A Basic Study on Methodology of Maintenance Management Using MR

T. Kim[a], J. Jeong[a], Y. Kim[a], H. Gu[a], S. Woo[b], and S. Choo[a]

[a]School of Architecture, Kyungpook National University, South Korea
[b]Department of Architecture, Kyungil University, South Korea
E-mail:thlouiskim@gmail.com, jjw6720@gmail.com, ye_d_@naver.com, ghm3186@naver.com, openbim@naver.com, choo@knu.ac.kr

Abstract -

Today, with the development of technology, various buildings can be constructed in the field of architecture, and the size and complexity of construction are increasing, and the life cycle of buildings is also increasing. As a result, the importance of technology and systems that can maintain and manage not only old buildings but also newly constructed complex buildings is emphasized in modern society. Therefore, in this study, we propose a methodology to improve the efficiency of utilizing MR in the visible aspect of the maintenance of buildings and try to find a way to improve the efficiency of the actual worker by verifying the feasibility of the methodology. The information obtained from the BIM model was uploaded to the MR device, confirming its effectiveness in terms of visibility. We have developed an add-in that can complement the interoperability problems such as data exchange and uploading through the data that can be obtained through the current limited BIM model. By integrating it with other technologies such as artificial intelligence in the future, It is expected that we will be able to fill in deficiencies other than the problems of visualization presented.

Keywords –

Maintenance; BIM(Building Information Modeling); MR(Mixed Reality); Efficiency

1 Introduction

1.1 Research Background and Purpose

The shape of architecture has changed according to the trend of the times. In the modern era, buildings were widely distributed in internationalist style, and buildings built at that time are still continuing and aging. Also, with the development of technology today, various buildings can be built in the field of architecture, and the size and complexity of construction are increasing, and the life cycle of buildings is also increasing. As a result, the importance of technology and systems that can maintain and manage not only old buildings but also newly constructed complex buildings is emphasized in modern society.

Considering the safety performance of the building at the time of construction, maintenance and maintenance of the building, maintenance and replacement of the structure during the lifecycle of the building, and improvement of the performance are performed according to the aging of the structural materials. Building Information Modeling (BIM) has been introduced to manage such a series of work efficiently, so that it can cover all phases of design - construction - maintenance. Based on the information generated through BIM model, Facility Management System, FMS) as basic data. In other words, when creating the BIM model, the information necessary for maintenance should also be input to the BIM model as attribute information. Based on the information, the FIM can be utilized actively. In spite of this technology, however, it is still difficult to establish a complete link between BIM information and FMS. Therefore, in the maintenance stage, it is based on the existing 2D drawings. Especially, when the lifecycle of construction materials is confirmed, BIM information is utilized for intuitive visualization. It depends on human eyes and 2D drawings.

In recent years, 'Microsoft' in the United States has introduced Mixed Reality (AR), which is a mixture of augmented reality (AR) that adds virtual information based on reality and augmented virtuality (AV) , MR) devices have been developed for 'Hololens' HMD (Head Mounted Display). In the field of construction, it is used as a tool to visualize parts that are difficult to understand in drawings and to help constructors understand them. Therefore, this study suggests a methodology that can improve the efficiency of utilizing the existing ineffective method in the maintenance of buildings, especially MR, in terms of visual aspect, and by verifying the feasibility of the methodology, I want to find a way to do that.

1.2 Scope and method of research

This study is a basic study to find a methodology for efficient operation using MR devices in the field of building maintenance. Therefore, this study limited the MEP(Mechanical Electrical and Plumbing) area in terms of visualization, which was especially difficult even in the inefficient way that has been done with the existing drawings in the maintenance process of the buildings. The flow of research is shown in Figure 1.

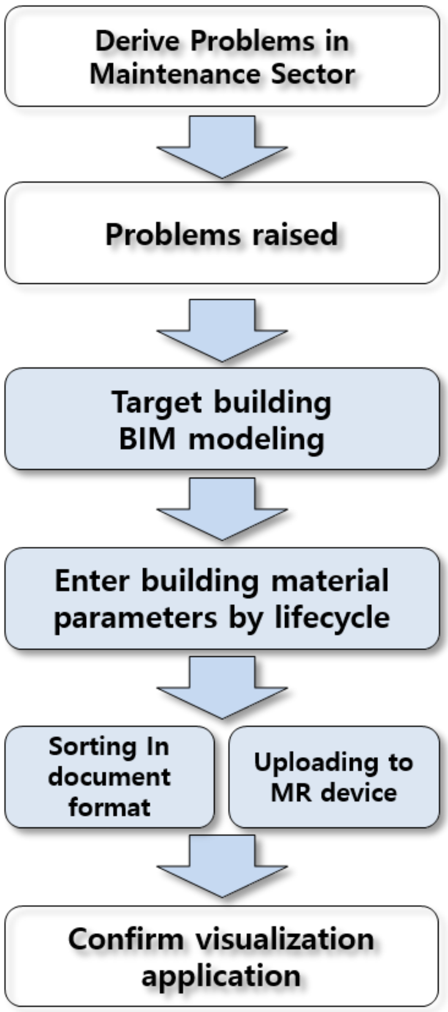

Figure 1. Flow of Study

First, the verification target building for method validation is modeled using BIM tool. After inputting attribute information such as life cycle to the completed MEP model, coloring is performed on the material in the BIM model so that efficient visualization can be performed by filtering according to the information required for maintenance. At the same time, data sorting is performed to increase the efficiency of actual workers by using information of materials according to attribute information. After the work as a BIM tool is completed, the BIM model is uploaded to the MR device and the verification step is performed in an actual 1:1 size AR model.

2 Background and Related Research

In Korea, since the approval of the use of buildings since 2013, the maintenance management system of existing buildings, which was maintained only by the unilateral intention of the owner or manager, is supplemented, and periodic maintenance and inspection of collective structures and multi-use building. Maintenance and inspection system of buildings is being implemented. [1] In the Building Act before the revision in 2012, owners or managers of buildings were legally required to maintain and manage buildings, land, and building facilities. However, the willingness of the relevant authorities to supervise and supervise the maintenance of such buildings was weak, the contents of the management check items are unclear, the maintenance reporting time and the report maker are not clear due to the use and size of the building, and the overall control system is lacking. [2] Since the current buildings are approved by the law, they are maintained and managed only by the unilateral will and intention of the owner and the manager. In the process of using after the completion, there is no specific regulation for the maintenance of the building, but it has not fulfilled the role of protection. [3]

In the United States, each state or city is operated as a form of each ordinance. Especially, evaluation items and criteria for the specific performance of the building are developed and maintained for the purpose of improving the specific performance of the building.

In the UK, maintenance and management are being carried out to build a healthy and comfortable residential complex based on HQI (Housing Quality Indicators) and to improve the quality of the residential level. This provides comprehensive and specific performance evaluation criteria by providing information on performance certification and standard setting related to residential buildings.

In Japan, the Architectural Standard Law, which introduces concrete and strengthened regular reporting systems at the government level, has been amended to take a more active attitude toward maintenance. As such, internationally, maintenance-related systems are approaching from a broad perspective, such as environment, energy, performance evaluation, and urban environment, from a futuristic point of view. However, in each country, improvement is being made in terms of the system by laws and regulations.

Through a series of efforts, the BIM technology mentioned above is introduced to process the data generated during the construction process at once and utilize it throughout the life cycle of the building. However, this is also due to the various information required by various software functions, and several owners of BIM data are created, but there is a lack of a single integrated information system. [4] Even if the integrated BIM model is constructed to manage all information, there is still a lack of research on visualization of work such as supplementing and replacing aged building components in the maintenance field.

MR technology has been applied as a means to overcome the problems of visualization and has already been widely used in the field of architecture. 'MIDASI'T introduced a display house using VR (Virtual Reality) equipment and introduced a virtual reality in the field of architecture. The company called 'Urbanbase' developed the interior application using AR to maximize the visual effect thereby increasing the satisfaction of actual users. In addition, 'Hololens for Sketchup Viewer', developed by 'Trimble', improves the efficiency of work by showing MR parts to the contractor not only in MEP field but also in difficulties. However, there is not yet a methodology and research that utilize this in the maintenance field.

Figure 2. VR Display House from 'MIDASIT'(vr.midasitonline.com)

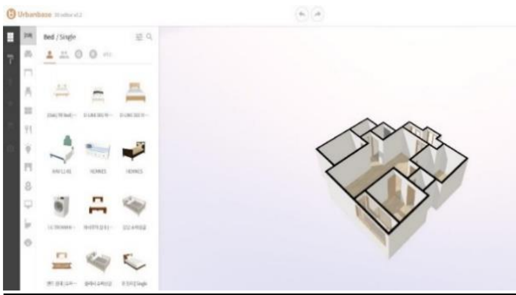

Figure 3. AR Interior System from 'Urbanbase'(https://urbanbase.com)

3 Target building analysis and BIM modeling

In this study, the building is one of the lectures within Kyungpook National University located in Daegu, Korea. The outline of the building is shown in Table 1 below.

Table 1. The Outline of Target Building

Type	Straight Type
Height	14.6 m
Each Floor Area	1278.5 ㎡
Floor	4
Long side/ Short side	70000mm/18800mm

This building is a building that has been over 20 years old since its completion and is in need of maintenance but not properly maintained. In particular, although the remodeling has been carried out twice in the past, there is no work to supplement the performance of the building such as elevator installation, rooftop solar panel installation, and structural aspects. Autodesk's Revit 2017 was selected as a tool to make this target building a BIM model. Revit is a BIM modeling tool that not only provides basic modeling but also has an embedded energy performance analysis program that can be used in many aspects of building performance in terms of maintenance.

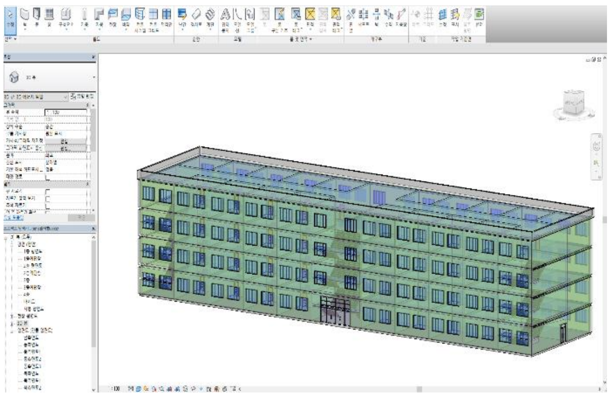

Figure 4. BIM Model of Target Building

The modeling level is defined as LOD 100 based on document E202TM-2008 and AIA Document G203TM-2013 document considering the level of visualization of the target object only in view of maintenance rather than accurate numerical information. In this document, LOD is used in combination with 'Level of Detail' and 'Level of Development'. However, in order to prevent confusion, this study used 'LOD Development'. Contents are shown in the following Table 2. [5]

Table 2. Contents of LOD(Level of Development)

LOD	Contents
LOD 100 Conceptual	The type, volume, and type of mass are defined at the level of the planning task, and the area, height, volume, position, and orientation of the entire building are set.
LOD 200 Approximate Geometry	Space program, space plan and spatial relation are defined and main architectural general system is determined as conceptualized planning stage. The rough floor area, coverage ratio, floor area ratio, floor height, number of floors, main structure, envelope structure, facility system, etc. are planned
LOD 300 Precise Geometry	The LOD 200 is a step in which the outline of the building process is determined. The building system including the specific facility elements is determined, and all the building elements are modeled.
LOD 400 Fabrication	The size, shape, quantity, etc. of all systems determined as modeling steps for actual construction are modeled. All the elements related to construction, fabrication, and assembly are modeled, such as materials, structures, equipment, piping, and wiring.
LOD 500 As Built	The LOD 500 model is a completion model. The modeling data is the same as the actual building, and includes the entire maintenance/operation.

In this study, MEP, which is an architectural material to be confirmed in this study, is modeled only in the pipes(Plumbing) so that it can be visually and clearly seen at the same LOD level as the same BIM tool, and detailed piping is omitted and three main piping models are modeled.

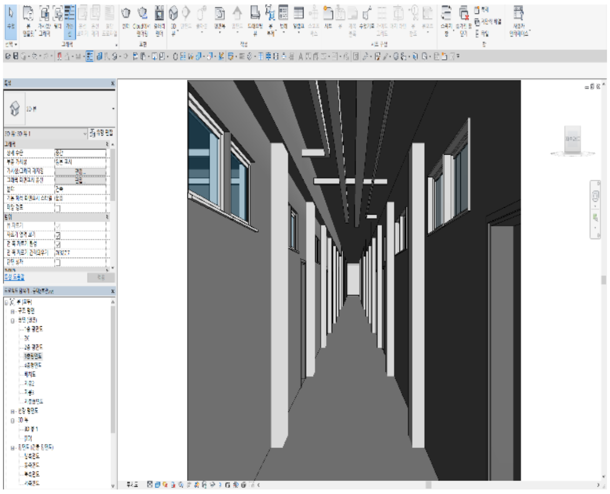

Figure 5. MEP(main pipes) Modeling by BIM

4 Experiment

The detailed experimental scenarios are as follows.

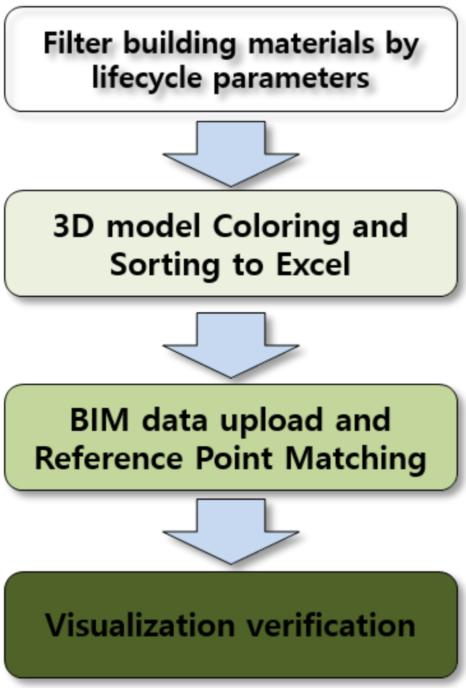

Figure 6. Experimental Scenario

In order to investigate the degree of deterioration of the main piping in Kyungpook National University 's maintenance lecture, we firstly input the life cycle information of each pipe as a parameter in BIM. Also, the degree of replacement according to input parameters was filtered with different colors.

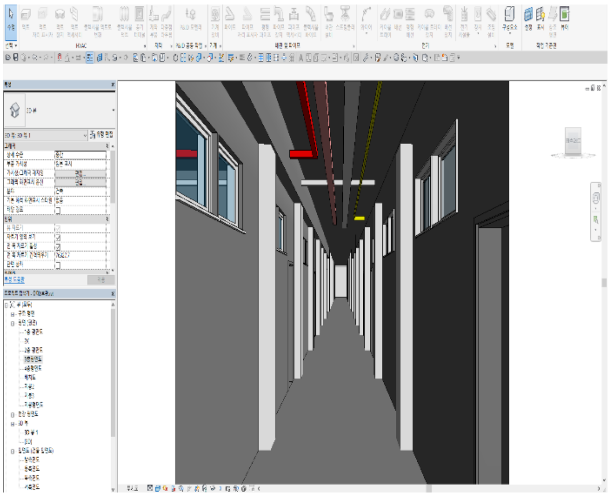

Figure 7. Coloring each Pipes by Life Cycle Parameter

In Revit, you can extract the filtered data using the input parameters according to the desired modeling material. Figure 7 shows data obtained by sorting the coloring data of the piping according to the life cycle into an Excel file.

	A	B	C	D	E	F
1	Name	Floor	Life Cycle	Construction	Coloring	
2	E02-MEP-Pipe01	E02-1	10 year	1990's		
3	E02-MEP-Pipe01	E02-1	10 year	1990's		
4	E02-MEP-Pipe01	E02-1	10 year	1990's		
5	E02-MEP-Pipe02	E02-1	15 year	1990's		
6	E02-MEP-Pipe02	E02-1	15 year	1990's		
7	E02-MEP-Pipe02	E02-1	15 year	1990's		
8	E02-MEP-Pipe03	E02-1	20 year	1990's		
9	E02-MEP-Pipe03	E02-1	20 year	1990's		
10	E02-MEP-Pipe03	E02-1	20 year	1990's		
11	E02-MEP-Pipe04	E02-1	25 year	1990's		
12	E02-MEP-Pipe04	E02-1	25 year	1990's		
13	E02-MEP-Pipe04	E02-1	25 year	1990's		
14	E02-MEP-Pipe05	E02-1	30 year	1990's		
15	E02-MEP-Pipe05	E02-1	30 year	1990's		
16	E02-MEP-Pipe05	E02-1	30 year	1990's		
17				Total number : 15		
18						
19	Name	Floor	Life Cycle	Construction		
20	E02-MEP-Pipe01	E02-2	10 year	1990's		
21	E02-MEP-Pipe01	E02-2	10 year	1990's		
22	E02-MEP-Pipe01	E02-2	10 year	1990's		
23	E02-MEP-Pipe02	E02-2	15 year	1990's		
24	E02-MEP-Pipe02	E02-2	15 year	1990's		
25	E02-MEP-Pipe02	E02-2	15 year	1990's		
26	E02-MEP-Pipe03	E02-2	20 year	1990's		
27	E02-MEP-Pipe03	E02-2	20 year	1990's		
28	E02-MEP-Pipe03	E02-2	20 year	1990's		
29	E02-MEP-Pipe04	E02-2	25 year	1990's		
30	E02-MEP-Pipe04	E02-2	25 year	1990's		
31	E02-MEP-Pipe04	E02-2	25 year	1990's		

Sheet1

Figure 8. Sorting from BIM Parameter Data

When the modeling work using the BIM tool is finished, the BIM data is uploaded to the MR device Hololens. The experiment was carried out using 'BIM Holoview' which is a program to link BIM with Hololens. From the BIM Holoview homepage, create the user ID and upload the BIM model. After logging in with the same user ID in Hololens, you can view the uploaded BIM model as Viewer.

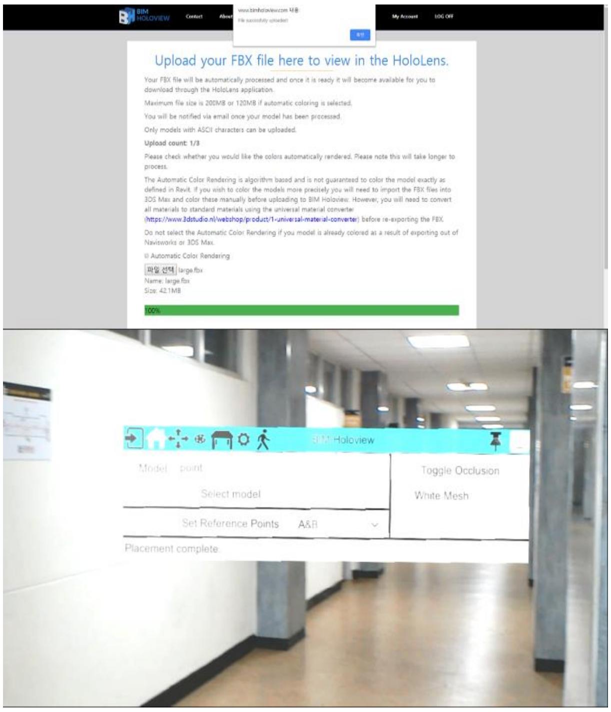

Figure 9. Uploading BIM Data to BIM Holoview

The operation of Hololens is simple. Speech recognition is possible and you can use a remote controller, but the function of clicking on the computer mouse is called 'Air Tap'. You can select it according to the point of sight by hitting your finger on Hololens screen. Another function is 'Bloom' which makes the windows on the screen disappear.

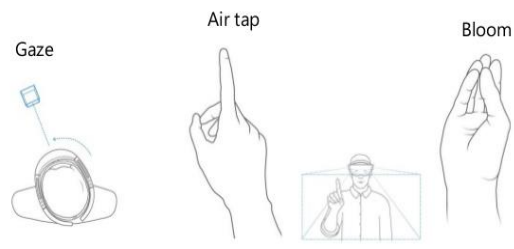

Figure 10. Gestures for Hololens(https://www.microsoft.com/en-us/hololens/)

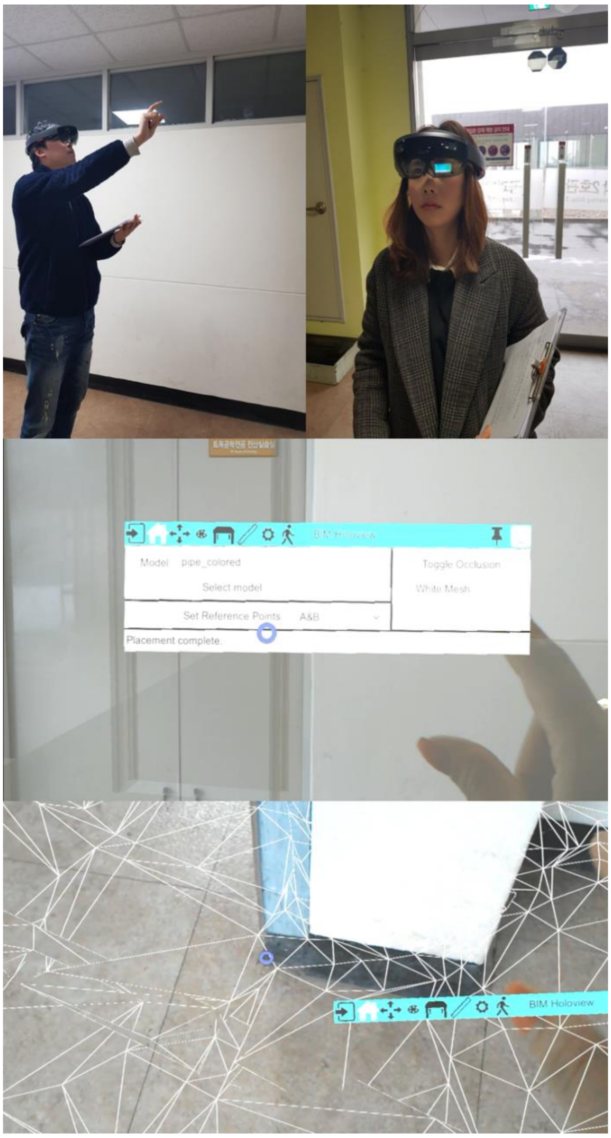

Figure 11. Control the Hololens

A In this study, BIM data did not include any information other than life cycle parameters other than basic building information. BIM model can have location information and can contain a lot of information such as other energy performance, Time Data (meaning 4D), and Cost Estimate (meaning 5D).

However, as mentioned above, due to the limitation of interoperability in information exchange, only the data required in this study is omitted.

In this case, since the location data is not input, the Reference Point matching the existing BIM data should be prioritized with the Reference Point of the building on the actual Hololens.

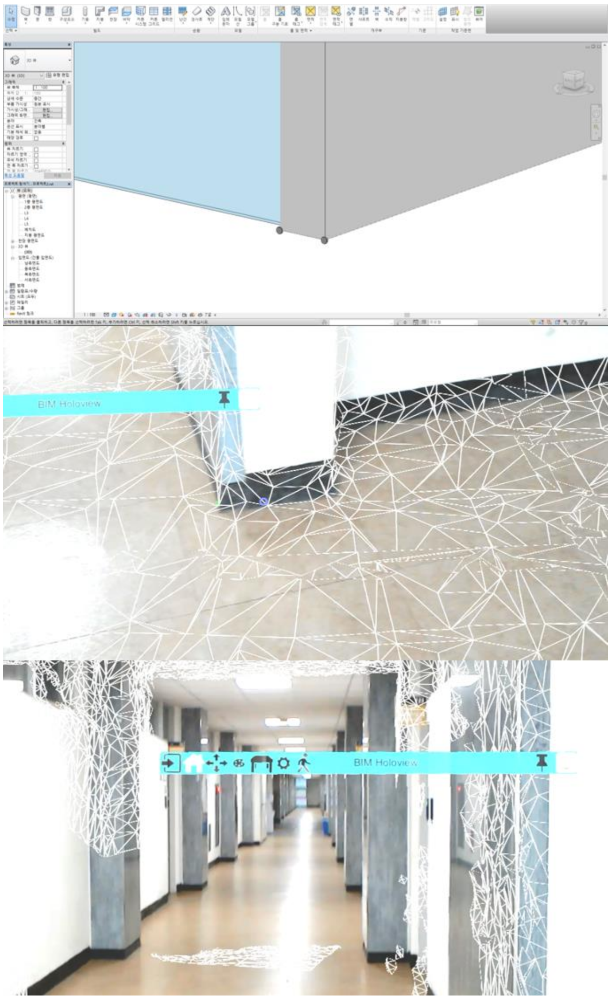

Figure 12. Matching the Reference Point

Then, the verification of the visualization to the MR device was performed based on the sorted Excel data.

5 Discussion

As described in Chapter 4, the BIM model in Hololens was viewed through the Viewer. In addition, the results of the coloring of the piping life cycle as a parameter were also confirmed.

However, the object information in the BIM model, that is, the wall as a wall-specific object and the slab as a slab-specific object, can not be recognized.

Hololens, which is the MR device used in this study, recognizes the wall and space itself in the MR device itself, but the object information of the BIM data disappears in the exporting process and does not reach the step of selecting or modifying the wall in the MR. However, it shows almost 100% synchronous rate, and it is confirmed that MEP which is the target of this study can be utilized in the maintenance field through the model fitted according to the reference point, and that it is an efficient visualization methodology.

Figure 13. Verification of BIM-MEP model visualization through MR device

6 Conclusion

This study suggests a methodology to increase the efficiency between work during the maintenance and repair process according to the aging of the MEP in the maintenance stage of the building. Especially, it is a method to improve the work efficiency of the actual worker.

Based on the BIM model filtered through the BIM model, the method using the MR device was proposed. The model generated by BIM contains a lot of basic data and can manipulate the parameters to contain more data. However, at present technology level, there is a limit to bring all the data of BIM into MR device.

However, this study shows that it is possible to upload the location information of the desired material and the filtered data according to the life cycle to the MR device. Based on these results, it was confirmed that colorized materials were observed according to the life cycle. And compared to the method of replacing and repairing by relying on the existing 2D drawings, it was able to grasp the exact position, and it was possible to locate the piping of the MEP which was mainly installed in the ceiling duct, And confirmed the possibility of reducing manpower.

In the maintenance stage, the replacement and maintenance of the obsolete materials, which were limited in this study, are part of the maintenance and maintenance in various aspects is needed. If add-in is developed that can complement interoperability issues such as data exchange and uploading through the data obtained through the current limited BIM model, it will be possible to maintain and manage the performance of various buildings such as energy and safety. And it is expected that it will be able to fill deficiencies other than the problems of visualization presented in this study through fusion with various technologies such as artificial intelligence in the future.

Acknowledgements

This research was supported by a grant(19RDRP-B076268-06) from R&D Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

This research is a basic research project funded by the Korean government (Future Creation Science Department) in 2016 and supported by the Korea Research Foundation. Assignment number: 2016R1A2B4015672

References

[1] Yoo Chul-Jong. A Study on Efficient Building Maintenance Plan – Focusing on the Importance Calculation of the Check Items – *Journal of the Architectural Institute of Korea Structure & Construction,* 31(9):3-10, 2015.

[2] Yoon Hyo-Jin. A Study on the Improvement of Building Maintenance System – Focusing on Comparison with Japanese Case. *Journal of the Korean Society of Civil Engineers,* 35(3):737-745, 2015.

[3] Yoo Hyo-Jin. A Study on Building Maintenance Institutionalization by Comparing with the Foreign Countries's cases. Journal of the Korean Society of Civil Engineers D, 31(6D):857-865, 2011.

[4] Choi Tae-Sook. Study on the Integrated Management System Configuration for Building Maintenance. *Journal of the Korean Society of Living Environmental System*, 22(5):696-704, 2015.

[5] AIA. AIA Document G203TM-2013, 2013.

[6] Iveta Pukite., Mg. sc., Ineta Geipele, Prof., Dr. oec. Different Approaches to Building Management and Maintenance Meaning Explanation. *Procedia Engineering*, 172:905-912, 2017.

[7] Ibrahim Motawa, Abdulkareem Almarshad. A knowledge-based BIM system for building maintenance. *Automation in Construction*, 29:173-182, 2013.

[8] Enrique Valero, Frederic Bosche, Alan Forster. Automatic Segmentation of 3D point clouds of rubble masonry walls, and its application to building surveying, repair and maintenance. *Automation in Construction*, 96:29-39, 2018.

[9] Xinghua Gao, Pardis Pishdad-Bozorgi. BIM-enabled facilities operation and maintenance: A review. *Advanced Engineering Informatics,* 39:227-247, 2019.

[10] C. Nzukam, A. Voisin, E. Levrat, D. Sauter, B. Iung. A dynamic maintenance decision approach based

on maintenance action grouping for HVAC maintenance costs savings in Non-residential buildings. *IFAC-PapersOnLine,* 50(1):13722-13727, 2017.

[11] Moshood Olawale Fadeyi. The role of building information modeling(BIM) in delivering the sustainable building value. *International Journal of Sustainable Built Environment*, 6(2):711-722, 2017.

[12] Lucy Linder, Damien Vionnet, Jean-Philippe Bacher, Jean Hennebert. Big Building Data – a Big Data Platform for Smart Buildings. *Energy Procedia,* 122:589-594, 2017.

[13] Gunther Riexinger, Andreas Kluth, Manuel Olbrich, Jan-Derrik Braun, Thomas Bauernhansl. Mixed Reality for On-Site Self-Instruction and Self-Inspection with Building Information Models. *Procedia CIRP*, 72:1124-1129, 2018.

[14] Jad Chalhoub, Steven K. Ayer. Using Mixed Reality for electrical construction design communication. *c*

[15] Danubia Bueno Espindola, Luca Fumagalli, Marco Garetti, Carlos E. Pereira, Silvia S.C. Botelho, Renato Ventura Henriques. A model-based approach for data integration to improve maintenance management by mixed reality. *Computer in Industry,* 64(4):376-391, 2013.

[16] Choo Seung-yeon, Lee Kweon-Hyoung, Park Sun-Kyoung. A Study on LOD(Level of Development) for Development of Green BIM Guidelines – Focused on Energy Performance Estimation -. *Journal of the Architectural Institute of Korea Planning & Design,* 28(6):37-47, 2012.

[17] Kim Tae-Hoon, Seo Ji-Hyo, Choo Seung-Yeon. An Energy Performance Comparison of University Lecture Facilities for Energy Saving Building Design. *Journal of the Architectural Institute of Korea Planning & Design,* 34(11):105-112, 2018.

[18] Sara Madureira, Ines Flores-Colen, Jorge de Brito, Clara Pereira. Maintenance planning of façade in current buildings. *Construction and Building Materials*, 147:790-802, 2017.

[19] P. Paulo, F. Branco, J. de Brito, A. Silva. BuildingsLife – The use of genetic algorithms for maintenance plan optimization. *Journal of Cleaner Production,* 121:84-98, 2016.