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Linking LOD and MEP Items towards an Automated LOD Elaboration of MEP Design

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Abstract: Current MEP designs are mostly applied by 2D-based design methods and tend to focus on simple modeling or geometry information expression such as converting 2D-written drawings into 3D modeling without taking advantage of the strength of BIM application. To increase the demand for BIM-based MEP design, geometric information, and property information of each member of the 3D model must be conveniently linked from the phase of the Design Development (DD) to the phase of Construction Document (CD). To conveniently implement a detailed model at each phase, the detailed level of each member of the 3D model must be specific, and an automatic generation of objects at each phase and automatic detailing module for each LOD are required. However, South Korea's guidelines have comprehensive standards for the degree of MEP modeling details for each design phase, and the application of each design phase is ambiguous. Furthermore, in practice, detailed levels of each phase are input manually. Therefore, this paper summarized the detailed standards of MEP modeling for each design phase through interviews with MEP design companies and related literature research. In addition, items that enable auto-detailing with DYNAMO were selected using the checklist for each design phase, and the types of detailed methods were presented. Auto-detailing items considering the detailed level of each phase were classified by members. If a DYNAMO algorithm is produced that automates selected auto-detailing items in this paper, the time and costs required for modeling construction will be reduced, and the demand for MEP design will increase.

Key words: MEP, BIM, LOD, Automated Design, Dynamo

1. INTRODUCTION

The current method of MEP (mechanical electronic plumbing) design only focuses on simple modeling or geometry information expression, such as converting 2D-written drawings into 3D modeling without taking advantage of the strengths to apply building information modeling (BIM); strengths which include productivity improvement, convenience of quantity take-off, and efficiency of maintenance [1]. In order to increase the demand for BIM-based MEP designs using BIM from Schematic Design, it is important that a detailed model of each member is conveniently implemented as it is connected from the phase of Design Development to the phase of Construction Document. This is because making detailed modeling from Design Development to Construction

Document phases are basic tasks in BIM-based MEP design. Although each MEP member must be linked with geometric information and property information of the BIM at each design phase, in practice, the detailed level of each phase is input manually. Currently, since it is mainly carried out depending on the labor force, and the time and costs required to build the modeling are increasing, it is now in practice limited to simple modeling such as converting 2D drawings into 3D modeling. In order to conveniently implement detailed models of each phase, it is important to present detailed levels for each member of the 3D model, automatically generate objects by phase, and produce auto detailing modules for each Level of Development (LOD). The Ministry of Land, Infrastructure and Transport in South Korea has BIM Basic Guidelines of Construction Industry to deal with basic principles and standards for BIM application in the construction industry, which describe the BIM detailed levels as six phases of 100 to 500. Furthermore, the Public Procurement Service presents BIM data documentation guidelines for each structural, architectural, civil, mechanical, and electrical field and the level of expression by BIM through the basic guidelines of the Ministry of Land, Infrastructure, and Transport. Contrary to the construction sector, however, the guidelines presented require research to present detailed modeling standards for each design phase because they have excessively comprehensive standards for the degree of MEP modeling details for each design phase and ambiguous application for each design phase [2]. Moreover, in order to solve the labor-intensive problem of detailing work on design documents, research is needed to organize items that can be automatically detailed for each design phase and automatically implement detailed models. Therefore, this paper summarizes LOD of MEP modeling for each specific design phase and presents the types of items and detailed methods to enable auto-detailing.

Through related literature on MEP automation and interviews with a MEP design company, the MEP design process and MEP Level of Development in practice were derived. The MEP design company was selected as an organization using BIM from the initial design phase, and interviews were conducted while at the company for five days. For those five days, we investigated the MEP design constraints, the design process when utilizing BIM, the disadvantages and improvements of BIM design, and the task that has the highest workload. After organizing the MEP design process, LOD of MEP modeling for each specific design phase were summarized in consideration of the literature on MEP detailed standards and the guidelines of the Public Procurement Service to elaborate on the MEP detailed standards by the Ministry of Land, Infrastructure and Transport. DYNAMO is a program widely used in the design automation field because it is able to be linked to REVIT and automatically produce the desired model through algorithms. With DYNAMO, it is possible to produce an algorithm that draws various design alternatives by designating algorithms, constraints, and parameters for automating a simple work model in which the same work is repeatedly performed. Therefore, in this paper, in order to increase the linkage of the BIM model by each detailed level summarized above, auto-detailing items that can be automated with DYNAMO were selected. In addition, data were collected using MEP design constraints surveyed by interviews and the checklist for each design phase to select auto-detailing items for each LOD.

2. RELATIVE WORKS

BIM libraries and templates are the common criteria that are the most universally applicable and allow the stable application of automation processes [3]. DYNAMO is effective in increasing the usability of libraries by building an automatic library creation system and makes multiple calculations a process for the desired purpose. In practice, there is a case of constructing an algorithm using DANAMO. The interior panel pattern algorithm sets an object on which the panel is to be placed, models the geometry of the panel as a Family, and then injects a property for parameter application to generate a panel assembly [4]. Also, there is a case in which a restaurant furniture placement plan algorithm was constructed using DYNAMO. It is enabled to automatically place modeling tasks such as horizontal arrangement, free horizontal arrangement, and vertical arrangement, which were manually performed in practice, through parameter input. Automatically arranging furniture is meaningful in that it minimizes inefficient use of restaurant spaces and increases the efficiency of designers' work by quickly creating various drawings [5].

In order to select Auto-detailing items that can be solved with DYNAMO, the criteria for writing BIM data at each design phase must be clear. Cho (2013) established LOD standards required for BIM modeling in the design phase and defined BIL to improve the division of labor and collaboration conditions, enhance work efficiency, and upgrade design quality based on the creation of integrated BIM models for each design phase [6]. Park (2017) calculated the quantity and construction costs by phase in accordance with the documentation guidelines in the BIL mechanical equipment field described in domestic and foreign BIM guidelines, and then drew the minimum documentation items of members suitable for the purpose and use of the design phase [2]. Choi (2021) presented the supplemented BIL criteria by referring to Park (2017)'s BIL criteria table. Choi (2021)'s criteria table referred to the possibility of lowering work efficiency due to an increase in the size of the BIM file when expressing the BIM model in detail in order to consider LOD from a more practical point of view [1].

3. WORK PROGRESS BY DESIGN PHASES AND THE DETAILED LEVEL OF MEP MODELING

3.1. Work Progress by MEP Design Phases Based on BIM

The BIM-based MEP design process was summarized by incorporating the application design phases and similar standards for each construction detailed levels from the Basic Guidelines for BIM in the Construction Industry by the Ministry of Land, Infrastructure and Transport into Figure 1. The MEP design process is largely divided into Schematic Design phase (LOD200, BIL10 to BIL20), Design Development phase (LOD200, BIL30), Construction Document phase (LOD300 to LOD350, BIL40), and Construction phase (LOD 400, BIL 50). First, in the schematic design phase, it reviews the owner requirements and related laws and regulations, and writes a BIM perform plan to organize BIM templates and libraries and to establish coordination between BIM design processes and construction departments. In the Design Development phase, it determines the MEP systems such as heat source facilities and air conditioning methods, and checks energy performance of buildings. In addition, it confirms the main SPACE related to MEP with the arrangement of sketchy equipment in the mechanical room and the air conditioning room along with the placement of main ducts and main pipes. The construction document phase is divided into LOD300 and LOD400 phases. In the phase of LOD300, sub-ducts, sub-pipes, and most equipment are placed and design errors are adjusted through clash detection function of BIM. Most of the designs are made at the LOD300 phase, and in the subsequent LOD400 phase, detailed drawings and specifications are prepared and the detailed quantity is determined to calculate the main quantity table.

3.2. MEP Modeling Detailed Levels by Design Phases

< LOD of MEP by Design Phase > was produced by reflecting the detailed levels proposed by Choi (2013), Choi (2021), and Park (2017) along with the Public Procurement Service's Basic Guidelines for Applying BIM to Facility Business as well as work progress by design phases. In the vertical axis of < LOD of MEP by Design Phase >, data creation criteria are presented by equipment and electricity.

In the schematic design phase where major facility spaces must be determined, the appearance of the main duct and main pipe is modeled for space check by classifying it with function and purpose. In addition, for a brief quantity take-off, information on insulation properties must be entered in ducts and pipes. The main equipment of the mechanical room, the air conditioning room, and the electric room is modeled to check major MEP spaces, and if space for inspection and undecided space is required, spare space objects are modeled. In the construction document phase of the LOD300, the appearance of a sub-duct and a sub-pipe is schematically modeled to perform clash detection. In LOD350, duct and pipe modeling is modified according to specific calculations, and instruments such as hangers and supports are modeled. The joint fittings of duct and pipe such as a union, a reducer, a socket, a cap are modeled from LOD300 to LOD350 are modeled, and a detailed expression of insulation and equipment input as a property in the previous phase of LOD200 should be modeled. In the construction phase, when it is necessary to secure space for AS-Built inspection, spatial object modeling and objects are modeled attached to the surface of ducts and pipes, such as freeze protection heating wires and snow management stickers, should be performed.

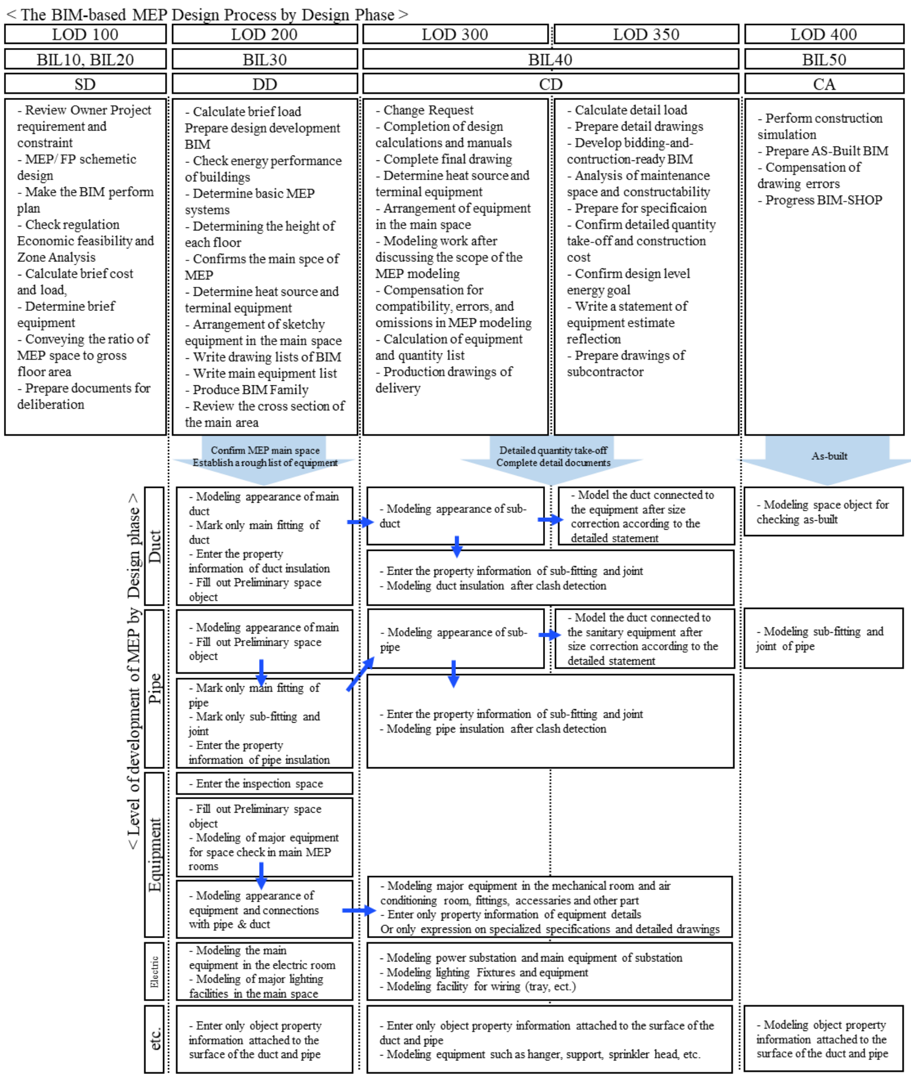

Figure 1. The MEP Design Process and Level of Development by Design Phase (Arrow represents: Recommended modeling sequence)

4. AUTO-DETAILING ITEMS FOR EACH DESIGN PHASE

4.1. Types by Detailing Methods

In order to implement the LOD of the BIM model in connection with each design phase, this paper proposes Auto-detailing items for each LOD and types according to detailing methods. Items and methods that can be automated using REVIT's DYNAMO were drawn, and types according to detailing methods include object detailing, object creation, family modeling, and design alternatives suggestion. The explanation for each type is as follows:

1) object detailing

Object detailing is a type of modifying or generating characteristics or properties of an object with the appropriate content in order to increase the detailed levels of an object already modeled. Object detailing includes entering properties for purposes or materials in modeled ducts, or entering properties' information in water temperature fluctuation prevention pipes.

2) object creation

Object creation is a type of creation for an object at a necessary location according to an already set design criteria or creating an additional model depending on the properties' value input in the object. Object creation includes modeling the appearance of a routed duct, or creating an insulation model according to insulation property value input to a duct and a pipe, an electric heating wire model when an FCU floor and pipe are outdoor pipes, open/close valve model to sub-pipes, and ducts trestles. Most of the detailed items belong to the object creation type, and the quality of the detailed module depends on the degree of investigation and understanding of the design criteria for each MEP detailed item.

3) family modeling

Through family modeling, the family necessary for the project should be configured so that it can be used if needed. Items, such as modeling pipes with families in which sleeves are automatically generated in parts where pipes penetrate the wall, or modeling pipes and duct connections of major equipment such as pumps or air conditioners, belong to family modeling [7].

4) design alternatives suggestion

The design alternatives suggestion is a type that presents several design alternatives according to design constraints and objective functions using REVIT DYNAMO's Generative Design. Items, such as routing pipes and ducts, and placing major equipment including pumps, air conditioners, boilers, and chillers in the mechanical room and the air conditioning room, belong to the types of suggesting design alternatives.

4.2. Auto-detailing item List According to the LOD for Each Design Phase

This paper summarizes the detailed levels for each design phase organized above. And identifies the MEP design criteria with a checklist for each design phase to draw detailing items (Table 1).

First, in the Design Development phase, is the type of object creation that models the appearance of main ducts and pipes and the type of the design alternatives suggestion that places major equipment in the MEP space. Also, there is the type of family modeling that uses pipe connections of sanitary equipment or connections of major equipment. In the construction document phase, the detailed level of the model must be completed to some extent.

Hence, the construction document must generate the appearance of a routed sub-pipe, or create objects that are composed of pipes and ducts such as diffusers, insulation, elbows, traps, valves, and model the details of equipment and instruments. Lastly, in the construction phase, there is an item for space modeling for damper operation or pipe cleaning and repair replacement because space modeling is needed when it is required to ensure a space for inspection.

Table 1. Auto detailing items by LOD

	LOD200 (BIL30, SD)	**LOD300 (BIL40,** DD)	**LOD350 (BIL40,** CD)	**LOD400(BIL50,** CA)
Air conditioning duct	- Routing main duct line - Modeling appearance of main duct line (Using routing properties) - Modeling preliminary space object (for construction and inspection space)	- Routing sub-duct line - Modeling appearance of sub-duct line - Modeling pressure reducing valves - Arrangement diffuser - Modeling flange joint - Modeling muffler, noise elbow, noise-absorbing flexible duct - Modeling lightning duct	- Enter the property of duct material - Modeling duct insulation - Changing duct size (by the detailed statement) - Modeling details of diffuser	- Modeling operation space of damper - Modeling the inspection space object
Ventilation Duct	- Routing main duct line - Modeling appearance of main duct line (Using routing properties)	- Modeling duct insulation - Routing sub-duct line - Modeling appearance of sub-duct line	- Enter the property of duct material - Enter corrosion-resistant materials property on exhaust duct - Changing duct size (by the detailed statement) - Extend exhaust duct to the bottom	
HVAC Plumbing	- Routing main pipe line - Modeling appearance of main pipe line (Using routing properties)	- Installation anchor of riser pipe and expansion joint - Modeling Automatic electric valve, balancing valve, Pressure Reducing Valves, Differential pressure and flow control valve - Modeling open/close valve of sub-pipe - Modeling auto flow control valve by space - Modeling humidification valve, union, trap - Modeling air escape valve on the top of the riser pipe and drain valve on the bottom of the riser pipe - Routing sub-pipe line	- Modeling electric heating wire - Modeling refrigerant pipe cover	- Modeling space object for cleaning and repairing pipes

		- Modeling appearance of sub-pipe line		
Sanitary Plumbing	- Routing main pipe line - Modeling appearance of main pipe line (Using routing properties)	- Installation anchor of riser pipe and expansion joint Modeling service valve on sub-pipes by floor - Modeling water hammer cushion on the top of the water pipe and drain valve on the bottom of the water pipe Modeling yoke vent pipe Modeling grease trap on basement level. - Modeling drain valve on the supply water pipe Modeling Relief vent pipe on drain riser Modeling open/close valve of water and hot-water supply pipe - Modeling floater of constant water level control valve on basement level Modeling U-trap of outdoor pipe - Routing sub-pipe line - Modeling appearance of sub-pipe line	- Enter property information of water temperature fluctuation prevention pipe - Modeling electric heating wire	
Equipment and electricity	- Modeling the main equipment in the main MEP room - Modeling connections of pipe & duct Modeling duct connection of PAC aircon	- Modeling Air conditioning blower, electric motor, coil - Modeling gas leak detector of boiler - Modeling flow meter of boiler - Modeling boiler air separator - Modeling chiller, air blower, PAC - Modeling water tank, hot water tank, VAV unit, FCU of PAC aircon - Modeling valves of PAC aircon - Modeling trench of mechanical room and sump pit - Modeling by-pass pipe - Modeling dustguard - Modeling check valve of return pipe		- Modeling boiler service space object - Modeling space object for repairing equipment and withdrawing coil
Etc.			- Modeling hanger and supports of duct and pipe	

5. CONCLUSION

The research summarized the MEP design process in current practice through interviews with the MEP design company. It then drew specific MEP model detailed standards for each design phase by organizing literature on South Korea's BIM guidelines and BIM detailed levels. Moreover, to connect the BIM model to each design stage, Auto-detailing items by LOD and types according to detailing methods were proposed, and items that enable auto-detailing with REVIT's DYNAMO were selected through a checklist by each design phase. For the BIM model to be accurately embodied according to its goals, the level of demand for deliverables at each design phase is important. Automation begins with the standardization of design methods. Standardizing the detail level and applying it to BIM guidelines is effective in producing DYNAMO algorithms that automatically model selected items in detail. Through automatic model detailing, the time and cost required to build modeling will be reduced and the demand for BIM usage will increase. Creating a DYNAMO algorithm that automates selected detailing items will reduce the time and costs of building a 3D-model and increase the demand for BIM-based MEP design.

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