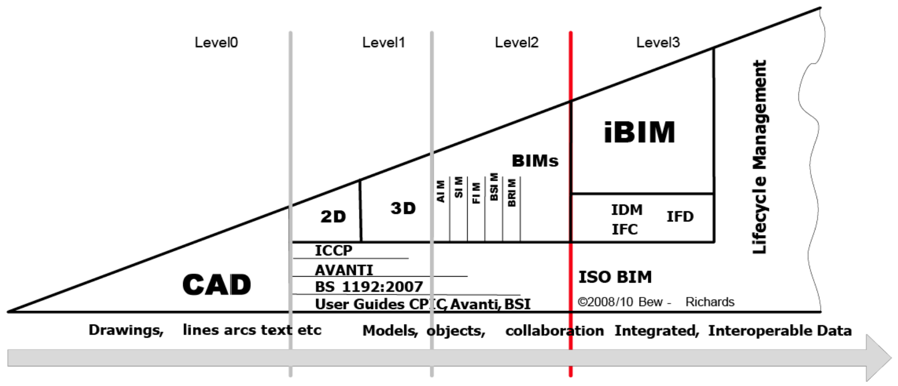


Figure 5. BIM maturity levels [24].

At maturity level 0, CAD is used to produce 2D drawings. Drawings and specifications are distributed through the traditional paper-based method. Drawings are printed electronically and provided to the site. The co-ordination among AEC professionals does not exist at this level. [23.]

At maturity level 1, both 2D and 3D CAD is used for drafting. Basically, 3D CAD is used for visualizations or concept development while 2D CAD is used for the generation of statutory support documentation and production information. At this stage, the data are shared electronically among project members through a common data environment (CDE) which is generally managed by contractors. Despite the use of CDE, there is a low collaboration as every disciple creates and manage their own data and models. [23.]

At maturity level 2, BIM is used in a collaborative way. All parties of the project create their own 3D models which are data rich and intelligent. The separate models are shared through a common file format such as IFC (Industry Foundation Class) and combined to form a single model without losing any information and data. The data-rich information at this level enables construction scheduling (4D BIM) and cost estimation (5D BIM). Most of the developed countries are currently at this stage. [23.]

At maturity level 3, all project teams are able to work in a single, shared model for data integration, in which any stakeholders can get access and modify their own information. The model in IFC format can be shared and preserved in a cloud-based environment so that all stakeholders can access it to the exact same information and data. Therefore, the management of the entire building lifecycle (6D BIM) is possible. The construction industry in the UK is in the preliminary stage to adopting BIM level 3. [23.]

2.4 Construction Status and BIM Uptake in Developing countries

According to the world population review, there are 126 developing countries. Five of these were selected for this thesis [25]. They are China, Malaysia, Nepal, and South Africa. All of them but Nepal are classified as newly industrialized countries. The current status and trends in the construction industry of the countries are discussed below.

China

The Chinese National Bureau of Statistics has stated that the share of GDP contributed by the Chinese construction industry has risen twice during the last decade, from approximately RMB 750 billion in 2010 to RMB 2,050 billion in 2019 as summarized in figure 6. [26.] However, the construction activities are still carried out with traditional methods and old technology. The construction companies are still using old and outdated construction equipment. About 30 % of the Chinese construction equipment is reported to be outdated. Furthermore, corruption, poor quality control and weak construction management have been major problems in the recent years. Contractors and developers cut corners when they build with poor quality materials, for example, substituting quality floor or wall materials with inferior ones, using cheaper plumbing and electrical equipment. [27.]

Figure 6. GDP from construction 2010-2019 [26].

In the past, executing a project without a budget overrun was the main point, but nowadays improving the quality of construction has been a challenging part of the Chinese construction industry. Daud and Zong stated that poor designs and construction plans, weak management, and unskilled workers have resulted in the poor quality of existed infrastructure. [27.]

The usage of BIM technology across the AEC industries in China is growing slowly. In China, The Ministry of Housing and Urban-Rural Development (MOHURD) is responsible for any construction-related activities. MOHURD has issued several BIM policies to support and promote the adoption of BIM technology, shown in table 1. [28.]

Table 1. BIM policy in China [28].

No.	Title	Department	Published Time
1	Outline of Development of Construction Industry Informatisation (2011 – 2015)	MOHURD	2011
2	"12th Five-Year" Science and Technology Development Planning	MOST	2011
3	Some Opinions on Promoting the Development and Reform of the Construction Industry	MOHURD	2014
4	Evaluation Standard for Green Building	MOHURD	2014
5	Guidance on Building Information Model Application	MOHURD	2015
6	Outline of Development of Construction Industry Informatisation (2016 – 2020)	MOHURD	2016
7-1	Deliver Standard of Building Design-Information Modelling	MOHURD	In formulation
7-2	Standard for Classification and Coding of Building Constructions Design Information Modelling	MOHURD	In formulation
7-3	Unified Standard for Building Information Modelling Application	MOHURD	Be authorized in 2016, will be enforced in 2017
7-4	Storage Standard of Building Information Modelling	MOHURD	In formulation
7-5	Application Standard for Manufacturing Industry Design Information Modelling	MOHURD	In formulation
7-6	Standard for Building Information Modelling in Construction	MOHURD	In formulation

However, most of the guidelines, policies, and standards are immature and they are not clearly defined. For example, as shown in table 1 in 2015, MOHURD issued a guideline on BIM applications that aimed at the adoption of BIM at the rate of 90% by the year 2020. However, there was no clear vision or definition at which of the maturity levels, discussed above, the adoption of BIM should be achieved. [28.]

Jiang et al. carried out a case study on 30 projects that claimed to have utilized BIM in China. It was revealed that the majority of the projects adopted BIM more in design and construction processes, but very few used BIM in building maintenance. In addition, it was established that Autodesk software, especially Revit, was mostly utilized by the project teams. [29.] A similar result was noted by Herr and Fischer, who showed that BIM utilization is limited to the design and construction phases of projects. According to them, most of the Chinese enterprises adopt BIM merely to fulfil the policy requirements, but they do not use BIM to support the design and construction process. Moreover, official contract documents are still limited to traditional 2D drawings. [30.]

Currently, the 13th five-year plan (2016-2020) issued by the MOHURD is ongoing. The plan does not only focus on the promotion of BIM technology but also on its practical implementation through the usage of BIM. Similarly, different Chinese organizations have carried out research and development to promote the implementation of BIM. For instance, the China BIM Development Union proposed a P-BIM (practical based BIM) which is a practical approach for implementing BIM. Likewise, in order to support the BIM implementation, universities are offering extensive resources for any BIM related research and development projects. [31.] This indicates that China is really committed towards the development of BIM in the construction industry.

Malaysia

In Malaysia, The Construction Industry Development Board (CIDB) is responsible for the development, improvement, and expansion of the construction industry. The CIDB outlined the Construction Master Plan 2005-2015 that consisted of seven strategic thrusts aiming to enhance overall construction productivity, construction quality, occupational health and safety, sustainability practices, and the adoption of new technological construction methods. In 2011, Chan and Theong carried out a study to determine the performance made in the six years between 2006 and 2011. According to the research, the overall achievements in the construction industry were still unsatisfactory. The data indicated poor worker productivity, poor safety performance and poor-quality control. [32.]

The low productivity in construction industry is the result of the dependency on many low skilled foreign labourers and a lack of investment in new technology or technological equipment [33.] According to the CIDB, 69% or 552,000 out of a total 800,000, foreign workers were registered in June 2007 [34]. The outflow of local currency to foreign countries obviously affects the economic growth of Malaysia. Researchers established that most of the foreigners working in the construction industry were unskilled, lacking experience and had communication barriers, which influence the quality in the construction environment. [33.]

Traditional procurement methods in the construction industry still dominate in Malaysia. The separation of the design and construction phases through traditional contracting practices has created problems, for example there is lack a of interaction and coordination among contractors, owners, and designers. This often results in rework due to errors, delays in delivery times, poor quality and budget overruns during the construction phase. [35.]

However, many BIM based projects have been constructed in Malaysia. They include the Pan-Borneo Highway, National Cancer Institute in Putrajaya, Malaysian Anti-Corruption Commission Building in Shah Alam, the Educity Sports Complex in Nusajaya and the Ancasa Hotel in Pekan, Pahang [36]. Furthermore, it is interesting to notice that the Klang Valley Mass Rapid Transit Project (Sungai Buloh-Serdang-Putrajaya Line) has won the Bentley's Be inspired award in 2017 in the category of BIM Advancements in Rail and Transit. Therefore, the Malaysian construction industry has the capability to utilize BIM technology. [37.]

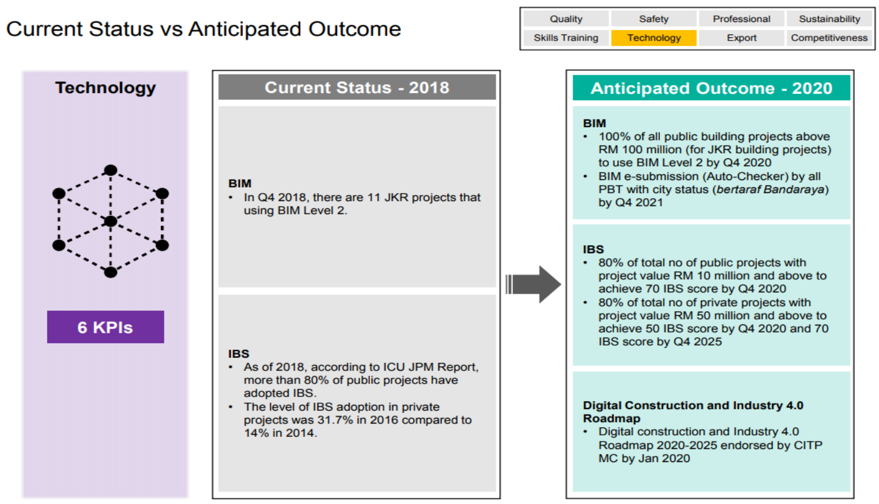


Figure 7. Construction technology implementation plan (CITP) [38].

The CIDB announced its Construction Industry Transformation Programme (CITP) 2016-2020 to transform the Malaysian construction industry into a highly productive, environmentally sustainable activity with high safety and quality standards. The transformation of the industry is going on now. By 2020, the CITP aims to change the Malaysian construction industry with the implementation of level 2 BIM on any governmental project worth over RM100 million as shown in figure 7. [38.]

The CIDB has organized several seminar programs, a lot of training, and workshops to facilitate the usage of BIM. The CIDB has invested RM 3 million to initiate Malaysia's first one-stop resource centre called myBIMcentre to promote the adoption of BIM by the construction parties. The reference centre offers BIM software and proficiency training curricula to all developers, consultants, students, suppliers, contractors and others connected with the construction industry. It is reported that over 2,000 members of BIM personnel have been trained and certified with the programs so far. However, according to a report by the CIDB (2016), the adoption rate of BIM in Malaysia was only about 17% which is relatively low when compared to the adoption rates in the United States (71%) and United Kingdom (54%). [36.]

In order to promote in the implementation of BIM in governmental projects, the CIDB has invested RM 1 billion in a fund called Transformation Scheme Fund in 2017 to attain BIM software and fund free training programs. In 2018, around RM 350 thousand was allocated for the Scheme and 30 companies were benefited. [39.]

South Africa

The share of the construction industry in the national Gross Domestic Product (GDP) in South Africa is around 4% which is a small share compared to other sectors such as finance, government, trade and manufacturing. According to the data (figure 8) provided by the CIDB of South Africa, the growth of the construction industry has declined since 2008. The maximum growth in construction output was about 16% in 2007, and the maximum year to year decline was -1.2% in 2018. [40.] The industry is facing numerous problems like a lack of both skilled and unskilled workers, expensive building materials, low standard of health, and safety performance [41.]

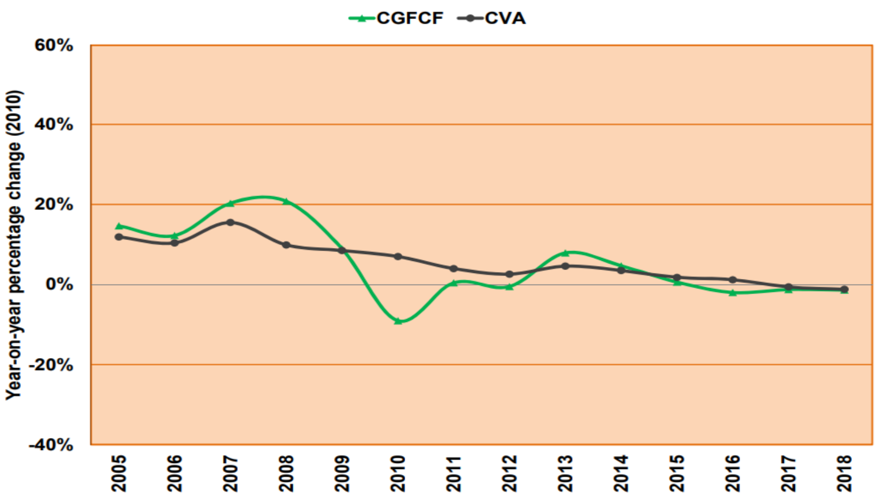


Figure 8. Change in Construction Fixed Capital Formation (CGFCF) and Construction Value Add (CVA) in South Africa (2005-2018) [40].

There are some projects where BIM technology has been utilized in South Africa like the construction of the Nelson Mandela Bay and Mbombela football stadiums for the 2010 FIFA World Cup. In those projects, modelling of the structure was done with Tekla software. The modelled 3D visualization image was further used to create shop drawings, timelines, and scheduling. The projects gave the South African AEC sector an opportunity to experience and examine the advantage of BIM technology. Since then, the usage of BIM software such as Autodesk Revit, Tekla and BIMx has increased in the construction industry in South Africa. However, the implementation of BIM is only limited to 3D modelling and clash management while the complete usage of BIM is not achieved yet. [42.]

In South Africa, the support for the implementation of BIM technology from governmental bodies, including the CIDB of South Africa, is still poor. There are no uniform BIM standards and guidelines regarding the implementation of BIM. Private companies are mostly adopting BIM either with organization-specific BIM standards or by borrowing from other countries leading in BIM. Moreover, there is a lack of demand from both public and private clients as the implementation of BIM involves new tools and systems, which is expensive. Therefore, the adoption of BIM in South Africa is low in the AEC sectors. [43.]

According to a survey conducted by Kekana et al., the construction industry of South Africa is technologically aware, but still the usage of BIM is low due to an unwillingness to change traditional methods of practice. Kekana et al. further pointed out that most of the BIM users in organizations were managers or designers and they usually utilized BIM for cost estimation, construction simulation and management purposes. [44.]

According to Sera, BIM implementation in the construction industry in South Africa has slowed down due to an underfunded public sector, disinterest in the private sector towards BIM uptake, and cheap labour force [45].

Currently, there are some organizations, namely the BIM Institute for Africa, the BIM Academy Africa, and BIM Africa, who support, promote and improve the implementation of BIM in the AEC industry across several African countries. Furthermore, the organisations help to formulate locally adapted standards and guidelines required for the adoption of BIM. By 2025, BIM Africa is aiming to educate over 500,000 African construction organizations and to facilitate policies for public projects in at least three African countries on BIM implementation. [46.] Likewise, BIM Academy Africa has managed to provide different curricula BIM courses to sixteen universities [47].

Furthermore, the BIM institute for Africa and BIM Academy Africa offer a wide range of online BIM training courses and certifications to the entire industry, from developers to consultants, construction parties to contractors. However, the South African government is not endorsing the implementation of BIM although strong governmental support is critical to accelerate the adoption of BIM [43].

Nepal

The share of the construction industry of Nepal is around 10 to 11% of the GDP, after the agriculture sector which covers about 40% of the GDP. It is reported that the construction sector has created job opportunities for around one million people who are unemployed, underemployed or seasonal workers. [48.] After the devastating earthquake in 2015, the government of Nepal has been investing large sums in reconstruction. The government has allocated more than 70% of the development budget in construction projects. [49.] However, the Nepalese construction industry has many problems that include poor quality construction, budget and time overruns, occupational health and safety problems, corruption, limited construction equipment and the use of traditional procurement methods [50].

Kusi et al. identified that inadequate skills and lack of quality management of contractors has led to poor construction quality in Nepal [49].

Figure 9. Workers at the construction site without safety equipment in Nepal [51].

The government rarely keep a record of construction workplace-related deaths and accidents in Nepal. Although the Labour Act of 2017 dictates that an employer should be responsible of protecting the workers from possible work-related hazards or risks, workers on construction sites are seen without any safety equipment like a protective helmet, gloves, glasses, boots or all of them as shown in figure 9. [51.]

In Nepal, there is no balanced and proper bidding system. Contracts for projects are mostly awarded to the lowest bidders even though there can be numerous other factors to be considered specified in the tender documents. When the contractor lowers the bid to uneconomic levels, there is a high possibility that contractors cut corners and build the infrastructure with cheap and low-quality building materials. [50.]

The traditional construction method where design work is separated from the construction still exists in Nepal. Most projects largely follow the Design-Bid-Build project delivery method. The AEC industry in Nepal still uses the traditional 2D CAD method although nowadays some companies have started to use Autodesk programmes Revit and ArchiCAD as 3D design tools. The syllabus in the Nepalese engineering institutions and universities even lacks the teaching of basic CAD, a fundamental requirement to create 2D drawings. [52.]

A survey conducted by Subash Phuyal in 2017 on 68 consulting firms found out, that only sixteen respondent firms used BIM technology. A further study showed that the majority of firms were using Autodesk Revit followed by ArchiCad. However, Phuyal did not mention the level of BIM adoption in the consulting firms. [53.]

So, it can be said that the utilization of BIM is quite low in Nepal, and the construction stakeholders are unaware of BIM technology and its benefits. In addition, most of the large projects in Nepal are carried out by foreign countries like India, China, Italy and Finland as joint ventures with Nepalese contractors. [52.] After the destruction of many buildings and structures due to earthquakes, there is a need for new buildings, roads, airports, stadiums, and other infrastructure. Thus, this is the best time to adopt BIM in Nepal.

Recently, the Nepal BIM Forum (NBIMF) was established to offer help, support and education for the Nepalese AEC industry in BIM. The NBIMF mainly assists in BIM research, implementation, standardization and education. The first BIM event in Nepal was organized by the NBIMF in collaboration with Trimble in August 2019. The event mainly focused on discussing the essential digital BIM tools and processes to initiate the digital transformation of the Nepalese construction industry. The event was well supported by the Department of Urban Development and Building Construction (DUDBC), government organization. The participants in the event ranged from public to private organizations, contractors to consulting firms to engineering professionals like architects, engineers, and designers. [54.]

2.5 Challenges in Adopting BIM in Developing Countries

Further data related to the obstacles against BIM adoption were collected on other developing countries on scientific repositories like ResearchGate, ScienceDirect, and Emerald Insight. The search was carried out with different key words, such as obstacles and challenges to BIM implementation in a certain country. The result in table 2 below shows the list of available materials encountered with google scholar in ten different countries related to BIM obstacles. Altogether, fifteen relevant papers were selected for study on the basis of an overview of the abstracts of the articles or documents.

Table 2. Search result from google scholar

Google Scholar (Since 2014)	**Available materials**		
Countries	Keyword (Obstacle)	Keyword (Challenge)	Selected
Malaysia	956	3260	2
South Africa	3550	3440	2
China	2840	8850	2
Pakistan	356	988	2
Indonesia	1390	1400	2
Jordan	495	1720	1
Nepal	182	635	1
Palestine	314	392	1
Libya	97	240	1
Nigeria	484	1560	1

Despite the great number of materials on BIM obstacles, only few were relevant to this specific topic, and the number of publications selected is provided in table 2. Keywords like challenge, obstacles, and critical factor of BIM implementation were used to gather more information, but there was not enough information. For the consistency of the result, different authors with similar results for each country were illustrated. Table 1 in appendix presents the major obstacles to BIM implementation in ten developing countries, as established by various studies.

The bar chart in figure 10 shows the list of obstacles to BIM implementation cited in literature and the frequency they were mentioned in percentage for ten developing countries. The literature mentioned 15 different obstacles to BIM implementation.

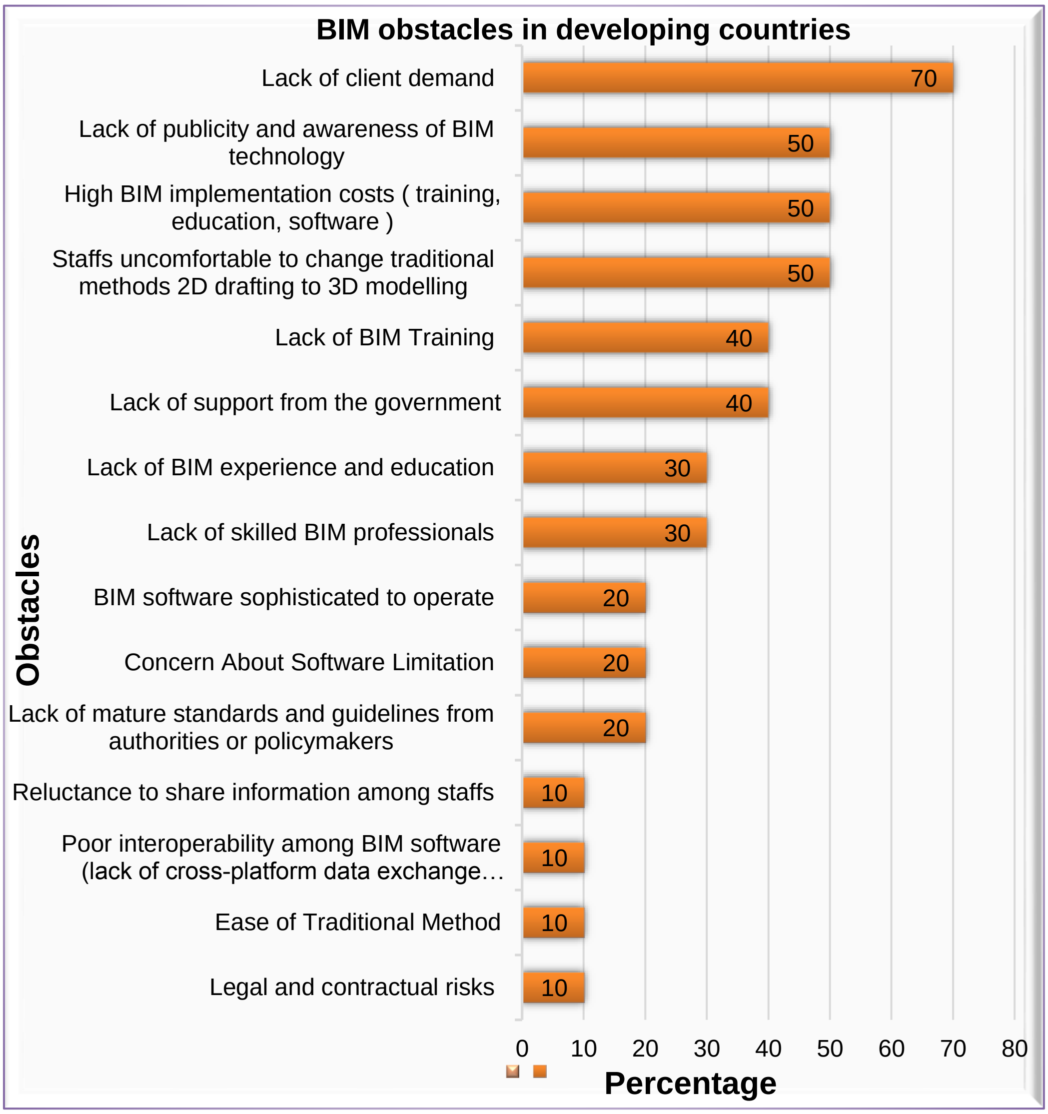


Figure 10. Obstacles against BIM implementation in developing countries [68].

As shown in figure 10 above, the obstacles are similar and persistent in several developing countries. The result indicates that a lack of client demand on BIM use is the most critical obstacle at around 70%, which means that there are seven different countries that have the same problem. Likewise, resistance to changing the traditional 2D drafting method to 3D modelling (50%), high implementation cost (50%), lack of publicity and awareness of BIM technology (50%), lack of support from government (40%), and lack of BIM training (40%) are the other top obstacles to BIM implementation as shown in figure 10.

2.6 Plans for BIM Implementation in Developing Countries

Based on the top six obstacles against the implementation of BIM in developing countries identified above, possible suggestions and recommendations for the development and adoption of BIM in AEC industry of developing countries are discussed.

BIM education

BIM education plays a significant role in the implementation of BIM in developing countries. Most of the developed countries like Finland, Sweden, Australia, Singapore, Netherlands, the UK, and the USA are incorporating several BIM courses and subjects in higher education institutions and vocational institutions [68]. In Finland, some universities of Applied Sciences provide a Bachelor of Engineering degree in Construction Architecture where the key areas are modelling and model utilization that comprises visualization, building renovation, maintenance, energy efficiency and sustainability. In developing countries, the government, BIM practitioners and tertiary educational institutions should also provide integrated BIM courses within the educational curricula to increase the uptake of BIM. The education should not only focus on the use of BIM software but also on open BIM concepts, BIM management, sustainable BIM, BIM for facility management, collaborative working skills in the built environment, and overall, on data driven construction technologies and processes. This would provide the future professionals, current students, with various skills and knowledge required in the construction industry. On the other hand, a company could then hire ready BIM professionals saving the BIM training cost for their employees.

Similarly, the government should establish a platform to train stakeholders in the AEC industry. As mentioned above, the Malaysian CIDB and some private organizations in South Africa have already initiated an organization platform to educate the construction parties [36,47]. This might also give a great push for construction firms to adopt BIM in these countries.

Organizational support

To ensure organizational support, the top-level management of an organization should be aware of BIM, its benefits and challenges. The project manager in a company should be able to develop a business case for BIM adoption to support and justify investment in BIM. Along with it, the manager should strongly support, encourage and motivate their staff to undergo BIM training, and facilitate the BIM implementation process within the organization. This may reduce the resistance from staff against changing the traditional 2D drafting method to a 3D modelling method. Furthermore, to reduce the cost of training, the company could hire an employee with skills and experience in creating a 3D model with BIM applications. This approach to the recruitment process might create a knowledge-sharing environment among staff within the organization. This means an employee with 3D modelling skills and experience in BIM could teach other employees reducing the cost of training for the company.

In order to move towards the transition from 2D CAD to BIM, a company could plan to start a pilot BIM project. They could provide BIM training to a limited number of employees from different departments who would be involved in the pilot project. During the project, the team would learn about BIM tools and become aware of the benefits of BIM at different stages of a construction project. Moreover, the pilot team could teach other staff members what they learn in the project, which could save money for the company. At the end of the project, the team could evaluate and measure the difference in productivity due to the transition from 2D CAD to BIM. Based on this, the company can set a new goal to achieve the optimum result in following projects.

Government support

The government should take a leading role in the implementation of BIM in all developing countries. There are different ways the government can support the implementation of BIM in a country. For example, the government could

- collaborate with BIM practitioners to develop a mature BIM national standards, guidelines and policies.
- impose the use of BIM in a governmental project. The government of UK has already put BIM level 2 mandatory in all governmental construction project since 2016.
- give tax reductions and support tax policies that favour the purchase of BIM software and other infrastructure required for BIM project implementation.

- collaborate with the industry and educational institutions to establish a platform for BIM education, training and research.
- organize seminars, workshops and training focused on BIM in order to raise awareness among all stakeholders in the AEC industry.
- endorse the implementation of BIM by conducting and funding in BIM research and development.

As can be seen, the government's involvement plays a very central role in changing the construction industry so that it embraces the digital technology like BIM.

Client consultation

In any construction project, there are public and private sector clients. Public sector clients are governmental bodies while private sector clients include individual, owners, companies, developers, and NGOs. Both types of clients are the primary drivers for the implementation of BIM. However, BIM can be demanded by the clients only if they can see the benefits of it. Therefore, the contractors, BIM consultants or project managers should act as communicators, facilitators and advisors to the clients in the early phases of a project. They should be able to discuss BIM and create awareness about how BIM utilization in projects help the clients in the long run against the initial investment.

A BIM consultant should analyse the client's objective together with the client and develop a business case where the client gets a competitive benefit with the use of BIM technology. Thus, the client invests in BIM right at the beginning of a project rather requests it later. There are numerous documents and case studies that show BIM adoption assists clients through improved data sharing, improved design quality, reduced design errors, improved productivity, reduced cost, and project delivery time. For example, a 3D visualization model can help clients in their decision-making process. Clients can have a realistic sense in 3D of how the completed facility looks like and operates. Hence, if the clients have a deeper knowledge and understanding about BIM application, they might be interested in implementing BIM.

In the public sector, the client, such as the government, should play a leading role in BIM implementation in their projects. This would encourage contractors to prepare themselves for the use of BIM in their projects.

3 Structural Modelling of Badigad River Bridge with Tekla Structure

The practical part of the final year project comprises the design of a structural model of the bridge over the Badigad river with the BIM application Tekla Structure and its structural validation and information take-offs using Solibri Model Checker. The purpose of this approach is to show the benefits of applying BIM in projects and to suggest a possible workflow for BIM implementation in the preconstruction phase. The bridge modelling project discussed here is in the Baglung district in Nepal.

Nepal is a landlocked country between China and India with an area of 147,181.25 km^2, divided into three regions: the Himalayan or mountains region, the Hilly region and the Terai or flatland region, covering 15%, 68% and 17% of the land, respectively. Thus, Nepal is predominantly a hilly country. [69.] The trekking in the hills from one town to another is a great challenge which might even take a day. Furthermore, Nepal has more than 6,000 rivers and rivulets that flow from the Himalayas down to the south, where the crossing of the large rivers might in places pose a threat to the people in the rainy seasons. Therefore, the geography of Nepal itself explains the importance or need of trail bridges in the various parts of Nepal.

The government of Nepal along with the support of the SDC (Swiss Agency for Development and Co-operation) has constructed and developed cost effective and sustainable trail bridges based on simple technology in Nepal. Today, more than 8,000 trail bridges have been constructed in Nepal, two thirds under Swiss assistance. The technical specifications of the bridges are verified by the engineers of Helvetas on behalf of the SDC. [70.] According to the MoFAGA (Ministry of Federal Affairs and General Administration), over 1.3 million people use the trails on a daily basis. Following the construction of trail bridges, 61% of disadvantaged groups, or 823,134 people, were provided with safer routes, the school attendance increased by 16%, the number of patients visiting medical centres rose with 26%, and the number of shops opened at the new bridge sites with 20%. In addition, it is interesting to note that 1,335,037 person-workdays of employment were generated during bridge construction. [71.] Thus, bridge construction can contribute significantly in rural Nepal, where unemployment is a major cause of poverty.

3.1 Project Information

The project discussed in the thesis is the bridge over the Badighat river which is located at Baglung district, Nepal. The super structure of the bridge comprises a cast in-situ prestressed concrete single box girder, railings, and a deck with footings and two abutments as a sub structure at the end of the bridge. The bridge is constructed along the Bhimgithhe Darling Road Baglung that connects two villages. The bridge with a span of approximately 58 m was constructed by the government of Nepal with the aid from the SDC. [72.]

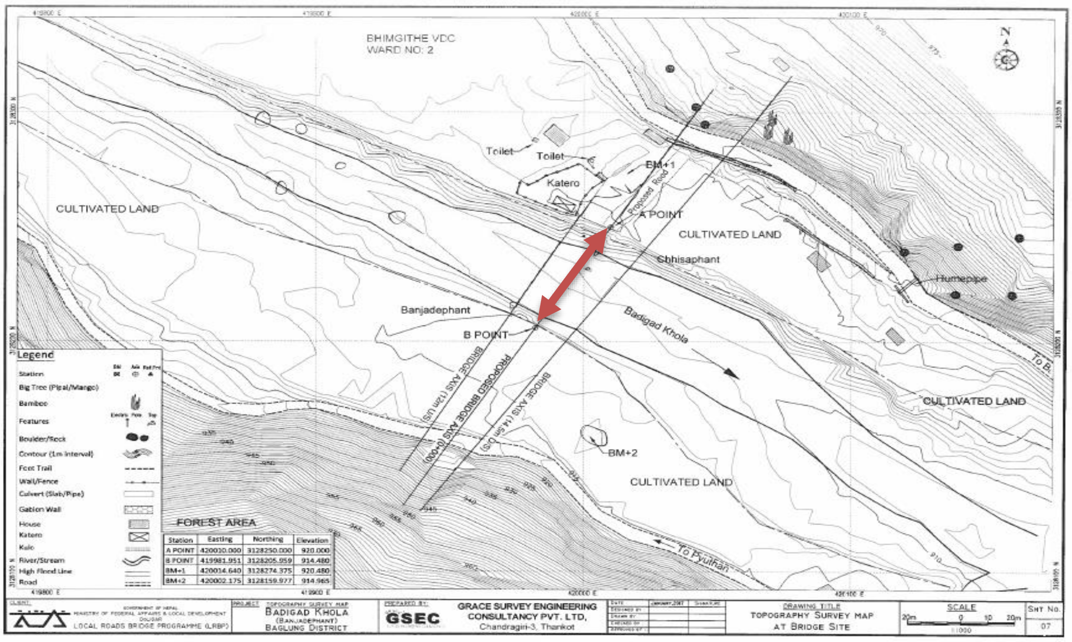


Figure 11. Location of bridge [72].

The general technical data of a super structure and sub structure of the bridge is shown below in table 3.

Table 3. The technical specifications of the pre-stressed single box girder bridge [72].

MATERIAL SPECIFICATIONS	
Concrete grade for superstructure	M45
Concrete grade for substructure (except for abutment cap)	M20
Concrete grade for abutment cap	M25
Reinforcement grade	Fe 500
Cable grade	1860 N/mm^2
Cable type	19KI3
Number of prestressing cables	18 Nos
Number of dummy cables	2 Nos
Internal Diameter of sheathing duct	90 mm
Friction coefficient between duct and cable	0.17 per radian
Friction coefficient for wave effect	0.0015 per me-tre
COVER AND OTHER REQUIREMENTS	
Cover for superstructure	40 mm
Cover for abutment	75 mm
Cover for foundation	75 mm
Minimum lap in reinforcement	65 dia
Minimum allowable slip in cable	10 mm
Ultimate prestressing force	2668.4 KN
Maximum allowable jacking force	2330 KN
Jack capacity to lift web to change bearing	2385 KN
DESIGN DATA FOUNDATION	
Dead load reaction	3855 KN
Live load reaction including impact factor	1280 KN
DESIGN DATA FOR BEARING DESIGN	
Dead load reaction	2165 KN
Live load reaction including impact factor	725 KN
Horizontal reaction	305 KN
Maximum support rotation	0.00348267 Ra-dian

During the structural modelling in the thesis, European standards were used for the concrete and steel grades as the Nepalese standards were not available in Tekla Structure. For example, concrete grade of C20/25 was used for foundation and a A500HW as a rebar grade for reinforcement.

3.2 Tekla User Interface

The default user interface display for a new project created on Tekla Structure is shown in figure 12 below.

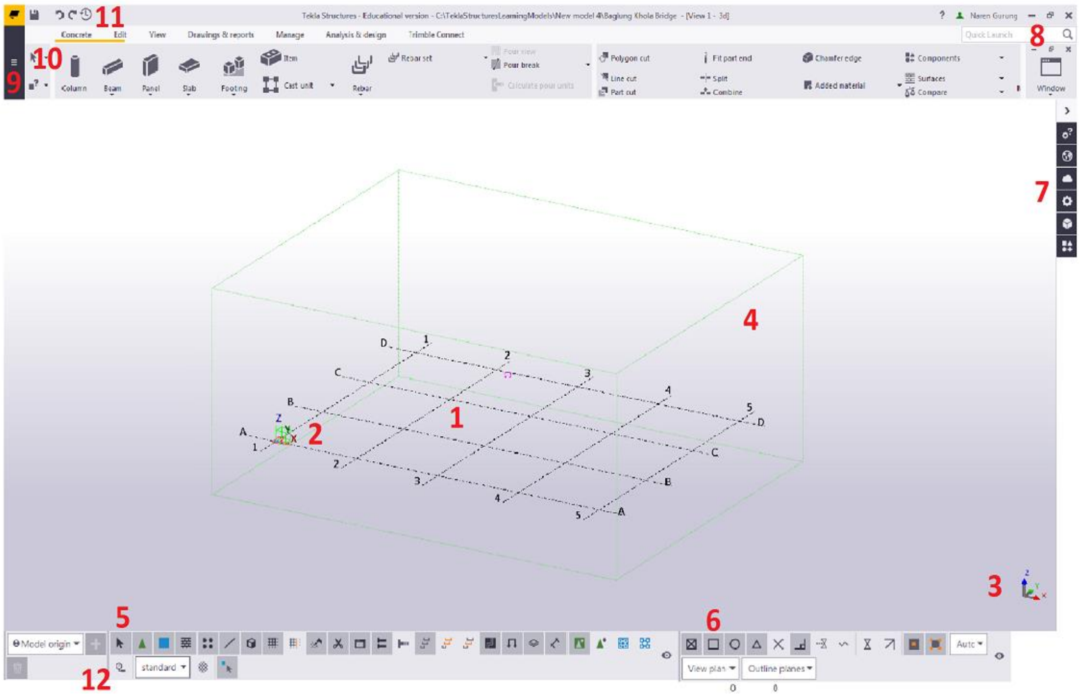


Figure 12. User interface elements in Tekla Structure 2018i

There are various functions and tools which users can learn and use easily in this application. Some of the ones used in the bridge project are described. The numbering list below corresponds the numbers shown in figure 12 and its functions.

1. A 3D model view with default grids on x and y directions. The grid can be created and modified as per need along the x, y and z directions. It is also possible to create several more view types by picking different points with the help of the view tabs on the ribbon displayed on number 7.
2. The green cube denotes a global coordinates system which acts as a reference point and helps to locate the objects in the model. The coordinates of the cube cannot be changed, it lies at x=0, y=0 and z=0.
3. A local coordinate system (work plane) can be created by the users at any position. Usually, it is used in positioning parts when modelling sloped parts.
4. The bounding box represents a work area that covers the grid lines. Any objects that are created outside the box will not be visible in views even though they exist in a model.
5. The tool bars at the bottom of the screen signify the selecting tools which help to select objects or object types to the model.

6. The snapping tools help users to snap accurately at the objects. For example, while placing objects this tool helps to pick the exact position without using co-ordinates.
7. The side pan has various functions. Users can add a reference model to help in the creation of a grid. Any default available components can also be added automatically which is easy and fast. Users can do custom inquiries and also get direct access to Tekla online services through the side pan if they need help.
8. The quick launch in the top right corner helps users to find any missing command, dialogue box, toolbar or any other functions.
9. The menu bar in the top left corner saves the model, prints drawings, exports and imports IFC files, defines profiles, customizes the user interface elements, and gives easy access to tutorials and learning materials.
10. The ribbon contains all the necessary commands which are useful when building an entire model. Users can customize the commands as required. They can edit, hide or add commands at any time to make working easy.
11. There are many keyword shortcut tools in the application. There is a default quick access toolbar icon in the top left above a corner of the screen, which helps to save, redo, undo and undo history while working on the model.
12. The status bar in the left bottom corner displays the information on how to proceed when any commands are used to create an object.

These user interface elements are included on Tekla Structure version 2018i as the project was conducted on this version. There might be an improved user interface with some new features on upgraded version, making the work even easier and more efficient.

3.3 Bridge Modelling

As mentioned above, the structural modelling of the bridge over the Badigad river was created using the BIM software Tekla Structure. For this project, default Tekla Structure setup was selected, as country specific information on various profiles, material grades, drawing and components settings was not available.

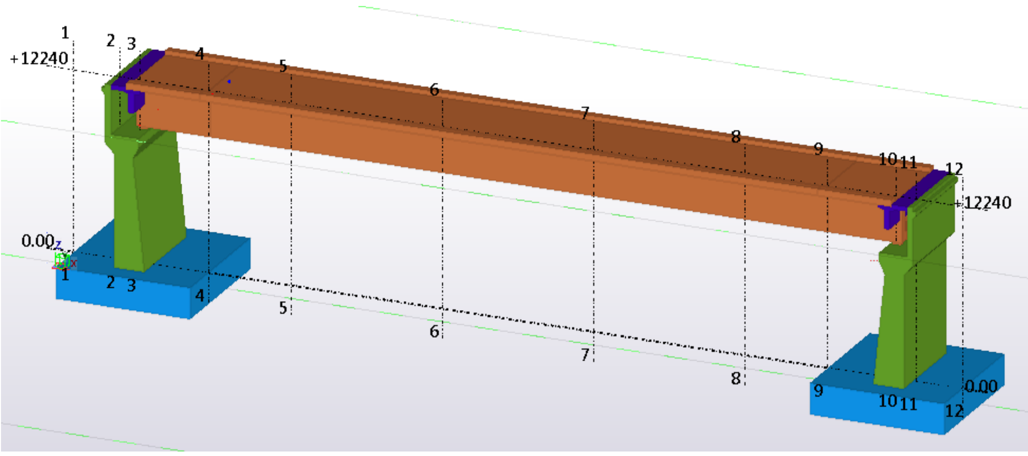


Figure 13. 3D View created in Tekla Structure

To create the model, the required grid line was first created along the x, y and z axes to help to locate the components in the model. Figure 13 above is a screen shot of the 3D view model in Tekla Structure. The footing (blue colour) which supports the abutment (green colour) was designed using the pad footing properties in the property pane as illustrated in figure 14.

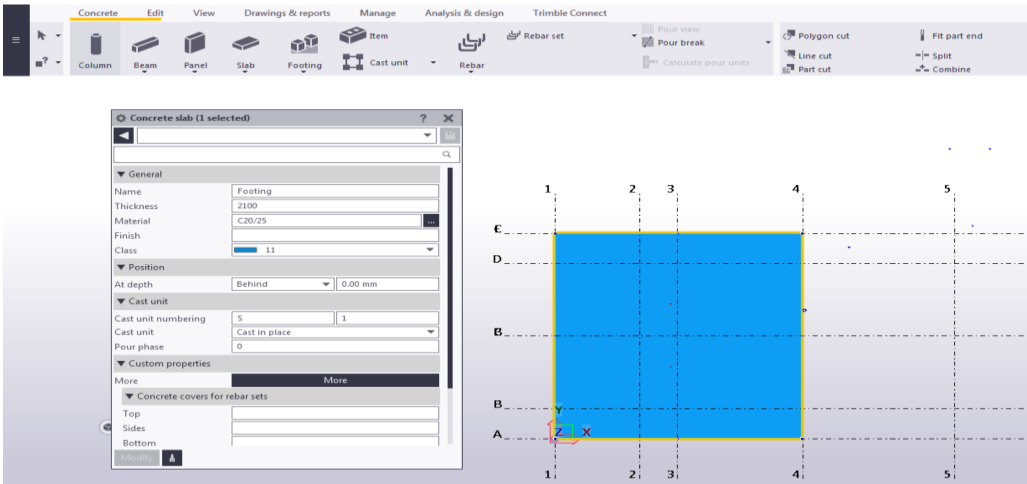


Figure 14. Properties of footing modified in property pane

The footing was selected from a ribbon toolbar and placed with a single click in a required position. Then the properties of the footing, such as the sizes, materials, class, and position were modified as required with a double click on the footing.

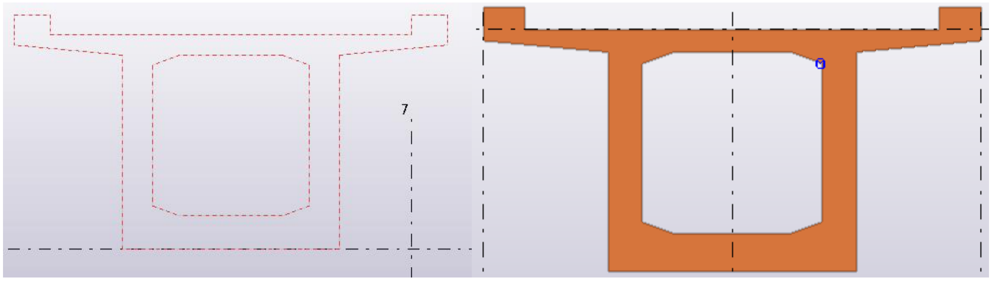


Figure 15. Cross section with construction line (left) and created profile cross section (right)

In order to create an abutment, a single box girder and ribs, shown in green, brown and blue, respectively in figure 13, a user defined fixed profile was created by defining the cross section by first drawing the cross-section shape in a model with a construction line and then defining the shape using a polygon (figure 15). Similarly, the reinforcements were placed using the planer, a longitudinal and crossing rebar sets command which can be found in the ribbon (figure 12), and later modified as needed. In some cases, manual reinforcement was also used which was easy and fast. Figure 16 below illustrates one of the planer rebar sets created for an abutment.

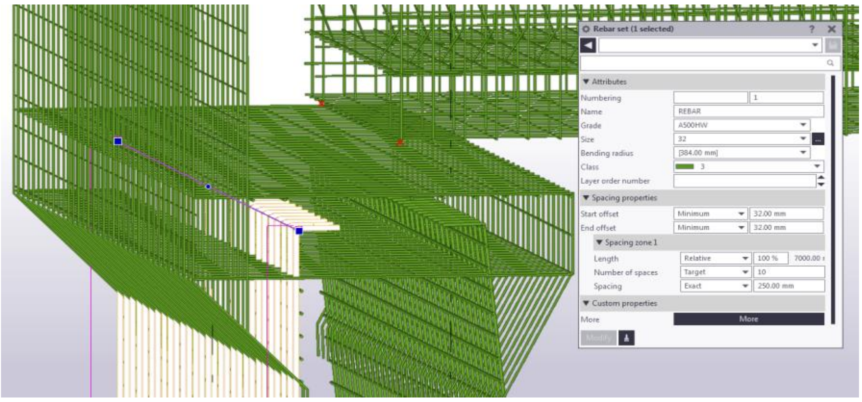


Figure 16. Reinforcement created with rebar sets

After the modelling the Badigad bridge, an IFC file was exported from Tekla Structure and imported to Solibri Model Checker for structural validation and information take-offs which could be used for cost estimation. For clash detection, a structural validation role and various rulesets were selected or added in the layout as demonstrated in figure 17, and the checking process were performed with a single click.

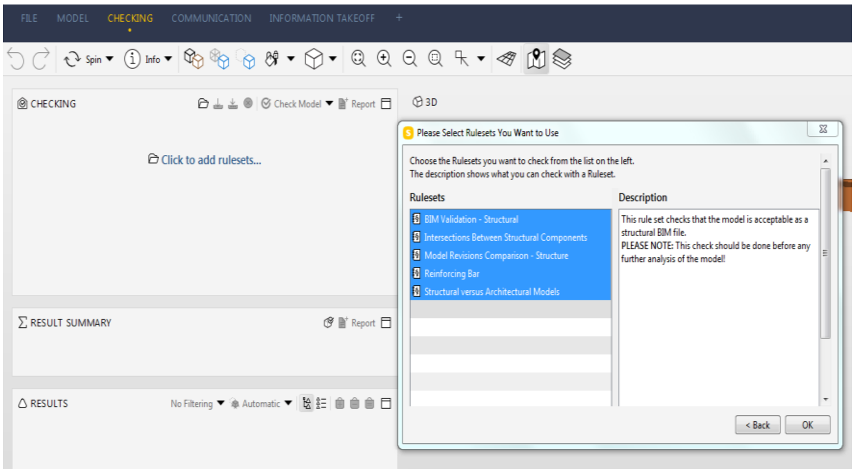


Figure 17. Selection of rulesets for checking

For information take-offs (ITO), a building elements classification was added based on the role chosen. After that, structural quantities were selected from open ITO definitions and then with a single click on ‘Takeoff all’, a result was displayed as shown in figure 18. Each component of the bridge is displayed with a different colour for better visualization and easier understanding.

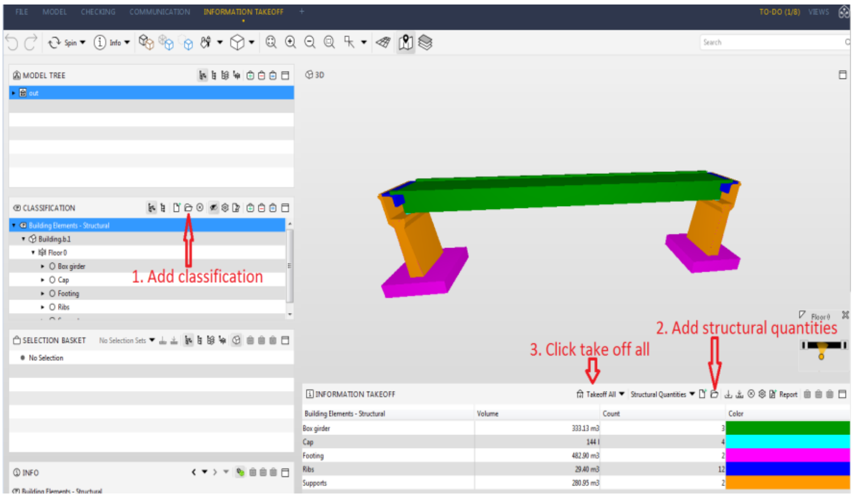


Figure 18. ITO procedure

The ITOs were also reported in the form of excel spread sheet (figure 23) which can be used for communication among the design team members. Furthermore, Solibri Model Checker users can create their own classifications of elements as required, choose new ITO definitions of the model and produce ITOs.

3.4 Advantage Through Practical Model

Better visualization and communication

The use of BIM software in this bridge project has helped the visualization greatly. Not only was it possible to separately visualize all the elements of a model closely but the visualization also revealed the problems in the design. In addition, the users can select the components they want to work with and hide the rest of the components, which makes it easy to work and reduces possible mistakes while working.

The 3D model can be used for communication between the architect and the clients. It allows both technical and non-technical clients to see what the entire model looks like, offering the ability to validate changes and understand the space before the construction even starts. Identifying problems at the early stages may prevent the need for rework and delays in the project schedule. Thus, BIM usage improves the design and client satisfaction by delivering a quality final product. Figure 19 shows the reinforcement details of a bridge model in Tekla Structure.

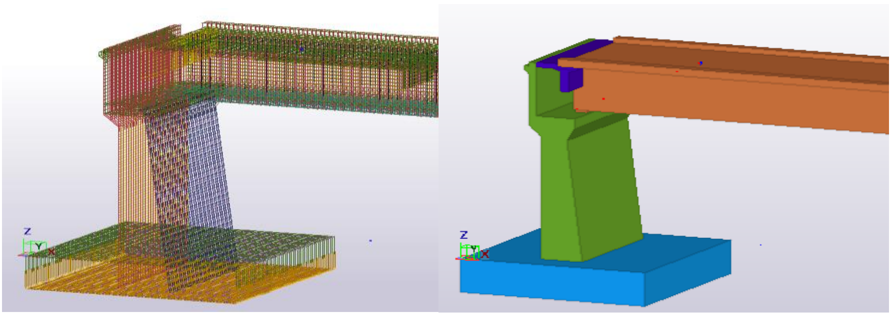


Figure 19. Detailed reinforcement of box girder and end support

Within different construction parties, a model can be shared in the form of IFC file for better coordination. For example, a structural engineer can add a structural detail using Tekla Structure in a model where an architect previously created an architectural model with ArchiCAD or Revit. With BIM technology, multifile formats from different disciplines can be integrated into a single project model, which makes team coordination and communication efficient, unlike paper-based drawings. Nowadays, these files can be opened through various internet browsers as well as with several applications, which makes it easy to send the information to stakeholders and collaborate in real time. Various functions for effective teamwork, information visualization and so on have been developed within BIM applications.

Clash detection

Solibri Model Checker was used in this project to perform clash detection and create information take-offs (ITO) for cost estimation. The model checking was performed on the basis of various rulesets such as BIM structural validation, intersections between structural components, structural versus architectural components and reinforcing bars. A check in the Badigad river bridge model gave the results displayed in figure 20. The red, orange and yellow triangles indicate major, moderate and minor issues, respectively. Out of the rulesets selected (figure 17), intersections between structural elements were found as major clashes in this project (figure 21). However, minor clashes often called soft clashes should also be taken into consideration and fixed. A minor issue could often be fixed on site.

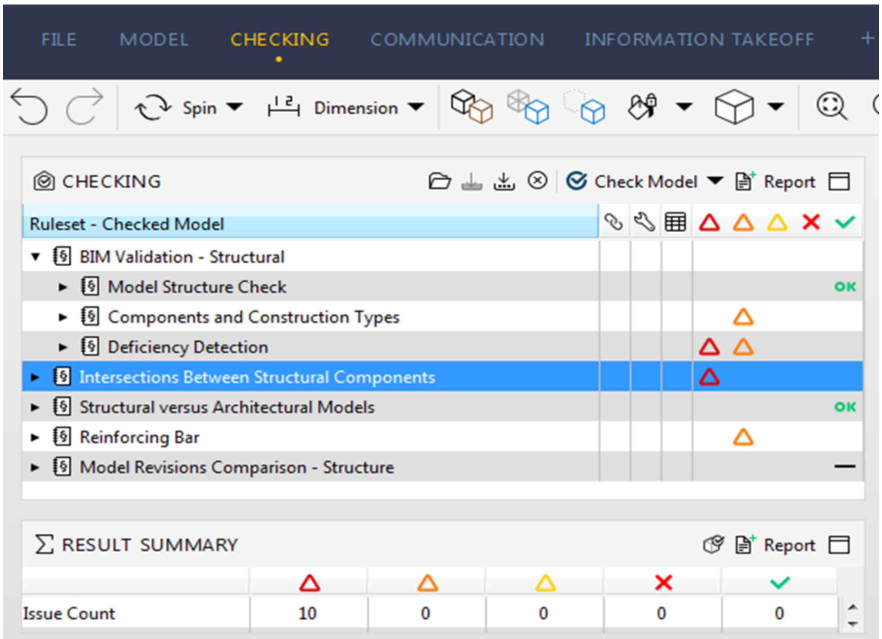


Figure 20. Clash detection checking

There are different types of clashes: hard clashes, soft clashes and workflow clashes that might occur during the construction stage. A Hard clash occurs when two elements occupy the same space. A soft clash situation means that two or more elements of inter-disciplinary models are too close to each other, restricting an easy and safe maintenance access in the future. Workflow clashes are conflicts in contractor scheduling, equipment and material supply and general workflow timeline. [73.] Figure 21 below shows a hard clash between a box girder (red) and ribs (blue) in the project.

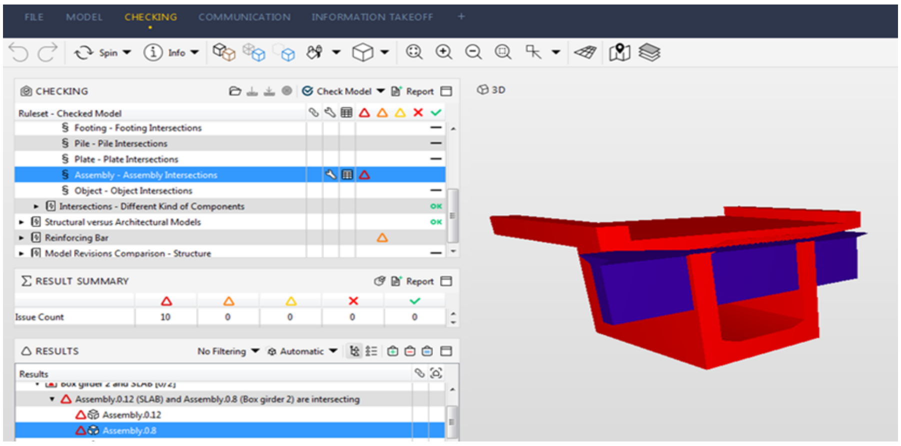
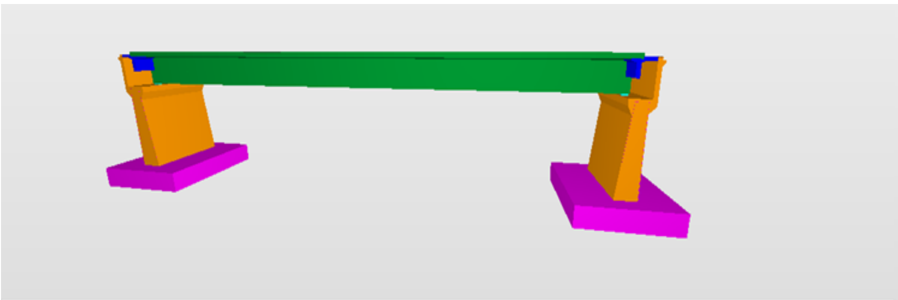


Figure 21. Box girder (red) and ribs intersecting (blue)

When a major clash emerges at a construction site, the construction design will need to be fixed at the spot. This is a high-cost process that delays the schedule of the project, which might, ultimately, raise the project costs even more. With the use of BIM software like Solibri Model Checker, this kind of clash problems can be eliminated as they are spotted during the design phase of the project, before the work on site begins.

Model based cost estimation

The use of Solibri Model Checker in the Badigad river bridge project made the generation of accurate bills of quantities easy and fast. During the bridge project, the information take-offs (ITO) was only created with the concrete part just to show an example of cost estimation. Figure 22 displays the volume of concrete used in the various elements of the Badigad bridge.



Building Element Type	Volume	Count	Color
Box girder beam	333.13 m3	3	
Cap	144 l	4	
Footing	482.90 m3	2	
Ribs	29.40 m3	12	
Supports	280.95 m3	2	

Figure 22. ITO from Concrete

Figure 23 also shows the ITO in an excel spread sheet which can be used for communication among design teams and for procurement purposes during construction bidding.

Building Element Type	Volume	Count	Color
Box girder beam	333.13	3	
Cap	0.144	4	
Footing	482.9	2	
Ribs	29.4	12	
Supports	280.95	2	

Figure 23. ITO exported in excel

ITOs extracted from Solibri Model Checker help in cost estimation. The designers can choose various designs and quantities for comparative cost analysis to support better decision making and cost savings without compromising the quality of the project. The owners can also visualize and change the model as desired and analyse the cost impact of the changes in the beginning of the project, staying within the budget. Therefore, BIM provides reliable cost feedback in the early stages of construction, identifying the risks earlier and helping to make better decisions. According to the study of McKinsey et al., 75% of companies who adopted 5D BIM have received a positive return in investment [74.]

Creation of drawings

The use of Tekla Structure allows users or designers to generate different drawings, such as single part drawings, assembly drawings, general arrangement (GA) drawings and cast unit drawings as needed. The drawings can be created individually, in groups or they can also be extracted automatically. Furthermore, any changes made in the model will be updated automatically in the generated drawings document. After the drawing is created, the properties of the views and layouts of the drawings, dimensions and marks in the drawings and texts on the drawing, as well as other markings, can be edited or added. Figure 24 below shows GA drawing created in the project.

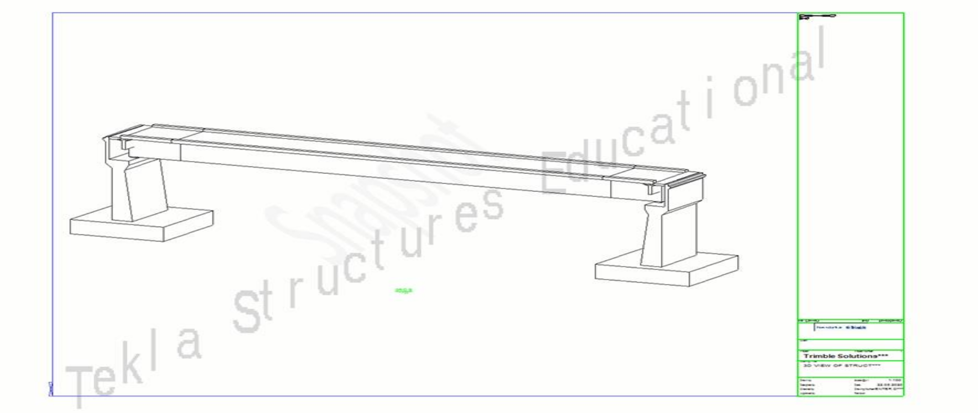
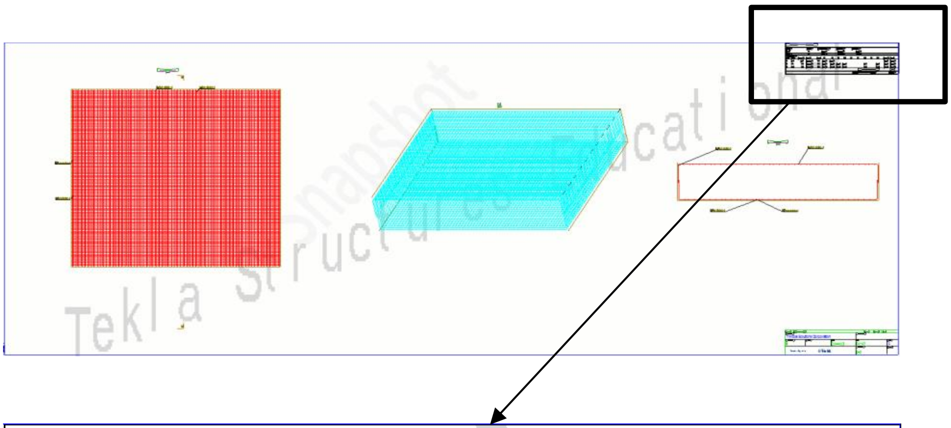


Figure 24. 3D GA drawing

When creating cast unit drawing as demonstrated in figure 25, reinforcement details are automatically displaced in the drawing, along with a bill of materials that contains information like the volume and weight of structures, which can also help in cost estimation.



CAST UNIT BILL OF MATERIAL

Cast unit	Quantity	Main part material	Weight (kg)	Volume (m³)
S/9	2	C20/25	503798.4	209.92
Footing	1	C20/25	503798.4	209.92

Reinforcement:

Type	Pos	Quantity	Grade	Diam	L	a	b	c	d	e	u	v	D	kg/one	kg/all
1	34	129	A500HW	16	10150	10150								16.0	2068.8
4	1	51	A500HW	20	11740	1075	9692	1075			90		100	29.0	1478.9
4	35	68	A500HW	25	11730	1064	9750	1064			90		176	45.2	3070.9

Reinforcement total weight (kg): 6618.6

CAST UNIT TOTAL WEIGHT (kg): 508431.4

Figure 25. Cast unit drawing of footing with bill of material

With a CAD system, a plan view is created first, and only after the approval of the client are elevations and sections created. So, there is a chance of missing component information while creating the drawings separately. With the BIM process, the elevation and section drawings are automatically processed and generated without missing component information, which is easy and saves time.

4 Conclusion

This final year project aimed at identifying the trends of BIM implementation and obstacles against adopting BIM in developing countries. The study on BIM implementation obstacles was carried out in ten developing countries: China, Nepal, Malaysia, South Africa, Pakistan, Palestine, Jordan, Indonesia, Libya and Nigeria. Based on the study, possible BIM implementation strategies were also recommended in chapter 2. It was observed that the most critical obstacles for the implementation of BIM in developing countries were a lack of client demand on BIM use, resistance to change the traditional 2D methods, high implementation costs, a lack of awareness of BIM technology, a lack of government support and a lack of BIM training. According to the analysis of these findings, a BIM consultant should act as a communicator and advisor to the clients in an early stage of a project, explaining the benefits of BIM. This would be the best way to increase the implementation of BIM. BIM based curricula should be added in architecture and engineering universities and training. The universities and polytechnics should make a serious effort to introduce the concept of BIM to engineering students. Along with client consultation and BIM education, there should be strong support from organizational and governmental level as well.

In order to support BIM implementation in developing countries, a practical approach was adopted to show the benefits of BIM. A pre-stressed single box girder bridge was modelled using Tekla Structure, and the structural validation of the bridge was done using Solibri Model Checker. The entire bridge was not modelled, the bridge modelling covered the abutments, and single box girder beam with their reinforcement details, to demonstrate the workflow of BIM process and to verify the advantages of BIM usage in a project. Throughout the modelling process, several advantages were pointed out and discussed. For example, the visualization of the model can help clients to virtually experience what the entire model looks like, offering the ability to change the design as desired. Furthermore, the owner can identify potential risk factors, which enables a better decision-making process. Similarly, the automatic extraction of drawings with the help of a BIM application can ultimately save time, as the amount of repeated manual tasks is significantly reduced. Likewise, BIM-based clash detection tools can reduce the chances of clashes between the components at the design phase already. Detecting the clashes at the construction stage would be expensive.

Only 10 developing countries were studied in the final year project, which is not large enough a sample out of 126 developing countries. Further study should be conducted on developing countries of a specific region. Moreover, further study into methods of teaching BIM concepts to students at universities is recommended, as well as into organizational policies that would encourage the implementation of BIM in developing countries. Nowadays, there are several free resources and materials available on the internet about BIM, such as user guidelines and video tutorials to learn about BIM software and process. Software vendors are providing free trials and educational versions of their products in different languages for a certain period of time to encourage the students and working professionals and to increase the adoption of BIM technology. Therefore, in this technological era, any students or employees interested in BIM could get an easy access to the internet and download a free trial or an educational version of software and learn by themselves, not needing to depend on anyone for guidance.

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Challenges of BIM implementation

Table 1. List of obstacles of BIM implementation in developing countries

Malaysia	
Studies	**Findings/Conclusion**
CIDB (2016) [55.]; Syazwani W, Abdullah M, Ismail S, and Takim R. (2018) [56.]	• High implementation cost • Lack of awareness/knowledge on BIM • Resistance to initiation of new workflows for the implementation of BIM • Lack of BIM training
South Africa	
Froise T, Shakantu W. (2014) [57.] ; Akintola A, Root D, Venkatachalam S. (2017) [43.]	• Lack of drive for BIM adoption and implementation from government and related institutions • Lack of client demand. • A procurement process that discourages collaborative processes. • Lack of BIM professionals
China	
Zhou Y, and Yang Y. (2018) [31]; Zhao X, and Pienaar J. (2019) [58.]	• Lack of mature standards and guidelines • Resistance of staffs to adaption of new technology • Reluctance to openly share information among staff • Lack of client demand for BIM use • Poor interoperability of BIM software
Pakistan	
Siddiqui F, Akhund M, and Ali T. (2019) [59.]; Fatima A, Saleem M, and Alamgir S. (2015) [60.]	• Lack of Skilled BIM personnel • Legal and contractual concerns • High cost of implementation • Reluctance to change the traditional 2D practice • Concern about software limitation or complexity
Jordan	
Rana M, and Sadeq H. (2017) [61.]	• Lack of support from the government • Lack of awareness of BIM technology • Lack of demand from the client • Resistance to changes in current workflow, practices, and procedure • Expensive implementation of BIM

Indonesia	
Hatmoko J, Fundra Y, Wibowo M, and Zhabrinna Z. (2019) [62.]; Zhabrinna Z, Davies R, Pratama M, and Yusuf M. (2018) [63.]	• Expensive cost of investment • Absence of BIM requirement from clients • BIM software sophisticated to operate
Nepal	
Phuyal S. (2017) [53.]	• Lack of training and institutional education • Ease of traditional method • Lack of awareness on BIM • BIM requires changes in workflow • Concern about software limitation
Palestine	
Enshassi A, and AbuHamra L. (2017) [64.]	• Lack of awareness of BIM by stakeholders • Lack of education and training on the use of BIM • Lack of demand from clients • Lack of governmental regulations
Libya	
Saleh M. (2015) [65.]	• Lack of BIM education • Lack of publicity and awareness • Lack of understanding of BIM and its benefits • Lack of sufficient training • Lack of client and government demand
Nigeria	
Chen W, Shittu A, and Hamzah A. (2015) [66.]	• Lack of BIM expertise within the organizations • Lack of standardization and protocols • Lack of client demand • Lack of government policy and support • High investment cost