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Approach to Integrating Augmented Reality In Building Information Modeling Process

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من لا يشكر الناس لا يشكر الله، وأنتم جميعاً تستحقون الشكر والثناء

اهداء

أود أن أعبر لكم جميعًا عن امتناننا العميق وشكرنا الجزيل على دعمكم وتوجيهكم القيم خلال فترة كتابة مذكراتنا الأكاديمية. بفضلكم جميعًا، تمكنا من إتمام هذه المهمة الضخمة وتحقيق نجاح كبير.

لكل أستاذٍ وأستاذةٍ قدموا لنا الإرشاد والتوجيه، نحن ممتنون لكم على الخبرات والمعرفة التي قدمتموها. لقد شكلتمونا قوةً دافعةً لنا للنمو والتطور في المجال الأكاديمي. بفضلكم، استطعنا توجيه بحوثنا وتحليلاتنا بطريقة منهجية وعلمية. نقدر جهودكم في توجيهنا نحو المصادر المهمة والمنهجيات السليمة.

وإلى أسرنا العزيزة، نشكركم على الدعم الذي قدمتموه لنا بلا حدود والحب الذي أبديتموه لنا خلال فترة إعداد مذكراتنا. كنتم الركائز الثابتة التي استندنا إليها في أوقات الضغط والتحديات الأكاديمية. تشجيعكم المستمر وثقتكم بقدراتنا كانت الدافع الحقيقي لنا للتفوق والتحقيق.

انا الطالبة بن ميمون فريال :لامي التي كانت السند طوال هذه السنين ولازالت الى الان الى ابي الحنون الذي هو الداعم و الذي طوال حياته وهو يقدم لنا كل الأمن و الحب و الاستقرار . الى عائلتنا الكريمة كلا من اجدادي و اعمامي و اخوالي كل الحب و التقدير . بعميق الفرح والسعادة والسرور اهدي هذا التخرج إلى أبوي وإلى أمي الذَين لم ولن ينسى قلبي ما قدموه لي من من تضحيات ودعوات واهتمام بي في كل المجالات، بعميق الشكر والامتنان والتقدير لهما.

Abstract:

In the past decade, the Augmented Reality (AR) technology has made significant progress in various fields, especially engineering and industrial sectors.

Integrating AR technology into Building Information Modeling (BIM) poses a major challenge as it requires users to adopt different approaches in terms of both technical and managerial aspects of projects.

This thesis aims to explain the fundamental concepts of BIM and AR separately, and then survey all current methods of integrating these technologies at the software and hardware levels.

The research results were implemented through a series of experiments using various programs such as SketchUp Augmented Gamma on an IPHONE 13 PRO MAX.

A comparison table was established, evaluating the programs based on their ability to locate and orientate spatial elements (location, direction, and scale).

With an achieved accuracy of ±1mm, the result is highly satisfactory and can be relied upon in civil engineering projects.

Keywords: AR, BIM, Visualization.

Résumé:

La technologie de Réalité Augmentée (AR) a enregistré des progrès significatifs au cours de la dernière décennie, notamment dans les domaines de l'ingénierie et de l'industrie.

L'intégration de la technologie de AR dans la modélisation des informations de construction (BIM) représente un défi majeur, car elle nécessite que ses utilisateurs adoptent une approche différente à la fois sur le plan technique et managérial pour gérer les projets.

Ce mémoire vise à expliquer les deux concepts fondamentaux, le BIM et AR, séparément, puis à passer en revue toutes les méthodes actuelles d'intégration de ces technologies au niveau des logiciels et du matériel.

Les résultats de la recherche sont présentés à travers une série d'expériences utilisant une dizaine de programmes tels que: Sketchup Augin Gamma, en utilisant un téléphone cellulaire de type IPHONE 13 PRO MAX.

Un tableau comparatif a été élaboré pour évaluer les programmes en termes de leur capacité à la localization des objets dans l’espace (emplacement, direction et échelle).

Une précision de 1 ± mm a été obtenue, ce qui est très satisfaisant et fiable pour les projets de genie civil.

Mots-clés : AR, BIM, Visualisation.

الملخص :

لقد سجلت تقنية الواقع المعزز في العشرية الاخيرة تقدما ملحوظا في ميادين عديدة خاصة الهندسية منها والصناعية.

إدماج تقنية AR في نمذجة معلومات البناء (BIM) يعتبر تحديًا كبيرا اذ انه يلزم مستعمليه طريقة تعامل مع المشاريع مختلفة على مستوى التقني والإداري.

تهدف هذه الرسالة الى شرح مفهومين اساسين كل على حدى (BIM و AR) ومن ثم مسح لجميع الطرق الحالية لإدماج التقنيتين على مستوى البرامج و العتاد .

نتيجة البحث المقدم تم تجسيدها عبر سلسلة من التجارب على عشرات من البرامج كـ (SketchUp, augin, Gamma AR) باستعمال هاتف IPHONE 13 PRO MAX وتم عبرها انشاء جدول مقارنةً بين البرامج مع تصنيف طرف تعاملها في ايجاد المعلم الفضائي (الموقع و الاتجاه والسلم) .

الدقة المتحصل عليها (1±مم) كانت جد مرضية و يمكن الاعتماد عليها في مشاريع الهندسية المدنية.

الكلمات المفتاحية : تقنية نمذجة معلومات البناء ,الواقع المعزز , تصور

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Notation List

BIM: Building Information Modeling (digital representation of a building)

LOD: Level of Detail (level of development/accuracy of a BIM model)

LOI :Level of Information (amount and quality of information in a BIM model)

CDE: Common Data Environment (centralized platform for BIM collaboration)

FC: Fully Constructed (representation of a completed construction project)

IFC: Industry Foundation Classes (open file format for BIM data exchange)

GPU: Graphics Processing Unit (hardware component for rendering graphics)

APIs: Application Programming Interfaces (set of tools for software integration)

3D: Three-Dimensional (representation of objects in three dimensions)

QR: Quick Response (matrix barcode used for quick access to information)

AR: Augmented Reality (overlaying virtual content onto the real world)

VR: Virtual Reality (simulated environment that can be interacted with)

XR: Extended Reality (umbrella term for AR, VR, and other immersive technologies)

MX: Mixed Reality (combination of virtual and real-world elements)

HMD: Head-Mounted Display (wearable device for visualizing virtual reality)

SDK: Software Development Kit (collection of tools for creating software applications)

XDR OLED: Extended Dynamic Range OLED (display technology with improved color and contrast)

1TB: One Terabyte (unit of digital storage capacity)

ARK:Augmented Reality Kit (set of tools and frameworks for AR development)

ARC:Architecture, Engineering, and Construction

WebGL: Web Graphics Library (JavaScript API for rendering 2D and 3D graphics on the web)

GENERAL INTRODUCTION

I. General Introduction

The construction industry has been a major contributor to the global economy, and its impact is expected to increase in the coming years. However, the industry is facing various challenges, such as cost overruns, delays, safety issues, and lack of communication and collaboration among team members. To address these challenges, the industry has turned to advanced technologies such as Building Information Modelling (BIM) and Virtual Reality (VR) and Augmented Reality (AR) applications.

BIM provides a detailed and accurate representation of the physical asset, which can be used throughout the project lifecycle, from design and construction to operation and maintenance. BIM allows for better collaboration and communication among team members, reduces errors and omissions, and improves the quality of the project.

VR and AR technologies, on the other hand, allow users to experience a digital model in a virtual or augmented environment. VR creates a completely immersive experience where the user can interact with the digital model as if it were a physical object, while AR overlays digital information onto the real world, enhancing the user's perception of the physical environment. By combining BIM with VR and AR, designers and construction teams can experience a project virtually before it is built, detect design issues early on, and improve collaboration and communication among team members.

The use of BIM and VR/AR in the construction industry has the potential to improve productivity, reduce costs, and enhance safety. BIM provides a platform for information sharing and collaboration, which leads to more efficient and effective project delivery. VR and AR technologies allow for a better understanding of the project and enhance the communication and collaboration among team members. Moreover, the use of BIM and VR/AR can lead to cost and time savings and increased safety on construction sites.

However, there are still some challenges to be addressed, such as the need for better data interoperability and standardization, as well as the development of user-friendly interfaces and tools. The industry needs to ensure that the technologies are accessible and affordable for all stakeholders and that there is a common understanding of the benefits and limitations of BIM and VR/AR. In addition, the industry needs to invest in the training and development of the workforce to ensure that they have the necessary skills and knowledge to use these technologies effectively.

This theisis is subdivided in three chapter :

Chapter 1 of this study focuses on presenting the fundamental concept of BIM. Building Information Modeling is a digital representation of the physical and functional characteristics of a building or infrastructure project. It involves the creation and management of comprehensive data sets that encompass geometric, spatial, and non-geometric information. This chapter provides an overview of the key principles and benefits of BIM, highlighting its role in streamlining project workflows, reducing errors, and facilitating effective communication among stakeholders.

Chapter 2 delves into the world of AR and VR technologies with a specific focus on their application in civil engineering. Augmented Reality enhances the real-world environment by overlaying digital information, such as 3D models, on physical objects or spaces. Virtual Reality, on the other hand, immerses users in entirely computer-generated environments. This chapter explores the capabilities and potential applications of AR and VR in civil engineering, highlighting their use cases in design visualization, construction simulation, and virtual walkthroughs.

Chapter 3 presents a comprehensive set of tests conducted on various AR applications within the context of BIM. The aim of these tests was to evaluate the performance, functionality, and usability of different AR tools for civil engineering tasks. The chapter offers a detailed comparison of the tested applications, analyzing their strengths, weaknesses, and overall suitability for different project requirements. Furthermore, it introduces a successful AR model and workflow method that emerged from the tests, showcasing a practical approach to implementing AR within BIM processes.

By combining the concepts and principles of BIM with the immersive and interactive nature of AR, this research endeavors to provide valuable insights into the integration of these technologies in the civil engineering domain. The subsequent chapters will delve deeper into each aspect, building upon the foundations laid in the introductory chapter. Through a comprehensive exploration of BIM, AR, and their mutual benefits, this study seeks to contribute to the advancement and adoption of this innovative approach in the construction industry.

CHAPITRE I:

<u>BUILDING INFORMATION MODELING</u>

Introduction

Building Information Modeling (BIM) is a digital approach to building design, construction, and management that has become increasingly popular in the construction industry in recent years. BIM is a collaborative process that involves the use of 3D models and other digital tools to simulate the entire building lifecycle, from conceptual design to construction and operation.

Many research studies have been conducted on BIM, focusing on various aspects such as its benefits, challenges, implementation, and impact on the construction industry. BIM theses, in particular, are research works that aim to contribute to the existing body of knowledge on BIM and address some of the gaps in the literature.

The theses on BIM cover a wide range of topics, including BIM adoption and implementation, BIM standards, BIM interoperability, BIM collaboration, BIM for sustainability, BIM for facility management, and BIM for construction safety. The aim of these theses is to provide insights into the current state of BIM adoption, identify best practices, and propose recommendations for improving BIM implementation and usage in the construction industry.

Overall, BIM theses play an important role in advancing the field of BIM and driving innovation and progress in the construction industry.

Figure 1 DR patrick hanratty and one of the earlier gams (https://www.itwocostx.com/company/blog/if-bims-a-mystery-heres-the-history)

1. History of BIM

The history of Building Information Modelling (BIM) can be traced back to the mid-1960s when computer-aided design (CAD) was first introduced in architecture and engineering. Over the next several decades, BIM gradually evolved as a tool for enhancing collaboration and information management in construction projects.

In the 1980s and 90s, the use of BIM expanded to other areas of the AEC industry, such as cost estimating, scheduling, and project management. The rise of the internet and advancements in computer technology also helped to increase the adoption of BIM, making it easier to collaborate and share information among project stakeholders.

By the early 2000s, BIM had gained widespread recognition and adoption as a standard tool in the AEC industry. Today, BIM is widely used in all stages of the construction process, from design and planning to construction and maintenance. Its use has been shown to improve project efficiency, reduce waste, and enhance overall project outcomes.

In recent years, BIM has continued to evolve, with the development of new technologies such as virtual and augmented reality, which are being used to enhance the visualization and communication of building designs. The use of BIM is also becoming increasingly integrated with other technologies such as the Internet of Things (IoT) and artificial intelligence (AI), further expanding its potential to revolutionize the construction industry.

Figure 2 :Life before AUTOCAD, (https://www.vintag.es/2018/08/life-before-autocad.html)

2. Definition of BIM

Building Information Modelling (BIM) is a process that involves creating a digital representation of a building's physical and functional characteristics. BIM involves the integration of information about design, construction, and operations into a single database, resulting in a comprehensive virtual model of the building. This virtual model is used to manage the entire building lifecycle, from the initial conceptual design phase to construction, commissioning, operations, and eventual decommissioning.

The term Building Information Modelling (BIM) has many interpretations and definitions. BIM is the acronym for Building Information Modelling or Building Information Model became over time Building Information Management. The different meanings of the same acronym is due to the fact that the applications of BIM have evolved over time and that the potential of BIM was wider than

Initially foreseen.In general, BIM is defined at two different scales. In this BIM handbook, we will typically refer to the first definition:

- BIM is a process in which different actors work together, efficiently exchange information (data and geometry) and collaborate to provide a more efficient construction process (e.g. less errors, faster construction) but also more efficient buildings that produce less waste and are cheaper but also easier to operate. With that vision the key is not the three-dimensional modelling itself but the information developed, managed and shared, in support of better collaboration.

- BIM can also be seen as a software platform allowing to coordinate or combine the work of different stakeholders into one Building Information Model. A Building Information Model, is a three dimensional (3D) object-oriented model with embed- ded information. It means that it is a three dimensional representation of the building in which all the elements that compose the buildings are considered as “objects” connected to each other. Each object has a unique identifier and relates information about its geometry and its properties. This object oriented approach allows to organize the virtual model and develop different behaviours or interactions according to the type of objects (for instance, windows have special relationships with walls, objects can be attached to floors, walls, ceilings or other objects). In addition to those relationships, an object oriented approach also allows to store information by objects. Therefore, each virtual object with its embedded information can be easily used to define and identify the real element built on-site. (d'Olivier Celnik & d'Éric Lebègue and all.,2004)

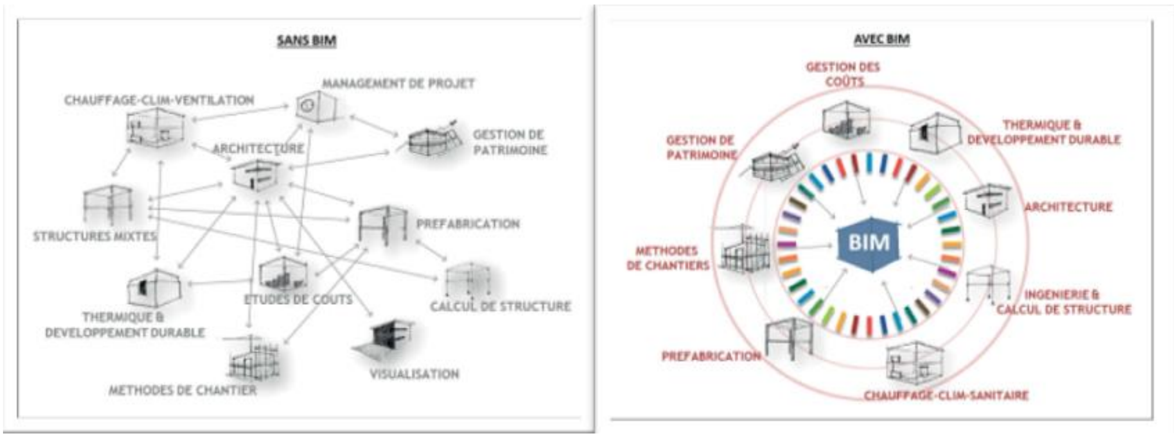


Figure 3 Without BIM vs with BIM (: Image By book (BIM & MAQUETTE NUMERIQUE)

3. Dimension of BIM

Contrary to what one might think, a digital model comprises more than 3 dimensions. These space dimensions are supplemented by a variable number of dimensions depending on the information provided in the model. .(OUSSAMA MOKRANI ,WAIL SAAD AZZEM,2019)

1- 2D BIM: From the digital model, we can extract as many 2D plans as necessary through views and sheets that are automatically updated with the project's evolution.

2- 3D BIM: It is through the model's 3 spatial dimensions, the different 2D views are automatically updated. 3D views can also be defined to visualize the project from any desired angle. The 3D allows characterizing and visualizing conflicts between different sub-projects and calculating quantities of materials or equipment.

3- 4D BIM: To these 3 geometric dimensions, the time vector is added. Geometric elements can be linked to a construction schedule. Thus, the project's different actors have the possibility to visualize the duration of an event or the progress of a construction phase over time.

5D BIM: With the fifth dimension, the model is completed by resource elements (methods, equipment, human resources...). The presence of these elements allows adding cost data to the digital model, thus estimating the construction costs of the project, or even the overall cost.

5- 6D BIM: We can go further by defining new dimensions for BIM. Each layer of data present in the model enriches the level of information of the digital model and adds a new dimension to the BIM concept.(OUSSAMA MOKRANI ,WAIL SAAD AZZEM,2019)

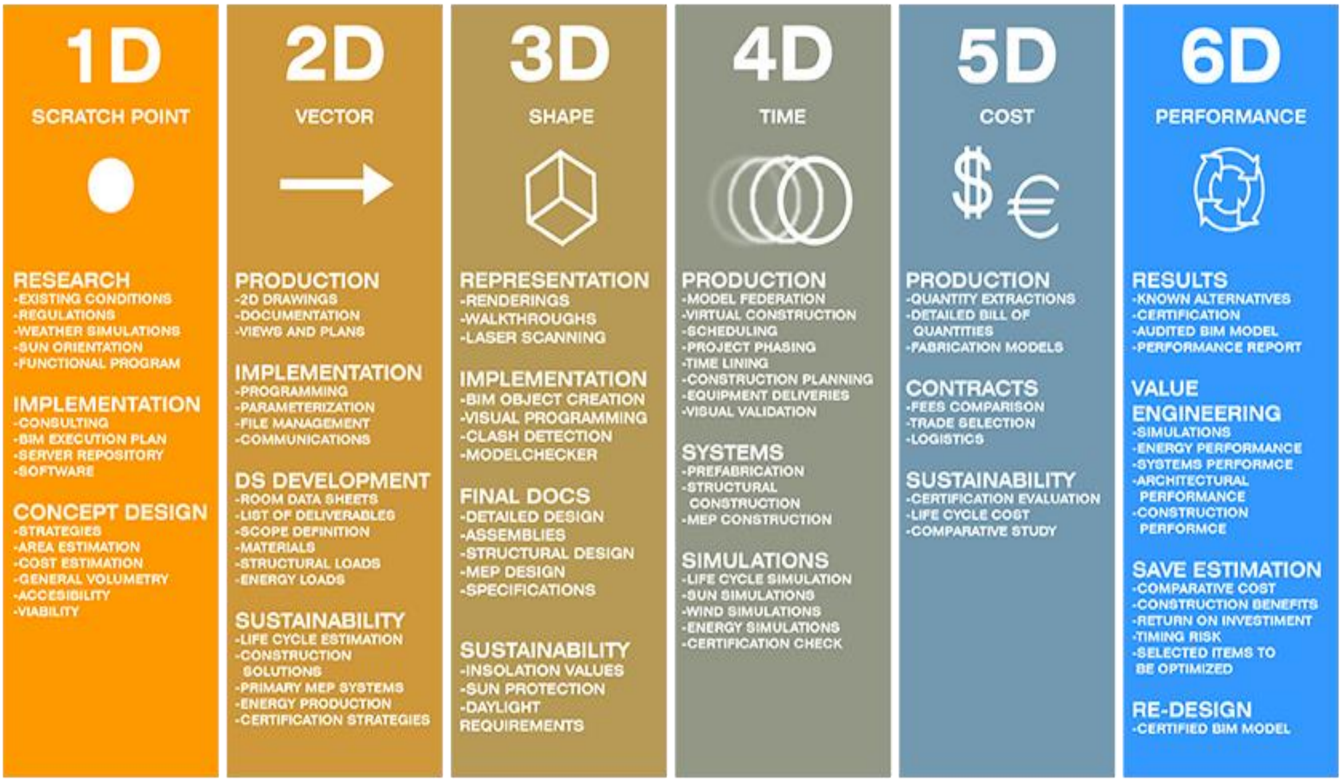


Figure 4 Dimension of BIM (https://www.abcdblog.fr/interview-startup-powerbim-le-jumeau-numerique-au-service-de-lefficacite-de-vos-actifs-en-phase-gestion-et-maintenance/)

4. The deference between digital Moquette and BIM

What definitions and references can we retain? Most judicious consists for each person in making his own part of the things between several competing definitions of BIM, independing on their experience and needs:

• the Wikipedia definition;

• the English standard (supported by Christophe Castaing in the national MINnD project);

•the definition that emerged fromtestimoniesga the redin the book.

Three competing notions should be compared: the 3D model, digital model and BIM. For BIM,three definitions seem to emerge, depending on the course of the acronym that we adopt:

•Building Information Model the filecreated with software specific profession, combining objects, geolocation, geometry ,information, semantics…;

•Building Information Modeling : the working process of those who use these tools, in a spirit of constitution of database of the project and exchanges between actors;

•Building Information Management : the management process of the project, through tools such as the digital model ric, the management of information and actors.

5. Usess of BIM

Building Information Modeling (BIM) is used for several purposes in the architecture, engineering, construction, and operations (AECO) industry, including:

Design: BIM is used to create a comprehensive digital model of a building's design, including the geometry, materials, and building systems (Eastman, Teicholz, Sacks, & Liston, 2011). Construction planning: BIM is used to plan construction schedules, coordinate activities, and manage resources, reducing the risk of errors and improving efficiency (Fischer & Kunz, 2004). Cost estimating: BIM allows for the creation of accurate cost estimates based on the detailed information contained in the digital model, reducing the risk of errors and improving project efficiency (Azhar, Hein, & Sketo, 2008).

Project management: BIM provides a centralized source of information about the building, allowing for better project management and improved decision-making (Levy, 2011). Collaboration: BIM facilitates collaboration and communication among all stakeholders involved in a construction project, reducing misunderstandings and conflicts (Eastman et al., 2011).

5.1. The Value of BIM in Construction

The value of BIm in construction comes in many shapes and sizes. Whether it’s the ability to save time through automated functions, eliminate the need to travel to a meeting, or save money because better information is available earlier to make cost- effective decisions, they all have the same focus: results. It’s hard to imagine an area of our daily lives in which technology doesn’t affect us, particularly in the work place. The same is true within the construction industry. The advent of BIm and the rise of application-based technologies have opened doors and arguably created one of the most exciting new dynamics since microsoft excel. over the last 50 years, the construction industry has had just a handful of notable technological innovations compared to other industries. granted, there were many innovations in material research, installation methodologies, and energy efficiency, such as prefabrication, eco-friendly materials, and green building design. however, the technologies used by project teams for construction management remained largely the same. now, innovation is becoming a part of the way contractors deliver their work and differentiate themselves from their competitors. as a result, we are starting to see a healthy ecosystem of supply and demand for ever better tools between technology vendors and construction management firms willing to invest to drive efficiencies, as is evident in the rise of contractors adopting BIm technologies

Improved accuracy and efficiency: BIM allow for the creation of a comprehensive digital model of a building, providing a more accurate representation of the building's design, construction, and operations. This can help to reduce errors and improve the efficiency of the construction process.

Enhanced collaboration and communication: BIM facilitates collaboration and communication among all stakeholders involved in a construction project, reducing misunderstandings and conflicts.Better decision-making: BIM provides a centralized source of information about the building, allowing for better decision-making and reducing the risk of errors.Increased sustainability: BIM allows for the analysis of a building's energy efficiency, helping to identify areas for improvement and reducing the building's overall environmental impact.Increased project efficiency: BIM allows for the creation of accurate cost estimates, schedules, and quantities, reducing the risk of errors and improving project efficiency.Improved overall project outcomes: By improving accuracy, collaboration, and sustainability, BIM can help to enhance overall project outcomes and deliver better buildings to the community.Streamlined construction and maintenance: BIM provides a detailed digital representation of the building that can be used for construction and maintenance, reducing the risk of errors and increasing efficiency.

Improved safety: BIM can help to identify and mitigate safety risks in the building design and construction process, improving overall safety for building occupants and workers.

Building Information Modelling (BIM) is a digital tool that has become increasingly popular in the construction industry due to its numerous benefits. BIM facilitates collaboration among different stakeholders, enables better decision-making, improves efficiency and reduces waste, and enhances project quality and safety. In fact, research has shown that using BIM can lead to cost savings of up to 20% and time savings of up to 50% compared to traditional methods (Eastman et al., 2011). BIM can also improve sustainability by allowing designers and contractors to assess the environmental impact of their decisions (Zhang et al., 2016). However, the adoption of BIM is not without its challenges, including the need for training and the potential for information overload (Azhar et al., 2012). Despite these challenges, BIM is expected to continue to play a critical role in the construction industry as it evolves to meet the demands of the 21st century (Kassem et al., 2019).

5.2. BIM and Education

For many construction professionals, BIM training begins in academia. education, particularly in universities, is the perfect environment to challenge industry norms, experiment with new media, and explore what’s possible. Schools teaching architecture, engineering, and construction management have an enormous responsibility and challenge to present their student body with technologies and processes that are relevant to the environment they will be exposed to upon graduation. These institutions must realize that teaching critical thinking and encouraging creativity is just as important as the software and technologies in current BIM coursework. Students make decisions on where to attend based largely on the following factors:

- A college or institution is often noted for what level of technological advances the school has embraced. If the university is deaf to the industry and its trends, this will be carried through in the school’s reputation as well as its graduates. For this reason, it is critical that university systems be grounded in current issues and technologies, because these will be the issues their graduates will face in the industry.

- Institutions have the ability to be extremely advanced. There is little to no risk in exposing students to new technologies. exploring new software and different processes should be done at this level, because it pushes students to learn and formulate views and solutions of their own. This will enable them to hit the ground running after graduation. This education might not result in a complete understanding of all BIM tools in the architecture or construction profession, but it should include a base-level knowledge of what the software is capable of doing and how it is to be used.

- universities have the potential to save companies training costs. Although this shouldn’t necessarily be a goal for universities since there are so many different pieces of BIM software, it is a marketable by-product of embracing and training students on new software and technologies.(Brad Hardin Dave McCoo,2015)

5.3. 3D Coordination

Collaboration of the construction team with the architect, engineer and the owner is preferred to be started on early stages of design phase. At that time, the Building Information Modelling shall immediately be implemented. If the architect is only providing 2D drawings, then the construction manager should convert the 2D drawings to 3D intelligent models. When the specialty contractors, especially the MEP contractors and the steel fabricators are involved, they need to spatially coordinate their work. The 3D coordination can be started right after the model is created to ensure that any same space interference (hard clash) or clearance clash (soft clash) conflicts are resolved. Overall, the coordination efforts of construction manager and specialty contractors in advance of construction help to reduce design errors tremendously and to better understand ahead of time the work to be done. For example, Research 2 Tower Project for Colorado Denver Health Science Centre distinguished itself with the implementation of BIM in comparison to Research 1 Tower project which had major complex mechanical system problems. The BIM usage for Research Tower 2 included 3D MEP coordination14as shown in figure 6, work planning for concrete placement, and assembly instruction models. The benefits for Research 2 project included 37% reduction in coordination RFIs, and 32% reduction in coordination change orders (Young, 2009).

5.4. Construction Planning and Monitoring

The construction planning involves the scheduling and sequencing of the model to coordinate virtual construction in time and space. The schedule of the anticipated construction progress can be integrated to a virtual construction. The utilization of scheduling introduces time as the 4th dimension (4D).There are two common scheduling methods that can be used to create 4D Building Information Model. These are critical path method (CPM) and line of balance.In the Critical Path Method, each activity is listed, linked to another activity, and assigned durations. Interdependency of an activity is added as either predecessors or successors to another activity. Moreover, the duration of the activities are entered. Based on the dependency and duration of the activities, the longest path is defined as the most critical path. The activities defined in the longest path are defined as the critical

activities. These activities do not have any float. In other words, if these activities are not completed within anticipated duration, the total duration of the project will be further pushed out. Overall CPM is a commonly used technique that helps projects stay within schedule.Line of Balance technique uses location as the basis for scheduling. This methodis an alternate to the CPM. It is advantageous for repetitive tasks to increase lab or productivity. In this method, activity durations are based on the available crew size and the sequence of the location. Productivity of the labor force can be altered as needed to accurately depict the construction schedule. The approach focuses on the locations being completed by a trade before the other trade moves in. This reduces the number of mobilizations and resources. Overall, line of balance is a good scheduling method to plan and monitor repetitive tasks during construction progress. (Kenley, 2010) The planning through using BIM enhances site utilization, space coordination, and product information. A 4D model can either include a site logistics plan or tools such as SMARTBOARD on top of a virtual construction can be utilized to visually depict the space utilization of the job site. The model must include temporary components such as cranes, trucks, fencing etc. Traffic access routes for trucks, cranes, lifts, excavators,etc. need to be incorporated into the BIM as part of the logistics plan. For example, the site logistics planning for the Hennessy Centre steel erection is depicted in figure 5 (Collins 2011). Moreover, the site utilization consists of lay down areas, site work progress, and location of trailers and equipment and hoist assembly. Similarly, when the building is being closed in, the space coordination must be managed for the roughing and eventually finishing activities.

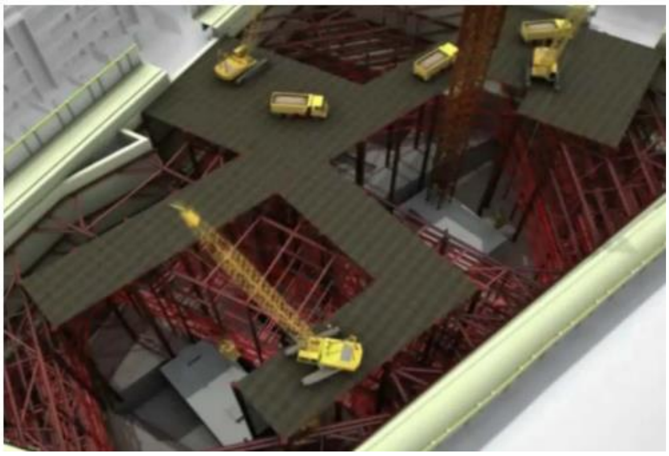


Figure 5: Hennessy centre safety and site logistes planning (colins,2011)

5.7. 3D Modeling of a House

Student licensed version of Revit Architecture 2010 was downloaded from Autodesk’s student community website to develop a 3D house model. First, a new Revit file was created and saved. Then, the perimeter walls were created. Once the perimeter walls were completed, the interior walls are created. Then, the foundation walls, flooring, doors windows, roof, stairs, deck were created. Furthermore, the rooms were tagged. No mechanical, electrical, plumbing elements were created for this study. The differences of 3D modelling and 2D drafting were reviewed. Furthermore, the granularity of objects including the decomposition of the elements was explored.

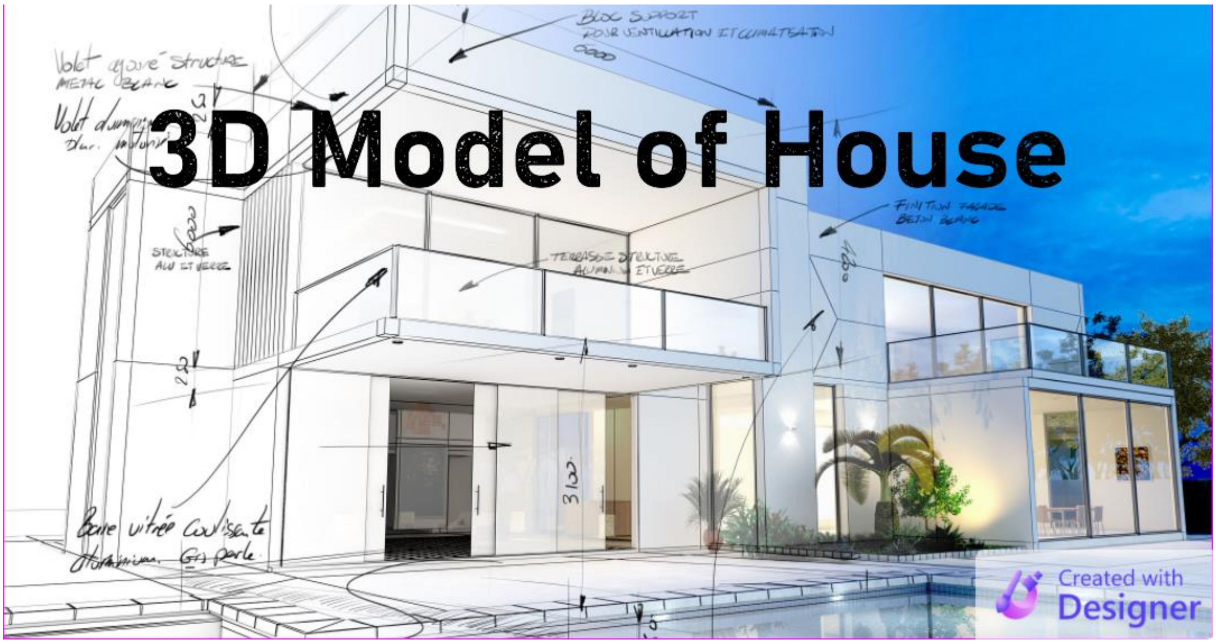


Figure 6 :3D model of house (Microsoft designer)

5.8. 4D Modelling of a House

4D modelling required the development of a 3D model as well as the schedule. The 3D model was created in Revit Architecture 2010. The Microsoft Project used the critical path method to create the schedule. Synchro's 4D BIM tool was downloaded through its website. In this project, it was utilized as the integrator of the Revit model in IFC format and the Microsoft Project in xml format. Once the model and the schedule

were imported in to the Synchro's integration tool, the IFC resources which was a list of building elements created in BIM was linked to the activities. Once the 4D linking was completed, play focused time and animation could be utilized to create videos of the 4D model. Finally, the video file could be exported as an avi movie format.(ByMehmet F. Hergunsel ,2011)

6. The difference between 3D CAD modelling and BIM

3D CAD modeling and Building Information Modeling (BIM) are both powerful tools used in the field of architecture and construction. While they share similarities in terms of creating digital representations of buildings and structures, there are distinct differences between the two approaches.

3D CAD modeling primarily focuses on the creation of three-dimensional geometric models of individual components or objects within a building. It is often used by architects and designers to visualize and develop detailed representations of various building elements, such as walls, floors, doors, and windows. CAD software allows for precise measurements, accurate scaling, and intricate detailing, enabling architects to create comprehensive designs. (Gopi, R., & al S,2017).

On the other hand, BIM takes a more holistic approach by integrating multiple aspects of the building process into a single digital model. BIM incorporates not only the geometric representation of building elements but also encompasses additional information such as material properties, cost estimates, construction schedules, and even facility management data. This comprehensive model allows stakeholders, including architects, engineers, contractors, and facility managers, to collaborate and share data throughout the entire lifecycle of the building. (Azhar, S., Hein, M., & Sketo, B. (2012).

One of the key differences between 3D CAD modeling and BIM lies in their level of detail and information integration. While 3D CAD modeling focuses primarily on the visual representation of individual building components, BIM goes beyond visual aspects to include a wide range of data associated with each element. This information-rich approach in BIM enables more accurate analysis, simulation, and decision-making throughout the building's lifecycle. (Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011).

Furthermore, BIM facilitates better collaboration and coordination among various project stakeholders. Since all relevant information is stored within the BIM model, it allows architects, engineers, and contractors to work concurrently and detect and resolve potential conflicts or clashes between different building systems at an early stage. This collaborative environment promotes efficient communication and reduces errors, resulting in enhanced project delivery and reduced costs. (Succar, B. (2009).

7. the advantages of BIM over CAD

Building Information Modeling (BIM) offers several advantages over traditional 2D Computer-Aided Design (CAD):

Improved accuracy: BIM provides a more comprehensive and accurate representation of a building's design, construction, and operations, reducing the risk of errors and improving the overall efficiency of the construction process.

Enhanced collaboration and communication: BIM is designed to facilitate collaboration and communication among all stakeholders involved in a construction project, reducing misunderstandings and conflicts.

Better decision-making: BIM provides a centralized source of information about the building, allowing for better decision-making and reducing the risk of errors.

Increased sustainability: BIM allows for the analysis of a building's energy efficiency, helping to identify areas for improvement and reducing the building's overall environmental impact.

Increased project efficiency: BIM allows for the creation of accurate cost estimates, schedules, and quantities, reducing the risk of errors and improving project efficiency.

Improved overall project outcomes: By improving accuracy, collaboration, and sustainability, BIM can help to enhance overall project outcomes and deliver better buildings to the community.

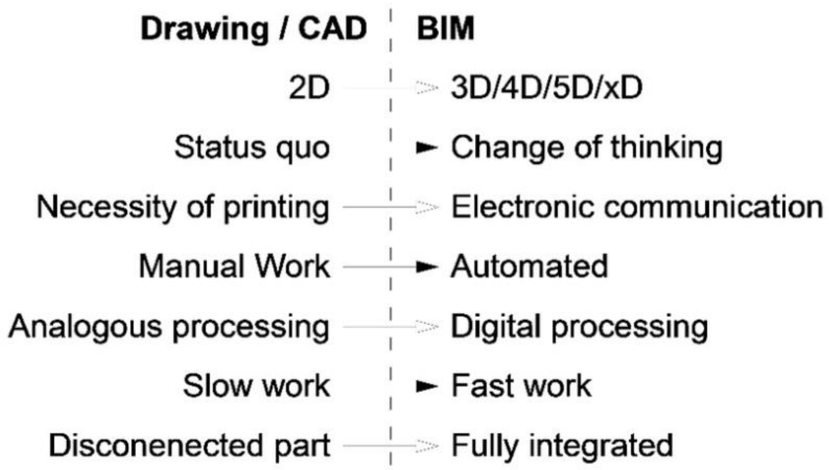


Figure 7 :*BIM/CAD*

(https://www.researchgate.net/figure/Process-of-changes-Cad-vs-Bim-1-3-3-BIM-as-a-team-tool-During-works-associated_fig1_274176930 PHOTO)

8. Levels of BIM

8 .1. Level of BIM maturity:

The level of Building Information Modelling (BIM) maturity refers to the extent to which an organization has adopted and integrated BIM into its processes and workflows. Level 0: 2D drafting. This is the most basic level of BIM, using 2D drafting tools for design and documentation.

1. Level 1: 3D modelling. This level involves the creation of a 3D model of the building, providing a visual representation of the design.
2. Level 2: BIM collaboration. This level involves collaboration between multiple parties, such as architects, engineers, and contractors, to create a shared digital model of the building.
3. Level 3: Integrated BIM. This level involves the integration of data from multiple sources, such as cost estimates, schedules, and building systems information, into a single digital model.

4. Level 4: Intelligent BIM. This is the highest level of BIM maturity, where the digital model is used for simulation, analysis, and asset management, providing a comprehensive view of the building throughout its lifecycle.

In conclusion, the level of BIM maturity refers to the extent to which an organization has adopted and integrated BIM into its processes and workflows, with higher levels of BIM maturity providing increased levels of detail and functionality.

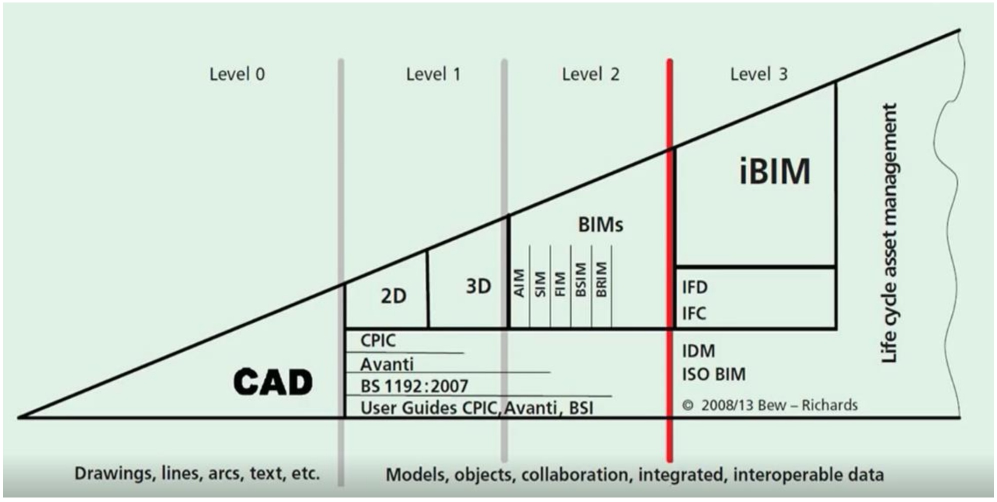


Figure :8 LEVEL OF MATURITY (By BIM Maturity ___ Easy as 1, 2, 3 _ The B1M)

7 .2. level of detail

Level of Detail (LOD) refers to the level of completeness and accuracy of the information contained in a BIM model. There are different standards for defining LOD, such as the American Institute of Architects (AIA) guidelines and the UK BIM Level 2 standards. LOD ranges from 100, which represents conceptual design information, to 500, which represents construction and fabrication information (Eastman et al., 2011). The level of detail required for a project depends on its stage, scope, and complexity, as well as the stakeholders' needs and preferences. While high LOD can enhance project efficiency, accuracy, and communication, it also increases the modelling effort and cost, and may not be necessary for all projects (El-Naas et al., 2020). Therefore, it is important to establish clear and consistent LOD requirements and communicate them effectively among stakeholders (González et al., 2016). Moreover, LOD can be dynamic and evolve over the project life cycle as more information becomes available or new requirements emerge (Wong et al., 2018).

Level 0 represents the traditional 2D CAD drawings, where there is no integration of data or collaboration between project stakeholders.

Level 1 represents the use of 3D models with minimal data, and limited collaboration between project stakeholders.

Level 2 represents the use of 3D models with more data and collaboration between different project stakeholders.

Level 3 represents the use of 4D models, which are 3D models with a time dimension and schedule integration, this level is mainly used for construction planning and coordination.

Level 4 is the most advanced level and it represents the use of 5D models, which are 4D models with cost integration and facilities management information.

It is important to note that the level of BIM implemented in a project can vary depending on the project's complexity, budget, and the client's requirements and that the level of BIM maturity can be used as a benchmark to evaluate the level of BIM implementation in a project.

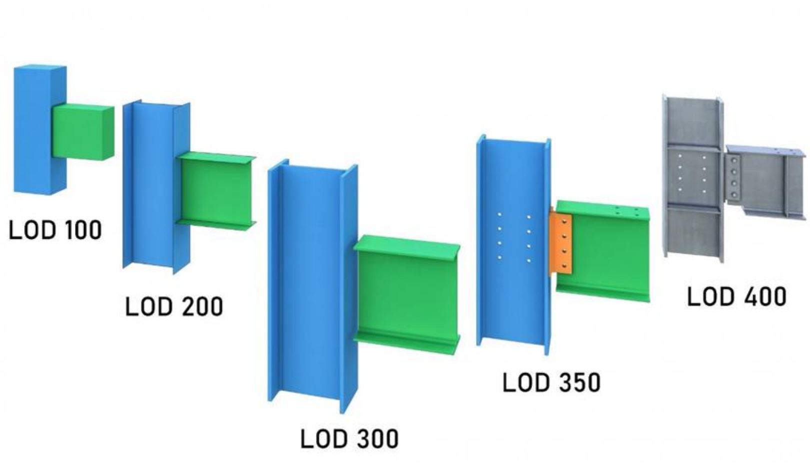


Figure 9 : Level of detail (https://www.oneistox.com/blog/what-is-lod)

7.3. Difference between level of maturity and detail

Level of detail (LOD) and level of maturity (LOM) in Building Information Modeling (BIM) are two different concepts.

Level of detail (LOD) refers to the level of specificity and completeness of the information included in the BIM model at a particular stage of the project. LOD is used to describe the quality of the data in the BIM model. It ranges from LOD 100, which is the least detailed, to LOD 500, which is the most detailed.

Level of maturity (LOM), on the other hand, refers to the level of integration, collaboration, and standardization of BIM processes and practices within an organization or project. LOM describes the extent to which an organization is utilizing BIM in its workflows and processes. It ranges from Level 0, which is no BIM capability, to Level 5, where BIM is fully integrated and embedded in the organizational culture.

In summary, LOD describes the data in the BIM model, while LOM describes the organization's or project's usage and integration of BIM in their workflow.

7.4. Levels of development (LOD)

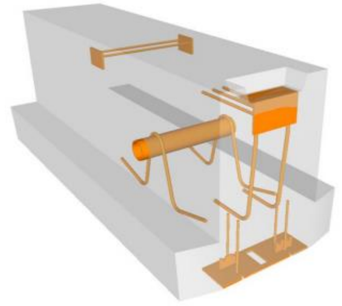
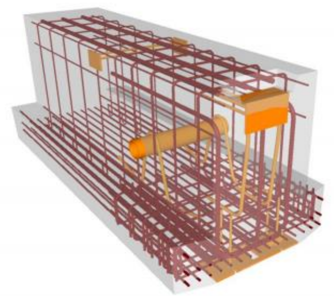
The level of detail (LOD) in BIM refers to the level of specificity and completeness of the information included in the model at a particular stage of the project.

There are several commonly used levels of detail in BIM, with LOD 100 being the least detailed and LOD 500 being the most detailed.

- LOD 100: This level includes basic geometric shapes that represent spaces and structural elements, with minimal information about their properties or characteristics.
- LOD 200: This level includes more detailed geometric shapes and information about the properties and characteristics of building elements, such as dimensions and materials.

- LOD 300: This level includes detailed information about systems and equipment, such as HVAC and plumbing systems.
- LOD 350: This level includes detailed information about furniture and equipment, such as lighting fixtures and appliances.
- LOD 400: This level includes detailed information about the construction of building elements, such as assembly details and fabrication drawings.
- LOD 500: This level includes as-built information, such as actual measurements and installation details, and can be used for facilities management and maintenance.

Figure 10: Levels of development (LOD) https://biblus.accasoftware.com/fr/lod-et-loin-dans-le-bim-leurs-definitions-et-a-quoi-ils-servent/)

350	Element modeling to include: • Reinforcing Post-tension profiles and strand locations • Reinforcement called out, modeled if required by the BXP, typically only in congested areas • Chamfer • Pour joints and sequences to help identify reinforcing lap splice locations, scheduling, etc. • Lifting devices • Expansion Joints • Embeds and anchor rods • Post-tension profile and strands modeled if required by the BXP • Penetrations for items such as MEP • Any permanent forming or shoring components	 16 B1010.10-LOD 350 Precast Structural Inverted T Beam (Concrete), From lkerd.com
400	Element modeling to include: • All reinforcement including post tension elements detailed and modeled • Finishes	 17 B1010.10-LOD 400 Precast Structural Inverted T Beam (Concrete), From lkerd.com

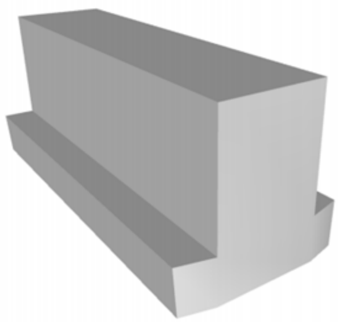
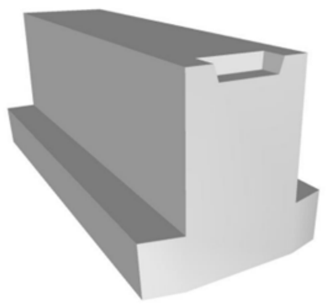
100	See B10	
200	Element modeling to include: • Type of structural concrete system • Approximate geometry (e.g. depth) of structural elements	 14 B1010.10-LOD 200 Precast Structural Inverted T Beam (Concrete), From lkerd.com
300	Element modeling to include: • Specific sizes and locations of main concrete structural members modeled per defined structural grid with correct orientation • All sloping surfaces included in model element with exception of elements affected by manufacturer selection	 15 B1010.10-LOD 300 Precast Structural Inverted T Beam (Concrete), From lkerd.com

Figure 11: Levels of development (LOD) (https://www.bimaxon.com/lod-is-wasting-our-time-and-holding-bim-back/)

7.5. Level of Development (LOD)

Model Content	LOD 100	LOD 200	LOD 300	LOD 400	LOD 500
3D Model Based Coordination	Site level coordination	Major large object coordination	General object level coordination	Design certainty coordination	N/A
4D Scheduling	Total project construction duration. Phasing of major elements	Time-scaled, ordered appearance of major activities	Time-scaled, ordered appearance of detailed assemblies	Fabrication and assembly detail including construction means and methods (cranes, man-lifts, shoring, etc.)	N/A
Cost Estimation	Conceptual cost allowance Example $/sf of floor area, $/hospital bed, $/parking stall, etc. assumptions on future content	Estimated cost based on measurement of the generic element (i.e. generic interior wall)	Estimated cost based on measurement of specific assembly (i.e. specific wall type)	Committed purchase price of specific assembly at buyout	Record cost
Program Compliance	Gross departmental areas	Specific room requirements	FF&ampE, casework, utility connections		
Sustainable Materials	LEED strategies	Approximate quantities of materials by LEED categories	Precise quantities of materials with percentages of recycled and/or locally purchased materials	Specific manufacturer selections	Purchase documentation
Analysis/Simulation	Strategy and performance criteria based on volumes and areas	Conceptual design based on geometry and assumed system types	Approximate simulation based on specific building assemblies and engineered systems	Precise simulation based on the specific manufacturer and detailed system components	Commissioning and recording of measured performance

Figure 12: Level of Development (LOD) (byLOD-Specification-2015)

Level of Development (LOD) specification allows professionals in the industry to clearly articulate how an element's geometry and associated information has evolved throughout the entire process. It signifies the degree to which different members of the team can rely on information associated with an element. The LOD specification helps designers define the inherent characteristics of the elements in a model at different stages of development. The clarity in illustration gives depth to a model, signifying how much and at which level someone should rely on a model's element. Using LOD, designers and engineers can clearly communicate with other professionals who will be using the model further about the usability and limitations of a model. LOD specifications were designed to standardize the use of the LOD framework and use it as an efficient and collaborative communication tool. By BIM Level of Development Explained LOD 100 200 300 350 400 500 (B1M)

7.6. Level of information

In addition to the four levels of development (LOD) in Building Information Modelling (BIM), there are also five levels of information (LOI) that are used to describe the level of information included in a BIM model at each stage of the building's lifecycle. The LOI levels are as follows:

LOI 1: Identification - This level includes basic identification information about the building's components, such as their names and locations.

LOI 2: Classification - This level includes information about the building's components, such as their types, sizes, and materials.

LOI 3: Representation - This level includes detailed information about the building's components, such as their geometries, shapes, and orientations.

LOI 4: Performance - This level includes information about the building's performance and functionality, such as energy efficiency, fire safety, and acoustics.

LOI 5: Maintenance - This level includes information about the building's maintenance and operations, such as the location of equipment, schedules for maintenance, and the replacement of components.

It is important to note that LOI is closely related to LOD, but they are not the same. LOI describes the level of information included in the BIM model, while LOD describes the level of detail and completeness of the model.

7.7. Level of definition

BIM, which stands for Building Information Modelling, is a digital process that involves creating and managing a data-rich 3D model of a building or structure. BIM uses intelligent objects that represent physical and functional characteristics of the building, such as walls, floors, windows, doors, and mechanical, electrical, and plumbing (MEP) systems. The objects contain information such as dimensions, materials, performance data, and other relevant parameters.

BIM allows for the coordination of design and construction information across multiple disciplines and stakeholders, enabling teams to work collaboratively and efficiently. The model can be used to simulate construction sequencing, analyse energy performance, estimate costs, and schedule construction activities.

BIM is not just a technology, but also a process and a mindset that requires collaboration, communication, and standardization. It is becoming increasingly important in the construction industry as a way to improve project outcomes, reduce costs, and enhance sustainability.

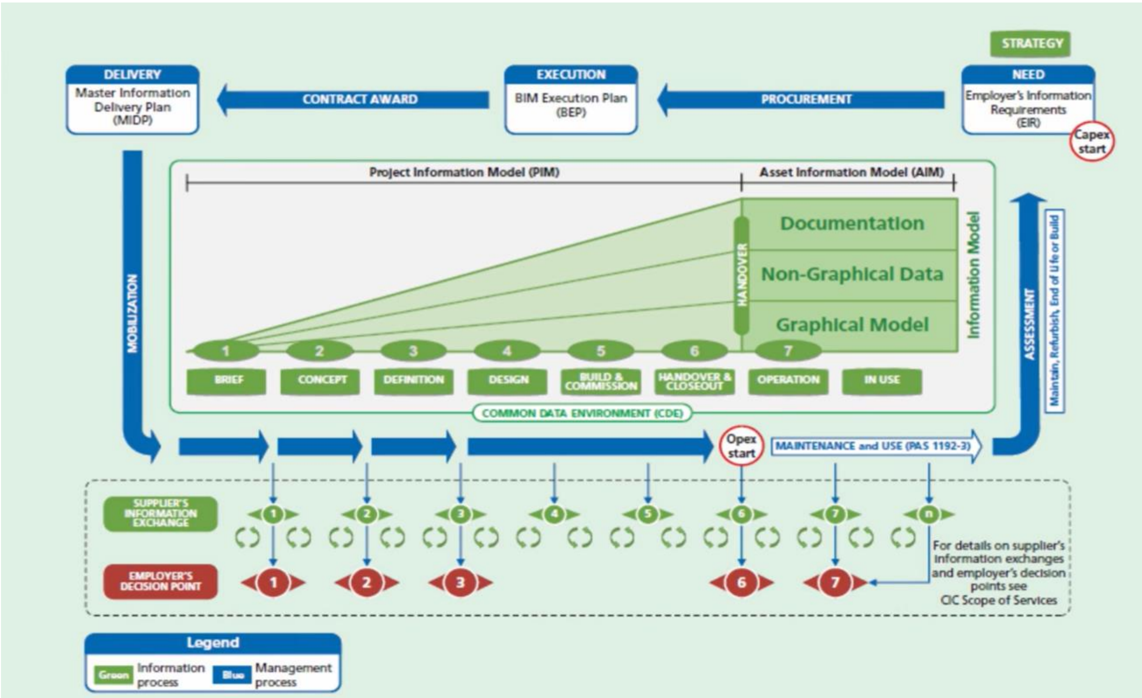


Figure 13 : Levels of definition (LOD By BIM Level of Development Explained LOD 100 200 300 350 400 500 Video)

8. The Benefit of Clarity Due to LOD for an AEC Project

In an era where everything is handled digitally and all critical projects make use of 3D model, it becomes hard for designers to make other teams understand the project expectations. Most often, handling a BIM model comes with a unique challenge- different people perceive different definitions of completion. LOD creates a standardized definition of what completion means and eliminates chances of discrepancies associated with project completion. Using LOD, teams working under different disciplines can communicate with each other in a better way with greater clarity. LOD enhances clarity in design by making use of advanced techniques and technology.

9. The common data environment (CDE) in construction

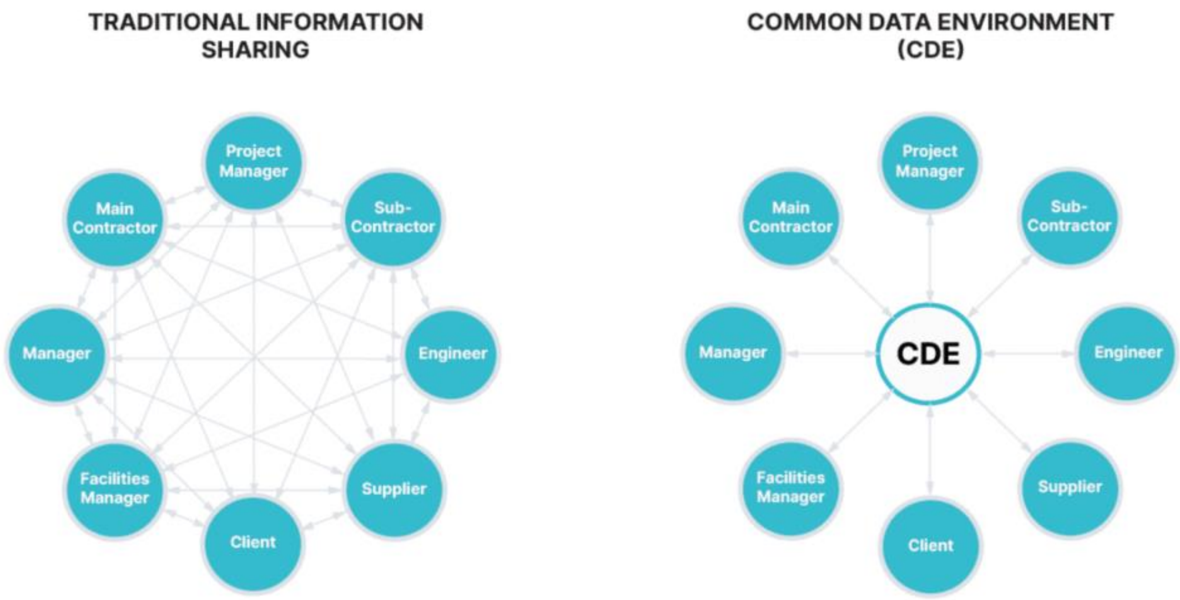


Figure 14: CDE VS traditional information (by Levels of Definition Explained _ The B1M)

A Common Data Environment (CDE) is a centralized repository used in construction projects to store, manage, and share project information and data between all stakeholders, including design team members, contractors, and clients. The purpose of a CDE is to ensure consistency, accuracy, and up-to-date information throughout the project lifecycle.

10. Interevent

In the construction industry, there are several key participants or stakeholders involved in the design, construction, and management of building structures. Some of the main participants include:

1. Owners: The individuals or organizations that commission and fund the construction of a building. They are responsible for making decisions about the project's scope, budget, and schedule.
2. Architects: Professionals responsible for the design of a building's layout, appearance, and functionality. They are responsible for creating plans and specifications that meet the owner's needs and comply with building codes and regulations.
3. Engineers: Professionals responsible for the analysis, design, and construction of a building's structural, mechanical, electrical, and plumbing systems. They work closely with architects to ensure that the design is safe and efficient.
4. Contractors: The individuals or companies responsible for the physical construction of a building. They are responsible for managing the construction process, including hiring subcontractors, ordering materials, and coordinating with other participants.
5. Subcontractors: Specialized companies or individuals hired by a general contractor to perform specific tasks, such as electrical work, plumbing, or masonry.
6. Inspectors: Professionals responsible for inspecting the work performed by contractors and subcontractors to ensure that it complies with building codes and regulations.
7. BIM Managers: Professionals responsible for the management of the BIM process and the coordination of the different participants in the project. They also responsible to ensure the compliance and the quality of the BIM model throughout the project.
8. Facility Managers: Professionals responsible for the maintenance and operation of a building once it is completed. They are responsible for ensuring that the building's systems and equipment are functioning properly and efficiently.
9. The community: The people who live and work near the construction site, they may be affected by the construction and have an interest in the final outcome of the building.
10. Regulators: Government agencies responsible for enforcing building codes and regulations, they have an interest in the safety and compliance of the building.

11. Financiers: Banks, investors or other financial institutions that provide funding for the project, they have an interest in the financial success of the project.
12. Suppliers: Companies that provide materials and equipment for the construction, they have an interest in the timely delivery of the materials and the payment for their services.

10.1. Benefits of Using a Common Data Environment for Construction Projects

Using a Common Data Environment (CDE) in construction projects offers numerous benefits that contribute to improved project outcomes and streamlined collaboration among stakeholders. Here are some key advantages of implementing a CDE:

Enhanced Collaboration: A CDE provides a centralized platform where all project participants can access and share information, documents, and models in real-time. This fosters improved collaboration and communication among architects, engineers, contractors, and other team members, leading to better decision-making and problem-solving. (Construction Industry Institute. (2019).

Improved Data Quality: A CDE ensures that all project data is stored and managed in a consistent and organized manner. This reduces errors, duplicates, and inconsistencies in data, resulting in improved data quality. Additionally, a CDE enables version control and change management, ensuring that all stakeholders have access to the latest information. (Construction Industry Institute. (2019).

Increased Efficiency: A CDE eliminates the need for multiple data repositories, reducing the time and effort required to manage project data. This improves project efficiency, allowing stakeholders to focus on delivering the project on time and within budget. Additionally, a CDE enables automation of manual processes, such as document approval workflows, further streamlining project delivery. (Royal Institution of Chartered Surveyors. (2019).

Enhanced Risk Management: A CDE enables better risk management by providing a centralized repository for all project information. This ensures that all stakeholders have access to the same information, reducing the risk of miscommunication and errors. Additionally, a CDE enables stakeholders to track project progress and identify potential issues early on, enabling proactive risk mitigation. (Royal Institution of Chartered Surveyors. (2019).

Improved Project Delivery: The benefits of using a CDE, including improved collaboration, data quality, efficiency, and risk management, ultimately lead to improved project delivery. A CDE enables stakeholders to work together more effectively, delivering projects on time, within budget, and to the required quality standards. (Royal Institution of Chartered Surveyors. (2019).

11.AEC BIM

stands for Architecture, Engineering, Construction and Building Information Modelling (BIM). It is a digital process that involves the use of 3D modelling software to create a virtual representation of a building or structure that can be used throughout its entire lifecycle, from design and construction to operation and maintenance.

AEC BIM is used by architects, engineers, and contractors to collaborate and share information during the building design and construction process. It allows for better communication and coordination among the different teams involved in a building project, as well as improved accuracy, increased efficiency, and reduced errors.

AEC BIM software allows users to create and manage 3D models of buildings and their components, as well as to integrate data from other sources, such as cost estimates, schedules, and energy analysis. It also allows users to run simulations and perform analysis to ensure that the building meets the design requirements and codes.

AEC BIM is widely used in the architecture, engineering, and construction (AEC) industry, and is becoming increasingly important as building projects become more complex and the need for more accurate and efficient processes increases.

We shoulde note

Construction (AEC) industry as a means of improving project delivery, collaboration, and performance. BIM enables stakeholders to create a virtual model of a building or infrastructure project, which can be used for design, analysis, visualization, and communication purposes (Kassem et al., 2017). BIM can also facilitate the integration of different disciplines and phases of the project, such as architecture, structure, MEP, construction, and facilities management (Fattah et al., 2021). BIM is not only a technological solution but also a process and a mindset that require changes in the way stakeholders work and interact (Liu et al., 2018). Therefore, the successful implementation of BIM in the AEC industry requires not only technological competence but also organizational and cultural transformation (Yan et al., 2019). Moreover, BIM can benefit from the integration with other digital technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain (Al-Zahrani et al., 2021).

12. FC File Format

IFC (Industry Foundation Classes) is a data format and data model for building and construction information. It is used to exchange digital building information between different software applications and to support building information modeling (BIM) workflows. IFC files can be opened by BIM software programs and can be used to share information between architects, engineers, contractors, and building owners.

The FC file format is a data exchange format used in the field of architecture, engineering, and construction (AEC) to transfer information between different software applications. The FC format was developed by the building SMART International organization and is based on the Industry Foundation Classes (IFC) standard for building data modelling (Zhang et al., 2021). The FC format allows for the exchange of both geometric and non-geometric data, such as object properties, materials, and relationships (Shim et al., 2020). The FC format has several advantages over other data exchange formats, such as the ability to transfer complex geometry and the support for version control and change management (Sacks et al., 2019). However, the adoption of the FC format is still limited, and several challenges need to be addressed, such as the lack of standardization and interoperability with other formats (Huang et al., 2019). Therefore, efforts are being made to enhance the functionality and usability of the FC format, such as the development of software tools for validation and conversion (Boukamp et al., 2021).

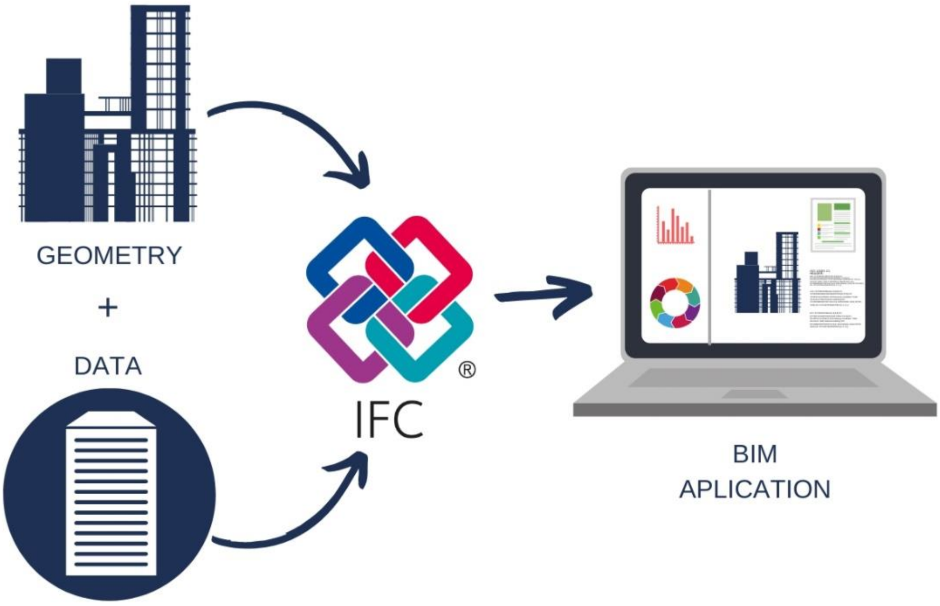


Figure 15 :IFC file exlplaintion(by Levels of Definition Explained _ The B1M)

12.1. What are IFC models

IFC (Industry Foundation Classes) models are digital representations of building or construction projects in the form of a file format. They are used for data exchange and collaboration between different software applications and building stakeholders, such as architects, engineers, and contractors. IFC models are an open standard and can be used with different building information modelling (BIM) software tools.

IFC models store information about the geometry, properties, and relationships of building components and systems in a structured format. This information can be used to simulate building performance, analyse data, and generate visual representations of the building design. IFC models help improve the accuracy, efficiency, and collaboration in construction projects by enabling seamless exchange of information between different software applications and stakeholders.

13.The process of BIM

Building Information Modelling (BIM) is a process for creating and managing digital information about a building or infrastructure project. BIM allows architects, engineers, contractors, and other stakeholders to collaborate on a project using a single, shared digital model of the building.

The BIM process generally involves the following steps:

Project Planning and Scoping: In this phase, the project team identifies the scope and requirements of the project, including the project objectives, the stakeholders involved, and the expected outcomes.

Conceptual Design: In this phase, the team creates a preliminary design of the building, including sketches, diagrams, and other conceptual models.

Detailed Design: In this phase, the team develops a detailed design of the building, including floor plans, elevations, and sections, using specialized BIM software tools.

Construction and Fabrication: In this phase, the team uses the BIM model to plan and coordinate the construction process, including site logistics, material selection, and fabrication.

Commissioning and Handover: In this phase, the team uses the BIM model to manage the commissioning process, including testing and validation of building systems, as well as the handover of the building to the owner or operator.

Throughout the BIM process, the digital model serves as a shared source of information for all stakeholders, allowing them to collaborate and coordinate their efforts more effectively. The BIM model can also be used to simulate and analyse various aspects of the building, such as energy efficiency, acoustics, and lighting, allowing the team to optimize the design and construction process for improved performance and sustainability.

14.BIM Software

Building Information modelling (BIM) software is a digital tool used in the architecture, engineering, and construction (AEC) industry to create, manage, and exchange building information. Examples of BIM software include Autodesk Revit, ArchiCAD, and Vector works. These programs allow architects, engineers, and contractors to collaborate in a virtual environment, reducing the chances of mistakes, and improving the efficiency of the design and construction process.

14.1. AUTODESK

Autodesk, Inc. is an American multinational software corporation that makes software products and services for the architecture, engineering, construction, manufacturing, media, education, and entertainment industries. Autodesk is headquartered in San Francisco, California, and has offices worldwide. Its U.S. offices are located in the states of California, Oregon, Colorado, Texas, Michigan, New Hampshire and Massachusetts. Its Canada offices are located in the provinces of Ontario, Quebec, and Alberta. The company was founded in 1982 by John Walker, who was a coauthor of the first versions of AutoCAD. AutoCAD, which is the company's flagship computer-aided design (CAD) software and Revit software are primarily used by architects, engineers, and structural designers to design, draft, and model buildings and other structures. Autodesk software has been used in many fields, and on projects from the One World Trade Centre to Tesla electric cars .Autodesk became best known for AutoCAD, but now develops a broad range of software for design, engineering, and entertainment—and a line of software for consumers. The manufacturing industry uses Autodesk's digital prototyping software—including Autodesk Inventor, Fusion 360, and the Autodesk Product Design Suite—to visualize, simulate, and analyse real-world performance using a digital model in the design process. The company's Revit line of software for building information modelling is designed to let users explore the planning, construction, and management of a building virtually before it is built .Autodesk's Media and Entertainment division creates software for visual effects, colour grading, and editing as well as animation, game development, and design visualization. 3ds Max and Maya are both 3D animation software used in film visual effects and game development.

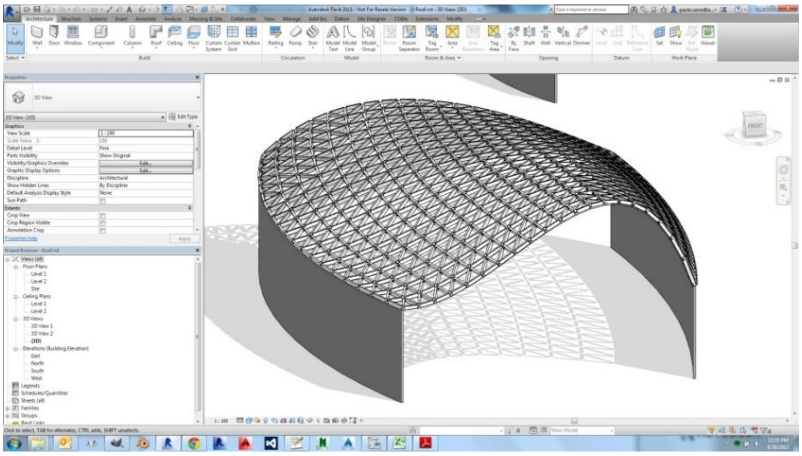


Figure 16: Screenshot AUTODESK model (https://bimcorner.com/everything-worth-knowing-about-the-ifc-format/)

14.2. ARCHICADE

ArchiCAD is a software application developed by Graph iSOFT that is used for building information modelling (BIM) in the field of architecture and construction. It is a popular tool for architects, designers, and engineers who want to create and manage virtual building models.

ArchiCAD allows users to create 2D and 3D architectural designs and models, and includes a wide range of tools and features for design and documentation. Some of the key features of ArchiCAD include the ability to create floor plans, elevations, sections, and 3D models, as well as the ability to manage and coordinate the design process with other team members and stakeholders.

In addition, ArchiCAD allows users to perform energy analysis and other simulations to evaluate the environmental impact of their designs. It also offers a variety of collaboration tools, such as the ability to share project files and coordinate design changes with other team members in real time.

Archicad is available for both Windows and Mac operating systems, and is widely used in the architecture and construction industries around the world.

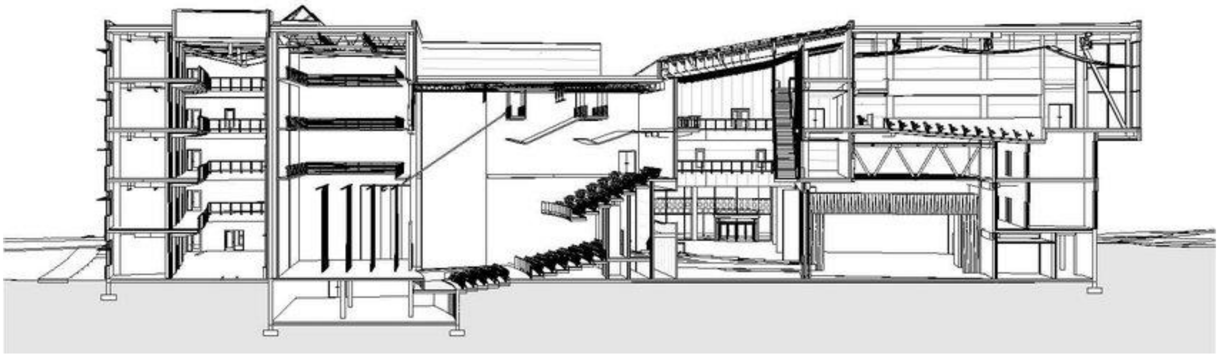


Figure 17: ArchiCAD Architect model (https://www.google.com/url?sa=i&url=https%3A%2F%2Fictacademy.com.ng%2Fhow-to-load-steel-connection-using-dynamo-revit%2F&psig=AOvVaw1lnGjf9nZz_xkyh0mUj3be&ust=1682370818254000&source=images&cd=vfe&ved=0CBMQjhxqFwoTCMjg4tX2wP4CFQAAAAAdAAAAABAE)

14.3. Vector work

Vector works is a 2D and 3D design software developed by the American company Nemechek. It is used in architecture, landscape design, and entertainment design for creating 2D and 3D models, drawings, and presentations. Vector works features a comprehensive set of tools for design, documentation, and collaboration, as well as an intuitive user interface. The software is known for its versatility, allowing users to perform a wide range of tasks, from conceptual design to construction documentation. Vector works supports BIM (Building Information modelling) and provides tools for information management and collaboration with other stakeholders in the design and construction process.

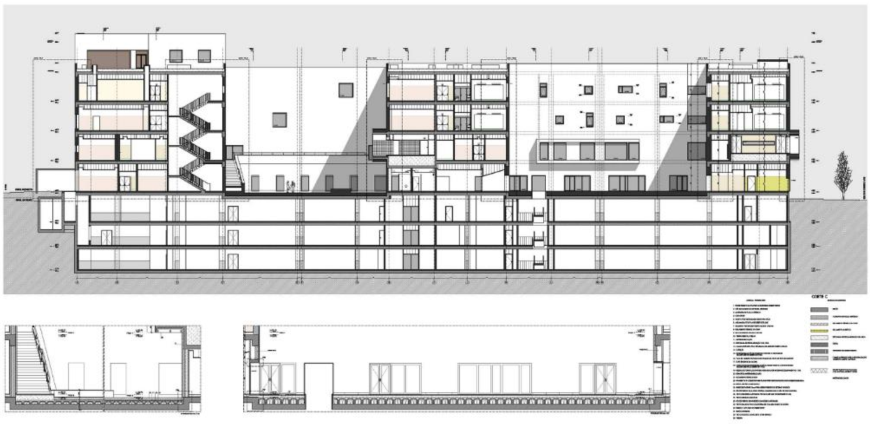


Figure 18 :Model in Vector Work (https://www.vectorworks.net/storage/media/vw-2018/products/architect/presentation_slider/arch_section_slider_3.jpg)

14.4. Bentley

Bentley Systems, Incorporated is a software company that specializes in providing software solutions for the architecture, engineering, construction, and operations (AECO) industry. The company was founded in 1984 and is headquartered in Pennsylvania, USA.

Bentley's software products cover a wide range of applications, including building design, civil engineering, construction, geospatial analysis, and asset management. Some of the company's most popular software products include MicroStation, Open Roads, Context Capture, and ProjectWise.

MicroStation is a 2D/3D CAD software platform that is widely used in the AECO industry. It allows users to create, annotate, and publish design drawings, models, and documentation. Open Roads is a comprehensive software platform for civil engineering design, analysis, and construction. It offers a range of tools and features for road and highway design, including 3D modelling, analysis, and visualization.

Context Capture is a software solution for reality modelling, which enables users to create digital 3D models of real-world objects and environments using aerial and terrestrial photography. Finally, ProjectWise is a cloud-based software platform for managing project information and collaboration across teams and stakeholders.

Bentley's software products are used by architects, engineers, contractors, and owners in a variety of industries, including transportation, utilities, buildings, and industrial plants. The company is known for its focus on innovation and sustainability, and is committed to developing software solutions that enable its customers to design and build more sustainable and resilient infrastructure.

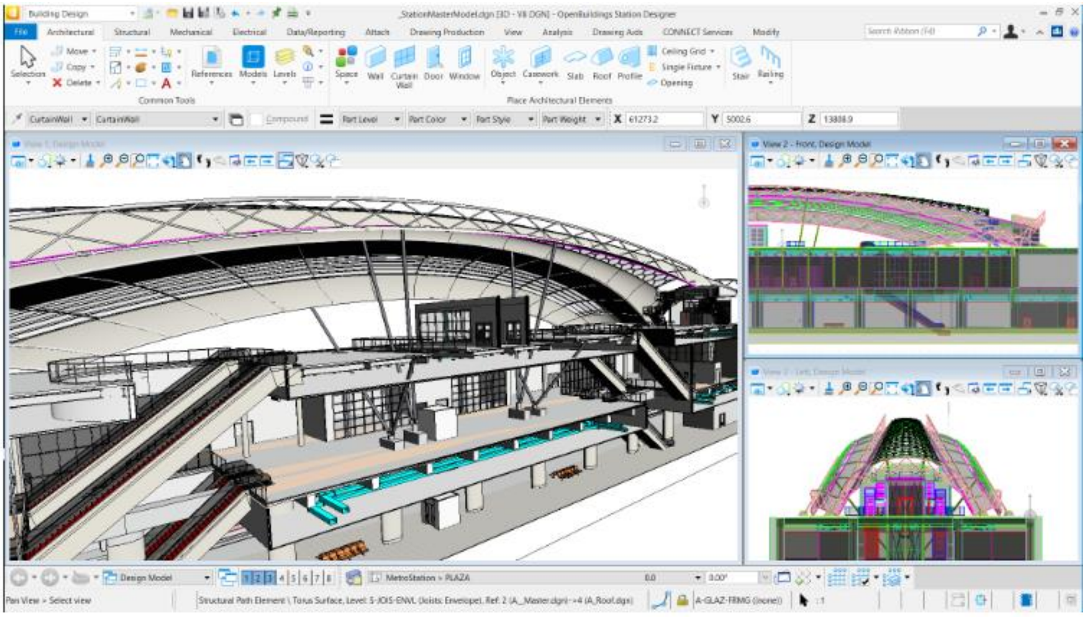


Figure 19: Bentley interface (https://www.reisoftwareth.com/products/OpenBuildings-Designer/)

Chapitre 2 : *AUGMENTED REALITY (AR)*

1. History of XR:

The history of XR (extended reality) can be traced back to the early 19th century when Charles Wheatstone invented the stereoscope, which created the illusion of a 3D image from two 2D images (Wheatstone, 1838). Later in the 20th century, Ivan Sutherland created the first head-mounted display (HMD), which paved the way for modern VR (virtual reality) technology (Sutherland, 1968). In the 1990s, the term "augmented reality" was coined by Tom Caudell and David Mizell, who developed an AR system for Boeing (Caudell & Mizell, 1992). In the early 2000s, mixed reality (MR) was introduced, which combined both VR and AR technologies (Milgram & Kishino, 1994). The concept of XR, which includes VR, AR, and MR, was first introduced in 2016 by Jaron Lanier, a pioneer in the field of virtual reality (Lanier, 2016). Since then, XR has continued to evolve and gain popularity in various industries, including gaming, education, and healthcare, with new advancements such as haptic feedback and eye-tracking technology being developed. The future of XR is expected to bring even more immersive and interactive experiences for users.

Figure 20 First VR in history (https://virtualspeech.com/blog/history-of-vr)

2. Définitions ;

2.1. Virtual reality :

Virtual reality (VR) is a computer-generated simulation of a three-dimensional environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a headset or gloves (Milgram & Kishino, 1994). The technology has grown in popularity over the past few years, and its use has extended beyond gaming and entertainment to industries like education, healthcare, and even business (Suh & Kim, 2018; Sbordone et al., 2019). In the education sector, VR has been shown to improve learning outcomes by enhancing the student's experience and engagement (Chen et al., 2018). In healthcare, VR has been used to treat mental disorders such as anxiety, phobia, and PTSD (Parsons & Rizzo, 2008; Freeman et al., 2017). Furthermore, in business, VR is being used to simulate and visualize designs, enabling stakeholders to experience the product before it is built (Ahmed et al., 2018). As the technology continues to develop, there is no doubt that its applications will continue to expand across various industries and domains.

Figure 21 Virtual live show example (https://www.futura-sciences.com/tech/definitions/technologie-realite-virtuelle-598/)

2.2. Augmented reality :

Augmented reality (AR) is a technology that enhances the real-world environment by overlaying digital information and objects onto it (Azuma, 1997). AR can be experienced through a variety of devices, including smartphones, tablets, and AR headsets (Krevelen & Poelman, 2010). AR has numerous applications in different fields, including education, tourism, and gaming (Dunleavy & Dede, 2014; O'Hanlon, 2018; Bilgihan et al., 2016). In education, AR has been used to create interactive and immersive learning experiences, allowing students to engage with the material in a more engaging way (Lee & Kim, 2018). In tourism, AR has been used to provide visitors with additional information about the places they are visiting, creating a more engaging and informative experience (Chen & Chen, 2016). In gaming, AR has been used to create immersive and interactive games that blend the real and virtual worlds (Geroimenko & Chen, 2015). As AR technology continues to develop, it is expected that its applications will continue to expand, and its potential in various industries will continue to be explored..

Figure 22 Augmented reality shown example (https://www.softwaretestinghelp.com/what-is-augmented-reality/)

2.3. Extended reality :

Extended reality (XR) is an umbrella term that encompasses various immersive technologies, including virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Milgram & Kishino, 1994). XR can be used to create immersive and interactive experiences that allow users to interact with digital content in a more natural way (Chen et al., 2020). One of the potential applications of XR is in education, where it has been used to create interactive and engaging learning experiences (Baran & Maskan, 2020). XR can also be used in healthcare, where it has been used for training medical professionals and for patient rehabilitation (Hou et al., 2021). In addition, XR has been used in entertainment, such as in the gaming industry, where it has been used to create more immersive gaming experiences

(Lin & Sun, 2020). As XR technology continues to develop, it is expected to have even more applications in various industries, from education to healthcare to entertainment.

3. Deference :

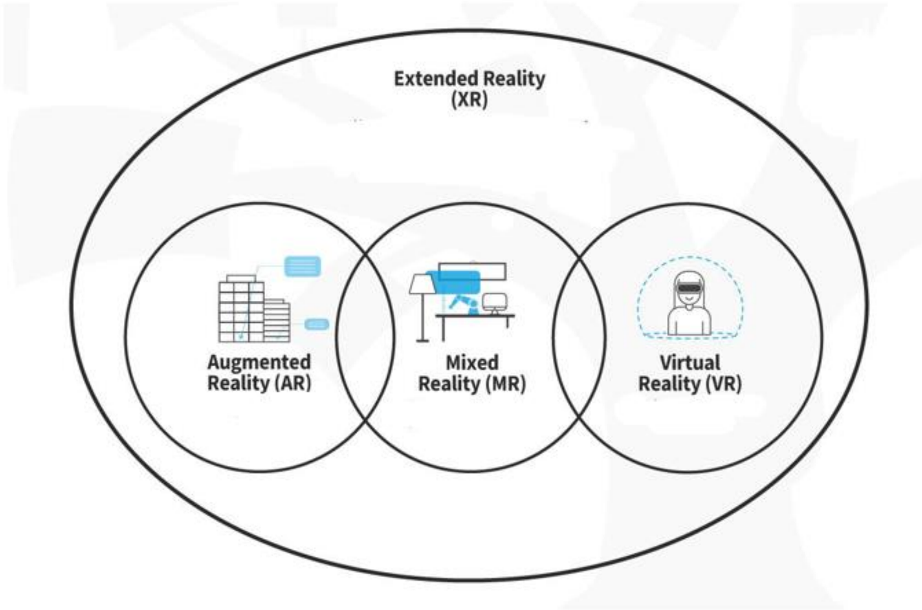


Figure 23 Extended reality explained (modified)(https://www.interaction-design.org/literature/topics/extended-reality-xr)

3.1. Deference betwin AR and VR :

Augmented reality (AR) and virtual reality (VR) are both immersive technologies that offer users a more engaging and interactive experience than traditional media. However, there are some key differences between the two.

AR overlays digital information onto the real world, allowing users to interact with digital content while still being aware of their real-world surroundings. AR technology typically uses a smartphone or tablet camera to capture a real-world environment and then adds digital information to that environment in real time (Azuma, 1997).

VR, on the other hand, completely immerses users in a digital environment, typically through the use of a headset or other specialized equipment. VR technology creates a fully artificial environment that users can interact with in a variety of ways, such as through hand controllers or motion tracking (Slater & Wilbur, 1997).

While both AR and VR offer immersive experiences, they have different applications. AR is often used in industries such as retail and advertising, where it can be used to create interactive and engaging experiences for customers. VR, on the other hand, is often used in gaming and entertainment, as well as in education and training, where it can be used to create realistic simulations for learning and practice (Shelton & Hedley, 2002).

3.2. Defrence betwin AR and XR:

Augmented reality (AR) and extended reality (XR) are both immersive technologies, but there are some key differences between them.

AR overlays digital information onto the real world, allowing users to interact with digital content while still being aware of their real-world surroundings. AR technology typically uses a smartphone or tablet camera to capture a real-world environment and then adds digital information to that environment in real time (Azuma, 1997).

XR, on the other hand, is an umbrella term that encompasses various immersive technologies, including VR, AR, and mixed reality (MR). XR can be used to create immersive and interactive experiences that allow users to interact with digital content in a more natural way (Chen et al., 2020). XR technologies can provide a more seamless experience by blending real and virtual elements to create a mixed reality experience (Milgram & Kishino, 1994).

While AR is a specific type of XR, the key difference between the two is that AR overlays digital information onto the real world, whereas XR can include both virtual and real-world elements. XR can be used in a variety of applications, including education, healthcare, and entertainment, while AR is often used in industries such as retail and advertising, where it can be used to create interactive and engaging experiences for customers.

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While VR is a specific type of XR, the key difference between the two is that VR creates a fully artificial environment, while XR can include both virtual and real-world elements. VR is often used in gaming and entertainment, as well as in education and training, where it can be used to create realistic simulations for learning and practice. XR can be used in a variety of applications, including education, healthcare, and entertainment.

4. Architecture systeme of VR/ AR /XR :

4.1. Architecture systeme of VR

The architecture of a VR system typically includes the following components:

4.1.1.Input devices: VR systems use specialized input devices, such as handheld controllers or body-tracking devices, to allow users to interact with and control the virtual environment.

4.1.2. Head-mounted display (HMD): The HMD is the device that covers the user's eyes and displays the virtual environment. Modern HMDs typically include high-resolution displays, low-latency head tracking, and built-in audio systems.

4.1.3. Computer system: The VR system is powered by a computer system that generates the virtual environment, processes user inputs, and renders the images for display on the HMD. A high-performance computer is required to provide an immersive and responsive VR experience.

4.1.4. Graphics processing unit (GPU): The GPU is responsible for rendering the virtual environment in real-time and displaying it on the HMD. A high-performance GPU is critical to ensure smooth and responsive graphics in VR.

4.1.5.Tracking system: The VR system uses a tracking system to determine the position and orientation of the HMD and the user's input devices in the virtual environment. This information is used to update the virtual environment in real-time and provide a sense of presence for the user.

4.1.6.Software and APIS: VR systems use specialized software and APIs to generate and render the virtual environment, process user inputs, and interact with the hardware components. These include game engines, VR middleware, and platform-specific APIs.

The architecture of a virtual reality (VR) system typically involves a combination of hardware and software components that work together to create an immersive and interactive experience for users.

The hardware components of a VR system include a headset, which typically consists of a display screen, lenses, and sensors to track head movements and orientation. The headset is connected to a computer or mobile device that runs the software applications used to create and render the virtual environment (Wang et al., 2020).

The software components of a VR system include the applications used to create the virtual environment, as well as the software used to render and display the environment in real time. The software may also include tools for interacting with the virtual environment, such as hand controllers or motion sensors (Kobayashi et al., 2017).

In addition to the hardware and software components, VR systems may also include other peripherals such as haptic feedback devices, which provide tactile feedback to enhance the sense of immersion in the virtual environment (Razzaque et al., 2001).

Overall, the architecture of a VR system is designed to create a seamless and immersive experience for users, where they can interact with a virtual environment in a natural and intuitive way.

4.2.VR technology infrastructure :

Virtual Reality is a computer-generated environment. It uses high information technology to generate this environment. To create the environment, it uses both hardware and software elements. The hardware contains display systems with high graphic processing power. The software is a game design that uses three-dimensional technology to develop a Virtual Immersion Environment. The following figure shows the VR system components, according to the VRAR Association. (Aly HASSANEIN,2020)

The infrastructure required for virtual reality (VR) technology can be divided into three main categories: hardware, software, and network infrastructure. The hardware infrastructure includes the headset, computer or mobile device, and controllers (Deng & Zhang, 2018). The software infrastructure includes the programs and applications used to create and render the virtual environment, as well as software for user interfaces, networking, and other functionalities (Steinert et al., 2018). Network infrastructure is becoming increasingly important for VR technology, as a robust and reliable network is necessary to ensure real-time data transmission and support multiplayer experiences (Deng & Zhang, 2018). Overall, the infrastructure required for VR technology is complex and requires a combination of hardware, software, and network components to function properly.

4.3.architecture systeme of AR

The architecture of an AR system typically includes the following components:

1. Input device: AR systems typically use a smartphone or tablet camera, or a specialized AR headset, such as Microsoft HoloLens, to display the augmented information and graphics
2. Image recognition and tracking: AR systems use computer vision algorithms and sensors to recognize and track objects and surfaces in the real world. This information is used to accurately overlay digital information and graphics on the physical world.
3. Graphics processing unit (GPU): The GPU is responsible for rendering the digital information and graphics and displaying them on the AR device's screen. A high-performance GPU is critical to ensure smooth and responsive graphics in AR.

4. Location-based services: AR systems use GPS, Wi-Fi, and other location-based services to provide context-aware information and graphics to the user.
5. Software and APIs: AR systems use specialized software and APIs to recognize and track objects and surfaces in the real world, generate and render digital information and graphics, and interact with the hardware components. These include AR middleware, game engines, and platform-specific APIs.

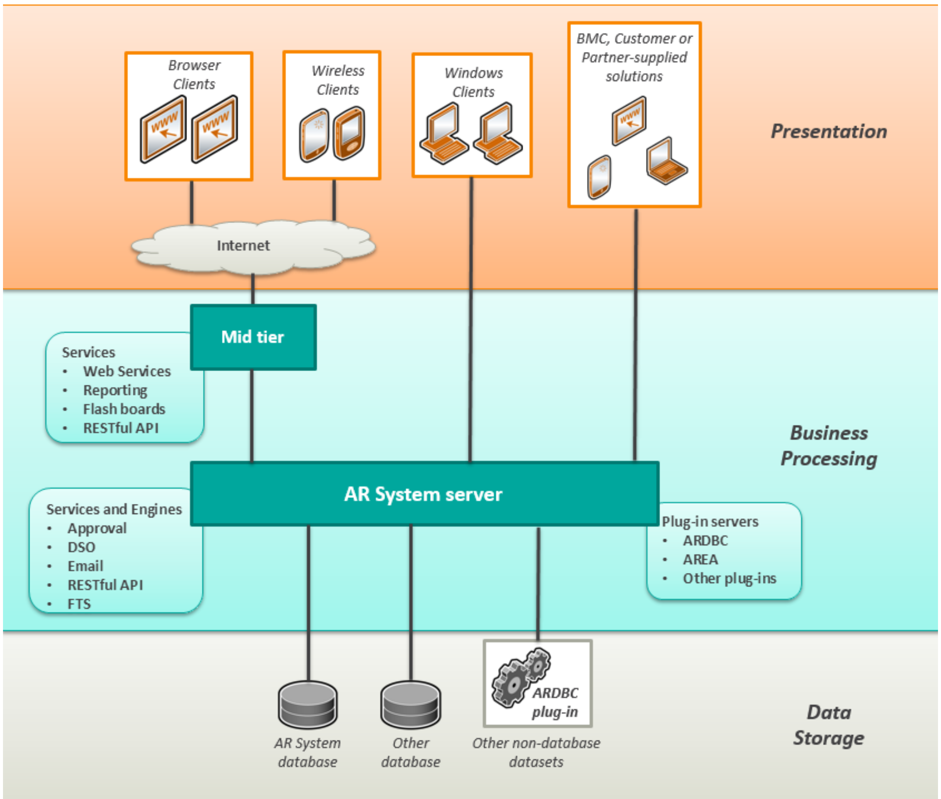


Figure 24 The architecture of an AR system (https://docs.bmc.com/docs/ars2102/ar-system-architecture-1026885133.html)

The architecture of an augmented reality (AR) system consists of three main components: the hardware, the software, and the tracking system. The hardware of an AR system includes the display device, which can be a mobile device or a specialized headset, and a camera or sensors to capture the real-world environment (Chen et al., 2018). The software of an AR system includes the algorithms and programming necessary to overlay virtual information onto the real world environment. The software must be able to recognize and track real-world objects, understand their position and orientation, and overlay virtual objects in a way that appears seamless and natural (Azuma, 1997). The tracking system of an AR system is responsible for tracking the position and orientation of the user's device or headset, as well as tracking the position of real-world objects to be overlaid with virtual content (Azuma, 1997).

4.4.architecture systeme of XR

The architecture of an XR system typically includes the following components:

1. Input devices: XR systems use a variety of input devices, including handheld controllers, body-tracking devices, and gesture recognition systems, to allow users to interact with and control the virtual and augmented environments.
2. Head-mounted displays (HMDs) or AR devices: XR systems use HMDs, such as VR headsets, or AR devices, such as smartphones and tablets, to display the virtual and augmented environments. HMDs provide a fully immersive experience by replacing or blocking out the physical world, while AR devices overlay digital information and graphics on the physical world.
3. Computer system: The XR system is powered by a computer system that generates the virtual and augmented environments, processes user inputs, and renders the

images for display on the HMD or AR device. A high-performance computer is required to provide an immersive and responsive XR experience.

4. Graphics processing unit (GPU): The GPU is responsible for rendering the virtual and augmented environments in real-time and displaying them on the HMD or AR device. A high-performance GPU is critical to ensure smooth and responsive graphics in XR.
5. Tracking system: The XR system uses a tracking system to determine the position and orientation of the HMD or AR device and the user's input devices in the virtual and augmented environments. This information is used to update the virtual and augmented environments in real-time and provide a sense of presence for the user.
6. Software and APIs: XR systems use specialized software and APIs to generate and render the virtual and augmented environments, process user inputs, and interact with the hardware components. These include game engines, XR middleware, and platform-specific APIs.

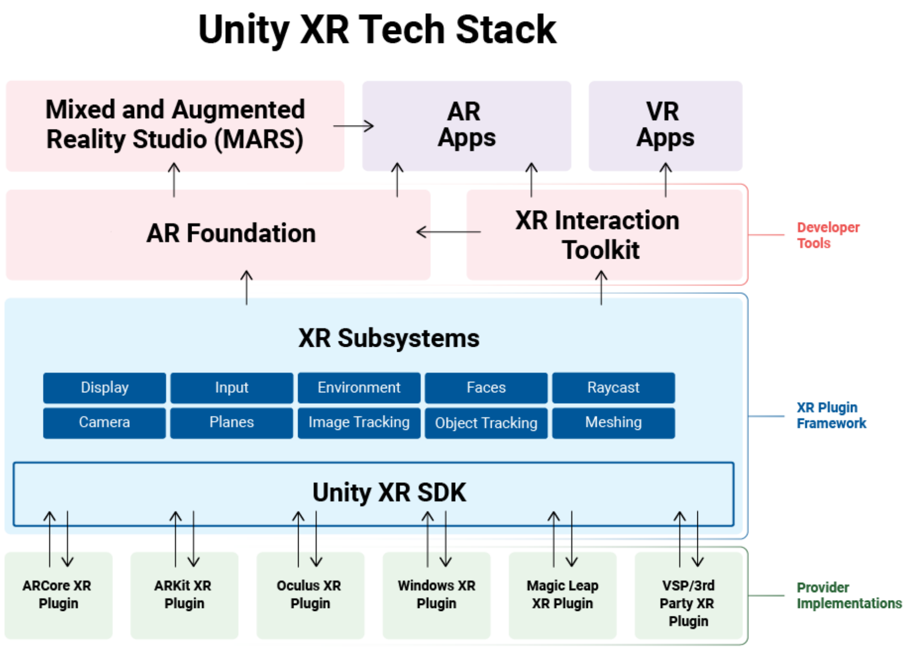


Figure 25 Architecture of XR example of unity (https://docs.unity3d.com/Manual/XRPluginArchitecture.html)

5.Application of AR :

Augmented Reality (AR) has a wide range of applications across several domains, including:

- Gaming: AR games provide a unique gaming experience by overlaying digital information and graphics on the physical world, allowing users to interact with the virtual elements in real-time

Figure 26 Example Game use AR (https://blogs.geniteam.com/ar-future-game/)

- Education and training: AR is being used in education and training to provide hands-on learning experiences, simulate real-world scenarios, and enhance the learning process.

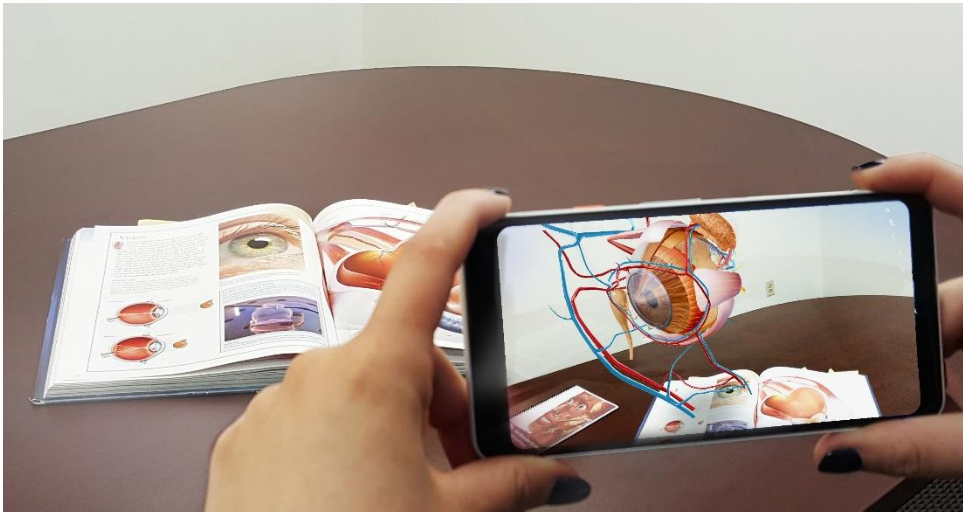


Figure 27 AR in education usess (https://rubygarage.org/blog/augmented-reality-in-education-and-training)

- Healthcare: AR is being used in healthcare to assist with surgeries, provide visual aids for medical procedures, and to educate patients and healthcare professionals.

Figure 28 AR in healthcare usess (https://www.linkedin.com/pulse/what-future-ar-healthcare-pooja-mahajan?trk=articles_directory)

- Retail and e-commerce: AR is being used in retail and e-commerce to allow customers to try on clothes, makeup, and accessories virtually, reducing the need for physical fittings and returns.

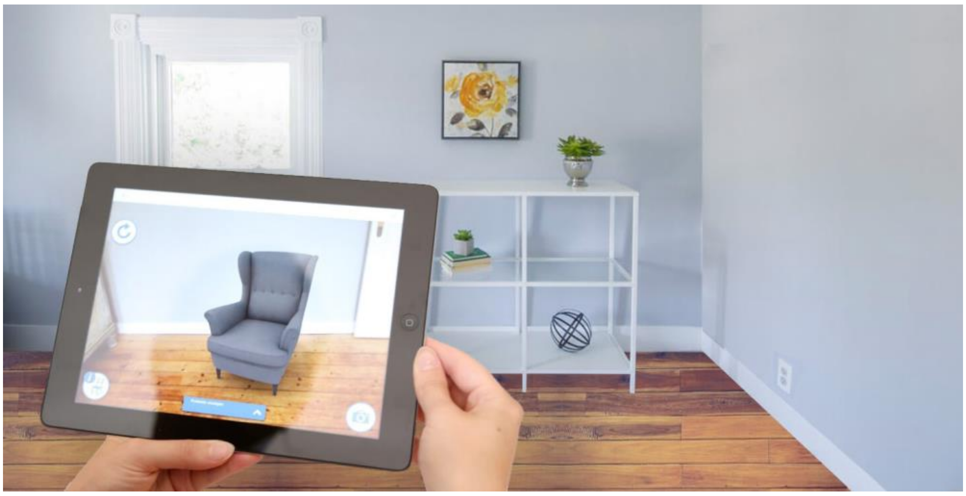


Figure 29 AR in marketing commerce use (https://www.rootinfosol.com/how-augmented-reality-transforming-e-commerce-industry)

- Manufacturing and industrial design: AR is being used in manufacturing and industrial design to provide workers with visual aids, assembly instructions, and to improve the design and prototyping process.

Figure 30 AR in manufacturing uses (https://www.imeche.org/news/news-article/%27working-faster-and-smarter%27-5-product-design-trends-to-keep-an-eye-on-in-2019)

- Military and defense: AR is being used in military and defense to provide soldiers with real-time situational awareness, navigation aids, and to enhance training simulations.
- Marketing and advertising: AR is being used in marketing and advertising to create interactive and immersive experiences, promote brand awareness, and engage customers in new and innovative ways.

Figure 31 AR in shoping from market(https://appdevelopermagazine.com/why-ar-advertising-is-hard/)

6.Application of VR in the Construction Industry

The extension of BIM to emerging technology like VR enables us to combine the accessibility and manipulation and creation of design data from BIM and interactivity and visualization from VR. That is why software companies aim to provide advanced products to optimize the link between BIM and VR. VR has different business drivers in construction with the potential to add value and create a good impact in terms of time, cost, and quality.

7.Benefits of AR in construction industry :

- Better Design Visualization: With AR, construction professionals can see how their designs will look in real-world environments. This enables them to identify any design issues and make necessary adjustments before construction begins.

- Improved Communication: AR can be used to share designs and other information with clients and stakeholders in a more engaging and interactive way. This can help to improve communication and collaboration throughout the project.
- Enhanced Safety: AR can be used to simulate potentially hazardous scenarios, allowing workers to practice safety procedures without putting themselves at risk. This can help to reduce accidents and injuries on the job site.
- Increased Efficiency: AR can be used to streamline construction processes by providing workers with real-time information and guidance. This can help to reduce errors, improve productivity, and save time and money.
- Cost Savings: AR can help to reduce costs by allowing construction professionals to identify and resolve issues earlier in the design process. This can help to prevent costly mistakes and delays during construction.

8.limitations of Virtual Reality in construction

- Cost: The cost of developing and implementing VR technology can be quite high, which can be a barrier for smaller construction companies or projects with limited budgets.
- Limited Realism: While VR can provide a highly immersive experience, it still lacks the same level of realism and detail that can be found in the physical world. This can limit its effectiveness for certain types of construction tasks, such as fine detailing or complex installations.
- Safety Concerns: While VR can provide a safe and controlled environment for training and simulation, there is always a risk that workers may become overly reliant on VR technology and fail to properly follow safety protocols in the physical world.
- Accessibility: VR technology requires specialized equipment, such as a headset or other devices, which may not be accessible or comfortable for all users. This can limit the ability of certain workers to effectively use VR in their work.
- Limited Scope: While VR can provide a highly detailed and immersive experience for specific construction tasks or scenarios, it may not be as effective for broader planning and coordination efforts.

9.domain application of AR in civil engennring;

Augmented Reality (AR) has several applications in the field of civil engineering, including:

- Construction: AR can be used to visualize building designs and construction sites, to provide workers with visual aids, and to improve communication between architects, engineers, and contractors.
- Surveying and mapping: AR can be used to visualize topographical data, to provide real-time information on elevations and contours, and to improve the accuracy of land surveys.
- Maintenance and repair: AR can be used to provide workers with visual aids and instructions, to reduce the need for physical inspections and manual measurements, and to improve the maintenance and repair process.
- Infrastructure planning: AR can be used to visualize infrastructure plans and proposals, to provide stakeholders with a better understanding of the projects, and to improve communication and collaboration between project teams.
- Environmental impact assessments: AR can be used to visualize environmental data, to provide stakeholders with a better understanding of the potential impacts of infrastructure projects, and to improve the decision-making process.
- Employee training and safety management program: Safety management system is a very concerning issue in modern days in the construction industry. Thousands of people die every year in the world in construction accidents. The training of employees is another most important thing for every construction project. These issues are not easy at all to perform at the desired or standard level. However, AR technologies assist both issues to give the employees an effective training and implement the safety management system as the specification. (Shakil Ahmed,2018)

- Time and cost management: Time and cost are undoubtedly the major issues of construction process. All the management of construction project is to reduce the time of completion and save the expenses of the construction. Time and cost management of construction exists in the construction process from the beginning of construction history but is not significantly effective at any time. To increase the effectiveness of construction management, technological changing take place in different form with the changing in time. For the continuation of this changing, AR-based applications in construction management for monitoring and controlling the time and cost issues are appeared significantly.(Shakil Ahmed ,2018)

10.Start of art

10.1.Start of art of VR

10.1.1.VR companies

There are many companies that are involved in the development and production of virtual reality (VR) technology and applications. Some of the leading VR companies include:

- Oculus (owned by Facebook): Oculus is a leader in VR technology, with its flagship product, the Oculus Quest 2, being one of the most popular VR headsets on the market.

Figure 32 Oculus headset (https://www.lemondeinformatique.fr/actualites/lire-oculus-disparait-place-a-meta-quest-et-ses-casques-vr-84665.html)

Meta Quest, anciennement Oculus VR, est une société américaine créée par Palmer Luckey et Brendan Iribe, et filiale de Meta Platforms. Oculus VR a été rachetée par Facebook en mars 2014 pour 2 milliards de dollars et a pour secteur d'activité la réalité virtuelle. (Wikipédia)

- HTC: HTC is a Taiwan-based company that produces a range of VR headsets, including the Vive and Vive Pro, which are popular among gamers and businesses.

HTC Corporation, anciennement High Tech Computer Corporation, est un fabricant taïwanais de smartphones destinés au départ à la plate-forme Windows Mobile de Microsoft et depuis 2008, à Android, le système d'exploitation open-source de Google en plus de Windows Phone, ainsi que le casque de réalité virtuelle HTC Vive. (Wikipédia)

- Sony: Sony's PlayStation VR headset is designed specifically for use with the PlayStation gaming platform, and has been well-received by gamers.

Figure 33 Playstation vr headset (https://www.playstation.com/ar-qa/ps-vr2/)

- Valve: Valve is a software company that produces the SteamVR platform, which is used by a number of VR headset manufacturers, including HTC and Oculus.

Figure 34 Steam vr example game (steam vr.com)

- Pico Interactive: Pico Interactive is a China-based company that specializes in the development of standalone VR headsets, which do not require a computer or mobile device to operate.

Figure 35 Pico VR headset (https://www.thevrist.com/piconeo2)

- Unity Technologies: Unity Technologies is a software company that produces the Unity game engine, which is used by many VR developers to create VR experiences and applications.

- Google: Google is a technology company that has a range of VR products, including the Daydream VR platform and the Google Cardboard VR headset.

10.1.2.VR tools :

Virtual reality (VR) tools are software programs and hardware devices that are used to create, develop, and experience VR content. Some common VR tools include

- VR Headset: A VR headset is a device worn on the head that displays a VR environment to the user. Examples include

Figure 36 Oculus headset (https://www.lemondeinformatique.fr/actualites/lire-oculus-disparait-place-a-meta-quest-et-ses-casques-vr-84665.html)

Figure 37 Htc headset (htc.com)

Figure 38 Playstation vr tools (https://www.playstation.com/ar-qa/ps-vr2/)

- VR Controllers: VR controllers are handheld devices that allow the user to interact with the VR environment. Examples include the Oculus Touch, the Vive Wand, and the PlayStation Move.
- VR Software Development Kits (SDKs): SDKs are software tools that allow developers to create VR content for a particular platform or headset. Examples include the Oculus SDK, SteamVR SDK, and Unity VR SDK.
- VR Game Engines: VR game engines are software tools that are used to develop VR games and applications. Examples include Unity, Unreal Engine, and CryEngine.
- 3D Modeling and Animation Tools: 3D modeling and animation tools are software programs that are used to create 3D assets for VR content. Examples include Blender, 3ds Max, and Maya.
- VR Audio Tools: VR audio tools are software programs that are used to create immersive audio experiences for VR content. Examples include FMOD, Wwise, and Unreal Engine's audio tools.
- VR Simulation and Training Tools: VR simulation and training tools are software programs that are used to create immersive training and simulation experiences in VR. Examples include HTC's Vive Enterprise Suite and Microsoft's Windows Mixed Reality.

10.1.3.Apps for VR :

There are many virtual reality (VR) apps available for various VR platforms like Oculus, HTC Vive, and PlayStation VR. Some of the most popular VR apps include:

- Unity Reflect: This is a real-time 3D rendering software that enables architects, engineers, and construction professionals to create interactive VR simulations of their projects. It allows users to collaborate in real-time, making it easier to identify and resolve issues before construction begins.

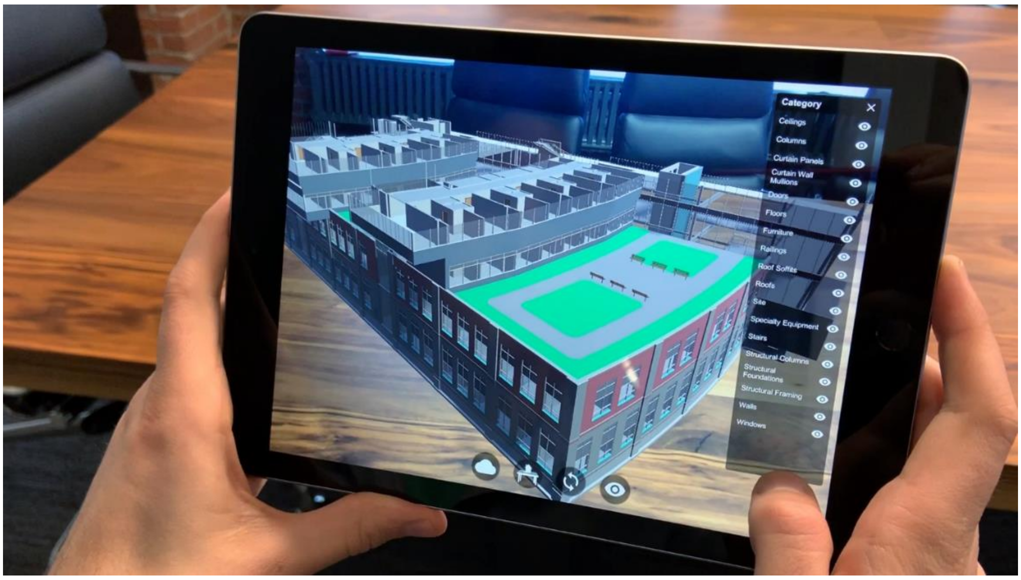


Figure 39 Unity reflect screenshot (unity.com)

- IrisVR: IrisVR offers a suite of VR software tools that allow users to create, share, and collaborate on VR experiences. Its main product, Prospect, lets users create immersive VR walkthroughs of their designs and construction projects.

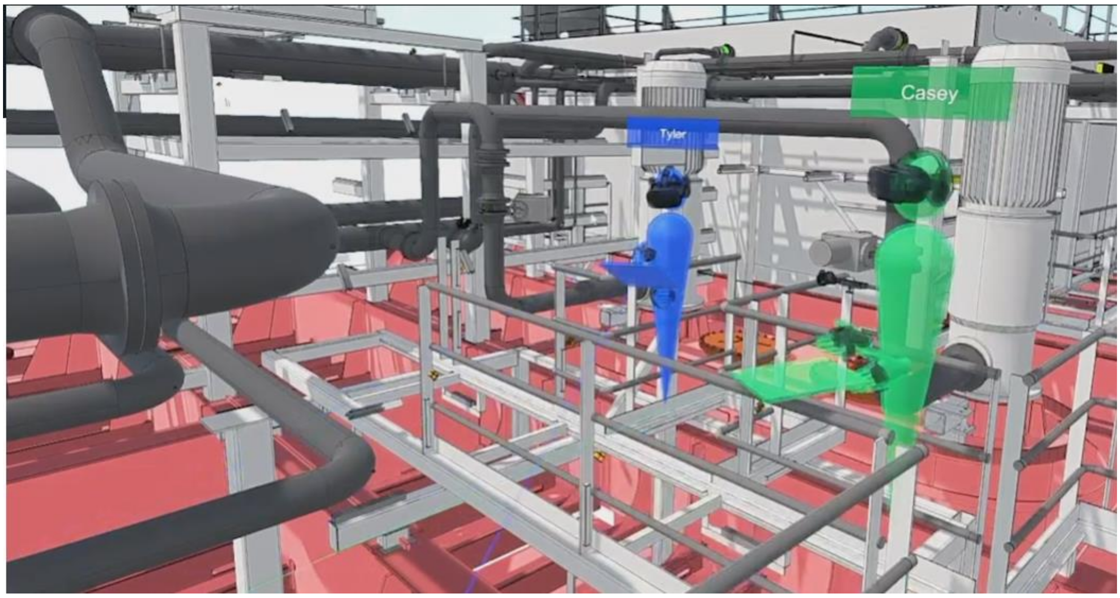


Figure 40 Iris VR screenshot inside view (iris vr.com)

- Autodesk BIM 360: Autodesk's BIM 360 platform includes a VR capability that allows users to experience their designs in a fully immersive environment. It also allows teams to collaborate and review designs in real-time, helping to identify and resolve issues early on in the project.

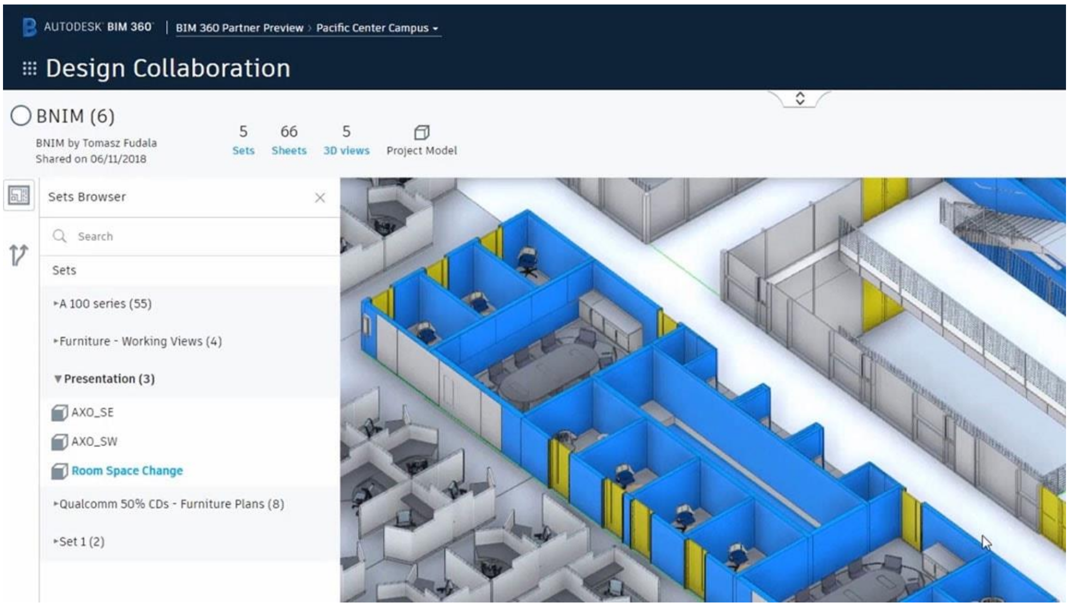


Figure 41 Autodesk BIM 360 interface (Autodesk bim360.com)

- Fuzor: Fuzor is a VR application that enables users to create 3D models of their projects and experience them in VR. It includes features such as clash detection, construction sequencing, and cost estimation, making it a useful tool for construction teams.

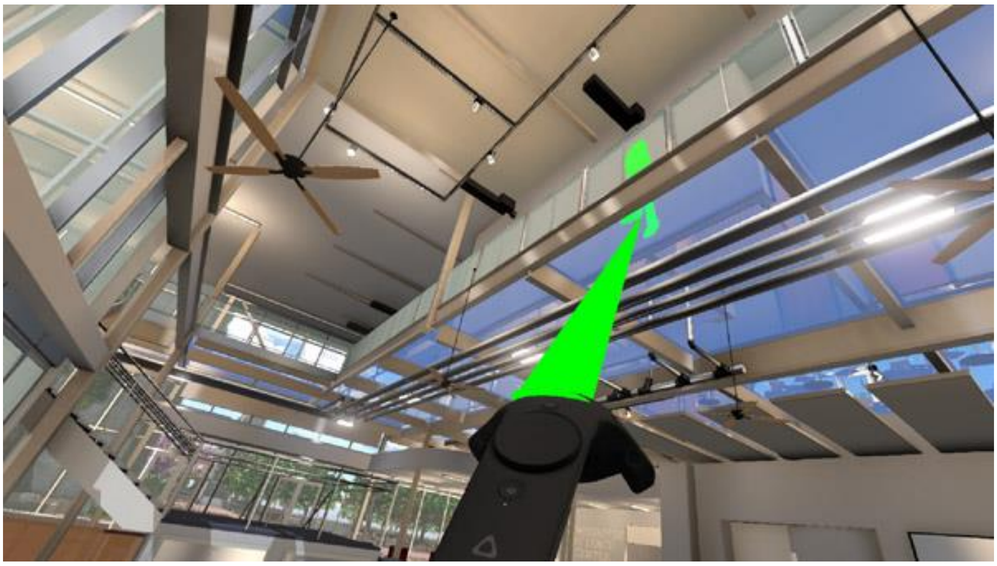


Figure 42 Fuzor screenshot inside VR (fuzor.com)

10.1.3.softwar to export to vr

There are several software tools that can be used to create and export content for virtual reality (VR) experiences. Some of the most popular software tools include:

- Unity: A popular game engine that supports VR development and has a large community of developers and assets.
- Unreal Engine: Another popular game engine that is often used for VR development, providing developers with powerful tools for creating high-quality VR experiences.
- Blender: A free and open-source 3D modeling and animation software that can be used to create 3D assets for VR experiences.
- Maya: A professional-grade 3D modeling and animation software that is often used in the creation of VR experiences.

- 3DS Max: A 3D modeling and animation software that is used in a variety of industries, including VR, for the creation of 3D assets.
- A-Frame: A web-based VR development platform that allows developers to create VR experiences using HTML, CSS, and JavaScript.

10.2.Start of art of AR

10.2.1.AR companies

There are many companies that are involved in the augmented reality (AR) industry, ranging from start-ups to large tech firms. Here are a few examples of notable AR companies:

- Apple: The tech giant has made a significant investment in AR technology, with ARKit and ARCore, its AR development platforms, becoming widely used among developers.
- Google: The company has been actively involved in the AR industry through its Tango and ARCore projects, which aim to bring AR experiences to a wide range of devices.
- Microsoft: The company has a long history of investment in AR technology, with HoloLens, its mixed reality headset, being a notable example.
- Niantic: The company behind the popular AR game Pokémon Go, which became a global phenomenon in 2016.
- PTC: A leading AR software provider that offers a range of AR solutions for businesses and enterprise customers.
- Snap: The company behind Snapchat, which has embraced AR technology, allowing users to add augmented filters to their snaps.
- Magic Leap: A start-up that has received significant investment for its AR technology and hardware, including a mixed reality headset.

10.2.2.apps for AR

There are many apps that utilize augmented reality (AR) technology to provide unique and interactive experiences for users. Some popular AR apps include:

- Pokemon Go: Pokemon Go is a mobile game that uses AR to allow players to catch virtual creatures in the real world.

Figure 43 Pokimon go game AR interface (https://apkpure.com/de/pokemon-go/com.nianticlabs.pokemongo)

- Snapchat: Snapchat uses AR to provide users with filters and lenses that they can use to enhance their photos and videos.

Figure 44 Snapchat screenshot (https://images.macrumors.com/t/eGjMDR5aJw04OK8EjMO_Umhxo1U=/400x0/article-new/2016/11/snapchat-update.jpg?lossy)

- IKEA Place: IKEA Place is an app that allows users to visualize how furniture from IKEA would look in their homes using AR.

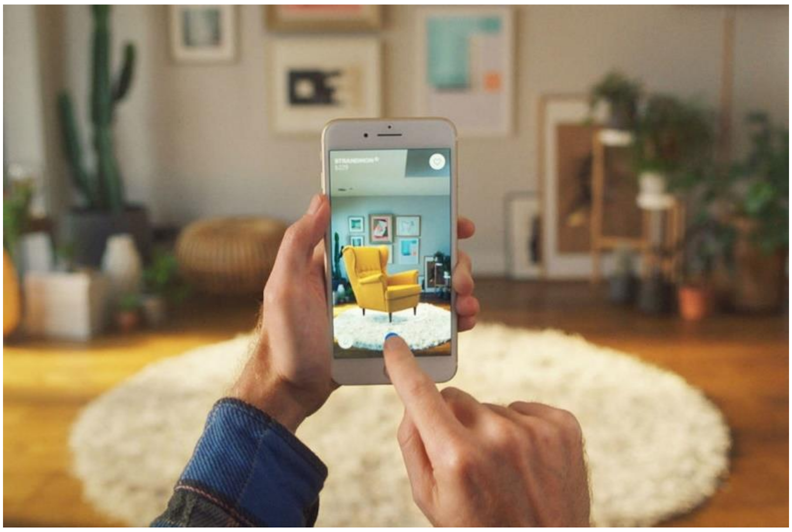


Figure 45 Ikea interface (https://www.ikea.com/ma/fr/)

- ARkit Measure: ARkit Measure is an app that allows users to measure objects and distances in the real world using AR.

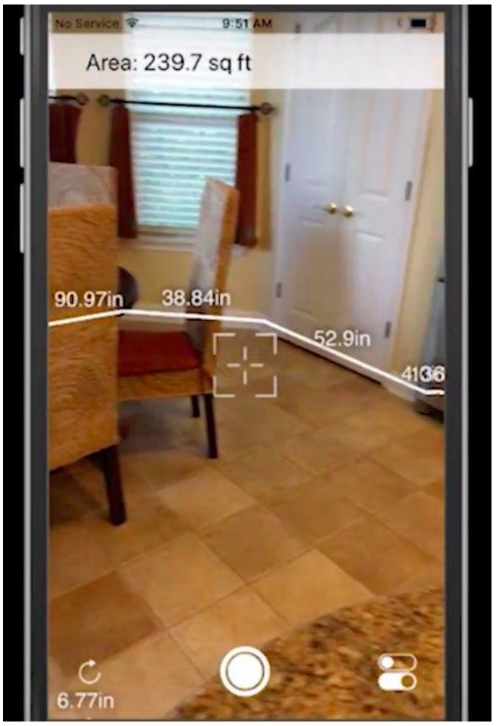


Figure 46 Arkit measure screenshot (https://www.idownloadblog.com/2017/07/13/arkit-demo-accurate-room-measurement-in-augmented-reality/)

- Star Chart: Star Chart is an app that provides a virtual map of the stars and planets in the night sky using AR.

- HoloLens: HoloLens is a mixed reality headset produced by Microsoft that allows users to interact with holographic objects in the real world using AR.

Figure 47 Hololens mx headset (hololens.com)

- AR Dragon: AR Dragon is a mobile game that allows players to raise and interact with a virtual dragon using AR.

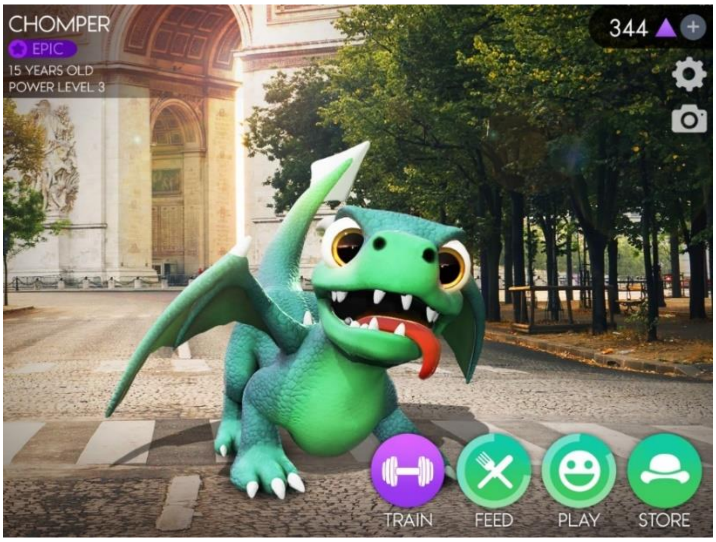


Figure 48 AR dragon interface screenshot (https://www.playsidestudios.com/ar-dragon)

10.2.3.Softwar to export to AR

There are several software programs that can be used to export content to augmented reality (AR). Some popular AR software tools include:

- Unity: Unity is a game engine and development platform that allows developers to create AR experiences for a variety of platforms, including iOS, Android, and Windows.

- Vuforia: Vuforia is an AR development platform that allows developers to create AR experiences for mobile devices.
- AR Core: AR Core is a software development kit (SDK) created by Google that allows developers to create AR experiences for Android devices.
- AR Kit: AR Kit is an AR development platform created by Apple that allows developers to create AR experiences for iOS devices.
- Unreal Engine: Unreal Engine is a game engine that allows developers to create AR experiences for a variety of platforms, including iOS, Android, and Windows.
- Maxon Cinema 4D: Maxon Cinema 4D is a 3D animation and modeling software that can be used to create assets for AR experiences.

10.2.4.AR Tools

There are various Tools That are used in the development of augmented reality (AR) experiences. Some of the most commonly used AR tools include:

- AR development platforms: AR development platforms like Unity, Vuforia, ARCore, and ARKit provide developers with the tools they need to create AR experiences for a variety of platforms.
- 3D modeling and animation software: 3D modeling and animation software like Maxon Cinema 4D, Blender, and Autodesk 3DS Max can be used to create 3D assets for AR experiences.
- AR authoring tools: AR authoring tools like Adobe Aero, zSpace, and C4DtoA allow developers to create AR experiences using existing 3D assets
- AR SDKs: AR software development kits (SDKs) like ARKit, ARCore, and Vuforia provide developers with the tools they need to create AR experiences for a variety of platforms.

- AR cloud platforms: AR cloud platforms like 6D.ai and 8th Wall allow developers to create AR experiences that are anchored to specific real-world locations and persist over time.
- AR engines: AR engines like Unreal Engine and Unity provide developers with the tools they need to create high-quality AR experiences, including lighting and physics simulations.

XR companies

- Unity Technologies: Unity is a leading provider of XR development tools and platforms, used by developers to create immersive and interactive experiences across a wide range of industries.
- Magic Leap: Magic Leap is a technology company that focuses on developing AR and MR technologies for various industries, including healthcare, entertainment, and education.
- Oculus: Oculus is a subsidiary of Facebook that specializes in developing VR technologies, including headsets and software platforms.
- Microsoft: Microsoft develops a variety of XR technologies, including the HoloLens AR headset and the Windows Mixed Reality platform.
- HTC Vive: HTC Vive is a leading provider of VR hardware and software, including the Vive headset and associated development tools.
- Vuzix: Vuzix is a company that specializes in developing AR smart glasses for enterprise and industrial applications, such as field service and remote training.
- Google: Google has developed a range of XR technologies, including ARCore for Android devices and the Google Cardboard VR headset.
- Apple: Apple has developed ARKit, an AR development platform, and is rumored to be working on its own AR headset.
- PTC: PTC is a software company that specializes in AR and IoT technologies for industrial applications, such as remote maintenance and training.
- NVIDIA: NVIDIA is a leading provider of graphics processing units (GPUs) used in XR development, as well as other industries such as gaming and artificial intelligence.
- Sony: Sony develops VR hardware and software, including the PlayStation VR headset.

- EON Reality: EON Reality is a company that specializes in developing AR and VR solutions for various industries, including education, healthcare, and manufacturing.
- Qualcomm: Qualcomm is a leading provider of mobile processors used in many AR and VR devices, and has also developed its own AR development platform.
- Meta Company: Meta Company is a technology company that specializes in developing AR smart glasses for enterprise applications.

CHAPITR 3:

<u>INTEGRATION AR IN BIM</u>

Before discussing the used method for our application chapter, we describe bellow at first some AR software applications, followed with a comparison. Our fist important synthesis is presented in the organigram of the classification of reconstruction method used in AR apps.The chapter will describe also our test in each application followed with our constate of advantage and disadvantage faced.

1. AR Software applications

Visual live applications are becoming increasingly popular in today's society due to their ability to provide immediate visual feedback and interactive features. These applications are designed to engage users and provide a more intuitive way to interact with information. According to Johnson et al. (2018), visual live applications can improve learning outcomes by enhancing engagement and promoting active learning. Additionally, in a study by Xu et al. (2021), it was found that visual live applications can also be used to support the development of problem-solving skills. This is because these applications often require users to apply critical thinking and problem-solving strategies in order to complete tasks. Furthermore, these applications have also been shown to be effective in the medical field. For example, in a study by(Han et al.,2019), a visual live applicationwas developed to help doctors accurately diagnose skin conditions. This applicationused artificial intelligence to analyze images of skin lesions and provide real-time feedback to the user. Overall, visual live applications have the potential to revolutionize the way we learn, problem-solve, and work in various industries.

1. **VT-Platform :**VT-Platform is a platform that not only makes it possible to visualize BIM models in Virtual and augmented reality, but it also allows you to work directly on them in real time

1.1. These are the functionalities

1.1.1. BIM in Augmented Reality

Bring BIM models to the field and work directly on them, superimposing them on the real space on a 1:1 scale. Visualize your BIM model from anywhere you are in mock-up mode.

1.1.2. BIM in Virtual Reality

Work with your BIM models immersively in virtual reality, submersing yourself inside them on a 1:1 scale.

1.1.3. BIM on web

Manage your BIM models from your web browser and visualize them in the web BIM viewer.

Figure 49 The Method of Work of apps (https://www.vt-lab.com/en/home/#1678712436677-63cd6bc0-86d3)

1.1.4. One platform, many use cases

Design and planification

Interact and work in real time in VR and AR on your BIM model to organise and review the project in an immersive environment. Improves and simplifies coordination.

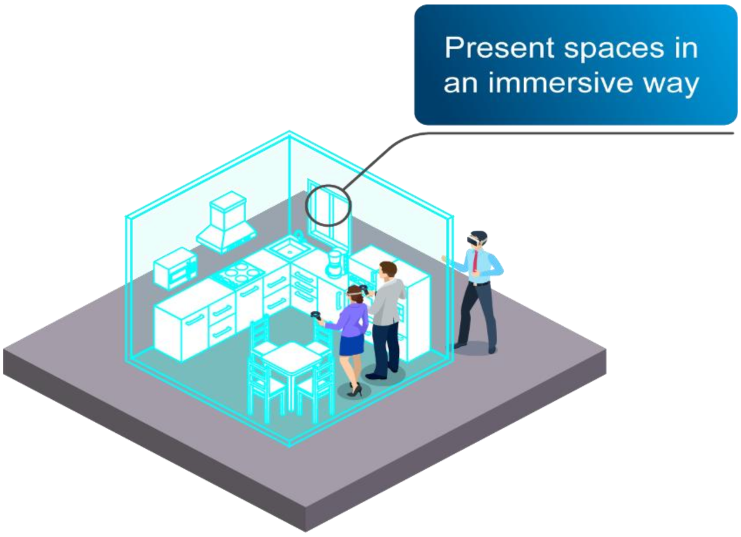


Figure: 50 Present spaces in an immersive way

(https://www.vt-lab.com/en/home/#1678712436677-63cd6bc0-86d3)

Site execution:

The application of virtual and augmented reality in the execution phase allows to bring BIM models to the construction site and superimpose them on the real space to carry out work processes in a more efficient way, reducing time and costs.

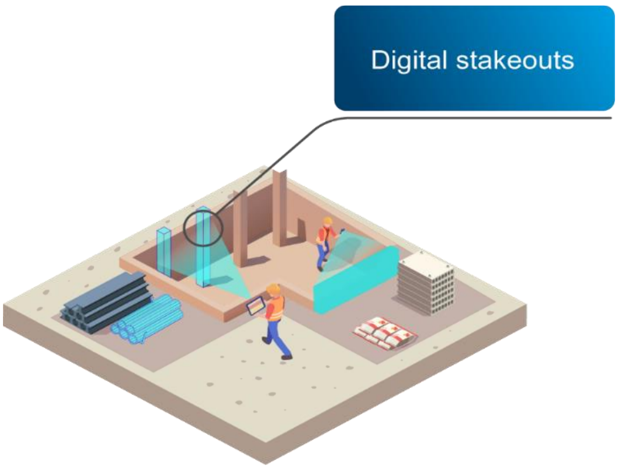


Figure 51: Site execution screenshot

(https://www.vt-lab.com/en/home/#1678712436677-63cd6bc0-86d3)

Fabrication and distribution

Extract the full potential of the BIM models of your products through virtual and augmented reality. Make your market implementation more efficient by creating a virtual catalog that allows you to place BIM models in the field and keep track of stock in real time.

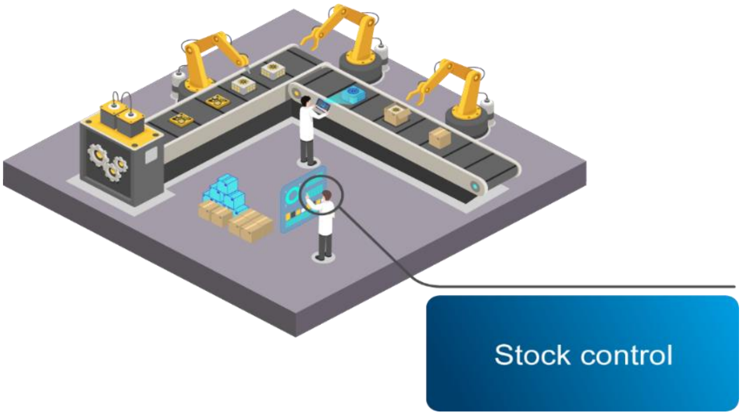


Figure 52: Fabrication and distribution

(https://www.vt-lab.com/en/home/#1678712436677-63cd6bc0-86d3)

Operation and maintenance

Carry out and manage maintenance and operation works on the BIM model in a efficient, simple and interactive way thanks to virtual and augmented reality.

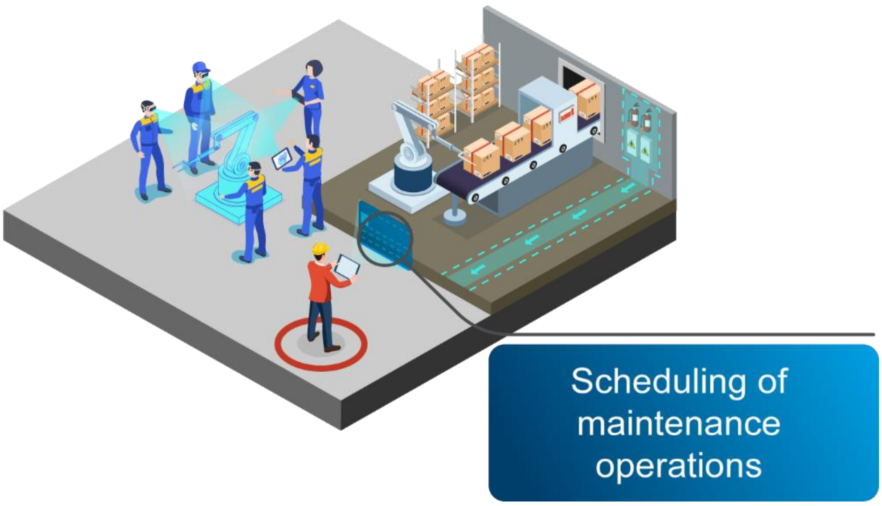


Figure 53 :Operation and maintenance

(https://www.vt-lab.com/en/home/#1678712436677-63cd6bc0-86d3)

Industrialized construction

The implementation of augmented and virtual reality in industrialized construction allows to extract the full potential of BIM models and to perform a collaborative and parametric design for all phases: design, manufacturing, logistics and assembly.

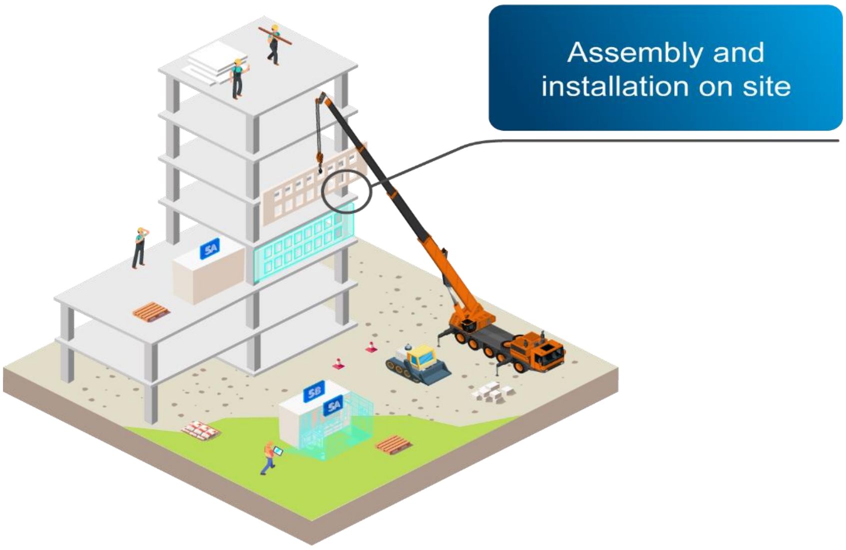


Figure 54: Industrialized construction

(https://www.vt-lab.com/en/home/#1678712436677-63cd6bc0-86d3)

2. **Visual live**

Visual Live is first to the market and the AEC's leading platform that offers easy-to-use and off-the-shelf augmented reality software on Microsoft HoloLens, Android, and iOS for design, engineering, and construction companies.

Using Visual Live's Autodesk Revit or Navisworks plugins or web uploader interface (with 70+ 3D file formats support), users can push large BIM/CAD model files to mobile, tablet, or HoloLens headset as simple as one-click for augmented reality overlay on the job site with no coding. Visual Live allows real-time 3D visualization, collaboration, and field to office communication.

Visual Live applications are currently being used in all stages of construction projects such as design review, coordination, constructability planning, fabrication QA/QC, install verification, field inspection, and facility management

2.1. - Step by Step

With the developments in the augmented reality industry, the great challenge of how to get large content onto these amazing devices quickly took center stage. With Visual Live applications and integrated plugins, this process couldn't be any easier. With a few simple clicks, you can take your large BIM models to HoloLens and mobile devices within a few minutes of the process. Our cloud-based software quickly converts your files, keeping all geometries, textures, and materials, so that they are optimized while maintaining the critical information and data that you need in the field.

2.2. Showcase of Mechanical Systems BIM Model

Utilizing Visual Live mixed reality technology, mechanical contractors are now able to experience their design in the field virtually. Once the model is quickly and accurately loaded, users can freely walk through the design, checking openings and tolerances within the true space that these systems will occupy. Routing issues can be quickly identified and fixed before they can become a costly issue later in the project.

2.3. Showcase of Electrical Systems BIM Model

Through Visual Live mixed reality technology, end users can inspect cable trays virtually, to ensure that clearances are maintained. Electrical schematics and routing can be verified in the field, ensuring that connections are done correctly and accurately. Conduit run routing can quickly be checked to ensure that physical clashes are avoided and hangers can easily be installed in the proper location. Through the use of HoloLive, field issues can quickly be conveyed to the design group where issues can be identified and corrected, saving time and money.

2.4. Install Verification - QA/QC

1:1 True scale hologram projections enable quick field inspections, allowing the end user to see and experience the BIM model like never before. While walking through the project, you can quickly identify discrepancies between the design and installed conditions. Future physical clashes can easily be identified and corrected, saving time and resources by addressing issues virtually before they result in costly rework and field modifications.

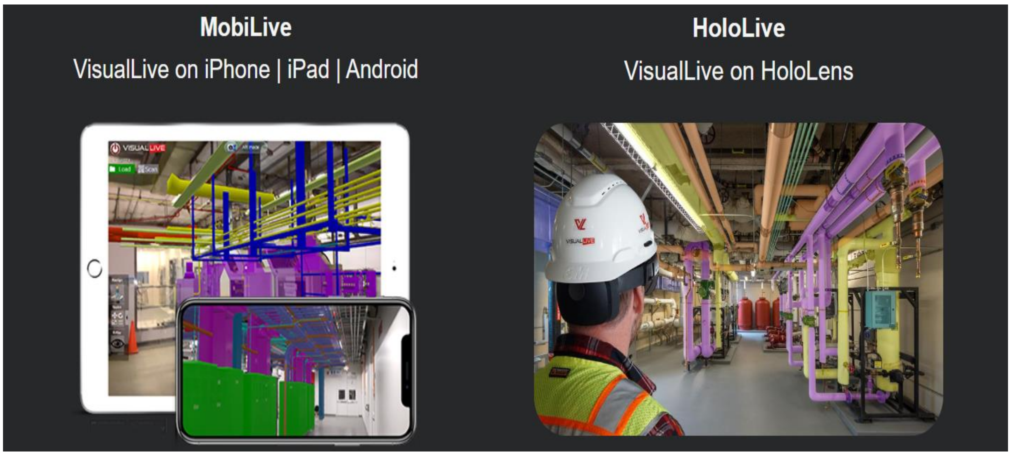


Figure 55 Visual live screenshot apps interface (https://visuallive.com/)

2.5. The benefits and the disadvantages.

2.5.1. The benefit

Here are some potential benefits of using visual live applications:

1. Real-time feedback: One of the key benefits of visual live applications is that they provide real-time feedback on data. Users can see changes to data as they happen, which can help them make more informed decisions.

2. Interactive and engaging: Visual live applications are highly interactive and engaging, making it easier for users to explore and analyze data. This can be especially helpful when working with complex data sets.

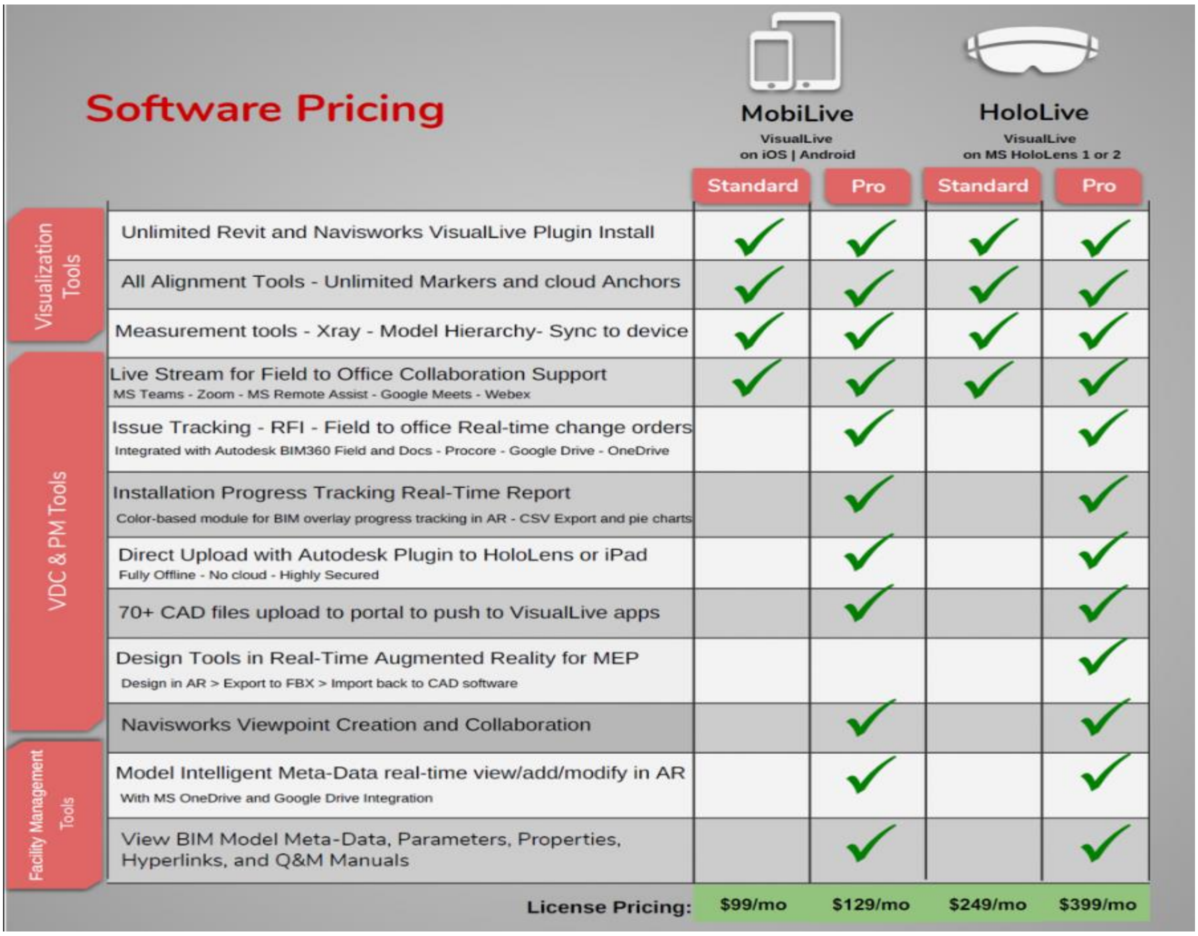
3. Customizable: Visual live applications are highly customizable, allowing users to tailor the visualizations to their specific needs. This can help users create more accurate and relevant visual representations of their data.

4. Collaboration: Visual live applications can be used to facilitate collaboration among team members or stakeholders. By providing a shared visual representation of data, it can be easier for people to work together to identify patterns, trends, and insights.

2.5.2. the disadvantages

Here are some potential disadvantages of using visual live applications:

1. Limited data sets: Visual live applications may have limitations when it comes to handling large or complex data sets. This can limit their usefulness in certain situations.
2. Technical issues: As with any software application, visual live applications may experience technical issues or bugs that can impact their functionality. This can be frustrating for users and can potentially affect the accuracy of the visualizations.
3. Dependence on internet: Visual live applications may require a stable internet connection to function properly. This can be problematic in areas with poor connectivity or if the internet connection is lost.
4. Cost: Depending on the specific visual live app, there may be costs associated with purchasing or licensing the software. Additionally, using visual live applications may require specialized hardware or training, which can also be costly.



		MobiLive VisualLive on iOS | Android		HoloLive VisualLive on MS HoloLens 1 or 2	
Software Pricing		Standard	Pro	Standard	Pro
Visualization Tools	Unlimited Revit and Navisworks VisualLive Plugin Install	✓	✓	✓	✓
	All Alignment Tools - Unlimited Markers and cloud Anchors	✓	✓	✓	✓
	Measurement tools - Xray - Model Hierarchy- Sync to device	✓	✓	✓	✓
VDC & PM Tools	Live Stream for Field to Office Collaboration Support MS Teams - Zoom - MS Remote Assist - Google Meets - Webex	✓	✓	✓	✓
	Issue Tracking - RFI - Field to office Real-time change orders Integrated with Autodesk BIM360 Field and Docs - Procore - Google Drive - OneDrive		✓		✓
	Installation Progress Tracking Real-Time Report Color-based module for BIM overlay progress tracking in AR - CSV Export and pie charts		✓		✓
	Direct Upload with Autodesk Plugin to HoloLens or iPad Fully Offline - No cloud - Highly Secured		✓		✓
	70+ CAD files upload to portal to push to VisualLive apps		✓		✓
	Design Tools in Real-Time Augmented Reality for MEP Design in AR > Export to FBX > Import back to CAD software				✓
	Navisworks Viewpoint Creation and Collaboration		✓		✓
Facility Management Tools	Model Intelligent Meta-Data real-time view/add/modify in AR With MS OneDrive and Google Drive Integration		✓		✓
	View BIM Model Meta-Data, Parameters, Properties, Hyperlinks, and Q&M Manuals		✓		✓
	License Pricing:	$99/mo	$129/mo	$249/mo	$399/mo

Figure 56: Software pricing screenshot (https://visuallive.com/pricing/)

1.6. Comparison of results from different evaluation methods

During our testing, we encountered several issues, particularly with the sign-up process. We experienced difficulty signing in every time we attempted to use the platform. Additionally, we encountered problems with the QR code feature. Specifically, when attempting to scan a QR code, the model was displayed horizontally rather than vertically, despite our attempts to change it. We tried various solutions, but the issue persisted.

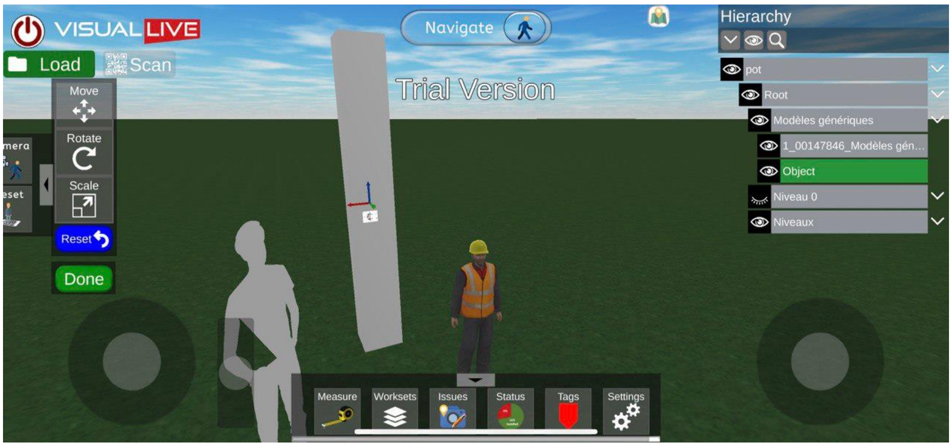


Figure 57 :Our pole testing apps screenshot

Figure 58: Model DEMO augmented screenshot from the application

Figure 59: Code QR that you need to scan for you get your model screenshot

3. GAMMA AR

GAMMA AR (Augmented Reality) applications are applications that use augmented reality technology to enhance the user's perception of the real world by overlaying computer-generated images, graphics, or data onto their view of the physical world. This technology allows users to interact with digital content in a more immersive and engaging way, blurring the line between the digital and physical worlds. GAMMA AR applications can be used for various purposes such as gaming, education, training, and marketing.

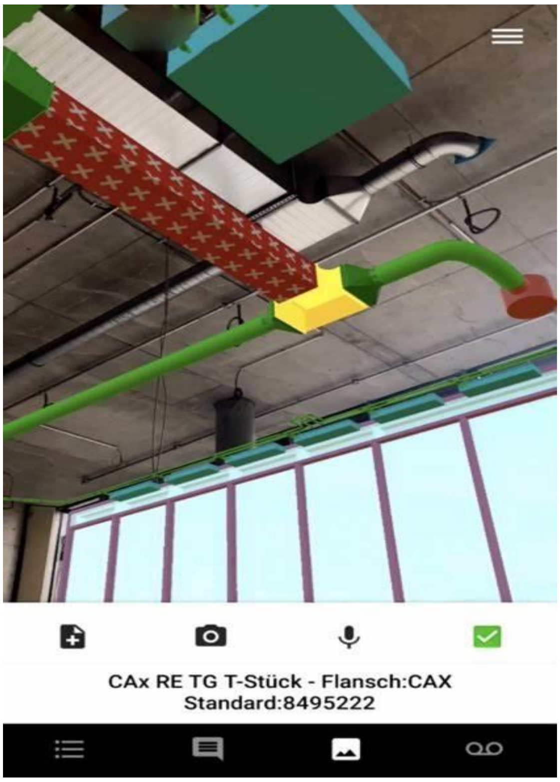


Figure 60: GAMMA AR interface screenshot

3.1. way of work

GAMMA AR (Augmented Reality) applications work by using the camera and sensors on a mobile device to detect the user's surroundings and superimpose computer-generated images or data onto the view of the physical world. The application analyzes the real-world environment and identifies specific points of interest, such as markers or objects, and tracks them in real-time.

Once the application identifies the target, it uses computer vision algorithms to overlay digital content on top of it. This content can be in the form of 3D models, animations, videos, or text, and can be interactive or static. The user can interact with the content through touch, voice, or other input methods, creating an immersive and interactive experience.

GAMMA AR applications require a device with a camera and sensors, as well as software that can recognize and track the target in real-time. Some applications may also require an internet connection to access additional data or content.

Figure 61: GAMMA AR application in field

3.2. The benefits and the disadvantages

3.2.1. Benefits of GAMMA AR applications:

- Enhanced user experience: GAMMA AR applications provide an immersive and engaging experience that blurs the line between the digital and physical worlds.
- Interactive and engaging: GAMMA AR applications allow users to interact with digital content in a more intuitive and natural way, making it easier to understand and learn complex concepts.
- Real-time information: GAMMA AR applications can provide real-time information and feedback, which can be useful in various fields, such as education, training, and healthcare.

- Marketing and advertising: GAMMA AR applications can be used as a marketing tool to create interactive and engaging campaigns that capture the user's attention and increase brand awareness.
- Entertainment: GAMMA AR applications can be used for gaming and entertainment purposes, providing a unique and immersive gaming experience.
- This application is available for IOS and ANDROIDE

3.2.2. Disadvantages of GAMMA AR applications:

- Limited availability: GAMMA AR technology is still relatively new, and not all devices and platforms support it, which limits its availability to a certain extent.
- Technical limitations: GAMMA AR applications require powerful hardware and software to work properly, which can limit their functionality and performance on older or less capable devices.
- Cost: Developing GAMMA AR applications can be expensive due to the need for specialized hardware and software, as well as the expertise required to develop the app.
- Potential health risks: GAMMA AR applications require users to look at a screen for an extended period, which can cause eye strain, headaches, and other health issues.
- Privacy concerns: GAMMA AR applications require access to a device's camera and sensors, which raises privacy concerns about the collection and use of personal data

3.4. Comparison of results from different evaluation methods

In our testing, we encountered two issues. Firstly, the directions provided were helpful in determining the position by axes it don’t work with qr code , but we faced difficulty in accurately depicting the texture and colors as they appeared quite dark. Secondly, we faced challenges in creating a module using Revit that could be shared with Gamma platforms. We encountered multiple instances where the module was rejected due to the aforementioned mudole issues.

Figure 62 : Screenshot GAMMA AR DEMO MODEL (Meeting Room)

4. Sitevision Trimble

SiteVision Trimble is a professional-grade augmented reality (AR) solution designed for the construction and surveying industries. It combines hardware and software to provide accurate and real-time information about a job site, allowing construction and surveying professionals to visualize designs and data in the context of the physical environment.

The SiteVision Trimble hardware consists of a handheld device equipped with a high-precision Global Navigation Satellite System (GNSS) receiver, an electronic distance meter, and a camera. The software, which is installed on the device, uses AR technology to overlay digital models and data onto the live camera feed, creating a mixed reality view of the job site.

SiteVision Trimble is used for a variety of applications, including site layout, stakeout, and quality control. It allows construction and surveying professionals to visualize design data, such as building plans and 3D models, in the context of the physical environment, improving accuracy and reducing errors. It also enables real-time collaboration among team members, allowing them to share and annotate data in the field.

Overall, SiteVision Trimble is a powerful tool for professionals in the construction and surveying industries, providing an innovative and efficient way to visualize and manage complex projects.

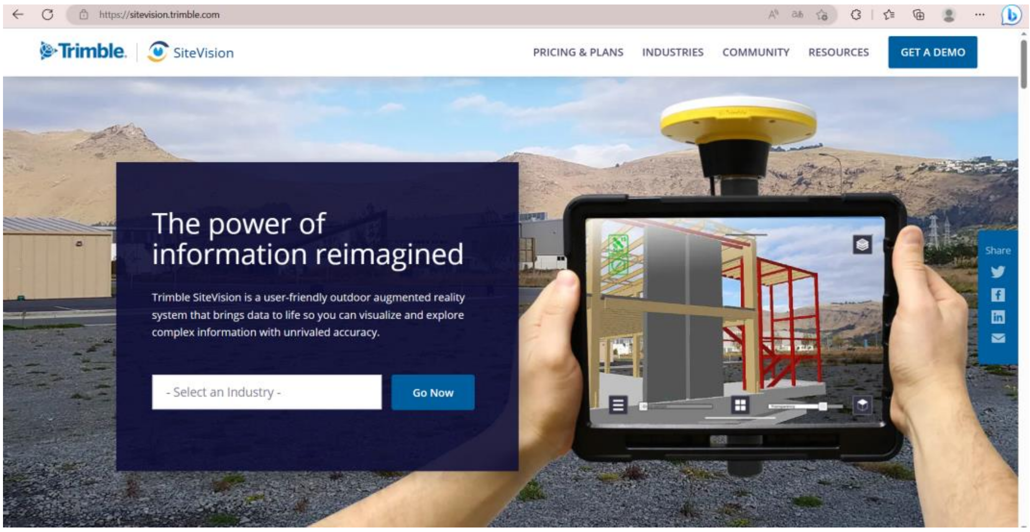


Figure 63 :Screenshot on WebSite of trimble sitevision (https://sitevision.trimble.com)

4.1. Way of work

The way SiteVision Trimble works is by using a combination of hardware and software to provide an augmented reality (AR) view of a job site. The hardware consists of a handheld device equipped with a high-precision Global Navigation Satellite System (GNSS) receiver, an electronic distance meter, and a camera. The software is installed on the device and uses AR technology to overlay digital models and data onto the live camera feed.

To use SiteVision Trimble, a professional first needs to create a 3D model or design using specialized software, such as Trimble Business Center or SketchUp. The design is then exported to the SiteVision Trimble software and uploaded to the device.

Once on-site, the professional activates SiteVision Trimble and points the camera at the desired location. The device uses the GNSS receiver and electronic distance meter to accurately locate the device in 3D space and determine its orientation. The software then overlays the 3D model onto the live camera feed, creating an AR view of the design in the context of the physical environment.

The professional can then use the AR view to guide construction and surveying activities, such as site layout, stakeout, and quality control. The device provides real-time information about the job site, allowing professionals to make informed decisions and work more efficiently. They can also collaborate with team members in real-time, sharing and annotating data directly on the device.

Overall, SiteVision Trimble provides a powerful and innovative way for professionals in the construction and surveying industries to visualize and manage complex projects.

4.2. The benefits and the disadvantages

4.2.1. Benefits of SiteVision Trimble:

- Accurate and real-time information: SiteVision Trimble provides accurate and real-time information about a job site, allowing construction and surveying professionals to make informed decisions and work more efficiently.
- Improved visualization: SiteVision Trimble allows professionals to visualize design data, such as building plans and 3D models, in the context of the physical environment, improving accuracy and reducing errors.
- Increased efficiency: SiteVision Trimble allows professionals to work more efficiently by providing real-time collaboration among team members and reducing the need for manual measurements and calculations.
- Time-saving: SiteVision Trimble saves time by reducing the need for rework and reducing the time spent on site.

- Reduced costs: SiteVision Trimble reduces costs by minimizing errors, reducing the need for manual measurements, and improving collaboration among team members.

4.2.2. Disadvantages of SiteVision Trimble:

- Cost: SiteVision Trimble is a professional-grade solution and can be expensive to purchase and maintain.
- Learning curve: SiteVision Trimble requires specialized knowledge and training to use effectively, which can have a steep learning curve for some professionals.
- Limited availability: SiteVision Trimble is a specialized tool and may not be widely available in all regions or industries.
- Technical limitations: SiteVision Trimble relies on hardware and software and may be subject to technical limitations, such as connectivity issues or hardware failures.
- Health and safety concerns: SiteVision Trimble requires users to pay attention to a screen while navigating a potentially hazardous environment, which may cause health and safety concerns.

4.3. Comparison of results from different evaluation methods

This one we face issue from the beginning she didn't work every time we try to sign up

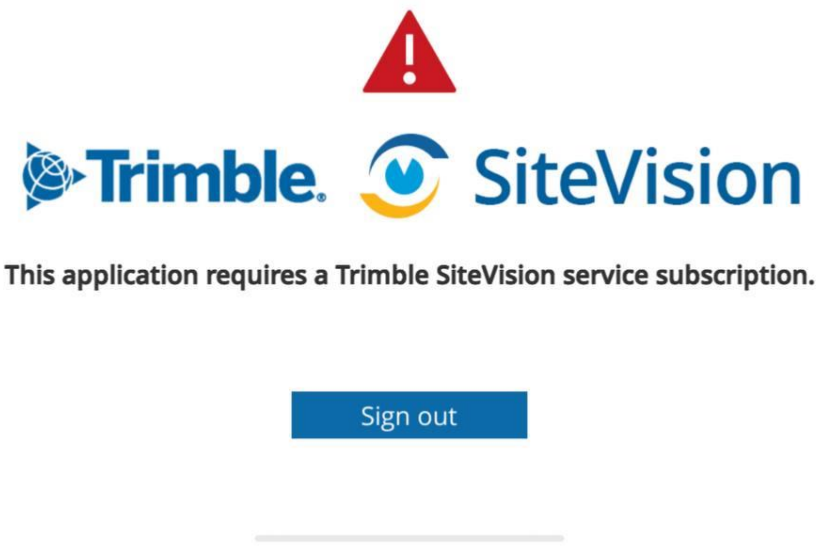


Figure 64 : Screenshot of problem of service subscription in Trimble site Vision

5. Kubity Go

Kubity Go is a mobile application that allows architects, designers, and 3D modelers to easily visualize and share their 3D designs in augmented reality (AR) and virtual reality (VR). The application is available for both iOS and Android devices.

With Kubity Go, users can import their 3D models from various sources, such as SketchUp, Revit, and Rhino, and instantly visualize them in AR or VR. The application supports various file formats, including SKP, OBJ, and 3DS. Users can also share their designs with others by generating a unique QR code that can be scanned with the Kubity Go app.

Kubity Go provides a range of features to enhance the AR and VR experience, including the ability to change the scale and position of the model, adjust the lighting and shadows, and add annotations and notes. Users can also switch between AR and VR modes with a single tap, allowing them to experience their designs in different ways.

One unique feature of Kubity Go is its support for multi-user AR experiences. Users can invite others to join a shared AR session and collaborate on the same design in real-time. This feature is particularly useful for teams working on large projects or for presenting designs to clients and stakeholders.

Overall, Kubity Go is a powerful and intuitive tool for architects, designers, and 3D modelers who want to visualize and share their designs in AR and VR. It provides a range of features to enhance the experience, including support for multi-user AR sessions, making it an ideal tool for collaboration and communication.

5.1. Way of work

The way Kubity Go works is by using the application to visualize and share 3D designs in augmented reality (AR) and virtual reality (VR). To use Kubity Go, an architect, designer, or 3D modeler first needs to create a 3D model using specialized software, such as SketchUp, Revit, or Rhino. The model is then exported to a compatible file format, such as SKP, OBJ, or 3DS, and uploaded to the Kubity cloud.

Once on the Kubity cloud, the model is optimized for use in AR and VR and can be accessed through the Kubity Go app. The user then opens the application on their mobile device, scans the unique QR code associated with their model, and instantly sees the model in AR or VR. In AR mode, the user can place the model in the real world and interact with it using their mobile device. They can adjust the scale and position of the model, add annotations and notes, and share the experience with others by inviting them to join a multi-user session.In VR mode, the user can immerse themselves in the model and explore it from different angles and perspectives. They can use a VR headset or Google Cardboard to enhance the experience and interact with the model in a more natural and intuitive way. Overall, Kubity Go provides an easy-to-use and intuitive way for architects, designers, and 3D modelers to visualize and share their designs in AR and VR. It streamlines the process of optimizing 3D models for use in AR and VR, making it accessible to a wider audience and enabling more efficient communication and collaboration.

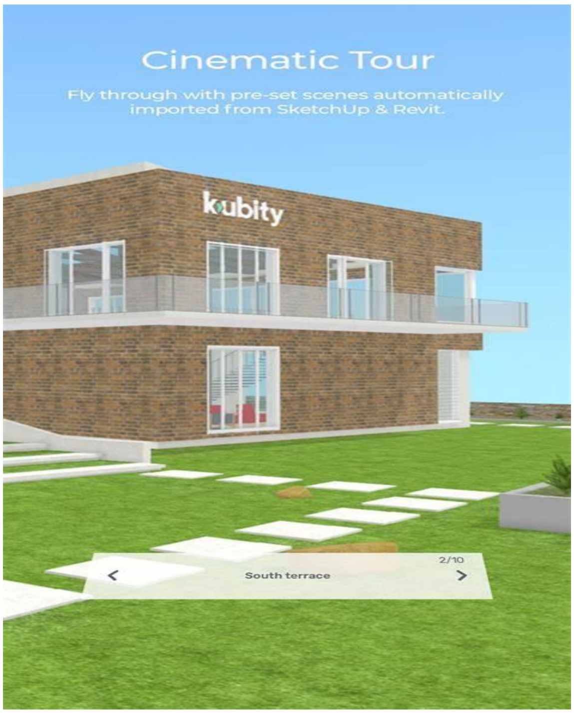


Figure 65 Screenshot kubity GO (https://image.winudf.com/v2/image1/Y29tLmt1Yml0eS5wbGF5ZXJfc2NyZWVuXzVfMTU1NDI2NjE2OV8wNTQ/screen-5.jpg?fakeurl=1&type=.jpg)

5.2. The benefits and the disadvantages

5.2.1. Benefits of Kubity Go:

1. Easy visualization: Kubity Go provides an easy way for architects, designers, and 3D modelers to visualize their designs in augmented reality and virtual reality. It

streamlines the process of optimizing 3D models for use in AR and VR, making it accessible to a wider audience.

2. Improved collaboration: Kubity Go supports multi-user AR sessions, which enable teams to collaborate on the same design in real-time. This feature is particularly useful for teams working on large projects or for presenting designs to clients and stakeholders.
3. Enhanced communication: Kubity Go allows users to add annotations and notes to their designs, making it easier to communicate ideas and feedback to others.
4. Accessible on mobile devices: Kubity Go is available on iOS and Android devices, making it accessible to anyone with a smartphone or tablet.

5.2.2. Disadvantages of Kubity Go:

1. Limited features: Kubity Go is designed primarily for visualizing and sharing 3D models in AR and VR. It does not provide the same level of functionality as specialized 3D modeling software, such as SketchUp or Revit.
2. Requires internet connection: To access 3D models on the Kubity cloud, users must have an internet connection. This can be a disadvantage for users who need to access their designs in remote or offline locations.
3. Limited file compatibility: Kubity Go supports a limited number of file formats, which can be a disadvantage for users who work with less common file types.
4. Requires additional hardware: To fully experience VR mode, users need a VR headset or Google Cardboard. This can be a disadvantage for users who do not have access to this hardware.

5.3. Comparison of results from different evaluation methods

This tool works well, but it is more suitable for simple models. It does not have features such as a QR code scanner, positioning capabilities, or the ability to add layers

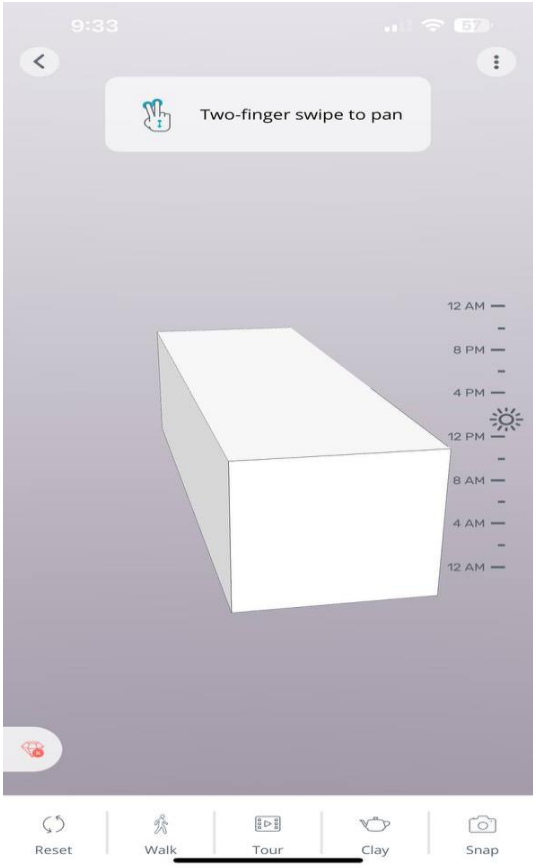


Figure 66 :Our model pole(1m width/3m length) generated in kubity GO

6. Adobe Aero

Adobe Aero is a software application developed by Adobe that enables the creation of augmented reality (AR) experiences. With Adobe Aero, users can import 2D and 3D assets from other Adobe Creative Cloud applications and design immersive AR scenes using a drag-and-drop interface. These scenes can then be viewed and experienced using a compatible mobile device or AR headset. Adobe Aero is commonly used for creating interactive product demos, educational materials, and marketing campaigns.

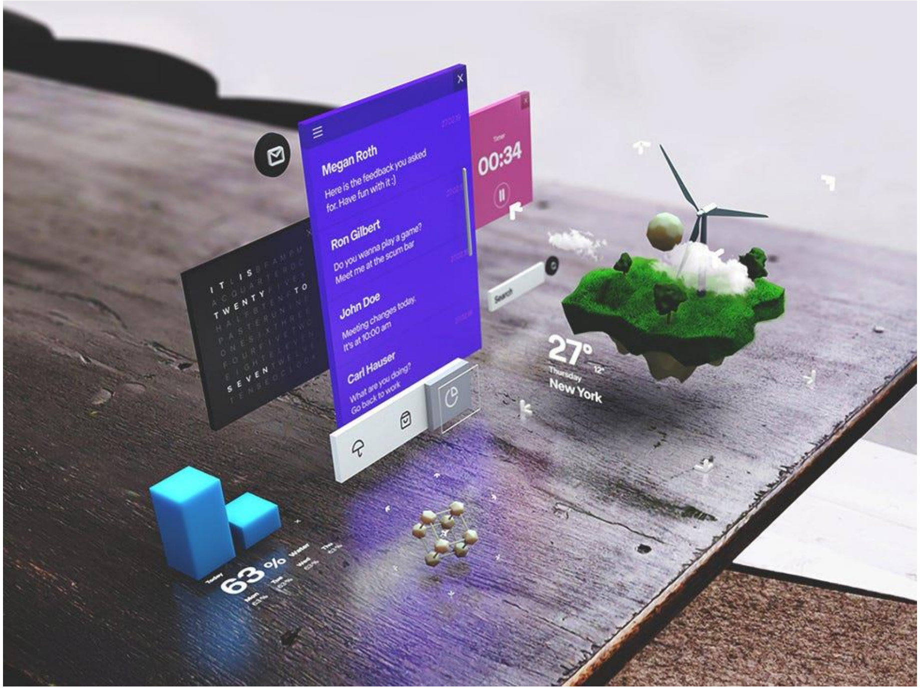


Figure 67: Adobe Aero use in news and weather informationin ect..
(https://dribbble.com/shots/6112246-floating-UI)

6.1. Way of work

The way of work for Adobe Aero involves using a visual drag-and-drop interface to create augmented reality (AR) experiences. Users can import 2D and 3D assets from other Adobe Creative Cloud applications, such as Photoshop and Illustrator, and then position and manipulate them in 3D space using Aero's intuitive controls. Adobe Aero also includes a range of interactive behaviors, such as animations and physics simulations, that can be applied to objects within the AR scene. Once the AR experience is created, it can be viewed and experienced using a compatible mobile device or AR headset. Overall, the way of work for Adobe Aero emphasizes ease of use and a visual approach to AR content creation.

6.2. The benefits and the disadvantages

6.2.1. The benefits of using Adobe Aero for creating augmented reality (AR) experiences include:

1. Ease of use: Adobe Aero has a visual drag-and-drop interface that allows users to create AR scenes without needing to write any code.

2. Integration with other Adobe Creative Cloud applications: Adobe Aero can import assets from other Adobe applications, such as Photoshop and Illustrator, making it easy to incorporate existing content into AR experiences.

3. Interactive behaviors: Adobe Aero includes a range of interactive behaviors that can be applied to objects within the AR scene, such as animations and physics simulations, which can enhance the user experience.

4. Mobile device and AR headset compatibility: AR experiences created with Adobe Aero can be viewed on compatible mobile devices or AR headsets, making it accessible to a wide range of users.

6.2.2. However, there are also some disadvantages to using Adobe Aero:

1. Limited feature set: While Adobe Aero is a powerful tool for creating AR experiences, it does not have the same level of functionality as more specialized tools that are designed specifically for AR development.

2. Limited device compatibility: Adobe Aero requires compatible mobile devices or AR headsets to view AR experiences, which may limit the audience for the content.

3. Steep learning curve: While Adobe Aero is easy to use for simple AR experiences, more complex projects may require significant time and effort to master.

4. Cost: Adobe Aero is only available as part of an Adobe Creative Cloud subscription, which may be a significant expense for some users or organizations.

6.3. Comparison of results from different evaluation methods

While this example may be suitable for basic models, it does not meet our needs for more advanced models

7. Sight Space Pro

SightSpace Pro is a software application developed by Limitless Computing that enables the creation and visualization of augmented reality (AR) experiences. With SightSpace Pro, users can import 3D models from various file formats and create interactive AR experiences using a range of tools, such as virtual reality (VR) walkthroughs, markups, and measurements. The AR experiences created with SightSpace Pro can be viewed using compatible mobile devices or AR headsets, allowing users to visualize their designs and projects in a real-world context. SightSpace Pro is commonly used in industries such as architecture, engineering, and construction for design visualization, collaboration, and communication purposes.

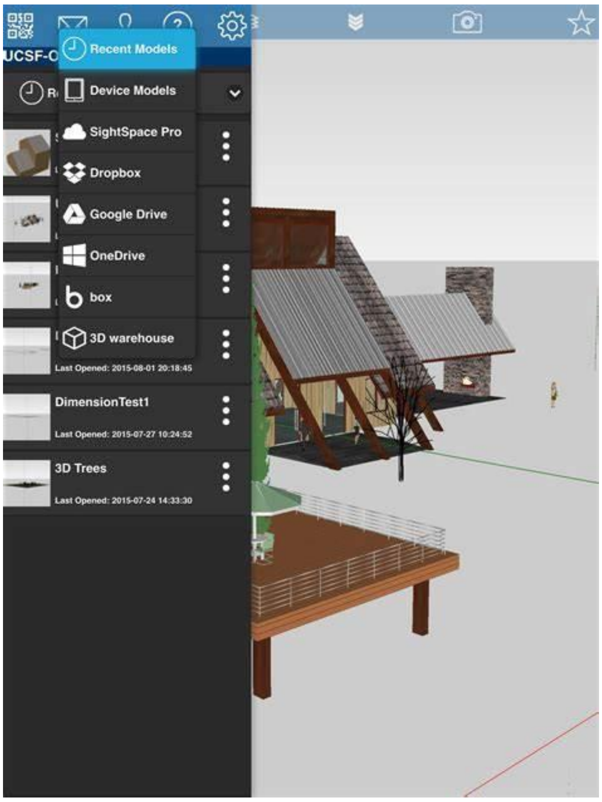


Figure 68 Saight space interface screenshot

7.1. Way of work

The way of work for SightSpace Pro involves importing 3D models from various file formats, such as SketchUp, Revit, and Rhino, and creating augmented reality (AR) experiences with them. Users can then view and interact with the AR experiences using compatible mobile devices or AR headsets.

To create AR experiences with SightSpace Pro, users can utilize a range of tools, including virtual reality (VR) walkthroughs, markups, and measurements. For example, users can walk through a 3D model in AR using VR mode, annotate the model with markups to communicate design changes, and take measurements of objects within the AR scene.

SightSpace Pro also includes collaboration features that allow users to share AR experiences with others and receive feedback. This can help facilitate communication and collaboration within teams and with clients.

Overall, the way of work for SightSpace Pro emphasizes the ability to visualize and interact with 3D models in a real-world context through AR, as well as collaboration and communication capabilities for design teams and clients.

7.2. The benefits and the disadvantages

7.2.1. The benefits of using SightSpace Pro for creating and visualizing augmented reality (AR) experiences include:

1. Real-world context: SightSpace Pro allows users to view and interact with 3D models in a real-world context, which can help with visualizing designs and communicating ideas.
2. Compatibility: SightSpace Pro supports various file formats, making it easy to import 3D models from different design software.
3. Collaboration: SightSpace Pro includes collaboration features that enable users to share AR experiences with others and receive feedback, which can improve communication and teamwork.
4. Mobile device and AR headset compatibility: AR experiences created with SightSpace Pro can be viewed on compatible mobile devices or AR headsets, making it accessible to a wide range of users.

7.2.2. disadvantages to using SightSpace Pro:

1. Learning curve: SightSpace Pro has a range of tools and features that may require significant time and effort to master, especially for users who are not familiar with AR or 3D modeling.

2. Limited device compatibility: SightSpace Pro requires compatible mobile devices or AR headsets to view AR experiences, which may limit the audience for the content.

3. Cost: SightSpace Pro is a paid software application, which may be a significant expense for some users or organizations.

4. Limited functionality: While SightSpace Pro is a powerful tool for visualizing 3D models in AR, it may not have the same level of functionality as more specialized tools that are designed specifically for AR development.

7.3. Comparison of results from different evaluation methods

This application requires payment for use. However, a free trial option is available if we wish to use it without cost, and she don’t work with QR code .

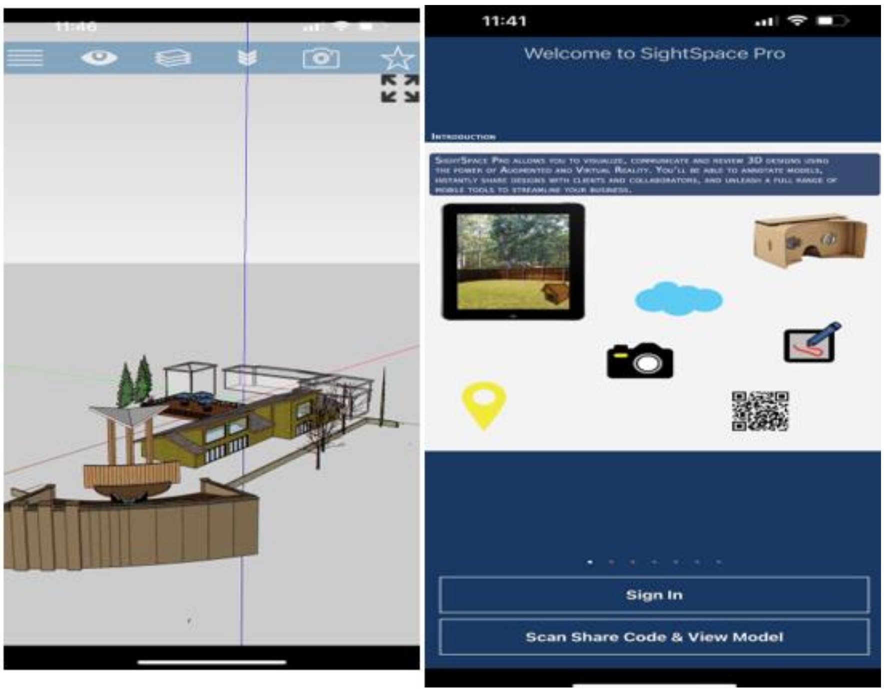


Figure 69 Demo model generated

8. Augin

The Augin platform is an augmented reality (AR) software solution developed by Augin Interactive. It allows users to create, publish, and manage AR experiences without the need for coding or technical skills.

The platform provides a user-friendly interface that enables users to easily upload 3D models, videos, images, and other media files to create AR content. Users can then publish their AR experiences to a variety of platforms, including iOS and Android devices, as well as web browsers.

Augin platform also provides advanced features such as image recognition and tracking, allowing users to create AR experiences that can be triggered by specific images or objects. This feature is particularly useful for marketing and advertising campaigns, as it allows businesses to create interactive and engaging content that can be easily shared with their target audience.

Moreover, the Augin platform provides analytics tools that allow users to track the performance of their AR experiences, including the number of views, interactions, and engagement rates. This data can be used to optimize and improve future AR experiences.

Overall, the Augin platform is a comprehensive solution for creating, publishing, and managing AR experiences, making it a valuable tool for businesses, marketers, and content creators.

Figure 70 Augin Interface in phone and tablet (augin.com)

8.1. Way of work

The Augin platform is an augmented reality (AR) software solution that enables users to create and publish AR experiences without the need for coding or technical skills. Here's a general overview of how the platform works:

1. Create AR content: Users can create AR content by uploading 3D models, images, videos, and other media files to the platform. They can then use the platform's user-friendly interface to add interactivity, animations, and other effects to their AR content.

2. Publish AR experiences: Once the AR content is created, users can publish their AR experiences to a variety of platforms, including iOS and Android devices, as well as web browsers. They can also choose to publish their AR experiences privately or publicly.

3. Trigger AR experiences: Users can use the Augin platform's image recognition and tracking feature to trigger their AR experiences using specific images or objects. This feature allows businesses to create interactive and engaging content that can be easily shared with their target audience.

4. Analyze AR performance: The Augin platform provides analytics tools that allow users to track the performance of their AR experiences, including the number of views, interactions, and engagement rates. This data can be used to optimize and improve future AR experiences.

Overall, the Augin platform makes it easy for businesses, marketers, and content creators to create and publish AR experiences that can be used for marketing, advertising, and other purposes.

8.2. The benefits and the disadvantages

8.2.1. Benefits of Augin platform:

User-friendly interface: The Augin platform provides a user-friendly interface that enables users to create and publish AR experiences without the need for coding or technical skills.

Advanced features: The platform provides advanced features such as image recognition and tracking, allowing users to create AR experiences that can be triggered by specific images or objects.

Cross-platform compatibility: Augin platform allows users to publish their AR experiences to a variety of platforms, including iOS and Android devices, as well as web browsers.

Analytics tools: Augin platform provides analytics tools that allow users to track the performance of their AR experiences, including the number of views, interactions, and engagement rates. This data can be used to optimize and improve future AR experiences.

8.2.2. Disadvantages of Augin platform:

Limited customization: While the Augin platform provides a user-friendly interface for creating AR experiences, it may be limited in terms of customization options for more complex or specific needs.

Learning curve: Although the platform is designed to be easy to use, there may still be a learning curve for users who are new to AR technology.

Cost: The Augin platform is a paid software solution, which may be a disadvantage for users who are looking for a free or low-cost option.

Overall, the Augin platform is a valuable tool for businesses, marketers, and content creators who want to create and publish AR experiences. However, it's important to consider the benefits and disadvantages before deciding whether to use the platform for your specific needs.

8.3. Comparison of results from different evaluation methods

We encountered problems with creating models, as there were numerous instances where we faced issues while adding the module to the platform. Additionally, this tool lacks features such as position tracking, and the ability to incorporate texture and layers.

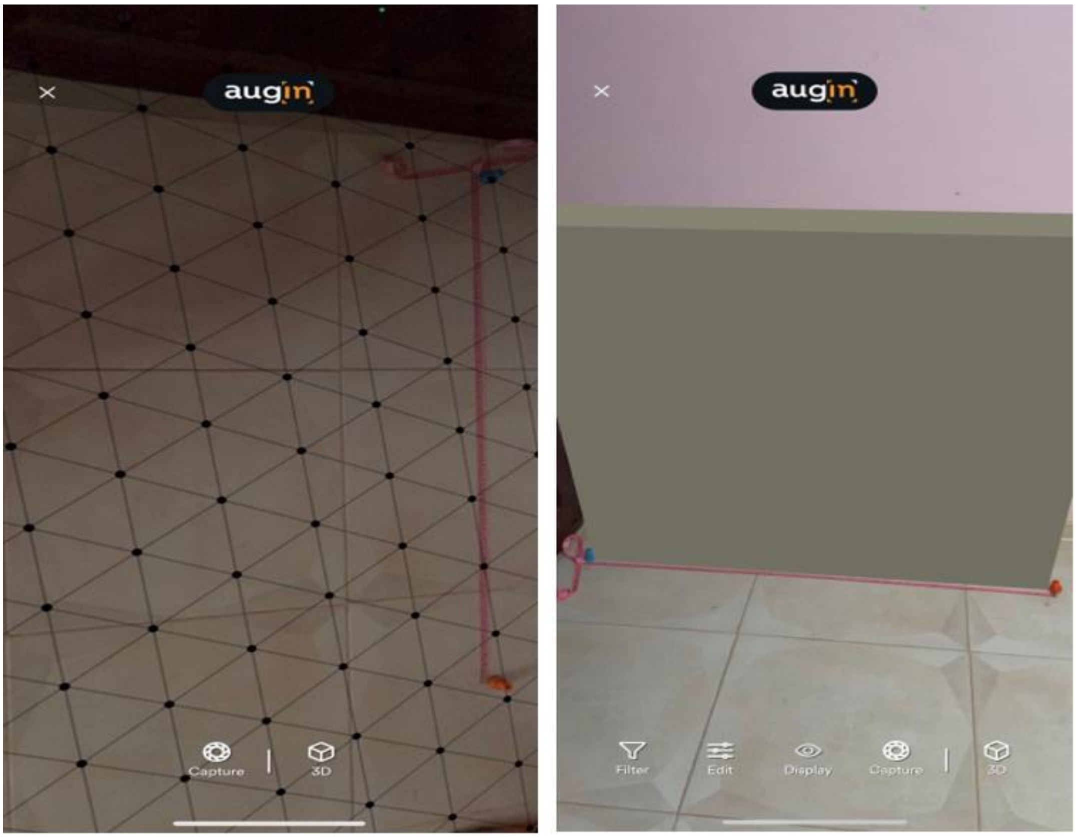


Figure 71: Quality control by measuring on a wall of 1m width

9. SketchUp viewer

SketchUp Viewer is a software application developed by Trimble Inc. that enables users to view and interact with 3D models created in SketchUp, a 3D modeling software. SketchUp Viewer is available for desktop, mobile, and web platforms and allows users to view and share 3D models with others, even if they do not have SketchUp installed.

With SketchUp Viewer, users can explore 3D models from different angles and perspectives, as well as apply different visualization styles, such as wireframe or shading, to better understand the design. Additionally, SketchUp Viewer allows users to measure distances, create annotations, and make notes directly on the 3D model, which can help facilitate communication and collaboration among design teams and clients.

SketchUp Viewer also supports augmented reality (AR) viewing, allowing users to overlay 3D models onto a real-world environment using compatible mobile devices. This can help provide a better sense of how the design will look in the real world and improve communication with clients or stakeholders.

Overall, SketchUp Viewer is a valuable tool for visualizing and sharing 3D models created in SketchUp, providing a range of features to support communication and collaboration among design teams and clients.

9.1. Way of work

The way SketchUp Viewer works is by allowing users to open and view 3D models created in SketchUp, a 3D modeling software. SketchUp Viewer is available for desktop, mobile, and web platforms, and it enables users to explore 3D models from different angles and perspectives, as well as apply different visualization styles.

To use SketchUp Viewer, users can import 3D models created in SketchUp, or they can access 3D models shared by others. Once a 3D model is opened in SketchUp Viewer, users can navigate the model using various tools, such as pan, zoom, and orbit. They can also apply different visualization styles to better understand the design, such as shading, wireframe, or x-ray.

SketchUp Viewer also includes tools for measuring distances, creating annotations, and making notes directly on the 3D model, which can help facilitate communication and collaboration among design teams and clients. Users can also share 3D models with others, even if they do not have SketchUp installed, using the SketchUp Viewer.

Additionally, SketchUp Viewer supports augmented reality (AR) viewing, which allows users to overlay 3D models onto a real-world environment using compatible mobile devices. This feature can provide a better sense of how the design will look in the real world and improve communication with clients or stakeholders.

Overall, the way SketchUp Viewer works is by providing users with tools to view, explore, and interact with 3D models created in SketchUp, as well as collaborate and communicate with others using annotations, notes, and sharing features.

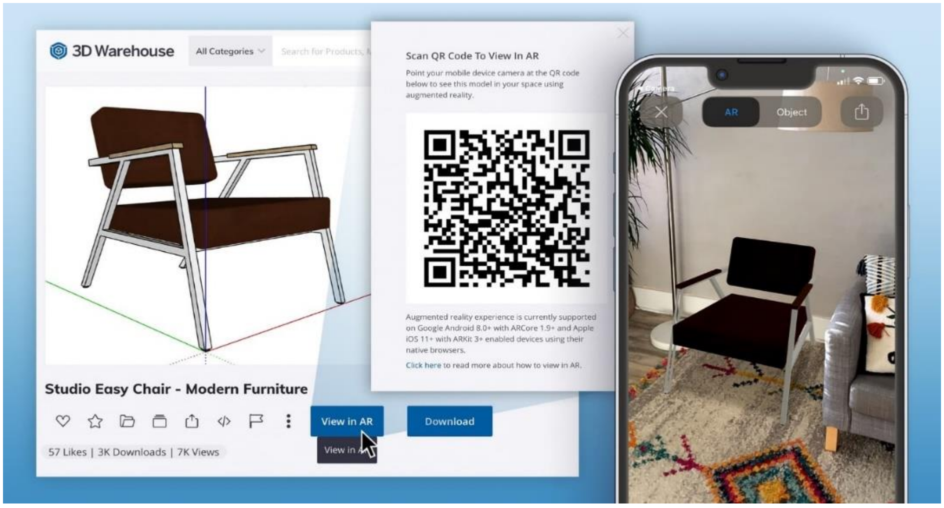


Figure 72: Interface of 3d warhouse (3d platfor warhouse)

9.2. The benefits and the disadvantages

9.2.1. Benefits of SketchUp Viewer:

1. Easy to use: SketchUp Viewer has a user-friendly interface that is easy to navigate, making it accessible for users of all levels.

2. Collaboration: SketchUp Viewer allows users to collaborate and communicate effectively with team members, clients, and stakeholders using annotations and notes on the 3D model.
3. Visualization: SketchUp Viewer offers different visualization styles that help users to better understand the design and how it will look in the real world.
4. Augmented Reality: SketchUp Viewer supports AR viewing, which can provide a better sense of how the design will look in the real world.
5. Compatibility: SketchUp Viewer is compatible with various platforms, including desktop, mobile, and web, making it accessible and easy to use for users on different devices.

9.2.2. Disadvantages of SketchUp Viewer:

1. Limited Features: SketchUp Viewer is primarily a viewing tool and lacks some of the advanced features available in SketchUp, such as modeling and editing tools.
2. Compatibility Issues: SketchUp Viewer may have compatibility issues with certain file formats, which can limit the types of 3D models that can be viewed.
3. Cost: While the basic version of SketchUp Viewer is free, some features may require a subscription, which can add to the cost.
4. Performance: SketchUp Viewer may experience performance issues when viewing large and complex 3D models, which can slow down the viewing process.
5. Security: SketchUp Viewer may pose a security risk when sharing 3D models with others, as the models may contain confidential or proprietary information.

Comparison of results from different evaluation methods: This tool is the best one for our purpose and is very user-friendly. It allows for the use of layers and adding models to the platform for augmented reality on a phone. However, it lacks an AR code for position tracking, which is a drawback.

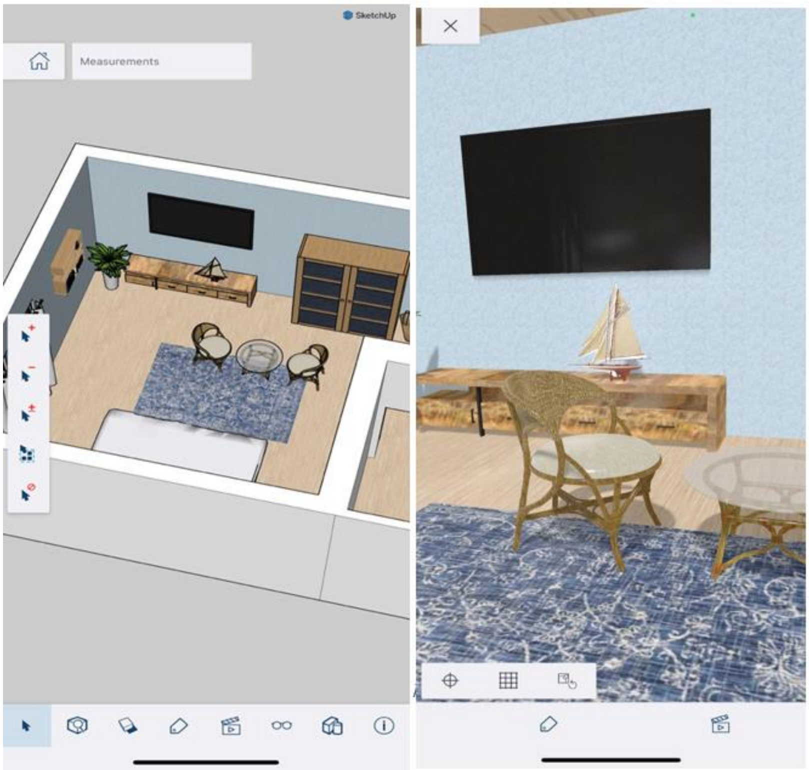


Figure 73: Beach hotel room model by us with different scale

Figure 74 : Beach hotel room model by us with scale 1:1

9.3 Used device :

We utilized the IPHONE 13 PRO MAX to gather data from the real environment. This device offers a multitude of options and features, as outlined below in its characteristics.

9.3.1 IPHONE 13 PRO MAX characteristics:

The IPHONE 13 PRO MAX is the latest flagship smartphone from Apple, which was released in September 2021. Here are some of its key characteristics:

1. Display: The IPHONE 13 PRO MAX features a 6.7-inch Super Retina XDR OLED display with a resolution of 2778 x 1284 pixels.
2. Processor: It is powered by Apple's A15 Bionic chip, which is a 5-nanometer chip that is faster and more efficient than the previous generation.

3. Cameras: The device has a triple-lens camera system that includes a 12-megapixel ultra-wide lens, a 12-megapixel wide lens, and a 12-megapixel telephoto lens. It also features Night mode and Deep Fusion technology for better low-light photography.
4. Battery life: The IPHONE 13 PRO MAX has a larger battery than its predecessor, which allows for up to 28 hours of talk time and up to 95 hours of audio playback.
5. 5G: The device is compatible with 5G networks, which provides faster download and upload speeds.
6. Design: The IPHONE 13 PRO MAX has a flat-edge design with a ceramic shield front cover for added durability.
7. Storage: It comes in storage options of 128GB, 256GB, 512GB, and 1TB.
8. Colors: The IPHONE 13 PRO MAX is available in four colors: Graphite, Gold, Silver, and Sierra Blue.

Overall, the IPHONE 13 PRO MAX is a powerful and advanced smartphone with impressive features, including a high-quality display, powerful processor, advanced camera system, and long battery life.

Figure 75: IPHONE 13 PRO MAX model triple camera (IPHONE platform)

Figure 76 : IPHONE 13 PRO vs and PRO MAX dimension

9.3.2 IPHONE leader sensor:

For aerial uses such as terrain surveying, both LiDAR and photogrammetry can provide an accuracy of 1 to 3 cm (0.4 to 1.2 inches). When scanning at very short distances like 10 cm (4 in) away from the object, the accuracy of LiDAR can be as precise as 10 µm, less than the thickness of a hair.

Percentage of accuracy between measured and real values of small objects for length, width and height. Lines show precision of measured values for repeated scans (n = 5) of the same object. Accuracy and precision are increasing with object size in all directions. Lines indicate linear trend lines

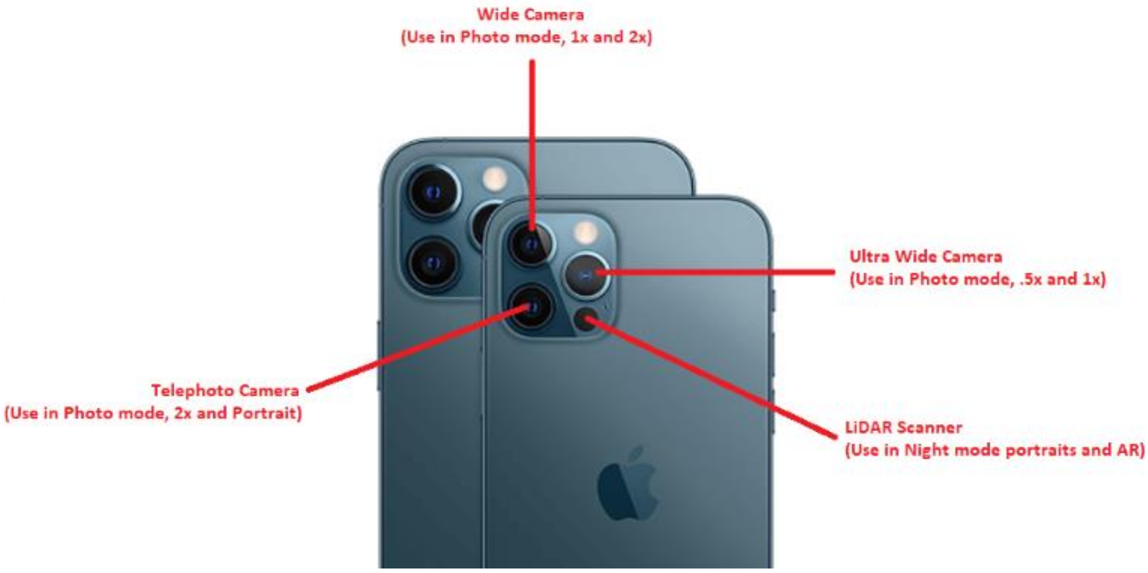


Figure 77: IPHONE 13 PRO MAX camera devices

9.4Methodology of design in Sketchup viewer

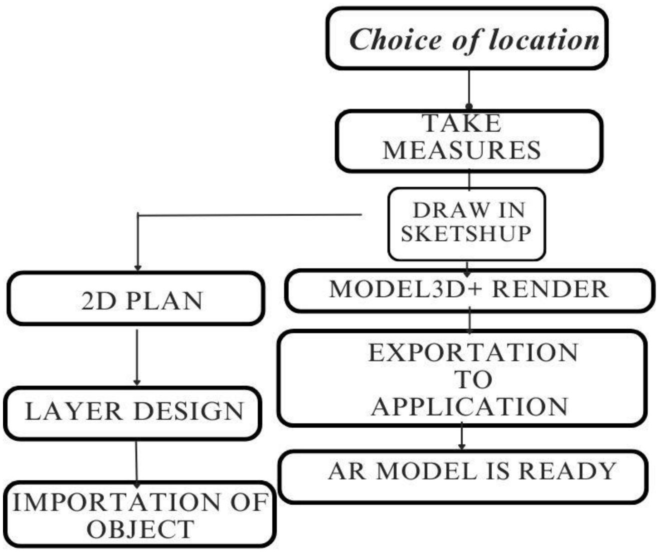


Figure 78: Organigramme of methodology in SketchUp viewer

9.4.1Choice of location :

The test environment in SketchUp Viewer was selected arbitrarily from the classroom of the Civil Engineering Department.

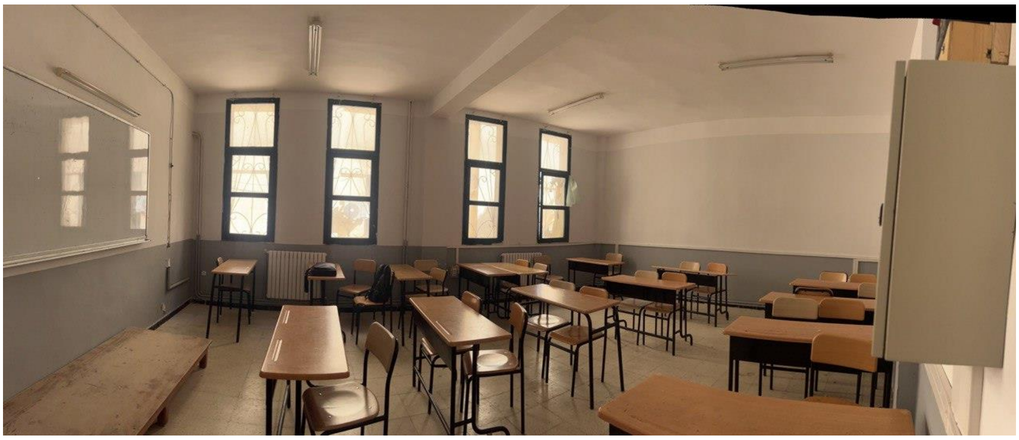


Figure 79: Chosen classroom for SketchUp viewer test

9.4.2 Take measures : We took measurements using the measurements app available on IPHONE 30 PRO MAX which contains Lidar sensor. This options is very useful to generate precise 3D live reconstitution.

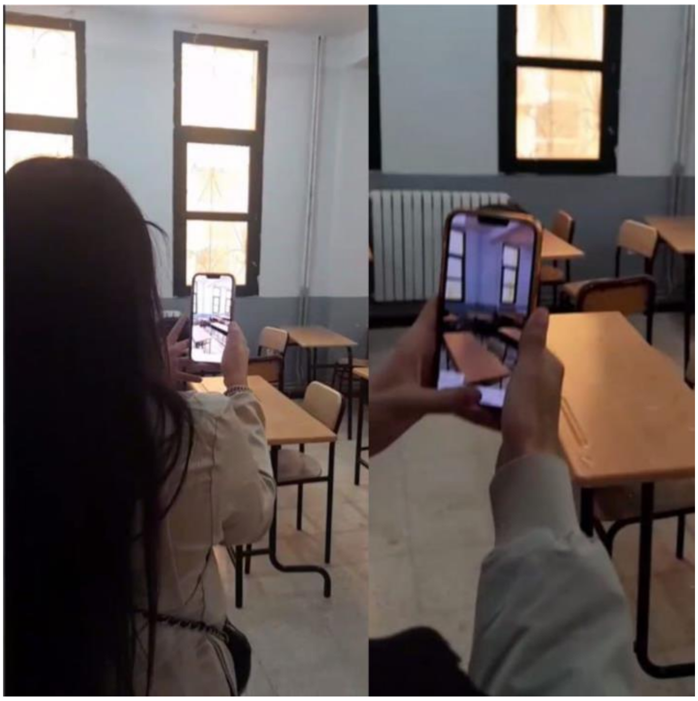


Figure 78 : Lidar scan operation

9.4.3 Drawing in Sketchup:

After the scan operation, we proceed the design drawing in SketchUp viewer. Note that we added all unseen elements as in BIM model; for this test , we choose to add only steel re-enforcement of classroom pillars (figure 83)

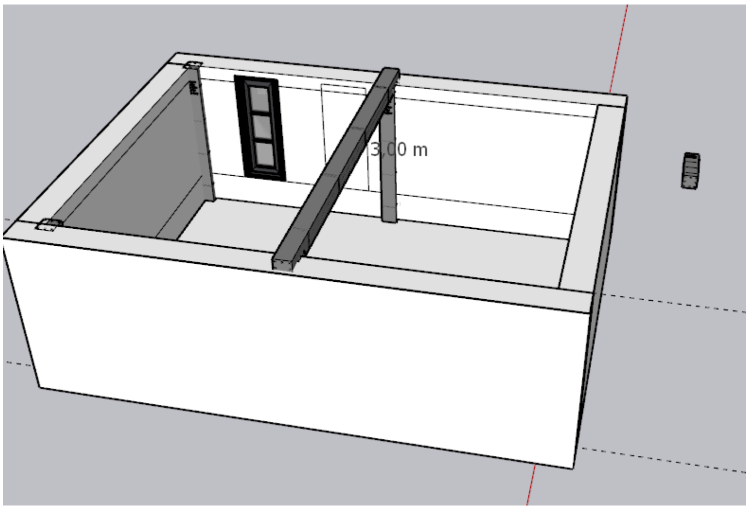


Figure 79 :Designed Classroom on SketchUp software

For more realistic model we added some details as shown bellow

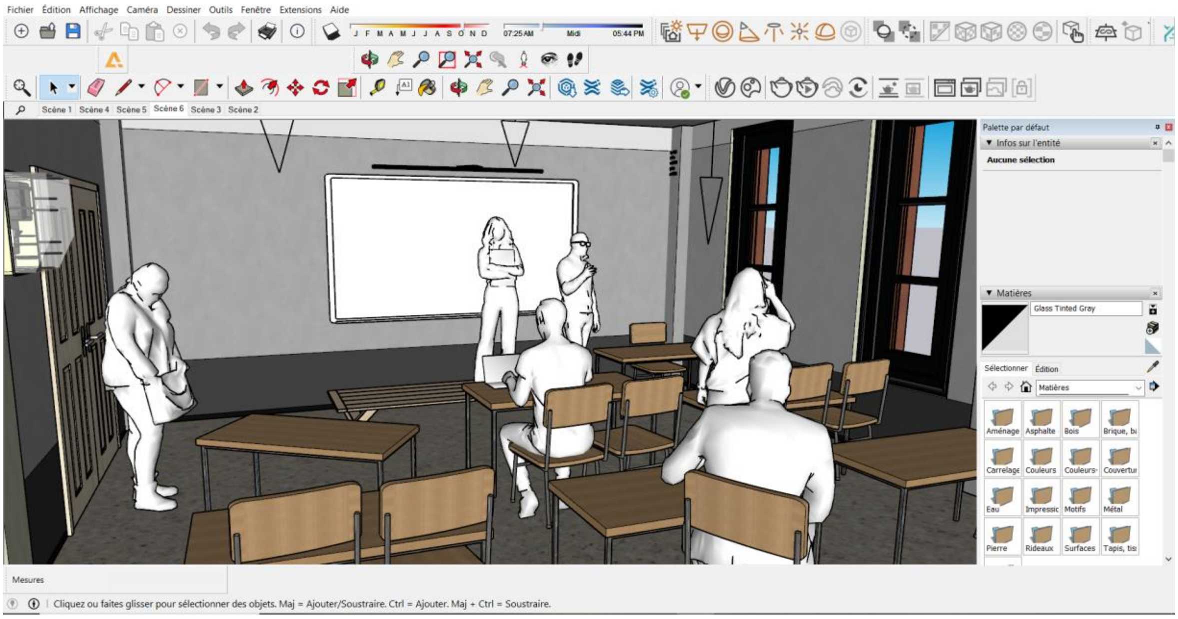


Figure 80 supplementary added objects

9.4.4 Exportation & visualization :

After obtaining the 3D design of the real environment, we exported to the AR apps (SketchUp viewer) . the model is projected on environment scale. The apps allow to manage all added layers , so we can visualize the unseen object

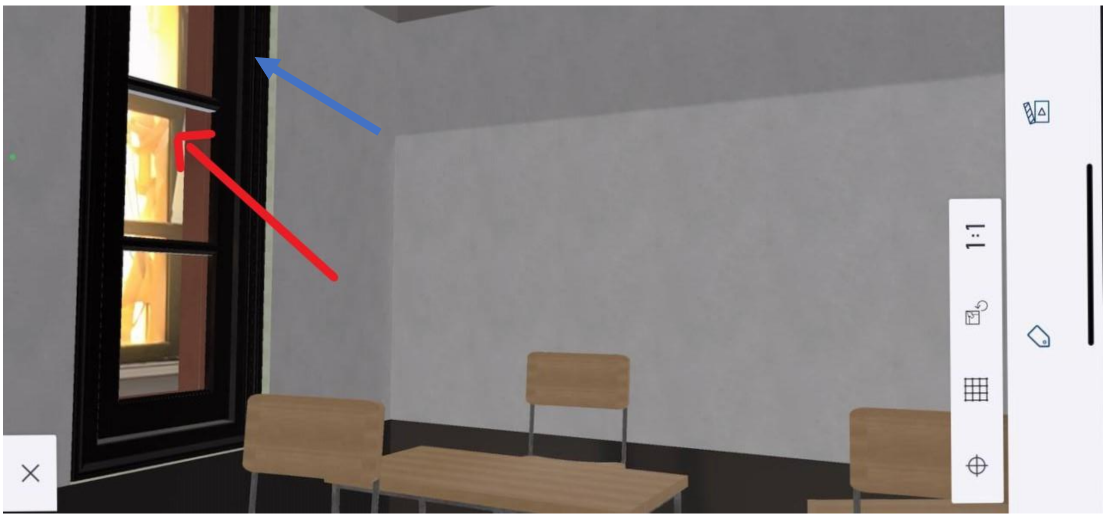


Figure 81: The virtual model augments reality in real-time. The blue arrow shows the virtual window, and the red one shows the real.

Figure 82 : Visualization on SketchUp viewer App (Classroom)

Figure 83: Classroom model with AR visualization

10. Web AR vs software AR

Web AR and software AR are two different approaches to implementing augmented reality (AR) experiences.

Web AR refers to AR experiences that can be accessed through a web browser, without the need for a separate application to be installed on a device. This is made possible through the use of web technologies such as WebGL, Web XR, and Web Assembly, which enable developers to create AR experiences that can be accessed through a browser on any device with internet access. Web AR is often used for simpler AR experiences, such as product visualizations, educational content, or marketing campaigns.

On the other hand, software AR typically requires the installation of a dedicated application on a user's device in order to access the AR experience. The application may be designed for a specific platform such as iOS or Android, and may leverage the device's native AR capabilities (such as ARK it or ARC). Software AR is often used for more complex AR experiences, such as interactive games or immersive training simulations.

Both approaches have their own advantages and disadvantages. Web AR is generally more accessible and easier to use, as users can access the experience directly through their browser without the need for an app. However, it may be limited in terms of the complexity of the AR experience that can be delivered. Software AR, on the other hand, can offer more advanced features and capabilities, but requires users to download and install a separate app.

11. Applications comparison:

After conducting tests on various applications, a comparison was made to evaluate their performance and features

✗ : Not available.

✓ : available

Application	Free	QR CODE	Texture	Scanning	position	For CE
VT-Platform	✗	✗	✓	✓	✗	✓
Visual live	✗	✓	✓	✓	✓	✓
Gamma AR	✗	✗	✗	✓	✓	✓
Sitevision Trimble	✗	✗	✓	✓	✗	✓
Kubity Go	✗	✗	✗	✓	✗	✗
Adobe Aero	✗	✗	✓	✓	✗	✗
Sight Space Pro	✗	✓	✓	✓	✓	✓
Sketchup Viewer	✓	✗	✓	✓	✗	✓
Augin	✗	✓	✗	✓	✗	✓

Table 1 Table of comparison between all application

11.1. Classification of 3D reconstitution By AR application :

The organigram bellow shows the different ways to get the 3D model in real environment. All of the AR Applications use the QR code to get link of 3D model file, but the difference lies how to get the position and the spatial orientation

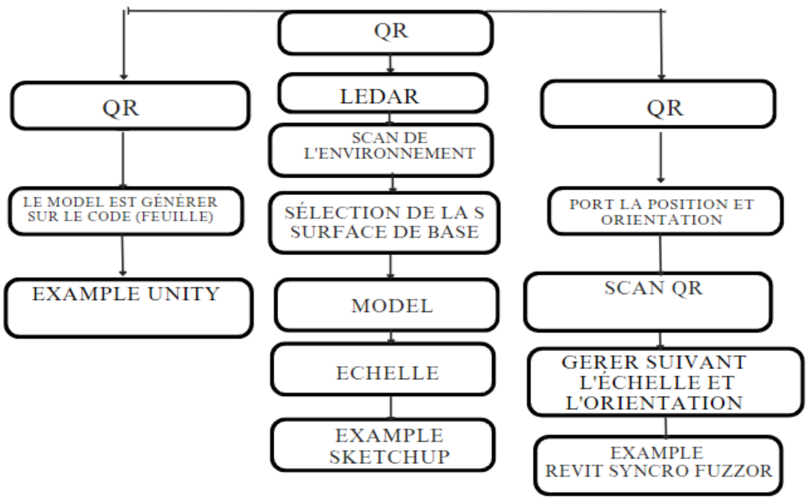


Figure 84 Organigramme of classification of reconstitution

Conclusion :

Before embarking on a comprehensive summary, it is worth mentioning the outlined millimeter accuracy.

The challenges faced were:

1. Understanding BIM as a digital model in order to effectively utilize it.
2. Understanding the process of modeling objects in virtual reality first, then augmented reality, and finally integrating them, regardless of the field of application, and determining how to transition a prepared model on the computer to the real world.
3. Resolving the issues related to the representation of the 3D model and its alignment with the real world.
4. Addressing the problem of determining the location of the plan without using GPS devices, as it dosn't provide services indoors.
5. Solving the problem of orienting the model (i.e., determining its azimuth angle within the building).
6. Finding the appropriate and unique application that provides all of the aforementioned services free of charge.

Through research on dozens of applications, it became apparent that free applications do not provide the required and important additional features. Therefore, we chose to utilize the distinctive features of each program's free version. The objective was not to study a specific structural engineering aspect based on civil engineering principles, but rather to solve the aforementioned integration problems and establish a clear workflow for integrating AR at each stage of BIM based on information levels.

The experiments were not limited to understanding the workflow but also involved assessing the quality of the virtual model after placing it in the appropriate scale, location, and orientation in the real environment. It is important to emphasize that non-professional equipment was used to achieve professional results, enhancing the value of the research findings.

Indeed, after measuring a reference point on a one-meter-high wall, the achieved accuracy was one millimeter as a margin of error in the virtual model displayed in the real environment.

This technologies (AR with BIM) allow us to:

- Facilitate communication and work on a BIM model by integrating it into the real world.
- Facilitate the process of identifying clashes between different networks (water, gas, electricity) visually.
- Determine the remaining stages of the project during construction.
- Transition the model from being displayed on a computer screen to a realistic integrated structure on the actual scale.
- Simplify maintenance and monitoring operations for buildings, where detailed information about the structural elements, even those not visible to the naked eye, can be obtained, saving time and money.

II. Referecens

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