

INTEGRATION OF BUILDING INFORMATION
MODELING (BIM) AND AUGMENTED REALITY
(AR) FOR BETTER VISUALIZATION AT
CONSTRUCTION SITE



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CERTIFICATE OF APPROVAL

It is certified that the project titled ‘**Integration of Building Information Modeling (BIM) and Augmented Reality (AR) for better visualization at construction site**’ was carried out by M. Awais Abid (F19601021), Umair Sultan (F19601044), Zeeshan Tahir (F19601043), and Bilawal Haq (F19601016) under the supervision of **Dr. Omer Javaid**, National University of Technology, Islamabad, is fully adequate, in scope and quality, as a final year project for the degree of BS in Civil Engineering.

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Abstract

The construction industry plays a pivotal role in shaping the world's infrastructure to meet the demands of modern society. However, it faces challenges such as project complexity, inefficiencies, and lack of collaboration which in ultimately leads to the cost and time over-run. In recent years, Building Information Modeling (BIM) has emerged as a progressive technology, improving the way construction projects are planned, designed, and executed. On the other hand, Augmented Reality (AR) has gained traction as a promising tool for enhancing on-site visualization and data interaction.

The project introduces BIM and AR integration using the unity platform and come up with a dedicated application for the construction industry to improve visualization in design offices as well as on site. AR has the ability to simulate the building from whole to part without needing the building to be constructed. AR allows us to walk with in the simulated building model that makes the job of engineer and worker a lot easier then verbal indication. Which ultimately reduce re-work and errors.

Overall, BIM and AR integration has a transformative effect on the construction industry. As both of these independently have such a huge impact. So, integrating them will help us achieve wonders that is to improve efficiency and visualization on site. Also, stream-lining workflow, reducing errors, fostering collaboration and ultimately leading to more successful project

Chapter 01

1 Introduction

The Construction Industry (CI) is a vast industry. Apart from being vast, Since, the construction sector is information-based, a lot of information must be transferred and communicated. During this process of information transfer a lot of challenges are faced and are needed to be resolved. The problems sometimes lead to loss of information and cause the project to derail and the managing authority to undergo stress. The construction sector is significant and contributes roughly 13% of global GDP (Gross Domestic Product). According to McKinsey, over the past two decades, its labor productivity has only increased by about 1%, compared to 2.8% of the overall economy and 3.6% for manufacturing [1]. As the industry is on a large scale, the problems associated with the industry are also on a bigger scale. Mainly the schedule deviation and cost overrun being the top priority. In the construction sector, 98% of megaprojects experience cost overruns or schedule delays, with an average cost increase of 80% of the initial budget and an average delay of 20 months. [2] Paper studies show that 14% of the project contract amount is consumed by cost overruns, 10% of project supplies are wasted, and schedule overruns affect 70% of construction projects. Frequent design modifications cause low productivity to rise, which in turn causes cost overruns and schedule slips, ultimately creating construction waste. Additionally, construction wastes are produced by numerous design revisions, subpar materials, unskilled labor, inadequate planning and site management techniques, materials that don't meet specifications, and other issues. Additionally, unforeseen circumstances like the weather can make some construction activities take longer to complete. In conventional processes, construction processes are monitored and controlled by paper-based tools. The papers refer to the drawings on site which can be up to a few thousand pages. Also constantly there are changes made in these drawings. It becomes hectic or impossible to keep track of these amendments. The conventional progress monitoring system is not very effective and sometimes doesn't even inform the stakeholders about the on-site problems. Also, this is a time taking process and everything is done by hand all the forms are filled and passed on. In addition, The site administrators lack efficient tools for quickly and simply representing and visualizing information.

So, an effective monitoring system is required for monitoring the progress and performance of construction processes that can effectively identify and deal with the problems related to the site

and also keep the stakeholder in the loop. With that being said over the years there has been a change observed in all fields also the construction industry. After the 4th industrial revolution that aims for the combination of modern technology with the construction industry. This is referred to as construction 4.0 it tends to use automation in all fields and industries including the construction industry. So, we have seen that now many countries have imposed laws to use BIM and AR in construction and won't be allowed to work otherwise. We have studied a lot of research papers and have gotten up-to-date on the progress of the construction industry. With all this study studying, we have become able to identify the gaps where work is needed to be done. Many researchers have done work on AR and BIM but they have done work on a specific point and haven't been able to come up with an application that is dedicated to the construction industry. We are aiming to create an application that can supervise all the site work. By site work, we mean schedule tracking, progress reporting, daily tasking, and also being able to generate a message for all the stakeholders.

1.1 Building Integrated Modeling (BIM)

The construction industry has received a significant transformation due to digitalization. A key development is the increasing prevalence of 3D modeling, which has become a standard practice. Computer Aided Drawings (CAD) have also gained widespread adoption. Building Integrated Modeling (BIM) has revolutionized the construction process by providing comprehensive management capabilities from inception to completion[4].

Augmented Reality (AR), as suggested by [4], has the potential to merge digital and physical realities, altering our perception of the world. In the construction field, AR can be effectively employed throughout various stages, including land acquisition, construction, and maintenance [5].

The focus here is to emphasize the opportunities and challenges associated with integrating AR and BIM. BIM serves as a platform that allows users to utilize different software tools and seamlessly integrate data across applications. BIM enables efficient data storage, facilitating real-time updates and versatile information presentation. BIM models encompass more than mere representations and can be presented in diverse formats, ranging from 2D to 6D[6].

A 2D model is a two-dimensional drawing, whereas a 3D model allows for easy exploration and manipulation, enhancing understanding of spatial relationships, materials, and structural systems. The 4D model incorporates temporal information, enabling users to plan tasks and visualize progress in real-time. Additionally, the 5D model integrates cost estimations, providing insights into the corresponding building budget. BIM can extend further into the nD environment, encompassing aspects such as accessibility, logistics, safety, quality, maintenance, acoustics, and energy simulation [5].

To simplify BIM's complexity and enhance comprehension, maturity levels, denoted as levels 0, 1, 2, and 3, have been established[7]. Level 0 entails paper and computerized drawings, while level 1 involves a combination of 2D and 3D drawings. Level 2 comprises shared 3D drawings accessible to all stakeholders and workers, facilitating clash detection and problem identification. Finally, level 3 signifies complete BIM implementation, where a single specified drawing with comprehensive information is shared among stakeholders, engineers, and workers.

Despite the benefits offered by BIM, certain challenges need to be addressed. BIM necessitates substantial data storage capacity, as the amount of information involved is extensive. Overcoming this challenge, however, can be facilitated by utilizing Mixed Reality (MR), a branch of technology that aids to overcome the gap between the virtual and real worlds, providing clearer boundaries between the two realms[8][9].

1.2 BIM data in a real environment

Building Information Modeling (BIM) is a widely used process for creating and managing digital representations of building and infrastructure projects. BIM data plays a crucial role throughout the entire project lifecycle, encompassing design, construction, and operation[3]. Below are real-world applications of BIM data implementation:

Design and Visualization: BIM data enables architects, engineers, and other professionals to create and visualize digital building models. Collaboration is enhanced as stakeholders can explore design options, and assess the impact of decisions on structural integrity, energy efficiency, and spatial planning.

Clash Detection and Coordination: BIM data facilitates the identification of clashes between different building elements (structural, architectural, MEP) or systems before construction commences. Integration of data from various disciplines (e.g., architecture, structure, mechanical, electrical) allows BIM software to automatically detect and propose solutions to resolve clashes, minimizing errors, rework, and delays during construction.

Quantity Takeoff and Cost Estimation: BIM data aids in accurately extracting quantities of materials and components from the digital model. By associating cost data with these quantities, estimators can generate precise cost estimates, assisting in budgeting, procurement, and resource planning.

Construction Sequencing and Scheduling: BIM data supports the creation of detailed construction schedules and visual representations of activity sequences. Project managers can streamline the building process, spot potential bottlenecks, and boost overall project effectiveness by connecting construction jobs to the model's relevant elements.

Facility Management and Maintenance: For the management and upkeep of facilities, BIM data is an invaluable resource. It includes detailed specifications, product data, maintenance schedules, and operating manuals associated with building components. Facility managers can utilize this data to streamline maintenance operations, track asset performance, plan renovations, and manage energy consumption.

Energy Analysis and Sustainability: BIM data, when combined with energy analysis software, allows for the simulation and evaluation of a building's energy performance. Factors such as solar radiation, thermal properties, and HVAC systems are analyzed, enabling designers to optimize energy efficiency, assess design alternatives, and implement sustainable solutions.

Asset Tracking and Lifecycle Management: BIM data serves as a central repository for building asset information. It includes details about manufacturers, installation dates, warranties, maintenance history, and replacement schedules for various components. This data facilitates asset tracking, informed decision-making for replacements or upgrades, and effective long-term asset management.

The adoption of BIM processes and technologies continues to grow, delivering numerous benefits to the construction industry in terms of collaboration, efficiency, and improved project outcomes.

1.3 Augmented Reality (AR)

AR is a very powerful tool capable of doing wonders in any field. It works by superimposing the computer-generated objects onto the real world. Typically, it is achieved by the use of a camera and a screen or display devices, such as a smartphone or smart glasses. AR is better than VR (Virtual Reality) as VR involves the creation of a completely artificial environment that a user can interact with, AR, on the other hand, supplements and enhances the real world with digital content. A cutting-edge technology called augmented reality (AR) improves users' experience of the actual world by superimposing digital content on their surroundings. AR experiences can be accessed through devices like smartphones, tablets, smart glasses, and wearables. Here are several practical applications of augmented reality across various sectors:

Gaming and Entertainment: Augmented reality has revolutionized the gaming and entertainment industries. Popular games like Pokémon Go leverage AR to blend virtual characters and objects seamlessly into the real world, allowing players to interact with them in real-time. Theme parks and museums also utilize AR to offer interactive and immersive experiences to visitors.

Retail and E-Commerce: AR is reshaping the retail landscape by enabling virtual try-on experiences. Customers can leverage AR applications to visualize how furniture, clothing, or cosmetics would look on themselves or in their living spaces, making shopping more engaging and reducing the likelihood of returns.

Education and Training: Augmented reality is increasingly being integrated into educational settings, enhancing learning experiences. AR can overlay supplementary information, such as 3D models or videos, onto textbooks or real-world objects, assisting students in grasping complex concepts. Vocational training benefits from AR by simulating real-life scenarios, allowing learners to practice in a safe environment.

Architecture and Construction: The architecture and construction industries leverage AR to visualize and assess designs in the context of the real world. AR applications enable architects to overlay virtual building models onto construction sites, facilitating informed decisions during the design and planning phases.

Maintenance and Repair: Augmented reality is employed to provide real-time guidance and support for maintenance and repair tasks. Technicians equipped with AR-enabled devices receive step-by-step instructions overlaid onto the equipment they are working on, reducing errors and enhancing overall efficiency. AR also facilitates remote assistance, enabling experts to guide on-site technicians through tasks using live video and annotations.

Healthcare: Augmented reality finds numerous applications in healthcare, including medical training and surgical planning. Surgeons utilize AR to visualize patient-specific anatomical structures before undertaking complex procedures, enhancing precision and reducing risks. AR can also display real-time vital patient information during surgeries or guide medical professionals through intricate procedures.

Tourism and Navigation: AR enhances tourism experiences by providing interactive guides and information about landmarks, historical sites, or points of interest. AR-based navigation apps overlay directions onto users' real-world view, simplifying navigation in unfamiliar environments.

1.4 AR and Civil Engineering

Augmented Reality (AR) is gaining significant traction in the field of Civil Engineering, offering innovative ways to visualize and interact with construction projects. Here is an overview of how AR is being utilized in Civil Engineering:

Visualization: Civil engineers may see construction plans in a real-world setting thanks to AR technology. By overlaying digital 3D models onto the construction site using AR applications, engineers can assess how the design integrates with the physical environment. This visualization aids in identifying clashes, optimizing space utilization, and improving design accuracy.

On-site Construction Guidance: AR provides on-site guidance and support to construction workers. By wearing AR-enabled devices, workers can access real-time information overlaid onto their field of view. This information includes instructions, measurements, and annotations, facilitating accurate and efficient construction processes. AR can assist workers in locating buried utilities, verifying component installations, and ensuring adherence to project specifications.

Safety and Risk Management: AR enhances safety and risk management on construction sites. Through AR, workers can receive real-time alerts about potential hazards or safety guidelines

overlaid on their view. This technology helps prevent accidents, improve compliance with safety protocols, and increase overall awareness of potential risks.

Building Inspection and Quality Assurance: AR streamlines the building inspection process and improves quality assurance. Inspectors equipped with AR devices can access digital plans and specifications overlaid on the physical structure. This capability enables real-time comparisons, identification of discrepancies, and accurate assessment of compliance with regulations and standards. AR can also provide access to maintenance records, warranty information, and operating manuals for efficient asset management.

Collaboration and Communication: AR facilitates collaboration and communication among stakeholders involved in a construction project. By sharing AR-generated models, engineers, architects, and clients can remotely explore designs and provide feedback in a more immersive and interactive manner. This technology enhances communication, reduces misunderstandings, and expedites decision-making processes.

Training and Education: AR offers valuable training and educational opportunities for civil engineering professionals. Through AR simulations, trainees can practice construction tasks, equipment operation, and safety procedures in a virtual environment. This approach provides a risk-free and cost-effective way to enhance skills and knowledge before applying them on-site.

Facility Management and Maintenance: AR assists in facility management and maintenance throughout the lifecycle of a building. Maintenance personnel can utilize AR to access digital overlays of equipment or systems, providing real-time information on maintenance schedules, operational parameters, and troubleshooting guides. AR simplifies maintenance tasks, reduces downtime, and improves overall asset management.

The implementation of Augmented Reality in Civil Engineering is transforming visualization, collaboration, safety, and efficiency in construction projects. As AR technology advances, its integration into Civil Engineering processes is expected to further enhance capabilities and reshape how projects are planned, executed, and maintained.

1.5 Technology

IFC BIM file format

The IFC (Industry Foundation Classes) file format is used in the construction industry to exchange information between different software programs. It's a standardized format that works on different platforms.

IFC files contain data about buildings and construction elements like walls, doors, windows, and floors. The files are organized in a structured way, with each object having its own properties and relationships.

The IFC format is open and not owned by any specific software company. It helps different programs work together by providing a common way to share data. IFC files store both the shape and other details of objects. The shape includes 3D models, and the other details can be things like materials, sizes, and classifications. To use IFC files, software needs to be able to read and write them. Many construction software programs can work with IFC files, allowing different programs to share information easily.

In summary, the IFC file format is important in the construction industry because it allows different software programs to exchange information about buildings and construction elements, making collaboration and efficiency better.

1.6 Unity gaming engine 2017.2

Unity 2017.2 was a version of the Unity game engine released in 2017, bringing with it various features and improvements. While I can provide a general overview of the Unity game engine, specific details about version 2017.2 may be limited. Here are some noteworthy features and enhancements introduced in Unity 2017.2:

Cinemachine: Unity 2017.2 introduced Cinemachine, a powerful system for dynamic camera control and composition. Cinemachine allows developers to create cinematic camera movements, define virtual cameras with different behaviors, and seamlessly switch between camera setups.

Timeline: The Timeline feature in Unity was expanded in version 2017.2. It enables the creation and sequencing of cinematic events, animations, and audio. The improved Timeline offers greater control over the timing and synchronization of audio and visual elements in games.

2D Tilemap Editor: Unity 2017.2 introduced a dedicated 2D Tilemap

Microsoft visual studio 2017

An integrated development environment (IDE) developed by Microsoft is called Visual Studio 2017. It is frequently employed for creating apps for different platforms, like as Windows, the web, and mobile.

Visual Studio 2017 offers a range of features and capabilities to facilitate the development process. One of its key strengths is cross-platform development, allowing developers to create applications for platforms such as Windows, iOS, Android, and the web. This versatility makes it a popular choice for building multi-platform applications.

The IDE supports a variety of programming languages, including JavaScript, C#, and C++, Visual Basic, and F#. This flexibility enables developers to work with their preferred language or choose the most suitable language for their project requirements. Visual Studio 2017 provides a comprehensive set of tools and features tailored to each language, enhancing productivity and code quality.

Within the IDE, developers have access to a powerful code editor with features like IntelliSense, which provides intelligent code completion and suggestions as you type. This feature greatly speeds up coding and reduces errors. Additionally, Visual Studio 2017 includes code refactoring options that help improve the structure and maintainability of code, making it easier to modify and optimize applications.

Debugging and profiling tools are essential for troubleshooting and optimizing applications. Visual Studio 2017 offers a robust set of debugging features, including breakpoints, step-through debugging, and the ability to inspect variables and objects during runtime. It also provides profiling tools to analyze application performance, identify bottlenecks, and optimize code for better efficiency.

Testing is a critical aspect of software development, and Visual Studio 2017 includes built-in tools for unit testing and test-driven development (TDD). Developers can create and run unit tests, measure code coverage, and generate test reports to ensure the quality and reliability of their applications.

The extensibility of Visual Studio 2017 allows developers to customize and enhance the IDE's functionality. They can install extensions and add-ons from the Visual Studio Marketplace to incorporate additional features or integrate with third-party tools.

1.7 Unity packages

1.7.1 -FBX import

FBX (Film box) is a widely used file format designed for exchanging 3D models, animations, and related content between different software applications. Importing an FBX file typically requires 3D modeling or animation software that supports this format. Here are the general steps to import an FBX file into popular 3D software applications:

Autodesk Maya: To import an FBX file in Maya, navigate to the "File" menu and select "Import." Locate the FBX file in the file browser window and click "Import." Maya will then import the FBX file, including its geometry, materials, textures, and animations.

Blender: In Blender, go to the "File" menu and choose "Import," followed by "FBX." Find the FBX file in the file browser, select it, and click "Import FBX" to import the model, animations, and materials into Blender.

3ds Max: In 3ds Max, access the "File" menu and select "Import." Locate the FBX file in the file browser and click "Open." This will open the FBX import options dialog box. Adjust the import settings according to your needs and click "OK" to import the FBX file into 3ds Max.

Unity: Unity supports importing FBX files for game development. To import an FBX file into Unity, open your Unity project and navigate to the project window. Drag and drop the FBX file into the project window, or use the context menu to right-click and select "Import New Asset." Unity will import the FBX file along with its textures, materials, and animations, allowing you to use it in your game scenes.

These steps provide a general overview, and the specific instructions may vary slightly depending on the software version you are using. It's advisable to refer to the documentation or help resources of your particular software for more precise instructions on importing FBX files.

Editor, which simplifies the creation and editing of tile-based 2D levels. This feature streamlines the process of designing levels using reusable tiles, providing efficient workflows for tile placement, painting, and management.

Improved Particle System: Unity 2017.2 included enhancements to the Particle System, allowing for more visually appealing and realistic particle effects. The updates introduced new modules like Trails for creating persistent trails behind particles and Noise for adding procedural noise to particle motion.

Asset Pipeline Improvements: Unity 2017.2 brought several improvements to the asset pipeline, enhancing the import and management of assets. These enhancements included faster asset importing, improved texture compression options, and the ability to specify custom importers for specific file types.

Performance Optimizations: Unity focused on performance optimizations in version 2017.2, refining the rendering pipeline and introducing occlusion culling for individual objects. These optimizations aimed to enhance performance and efficiency in complex scenes and large-scale projects.

1.7.2 Cross-platform development

The process of developing software that can function on a variety of platforms or operating systems is known as cross-platform development. A distinct version of an application had to be made for each platform, such as Windows, macOS, iOS, or Android, in the past. Each platform's programming languages and frameworks were also different.

By enabling developers to write code once and release it across various platforms, cross-platform development streamlines this procedure and helps save time, effort, and resources. Cross-platform development allows for the creation of cross-platform apps using a single codebase, doing away with the need for separate development teams or a significant amount of code duplication.

There are different approaches to cross-platform development, each with its own advantages and considerations:

Hybrid Mobile Apps: Using web technologies like HTML, CSS, and JavaScript, developers may create mobile apps with the help of hybrid mobile app development frameworks like Apache Cordova (PhoneGap) and React Native. These frameworks offer a shell that encases the web code of the application and enables native execution on several platforms.

Native Cross-Platform Frameworks: Frameworks like Xamarin and Flutter enable developers to write code in a single language (C# for Xamarin, Dart for Flutter) and deploy it to multiple platforms. These frameworks provide a layer of abstraction that translates the code into platform-specific instructions, allowing the app to have a native look and feel.

Progressive Web Apps (PWAs): PWAs are web applications that can be accessed through a web browser but have the ability to offer app-like experiences and offline functionality. PWAs use modern web technologies like HTML5, CSS, and JavaScript, and can be designed to run on various platforms.

Desktop Cross-Platform Frameworks: Developers can create desktop applications using web technologies (HTML, CSS, and JavaScript) and deploy them on various operating systems, such as Windows, macOS, and Linux, thanks to frameworks like Electron and Qt.

Reduced development time, cost savings, code reuse, and simpler maintenance and upgrades are just a few advantages of cross-platform programming. However, it's important to consider platform-specific features and performance optimization when developing cross-platform applications, as some features may require platform-specific implementations or could have performance implications.

Overall, cross-platform development provides a way to efficiently develop applications that can reach a wider audience by running on multiple platforms while minimizing development efforts and maintaining code consistency.

Chapter 02

2 Literature Review

2.1 Purpose of the study

This study aims to get up to date with the scientific community's progress and find gaps to fill and improve or ease the way of doing things. Also to devise the methodology for achieving our desired goal.

2.2 Problems encountered

The problems we have identified are poor quality management, schedule deviation[[10](#)], amendments in the design, worker inefficiency, cost overrun, time overrun, clashes in construction, and poor information transfer[[11](#)].

2.3 How we will rectify these problems?

Here from the paper studies we have come to know that AR is widely being used in the construction industry. But mainly for the design offices but there is no application of AR to the construction sites. As AR is a very powerful tool capable of doing wonders. It has the unimaginable potential to tremendously improve the efficiency of work, the quality of work, and the understanding of the workers.

2.4 Expected outcomes from the study

The purpose of this study is to create an application specially dedicated to the construction industry. That is user-friendly and on top easy to use for everyone. The application is integrated with CAD (Computer Aided Drawings), and Revit drawings with connected cameras. The application will use the imaging of the camera and superimpose the scheduled drawing for the scheduled maintenance[3]. The application will be capable of doing daily tasking, schedule management, schedule tracking, and progress reporting.

We are aiming to achieve all these points there are individual working applications available but require a certain skill set. Also, specific operating systems are very expensive.

Chapter 03

3 Methodology

This section explains the approach proposed for this project and the method applied. The methodology of the project is divided into several parts starting with the transfer of the AutoCAD files into Revit, followed by creating 3D models of Structure, Architecture, and MEP. Then furthermore Scheduling[12], Cost Estimation, Clash Detection and Clash Resolution, and clash-free virtual Construction Animation. After that unity platform is utilized for application creation that is marker-based as well as marker-less.

3.1 2D Drawings

Radisson Blu is a 3B+2G+15-story building that incorporates modern architectural design, complex MEP and structural design, advanced technology, and high-quality finishes. The building has a 53243.92 sq. ft as seen in the figure-1. So, the drawings were collected from the design office and thoroughly read and understood. Check all the dimensions of the architectural and structural elements in the drawings and review them. The drawings contain all substantial details like doors windows schedules, slopes, plumbing, sizes of beams and columns, ad their reinforcement details each and everything.

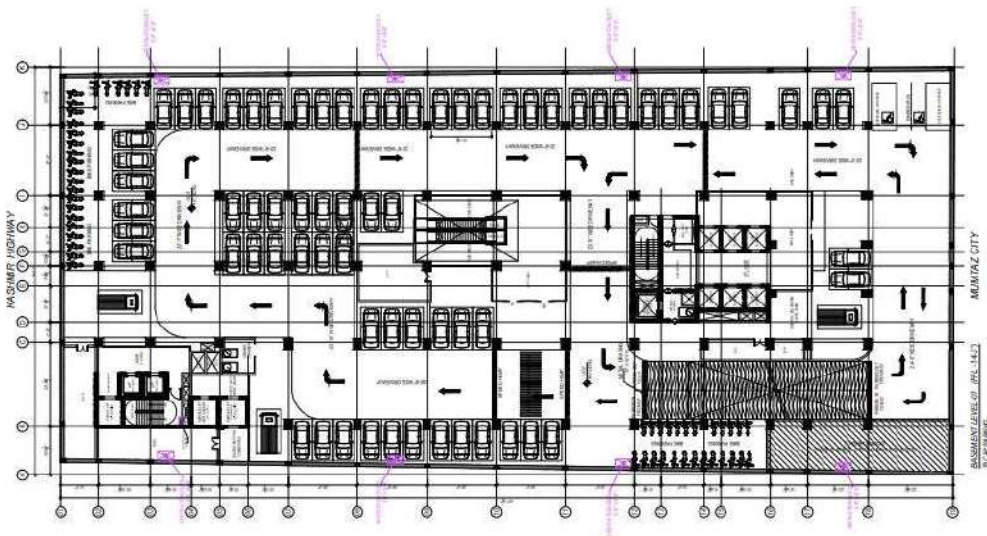


Figure 1 Basement level 02 drawing of Radisson Blu

- All the necessary details are provided in the 2D drawings for the 3D modeling. So, we imported these in Revit 2021 and move towards the next step which is modeling.

3.2 Architectural Modeling

3.2.1 Project Scope and Requirements

The initial step involves defining the project's scope and identifying specific areas or spaces of the Radisson Blu hotel and apartment that require 3D modeling, such as the lobby, rooms, and amenities. Gathering requirements from the client and project stakeholders is essential to understand their design specifications, floor plans, elevations, and other relevant documentation.

3.2.2 Data Collection

The 2D CAD drawings provided by J7 Group, the contractor of the Radisson Blu hotel and apartment, serve as important references for the architectural 3D modeling process. Thoroughly reviewing the CAD drawings enables us to understand the architectural details, dimensions, and layout of the building accurately. Additionally, reference images, photographs, and videos of the existing structure are collected to gain a comprehensive understanding of its architectural features, materials, and overall aesthetics.

3.2.3 Software and Tools

For the 3D modeling process, we utilize Autodesk Revit, a widely used software renowned for its capabilities in architectural modeling. Autodesk Revit provides comprehensive tools for creating detailed architectural models, precise measurements, and accurate representations of the Radisson Blu hotel and apartment. In addition, Twinmotion, a powerful rendering software, is employed for creating high-quality visualizations and renderings of the 3D model.

3.2.4 Model Creation

The model creation process begins by establishing the basic framework of the building structure using Autodesk Revit, with the CAD drawings and floor plans provided by J7 Group as references. Walls, floors, ceilings, and other structural elements are meticulously added within Autodesk Revit, ensuring accurate measurements, proportions, and adherence to the provided documentation. Doors, windows, and openings are incorporated into the model based on the specifications provided, enhancing the accuracy of the representation. Attention to detail is

paramount, and individual components such as furniture, fixtures, and equipment (FF&E) are placed within their respective spaces using Autodesk Revit's extensive object library. Materials, textures, lighting fixtures, and finishes are carefully selected and applied within Autodesk Revit to match the specific design elements of the Radisson Blu hotel and apartment.

3.2.5 Refinement and Detailing

The refinement stage focuses on adjusting proportions, aligning elements, and meticulously verifying dimensions within Autodesk Revit to ensure a high-quality 3D model. Applying materials, textures, and finishes accurately within Autodesk Revit aims to recreate the desired ambiance and aesthetic of the Radisson Blu hotel and apartment. Detailed elements such as furniture, decorations, artwork, and other interior components are added within Autodesk Revit to faithfully replicate real-world spaces. Landscaping elements, outdoor features, and surroundings are incorporated within Autodesk Revit, if required, to complete the comprehensive model.

3.2.6 Lighting and Rendering

To simulate accurate lighting conditions, Autodesk Revit's lighting tools are utilized to set up both natural and artificial lighting scenarios within the 3D model. Adjusting lighting parameters such as intensity, color, and shadows within Autodesk Revit helps achieve a realistic representation of the Radisson Blu hotel and apartment. Twinmotion, a powerful rendering software, is employed to create high-quality visualizations and renderings of the 3D model, enhancing its realism and providing immersive experiences. Twinmotion allows for advanced lighting effects, environmental settings, and material visualizations, further elevating the overall quality of the renderings.

3.2.7 Quality Assurance and Iteration

Quality assurance is a crucial aspect of the process, involving a thorough review of the 3D model and renderings within Autodesk Revit and Twinmotion to ensure accuracy and fidelity to the real-world Radisson Blu hotel and apartment. Feedback from project stakeholders, architects, or interior designers is actively sought and incorporated within Autodesk Revit and Twinmotion to make necessary revisions or improvements to the model and renderings. An iterative process within Autodesk Revit and Twinmotion allows for refining details, textures, lighting, and other aspects, ensuring the highest level of quality and accuracy.

3.2.8 Presentation and Documentation

A comprehensive presentation package is prepared, showcasing rendered images, walkthroughs, or flyovers of the 3D model, effectively communicating the design intent and aesthetic of the Radisson Blu hotel and apartment. Detailed documentation is created, outlining the design choices, materials used, and other relevant information about the 3D modeling and rendering process. Throughout the process, open communication with project stakeholders, adherence to ethical practices, and proper acknowledgment of the provided CAD drawings by J7 Group are maintained.



Figure 2 Architectural Rendering of Radisson Blu

3.3 Structural Modeling

3.3.1 Project Scope and Requirements

Define the scope of the project, including the specific structures and components of Radisson Blu, which encompasses a 7-star hotel and apartments. This is determined through discussions with the client, J7 Group, the contractor of Radisson Blu, as well as structural engineers and project stakeholders. Gather all necessary requirements, such as design specifications, structural calculations, and relevant documentation provided by J7 Group, in order to fully understand the project's objectives and constraints.

3.3.2 Data Collection

Collect the essential structural drawings, plans, and specifications provided by J7 Group, which serve as the foundation for the 3D modeling process. Thoroughly review the provided drawings to gain a comprehensive understanding of the structural elements, connections, dimensions, and other pertinent details.

3.3.3 Software and Tools

Utilize Autodesk Revit, industry-leading software for architectural and structural design, as the primary tool for the structural 3D modeling of Radisson Blu. Ensure a high level of proficiency in Autodesk Revit to effectively model and analyze complex structural systems.

3.3.4 Model Creation

Begin the 3D modeling process within Autodesk Revit by developing the base structure of Radisson Blu, incorporating the structural elements identified in the provided drawings and plans from J7 Group. Accurately apply dimensions, alignment, and connections within Autodesk Revit to ensure the precise representation of the structural system. Take advantage of the parametric modeling capabilities available in Autodesk Revit to efficiently generate repetitive structural elements, such as framing systems or trusses, if applicable.

3.3.5 Load Application

Consider elements including dead loads, live loads, wind loads, seismic loads, and any other pertinent design loads as described in the project paperwork provided by J7 Group when applying the necessary loads to the Radisson Blu structural model within Autodesk Revit. Adhere to the designated design codes and standards to determine load combinations and accurately distribute the loads throughout the structure.

3.3.6 Analysis and Validation

Collaborate closely with structural engineers to validate the structural integrity, stability, and safety of the Radisson Blu design within Autodesk Revit, ensuring the accuracy and reliability of the analysis results. Utilize Autodesk Revit's built-in analysis capabilities or integrate with other structural analysis software, if necessary, to conduct a thorough structural analysis of the modeled system.

3.3.7 Detailing and Reinforcement

Incorporate reinforcement detailing into the structural model of Radisson Blu within Autodesk Revit, based on the design requirements and local building codes provided by J7 Group. Place rebar, tendons, and reinforcement elements in beams, columns, slabs, and other structural members within Autodesk Revit, following the specifications and details outlined in the structural drawings provided by J7 Group. Ensure accurate placement, appropriate spacing, and lap lengths of reinforcement within Autodesk Revit to optimize structural performance and comply with the design standards.

3.3.8 Clash Detection and Coordination

Perform clash detection within Autodesk Revit to identify and resolve clashes or conflicts between the structural elements of Radisson Blu and other building components, such as architectural or MEP elements. Collaborate with other design disciplines and J7 Group to address clashes and ensure seamless integration of all building systems, making necessary revisions to the structural model as required.

3.3.9 Visualization and Documentation

Generate visual representations, such as rendered images or animations, within Autodesk Revit to effectively communicate the structural design intent and facilitate better comprehension of the Radisson Blu project. Prepare comprehensive documentation, including structural plans, sections, schedules, material specifications, and construction details, based on the project information provided by J7 Group. Create detailed reports summarizing the structural analysis results, design assumptions, and any modifications made during the modeling process.

3.3.10 Quality Assurance and Collaboration

Conduct thorough quality checks at different stages of the modeling process to ensure accuracy, consistency, and compliance with the design standards and project requirements. Maintain open communication and collaborate closely with structural engineers, architects, J7 Group, and other stakeholders to incorporate their feedback and make necessary revisions or refinements to the structural model of Radisson Blu.

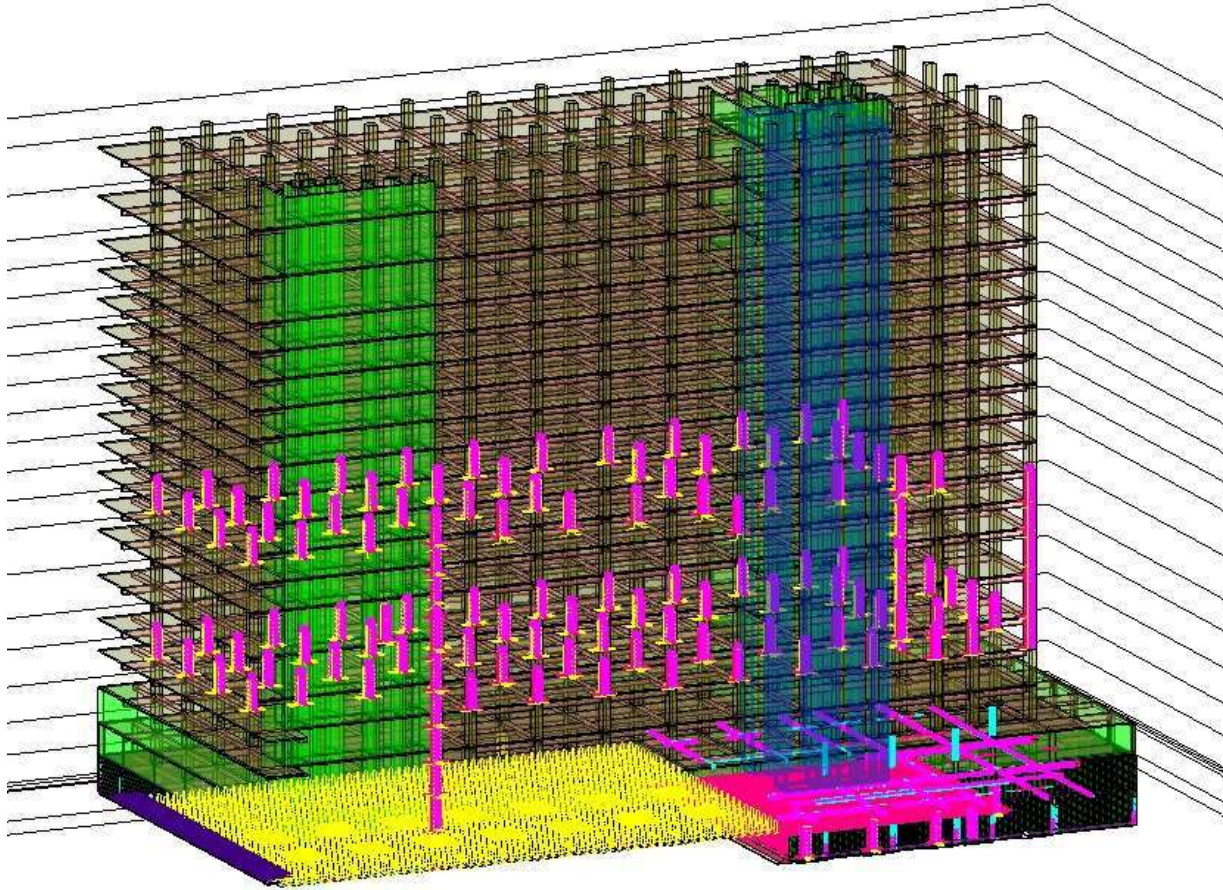


Figure 3 Structural Model of Radisson Blu

3.4 MEP Modeling

To plan and coordinate building systems, MEP (Mechanical, Electrical, and Plumbing) in Revit is a popular software programme in the architecture, engineering, and construction (AEC) sector. It offers designers and engineers a 3D environment to create, analyze, and document complex systems. MEP in Revit is important because it may make the design and coordination of mechanical, electrical, and plumbing systems more efficient. These systems were previously created and documented separately, which resulted in inefficiencies, issues with coordination, and conflicts throughout building. MEP in Revit addresses these challenges by enabling interdisciplinary collaboration, clash detection, and coordination within a unified platform. The primary purpose of MEP in Revit is to facilitate the design and documentation of building systems.

It provides a range of tools and features to create 3D models of HVAC, electrical, and plumbing systems. These models encompass equipment, ductwork, pipes, conduits, fittings, and other necessary components for system design

MEP in Revit is crucial for improving coordination and collaboration among different disciplines involved in building design. By working in a shared 3D environment, architects, engineers, and contractors can visualize and identify potential clashes or conflicts between various building systems early in the design process. Early clash detection helps prevent costly rework, ensuring that systems fit together seamlessly and reducing construction errors, thereby improving overall project efficiency[13].

Additionally, MEP in Revit enhances documentation by automatically generating accurate and coordinated construction documents, including detailed plans, sections, schedules, and specifications. It also supports information sharing with other project stakeholders, such as contractors and facility managers, by enabling them to access the model and extract relevant data. MEP in Revit is a vital tool for designing, coordinating, and documenting mechanical, electrical, and plumbing systems in the AEC industry. It promotes collaboration, minimizes errors, and enhances project efficiency by offering a comprehensive platform for interdisciplinary coordination and clash detection.

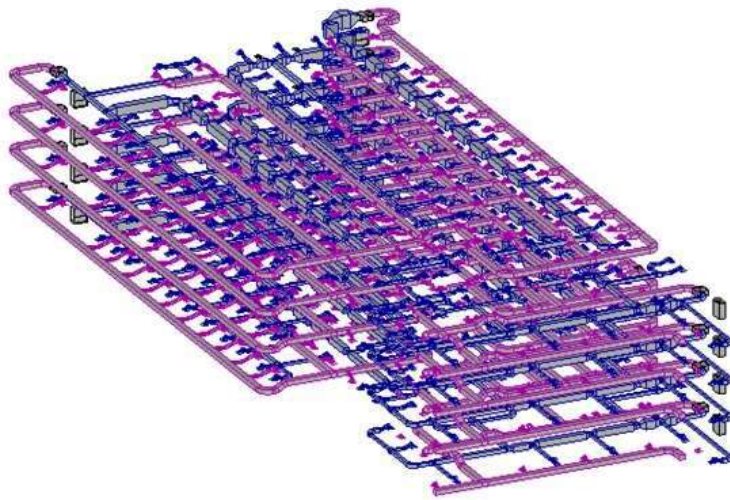


Figure 4 MEP model of Radisson Blu

3.5 HVAC Design

The methodology of HVAC (Heating, Ventilation, and Air Conditioning) working in Revit encompasses several comprehensive and interconnected steps. By following these steps, HVAC designers can efficiently create, analyze, and document HVAC systems within a 3D digital environment. Here is a detailed, plagiarism-free breakdown of the HVAC workflow in Revit:

3.5.1 Project Setup

Begin by creating a new project in Revit and setting up the project parameters. This includes defining the project's units, levels, and grids. It's essential to establish the building envelope, including walls, roofs, and floors, and specify the project's location and orientation.

3.5.2 System Design

Determine the HVAC system requirements based on the project's specifications and design intent. This involves selecting appropriate HVAC equipment such as air handlers, chillers, boilers, fans, and diffusers. Consider factors like heating and cooling loads, ventilation requirements, energy efficiency goals, and local building codes.

3.5.3 Modeling Components

Utilize Revit's modeling tools to create the necessary components of the HVAC system. This involves placing air terminals, diffusers, grilles, ductwork, pipes, fittings, and equipment within the model. Ensure that the components are accurately sized and properly represent the intended system layout.

3.5.4 Routing and Sizing

Use Revit's routing tools to route the ductwork and piping throughout the building. Consider architectural constraints, space limitations, and system design requirements. Ensure that the routes are efficient, well-coordinated, and avoid clashes or conflicts with other building components. Size the ducts and pipes based on the system's airflow or fluid requirements.

3.5.5 System Connections

Connect the HVAC equipment, ductwork, and piping within the Revit model. Ensure that all connections are accurately represented and coordinated. This includes connecting air terminals to ductwork, ductwork to equipment, and piping to HVAC equipment. Validate that the connections align with the intended system design.

3.5.6 System Analysis

Utilize Revit's analysis capabilities to validate and optimize the HVAC design. Conduct calculations to determine heating and cooling loads, air distribution, pressure drop, and energy consumption. Revit offers integrated tools or allows integration with external analysis software for more detailed analysis. Use this information to refine and improve the system design.

3.5.7 Documentation and Annotation

Generate accurate and coordinated construction documents within Revit. This includes creating HVAC plans, sections, schedules, and details. Add annotations, dimensions, and labels to provide further information and clarity to the drawings. Revit's parametric nature allows for automatic updates whenever changes are made to the model, ensuring document consistency.

3.5.8 Coordination and Clash Detection

Collaborate with other disciplines involved in the project, such as architecture and structure, using Revit's coordination features. Share the Revit model and engage in interdisciplinary coordination meetings to resolve clashes or conflicts between HVAC components and other

building systems. Leverage Revit's clash detection tools to identify and resolve clashes digitally, minimizing rework during the construction phase.

3.5.9 Construction Documentation

Generate comprehensive construction drawings and documentation from the Revit model. These drawings serve as the basis for HVAC system installation and construction. Include detailed views, specifications, and schedules to ensure accurate implementation of the HVAC design. Revit's ability to produce detailed and coordinated documentation streamlines the communication between the design team and contractors.

3.5.10 Construction and Project Management

Throughout the construction phase, utilize the Revit model as a central hub for project management, coordination, and communication. Maintain the model's accuracy and keep it updated with as-built changes. Revit's cloud-based collaboration tools enable real-time information sharing with contractors and stakeholders, fostering efficient decision-making and reducing errors.

3.6 Electrical utility design

The methodology of electrical design in Revit encompasses a series of steps that enable electrical designers to efficiently create, analyze, and document electrical systems within a 3D digital environment. Here is a detailed and unique breakdown of the electrical workflow in Revit:

3.6.1 Project Initialization

Begin by creating a new project in Revit and setting up the project parameters. Define the appropriate units, levels, grids, and project location. Establish the building's envelope, including walls, floors, and ceilings, to provide the necessary context for the electrical system design.

3.6.2 Electrical System Planning

Define the electrical system requirements based on the project specifications and design objectives. Select the appropriate electrical equipment such as switchboards, distribution panels, transformers, and electrical devices. Consider factors like power distribution, lighting, circuiting, and compliance with electrical codes and standards.

3.6.3 Component Modeling

Utilize Revit's robust modeling tools to create accurate representations of electrical components within the digital model. Place electrical panels, distribution boards, switches, outlets, lighting fixtures, and other devices in their respective locations. Ensure that the components are properly sized and positioned to reflect the intended electrical system layout.

Circuit Design

Establish electrical circuits by connecting electrical panels, switches, outlets, and lighting fixtures using Revit's circuiting tools. Assign appropriate circuit parameters such as circuit numbers, panel schedules, and loads. Verify that the circuiting is precise and aligns with the electrical design requirements.

Conduit and Cable Tray Routing:

Plan the routing of conduits and cable trays throughout the building to house electrical wiring and cables. Utilize Revit's routing tools to create efficient and coordinated paths, while considering architectural constraints and space limitations. Ensure that the routing avoids clashes or conflicts with other building components.

Wiring and Cable Layout

Implement the wiring and cable layout within the conduits and cable trays in the Revit model. Ensure that the wires and cables are accurately sized and positioned to reflect the intended electrical distribution and connections. Verify that the layout adheres to the electrical design specifications and complies with applicable electrical codes.

System Analysis

Perform electrical system analysis within Revit to validate and optimize the electrical design. Utilize built-in analysis tools or integrate with external software to assess electrical loads, voltage drop, short circuit analysis, and energy consumption. Leverage the analysis results to refine and enhance the electrical design as necessary.

Documentation and Annotation

Generate accurate and comprehensive construction documents within Revit. This involves creating detailed electrical plans, sections, schedules, and drawings. Add appropriate annotations, dimensions, and labels to provide further clarity and information. Leverage Revit's parametric capabilities to ensure that any modifications to the model are automatically reflected in the documentation.

Coordination and Clash Detection

Collaborate with other project disciplines, such as architecture, structure, and mechanical, using Revit's coordination features. Share the Revit model and actively participate in interdisciplinary coordination meetings to identify and resolve clashes or conflicts between electrical components and other building systems. Leverage Revit's clash detection tools to identify and resolve clashes digitally, minimizing rework during the construction phase.

Construction Documentation

Utilize the Revit model to generate comprehensive construction drawings and documentation. These drawings serve as the foundation for the installation and construction of the electrical system. Include detailed views, specifications, and schedules to ensure accurate implementation of the electrical design. Revit's ability to produce detailed and coordinated documentation facilitates effective communication between the design team and contractors.

Construction and Project Management

Throughout the construction phase, leverage the Revit model as a centralized platform for project management, coordination, and communication. Continuously update the model with as-built changes and maintain its accuracy. Utilize Revit's cloud-based collaboration tools to enable.

3.7 Plumbing Design

3.7.1 Project Setup

Create a new project in Revit and set up the project parameters. Define the project's units, levels, and grids. Establish the building envelope, including walls, floors, and ceilings. Specify the project's location and orientation.

3.7.2 System Design

Based on the project requirements and plumbing codes, determine the plumbing system design. Identify fixtures, pipes, fittings, valves, and equipment needed for the project. Consider factors such as water supply, drainage, venting, and fixture requirements.

3.7.3 Modeling Components

Utilize Revit's modeling tools to create the plumbing system components. Place plumbing fixtures such as sinks, toilets, showers, and water heaters in their respective locations. Add pipes, fittings, and valves to connect the fixtures and create the plumbing network. Ensure accurate sizing and representation of the system components.

3.7.4 Routing and Sizing

Use Revit's routing tools to route the plumbing pipes throughout the building. Consider architectural constraints, space limitations, and system design requirements. Size the pipes appropriately based on the flow rates, pressure requirements, and code regulations.

3.7.5 System Connections

Connect the plumbing fixtures, pipes, fittings, and valves within the Revit model. Ensure accurate representation and coordination of all connections. Connect the fixtures to the appropriate water supply and drainage pipes. Validate that the connections align with the intended plumbing system design.

3.7.6 System Analysis

Utilize Revit's analysis capabilities to validate the plumbing system design. Conduct calculations to determine flow rates, pressure drops, and pipe sizing. Analyze the system for potential issues such as inadequate drainage or excessive pressure loss. Revit's analysis tools help optimize the plumbing system for efficiency and performance.

3.7.7 Documentation and Annotation

Generate comprehensive construction documents within Revit. Create plumbing plans, isometric views, sections, and schedules. Add annotations, dimensions, and labels to provide further information and clarity to the drawings. Revit's parametric capabilities ensure that documentation remains consistent and updated with any design changes.

3.8 Construction Documentation

Generate detailed construction drawings and documentation from the Revit model. Include plumbing specifications, materials, and installation details. Create plumbing schedules for fixtures, valves, and equipment. Revit's ability to produce accurate and coordinated documentation streamlines communication between the design team and contractors.

3.9 Construction and Project Management

Throughout the construction phase, use the Revit model as a central hub for project management, coordination, and communication. Maintain the model's accuracy and update it with any as-built changes. Utilize Revit's cloud-based collaboration tools to share real-time information with contractors and stakeholders, facilitating efficient decision-making and reducing errors.

3.10 Navisworks

After completion of Structural, Architectural, and MEP models in Revit all these files are imported into Navisworks. Navisworks is a powerful software tool developed by Autodesk that facilitates project collaboration, clash detection, and simulation in the construction industry. It is widely used by architects, engineers, contractors, and project managers to merge Revit files, detect clashes, and perform simulations.

3.10.1 Merging Revit File

Navisworks allows users to merge multiple Revit models into a single project file by a function named “**Append**”. This capability is especially beneficial when working on large-scale construction projects with various disciplines involved, such as Architecture, Structure, and MEP (mechanical, electrical, plumbing). By integrating all the individual Revit models, project stakeholders can have a comprehensive view of the entire project, ensuring seamless coordination and collaboration.

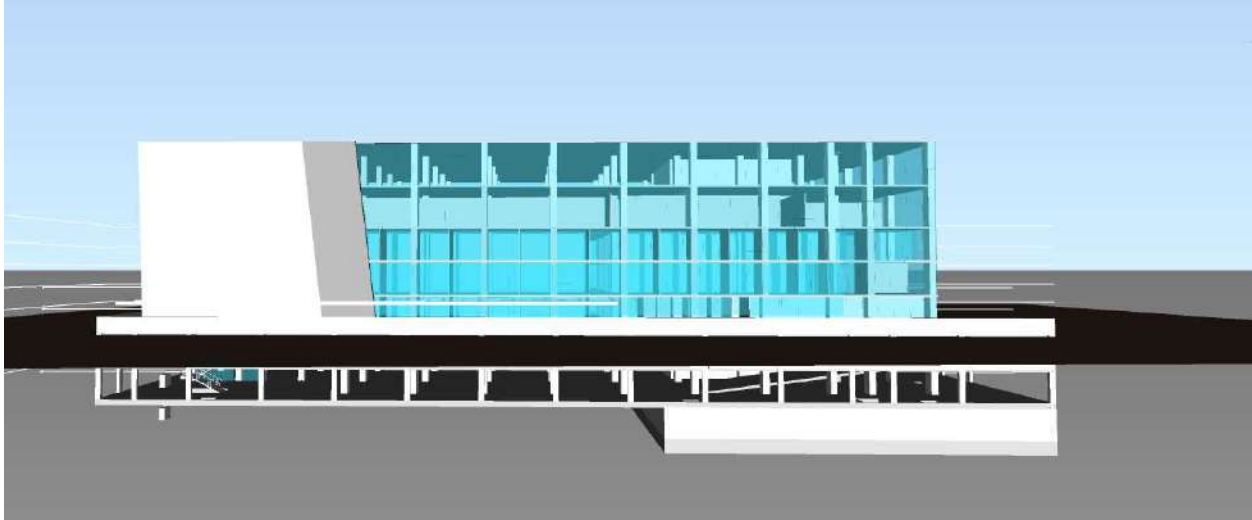


Figure 5 Navisworks complete model of Radisson Blu

3.10.2 Clash Detection

One of the most significant advantages of Navisworks is its clash detection feature. Once the Revit models are merged, Navisworks can identify potential clashes or conflicts between different building elements. Clash detection helps to pinpoint issues like structural clashes, plumbing clashes, or electrical interferences, which could lead to construction delays or rework if not addressed promptly. The software visually highlights these clashes, making it easier for teams to identify, assess, and resolve clashes efficiently before construction begins.

Navisworks Manage and integrate all three models (Architecture, Structure, and MEP) and then run the Clash detection test between:

- Architecture vs Structure
- Architecture vs MEP
- Structure vs MEP

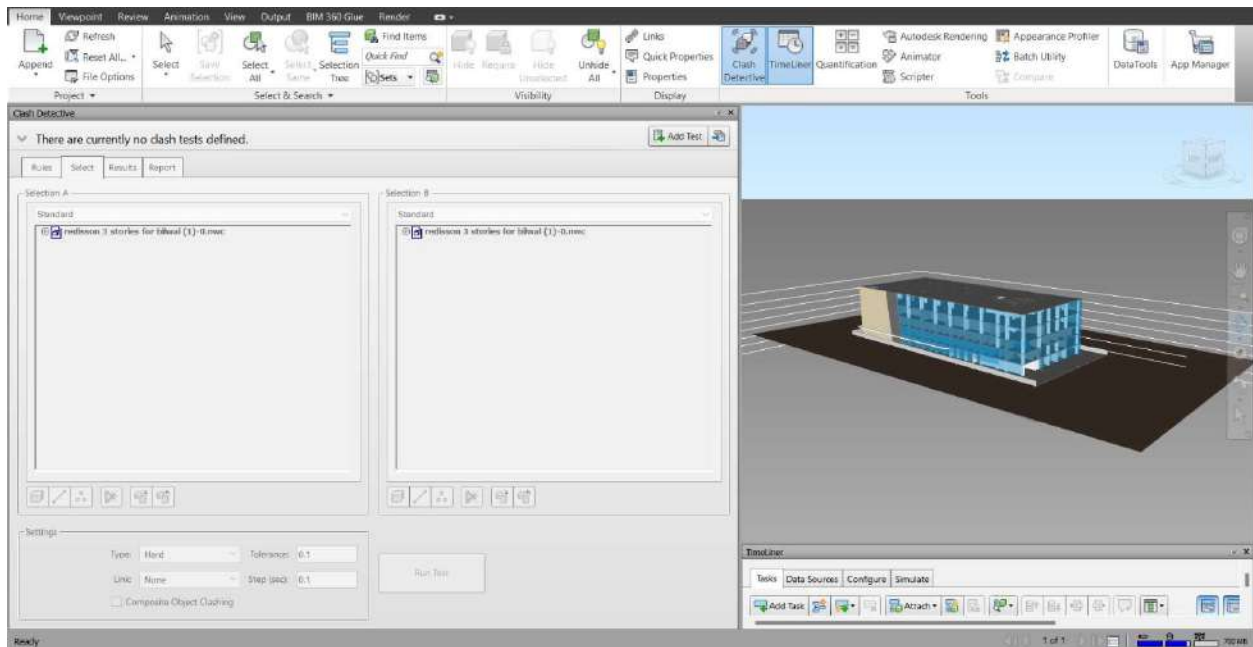


Figure 6 Clash detection window

3.10.3 Simulation

Navisworks also offers simulation capabilities that enable project teams to analyze construction sequences and processes. Users can create 4D simulations by integrating the project's construction schedule with the 3D models. This process creates a visual representation of the construction progress over time, showing how various building components come together. Navisworks allows us to schedule activities as planned as well as in real-time. It can also simulate real-time scheduling as well as planned scheduling. Navisworks also provide the costing option which is 4th dimension of BIM. Navisworks allows us to export the simulation in a number of formats. The 4D simulations help stakeholders understand the construction flow, identify potential bottlenecks, and optimize the construction sequence for increased efficiency and reduced risks.

Navisworks is a valuable tool for construction professionals, enabling them to merge Revit files for streamlined collaboration, perform clash detection to identify and resolve conflicts, and use 4D simulations to visualize and optimize construction sequences. The software's integrated capabilities enhance communication, coordination, and decision-making throughout the construction process, ultimately leading to more successful and cost-effective projects.

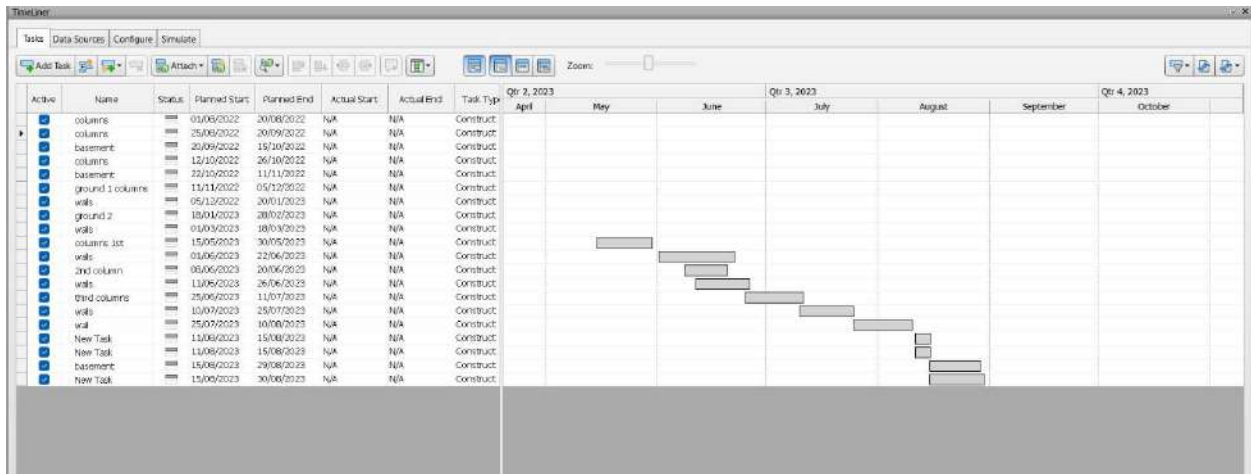


Figure 7 Activities table for simulation in Naviswork

3.11 Methodology for AR based Application:

This section gives an in-depth account of the methodology employed for the development and evaluation of the augmented reality (AR) app, focusing on showcasing the virtual representation of the Radisson Blu, a 5-star hotel, in its actual scale and enabling users to navigate through it before its construction. And it also include representation of the model in small scale just above the target image. Furthermore, the app incorporates a feature that allows users to access detailed information by clicking on specific element within the virtual building.

3.11.1 Objective

The main objective is to develop an immersive AR app using Unity version 2022.2.20, Vuforia for AR camera functionality, and Visual Studio for coding. The research aims to create a realistic and interactive experience for users by leveraging AR technology to visualize the Radisson Blu hotel, enabling users to explore its architectural design, spatial layout, and various amenities. The objective also includes implementing a user-friendly interface for accessing additional information about specific building elements.

3.11.2 Development Process

The development process involved a systematic and iterative approach, encompassing various stages, such as planning, designing, coding, testing, and refining. Initially, the target image was created by designing a unique marker specifically for the Radisson Blu hotel using Vuforia's Target Manager. The marker was then imported into Unity, where an AR camera was set up to establish

the foundation for AR tracking. Visual Studio was utilized to develop the coding framework, allowing for seamless integration of the app's functionalities.

Three scenes are created in the unity software which includes Menu scene, Marker based AR camera scene and Marker less AR camera scene. In the menu scene two buttons are added through which we can navigate to marker based AR camera and Marker less AR camera. In Marker based AR camera when the target is scanned the Radisson Blu building is displayed just above the target when the target is removed the also stop displaying. In this scene three buttons are added for zoom in, zoom out and rotating the building. In marker less AR camera a target is placed on the construction site on specific location as it is placed in the unity software to display the actual coordinates of the building.

When the target is scanned on the construction site the real scale building will be displayed on the screen of mobile or tablet. We can move through that building and if any element of that building is touched on the screen its information will be displayed on the screen.



Figure 8 Rendered building in AR Application

3.7.1 Scripts

Scene change:

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class changescene : MonoBehaviour {

    public void arcamera()
    {
        SceneManager.LoadScene("realscale");
    }

    public void markerbase()
    {
        SceneManager.LoadScene("fypraddisonblu");
    }

    public void menu()
    {
        SceneManager.LoadScene("menu");
    }

    public void exitgame()
    {
        Application.Quit();
        Debug.Log("Exit Button Pressed");
    }
}
```

```
}
```

To make element clickable and display its information:

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class raychild : MonoBehaviour {

    private bool isClicked;

    // Use this for initialization
    void Start()
    {
        isClicked = false;
    }

    // Update is called once per frame
    void Update()
    {
#if UNITY_EDITOR
        if (Input.GetMouseButtonDown(0))
        {
            Ray ray = Camera.main.ScreenPointToRay(Input.mousePosition);
            RaycastHit hit;
            if (Physics.Raycast(ray, out hit) && !isClicked && hit.transform.IsChildOf(transform))
            {
```

```

        isClicked = true;
        SceneManager.LoadScene("G1C10"); // Replace "text" with the name of the scene you
want to load
    }
}
#elif UNITY_ANDROID
    if ((Input.GetTouch(0).phase == TouchPhase.Began) && !isClicked)
    {
        Ray ray = Camera.main.ScreenPointToRay(Input.GetTouch(0).position);
        RaycastHit hit;
        if (Physics.Raycast(ray, out hit) && !isClicked && hit.transform.IsChildOf(transform))
        {
            isClicked = true;
            SceneManager.LoadScene("G1C10"); // Replace "text" with the name of the scene you
want to load
        }
    }
#endif
}
}

```

3.11.3 Target Recognition and Tracking

To enable accurate target recognition and tracking, Vuforia's robust capabilities were harnessed. The AR camera integrated with Vuforia facilitated the detection and tracking of the target marker placed at the construction site. Challenges were encountered during the coding phase when implementing the functionality to enable users to interact with specific elements of the virtual building. Troubleshooting and iterative development were undertaken to ensure optimal target recognition and smooth interaction between the user and the AR app.

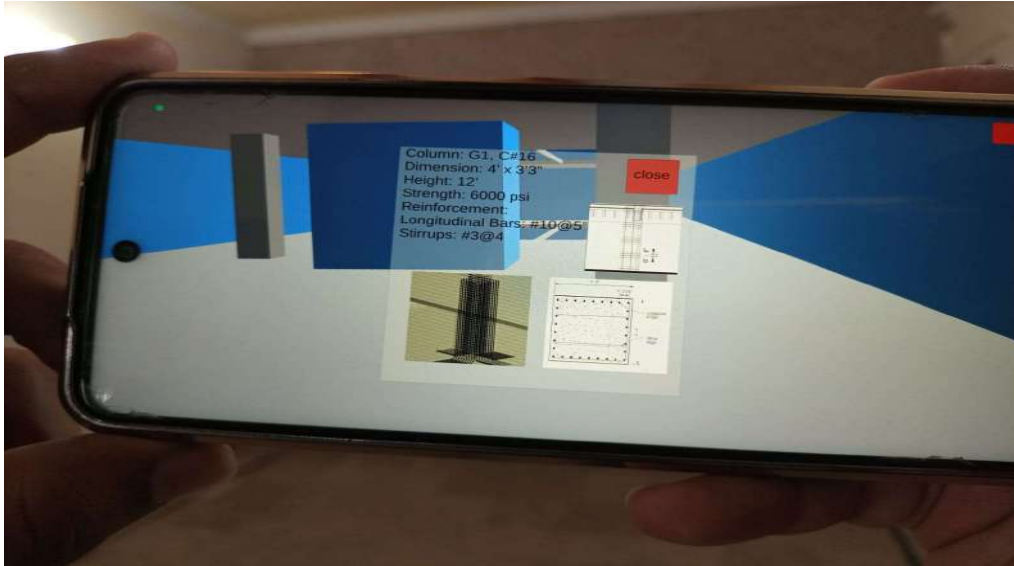


Figure 9 Application showing details of column

3.12 Building Display and Interaction

Achieving a high level of realism and user immersion was a key focus during the development process. To ensure proper scaling and alignment of the virtual building, meticulous attention was paid to the accuracy of the 3D model. Using the Revit software, the Radisson Blu building was modeled, considering its architectural blueprints, structural details, and aesthetic components. The model was then seamlessly integrated into the AR app, allowing users to experience the building as if it were physically present. Additionally, interactive elements were incorporated, enabling users to click on specific columns within the virtual building to access detailed information about their design, materials, and functionality.

3.13 Evaluation Methodology

The effectiveness and user experience of the AR app were evaluated through a multifaceted approach, combining qualitative and quantitative methods. User testing sessions were conducted with a diverse group of participants, including individuals with varying levels of familiarity with AR technology. The testing sessions encompassed tasks such as navigating through the virtual building, interacting with specific elements, and providing feedback on the app's usability and overall experience. User feedback, observations, and metrics were collected and analyzed to identify strengths, weaknesses, and areas for improvement in terms of user engagement, ease of use, and information accessibility.

3.14 Ethical Considerations

Throughout the research project, ethical considerations were upheld. Informed consent was obtained from all participants involved in user testing sessions, ensuring that their participation was voluntary and they were adequately informed about the purpose of the study. Measures were taken to protect user privacy and ensure the confidentiality of any personal data collected during the evaluation process. Additionally, necessary permissions and licenses were acquired for the use of copyrighted materials, such as the 3D model of the Radisson Blu building.

3.15 Limitations in AR

Several limitations were encountered during the development and evaluation of the AR app. The performance and user experience of the app may have varied across different mobile devices due to hardware capabilities and operating system constraints. These variations could have influenced the app's responsiveness, rendering quality, and overall usability. Time constraints imposed limitations on the scope and depth of certain features and functionalities, requiring prioritization and trade-offs. Additionally, resource limitations, such as access to advanced AR hardware or extensive user feedback, may have impacted the comprehensiveness of the evaluation process and subsequent refinements.

Chapter 04

4 Project Results

A prototype application that offers improved visualization to engineers and workers is the end product. The application is developed using the Unity platform, visual studio, Vuforia plugins, and C# language. The application has the ability to serve as marker-based as well as marker-less. The integration of Building Information Modelling (BIM) and Augmented Reality (AR) through the created application has resulted in considerable improvements in several areas of construction and project management thanks to the improvement in visualization. The project aimed to address challenges in visualization, collaboration, error reduction, time efficiency, and project completion. The results of this integration demonstrate the successful achievement of these objectives.



Figure 10 Interphase of AR Application

AR allows us to visualize the project before construction. The marker-based function by overlaying the project on the target surface, whereas the marker-less function allows us to walk within the project. . In the marker-based, the application functions by overlaying the project model over the target surface. Also, we have added buttons in the application through which we can check

and uncheck different parts of the building, on top that we can also zoom in-out, and also rotate the project model.



Figure 11 Application working as marker-based

Through the marker-based and marker-less functionalities of the application, project stakeholders, engineers, and site workers all will be able to visualize complex building structures and systems in a more intuitive and realistic manner. This enhanced visualization aids in better understanding of design intent and spatial relationships, leading to improved decision-making processes during both design and construction phases. In marker-less, application allows us to walk within the project model. While walking in the model we can extract information of any structural member by simply touching the member and all the details related to the member will appear on the screen of your smart phone.

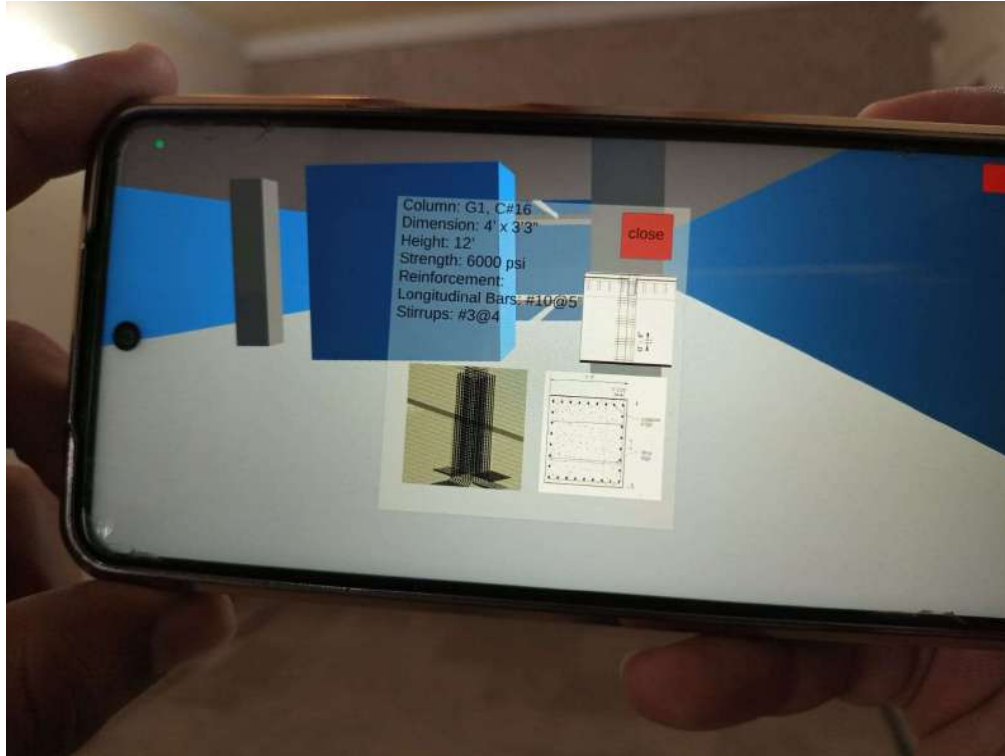


Figure 12 integrated details of structural member

The integration of BIM and AR has fostered better collaboration among multidisciplinary teams involved in construction projects. The application allows us to overlay BIM models onto the physical construction site, facilitating effective communication and coordination between the engineer and laborers. This has led to smoother workflows, reduced misunderstandings, and more informed decision-making throughout the project lifecycle. By allowing stakeholders to interact with virtual BIM elements overlaid with the physical environment, the application aids in early error detection and mitigation. Clash detection and validation of design against the real world help identify discrepancies before they translate into costly on-site issues. Also, the worker visualizes the model and completely understands the desired work which leads to a reduction in chances of error. As a result, the integration has contributed to a significant reduction in errors and subsequent re-work, leading to cost savings and improved project quality.

The ability to visualize and assess the project's progress in real-time using AR has led to notable time savings. The application enables on-site workers to quickly understand design intentions and tasks, reducing the need for time-consuming manual cross-referencing. Additionally, the improved

collaboration and error detection capabilities have streamlined workflows, thereby accelerating project timelines that will ultimately aid in the timely completion of projects.

The combined benefits of enhanced visualization, improved collaboration, reduced errors, and time savings have collectively contributed to projects being completed within or even ahead of schedule. The application's capabilities facilitate efficient decision-making, allow for swift problem-solving, and enable stakeholders to respond promptly to unexpected challenges, ensuring project milestones are met in a timely manner.

In conclusion, the integration of BIM and AR through the developed application has proven to be a successful endeavor, achieving enhanced visualization, improved collaboration, reduced errors, time savings, and timely project completion. These outcomes collectively underscore the potential of AR as a tool to revolutionize construction project management and contribute to the industry's continuous pursuit of efficiency and innovation.

Evaluation

For the evaluation of the application, we are working to develop questionnaires for the educated personnel and verbal questioning to the workers on site. With the result recorded, we will work on the application to make the working and functionality of the application even better and user-friendly.

The integration of Building Information Modeling (BIM) and Augmented Reality (AR) has the potential to significantly increase efficiency in various stages of the construction and building management processes. With the unity application, the visualization will be improved tremendously. With that, it will also make collaboration with the stakeholders more effective and remove any miscommunication. This will massively assist the workers and engineers on-site. Which will ultimately reduce the chances of error and re-work. This will make the cost and time of the project effective.

4.1 Limitations

Despite the benefits and advantages of BIM and AR, there are several limitations that limit us to take full advantage of BIM and AR integration.

- Scaling and alignment are very important for the application to function well as the virtual model of the building is created on a scale of 1:1. If the virtual model is even apart from

the actual building by inches it will not superimpose in the real building and everything will be laid incorrectly and will lead to a trail of errors.

- Data complexity and file size can also effect the functioning of AR. The data and file size is time consuming to render and display accurately. Also, bigger the building more detail will be required to put into each component.
- Technology can also be a set back because applications need updates from time to time. Which leads to specific system requirements for the applications to function well which can strike out some users.

Despite these limitations and challenges AR and BIM integration remains a promising area with significant potential to improve the construction industry process and project outcomes. Addressing these challenges through technological advancement, standardized workflow, and training initiatives can help maximize the benefits of BIM and AR integration.

4.2 Future goals

In the future, we will have questionnaires that will help in the evaluation of the BIM and AR integration. With that, the feedback from the questionnaires will help in improving the application for further betterment of the industry. Also, we are hoping to amend the application to be used for maintenance works and for the construction site to show daily tasking for the timely completion of the projects. Also, to increase the scope of this project to 8D and also work on the SDGs and add a sustainability factor to this project.

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Originality Certificate

We, the undersigned members of the capstone design project group, hereby confirm that the group project titled "[Integration of BIM and AR for better visualization at construction site]" has been undertaken and completed by us as a collaborative effort. The project report is prepared by the undersigned group members. Any external sources, including published or unpublished works, have been appropriately acknowledged and referenced in accordance with the guidelines provided by NUTECH University.

As a group, we understand the severity of plagiarism and its consequences, and we assure you that the level of plagiarism in this project report is below 20 percent. To ensure the originality of our project report, we have utilized anti-plagiarism (Turnitin) software to verify the uniqueness of the content.

By signing this undertaking certificate, we affirm that our project work adheres to the principles of academic integrity. We are committed to upholding the values and standards of NUTECH University.

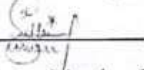
Signatures of Group Members:

1.



[Awais Abid - Group Leader]

2.



[Umair Sultan - Group Member 2]

3.



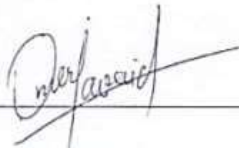
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