A REVIEW: INVESTIGATION OF AUGMENTED REALITY –BIM BENEFITS IN DESIGN PROCESS IN AEC INDUSTRY

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The industry of Architecture, Engineering, Construction, has long been known as dynamic and complicated. A Growing demands on building projects in areas such as safety, energy, time, and financial management have driven the sector toward new tools and processes, including more effective utilization digital technology, in recent years. Building Information Modelling (BIM) is gradually establishing itself as a core technique among the several accessible digital solutions, with its practices and technologies being progressively used. The existing barriers to BIM adoption, on the other hand, give an opportunity for the creation of supporting technologies. The current article examines Augmented Reality (AR) as a tool in this regard. A comprehensive study was carried out to investigate existing research in the domain of BIM-based AR, revealing insight on its integration in the AEC industry. PRISMA-P is the reviewing approach that was adopted. A total of 79 articles were chosen for the study from a sample of 120 articles. This assessment demonstrates that AR implementation is far from complete, with various constraints such as connectivity and localization issues, a lack of non-geometric information, and other difficulties in employing AR techniques on the building site. The motivation of this paper comes from the lack of attention in augmented reality through BIM among previous studies adding that previous theorist included augmented reality adoption alone. This paper distinguished by its content for AR application into BIM from conceptual stage, architecture stage, construction stage and maintenance stage.

Povzetek: Industrija arhitekture, inženiringa in gradbeništva je že dolgo znana kot dinamična in zapletena. Naraščajoče zahteve pri gradbenih projektih na področjih, kot so varnost, energija, čas in finančno upravljanje, so sektor v zadnjih letih usmerile k novim orodjem in procesom, vključno z učinkovitejšo uporabo digitalne tehnologije. Informacijsko modeliranje stavb (BIM) se postopoma uveljavlja kot osrednja tehnika med številnimi dostopnimi digitalnimi rešitvami, njegove prakse in tehnologije pa se postopoma uporabljajo. Obstoječe ovire za prevzem BIM pa dajejo priložnost za ustvarjanje podpornih tehnologij. Ta članek obravnava obogateno resničnost (AR) kot orodje v zvezi s tem. Izvedena je bila obsežna študija, da bi raziskala obstoječe raziskave na področju AR, ki temelji na BIM, in razkrila vpogled v njegovo integracijo v industrijo AEC. PRISMA-P je pristop k pregledovanju, ki je bil sprejet. Za študijo smo iz vzorca 120 člankov izbrali skupno 79 člankov. Ta ocena kaže, da implementacija AR še zdaleč ni dokončana, z različnimi omejitvami, kot so težave s povezljivostjo in lokalizacijo, pomanjkanje negeometrijskih informacij in druge težave pri uporabi tehnik AR na gradbišču. Motivacija tega prispevka izhaja iz pomanjkanja

pozornosti razširjeni resničnosti prek BIM med prejšnjimi študijami in dodaja, da je prejšnji teoretik vključil samo sprejetje razširjene resničnosti. Ta dokument se razlikuje po svoji vsebini za uporabo AR v BIM od konceptualne stopnje, stopnje arhitekture, stopnje gradnje in stopnje vzdrževanja.

1 INTRODUCTION

Architecture, Engineering, Construction sector is known for its growing difficulty and competitive nature, which is largely due to tight timeframes, complicated tasks, and limited cost , which has driven the exploration for automatically generated and technically sophisticated solutions and methods. the architecture design process is the sequential development and analysis of a building project (Kirschke, 2015). This procedure is often divided into seven phases to offer control to the project by establishing review intervals, developing a systematic distribution of design information, and identifying the natural stages of design. This is why design process is critical; it organizes project management and provides effective communication on design purpose. The stages of the design process provide for effective and transparent production planning, reducing risks that might lead to costly, time-consuming delays(Nanisa et al., 2021).

Automation and digitization have recently provided this industry with the capabilities to achieve improved performance and reliability, lowering costs and updating operations (Matarneh & Hamed, 2017). The attempts to spread and integrate Building Information Modelling (BIM) are a prime illustration of the company's radical transformation(Doan et al., 2019). The adoption of BIM approach has yielded evident benefits in terms of cooperation, budgeting, 3D designs, maintenance, quantities, and material categorization, besides other aspects(Moum, 2010).As a result, more integrating and adaptable techniques that can leverage on the diverse characteristics and established on the basis of construction project participants, personnel, everyday activities, and understanding are needed(Ibrahim, 2011).

BIM-based Augmented Reality (AR) innovations in the AEC industry have been documented, with a variety of applications. Recent researchers have defined AR as a subset of Virtual Reality (VR) that might also provide a real-world environment with both the incorporation of virtual elements. Moreover, AR technology has progressed beyond marker-based implementations to tracking solution systems(Kara, 2015). AR/VR market valuations are anticipated to be $18.8 billion through 2020 as well as $60.55 billion as for 2023, with an annual growing rate of 40.29 present. AR has also been listed as one of the primary BIM-related study disciplines(Ahmed, 2019).

This research offers an outline of building information modelling as well as the current state of the art inside the application of augmented reality in different building information modelling user situations. It covers many issues that must be solved, in addition to a range of end-user applications and use-cases for AR applications in design, engineering, including construction (AEC).

2 Literature review

Augmented Reality overview

Augmented Reality (AR) is a computer-generated multimedia overlay over the actual world that may interact with the environment in real time. There is no occlusion among computer-generated information and real-world stuff in AR. In most situations, computer-generated information can only be seen on smartphones or tablets (Albahbah et al., 2021). The immersive viewing environment provided by phone-based AR devices is quite restricted. Furthermore, limited wearable AR technologies and Google Glasses are meant to overlay information objects or digital items on top of the real-world surroundings (Davila Delgado et al., 2020).

AR is classified into four types: 1. maker-based AR (for example, scanning a QR code); 2. Location-based AR

(for example, integrated with GPS for location information); 3. Projection-based AR (as projecting illumination on to the actual surfaces). And 4. Implementing innovation AR (for example, the Furniture app that positions virtual object in a real environment) (Guney, 2015).

AR is a setting in which computer-generated data is supplied into the operator's view of a real scene. AR allows viewers to access, visualize, and communicate with complicated information in the sense of the environment (Nassereddine et al., 2022). In other phrases, computer-generated components have been got to add to the real world situation. observed reality (Hadjri, 2001).

AR systems are often divided into three stages: data input, computing, and visualization. The data input phase focuses on the generation, processing, and structuring of data. As in framework of BIM-related activities, this entails creating a BIM model that can be utilized to augment reality (Kocaturk et al., 2013). Integrating virtual information as 3D geometry, particular element data, and so on) and actual settings is a very complicated phase that can occur on the mobile device or on a distant server. Furthermore, the mixed visualizations may be displayed on portable mobile devices such as smartphones or tablet devices, as well as head mountable gadgets(Azhar, 2011).With the advancement and development of AR applications, developments for education, design, production, construction, and enjoyment become more feasible help enhance educational outcomes(Al-matarneh & Fethi, 2017).

Building information modelling

Building Information Modelling (BIM) may be traceable to the initial thoughts regarding ways to employ the notion of product models in architecture design employing multiple media, as stated by previous theorists discussing the emergence of BIM further into AEC industry (Dinh, 2020). Along this progression, the Industry Alliance for Interoperability (IAI) was founded in 1995, with the goal of developing a standard for characterising buildings that would enable the sharing of information about structures without losing its semantic content. This functional style is known as Industry Foundation Classes (IFC), and it was initially released in 1997 (Kocaturk & Kiviniemi, 2016).

BIM digitized symbolizes the physical and functional characteristics of a building, allowing different stakeholders to collaborate all across the project life to input, update, or adjust information inside the BIM process (J. Kim & Kim, 2023)BIM is continually changing, trying to seek to optimize new tech in response to the sophistication of civil construction procedures, as well as the construction municipality has always been searching to keep innovating with BIM thru all the particular work - flow techniques including such AR / VR, that are currently being implemented straightforwardly to solve real-life issues such as configuration verifying and assessing (Y. Chen et al., 2020). Table 1 illustrates a comparison between VR, AR, MR in real and virtual environment. The basis of building information modelling is the capacity to add meaningful information employing Building information models that go beyond geometric representation; hence, they can also be examined in many levels, including 3D (designs planning), 4D (schedule), 5D (expected to cost), 6D (product lifecycle information), to 7D (facility managing), the data structures used vary ranging from based on the format used both to organize the information and the model language to transfer the data (Cristina et al., n.d.).

TABLE 1
VR, AR, MR COMPARASION

VR-AR-MR	*Virtual environment*	*Real environment*	*Interaction*	*Type*
				Mobile
				Standalone
				desktop
Virtual reality	*high*	*low*	*low*	*Desktop-standalone - mobile*
Augmented reality	*low*	*high*	*middle*	*Desktop-standalone*
Mixed reality	*middle*	*high*	*high*	*standalone*

Augmented reality based BIM

augmented reality can be defined as a system where a BIM is employed to augment the real world(Riera & Diagonal, 2012). AR increased BIM modeller, in which BIM model information is modified in an AR environment may also be anticipated. AR is nowadays being regarded as a "New Golden age" of information thru all the sophisticated tech by scholars and professionals in the field of knowledge, due to the beneficial impacts of its developing technologies that its accurate use offers to the construction sector, particularly during the construction phase, supplying considerably impacts the efficiency of projects, performance, safety and health. And thus the project costs and duration, optimistically. However, integrating real-world and virtual objects can indeed be complicated(Nushi & Basha-jakupi, 2017).Investigators identified four key issues that must be addressed: (1) the traceability system's origin also isn't associated with the world's coordinate system; (2) the shift from origin to item is not precise; (3) the simulated camera's placement is not accurate - mainly due to gravity and kinetic sensor mistakes; and (4) virtual webcam mapping doesn't really appropriately model the proper camera(Bozoglu, 2016) .

First, it is necessary to create geo - spatial characteristics for each BIM element so that the mobile AR system can use location data to determine the current location of the user and, as a result, be able to provide information about the regarded item (Arkitek, 2019).Second, from the point that the data demonstrated in mobile AR relates to a user's position, a few points survey conducted inside of BIM also must be recognised. Third, for BIM to be workable in a smartphone AR environment (Kotecha et al., 2021).

Design process phases

The design process is the fundamental basis upon which any component is built; it investigates how we accomplish what we accomplish. Mainly, it is a set of procedures that creative types use to create functional processes and products(Abowardah, 2016).The design process is the sequential development and analysis of a construction project. This method is usually divided into seven five phases to provide sequence to the project by recognising review periods, cycles developing a structured transfer of design documentation, and establishing the stages of construction. That is how the design process is critical; it organises project work and provides effective communication on design aim (Ulug, 2010). The stages of the architectural design process enable fast and straightforward production order, minimizing risk that might lead to costly, time-consuming disruptions. The architectural design process is consisted of main five phases; conceptual design, design, pre-construction, construction, operation and maintenance. as for each stage there are set of checklist included in(S. A. Kim & Kim, 2007) . Figure below clarifies design stages and main checklist for each stage.

Conceptual phase: The conceptual design stage formalises the preliminary concept. It helps to absorb engineering to give organisations a reliable assessment of commonly performance, potential looks, and a basic knowledge of the field of view of the on-going development, such as marketability, labour, and anticipated costs (Gericke & Blessing, 2012)

Design phase :A process concerns about a lifecycle of the project, concepts, procedures, materials, and milestones Discover how project design can enhance the productivity of a team with thorough resources and graphic elements (Aburamadan & Trillo, 2020).

Pre-construction phase: Includes developing a project strategy, designing the project, obtaining permits or allowances, and assembling the labour and resources needed for construction. Pre-construction solutions may provide shareholders a structured approach to working to evolve cost, scope, and timetable in order to complete the building on time and within budget. it is critical to the success of a project(Wang & Kang, 2011).Throughout this process, the development team organises, becomes associated in their perception,

And the basis of effective communication as well as process is set. A building project could indeed rapidly

become unorganised without a solid foundation, resulting in ineffective communication, gaps in the process, and prospective project delay (Mukkavaara & Sandberg, 2020).

Construction phase: the construction phase is a physical procedures of building, as well as all related processes including such landscaping, renovating, site preparation, and demolition(Rezaei et al., 2019).

Operation and maintenance phase :The Operations and Maintenance Phase's goal is to guarantee that the data system is fully operational and performing optimal way until the construction end of life(Basbagill et al., 2013).

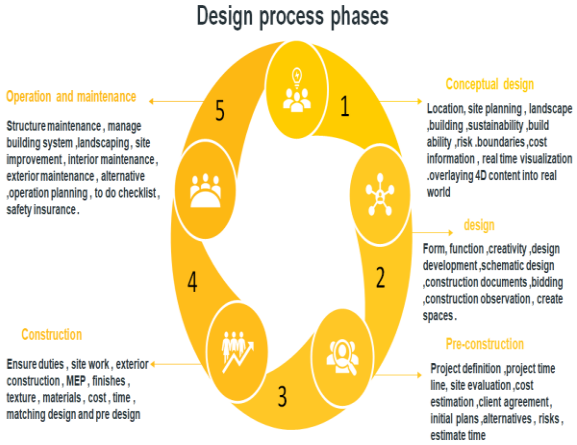

Fig.1: design process phases duties from previous studies by author

Previous theorist conducted augmented reality application separated without considering the transition towards BIM., as for that this paper distinguished in including case studies of AR through design stages as multi aspects ; architecture design and other (pre design ,interior design ,construction ,maintenance) . (Calderon-hernandez & Brioso, 2018)(Zollmann et al., 2013)(Morton, 2001). The objectives of this paper a to investigate potentials of AR_BIM in AEC industry, and compare the adoption percentage of AR_BIM in AEC in design phase.

2. Methodology

PRISMA-P approach has been used to conduct this systematic review. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), it is a minimal collection of evidence-based elements for reporting in systematic reviews and meta- analyses (Kamioka, 2019). This method was developed in 2009 and, owing to its repeatability and It is employed in an expanding variety of scientific and technology research domains due to its capacity to facilitate the creation of increased syntheses(Donthu et al., 2021). All relevant research processes were detailed, including information source materials, search method, inclusion and exclusion criteria, as well as the primary instruments for assessing bias in eligible research(Stewart et al., 2015).

The purpose of this study is to establish a framework for and classification of AR applications in architectural design. Researchers adopted a systematic literature review by the investigation of augmented reality-BIM in AEC .The major two academic sources, Scopus and Web of Science, were employed for the study As shown in Table 2. Procedure were AUGMENTED REALITY, BUILDING INFORMATION MODELLING, BIM BASED –AR, AEC, PRACTICE. The rules for research was based on :(augmented reality), (BIM Bases AR), and (AR adoption in AEC). All articles with the above keywords in the title/abstract/keywords were selected to this study .A 79 articles were selected from total 120 after inclusion criteria for further analysis.

TABLE 2
INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria	Exclusion Criteria
Related to AR	Related concepts as VR and MR
Related to BIM	Non BIM concept
Published from 2010-2022	Published before 2010
English language	Publication as non-English
Peer reviewed	Non peer reviewed
Published article	Unpublished article

As for inclusion criteria the bolometric method was adopted as following steps:

1. identify key words; BIM, Augmented reality, construction, design process.
2. Include articles from the period 2010 to 2022
3. Include articles which are published
4. Articles from web of science, science of direct and Scopus
5. Include articles in English language

However the adopted PRISMA method is shown in figure 2 the articles were extracted from multiple databases in about 120 articles, after the inclusion criteria it was about 79 articles for the study.

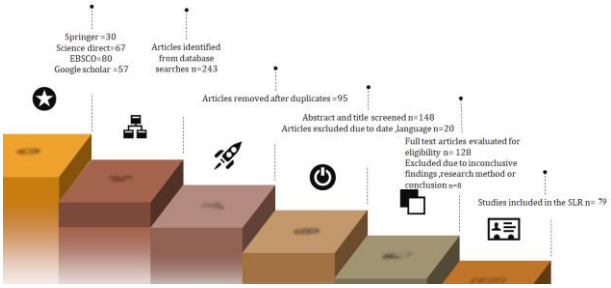

Fig 2 : Bolometric analysis of the selected keywords and prisma method (J. Grant, 2015)

After adopting PRISMA method about 234 articles were found associated with the identified keywords and from 2010 to 2022.as figure 3.

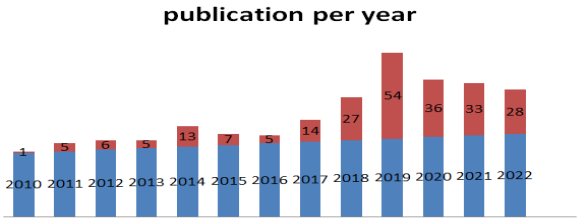

Fig 3: Publication articles per year of the keywords "BIM"AND AUGMETED REALITY

The following chart illustrates the selected articles from the previous method, before applying inclusion and exclusion criteria. Moreover these articles are categorized into five phases based on design process that includes conceptual design, design, pre-construction, construction, operation and maintenance .Figure 4 illustrates numbers of articles based on design process.

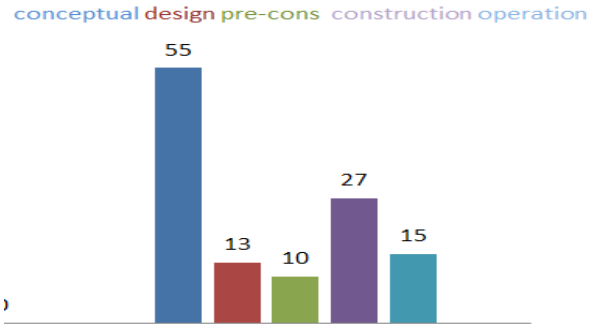

Fig 4: Number of articles based on design process

Data collection: this research is focused on identifying AR research and applications in architectural practice and education based on previous studies. Academic journal and conference publications from 2010 to 2022 were primarily evaluated for paper retrieval. For scanning, the most comprehensive academic databases, Scopus and Web of Sciences, were employed. The keywords set including AR, AEC industry, architecture education, BIM aided AR

Data analysis: A few keywords are used to examine the selected papers. The keywords were taken from a few previous content analysis studies. This study's keywords include augmented reality in AEC, the concept of augmented reality, and applications. Data is categorized under the architectural discipline, where augmented reality is deployed.

3. Augmented Reality: Use-Cases, and Benefits

This study will focus on AR_BIM through design stage among different projects it will be divided into architecture design cases and engineering and construction

Including design phase revisit of suggested solution, an d construction stage tracking of project construction.Ho wever other pertinent utilise scenarios, such as layout enh ancement, excavation, placement, inspection, cooperatio n, supervisory, commenting, , must be considered, as not ed by earlier theorists(Al-kazzaz, 2018).

Various representative utilise cases are defined throughout the preceding sub - sections. focused on construction projects (tunnel, railways and bridge) and an office complex A BIM-specific software device was used in each of the provided use cases to obtain BIM models

in addition to use the fully integrated AR solution (Redondo et al., 2012).The phone applications make use of a BIM shared information environmental solution, which serves as a central gateway for all individual interaction, information sharing, and other functions (Elsamahy, 2016).

AR has evolved into a powerful visual tool for architectural learning and education, and it is currently undergoing significant growing research (Kopiec, 2018). AR models have been utilised in learning and design environments to present learners with previously unavailable real-life experiences. Once architectural designers use VR, they will be able to rapidly understand the spatial features of their projects(Brusaporci, Ruggieri, & Sicuranza, 2017) . It will be able to comprehend their creations by strolling around the augmented area and seeing the colouring and textures of the given materials, the proportion of the spatial structure, and the aesthetic representation.(Alizadehsalehi et al., 2020). Furthermore, interactive and immersive virtual augmented reality (AR) technology assisted its building industry clients in the design, simulation, branding, and new project sales by conducting a pre-construction walk-through in the augmented townhouse where last-minute design concepts were evaluated. AR will be crucial in the teaching of cultural structures. Designers can use AR technology to create a training application in which they can engage with virtual objects to learn how to construct traditional buildings. Furthermore, research on the adoption of AR revealed that the architecture was changed, employee happiness rose, and costs were reduced (Hajirasouli & Banihashemi, 2022).AR may encourage some of the same behaviour as virtual reality and practical mock-ups, such as decision-making, alternative , descriptive, interpretive, in design and build ability analysis sessions, and problem-solving actions (Sirror et al., 2021).

Case studies of augmented reality projects

This study includes fifteen case studies in AEC industry. Despite the fact that the construction sector is among the earliest and most vital in the world, new tools for the employment frequently perform poorly to gain traction. There is lack in articles which are consisted of AR_BIM cases studies and projects(Lee et al., 2020) . From the other hand author have collected the most significant and available case studies in this field .case studies selected and justified by Table 3:

Table 3
DESIGN PROBLEM SOLVING THROUGH CASE STUDIES

Case	Real site problem
1	Provide data before going to the high safety risk zone underground the construction site
2	Hard Topography in the location to perceive design heights
3	The shifting towards modernism architecture covered the importance of saving historical buildings
4	The challenge of Different materials and components in one staircase
5	There was concealed items under the plumping system which makes design imposed
6	It was difficult to educate graduate in prototyping a specific design in a physical location by traditional learning
7	The environment around this construction project was unsafe besides the infrastructure was covered with muds
8	During Coved pandemic exhibition and galleries was shut off.
9	Design waste by users was at the maximum stage
10	Designers must present their works in a certain location ,users travelling was necessary
11	Exhibition carbon emission was high at the physical enrolment.
12	Project teams are from around the world and not in the same site.
13	Coordination by Google map was not enough to design and positioning and scaling
14	Imagination that was based on calculation is difficult to be generated by human
15	Difficulties in site topography and perceptions in mocking up design.

The selection process of case studies and project is based on identify AEC projects of augmented reality which is implemented in design process .specifically as representation tool adding that the adoption of AR must be integrated into BIM .

1. Lukasz Carnot Mercantile Hotel

The planned structure is the current Mercantile Hotel. The suggested AR app process for monitoring and inspecting construction phase will be analysed by viewing the segmental accomplishment of construction operations on the projected development of the current

Mercantile Hotel. AR technology employed to overl the intended 3-D model on the actual world in order lead the construction crew through the assessment a monitoring of planned worksite operations. The approa starts by combining the BIM with the constructi programme to produce a construction sequenc animations to observe and track construction pha enabled the identification of important project stages and the communication of the anticipated project timetable to all project participants (Ordóñez et al., 2020).

The application's key advantage is its marker-based innovation, which enables the user to rapidly and accurately match the suggested BIM with the actual environment, as illustrated in Figure 5. The following are the tasks conducted by the researcher to evaluate the procedure and the augmented reality app for tracking work progress.(Ordóñez et al., 2020)

Fig5: Proposed hotel and marker based tech on the real environment

2. IGA 2017 Berlin channel

A digital walk by this area was created by radar .The RADAR-system was created by the Kaiserslautern Research Artificial Intelligence Centre (DFKI) as shown in figure 6. RADAR is a platform that allows people to place their own geo information on a map and link it to related information and material. The geo-referenced material may then be delivered to AR browsers such as Layer. The RADAR system provided clients with an easy programme that allowed them to quickly materialize their own concepts (Broschart & Zeile, 2015).

Fig 6: channel of IGA berlin 2017 between the conceptual AR and executed project

3. Building Culture Saarbrucken projects in 1950s (vision)

The town of Saarbrucken intended to employ innovative methods to educate and sensitize property owners about the unique features of this building. Especially with certain "poor" modernizations going on by the landlords, or a large amount of outdoor advertising on street level, the city's effort is critical to keeping the heritage alive(Nayyar et al., 2018). Original colour photos from of the 1950s were exhibited in the current scenario on the phone's screen to examine what the town looks like at the period. As augmented information upon that façade, features of 1950s design were emphasized. Images of the stairs were also presented as overlaying data on the exterior to indicate what type of treasure the structures hide on their insides. As shown in figure 7, the users can take a virtual walking through the project, gain a sense of the past, and learn how the town of Saarbrücken aims to bring the vibe again into modern-day life on the streets. Apart from the walking tour around Saarbrucken's streets, there was additionally central information station in the market place that allowed everyone to stay informed before, during, and after the event through using augmented brochures and flyers. Individuals who were unable to attend the physical tour seemed to have the opportunity to explore the town as a virtual three -

dimensional model. With common CAD application .every station that use AR seems to have four points marker which helps uses to enjoy light and shadow during day(Höhl, Wolfgang & Broschart, 2015).

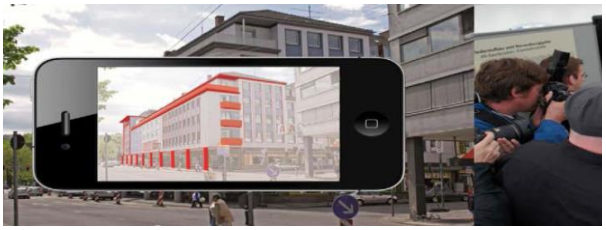

Fig 7 :Augmented architecture elements of 1950s structure in Saarbrucken

4. Railway Footbridges

Council members approved the second stage of the plan to preserve the railway line at Dawlish, which will result in significant advancements to a historic Brunel train station. Network Rail is adopting AR Technology to communicate future architectural projects into general public, designing city and allowing the audience to be actively engaged as from early stage of the design choice all the way through construction. AR enables the improved alignment between construction and design .also it supports the diversity in materials selection between clients and designer. The key variable in this design is the long span of the footbridge which was solved by the mock scaling that AR offers during design, each footbridge was visualized over various spans .Figure 8 shows the final design visualized on the real environment ,it shows alternatives for one design (Dawson et al., 2016).

Fig 8: Railway foot bridge alternatives designed by AR_BIM

5. Plumbing system

Maintenance employees must quickly learn a wide range of skills. Instead of discovering usable data from a huge number of plans or damaging existing buildings, sophisticated technical tools may swiftly locate the maintenance location in a significant number of concealed engineering as shown in figure 9. As companies make improvements to buildings and outdoor areas, AR systems may allow maintenance personnel to avoid concealed items such as underground plumbing, electrical cables, and structural components. This has the potential to either accelerate maintenance and reconstruction activities while also reducing the amount of unintended harm they typically cause. A "see-through" component for tracking the position of piping and ventilation system behind walls and panel, as well as other hidden components like walls and beams, might make maintenance tech and reconstruction easier (Panuwatwanich et al., 2013).

Fig 9: Review plumbing system mapping using AR_BIM in site

6. Studio project

This was a small project to educate architects in prototyping the same design using augmented reality, first the project modelled through BIM and then visualize

through augmented reality, then multi options for the same design came based on location, and weather, Figure 10 illustrate that AR helps designer to set the scheduling step exactly where the green colour views the items that under process .the construction of this project was implemented on time by the help of mixing AR into BIM. As for this study some advantages were seen by AR implementation as follows: it sets the existing building beside the real environment, and identifies colours and materials .also it identifies construction materials in details. (Sandkuhl & Lehmann, 2017).

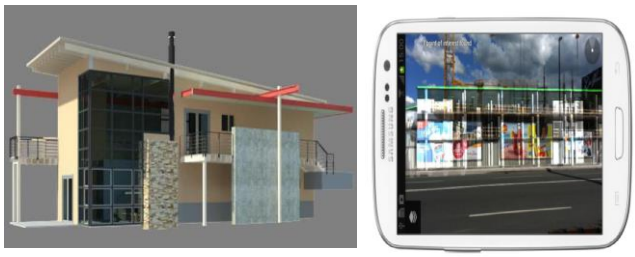

Fig 10: AR-BIM model for a studio project

7. Warsaw road swing bridge

Warsaw Road Swing Bridge was built in 1956. According to city employees, around 10,000 cars cross the Warsaw Road Swing Bridge per day. According to engineering examinations, this bridge was reaching the end of its usable life. Parks Canada offered a bridge repair as component of the infrastructure upgrades along the Waterway National Historical Site in 2020, following a period of study and design work. The goal of this initiative is to improve historical, tourist, waterway, and roadway assets inside national heritage landmarks, national parks, including national coastal nature preserves to provide safe, rising visitor experiences (Werner, 2017).Figure 11 illustrates the integration of AR_BIM in a real site plan.

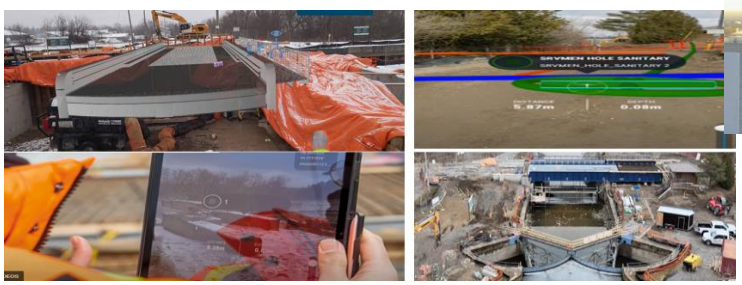

Fig11: Warsow road swing bridge design progress by AR

8. RIXC Centre for New Media Culture

Senses Art released by the RIXC Centre Culture in 2021. It is a Navigation augmented reality application that invites users to virtual exhibitions hosted outside. It presents digital art collections are housed close to the Latvian National Art museum near Riga. Figure 12 illustrates that Individuals may experience the outdoor exhibit securely and with their own time(Abboud, 2014).

Fig 12: RIXC Center exhibition through AR

9. AUGMENTED BERLIN art work exhibition

Anika Meier have produced an augmented reality art show as in Figure 13; Fashion Week This interactive group show including augmented reality art encourages virtual guests using a phone or tablet to put eight artworks by Berlin artisans in public spaces or even in their local walls. Such augmented reality program does not necessitate users travelling. Rather, people all over the globe are encouraged to utilise the application in their local communities to bring artwork by Berlin designers out of their local homes or public space(Alessandro & Luigi, n.d.).

Fig 13: Berlin exhibition using AR

10. The Seeing the Invisible exhibition

the unique exhibition of its sort created in partnership with botanic garden as well as art organizations from all around the globe as seen in Figure 14, Seeing the Invisible is a collaboration between the Jerusalem Botanic Garden as well as the Outset Art Collection Found that will take place in Twelve gardens around the world between September 2021 to August 2022.The exhibition includes Thirteen pieces by artisans using augmented reality. Visitors can join the exhibition by using a tablet or smartphone application that is enabled at the local gardens. Despite the fact that all gardens feature the identical exhibition, the artworks are presented in different places, providing spectators with diverse viewpoints depending on their location in the world. Because of the structure of AR, there has been little disruption to the grounds of the participating botanic garden, and the exhibition's carbon emissions have been reduced to a minimal(Cucuzzella, 2021).

Fig 14: The seeing exhibition using AR

11. Historical story telling (L'Aquila Historical Centre)

Due to the 2009 earthquake, the town of L'Aquila's urban layout has changed dramatically. There is a distinct gap between the physical ultimate reality of places, the result of history which has brought it to the current, and the dimension of the invisible as the junction of memories and daily existence Figure 15 clarify AR application in designing façade .(Brusaporci, Ruggieri, Sicuranza, et al., 2017).

Fig15: L'Aquila Historical Centre using AR

12. Iskra Mehanizmi Brnik industrial building

"Industrial and commercial building Iskra Mehanizmi Brnik"is split into to three main blocks, the commercial part which includes reinforced structure, the other two part is regarding to storage and production units constructed by prefabricated concrete. This case study focuses on the office building part, this case clarify AR adoption along lifecycle as shown in Figure 16. Different data was available and includes BIM model connected with augmented reality part. BIM model includes geometrical and non-geometric design data including as geography through location (3D), technical requirements(4D) as doors and windows manufacturers, and professional maintenance (5D).The correlation of the three - dimensional model BIM and augmented reality is accomplished basically through three key components: the three - dimensional BIM on its own, the entire readout, and the transition of the information for analysis in AR via a suitable app on a portable device, as tablet for this case. The 3d BIM provides and receives BIM data, including such installation modification needs and project planning evaluation, to allow visualisation on the AR system, enabling the user to engage with three - dimensional model BIM as well as other participants of the construction team. in actual environments(Scoresby & Park, 2021).

Fig 16: Industrial Building using AR

13. Railway project

This is a construction project as second railway track from Divaa to Koper, which comprises the construction of much more than 17.4 kilometres roads leading with different structures functioning as service areas for tunnels, retaining structures, and a 35-meter-long bridge. It is one of Slovenia's major infrastructural projects (Chi et al., 2013). This case study fits under design and planning stage of the whole life cycle, allowing AR to see the construction project structure in addition to the entire building in the real surroundings. the aim of this case was to investigate how AR and its application in the chosen smartphone app may be utilised in infrastructure projects which are largely defined by great distance(Dong et al., 2013).

To evaluate this case study, a tablet device with an augmented reality app was utilised in two distinct sites a few kilometres apart as shown in Figure 17. However, in a design model on the tablets .Both are mapped and correctly integrate the needed information in the three - dimensional model. It deploys AR technology to see 3D interactive simulations on site. It was able to inspect the tunnel entrance and MEP systems, in addition to the train line to be built, in addition to the overall magnitude and difficulty of the building site(H. M. Chen & Huang, 2013).

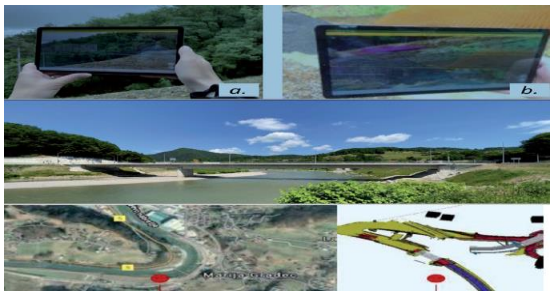

Fig17: Geo position by Google map and coordination by BIM model and AR

14. Gravity Garden by Ivo Ambrosi

Gravity Garden is a natural space created by applying external forces to a basic pre-defined shape as shown in Figure 18. The architecture is defined by the algorithm that describes its genetic code. The optimization of the mathematic algorithm that generates the structure, determined by software, defines its ultimate shape, much as nature uses the bones of a creature or the leaves of a tree. The size and dimensions are directly related to what is required for its own survival(Baumgartner-Kiradi et al., 2018).There is little opportunity for the architect's own creativity, and the "inventor" goes a step farther in this evolutionary process, watching and controlling the continual progress of his product from the outside. And manipulating project size and scale(Kerr & Lawson, 2020).

Fig 18: Gravity garden by AR –BIM

15. Extended building

Site Vision uses a BIM model to demonstrate how to envision a building using augmented reality, completely textured together with the environment. Because the house is on a slope, Site Vision displays how the model would seem in this difficult context as it seen in Figure 19. AR includes: - To use the "Create New Model" tool, place one of the border pegs. Setting up over a known point like this offers you a local coordinate system to operate with; the Sketch Up axes will be in this place. - Obtaining points - How the structure interacts with other structures. By AR it’s useful in assisting your design process and displaying how the design interacts with the real world with the location workflow (Agirbas, 2020).

Fig 19: Building integration with site

According to previous studies AR_BIM benefits summarized into a list as shown in Table 3

TABLE 3
AR BENEFITS THROUGH SELECTED CASE STUDIES

AR benefit code	AR benefit
B1	Real time visualization
B2	Design making
B3	Improve collaboration
B4	Spatial interaction
B5	Detect errors
B6	Problem solving
B7	Clients feedback
B8	Reduce waste
B9	Improve productivity
B10	Improve quality of design
B11	Improve safety
B12	Present details
B13	Improve communication
B14	Collect data easily
B15	Spatial aspect detection

The fifteen cases are selected based on AR_BIM adoption, there are two main parameters that were fulfilled through; form and function, each parameter has a specific reflection in designing a project, as shown in table 4.

TABLE 4
AR CASE STUDIES PARAMETERS

case	Parameters included through AR (A)Form/(B)function	case	Parameters included through AR (A)Form/(B)function
1	Geometry alternatives- A	8	Reduce time and effort -A
2	Movement track -B	9	Pick colours -A
3	Geometry /shade/shadow- A,B	10	Pick plants /shade /shadow -B
4	Accessibility - B	11	Track movement -B
5	Infrastructure - B	12	Building orientation - A
6	Geometry /materials/orientation- A,B	13,14	Façade reconstruction -A,B
7	Ensure safety- B	15	Decrease waste - B

Figure 20 illustrates AR_BIM projects that concentrate on function, form, form and function together; this was an indication that the majority of AR_BIM cases are reflecting function issues

, the majority of these cases are related to construction and engineering as:

(Form)A: 5 cases almost 33 %

(Function)B: 7 cases almost 47 %

(Form and function)AB: 3 cases almost 20%

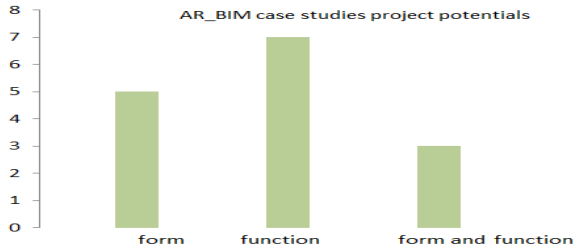

Fig 20:AR_BIM projects potentials in form, function, form and function

To discover the uses, advantages, and challenges of AR throughout the phases of the building project's lifetime, a literature review was accomplished involved thorough scan of the literature by using Google Scholar searching engine Several terms, including Augmented Reality, AR, utilization applications, advantages, literature evaluation, construction stages, construction projects lifecycle, design, construction, and maintenance to mention a few. This search produced With 120 papers gathered from conferences and journals between 2010-2022 as shown in Table 5 (Permodelan et al., 2019)(AlSawalqa et al., 2021)(Bekr, 2017).

TABLE 5
AR_BIM REFERENCES in DESIGN PHASE INCLUDING BENEFITS

Reference 1-79	AR-BIM phase code	AR-BIM benefits included in papers	Phase
25	CD	_visual construction details (MEP system. _underground visualisation _system mock up _real time project modelling _connect project with surrounding -conceptual layout _overlay 3D design into physical world	Conceptual design
13	D	_prepare 3D models -select materials and colours	Design
10	PRE	_Review along design _clash detection	Pre-construction

		_sequence planning _clarify design early _operate equipment's and set them _full site scale _safety orientation	
17	CON	_visualising models in field _layout preparation _site layout -4D simulation _monitoring workflow	Construction
13	OM	_locate building contents that needs maintenance _compare alternatives pros and cons	Operation maintenance

Table 6 illustrates the selected projects that adopted AR_BIM in design phase; each cases study has recorded specific benefits through adopting augmented realty application into BIM. The selected cases categorized as Architecture or construction. The project was varying into small projects, mega projects or details inside a project A small conclusion was defined by author correlated with AR-BIM.

TABLE 6
DESIGN STAGE for THE SELECTED CASE STUDIES

Case study (project)	**Phase Architecture/construction**	**Main aspect that fulfilled through AR-BIM**
1.Mercantile Hotel	construction	1.Project time line 2.presentation 3.montoring site progress 4.compare design workflow 5.geometric sequence
.2.IGA 2017 Berlin	construction	1.movement tracking for the chairlifts 2.check how building fit surrounding 3.site layering 4.put geo located information and heights
3.1950s architecture in Saarbrücken	Architecture, construction	1.convinence way to persuade architects through A cultural style for this city 2.guided tour into the project 3. Adopted day lighting and shadow through the ex
4.staircases	Architecture	1.identify the specific area as 3D design
5.plumbing system	Architecture	1.rapid maintenance 2.see behind hidden infrastructures
6.studio project	Architecture	1.presentation technique better that traditional 2.prototyping based on weather and location 3.identify design scheduling 4.locating construction materials on site
7. warsaw road swing bridge	construction	1.reduce errors 2.improve productivity 3.simplify field work 4.redesign and renovation 5.improve heritage
8.RIXC Center for New Media Culture	Architecture	1.reduce efforts and time in visiting the station of this museum 2.give the sense of place for individuals who participate in this experience 3.propmots new forms of arts by AR
9.Berlin's AR artwork	Architecture	1.AR helps in designing Berlin fashion week 2.control colours 3.no physical attendance
10.The Seeing the Invisible exhibition	Architecture	1.presentation of arts through gardens 2.pick the appropriated kind of plants 3.check shade and shadow
11.Railway track	construction	1.junction of memories and actual design 2.best design façade
12.Iskara commercial building	Architecture	1.project planning evaluation 2.useres engagement in design
13.historical storytelling	Architecture	1.facad reconstruction 2.intersection between history and memory
14Gravity Garden by Ivo Ambrosi	Architecture	1.generate design shapes 2.life size model 3.perform an assessment of light 4.walk through model
15.site extended building	Architecture	1.facilitate workflow for construction site due to the difficult slope 2.provide accurate data to smooth design

This paper includes five design stages: conceptual, design. Pre-construction, construction and operation .each stage is given ten points including criteria that it concerns in. according to these criteria points are given for each phase in the selected cases as shown. Figure 21 illustrate design process checklist for conceptual design, design, preconstruction, construction, operation and maintenance .author conducted this checklist based on previous theorist.(Mahmoodi, 2001)

Design process /identify stage /points

Case no	Conceptual design %	Design%	Pre-construction %	Construction %	Operation and maintenance %
1	0	0	10	50	40
2	50	40	10	0	0
3	60	40	0	0	0
4	10	10	30	40	10
5	0	10	20	20	50
6	60	40	0	0	0
7	10	10	20	30	30
8	50	50	0	0	0
9	50	50	0	0	0
10	50	50	0	0	0
11	10	20	30	30	0
12	20	20	20	20	20
13	10	10	20	30	30
14	40	60	0	0	0
15	20	20	30	30	0

Design process checklist

Checklist	Conceptual design	Design	Pre-construction	Construction	Operation and maintenance
1	Analyze context	Meet demands	Project teams	Ensure construction duties	Building structure maintenance
2	Location	Create spaces	Project definition	Site work	Manage building system
3	Site planning	Form	Project timetable	Exterior construction	Landscaping
4	Building	Function	Site evaluation	MEP	Site improvement
5	Landscaping	Creativity	Cost estimation	Finishes	Interior maintenance
6	Sustainability	Design development	Clients agreement	Texture	Exterior maintenance
7	Build ability	Schematic design	Initial plans	Materials	Alternatives
8	risk	Construction documents	Alternatives	Cost	Operation planning
9	Boundaries	Bidding	Risks	Time	To do checklist
10	Cost information	Construction observation	Estimate time	Match between design and pre design	Safety insurance

Fig 21: case studies design stage points, and main design process checklist

From the previous checklist of design process each case study has adopted Augmented reality with building information modelling along design process components .it was noted that the majority adoption was referred to conceptual design in about 33 percentage and to design

phase which was about 28 percentage .followed by 17 percentage for construction .and 13 percentage related to pre-construction .as for operation and maintenance 9 percentage. As shown in Figure 22.

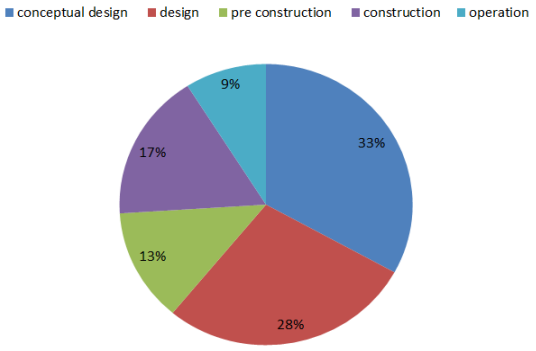

Fig 22: case studies and main aspect of AR_BIM adoption in design phase

Conclusion

This paper presents an overview of Augmented Reality (AR) applications associated with BIM across design process. According to the publications gathered from 2010 to 2022, AR offers a wide range of applications in architectural design, construction, and education. The primary applications included Many writers noted that architects found AR applications to be quite useful in overcoming a lack of time and other resources(Cannaerts, n.d). They also stated that AR assisted architects in understanding concepts in difficult courses such as buildings and surveys(Häkkinen et al., 2015).

Employing AR for architecture designers would allow them to comprehend the spatial aspects of their designs and understand their projects by walking around the virtual world. And visualize the texture as well as colour of the allocated materials(Wong, 2011). The ratios of the spatial structure and the artistic expression of the structural elements AR improves experiential learning and provides optimal engagement levels to successfully transmit knowledge to learners when it comes to improving construction education. Designers may use augmented reality (AR) technology to construct a learning tool that allows them to create conventional structures and interfacing with virtual models. Furthermore, research on the utilization of AR revealed that the architecture was changed, employee happiness rose, and expenditures were reduced. Improving construction education promoting practical learning using AR provides appropriate engagement levels to successfully convey knowledge to learners(M. P. Grant, 2012). Students and practitioners in construction must visualize various building approaches and attend field trips. This may necessitate visits to building sites to bridge the gap between theory and practice. AR enables researchers to follow, record, and evaluate human decision-making behaviours in a controlled setting with great precision and in short time periods.AR may integrate safety with construction materials and techniques instruction by offering a creative platform for spiritually enhancing hazard awareness ability, transmitting safety knowledge, and guiding learners. AR technologies have emerged for construction and have been utilized in architectural and design simulations, construction safety & health, in equipment's and operational duties, and analysis. (Freitas & Ruschel, 2013).

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