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BIM Improved with RV and AR Technologies

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Abstract

The study addresses the integration of the Building Information Modelling (BIM) methodology with Virtual Reality (VR) and Augmented Reality (AR) technologies in the context of the development of a multidisciplinary project, involving architecture, structures, water network and electrical system components. In order to cover in detail the various design features, the case study was limited to a specific area of a house, the sanitary rooms, as it presents sufficient complexity in modeling and the application of VR and AR software. The VR/AR functionalities applied over the BIM model increase the potential of BIM in the construction sector, contributing to the achievement of a high level of collaboration and control of the project based on an immersive and interactive environment. The elaboration of the different phases of a BIM design requires the transfer of models between BIM and VR/AR systems, allowing us to analyze the main advantages that BIM/VR/AR integration can introduce in the construction industry. The study contributes positively to achieving new knowledge in BIM, being disseminated in an academic research work and illustrated in a practical context.

Keywords

BIM, Multi-Disciplines Modeling, Virtual Reality, Augmented Reality, Integration BIM/VR/AR, Collaboration

1. Introduction

Building Information Modelling (BIM) is a methodology supported by advanced technology software that allows the development of virtual digital models composed of parametric objects associated with a height level of detailed information about the materials and related physical properties [1]. Using BIM software, a model is created for each project in progress, presenting a great geometric detail and behavior precision, supporting the elaboration of different phases concerning the design evolution, the construction work and, after occupation, the management and maintenance activities [2].

Erik Jan Van Nederveen and Frits Tolman mentioned the first reference to the term BIM in 1992 [3]. Since the 1960s, the fundamental concept, that is the modelling process associated with embedded information, was mentioned with the term Building Modelling. Currently, the acronym BIM refers to Building Information Modelling. Its main concept, its methodology of working and the large range of its applicability in a wide set of construction disciplines and related activities has been adopted by several countries [4]. In order to encourage BIM implementation in the construction industry, governments have carried out oriented legislation to promote the increase of its adoption [5]. In addition, Virtual Reality (VR), a technology that allows users to interact in an immersive way with digital models, has been widely applied in the context of building design and maintenance [6].

The construction industry has sought to increase the digital level in all sectors. The implementation of the BIM methodology has contributed very positively to the streamlining of procedures, productivity optimization and construction quality control. Additionally, VR and AR technologies have often been applied in the sector. However, the integration of the two resources is still limited. The objective of the work is to approach BIM + VR integration, analyzing procedures, available systems and applicability.

The BIM methodology allows the creation of models with diverse volume and type of information, supporting the development of different applications, and is applied within the scope of a multi-disciplinary project. In the present study, a building case was considered. The practical research explores the association of the integration of the technologies BIM and VR illustrating the improvement of BIM methodology when incremented with VR functionalities [7].

2. Virtual Reality

2.1. Concept and Evolution

Virtual Reality (VR) is a technology with the ability to represent environments, created by computers, and interact with the model, in order to provide users an immersive virtual simulation. The digital simulations can represent the reality or complex projects in development [8]. VR allows the user to experience situations in an interactive virtual three-dimensional (3D) environment [9]. In 1957, Morton Heilig created the first multi-sensory simulator, called the Sensorama Machine (**Figure 1(a)**).

This simulator was created with the purpose of allowing the user to experience sound, smell, wind and vibrations while watching a movie. The first time the idea of immersing oneself in a virtual world, simulating the real world, and interacting with it, was mentioned by Ivan Sutherland, in 1965 [10].

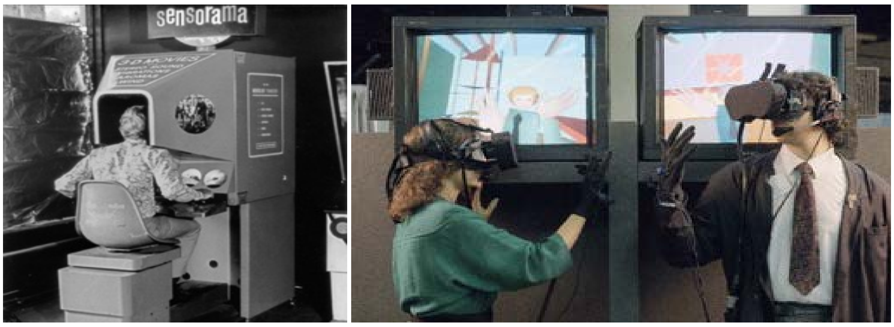
In 1982, Thomas Furness created the flight simulator, the Vehicular Collision Avoidance Support System (VCASS). It presents technological advances, enabling a helmet to display and provide the necessary information for learning simulated flight training. The first VR device commercially available was the DataGlove, in 1985, and after the head-mounted display (HMD) (**Figure 1(b)**). The main component of an immersive experience consists of visual stimuli, obtained from screens or stereoscopic displays, devices that allow the 3D visualization of the modeled objects. The way users can interact with the virtual environment that surrounds them is through hardware such as keyboards, mice, controllers or gloves.

2.2. BIM/VR Integration

For the construction sector, the main advantages are based on the use of VR as an aid tool in construction planning, in a more efficient layout of the construction site and in the verification of incompatibilities along the real construction work. In addition, the development of new construction procedures can be studied and trained in a VR environment. In the search for solving feasibility problems, it is possible, in the design phase, to analyze the alternative solutions that best suit the uniqueness of each one.

VR technology can be applied in addition to the BIM concept. The BIM model, composed with all the details defined for all disciplines, can be exported to a virtual reality system, allowing the user to experience the inherent advantages of immersion and interaction. In the present study, the export process from the BIM model, of the selected study case, to VR and AR software has been evaluated in order to identify the degree of interoperability between systems. In it, the main identified limitation was that the changes made directly on the VR system are not automatically updated in the original BIM model. However, the most recent technical advances, concerning the interoperability capacity verified between BIM and VR/AR systems, have brought some positive contributions. As so, more integrated systems have been developed, promoting better interoperability and, therefore, better efficiency of the BIM/VR/AR process [10].

The BIM model is an adequate basis for study and collaboration between partners, but the addition of VR leads to an increase in the ability to realistically visualize and understand the project. With the immersion of the user in the



(a) (b)

Figure 1. The Sensorama Machine (a) and head-mounted display (HMD).

model space, the level of communication and understanding between the various stakeholders is thus increased. The user can view the model at a full scale and even observe any inconsistencies identified in the project, being able to easily correct them in the BIM model. The simulation of the construction evolution in a VR environment allows the analysis of the different approaches to the construction design and planning. It can leads to a reduction in costs and construction time, as well as a reduction in eventual errors and to verify that the planned construction methods are effectively viable. In the present study, in order to support the illustration of the applicability of BIM/VR/AR a building case was modeled [7].

3. Case Study: The Sanitary Rooms

For the accommodation of the sanitary service facilities, it was necessary to first model the architectural component (**Figure 2**). The representative object of the exterior wall was defined, following the order of layers of material from the interior to the exterior, with porcelain stoneware tile, mortar, stucco, 11 cm thick brick, extruded polystyrene (XPS), air box, 15 cm thick brick and plaster. The generated parametric objects were used in the 3D representation of the walls of the model, based on the previously defined alignment grid and applying a restricted height to the two floors considered. A small wall was also modelled on the roof. The modelling base corresponds to the floor designated by the roof and its height was limited to the value of one meter.

The Revit material library contains several types of materials. However, it is possible to adjust the different physical properties associated with the materials and even create new ones from those available in the library. In this case, new materials were created in order to correctly model the project, not only in its geometric presentation, but also in the type to be applied.

In the surroundings of the two sanitary rooms, that were considered, distinct type of walls, windows and doors were modeled. In addition, the floor and the roof were represented as reinforced concrete slabs. Both components compose part of the structural solution, which is complemented with two columns and an upper beam, of reinforced concrete. The BIM system used was Revit (Autodesk).

The water and electrical supply systems were also modeled using the same system. The software contains a large library with some of the parametric objects related to the water supply and waste networks and electricity net definition. In addition, other complementary elements were easily found on web pages provided by Autodesk.

Prior to modelling of the water systems, it was necessary to insert, in the model already created, the equipment usually applied as sanitary facilities. As so, bathtubs, showers, washbasins, taps, bidets and toilets were imported from the BimObject website. In Revit, through the Systems menu, the Plumbing Fixtures option was selected, allowing the insertion and correct positioning of all equipment in the 3D model (**Figure 3**).

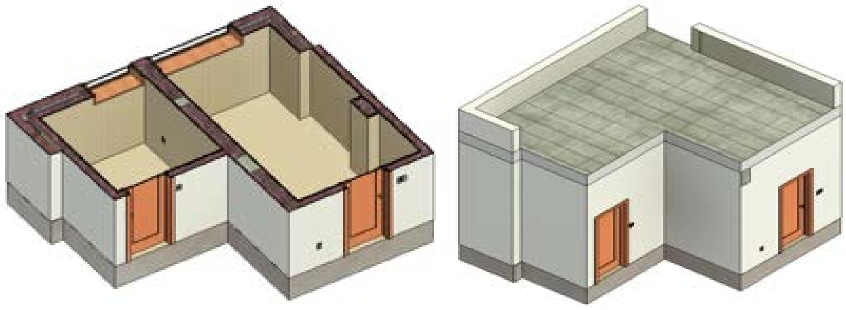


Figure 2. Architectural model (inside and outside views).

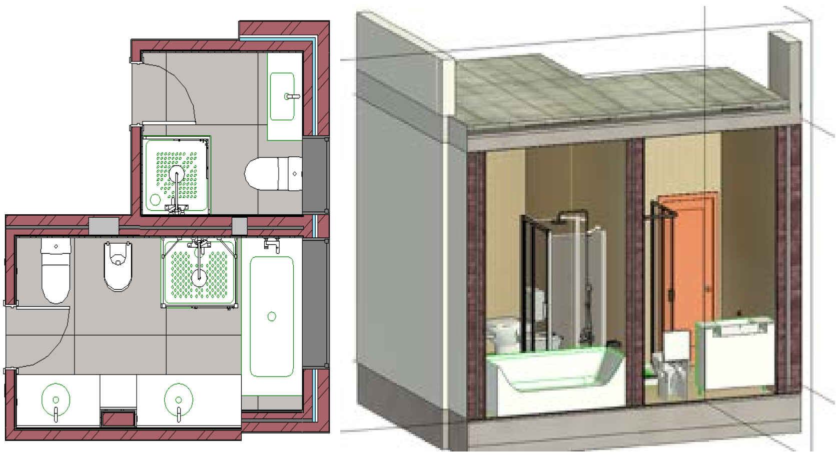


Figure 3. Model with the sanitary equipments.

The water supply network establishes the connection between the public network and the various equipment located in the sanitary rooms. Over the model, when selecting a device that requires water supply, two blue and red icons are displayed over the model, corresponding to cold and hot water, respectively. After selecting one of the icons, the chosen pipe network is generated. For that, it is necessary to indicate the characteristics of the pipe section such as the desired diameter and its elevated position (**Figure 4**).

The modelling of the piping network for water drainage is very similar to the design of the model for water distribution networks (**Figure 5**). As indicated in the project provided, the material applied corresponds to polyvinyl chloride (PVC). This material was created in Revit as a new material, and the graphical appearance and associated properties were properly established.

For the modelling of the electricity project, it was necessary to down load, to Revit system, the required families of parametric objects concerning several type of devices, namely, double switches, light points and single-phase sockets with earth. In the modeling process, the socket devices were selected, through the Power option, followed by the Edit Circuit icon, and they were added to the circuit. For the circuit of switches, only the lighting corresponding to each sanitary installation was selected and only the switch corresponding to it were connected (**Figure 6**).

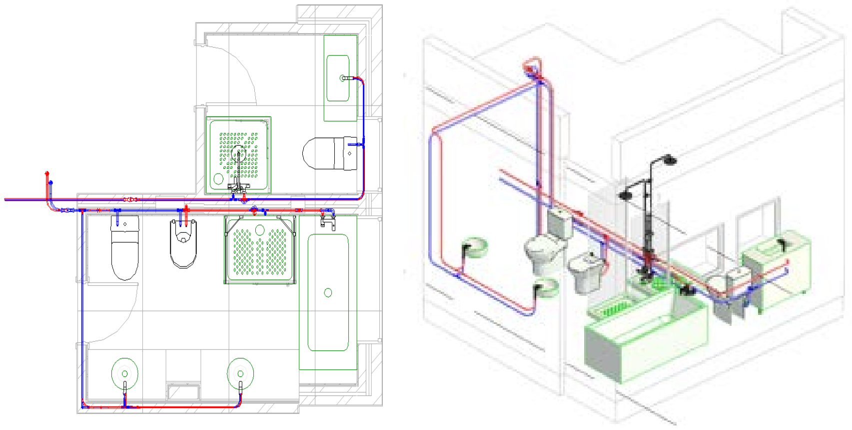


Figure 4. Model of the water supply network.

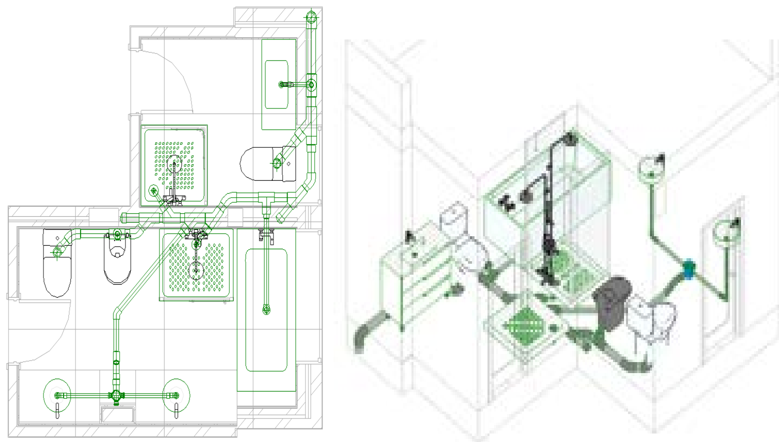


Figure 5. Model of the water drainage network.

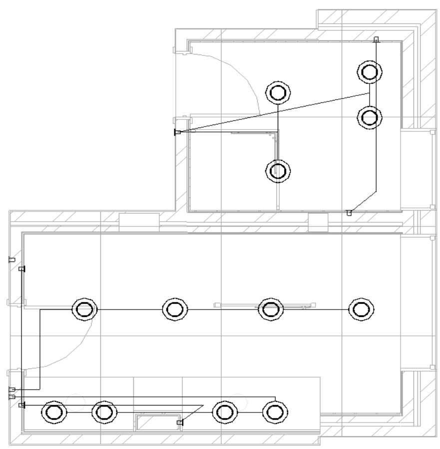


Figure 6. Model of the electricity network.

4. VR Software

Once the Revit model is complete, the user needs to choose the platform where the model in performed in VR functionalities. This choice is somewhat complicated because there are already numerous programs on the market where it is possible to export the model and enjoy the desired VR and AR features. In this way, a research was made of some programs available on the market and their applicability was evaluated, in order to facilitate the choice for their application in the model developed by the BIM methodology.

A research concerning the VR systems available in the market was first made and their applicability and functionality were evaluated, in order to facilitate the choice for their application in the BIM model developed within the present study. Some software simply serve to observe the model through VR walking inside the virtual model. Others, add the opportunity to observe the model inside and insert using avatars supporting a realistic collaboration between the professional team. In addition, other programs allow user to make changes applied over the model:

• The **Fuzor software** allows the engineer to simulate the construction planning and costs involved. Thus, it is possible to observe the progress of the work in loco and find out how the construction will take place through a virtual environment. Using this application, the management of materials and labor in the local is facilitated [11]. It is also possible to visualize the best construction methods for each situation and optimize all these aspects, minimizing costs and delays related to the work. With the simulation of the entire construction of the building, it allows to identify the distribution of the materials and components in the real site and in this way ensure that there are no inconsistencies or even problems related to safety. With the realization of animation scenarios, it allows the user to check the feasibility of all the construction process, observing the movements that, for example, machines need to make to carry out certain jobs.

• For a more collaborative purposes, **Arkio software** is suitable VR software. This is frequently applied on the development of conceptual models, visualized in a virtual environment, as it allows several users to participate simultaneously in the same project. This software contains modeling tools such as creating volumes, voids, changing colors, textures, among others. This type of tool, allows engineers to coordinate adequately the various specialties within each space of the building, to discuss dimensions and, in general, to analyze aesthetic aspects. Its use is very easy and intuitive, but it is necessary users to gain some confidence and ability in using adequately to handle VR environment [12].

• **AUGmenture software** is an Augmented Reality (AR) software. Using a 3D geometric model, previously created, it is possible to observe it as a mock-up from smartphones or tablets. This application is available for Android and iOS operating systems. It is frequently used as a collaborative tool supporting the discussion of ideas and alternative design solutions. The model visualized in an AR environment facilitates communication, the concepts presented to clients and facilitates the perception of inconsistencies in the project in elaboration or presentation. The user needs to install the plug-in for Revit and the application on the device where the model is visualized [13].

• The **Unreal Engine software**, developed by the company Epic Games, is oriented towards the design of interactive games, created in 3D environments and with a high capacity for immersion and interaction. Although the company's main focus is on the entertainment sector, the software has been explored in other industries, such as the presentation of architectural projects or the simulation of car traffic and transport [14]. The user can program their project by controlling the graphic appearance, the behaviour of each 3D component or the intensity of the lighting. The software provides templates with the basic definitions containing the necessary characteristics for each type of industry. An inexperienced user can develop a new program with satisfactory results, supported by consulting online forums, searching for different information to help how to solve common problems on web pages or even follow the development of specific projects through tutorials.

• Another program developed also by a company focused on the gaming industry is the **Unity software**. This application also allows user to develop immersive 3D environments. In the same way as the previous one, it is possible to develop the project completely through code. It also allows the choice to select pre-made projects and adjust it to the new created 3D model. So, any user can enjoy this tool even without any experience. The purchase of the program is free and there are numerous forums and support to learn how to develop a specific project using Unity [15].

• **VREX software** is a VR-focused program that allows teams to collaborate within a project developed by the BIM modelling software. From the immersive environment, the user can gather the inconsistencies found to later resolve such conflicts, handling the BIM model. Although the goal is to transport the model to a program that supports VR viewing, it is possible for other users to participate through the computer screen, thus being able to include any professional, as long as they have a computer with the necessary graphical capabilities. Thus, this program allows user to annotate, take measurements, communicate, and take photos [16].

• Another program similar to the previous one is the **Wild software**. This allows the teams to collaborate and examine the project in a VR environment, with the difference being that it allows users to model it. This application allows to create elements in different ways and discuss their aspect or consistency in the BIM model [17].

• **SentioVR software** is a plug-in of Revit. It is not necessary to install external software in Revit, facilitating its interoperability, and it is no longer necessary to be careful in exporting the project and in the correct format. There is no need to synchronize the project where all the changes have been made. This allows users to observe the model and also the possibility of collaborating. Its use is not free, it is necessary to subscribe to a monthly fee, and there is also the possibility of trying the program for free [18].

• Another plug-in of Revit that can be used is **Enscape**. Installed directly in Revit, it allows the user to visualize the model, giving the opportunity to demonstrate it to the client and assist in communicating with them. It also facilitates discussion between the different specialties involved and to check for any inconsistencies inside the model. This plug-in also requires a subscription, and the user can try it for free [19].

• **Shapespark software** allows the user to create renderings of 3D spaces. The visualization of the model can be done in the browser, so the demonstration of the space to the customer can be done easily without the need to install any other program [20].

5. BIM/VR Model

The VR technology system selected for the work was the Unreal Engine software, developed by the company Epic Games. This program is free and contains a wide range of templates, namely for the two modes, VR and AR, to be demonstrated. This program was the one initially chosen and used, specifically the Unreal Engine 5.2 version for the development of the project in VR.

The selected program serve to observe the model through VR, adding the opportunity to observe the model and collaborate, in the sense of communicating within the model itself through an easy walk inside the place. Both programs present the possibility of making changes to the model. It is important to note that these changes occur in the VR project, and it is later necessary to export the model with the desired changes and import it into the program where the BIM model was made, an undesirable issue in terms of interoperability. The Unreal Engine program was the one initially chosen and used, specifically the Unreal Engine 5.2 version for the development of the project in virtual reality. There was also the intention to use it for augmented reality, but due to certain complications with some degree of complexity, this was discarded and changed to AUGmentecture.

5.1. VR Experience

The model developed in Revit could not be exported directly to the Unreal Engine system [7]. To avoid this problem, previously, it was necessary to install the Datasmith plug-in in Revit, which allows the conversion of the .rvt file to the format to be accepted by the software.

With the plug-in installed in Revit, all the information required to export the model was selected. The model was then imported from the Unreal Engine system, and a new project was created. It was necessary to select the Collab Viewer template type, to promote navigation and interaction with the model in a VR environment.

This was placed next to the lower level of the virtual space, the soil surface. The user can view the model from the outside and from the inside. The incursion made into the interior of the model allowed the user to identify problems related to the textures of some of the sanitary devices, namely the toilet and the bidet, in both sanitary rooms (**Figure 7**).

Figure 7. Visualization of the VR model with errors.

The error found was due to the fact that the material applied was defined in an inverted side, and with some transparency. The problem was quickly solved by rectifying the texture applied to the surface material of the equipment. In this case, the material is porcelain. The correct model could be visualized through an internal walkthrough made using the Unreal Engine system. The point of view can be selected according to photographs obtained in loco. The images in **Figure 8** compare both images VR and real.

In the Material Property Overrides section, the Two Sided option was selected, demonstrating its proper appearance. The correct model can then be visualized through internal and external walkthroughs made in the Unreal Engine system and compared with reality. The peripheral devices used are of the Meta Quest 2 type, headset and two controllers. These devices were paired with the computer, allowing the manipulation of the virtual objects through movements with 6 degrees of freedom, according to translational movements in the three orthogonal directions and rotation around each coordinate axis.

The ability to move the point of view of the viewer provides the user a realistic feeling of immersion inside the space and interaction with the modeled components. In the Unreal Engine system, an interactive tour was performed through the interior of the virtual space. By placing the headset on the head and exercising control of the user's movement through the manipulation of the control devices, a very realistic appearance of the space is observed (**Figure 9**).

The user observes the virtual environment through the glasses of the headset. It is also possible for other people to see the same environment through the monitor connected to the computer. The operator, using the control device, manipulates the walking path through the interior of the model.

Over the model, visualized in a virtual environment, it is also possible to add or change objects by replacing them with others of identical functionality. Taking the washbasin in one of the toilets as an example, the model applied can be replaced by another that corresponds to the user's desire. Various solutions can then be analyzed and presented to the customer.

In addition, the visualization and interaction with the model, represented in virtual reality, makes it possible to observe the dimensions of the space, and evaluate the feeling of largeness or smallness that the real place will convey. The notion immersed in the representative model of the project, allows the surrounding parts to assess the constraints that the real space will provide. The user can also understand which layout of the space will be more ergonomic inside. Thus, when the development phase of the project is in a early stage, it is possible to note what changes will need to be made, allowing to facilitate communication and justify alternative solutions to be transmitted to partners.

5.2. AR Experience

From the website of the AUGmentecture system, the correspondent plug-in was installed in Revit. Once the installation was completed, the Revit model was opened and it was necessary to select the 3D view of it. Then, the Export option from the plug-in was selected and the plan to be exported was chosen, in which case the one on the first floor was exported and uploaded to AUGmentecture, and it was also necessary to install the application on the respective device. With the imported model, it was possible to view the model as a 3D perspective, using the browser (**Figure 10**).

Figure 8. Comparison between the VR model and a photography of the local.

Figure 9. User looking at the model in Unreal Engine via the Meta Quest 2 device.

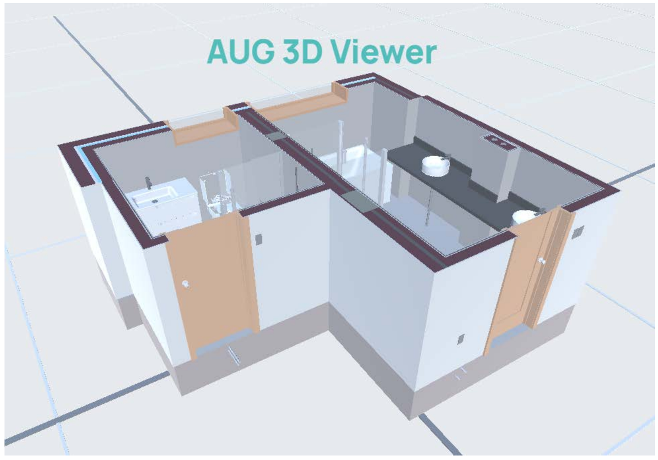


Figure 10. 3D representation of the model from AUGmentecture.

The user can zoom in, zoom out and move around without moving the model, allowing the user to view the details he/she wants with the desired proximity and point of view. The user can also change the size, direction, and position of the model by interacting with it from the device's screen. By interacting with the AR model, the user allows to change the scale of the perspective. It is possible to modify the visualized scale, transmitting the user a realistic perception of immersion in the model. In this way, not only the required scale and necessary details can be visualized, but also the perception of displacement within the model is also obtained in a realistic way.

6. Conclusions

BIM/RV/AR technologies bring a level of detail to an ease of interpretation that proves inexplicably advantageous in numerous ways. Using a BIM model, correctly representing the project in analyses, and guided by the different specialties, it can bring support to all stakeholders at all stages of the development process. It is important to mention that although there is some interest in applying such methodologies and technologies in construction projects, there is still some reluctance. However, governments in several countries have been implementing legislation that encourages the use of BIM, which can consequently increase the use of VR and AR, technologies that in all aspects make sense in partnership with BIM.

The observation of the model in VR facilitates the perception of feasibility on site, and helps with aesthetic and functional decisions as well as ergonomic issues. It is possible, in an immersive way, to move within the model, make changes, take dimensions and place annotations for future modifications. Depending on the level of experience of the user and/or the programmer, it is also possible to visualize the construction and, in this way, have an undeniable perception of the feasibility of the construction processes, the machines chosen and the distribution of the spaces on the site. However, as it is an immersive tool, there may be some difficulty for certain users to adjust to this environment, as it is something common to cause a certain discomfort. There are already different programs for different needs and each one requires different skills from the user, and it is also necessary to pay attention to the necessary skills that the computer needs to be able to put certain programs into practice.

With the diversity of the software available, interoperability problems between BIM and VR/AR programs are mitigated because it is easy to find the most appropriate partnership among the various options available. It was also possible to ascertain that both technologies are powerful tools with different possibilities. With the various programs available, some with specific features, it is possible to accommodate inexperienced users.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Smith, P. (2014) BIM Implementation: Global Strategies. *Procedia Engineering*, **85**, 482-492. https://doi.org/10.1016/j.proeng.2014.10.575

[2] Charef, R., Emmitt, S. and Alaka, H.A. (2018) Beyond the Third Dimension of BIM: A Systematic Review of Literature and Assessment of Professional Views. *Journal of Building Engineering*, **19**, 242-257. https://doi.org/10.1016/j.jobe.2018.04.028

[3] Sacks, R., Eastman, C., Lee, G. and Teicholz, P. (2018) BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers. 3rd Edition, John Wiley & Sons, Inc. https://doi.org/10.1002/9781119287568

[4] Ingram, J. (2020) Understanding BIM: The Past, Present and Future. Routledge.

[5] Al-Mohammad, M.S., Haron, A., Esa, M., Aloko, M.N., Alhammadi, Y., Anandh, K.S. and Rahman, R.A. (2022) Factors Affecting BIM Implementation: Evidence from Countries with Different Income Levels. *Construction Innovation*, **23**, 683-710. https://doi.org/10.1108/CI-11-2021-0217

[6] Haggard, K.E. (2017) Case Study on Virtual Reality in Construction. https://www.researchgate.net/publication/319076947_Case_Study_on_Virtual_Reality_in_Construction

[7] Sarmento, R.S. (2023) BIM Implementation in the Development of the Multidisciplinary Project: 4D and 5D Models and VR Integration. Master's Thesis, University of Lisbon.

[8] Giralde, G., Silva, R., Oliveira, J.C. and Giraldi, G. (2003) Introduction to Vitual Reality. *LNCC Research Report*, **6**, 1-19. https://www.lncc.br/~jauvane/papers/RelatorioTecnicoLNCC-0603.pdf

[9] Mazuryk, T. and Gervautz, M. (1999) Virtual Reality: History, Applications, Tech-

nology and Future.
https://www.researchgate.net/publication/2617390_Virtual_Reality_-_History_Applications_Technology_and_Future

[10] Sampaio, A.Z. (2018) Enhancing BIM Methodology with VR Technology. In: Mohamudally, N., Ed., *State of the Art Virtual Reality and Augmented Reality Know-how*, IntechOpen, 59-79. https://doi.org/10.5772/intechopen.74070

[11] Fuzor Software (2024) https://www.kalloctech.com

[12] Arkio Software (2024) https://www.arkio.is

[13] AUGmentecture Software (2024) https://www.augmentecture.com

[14] Unreal Engine Software (2024) https://www.unrealengine.com/en

[15] Unity Software (2024) https://unity.com/pt

[16] VREX Software (2024) https://www.vrex.no

[17] The Wild Software (2024) https://thewild.com

[18] SentioVR Software (2024) https://www.sentiovr.com

[19] Enscape Software (2024) https://enscape3d.com

[20] Shapespark Software (2024) https://www.shapespark.com