Smart Airport: Mobile Asset Information Modeling Management based on Gamificative VR Environment --- A Case Study of Ningbo Lishe International Airport Staff Restaurant

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Abstract. With the popularization of Virtual Reality (VR) technology, the application of the complementary advantages of BIM+VR collaboration in facility management (FM) and asset management (AM) is an emerging research field. This theory holds that BIM information generated and acquired in the life cycle of the facility can improve the management of the facility and asset based on the visual expression of VR technology. With this proposition as a starting point, based on the Ningbo Lishe International Airport's staff restaurant project, the purpose of this paper is to investigate the value of BIM and VR and the challenges they pose in influencing their adoption in AM applications. By establishing a BIM model and a quantitative asset information model, and using the 720 cloud VR platform and related smart devices to complete the visual expression of asset information. The results demonstrated that that the value of BIM+VR in AM comes from the improvement of the existing manual information transfer process, which reduces the data delay to a large extent. Secondly, the accuracy and accessibility of AM data are improved, and the efficiency of the management is improved. The originality of this paper is to prove the great potential of BIM and VR in AM optimization and improvement through real case study, and to provide empirical evidence for the value and challenges of BIM+VR in AM application.

1. Introduction

In recent years, more and more Architecture, Engineering, and Construction (AEC) professionals have applied BIM technology in building lifecycles. The operation and maintenance stage is the longest stage in the whole life cycle of a building, both asset management and facility management are major tasks in the construction operations phase, and both aim to improve the project's return on capital[1]. In the operation and maintenance phase of a building project, operational data of asset management and data in the design and construction phase should be collected from different teams, thus obtaining accurate information is difficult, time-sensitive and incomplete[2]. In the traditional property operation and maintenance mode, the facility and asset management personnel must grasp the operation and maintenance data through a large number of paper documents such as drawings and contracts[3]. BIM

model can be used as a database to provide abundant operation and maintenance data resources for FM and AM. Therefore, it is of great significance to combine BIM technology with FM and AM in the operation and maintenance stage.

The function of Virtual Reality (VR) tour can form an interactive information transmission mode between people and architectural model. VR has a much more powerful 3D display model than BIM[4]. VR's 3D immersive experience can perfectly compensate for the BIM model's presentation mode. VR's wearable device and operating handle can be used for immersive travel, realizing the visual expression effect from the interface to the space[5]. The advantages of BIM+VR technology can make up for the disadvantages of traditional building management method[6] and means to the operation and maintenance management of asset and bring new working scenes and work experience to the equipment operation and maintenance management personnel.

Airport, as an asset, consists of a variety of information that can be generated from a variety of data sources that can be used within the decision-making process. The Digital Assets are stored in a 3D format by the manufacturer and could be shared with the asset management team in order to integrate them into a new Asset Information Model (AIM)[7]. ISO19650 1-2 will be used for the creation, development, storage and maintenance of the new information. Each time the AIM is updated it will be easier. ISO19650 3-4 will help to advance security and asset modeling in a closed, private network such as blockchain[8], so the asset management team can run simulation and visualization exercises (prediction) by identifying optimum solutions for the suppliers. Through this approach the airport can be managed in an intelligent way because all mechanisms and technologies are integrated in an interactive environment and culture that helps decision makers to think proactively and react whenever required when standards are in place. Furthermore, if any airport plan changes, such as when expansion and maintenance are required, then the owner will be in a better position because they have access to the right information (following a high volume, valuable, velocity, variable and veracity amount of (non)structured data) from anywhere at any time. Experience in other construction projects confirms that Information Modelling can help to reduce project costs (design and construction) according to 2025 Construction Report by the UK Government by 33%, contribute to faster delivery of projects by 50%, reduce emissions by 50% and improve exports by 50%. Examples can be found in Spain (Autonoma Barcelona Football Sport Centre), UK (Heathrow Airport) and UK (Jubilee Line).

At present, most of Ningbo Airport's asset management is still in the traditional management mode, and most of the operation and maintenance information needs to be collected, integrated and managed manually, which seriously affects the management efficiency and increases the human cost. Therefore, it is a topic of great research value to explore how to improve the efficiency of the overall operation and maintenance of buildings and asset management through BIM-based digital technology, and how to visualize the expression based on VR technology.

2. Methodology

The research question of this paper is to investigate the value of BIM and Virtual Reality (VR), how to integrate them and the challenges they pose in influencing their adoption in asset management (AM) applications via a real case of Ningbo Lishe International Airport.

The whole research of the case study is roughly divided into BIM+VR technical module, database management module and VR application module. The following Figure 1 below clearly shows the technical route of the whole research.

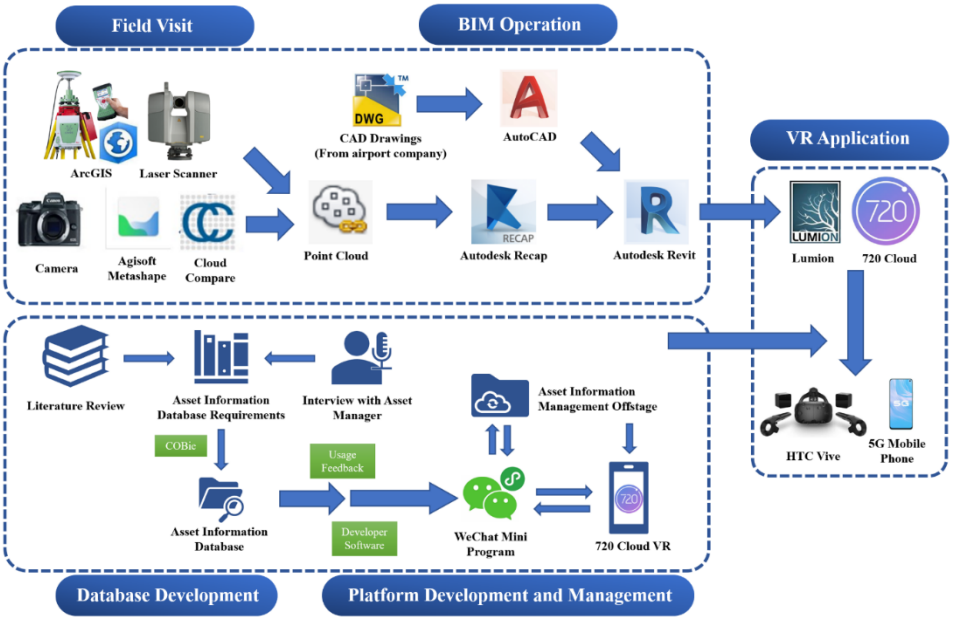

Figure 1. The BIM+VR asset management technical mind map of the case study

3. Case Study

Ningbo Lishe International Airport staff restaurant is taken as the case study for further research. Staff restaurant is located at the intersection of Hanghui Road and Hangkong Road, Haishu District, Ningbo, adjacent to the airport information centre and freight station (see Figure 2). The total floor area of the staff canteen is about 2300m^2, which is divided into kitchen area, processing area, cold storage area and rest area.

Figure 2. The Ningbo airport and staff restaurant

The case study involved personnel from the airport asset management department. They also participated in detailed discussions to investigate the value and challenges of BIM+VR in AM. The airport asset management department will use these values and challenges to implement a robust and integrated BIM strategy.

3.1. On-site Data Collection Process

The BIM+VR technical module contains data collection stage, basic modelling stage and model rendering. As shown in Figure 3 and Figure 4, in the data collection phase, a variety of advanced methods including laser scanning, GNSS and photogrammetry are used through field visit. Leica GS14 real-time dynamic Global navigation Satellite system was used to measure the location information in the process of collecting on-site data of the airport staff restaurant.

Figure 3. Use FARO Focus3D X 130 Laser Scanner to create point clouds

Figure 4. Use Leica GS14 GNSS RTK to collect on-site data

3.2. BIM Modeling Process

Scanning-point cloud modelling is modelling by scanning a target area or building using a 3D laser scanner. Based on the saved data, manual modelling was performed using Autodesk Recap software. In this project, this modelling method will be used in the rough machining room on the northwest side of the canteen. Its advantage lies in that it can restore the scene content and surface material to the maximum extent. For some special or complex structures in the scene, this method can also reduce the difficulty of modelling and improve the efficiency of modelling.

In the basic modelling stage of the case study, the main BIM operation methods are divided into point cloud modelling (based on collected building data) and Revit modelling (based on 2D CAD drawings), which reach LOD300 standard, and some areas reach LOD350 standard. Figure 5 below shows the modelling results of these two methods.

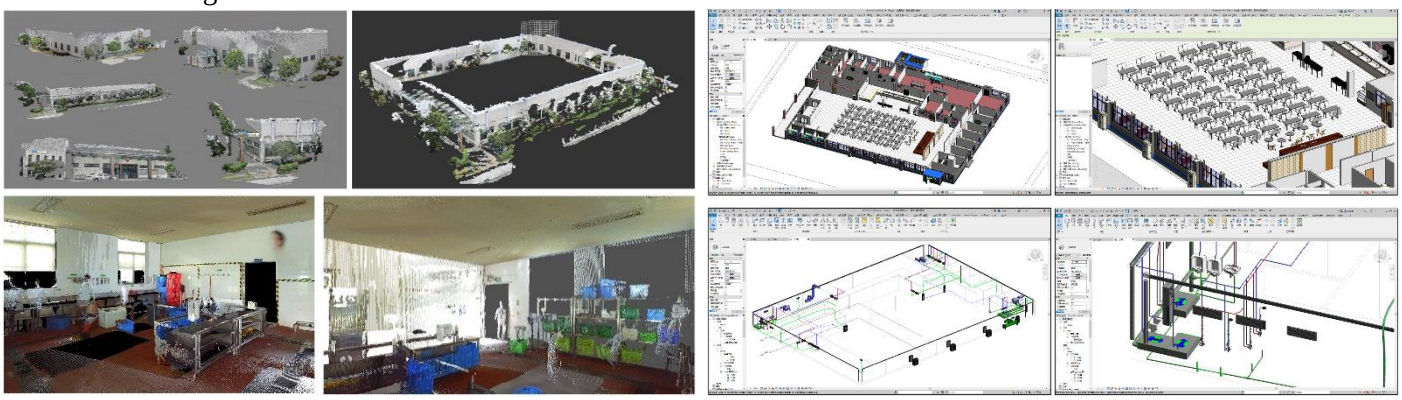

Figure 5. Staff restaurant external and internal Recap scanning results and Revit model

VR environments need to be built on high quality rendering results to get the best visual experience and more detail to enhance asset management. Based on the 3D models established by Revit and Recap, two commonly used rendering engines Enscape and Lumion are used for rendering process.

Lumion is a powerful rendering software, provides an extremely rich model library. Lumion can quickly render high-quality images and animations with various special effects. The operation of Lumion is also relatively simple, is currently the most widely used rendering engine.In addition, Enscape can export computer executable file (.exe) for administrators who don't have Enscape installed on their computers to view the rendered results.

As can be seen in Figure 6, this project takes the rough machining room as a pilot, using Enscape to export the rendering files and test them. For other area of the staff restaurant, Lumion was used as the rendering engine. This rendering output roaming video and still image, the combination of video and image is helpful for restaurant managers to better understand the project on the virtual side.

Figure 6. The real-time rendering results of the staff restaurant including hot machining room (.exe file with LOD350)

3.3. Common Data Environment (CDE)

In the modelling process of digital airport restaurant, data management is of great significance to the discipline integration of various software. Improve the efficiency of project collaboration through good data processing. The different equipment collect data, the public database serves as the data store, and the digital twin visualizes and analyzes the data.

This project uses the Autodesk Fusion 360 platform as the public data environment (see Figure 7). In Fusion 360, files can be shared whenever. At the same time, it provides modelling visualization capabilities. The software is also available for mobile devices such as the iPad and iPhone. The establishment of a shared database makes online collaboration possible, saving work costs and hours. Fusion 360 has different terminals that can be applied to different projects.

Figure 7. Building model information can be shared through different terminals and 3D viewed whenever via Fusion360 platform

3.4. BIM Asset Information Management

The asset information databases will be developed and managed as the entire BIM+VR technical effort proceeds. Firstly, according to the literature review and the interview with the asset manager, combined with the current situation of the airport staff restaurant, the demand for the asset management database is analyzed. The content of the interview questionnaire revolves around the research topic. The content of the interview mainly includes the interviewees' opinions on the operation management of building

assets and their information needs for the operation of building assets. The specific contents of the interview questionnaire are shown in Table 1.

Table 1. Interview questionnaires to identify building assets management information demand

Specific Contents of the Interview Questionnaire
1. Basic information
Question 1: What is your age, degree status and current position?
Question 2: How long have you worked in the construction field?
Question 3: What kind of work do you do in relation to building assets?
2. Main interview questions
Question 4: What role do you think building assets information plays in the operation management of building assets? Is information gathering necessary for building assets management?
Question 5: When you were engaged in building assets management, did the information of building assets not get in time affect the normal operation of the work? Please give an example.
Question 6: According to your work experience, what data information of building assets should be paid attention to in the operation stage?
Question 7: Does your company have specific regulations on information collection of building assets? What information is usually collected?
Question 8: Do you think the way information is collected and used in building assets has affected your work? If so, what impact has it had?
Question 9: What do you think needs to be improved in terms of building assets information collection?
Question10: Besides the above, do you have anything to add or discuss further?

Table 2. Actual Interviews Materials (Excerpts)

Original Interview Materials (Excerpts)	**Key Sentence**
First of all, we need to know **where the fixed asset** is so that we can arrange any work. Sometimes, the **location of the fixed asset** given in the drawing is wrong, which makes us very upset.	**Asset Location**
If **the value of this asset** is high, then we may need some special pay more attention to this kind of assets.	**Asset Value**

We sometimes have to contact the **manufacturer and supplier** and ask them to help us solve the problem.	**Manufacturer and Supplier Information**
We often need to know about the **loan, return or other conditions** of assets, in order to identify the current responsible person, to avoid asset damage or loss.	**Asset Conditions**
For the most basic information of the assets, **name, model, specification, installation date**, etc., we will establish a ledger to record this information, and each equipment will have a **code number**.	**Asset Specification and Information**

Since space is limited, excerpts from some of the actual interviews are presented here to further identify specific information needs for asset management (see Table 2 above).
The research methods of humanities and social sciences are mainly divided into two categories: quantitative and qualitative[9]. In this case study, NVivo 12 Pro was used for qualitative analysis of the interview content. As shown in Figure 8 below, this project used NVivo 12 Pro for qualitative analysis of the interview content.

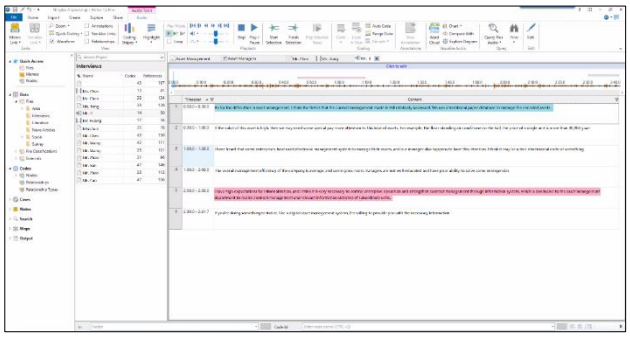

Figure 8. Use NVivo 12 Pro for qualitative analysis of the interview data

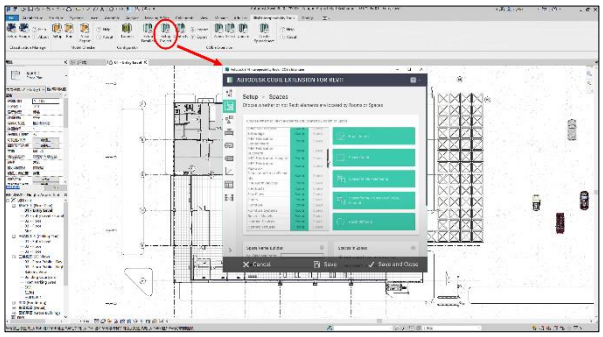

Figure 9. Use Autodesk COBie Extension plug-in to export asset information sets

Subsequently, the asset information modelling management framework was established, and the central goal was identified. Based on the Autodesk COBie Extension plug-in, first collect and add asset management information from the BIM model, then use the information to create a data set, integrate the data into a COBie data set (see Figure 9), and finally import the COBie data set into a facility management system compatible with the COBie standard.
Moreover, there are few cases of information exchange through ifcXML format. The use of this method requires that the asset management system be compatible with the COBie standard. Therefore, in this project, the main implementation form of this method is still based on the Excel spreadsheet. Figure 10 below shows the COBie table data exported from Revit to Excel.

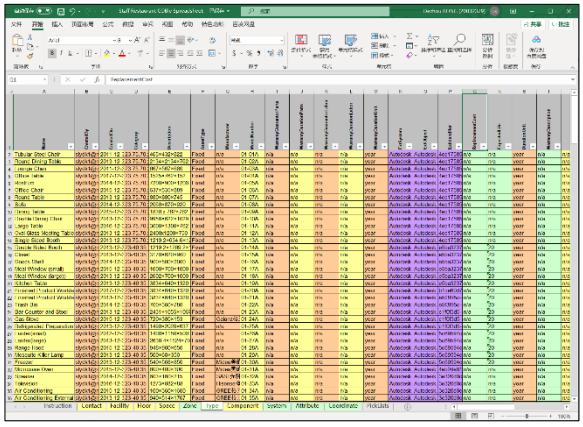

Figure 10. COBie standard format data table for staff restaurant model

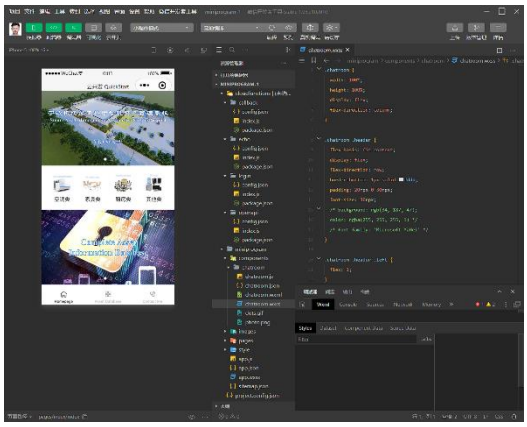

Figure 11. Use WeChat developer tools to develop WeChat mini program

The WeChat Mini Program is an innovative application in the WeChat ecosystem that can be used without downloading and has a strong traffic base[10]. Therefore, based on the previously established complete asset information database, this project takes WeChat mini program as the carrier, aiming to develop a fully functional asset management system platform. Figure 11 above shows the interface of WeChat developer tools. In WeChat mini program, airport management personnel can find different types of assets, including various types of detailed information, to enhance asset management (see Figure 12).

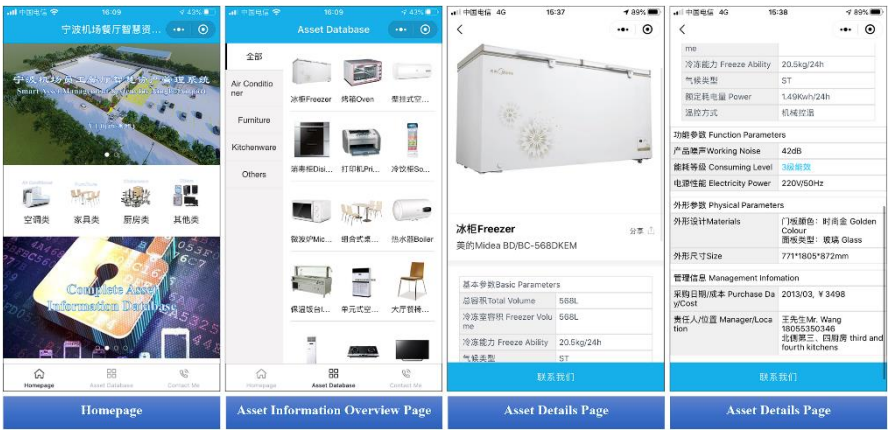

Figure 12. Display of assets management database via Wechat mini program (mobile phone)

3.5 VR for Asset Management Visualization

3.5.1 The Establishment of the integrated VR Environment. To fully present all asset information in the VR environment, some Info-Spot for observation and tracking is set up to indicate where users of the asset management system can access the appropriately registered the asset entity. For instance, select an Info-Spot near the northeast corner of the dining hall to indicate where the asset manager should stand (see Figure 13) in order to accurately register a three-dimensional geometry into a real-world object in a live view (see Figure 14).

Figure 13. Location of Info-Spot in Restaurant Hall

Figure 14. VR environment Info-Spot 1 view of airport staff restaurant based on 720 cloud platform

When the asset manager clicks on the hyperlink point in the interface, it will automatically jump to the asset details page of the asset management system as shown in the previous section. The asset manager can then view all relevant asset information, and if he/she has sufficient authority, the asset information is also allowed to be modified, updated, and supplemented.

3.5.2. Mobile Asset Information Management in Gamificative VR Environment. In order to explore a higher level of visual asset management in a gamified VR environment, and to further verify the data accessibility of the BIM+VR model in the asset information management model, it is necessary to choose more professional VR equipment as a carrier for experimentation. In this study, HTC vive was selected as the VR device, and the author rented an small meeting room as the experimental site for the test. The author assumed that he was an airport restaurant manager, used HTC vive to test the asset information database developed in the previous study and performed several different tasks. In addition, the author also invited 2 students and a campus asset manager from IT services to experience separately. (At the request of the subjects, they will not be photographed in this experiment)

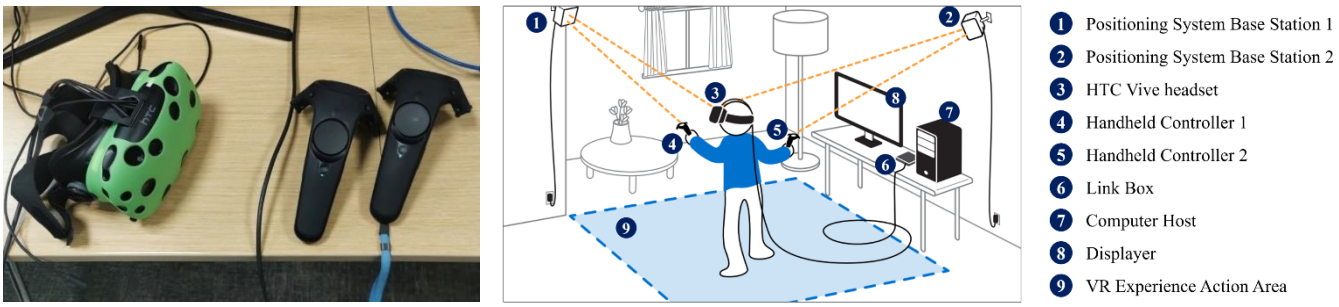

Figure 15. HTC vive Pro VR headset suit and experiment site arrangement

The arrangement of the experiment site is shown in the Figure 15 above, and the experimenter's range of action is limited to a delineated open area in the room. The headset gives the experimenter an immersive VR visual scene. The handheld controller can assist the experimenter in the operation. Two

positing system base stations installed on the diagonal side of the room capture the experimenter's actions.

As can be seen in Figure 16 and Figure 17 below, after all the devices are properly installed, the author and several other subjects will complete the following tests: (1) Enter the virtual room and find the target asset entity; (2) Select the asset entity and read the relevant information; (3) Mark the target asset, and then add relevant information in the WeChat mini program;

Figure 16. The author is testing the asset management system in HTC vive gamificative VR environment

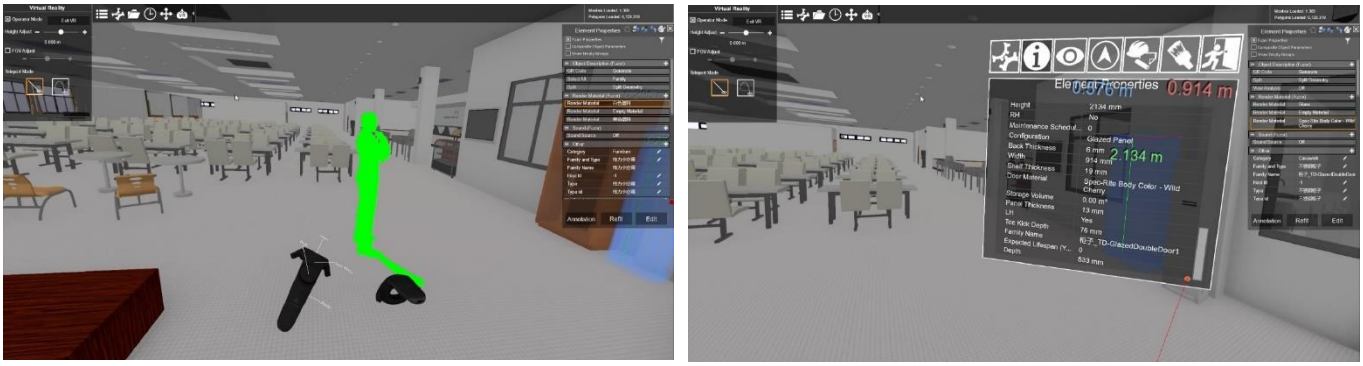

Figure 17. The scene inside the airport staff restaurant as seen by the subject in HTC Vive VR

Including the author, 4 subjects tested the system, and all of them were satisfied with how easy it is to use the system to complete experimental tasks.

Campus asset manager: The campus asset manager has previously experienced the 720cloud mobile terminal VR asset management system based on the Info-Spot mentioned in the previous section. For this HTC Vive VR immersive asset management experiment, his feedback is as follows: **(1)** In the HTC Vive VR environment, I can move freely instead of limited to a few information points, which makes it easier to identify asset entities and their locations; **(2)** The measurement function is very convenient, including geometric measurement and two-point measurement; **(3)** If it (HTC Vive VR) can use voice control to directly add notes to the asset to the WeChat mini program, that's too good job.

Other subjects: Feedback from other subjects is as follows: **(1)** It was a complicated task that only professionals could do, I thought at first, but this gamified environment made me feel relaxed; **(2)** I found this task (using HTC Vive VR) is less demanding than the actual reading of the paper plan (positioning the correct object in the test room), and even children can complete it.

3.5.3. Analysis of System Testing Results. Based on these real test results, the BIM+VR mode does improve the accessibility of asset information and data to a certain extent, optimizes the data transfer process and the efficiency of the execution of work orders for asset information management has also been improved. With the help of the introduction of VR equipment, the threshold to employment of asset managers are also expected to be lowered.
However, some obvious problems still exist. The first is that the cost of professional VR equipment like HTC Vive is too high, and the installation process is too complicated to meet the needs of daily asset management. Simultaneously, the real-time collaboration capabilities of multiple systems are not strong, and many data transfer processes still rely on manual completion to a large extent, namely, the degree of automation from BIM (such as Revit) to VR is not high, which is the focus of future work.
Generally speaking, in the future, it is necessary to integrate the multi-dimensional management requirements of asset management into the building data reading, application and optimization integrated management system platform with the help of BIM+VR tools. Eventually, a more scientific, advanced and intelligent building asset information management platform will be established.

4. Discussion and Conclusion

4.1. Main Findings

The results of the case study of Ningbo Lishe airport staff restaurant show that the this research establishes an effective integrated BIM+VR building asset information management solution for existing buildings, which significantly improves the accuracy and transmission process of data.
Moreover, the research of current stage also reflects some deficiencies and challenges.
These deficiencies include:

- Due to technical limitations, most of the assets information in the currently developed database still needs to be transferred and integrated manually, and the VR environment is also manually established on the rendering results;
- The interaction between BIM software (Revit, etc.) and building assets is not sufficient strong;
- The transmission of operation data of building assets still cannot meet the requirements of high efficiency and real-time performance. The data transmission is static and the goal of whole-process automation is not realized.

The main challenges are:

- The lack of methods to demonstrate the actual benefits of BIM in AM is reflected in the limited demand for AM in BIM+VR from clients and operators.
- In this regard, it is necessary to establish strict BIM specifications to specify modelling requirements;
- This management mode based on BIM+VR lacks a clear role, responsibility, contract and responsibility framework;
- The interoperability and life difference between BIM+VR technology and AM still need to be further studied;
- Lack of open systems and more standardized databases as a bridge between BIM+VR and AM technology;
- From the perspective of the different life cycles of current technologies and buildings, it is necessary to establish open source standards to help maintain the usability of models.

In conclusion, the results show that BIM+VR mode is conducive to the preliminary identification and further modification and supplementation of building operation decision information, as well as to promote the transformation of supply chain. Based on the results of the investigation, this paper proves that the value and potential of BIM+VR in AM are consistent. These values mainly come from the

improvement of accuracy and accessibility of AM data to a higher degree in the visual presentation environment. Also, the efficiency of work order execution is improved, including the speed of accessing data and locating interventions.

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Acknowledgments

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