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# ПРИЛОЖЕНИЯ НА ВИРТУАЛНОТО МОДЕЛИРАНЕ И МОДЕЛИРАНЕТО НА ВИРТУАЛНА РЕАЛНОСТ В СТРОИТЕЛСТВОТО

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# APPLICATIONS FOR VIRTUAL AND REALITY MODELLING FOR CONSTRUCTION

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**Abstract**: Virtual and Reality modelling applications to the construction industry has not been examined to the necessary degree, with researchers disagreeing as to how to best apply these applications to construction. As most Building Information Models (BIM) are created for design purposes (Eadie et al, 2013), this research concentrates on the design office environment. This study concentrates on firstly seeking to clarify the best means of importing a (BIM) into virtual reality (VR) for viewing and secondly, analysing how 360-degree camera work can be linked to Autodesk Revit™. Both these elements utilise plugins to import the elements to and from Autodesk Revit™. Sixteen plugins in total were examined: 13 Virtual Reality Plugins (on 2 different Head Mounted Displays) and 3 360-degree camera work plugins. The usability of the 360-degree camera work plugins were examined determining that Holobuilder was the preferred option. The VR plugins were measured against the 8 dimensions of service quality and ranked. This led to Iris VR: Prospect™ being ranked the top VR plugin. The study is unique in that there is little published work in the plugin area and this paper ranks the different plugins for the first time.

**Keywords**: Virtual Reality (VR), 360° Camera Work, Plugin, Revit, Building Information Modelling (BIM)

## 1. INTRODUCTION

With Covid-19 having created issues with construction and created situations where social distancing is vital to health, Virtual Reality (VR) and Augmented Reality (AR) are being examined as means to examine construction structures without actually being there. This has not been adequately examined in

literature and in the context of social distancing. This paper looks at the links between 360 degree photography, VR, AR and Building Information Modelling (BIM) through plugins. Bouchlaghem *et al.* (2005) [1] suggest that visualisation is critical to design development and minimising defects in the construction design process.

Visualisation is only one aspect of VR and AR. Drascic and Milgram (1996) [2] see VR and AR as being on a spectrum of visualisation. However, Raajana *et al.* (2012) [3] consider VR and AR to be very different. AR deals with data capture from a real environment [4] whereas VR can be defined as a '*computer-generated three-dimensional, interactive environment simulation'* [5]. What all these sources confirm is that interaction with this model can be accomplished using electronic equipment, such as a headset and handheld guidance systems. BIM has been defined as *generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way which includes 3D*

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*modelling* [6]. It therefore falls under the VR definition. However, with the advent of being able to import 360-degree camera work into the BIM model we now are merging AR and VR. 360-degree camera work is defined as '*Capture of two images or video files from dual lenses with a 180-degree field of view and either automatically stitches them together in-camera or offers free companion software with which you can stitch the files together – often with one click'*[7]. This combination has become known as '*Mixed Reality'* (MR) modelling [8].

The uses of AR, VR and MR technologies in construction can include improving Design [9], Clash Detection [10], Construction Scheduling [10], Education [10], Construction Progress [10], Safety Training, [11], Maintenance [11], Manufacturing [12], and Marketing [13]. While the individual uses of the different systems have been examined, the applications for automating interoperability in the creation of these models have not been adequately examined in literature.

## 2. APPLICATIONS (APPS) IN CONSTRUCTION

This paper examines the best means of importing a Building Information Model into VR for viewing models and secondly, analysing how 360-degree camera work can be linked to Autodesk Revit™ for AR. Both these elements utilise plugins to import the elements to and from Autodesk Revit™. Sixteen plugins in total were examined: 13 Virtual Reality Plugins (on 2 different Head Mounted Displays) and 3 360 degree camera work plugins. These are listed in Figure 1.

| **VR Plugins (Key - B tested on both Headsets, H - HTC Vive only, G Google Cardboard only)** | | | | **360ºcamera work plugins** |
|---|---|---|---|---|
| Iris VR: Prospect **H** | Enscape **H** | Modelo **G** | BIMx **G** | Cupix |
| Unreal Studio **H** | SimLab Soft **H** | Revizto **H** | | HoloBuilder |
| Rvt2VR **H** | SimLab Viewer **G** | Kubity Go **G** | | StructionSite |
| Iris VR: Scope **G** | Autodesk Live **H** | Shapespark **B** | | |

**Figure 1 Applications Examined**

The examination of the elements of each of the VR plugins are presented in the research method section. The three applications had slightly different aims. Cupix [14] is a programme that creates 3D tours from 360-degree photos. The plugin works for AEC professionals due to the connection with BIM. The BIM model can be uploaded into the tour to provide a comparison between virtual and reality. However, this process was quite complex, and the programme provided very little support. Using the 360-degree photos, Cupix could arrange the data to create a 3D model which could be exported to Revit. According to HoloBuilder (2019) [15] this application is the "*fastest and easiest way to document construction site progress*". It allows for easy job site capture with their Job Walk app. Holobuilder can help with "*As built documentation, pre-production planning, post production handover and improve meeting collaboration*". The model produced and a photo of a house is provided in Figure 2.

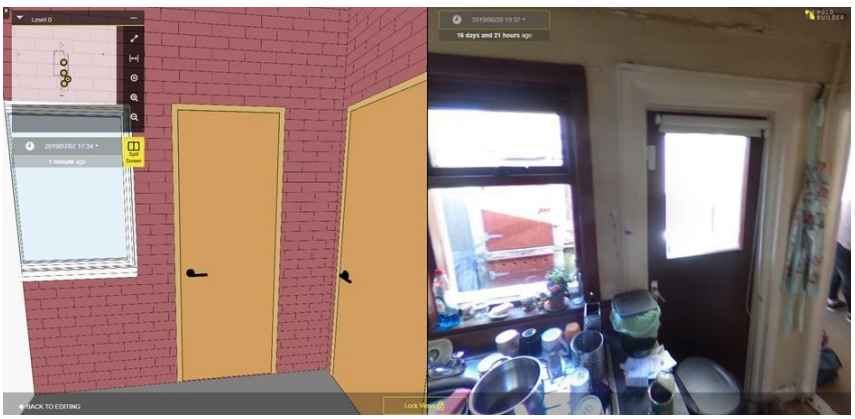

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**Figure 2 Holobuilder example**

For this use, Holobuilder was similar to Cupix. However, instead of uploading a model into a tour for a comparison, HoloBuilder exports specific viewpoints within the model via a plugin for comparison. This use of the plugin was a much simpler method than Cupix's version. The HoloBuilder plugin for Revit was easy to use and did not require many steps to upload the model. The split screen to compare the Revit model and camera photos was most useful. Visually the model and the photos were not tarnished after upload and the tools on offer within the programme were very useful. The last application was StructionSite which is very similar to HoloBuilder. The application allows for "*quick, seamless job site capture, viewable from anywhere, anytime*", StructionSite Inc. (2020) [16]. Using the app, the programme allows the user to "*collaborate quicker, easier and more efficiently*" and can integrate with the likes of Procore and Google Drive. However, issues with creating a free trial account meant that testing this plugin proved unsuccessful. Despite help being sought via StructionSite's support team this still proved unsuccessful as they just sent a link to help sign up which did not function. Efforts to contact them again were not successful. Therefore the results focus on the comparison of the first two applications. Figure 3 summarises the capabilities of the 360-degree camera plugins for producing the ranking.

| | Free trial Duration | Camera Compatibility | CAD Compatibility | Headset Compatibility |
|---|---|---|---|---|
| Cupix | 30 days | Ricoh Theta, Insta 360, Mi Sphere 360, MADV, Yi 360 cameras and GoPro Fusion | *Revit*, SketchUp and IFC files | HTC Vive, Oculus Rift, Google Cardboard and Samsung Gear VR |
| Holobuilder | 21 days | Ricoh Theta, Ricoh Theta S, Ricoh Theta SC, Garmin VIRB 360, LG360 CAM, Samsung Gear 360, NCTech iris360 and Insta360 pro | BIM360 | HTC Vive, Oculus Rift, Google Daydream and Google Cardboard |
| StructionSite | 22 days | Insta360 ONE, Insta360 ONE X, Ricoh Theta, LG 360 and Garmin VIRB | *Revit*, Sketchup and Navisworks | Unknown |

**Figure 3 360-degree camera plugin functions**

## 3. RESEARCH METHOD

The usability of the 360-degree camera work plugins were examined and ranked. Two Head Mounted Devices (HMD) were tested namely: the HTC VIVE and Google Cardboard. These two HMD's were chosen as they are at opposite ends of the spectrum in terms of price, providing an opportunity for comparison. The VR plugins were measured against the 8 dimensions of service quality and ranked. Only applications with a free trial or freely available were tested. Figure 4 demonstrates the factors considered and the means of ranking applied for each of these dimensions. The model tested was the same for each.

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| **8 Dimensions of Service Quality for VR Plugins** | | |
|---|---|---|
| 1. | Performance (Usability) | - Download Size (Especially important for small size computers) (Ranked on a 1-13 basis for VR Plugins)<br>- Download Effort ( Ranked Green = 1, Yellow = 2, Red = 3)<br>- Can the plugin create a VR model? Time and effort to upload model. (Ranked on a 1-13 basis for VR Plugins)<br>- How many uses does the plugin offer? (Ranked based on number) |
| 2. | Features (VR Tools) | - What tools do the VR plugin offer? (Ranked based on number) |
| 3. | Reliability | - Does the product lag? (Yes = 0, No = 1) |
| 4. | Conformance | - Are the features mentioned on the website the same on the plugin and the ability to find and use all the features mentioned on the website? (Ranked 1-5 where 1 is poor and 5 is excellent) |
| 5. | Durability | How long is the free trial? (Ranked on a 1-13 basis for VR Plugins) |
| 6. | Serviceability | - Is there help available via either a useful forum or a helpline?<br>- (Ranked on a 1-13 basis) |
| 7. | Aesthetics | - How good does the product look?<br>- Can you move or pickup objects?<br>- Are there sounds available?<br>- Is there animation?<br>- (Combination ranked on a 1-13 basis – 1 poor, 13 excellent) |
| 8. | Perceived Quality | - Customer & Website opinion (Ranked 1-5, 1 is poor & 5 is excellent)<br>- Price (Ranked on a 1-13 basis)<br>- Issues (Ranked on a 1-13 basis) |

**Figure 4 VR Plugin Ranking method (Adapted from Garvin (1987) [16])**

The factors in Figure 4 were applied to the VR applications to produce the findings in Section 4. The 360-degree camera plugins were ranked based on the following factors: Free trial Duration, Camera Compatibility, CAD Compatibility and Headset Compatibility. Due to issues with the installation of StructionSite, only Cupix and HoloBuilder were ranked. These were ranked based on a 1-2 ranking, best being 1. The criteria were kept as similar as possible to those used to rank the VR Plugins in Figure 4. This meant that conformance was ranked out of 5, where 1 is poor & 5 is excellent. Two different 360-degree cameras were used: the Insta360 Pro 2 and the RICOH Theta SC. Again, these two cameras are at opposite ends of the spectrum in terms of price.

## 4. FINDINGS ON THE CHANGES

The VR applications ranking is presented first in Section 4.1 with the ranking of the 360-degree camera work applications in Section 4.2.

### 4.1 FINDINGS ON THE VR APPLICATIONS

Figure 5 presents the ranking of the VR applications. This indicates that the top ranked application is the Iris VR: Prospect. It is therefore deemed the best suited plugin for a design office environment. This plugin is compatible with the HTC VIVE. In terms of comparing the two HMD's, Iris VR: Prospect is the best for the HTC VIVE and Modelo is the best for the Google Cardboard. When determining the best plugin for a design office environment, the price of the two HMDs should also be considered.

Out of the 13 different plugins successfully tested, there was a total of 173 tools found. Comparing the two HMD's, there were 134 tools found within the VIVE plugins and 48 within the Cardboard plugins. The most popular tool for the HTC VIVE was the Teleport tool and for the Google Cardboard was the Walk tool. Spaeth et al (2018) [17] states that VR will provide a "*visceral feeling of presence within a articular place*". These tools revolve around movement in the model and contribute to level of immersion.

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| | VR Plugin Product Quality Review | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.Autodesk Live | 2.BIMx | 3.Enscape | 4.Iris VR: Prospect | 5.Iris VR: Scope | 6.Kubity Go | 7.Modelo | 8.Revizto | 9.Rvt2VR | 10.Shapespark | 11.SimLab Soft | 12.SimLab Viewer | 13.Unreal Studio |
| Performance Download Size | 11 | 12 | 9 | 6 | 7 | 8 | 1 | 10 | 4 | 2 | 3 | 5 | 13 |
| Performance Download Effort | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 3 | 3 | 3 | 2 |
| Performance Time of Upload | 12 | 13 | 1 | 2 | 9 | 6 | 2 | 2 | 2 | 6 | 8 | 9 | 9 |
| Performance Upload Effort | 3 | 3 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 3 | 3 | 3 | 3 |
| Performance Number of Uses | 9 | 7 | 5 | 2 | 6 | 7 | 2 | 1 | 9 | 13 | 2 | 9 | 9 |
| Features | 6 | 11 | 5 | 2 | 13 | 8 | 7 | 4 | 11 | 9 | 3 | 9 | 1 |
| Reliability | Y | N | Y | Y | Y | N | N | N | Y | N | Y | N | Y |
| Conformance | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Durability | 6 | 1 | 10 | 5 | 10 | 10 | 1 | 6 | 10 | 6 | 9 | 1 | 1 |
| Serviceability | 1 | 11 | 1 | 1 | 1 | 11 | 7 | 7 | 11 | 7 | 1 | 7 | 1 |
| Aesthetics | 3 | 12 | 1 | 6 | 7 | 10 | 11 | 5 | 4 | 13 | 8 | 9 | 2 |
| Perceived Quality: Website | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Perceived Quality: Price | 12 | 2 | 5 | 10 | 11 | 4 | 7 | 13 | 3 | 8 | 9 | 1 | 6 |
| Perceived Quality: Issues | 12 | 11 | 1 | 1 | 1 | 1 | 8 | 1 | 8 | 13 | 1 | 8 | 1 |
| Total | 89 | 95 | 52 | 49 | 80 | 78 | 58 | 63 | 75 | 93 | 61 | 74 | 59 |
| Rank | 11 | 13 | 2 | 1 | 10 | 9 | 3 | 6 | 8 | 12 | 5 | 7 | 4 |

**Figure 5 VR Plugin ranking**

### 4.2 FINDINGS ON THE 360 DEGREE CAMERA APPLICATIONS

Figure 6 presents the ranking of the two 360-degree camera work applications. From the testing of the two plugins Cupix and HoloBuilder, it was found that HoloBuilder was easier to use. The issues that arose in Cupix meant that the plugin was not fully successful. Issues faced in Cupix related to the unsuccessful BIM comparison, 360-degree Tour and 3D model. Although, the quality of the images was not affected in the end result. HoloBuilder was a more successful plugin as it was easier to use and ranked best overall.

| | 360-Degree Plugin Product Quality Review | |
|---|---|---|
| | 1.Cupix | 2.Holobuilder |
| Performance: Camera Compatibility | 2 | 1 |

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| | 360-Degree Plugin Product Quality Review | |
|---|---|---|
| | 1.Cupix | 2.Holobuilder |
| Performance: CAD Compatibility | Yes through REVIT | Yes through BIM360 |
| Performance: Headset Compatibility | 2 | 1 |
| Features | 2 | 1 |
| Reliability | Yes | No |
| Conformance | 4 | 5 |
| Durability: Length of Free trial | 1 | 2 |
| Serviceability | Yes | Yes |
| Aesthetics | 2 | 1 |
| Perceived Quality: Issues | 2 | 1 |
| Total | 16 | 12 |
| Rank | 2 | 1 |

**Figure 6 Ranking of 360-degree Camera Work Applications**

## 5. CONCLUSIONS

Virtual Reality (VR) and 360-degree camera work modelling applications for the construction industry have not been fully examined prior to this paper. Sixteen Applications in total were examined: 13 Virtual Reality Plugins (on 2 different Head Mounted Displays) and 3 360-degree camera work plugins. Through ranking these applications against the 8 dimensions of service quality, this study confirms the best means of importing a BIM into VR and viewing models is through using the Iris VR: Prospect application in conjunction with the HTC VIVE and if using Google Cardboard, Modelo is ranked the best. Through analysing how 360º camera work can be linked to Autodesk Revit™, HoloBuilder was easier to use and produced the best results. There are a number of limitations to this study and further work is required to address these. For example, only those applications with free access were tested. If a grant could be achieved to pay for a comprehensive study, extra applications could be added and examined. Secondly the lag time shown on the Google Cardboard relied on the Honor 7 phone capacity to deal with this particular size of model. As phones are improving in speed and capacity this may reduce. Also, a study can be carried out to determine industry perceptions on the use of the various applications under different conditions. There is potential to widen testing of other HMD’s such as the Oculus Rift and different 360-degree cameras. However, the current study goes some way to providing initial guidance to organisations who are considering entering this element of the market for the first time.

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