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A Study on the Building Information Modeling for Residential Condominium Facility Management

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Abstract: Residential condominium projects currently utilize the benefits of building information modeling (BIM) in many aspects, although the use of the BIM in the facility management aspect has not been popularized as much as it should be. This research aims to study the BIM data necessary for condominium facility management nowadays so that building managers can accurately receive the BIM's building information and effectively handle the building management. Several interviews were conducted with five personnel from real estate companies of condominium projects which used the BIM to explore guidelines for the BIM data preparation for condominium management and analyzing the data with content analysis. The research results presented: (1) the BIM data that the condominium managers need for building maintenance; (2) the characteristics of data preparation for the building's facility management; (3) the determination of duties to perform various processes for the management of building facility which consists of the Level of Development (LOD) and the Level of Information (LOI); (4) the determination of management of information transmission and exchange for the building facility management. We concluded that BIM facility management could solve the problems of scattered or conflicting data by clearly identifying and checking specific building areas. In addition, it can reduce the working steps in a condominium development. Therefore, the research results can help real estate developers and those involved in project development and condominium facility management learn how to efficiently and effectively manage condominium facilities.

Keywords: building information modeling, facility management, residential condominium, level of development, level of information.

住宅公寓设施管理的建筑信息模型研究

摘要：住宅公寓项目目前在许多方面利用了建筑信息模型 (建筑信息模型）的优势，尽管建筑信息模型在设施管理方面的使用尚未得到应有的普及。本研究旨在研究当今公寓设施管理所需的建筑信息模型数据，使建筑管理者能够准确地接收建筑信息模型的建筑信息并有效地进行建筑管理。对来自公寓项目的房地产公司的五名人员进行了多次采访，他们使用建筑信息模型来探索公寓管理的建筑信息模型数据准备指南，并通过内容分析分析数据。研究结果呈现：（1）公寓管理人员进行建筑维护所需的建筑信息模型数据；(2）建筑物设施管理数据准备的特点；(3）确定执行建筑设施管理的各种流程的职责，包括开发水平 (细节层次）和信息水平 (意向书）; (4）确定楼宇设施管理信息传输和交换的管理方式。我们得出结论，建筑信息模型设施管理可以通过明确识别和检查特定的建筑区域来解决数据分散或冲突的问题。此外，它可以减少公寓开发中的工作步骤。因此，研究结果可以帮助房地产开发商和参与项目开发和公寓设施管理的人员学习如何有效地管理公寓设施。

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关键词：建筑信息模型、设施管理、住宅公寓、发展水平、信息水平。

1. Introduction

Currently, the design and construction process of real estate projects in Thailand is shifting to a 3D system by incorporating the use of building information modeling (BIM) and replacing traditional 2D systems. Up to now, BIM has been widely popular among the construction of large or high-rise buildings, which require a building facility management system that can be adapted for greater efficiency and safety. However, real estate companies in Thailand agree that using BIM as a database for important structures in real estate projects will facilitate the use of data from BIM work to analyze tasks and solve problems resulting from the design and construction processes. For example, a faulty or unsatisfactory design can lead to demolition or rebuilding, which is considered a waste of resources and expenses [1].

The BIM workflow takes place in every process throughout the project, ranging from the design and construction to the management of the building's facilities. Various stakeholders in the work process currently use technologies based on fragmented and unregulated databases, which result in work conflicts. The data cannot be transferred for the intended purpose, which affects the operation and the cost and leads to a possible process failure [2]-[4].

Once the building is delivered, the project's as-built documents become essential for the building management team to use for machine maintenance, cleaning, security, and emergency planning of the building. Therefore, the as-built documents serve as the "fundamental database" for several tasks. Such documents not only contain construction drawings but also manuals for the buildings' machine usage, such as backup power generators, elevators, and various IT systems [5]. At present, in the building's facility management process, the data are accessed only when a problem arises that needs to be fixed, but the documents and construction drawings are often fragmented, making it difficult to verify the accuracy of the information. Consequently, consistent technology is needed that responds to the need for use and that appropriately optimizes the management of the building facility, thereby making the management of the building facility more efficient [6]. Therefore, the application of BIM technology in building facility management is extremely necessary. BIM is also important for increasing the potential of building facility management [7].

This study therefore examines the preparation of BIM for managing building facilities in residential condominium projects. Details of the projects' various physical and virtual assets were created as a 3D model to transmit the data in each working process to systematic data management. The beneficial results obtained in this study will provide condominium projects with asset information that can be used to manage a building's facilities in terms of building maintenance and facility management.

2. Literature Review

2.1. BIM Standards and Project Assets

Haines [8] proposed lifecycle BIM as a practice by which to leverage building information from BIM to manage a building's operations and maintenance throughout its operational lifecycle. BIM is an innovation that can advance the construction industry because it can digitally manipulate data from virtual models of a building that contain precise information about the building at various stages of a project, including the design, procurement, manufacturing and construction processes, as well as the operation and maintenance of the building.

Northumbria University in Newcastle, UK, explained that using BIM technology to aid in data recording throughout a building's lifecycle will facilitate accurate data transmissions and enable efficient building management. Although the complete building information model was delivered after the project was finished, it did not contain all the information required for facility management purposes. Identifying and prioritizing facility management data is therefore essential for building facility managers [9].

Construction operations building information exchange (COBie) is the process of delivering information to building owners for effective asset management. It forms part of the BIM specified to be used with the asset data and helps record the project information, including the equipment list, the product data sheets, the warranties, the spare parts lists, and the preventive maintenance schedules. These data support operations, maintenance, and asset management [10].

The ISO 19650 data management standard defines information requirements from the beginning of and during project operation until project delivery to make the project run smoothly and efficiently at every step. The standard incorporates the following requirements [11]:

1) Organizational information requirements (OIR), which are the information requirements established by the organizational policies that specify the requirements for the entire asset portfolio. The information in the OIR describes the organization's policy for managing the asset over its lifetime, which allows the delegated working groups to act accurately

and efficiently. Therefore, OIR is an important source of information for organizations;

2) Asset information requirements (AIR), which refers to the information required to operate and maintain a construction asset throughout a building's lifecycle. The information must be usable and applicable according to clearly defined organizational purposes. The AIR accurately identifies the required information relating to annual equipment maintenance, emergency, device failure, insurance renewal completion, the sale of construction properties, and the demolition of construction assets. Sending the data back and forth in the AIR results in the data being collected or updated in the format of a real asset data model;

3) Project information requirements (PIR), which are similar to the OIR and define the data usage requirements in accordance with organizational policies for decision-making during the project design and construction process. Each project is assigned a single PIR. The information requirement in the PIR is determined by the project owner at the early stage of the project design and construction. The process must be done before the scheduled time, and the consultant or contractor will continue to deliver the information;

4) Exchange Information Requirements (EIR) are to be used for the facility management of structured buildings. It is a tool for employers to express their requirements for specific information to be used in conjunction with the project's working groups;

5) The BIM Execution Plan (BEP).

The Pennsylvania State University [12] recommended the BIM by arguing that all working groups of the projects should work together in developing the BEP so that all parties can understand the overall picture of the action plans. All steps of the action plan must take into account the establishment of the building's facility management models as follows:

(1) Determining the level of development (LOD) usage in each workflow and function and specific ways to display the results of various usages;

(2) Methods of displaying the building equipment, distance, and scope of usage for the building maintenance and repair;

(3) Methods of architectural and engineering analysis such as structures and areas;

(4) Methods of improvement of the 3D model data and coordination, in case of revision;

(5) Methods to apply the information in the building facility management.

There are four steps to developing a BIM application plan. The process is designed for project developers, project managers, and those involved in the project to develop plans following the project through the early stages of the detailed design structure. The first step starts with identifying the goals and benefits of using the BIM in the project, followed by designing the implementation process of the BIM, developing the information exchange, and finally defining the infrastructure that supports the BIM operations into various utilizations [13].

2.2. The BIM and the Physical Asset Simulation

For the work done with BIM, the information requirement will lead to the building management once the project is delivered. This process conveys information in construction and engineering works, including using the information in the BIM. In addition, it identifies the physical project assets and virtual assets created as the BIM during the operation. The data management is categorized as follows:

(1) The building owner's perspective: To formulate a strategy for managing the assets or the projects for business decisions;

(2) The user's perspective: To identify users' real requirements regarding quality and capability;

(3) Project delivery or asset management: To plan the work by accurately using resources for control and coordination.

Therefore, practitioners need to understand the information requirement related to the property or the project that comes from the organizational policies and present a way to work following such requirements as described in Fig. 1.

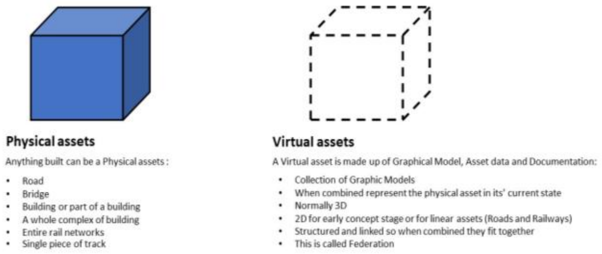

Fig. 1 Physical asset and virtual assets [14]

2.3. Characteristics of Information for the Building Facility Management

Building facility management mainly focuses on the management of physical assets such as structural work, architectural and system works of the project, simultaneously with the management of other additional services in the building such as cleaning, security, and tidiness maintenance services. In building facility management, the data set can be summarized into seven categories [15]:

(1) Information on buildings and real estate properties;

(2) Information on building and construction drawings;

(3) Information on building areas and function of space;

(4) Information on physical expenses;

(5) Information on materials and durable articles;

(6) Information on machine history data;

(7) Information on safety.

2.4. Procedure for the BIM Data Preparation for the Building's Facility Management

To prepare the BIM data for the building's facility management, the project developers are required to specify four types of information requirements: (1) Organizational Information Requirement (OIR); (2) Asset Information Requirement (AIR); (3) Project Information Requirements (PIR); (4) Exchange Information Requirements (EIR).

The project developers need to define the AIR in the pre-execution period to be able to continue forwarding information during the EIR process. The EIR plays a constant, key role from the operational to the delivery phases since the main stakeholders involved in the BIM usage can employ the EIR to determine the desired asset information. This information will be used to solve problems that arise during the use of assets in the project delivery process. The EIR specifications will be used as the primary standard for delivery. The data obtained from the AIR and the EIR will be developed into the OIR and the PIR information. Once a precise list of use is created, it will facilitate the creation of the BEP, which contains all the information requirements as laid out and prompts all parties to operate. The BEP will specify the physical details and the information details in 3D format, in the forms of the LOD and the LOI. Finally, the project developers will obtain the main information set described as follows:

(1) Project Information Model (PIM) is the specifications of the formats, methods, and guidelines for creating information, both the 3D models and the specific information, along with classifying the details, including the duties and responsibilities of each party involved;

(2) Asset Information Model (AIM) is the specification of the delivery of the asset information that enables those involved in the building's facility management to effectively use the information for the operations specified in the AIR requirements, such as the equipment which must be stored in a database, the installation documents, the maintenance information, and other asset information, as described in Fig. 2.

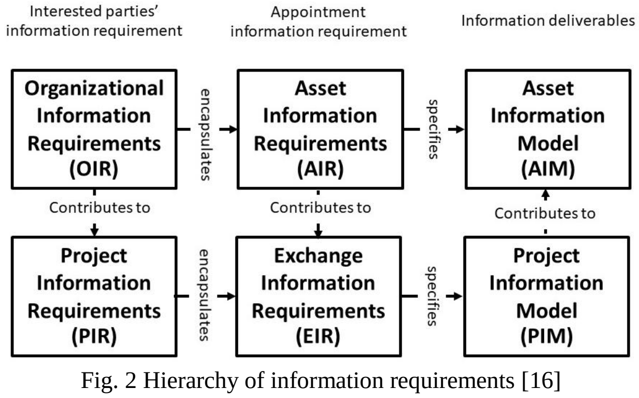

Fig. 2 Hierarchy of information requirements [16]

3. Methodology

The research process consists of the following steps:

1) Studying the related documents and research works: Studying the relevant documents and research works that contain the factors determining the working standards of the BIM in residential condominium projects and the theories about the BIM in the building's facility management both in Thailand and abroad;

2) Determining the source of data in the study: The researchers selected five high-rise residential condominium projects located in Bangkok, where such projects require the use of BIM in the operational process. Then, the researchers determined a group of informants for the interview, experts with experiences from five different projects. The informants can be categorized into three groups:

Group 1: Condominium managers with experience managing more than one residential condominium project;

Group 2: the BIM experts who have experience in using the BIM with more than one residential condominium project;

Group 3: Other key project stakeholders who used the BIM in operation, with more than two years of working experience in the BIM field, including designers, architects, engineers, and contractors.

3) Creating interview forms and Performing interviews: This step consisted of the following sub-steps:

(1) Designing the interview forms, presenting them to three experts to assess the content validity of the tool by finding the index of item–objective congruence (IOC), and improving the forms according to the experts' advice. The question being used yielded an IOC value of at least 0.60, more than 0.50 as suggested by Chaichanawirote & Vantum [17];

(2) Applying for approval from the Ethics Committee on Human Research of Thammasat University. This research has been certified according to Certificate No. 022/256 dated April 2, 2021.

4) Interviews with the informants: The researchers made appointments and collected data from the in-depth interviews with the condominium managers, the BIM experts, and the groups of people involved in five condominium projects, aiming to acquire the BIM data for the building's facility management following the building delivery. The method of collecting information from the informants through the interviews was used. The interview process was divided into three parts as follows:

Part 1: Interview with the condominium managers to know the nature of the information that the condominium managers would require to use in the management of the building facility. The answers obtained would be used for the analysis to prepare the data in the BIM format.

Part 2: Interview with the BIM experts to know the nature of the current residential condominium projects to be used as a guideline for applying the 3D data in the building's facility management.

Part 3: Interview with other stakeholders who used the BIM in the project operation, namely the designers and the contractors. The information from the abovementioned Parts 1 and 2 is to be summarized in detail for the works in different phases to utilize such information for further building facility management.

5) Analysis and discussions of the study results: The researchers studied the data obtained from the in-depth interviews, followed by using the content analysis and data processing to see the situation of the information requirement of the BIM for real estate developers to prepare the information for the management of building facilities in current residential condominium projects.

4. Research Results

4.1. The Results of the Interview with the Condominium Managers

From the interviews with the condominium managers, the researchers were able to summarize the data, as shown in Table 1, with the information that condominium managers pay attention to as follows:

1) Condominium management information consists of the facility information, financial information, owner information, project delivery documents, and land office documents;

2) 2D construction drawings files in .DWG and .PDF formats. This information consists of the architectural drawings, the structural drawings, and the system work drawings such as electrical system (EE), sanitary system (SN), fire protection system (FP), and air conditioning system (AC) that are accurate according to the actual as-built drawings;

3) Information for condominium management such as owner lists and documents, service contracts, documents issued by government authorities, accounting and finance documents, and the equipment and asset list documents;

4) Building maintenance information such as the as-built construction drawings and the contractor's warranty documents;

5) Administrative and financial information consists of the databases of owners and tenants, a list of unit ownership, budgets, income statements, etc.;

6) List of equipment and assets, i.e., common assets, which consist of: (1) Equipment warranty; (2) List of suppliers; (3) List of equipment and maintenance budget; (4) Equipment maintenance plans; (5) Detailed equipment specifications and warranty; (6) Maintenance records from the previous condominium management group.

Table 1 The results of the interview with the condominium managers

Questions	Informants				
	Company A	**Company B**	**Company C**	**Company D**	**Company E**
1. Information on the Building Construction for the Facility Management	- Official Documents; - Accounting and Finance Documents; - List of Equipment and Assets; - Warranty Certificates; - Maintenance History; - Actual Construction Drawings; - List of Materials and Machines	- Official Documents; - Accounting and Finance Documents; - Warranty Certificates; - Actual Construction Drawings; - List of Materials and Machines; - Information on the Construction Defects	- Official Documents; - Accounting and Finance Documents; - List of Equipment and Assets; - Warranty Certificates; - Maintenance History; - Actual Construction Drawings;	- Official Documents; - Accounting and Finance Documents; - List of Equipment and Assets; - Warranty Certificates; - List of Materials and Machines; - Information on the Construction Defects	- Official Documents; - Accounting and Finance Documents; - List of Equipment and Assets; - Warranty Certificates; - Maintenance History; - Actual Construction Drawings
2. Classification of Works and Information Storage for the Building Facility Management	1. The Asset Management Function 2. The Building Management Function	1. The Asset Management Function 2. The Building Management Function	1. The Asset Management Function 2. The Building Management Function 3. The Service for Homeowners' Function	1. The Asset Management Function 2. The Building Management Function	1. The Asset Management Function 2. The Building Management Function 3. The Service for Homeowners' Function
3. Characteristics of the Information Necessary for the Building Maintenance	1. Information about the System Works 2. Information about the Equipment Warranty 3. List of the System Works Manufacturers 4. List of Equipment and Budgets	1. Information about the System Works 2. Information about the Equipment Warranty 3. List of the System Works Manufacturers 4. List of Equipment and Budgets	1. Information about the System Works 2. Information about the Equipment Warranty 3. List of the System Works Manufacturers 4. List of Equipment and Budgets	1. Information about the System Works 2. Information about the Equipment Warranty 3. List of the System Works Manufacturers 4. List of Equipment and Budgets	1. Information about the System Works 2. Information about the Equipment Warranty 3. List of the System Works Manufacturers 4. List of Equipment and Budgets

	5. Maintenance Plan 6. History of Maintenance from the Previous Managers	5. Maintenance Plan	5. Maintenance Plan	5. Maintenance Plan	5. Maintenance Plan

4.2. The Results from the Interview with the BIM Experts

From the interviews with the BIM experts, the researchers were able to summarize the data, as shown in Table 2, with the following details:

4.2.1. The Preparation of the BIM Data to be Used in Condominium Facility Management

The information used in the building delivery process is indicated in a 3D model that contains both graphical and non-graphical data elements, displayed in a 3D format. These data include the parameters that record information such as width, length, space, volume, and material. These were also created for recording data to be used in the building facility management and called the facility management parameters (FM parameters). They consist of the following information: (1) Identification of materials and equipment; (2) Identification of property code; (3) Identification of maintenance cost; (4) Identification of maintenance period; (5) Identification of warranty period; (6) Identification of location; (7) Identification of manual document via URL; (8) Identification of manufacturer and contact information.

4.2.2. The Recording of the BIM Data in Current Residential Condominium Facility Management

The data management for the BIM dimension is recorded in the resolution of 3D models, known as the level of development (LOD), with current available resolution levels of LOD 100, LOD 200, LOD 300, LOD 350, and LOD 400. The data will record the resolution of information, known as the level of information (LOI), which project developers must specify in detail from the early stages of the design phase to the completion of the construction process. From the case studies, it was found that the resolution determination of the elements in the 3D model can be divided into two phases:

1) The design to the construction phases: including data resolution, size, shape, location, keyword or category and appearance, etc.;

2) The construction to the building delivery phases: The details from the design to the construction phases must be taken for the development of the LOD, including the workset for recording information of the building facility management into a 3D model and for collecting the images obtained from the actual construction, as shown in Table 3.

Table 2 The results from the interview with the BIM experts

Questions	**Informants**				
	Project A	**Project B**	**Project C**	**Project D**	**Project E**
1. Preparation of the BIM Information for the Building Facility Management	Specified in the Handbook Format	None	Specified in the BEP Format	Specified in the BEP Format	Specified in the Handbook and the BEP Format
2. The Information Characteristics for the Building Facility Management	1. Information on the Usable Areas in the Building 2. Information on the Building Law 3. Regulations of Passageways in the Building 4. Regulations of the Parking 5. Regulations of the Living Area in the Project 6. Regulations of the Service Area in the Building 7. Information on the System Work Installation 8. Identification of the URL in the Manual Documents	Provides Information According to the Designer's Standard	1. Information Defining the Types of Rooms 2. Information about the Common Area 3. Information on the Parking 4. Information about the Swimming Pool 5. Information about the Building's System Work 6. Information on Other Installation in the Building	1. Determination of Steps of the Data Recording in the 3D-Format Model 2. Entry of Specific Equipment Information 3. Determination of the Specific Budget for Maintenance 4. Determination of Warranty Period 5. Determination of the URL in the Manual	1. Information on the Usable Areas in the Building 2. Information on the Building Law 3. Regulations of Passageways in the Building 4. Regulations of the Parking 5. Regulations of the Living Area in the Project 6. Regulations of the Service Area in the Building 7. Information on the System Work Installation 8. Identification of the URL in the Manual Documents
3. Details of the Information on the Building Delivery	1. The 3D Model 2. Construction Drawings 3. List of Materials and Equipment	1. The 3D Model 2. Construction Drawings 3. List of	1. The 3D Model 2. Construction Drawings 3. List of Materials and	1. The 3D Model 2. Construction Drawings 3. List of Manufacturers and	1. The 3D Model 2. Construction Drawings 3. List of Materials and Equipment

	4. List of Manufacturers and Warranty Certificates 5. Cost Per Maintenance Cycle 6. The URL Information for the Access of Maintenance Documents 7. The Pictures of the Actual Construction	Materials and Equipment 4. List of Manufacturers and Warranty Certificates 5. Summary Table of the Machines and Common Area Equipments	Equipment 4. List of Manufacturers and Warranty Certificates 5. Summary Table of the Machines and Common Area Equipments	Warranty Certificates 4. Table of Detailed Information of the Project Assets 5. Cost Per Maintenance Cycle 6. The URL Information for the Access of Maintenance Documents	4. List of Manufacturers and Warranty Certificates 5. Cost Per Maintenance Cycle 6. The URL Information for the Access of Maintenance Documents 7. The Pictures of the Actual Construction

Table 3 The LOD and LOI data

	The Design to the Construction Phases			**The Construction to the Building Delivery Phases**
	LOD 100	**LOD 200**	**LOD 300-350**	**LOD 400**
Size	Y	Y	Y	Y
Shape	Y	Y	Y	Y
Location	Y	Y	Y	Y
Keyword/Category		Y	Y	Y
Appearance			Y	Y
Add-on			Y	Y
Workset				Y
Information on the Building Facility Management				Y***

From Table 3, it can be concluded that the project will determine the records of the data according to the details that must be specified in 3D model, differing in accordance with the duties of those responsible for the work in each phase, by entering details of the data, including size and shape, from the design to the construction phases. These are divided according to the categories that must appear in the 3D model: architecture, structural, and building systems. The details are divided into the following categories:

1) The recording of the element resolutions in the LOD-LOI, which includes: (1) As-signing the designers to name the family and type of data as specified in the BIM Execution Plan (BEP); (2) Recording the dimensions of shapes and contours in the 3D model; (3) Recording data of the building's system; (4) Recording the list of building materials according to the accurate information; (5) Recording the building facility management data during the phase of creating as-built construction drawings in the format of the FM Parameter as specified by the project;

2) The recording of the information about the building facility management: (1) Components that must provide details of 3D model specifications; (2) Type of the system work or system name; (3) Information about the FM data requirement; (4) Supplier contacts.

4.3. The Interview Results with the Designers during the Project Design Phase

It was found that during the design phase, the designers received the information on the control of design standards from the project's initial phase, providing details for controlling the work process through the BIM Execution Plan (BEP). As for the BEP in the design phase, it is mainly prioritizing operations through using the BIM so that all operational functions, such as architectural, structural, building systems, landscape and interior architectural departments, can coordinate and transfer information necessary for each design phase and collect the operational data as the main database. At present, the project developers have defined basic database details for a group of primary designers to use as the information in the design process for maintenance planning. This information includes room location information, floor level, material information, dimension information, width, length, and height of materials. The information on the system works must provide clear specifications and installation methods.

The database that the project developer group provides for the primary designers can be summarized into two types:

(1) The Project Information Requirements (PIR);

(2) The Design Standards Manual, compiled by the project developer, is prepared for the designers to be aware of from the beginning of the design process. The information defines the design standards, legal regulations, material identification, quality assessment, and risks from the design-construction to control the quality of work and transfer information to those involved in the project to use as a guideline for effective building maintenance. Then, the Revit program's 3D and 2D model data were collected. The information must pass the validation and the quality verification processes to meet the construction standards and requirements from the project developers so that the construction drawings can be delivered to

the main contractor as the following step.

4.4. The Interview Results with the Contractors during the Construction to the Building Delivery Phases

The interview results revealed that, for preparing the BIM data for the building facility management during the construction phase, the construction contractors are responsible for increasing the process of entering data into the 3D models, such as identifying the location of the equipment or specifying the maintenance period information. These data are to be used for the building facility management, i.e., specifying the lists of actual asset items that appear on the actual site, which is the original manual used for the building delivery. The details were then broken down into categories and prepared for connection to the 3D modeling system in digital file format to form a single database, which can be categorized as shown in Table 4.

Table 4 Specific information on the actual asset item list

Category	Information	Description	Remark
1. Specific Information	1.1 Brand 1.2 Model 1.3 Manufacturer 1.4 Manual	- Equipment Brands; - Manufacturer/Distributor; - Contact Information of the Dealers, Including Telephone Numbers and Email Addresses (Specifying the Dealer's Information); - URL Information for Accessing the Maintenance Documentation	URL is a Link Folder to Store the Asset Information
2. Warranty	2.1 Warranty Ownership 2.2 Warranty Date 2.3 Warranty Expire 2.4 Warranty Contact	- Warranty is Divided into Two Main Types According to the Insurers: (1) Manufacturer Warranty; (2) Contractor Warranty. - Date of Warranty; - Date of Expiry of Warranty; - Warranty contact information (specify the company information)	Information from Dealers/Contractors
3. Preventive Maintenance	3.1 Lifetime 3.2 Maintenance Period 3.3 Maintenance Cost 3.4 Maintenance Date 3.5 Next Maintenance Date	- Lifetime; - Maintenance Cycle such as Daily, Weekly, or Annually; - Costs per Maintenance Cycle, Based on Parts That Need To Be Operated; - Last Maintenance Schedule; - Next Maintenance Schedule	Information from Dealers/Contractors

5. Discussions of the Research Results

5.1. The Information for the Building Facility Management

From the analysis of data obtained from interviews with condominium managers, the researchers found that the information required for the building facility management was consistent with the data obtained from the literature review, as shown in Table 5.

Table 5 The information for the building facility management

Sequence	The Building Facility Management Data Obtained from the Literature Review	The Information Obtained from the Interviews with the Condominium Managers
1	Information on Assets in the Form of Buildings and Real Estate	1. Financial Budget Information 2. Details of Common Assets 3. Administrative and Financial Information Consists of Co-owner and Tenant Database, List of Ownership of Residential Condominium Units
2	Information on the Building and Construction Drawings	1. Architectural Drawings 2. Structural Drawings 3. System Works Drawings 4. Interior Design Drawings 5. Landscape Drawings
3	Information on the Building Areas and The Use of Spaces	1. Common Area Space 2. Rental/Room Space 3. Office Space
4	Information on the Physical Cost	1. Budget Documents and Income Reports 2. Expenses Document for Residents 3. Documents for the Area Work Delivery 4. Documents from the Land Office
5	Information of the Materials and Durable Articles	1. Specific Information about the Equipment 2. Plans for Schedule Inspections and Warranties
6	Information of the Machine History	Information of the System Works, Including - Electrical System Works

		- Sanitation System Works - Fire System Works - Air-Conditioning System Works
7	Information on the Safety and Security System	The Safety and Security Systems in the Building, Including the Communication Systems, the CCTV System Works throughout the Building, and the Fire Alarm System
8	Other Information	- Equipment Maintenance Plan - Records of Maintenance History from the Former Condominium Management Group - Information Regarding the Repairs in Common Area

From Table 5, it was found that the condominium manager has information requirements for all aspects of the condominium management. Therefore, the data must be classified into categories in collecting the BIM data for the building delivery to the condominium managers during the building facility management period. This is to reduce the complexity of information to cover the building management, including accounting, finance, assets, construction drawings, 3D models, and lists of equipment document entries to be more user-friendly. This can be done by using BIM technology to connect and link document databases and 3D models. All the as-built documents can be connected as one data to reduce the number of documents, making data search and improvement easier. This will help support the BIM model to easily and effectively become asset information management.

5.2. The Determination of the Project's BIM Information for Building Facility Management

5.2.1. Asset Information Requirements (AIR)

The research result showed that the project developers need to determine the information necessary for the operation and maintenance of the assets obtained from the construction in the information preparation for the building facility management. The nature of data preparation for the building facility management can be divided into two parts:

1) The 3D model data storage is the definition of details in a 3D model consisting of 2 phases:

(1) From the design to the construction phases, for example, the resolution of the data, size, shape, location, keyword/category, and appearance of the objects;

(2) From the construction to the building delivery phases, the details from the design to the construction phases must be used for the LOD development. The data include the workset for recording the construction data and the data for the building facility management in the 3D format to verify the accuracy of the actual on-site photos compared to the 3D model obtained from the BIM system. Any corrections made during the construction phase help record the defects from the construction site. It can be used to analyze the tendencies in maintenance locations and control the construction quality to avoid duplicating problems. Currently, some project developers are using applications for their companies' building facility management by using such applications for the inspection and the delivery of the building or the areas. The process is done by using the electronic device from the phone to check, collect, analyze and store the data reports in the cloud system to utilize and edit the information for the next phases of the project operation.

2) Additional data storage is in the form of asset data storage obtained from the actual construction, which consists of the following:

(1) General information is the data recording determined to be in the Parameter for-mat in the 3D model, according to the list of the FM Parameters mentioned in Section 4.2.;

(2) Specific equipment and warranty data are specified information about the real assets that appear on the actual sites used for maintenance, as explained in Table 4.

All the information is then collected into the asset management model for further use in the building facility management phase.

5.2.2. Project Information Requirements (PIR)

It was found that the project developers need to arrange the information for the delivery to be appropriate, efficient, and usable throughout all the project's execution phases. It is also the duty and responsibility of each party to identify the person or working group responsible for creating or modifying each element. These data are: (1) The resolution of the 3D model (level of development (LOD)), which is its physical details; (2) The resolution of the data (level of information (LOI)), which is the resolution of the data that is included in the components but cannot be seen in the 3D model. The information consists of physical information and other information about the suitable and sufficient components for the tasks in the pre-construction period until the actual construction occurs. To enable those involved in the building facility management to appropriately use the information for implementing the Project Information Model (PIM) by specifying the model and method of the data creation, both the 3D model and the specific data. Also, the levels of details and the responsibilities of each party involved must be classified following the PIR requirements.

5.2.3. Exchange Information Requirements (EIR)

The research results revealed that the project developers must identify key data for the information exchange to pass on to each responsible party in each project phase.

The mentioned data consist of two parts:

1) The information for the design, including information for primary building design, the building laws, the estimation of material and costs, defined for quality and design risk management. The information includes: (1) The type of usable space in the building; (2) Standard information on building laws; (3) Information on building systems; (4) Requirements of passageways in the building; (5) Requirements of parking in the building; (6) Requirements of living areas in the building; (7) Requirements of service areas or common areas in the building; (8) Specifying a URL for the storage of links in the manuals;

2) The main role of the contractors is to provide detailed information for the construction and delivery in accordance with the asset data list obtained from the AIR and meet the resolution requirements of each type of the 3D model obtained from the PIR. It can be categorized into three main groups as follows:

(1) General information is the basic information set in the 3D model according to the list of LODs such as location, type, size, and other details. Such information indicates the basic standard properties of the assets from the 3D model without the need for additional documentation or references;

(2) Equipment specification and warranty data are specified equipment information of more in-depth details used for maintenance such as brand, model, manufacturer, sales representative contact, and warranty information. It is the information that the contractors or the procurement personnel store in the purchasing process;

(3) Asset maintenance information is the information specific to the operations and maintenance of the assets, including lifetime, maintenance cycle, cost per maintenance cycle, and maintenance schedule.

5.2.4. List of the Information to be Delivered upon Completion of the Actual Construction Process

Storage of the asset data files for delivery upon completion of construction must consist of the following items: (1) The 3D models obtained from the Revit and the Navisworks programs that have been modified and approved according to the actual construction; (2) The 2D models which are the as-built CAD and PDF that were edited according to the actual construction; (3) The material and equipment manuals both in the forms of hard and soft copies; (4) Photos of actual on-site construction which are the photographs taken from the real construction site to be used for the inspection of the 3D models obtained from the construction and record the construction on site; (5) Warranty document is a contract document of the asset warranty given by the sales representatives or purchasing agent in soft copy form.

Therefore, it can be concluded that the data link is required to utilize the asset information efficiently. The data group is divided into three main parts as follows:

(1) The BIM models are the 3D models in Navisworks file format that provide a perspective of the 3D model, which differs according to the areas of use, and a link to the asset information index;

(2) Asset data is a tabular (Excel) file that provides a link to the asset document storage (asset document) necessary for the facility management in the project;

(3) Asset information documents are specific information and additional supporting documents relating to assets such as plans, supporting documents for the drawings, and photographs.

However, to apply the BIM data in the building facility management, there must be a useful database with the corresponding information and a single data source, making the data easily accessed and properly positioned for ease of use. Therefore, the project developers must constantly update the BIM data during the building facility management. This continuous update of the information after completing the building delivery phase will help users access and utilize one database without having to do the manual key-in methods. It will also keep the data accurate at all times and effectively help reduce data conflicts along the use of the BIM in the building facility management. This is because normally, once the construction process is completed, data updates may be ignored or overlooked and failed to be revised in the event of maintenance or changes after the building has been operational. Additionally, storing the 3D data in Revit format is convenient as it enables ongoing additions or modifications to the BIM data. This allows project managers to pass on accurate information to succeeding condominium management groups.

6. Conclusion

This research presents the data required for building facility management using the BIM process. This was established by analyzing the results of interviews with stakeholders in five project case studies. The findings reveal a process for defining AIR and PIR data according to the ISO 19650 standard and recording it in the project's BEP format, which is consistent with the standards of the Pennsylvania State University [12]. There are two periods of data compilation. The first is the design phase, at the beginning of which the project manager compiles the design standards manual for use by the designers. This defines the design standards, legal regulations, and estimates of material and costs for quality and design-construction risk control. The second part is the construction phase, in which the detailed property information that will allow the contractor to deliver the building is captured.

Building maintenance is one of the most important phases in the building life cycle. Systematic recording of all project data can help prevent problems occurring during the design phase and through to the maintenance phase. To effectively use BIM data in building facility management, all parties involved must have a shared database; this leads to greater efficiency and better quality because of fewer mistakes compared to a more conventional approach.

For the BIM facility management system to be effective, it is vital that project managers keep the information up-to-date and accurate at all times. Furthermore, the researchers suggest that anyone interested in using BIM should learn more about facility manager support features that are supplemental to the storage of building data, such as after-sales defects tracking and building maintenance coordination. These technologies help to reduce communication errors, which can waste time and money, and allow analysis of the data for use in future project development.

It should be noted that the application of BIM in the facility management of condominium buildings in Thailand is at an early stage and still has limitations because it requires all stakeholders to understand it thoroughly and collaborate extensively in order to reap the full benefits. Finally, this research used a limited number of informants because the research was designed to collect data from informants who worked on the same projects in order to acquire consistent data. However, interested researchers may wish to perform another survey with more informants, from a variety of projects, and compare the results with this study.

Data Availability Statement

The data set used in the current study is available on request from Associate Professor Dr.Kongkoon Tochaiwat, email: kongkoon@tu.ac.th.

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