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Configuring BIM models to Support A Systems-Driven Visualization Approach: A Case Study

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Abstract. Models developed through design and construction are not intended to support facility management. They don't generally have the life-cycle data and information required or they are not configured to support visualization of model graphics from a system's perspective. Current implementations for BIM-FM focuses mainly on including facility life cycle data in BIM models to support space management or asset management. Models are not customized with necessary data and classification that allow for isolating and visualizing components of a specific building system (e.g. supply air). This is necessary in an emergency situation to allow facility staff to diagnose the problem associated with the system and its components, identify the problem and make necessary and informed actions. In this paper, we discuss requirements for preparing an as-built BIM model to be systems-centric using a case study approach of a two-story science building. A system classification hierarchy was developed to classify the systems and sub-systems of the building. Sixteen systems-centric properties were defined to search, filter, isolate, and display elements in a specific system or sub-system. The configured systems-centric model will allow facility managers understand the dependencies across different systems to accurately determine impacts across the facility and develop strategies to rapidly respond to any emergency. The case study analysed the mechanical and plumbing systems in the building. This paper will focus on results from the analysis of the mechanical system. An example of emergency scenario is discussed and presented.

1. Introduction

Facility management (FM) is an integrated approach for operating and maintaining the facility to meet the main objectives of the organization, facility managers, owners, and the end users [1]. Facility operators or owners are responsible for preparing reasonable plans to effectively operate and maintain their facilities. Building Information Modeling (BIM) is one effective tool that can be used as a repository for storing information, supporting maintenance management, and improving decision making. At the same time, BIM can be used for model visualization as well as for locating the assets within the facility, saving time and cost [2]. However, due to different challenges and barriers such as process or organizational complications, the BIM implementation in the FM field has been slower compared to the design and construction phases [3,4,5,6]. Furthermore, models developed during design and construction do not fully address facility operation and maintenance (O&M) needs and that is mainly due to lack of proper data requirements set by the owners [5]. BIM models configured for FM should contain critical information to fully support FM and the challenges faced by it [4]. Such models are referred to as FM-Capable BIM or FM-enabled BIM [3].

2. Methodology

An FM-Capable BIM should have four main features. First it should be data-centric meaning that it should act as a repository for O&M data. Second, the graphics should be accurate and complete to fully represent the building. Third, it should be systems-centric to allow to view and isolate model elements and components based on its different systems and subsystems within the building as well as their relationship and dependencies. Fourth, it should allow for direct linking to the FM system used by the facility owner to allow data exchange and update.

This paper proposes an approach for configuring BIM models to be systems-centric. During facility emergency, this will allow to filter and isolate model elements belonging to a system or subsystem from the entire model. A four-level classification containing multiple systems and subsystems was developed for the HVAC and plumbing systems. Additionally, fourteen specific systems-centric properties were defined. The proposed approach was then tested and discussed using a case-study. The combination of the proposed classification and properties will allow facility managers to search, filter, and display elements belonging to a specific system or sub-system.

2.1. System Classification

The system classification has four levels (Table 1). The first level comprises two main systems: mechanical and plumbing. The second level was developed by breaking the first level into seven System Types based on function. The third level (System Classification) includes further breakdown of the System Type. The fourth level breaks down the third level based on specific functions of the assets. Table 1 presents part of the developed system classification. The table can be further developed and adjusted based on building systems that are identified. The multi-level hierarchy helps linking elements belonging to the same sub-system or system.

Table 1. Level 1-4 System Classification

System Type (Level 2)	System Classification (Level 3)	System Name (Level 4)	Abbreviation
	Mechanical System (Level 1)		
1. Cooling System	Hydronic Supply	Geothermal Well Supply	GWS
	Hydronic Return	Geothermal Well Return	GWR
	Hydronic Supply	Condenser Water Supply	CWS
	Hydronic Return	Condenser Water Return	CWR
2. Heating System	Hydronic Supply	Geothermal Well Supply	GWS
	Hydronic Return	Geothermal Well Return	GWR
	Hydronic Supply	Condenser Water Supply	CWS
	Hydronic Return	Condenser Water Return	CWR
3. Air System	Supply Air	AHU Supply Air	ASA
	Return Air	AHU Return Air	ARA
	Exhaust Air	AHU Exhaust Air	AEA
	Supply Air	DOAS Supply Air	DSA
	Return Air	DOAS Return Air	DRA
	Exhaust Air	FAN Exhaust Air	FEA
	Plumbing System (Level 1)		
4. Domestic Water System	Domestic Cold Water Supply		DCW
	Domestic Hot Water Supply	BLR Water Supply	DHW
5. Storm System	Storm Water	Storm Water	SW

2.2. Systems-Centric Properties

To configure a systems-centric BIM model and allow users to search, filter, and visualize elements and systems, fourteen properties were defined. Some of the fourteen systems-centric properties were derived based on the system classification discussed above. Table 2 provides examples of the identified properties with their description.

Table 2. System-Centric Properties

	Property	Description
1	ASSET_TAG	A unique identifier for the asset based on a defined naming convention (e.g. "GR-AHU-RT-Roof-AHU-1")
2	CATEGORY	The standard Revit category for the asset (e.g. "Mechanical Equipment")
3	SYSTEM	Identifies the building system (Level-1) that the asset belongs to (e.g. "Mechanical System")
4	SYSTEM_TYPE	Identifies the system type (Level-2) the asset belongs to. (e.g. "Cooling Systems")
5	SYSTEM_CLASSIFICATION	Identifies the system classification (Level-3) the asset belongs to (e.g. "Supply Air")
6	SYSTEM_NAME	Identifies the system name (Level-4) the asset belongs to (e.g. "Geothermal Wells Supply System").
7	FLOOR	The asset floor number (e.g. Roof)
8	LOCATION_SERVED	The room or space number that the asset is serving (e.g. "R-108")
9	EQUIPMENT_SERVED	The asset ID for the equipment that the ducts/pipes are serving.

The full list of properties include ASSET_TAG, ID, EQUIPMENT_DESCRIPTION, SYSTEM, SYSTEM_TYPE, SYSTEM_CLASSIFICATION, SYSTEM_NAME, CATEGORY, ASSET_GROUP, FLOOR, ZONE, LOCATION, LOCATION_SERVED, and EQUIPMENT_SERVED. The properties are generalizable and can be adapted for other facilities.

2.3. Case Study

A case study of a science building on the campus of a 4-year academic institution was used to test the proposed approach while providing a proof of concept for the generalizability of the developed system classification and systems-centric properties. The building was divided into five HVAC zones based on its cooling, heating, and ventilation systems used. Table 3 presents the areas and floors of each identified zone.

Table 3. Zones 1 through 5

	Zone-1	Zone-2	Zone-3	Zone-4	Zone-5
Location	Event Space	Entire building except event space, IT rooms, electrical rooms, and aquatic center	Aquatic Center	IT and Electrical Rooms	Mechanical Penthouses rooms 320 and 310
Floor	First and Second Floors	First and Second Floors	First Floor	First and Second Floors	Roof

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3. Systems-Driven Visualization

This section describes the process for configuring the BIM model as well as an emergency scenario example to present a use case for the configured model.

3.1. *Configuring BIM Model*

The Navistools plugin [7] for Navisworks was used to populate and configure the case study BIM model with the systems-centric properties. A user-defined tab was created which contained all the systems-centric properties identified.

Facility managers and experts can use the properties to filter and create various viewpoints presenting different systems and sub-systems to rapidly identify asset location, the dependencies between different elements and systems, and the impact of the situation and maintenance during emergency maintenances. For this paper, the authors have categorized the viewpoints based on room number and equipment. The room numbers are then broken down to specific assets serving that location. Figure 1 presents an example of viewpoint structure developed by the authors that has been also used for the following emergency scenario. Different facilities can have different folder structure for their viewpoints depending on their needs. For this case study the model was pre-configured with these necessary viewpoints before handover to the owner. It should be noted that additional viewpoints can be developed by the FM staff and saved either in the viewpoints hierarchy defined in this paper or in the viewpoint hierarchy that suits the need of the FM staff.

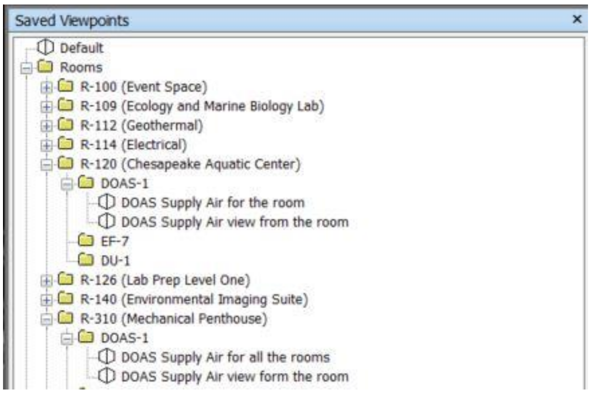

Figure 1. Example of the viewpoint structure

3.2. *Emergency Scenario: High CO2 levels in Aquatic Center (R-120)*

Room R-120 serves as the aquatic center and is dedicated to the study of marine ecology. Because of the nature of the lab, it is necessary to maintain adequate humidity, and CO_2 levels. To monitor these levels and to warn the researchers of any fluctuation in the pre-set levels, multiple sensors have been installed in the room. On a given day, the researchers noticed that the CO_2 sensor was showing a reading significantly higher than the set levels. As a result, a facility management staff was contacted to respond to the emergency issue. The facility staff proceeded to check the air quality and determine if there is proper air supply and exhaust in the lab.

Using a systems-centric model, a facility staff can use predefined viewpoints to identify the supply air and exhaust system connected to R-120 and determine the physical location of its different components to perform the needed inspections and determine the root of the problem. The facility staff can also visually determine if any other areas are impacted by the situation.

Using the viewpoints defined and saved under “R-120” folder (Figure 1), the Supply Air (SA) and Exhaust Air (EA) system servicing R-120 can be identified. Figure 2a shows all components of the Supply Air (SA) System supporting R-120. This includes: Dedicated Outside Air System (DOAS) coloured in orange, Supply Air Ducts coloured in blue, Diffusers coloured in orange, and Outside Air Valves (OAV) coloured in orange. While figure 2b shows all components of the Exhaust Air (EA)

System supporting R-120 which includes: Exhaust fan EF-7 coloured in orange, and Exhaust Air Ducts coloured in green.

Table 4 and Table 5 show the Navisworks search set functions that were used to create the viewpoint of Figure 2a and Figure 2b to isolate all components of the Supply Air System and Exhaust Air System respectively for lab R-120.

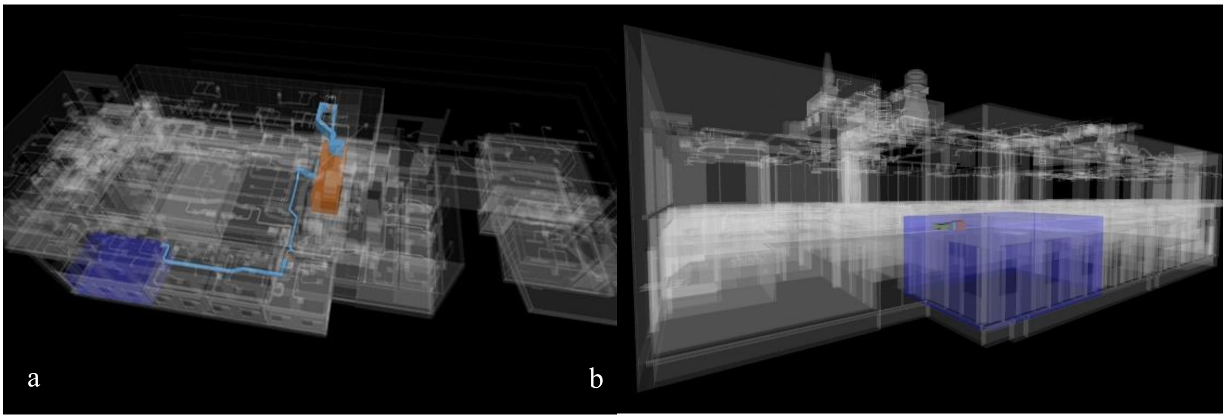

Figure 2. Components of supply (a) and exhaust (b) air systems supporting R-120

Table 3. Search sets for isolating supply system for room 120

Rule No.	Property	Condition	Value	Results
1	SYSTEM_NAME	Contains	DOAS Supply Air	Isolate supply air system associated with and serving lab 120 only
(and) 2	LOCATION_SERVED	Contains	R-120	

Table 4. Search sets for isolating exhaust air system for room 120

Rule No.	Property	Condition	Value	Results
1	SYSTEM_NAME	Contains	FAN Exhaust Air	Isolate exhaust air system associated with and serving lab 120 only
(and) 2	LOCATION_SERVED	Contains	R-120	

If the facility staff realizes that the problem is associated with the DOAS (e.g. DOAS is overly noisy indicating that it may not be functioning properly) and needs to shut it down, other areas impacted by the shutdown need to be identified to analyze the impact and inform affected individuals using these areas. To do so, the viewpoint structure (Figure 1) can be used to select the DOAS by its location (in this case R-310) and identify the areas that this equipment is serving (Figure 3). With reference to Figure 3 and the floor plan, rooms belonging to Zone 2 and Zone 3 will be impacted. Occupants of these rooms can be contacted if the DOAS must be shut down for maintenance.

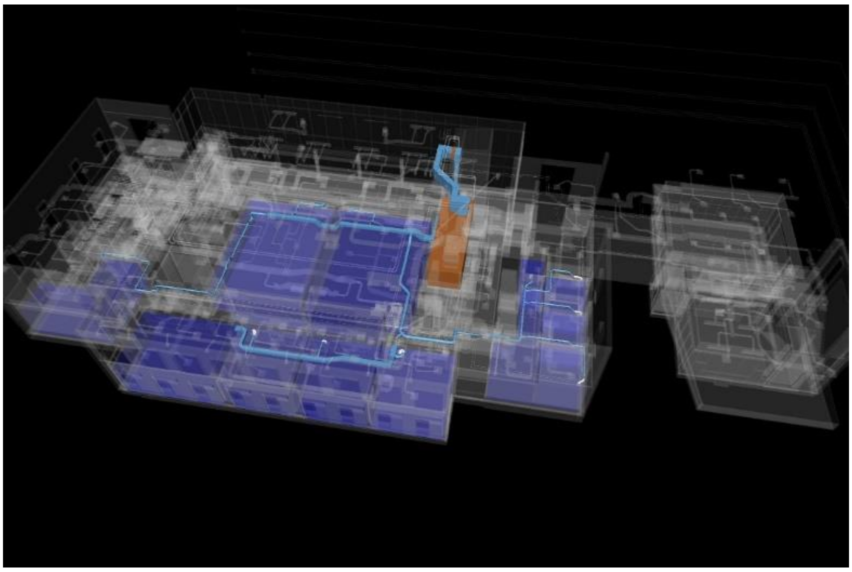

Figure 3. Supply system supported by the DOAS

4. Conclusion

In this paper, the authors presented a hierarchical system classification as well as a set of systems-centric properties to support their proposed approach in configuring BIM models for supporting FM needs during emergency maintenance. The proposed approach allows facility managers to search, filter, isolate, and display elements belonging to the same system or sub-system to understand the impact of an emergency situation or maintenance process and make timely decisions to respond. Additionally, preparing and configuring the models with viewpoints will allow facility staff to easily and rapidly navigate the model and visualize their desired elements, sub-systems, and systems without having a deep understanding of the software and its tools.

For future research, the authors are planning to conduct more case studies in order to determine the gaps in the proposed approach, and further adjust and develop the system classification, the systems-centric properties, as well as the workflow.

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