

# Exploring the Functional Breakdown Structure (FBS) of Facility Asset Management (FAM) for Smart Factories

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**Abstract:** Smart factories represent the Fourth Industrial Revolution and related emerging technologies across all industries. Among those emerging technologies, digital twin (DTw) enables smart manufacturing, resembling the factory's physical components and functional services. Nevertheless, from the owner-operator perspective, there has been only a paucity of studies defining the functional services of 'facility' and 'equipment' for the smart factory. This fact has also encouraged the construction industry to expand its role into factory operations by supporting digitalized production equipment and facilities. In order to address this issue, this study uses the proposed list of three-level facility asset management (FAM) breakdown structure by Jin et al. [12] that is under review for possible publication. The FAM breakdown structure is then validated with function lists from previous studies and existing ISO standards. It selectively covers the areas of traditional construction management (CM), asset management (AM), facility management (FM), and production operation management (OM). A mapping table with practical information systems used in the four areas (CM, AM, FM, OM) is also analyzed to verify the proposed FAM breakdown structure. It is expected that the result of this study can be used as a standard function to develop a smart factory FAM digital twin for researchers and practitioners.

**Key words:** smart factories, facility asset management, functional breakdown structure, construction management, operation management

## 1. INTRODUCTION

The Fourth Industrial Revolution focuses on manufacturing activities that build a network to create global value by integrating production facilities, warehouse systems, logistics, and social requirements [1]. Therefore, one of the represented fields of the Fourth Industrial Revolution is the smart factory. The construction industry is also pursuing innovation to transform the constitution and expand boundaries at the industrial level. Automating the facility for smart factory is emerging as one of the efforts to achieve this goal [2].

Facilities are evaluated through four performance indicators: cost, schedule, quality, and value [3]. Among the indicators, value can affect the improvement of the functions of owner-operator, and therefore, it is important to create synergies between the manufacturing industry and the construction industry [4]. Recently, the supply of new facilities has been reduced, and the demand for maintenance and performance improvement is rapidly increasing, and the proportion of investment for maintenance is also increasing [5]. In addition, the facilities were recognized as investment assets based on the potential influence to increase productivity, reduce costs through management, and emphasize investment, including quality improvement [6]. In this context, 'facility asset management (FAM)' for smart factory facilities is necessary, which not only provides simple maintenance and performance

improvement but also supports automated production processes and long-term asset management capabilities throughout the facility life-cycle.

In order to address this issue, this study proposed a complete list of three-level facility asset management (FAM) breakdown structure based on an extensive literature review. The FAM breakdown structure is validated with function lists from previous studies and existing ISO standards. It selectively covers the areas of traditional construction management (CM), asset management (AM), facility management (FM), and production operation management (OM). A mapping table with practical information systems used in the four areas (CM, AM, FM, OM) is also analyzed to verify the proposed FAM breakdown structure.

## 2. FACILITY ASSET MANAGEMENT (FAM)

The FAM proposed in this study includes AM and FM, the core concepts of traditional asset management, and integrates CM and OM, which can improve facility performance in terms of value.

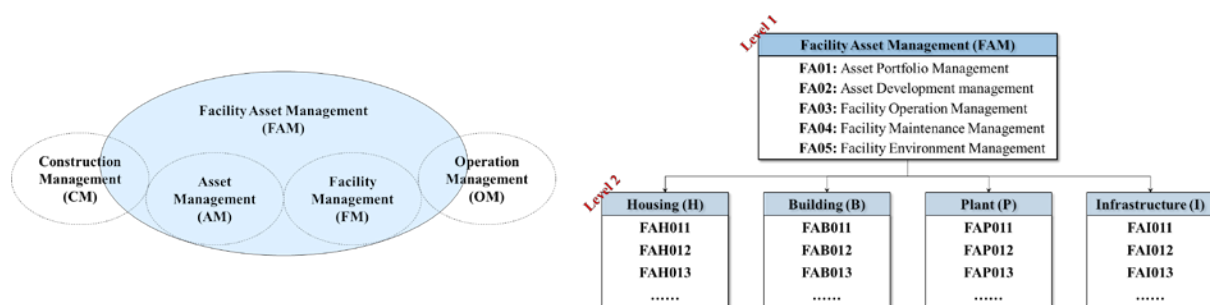
### 2.1. FAM definition

AM is defined in ISO 55000 [7] as the “coordinated activity of an organization to realize value from assets” and includes balancing costs, opportunities, and risks against asset performance to achieve the organization’s goals. AM has a strong nature of economic activity aimed at maximizing asset and profit value through managing and operating facility assets centered on the owners or investors.

FM is defined in ISO 41011 [8] as an “organizational function which integrates people, place, and process within the built environment to improve the quality of life of people and the productivity of the core business”. FM has a strong nature of technical activity aimed at increasing production activities, and the value of facility use through maintaining and improving facility performance centered on the facility users or operators.

CM can be defined as “planning, coordinating, and integrating various business functions throughout the entire life-cycle of a facility to improve performance” [9]. Traditionally, the performance of facilities was evaluated based on cost, schedule, and quality [10], and it has been expanded to consider the value [3]. Moreover, the facility’s value emphasizes the improvement of the original function of the owner-operators [4].

Nevertheless, to meet the requirements of smart facilities, the value must be further expanded to encompass the business issues of OM fields. In other words, the CM should accommodate the OM requirements of the owner-operators’ primary business. [11]



**Figure 1.** Concept and functions of facility asset management [12]

In this context, the concept of FAM was defined by integrating the characteristics of CM, AM, FM, and OM from the perspective of the facility managers of the owner-operator organization (Figure 1). Therefore, the FAM is “a management activity that maximizes asset value by carrying out the economic planning and technical performance of facility assets through asset portfolio management (FA01), asset development management (FA02), facility operation management (FA03), facility maintenance management (FA04), and facility environment management (FA05)” [12].

### 2.2. FAM functions (Level 1)

Based on the concept of FAM, the first-level business functions were developed with five, which include ‘asset portfolio management (FA01)’, ‘asset development management (FA02)’, ‘facility

operation management (FA03)', 'facility maintenance management (FA04)', and 'facility environment management (FA05)' [12]. The first-level FAM functions are a general model that can be applied to all facility types, including housing, building, plant, and infrastructure. The lower-level functions specify distinct characteristics for each facility type (Figure 1).

Asset portfolio management is the function of improving the economic asset value of multiple projects and is the most important part of FAM. The functions mainly considered in asset portfolio management are related to AM. Asset development management is the function of developing facilities, and the sub-functions are mainly related to CM. Facility operation management maximizes productivity through operating facilities, and functions related to OM (e.g., production management) are considered. Facility maintenance management is necessary to preserve the facilities and make improvements, repairs, and reinforcements through inspection and maintenance. The functions mainly considered in facility maintenance management are related to FM. Facility environment management is the function of internal and external environmental factors for the effective operation of facilities, and functions such as safety management and energy management are considered [12].

### **3. FAM FUNCTIONAL BREAKDOWN STRUCTURE (FBS) FOR SMART FACTORY**

In order to propose the FBS, this study, which is under review for possible publication [12], defined level 2 and level 3 functions for each of the five functions in a top-down manner by literature review. In this context, the FBS has three levels in a hierarchical structure and consists of five functions in level 1, fourteen in level 2, and forty-one in level 3 (Figure 2).

#### **3.1. Asset portfolio management (FA01)**

Asset portfolio management consists of 'asset management strategy (FAP011)', 'asset investment strategy (FAP012), and 'asset management administration (FAP013).

Asset management strategy is the function of evaluating assets to acquire new or dispose of existing assets and consists of 'asset acquisition management (FAP0111)', 'asset disposal management (FAP0112)', and 'asset evaluation management (FAP0113). Asset acquisition management is the function of enhancing asset value through the acquisition of tangible and intangible assets. Asset disposal management enhances asset value by disposing of tangible and intangible assets. Asset assessment management is the function that evaluates the financial status and management performance of assets.

Asset investment strategy is the function that plans investment strategies to improve asset value and consists of 'project planning (FAP0121)', 'asset allocation management (FAP0122)', and 'risk management (FAP0123). Project planning is the function of establishing plans to utilize investment assets. Asset allocation management distributes investment assets considering the expected rate of return and risk. Risk management is the function of minimizing risks by predicting and analyzing various potential risk factors of asset investment.

Asset management administration is the series of administrative functions for managing assets and consists of 'facility management planning (FAP0131)', 'administrative management (FAP0132)', and 'financial management (FAP0133)'. Facility management planning is establishing strategies to manage factory facilities effectively. Administrative management is a series of administrative management functions such as legal, personnel, and document management for managing assets. Financial management is planning and controlling capital flow and inventory for asset management.

#### **3.2. Asset development management (FA02)**

Asset development management consists of 'establishment (FAP021)', 'extension (FAP022), and 'rationalization (FAP023).

The establishment is the function of establishing new factories and consists of 'engineering management (FAP0211)', 'construction work management (FAP0212)', and 'commissioning management (FAP0213). Engineering management is the function related to managing engineering for new factories. Construction work management is the function of managing construction work for new factories. Commissioning management is the function related to managing commissioning for new factories.

Extension is the function of expanding already built factories and consists of 'engineering management (FAP0221)', 'construction work management (FAP0222)', and 'commissioning management (FAP0223). Engineering management is the function related to managing engineering for

the extension. Construction work management is the function of managing construction work for the extension. Commissioning management is the function related to managing commissioning for the extension.

Rationalization is the function of rationalizing already built factories and consists of ‘engineering management (FAP0231)’, ‘construction work management (FAP0232)’, and ‘commissioning management (FAP0233)’. Engineering management is the function related to managing engineering for rationalization. Construction work management is the function related to managing construction work for rationalization. Commissioning management is the function related to managing commissioning for rationalization.

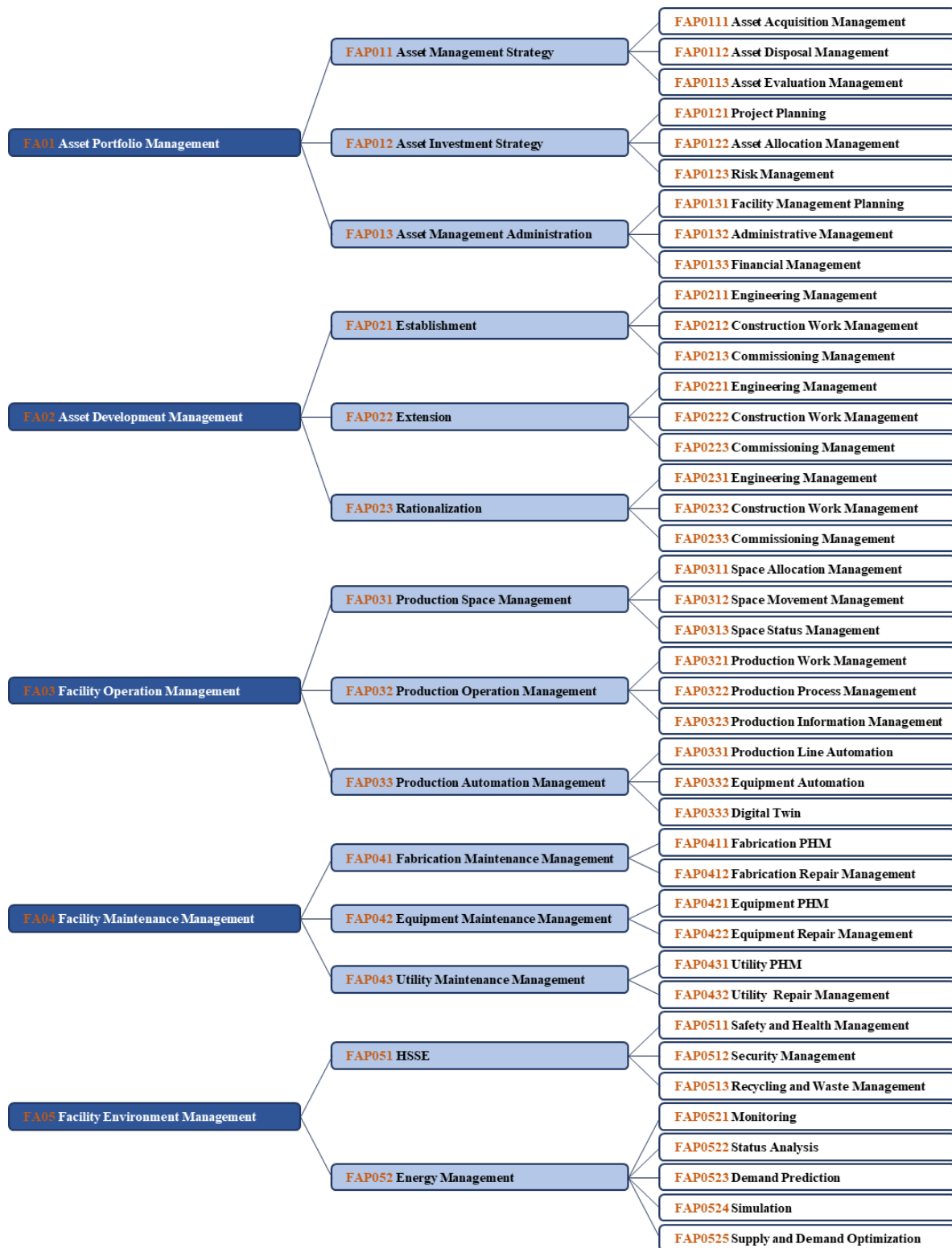


Figure 2. FBS of FAM for smart factory [12]

### **3.3. Facility operation management (FA03)**

Facility operation management consists of ‘production space management (FAP031)’, ‘production operation management (FAP032), and ‘production automation management (FAP033).

Production space management is the function to operate internal and external space for efficient production operation effectively and consists of ‘space allocation management (FAP0311)’, ‘space movement management (FAP0312)’, and ‘space status management (FAP0313). Space allocation management is the function of arranging the space of factory facilities. Space movement management is the function of effectively utilizing the movement of factory facilities’ space. Space status management is the function of analyzing whether the space is utilized efficiently.

Production operation management is the function for efficient production operation and consists of ‘production work management (FAP0321)’, ‘production process management (FAP0322)’, and ‘production information management (FAP0323)’. Production work management manages the operation status by constantly monitoring the lines and equipment for production operation. Production process management is the function of improving the work process by optimizing equipment. Production information management is managing productivity through the analysis of production information.

Production automation management is the function that automates the collection and analysis of data and equipment control and consists of ‘production line automation (FAP0331)’, ‘equipment automation (FAP0332)’, and ‘digital twin (FAP0333). Production line automation is the function of automated manufacturing processes such as design, manufacturing, and shipping for smart factory implementation. Equipment automation is the function that automatically collects, analyzes, and controls data through real-time connection of various equipment for smart factory implementation. Digital twin is the function to implement digital twin for the smart factory.

### **3.4. Facility maintenance management (FA04)**

Facility maintenance management consists of ‘fabrication maintenance management (FAP041)’, ‘equipment maintenance management (FAP042), and ‘utility maintenance management (FAP043).

Fabrication maintenance management is the function related to the maintenance of fabrications and consists of ‘fabrication prognostics and health management (PHM) (FAP0411)’ and ‘fabrication repair management (FAP0412)’. Fabrication PHM is the function of optimizing predictive diagnosis through collecting and analyzing the status information of fabrications. Fabrication repair management is the function of improving, repairing, and reinforcing fabrications.

Equipment maintenance management is related to equipment maintenance and consists of ‘equipment PHM (FAP0421)’ and ‘equipment repair management (FAP0422)’. Equipment PHM is the function of optimizing predictive diagnosis through collecting and analyzing equipment status information. Equipment repair management is the function of improving, repairing, and reinforcing equipment.

Utility maintenance management is the function related to equipment maintenance and consists of ‘utility PHM (FAP0431)’ and ‘utility repair management (FAP0432)’. Utility PHM is the function of optimizing predictive diagnosis through collecting and analyzing the status information of utility. Utility repair management is the function of improving, repairing, and reinforcing utilities.

### **3.5. Facility environment management (FA05)**

Facility environment management consists of ‘health, safety, security, and environment (HSSE) (FAP051)’ and ‘energy management (FAP052).

HSSE is the function for health, safety, security, and environment and consists of ‘safety and health management (FAP0511)’, ‘security management (FAP0512)’, and ‘recycling and waste management (FAP053)’. Safety and health management is the function of health, disasters, and indoor and outdoor environments while operating and maintaining facilities. Security management is the function of crime prevention, fire prevention, and information security while operating and maintaining facilities. Recycling and waste management is the function of recycling or disposal of resources such as rare metals during the operation and maintenance of facilities.

Energy management is the function of efficient management of various energy sources, such as electricity and gas, in smart factories and consists of ‘monitoring (FAP0521)’, ‘status analysis (FAP0522)’, ‘demand prediction (FAP0523)’, ‘simulation (FAP0524)’, and ‘supply and demand optimization (FAP0525). Monitoring is the function that monitors the energy of the entire factory through real-time measurement. Status analysis is the function that analyzes the multi-faceted status of energy consumption and production. Demand prediction is the function of predicting energy production

and consumption based on comprehensive information. Simulation is the function for simulating energy consumption changes. Supply and demand optimization minimizes energy costs and greenhouse gas emissions and optimizes energy production and consumption. [13]

#### 4. VALIDATION OF THE PROPOSED FAM FBS

This chapter is to validate whether the FBS of smart factory FAM was appropriately defined. The validation process was conducted from two perspectives. One was a comparison with international standards, and the other was with representative systems in real-world practice.

##### 4.1. Comparison with international standards

As described previously, the concept of FAM is explained by integrating CM, AM, FM, and OM. Therefore, the verification was attempted through comparative analysis with the functions presented in representative ISO standards in each field of CM, AM, FM, and OM (Table 1).

**Table 1.** Comparing FAM functions with international standards

| FAM functions |         | CM        | AM        | FM        | OM          | Remark                                |
|---------------|---------|-----------|-----------|-----------|-------------|---------------------------------------|
| Level 1       | Level 2 | ISO 21500 | ISO 55000 | ISO 41001 | IEC 62264-3 |                                       |
| FA01          | FAP011  | ○         | ○         |           |             | Strategic management                  |
|               | FAP012  | ○         | ○         |           |             | Risk management, Life-cycle costing   |
|               | FAP013  | ○         | ○         |           |             | Data management, Financial management |
| FA02          | FAP021  | ○         |           |           |             | Time management, Cost management      |
|               | FAP022  | ○         |           |           |             | Time management, Cost management      |
|               | FAP023  | ○         |           |           |             | Time management, Cost management      |
| FA03          | FAP031  |           |           |           | ○           | Inventory operations management       |
|               | FAP032  |           |           |           | ○           | Production operations management      |
|               | FAP033  |           |           |           | ○           | Information system management         |
| FA04          | FAP041  |           | ○         | ○         | ○           | Maintenance operations management     |
|               | FAP042  |           | ○         | ○         | ○           | Maintenance operations management     |
|               | FAP043  |           | ○         | ○         | ○           | Maintenance operations management     |
| FA05          | FAP051  |           | ○         | ○         |             | Emergency management                  |
|               | FAP052  |           | ○         | ○         |             | Energy management                     |

The representative reference standard in the CM is ISO 21500 [14], and the ten functions to describe project management (PM) can be included in asset portfolio management (FA01) and asset development management (FA02). The standard representing AM is ISO 55000 [7], which lists AM-related activities and can be included in asset portfolio management (FA01), facility maintenance management (FA04), and facility environment management (FA05). The standard representing FM is ISO 41001 [8], which focuses on five functions to implement the FM system and can be included in facility maintenance management (FA04) and facility environment management (FA05). A representative standard that can be referenced in the OM is IEC 62264-3 [15] in the manufacturing industry, and the four functions to explain manufacturing operation management (MOM) can be included in facility operation management (FA03) and facility maintenance management (FA04).

The comparative analysis verified that the defined FAM functions appropriately encompassed characteristics explained in the international standards representing CM, AM, FM, and OM.

##### 4.2. Comparison with representative practical systems

This part attempted verification through comparative analysis with the practical systems. To this end, an analysis matrix was created to express how the FAM functions are used as practical systems in CM, AM, FM, and OM.

| Level 1 | Level 2 | Level 3 | CM      |      |     | AM   | FM   | OM        |         |         |
|---------|---------|---------|---------|------|-----|------|------|-----------|---------|---------|
|         |         |         | BIM/PLM | PMIS | SWP | EAMS | CAFM | MES       | FEMS    | HSSEMS  |
| FA01    | FAP011  | FAP0111 |         |      |     |      |      |           |         |         |
|         |         | FAP0112 |         |      |     |      |      |           |         |         |
|         |         | FAP0113 |         |      |     |      |      |           |         |         |
|         | FAP012  | FAP0121 |         |      |     |      |      |           |         |         |
|         |         | FAP0122 |         |      |     |      |      |           |         |         |
|         |         | FAP0123 |         |      |     |      |      |           |         |         |
|         | FAP013  | FAP0131 |         |      |     |      |      |           |         |         |
|         |         | FAP0132 |         |      |     |      |      |           |         |         |
|         |         | FAP0133 |         |      |     |      |      |           |         |         |
| FA02    | FAP021  | FAP0211 |         |      |     |      |      |           |         |         |
|         |         | FAP0212 |         |      |     |      |      |           |         |         |
|         |         | FAP0213 |         |      |     |      |      |           |         |         |
|         | FAP022  | FAP0221 |         |      |     |      |      |           |         |         |
|         |         | FAP0222 |         |      |     |      |      |           |         |         |
|         |         | FAP0223 |         |      |     |      |      |           |         |         |
|         | FAP023  | FAP0231 |         |      |     |      |      |           |         |         |
|         |         | FAP0232 |         |      |     |      |      |           |         |         |
|         |         | FAP0233 |         |      |     |      |      |           |         |         |
| FA03    | FAP031  | FAP0311 |         |      |     |      |      | MES       |         |         |
|         |         | FAP0312 |         |      |     |      |      | MES       |         |         |
|         |         | FAP0313 |         |      |     |      |      | MES       |         |         |
|         | FAP032  | FAP0321 |         |      |     |      |      | MES       |         |         |
|         |         | FAP0322 |         |      |     |      |      | MES       |         |         |
|         |         | FAP0323 |         |      |     |      |      | MES       |         |         |
|         | FAP033  | FAP0331 |         |      |     |      |      | MES       |         |         |
|         |         | FAP0332 |         |      |     |      |      | EMS (MEL) | UMS/SSM |         |
|         |         | FAP0333 |         |      |     |      |      | EMS (MEL) | UMS/SSM | ISM     |
| FA04    | FAP041  | FAP0411 |         |      |     |      |      |           |         |         |
|         |         | FAP0412 |         |      |     |      |      |           |         |         |
|         | FAP042  | FAP0421 |         |      |     |      |      |           |         |         |
|         |         | FAP0422 |         |      |     |      |      | EMS (MEL) |         |         |
|         | FAP043  | FAP0431 |         |      |     |      |      |           | UMS/SSM |         |
|         |         | FAP0432 |         |      |     |      |      |           | UMS/SSM |         |
| FA05    | FAP051  | FAP0511 |         |      |     |      |      |           |         | CMS/ISM |
|         |         | FAP0512 |         |      |     |      |      |           |         | CMS     |
|         |         | FAP0513 |         |      |     |      |      |           |         | PEMS    |
|         | FAP052  | FAP0521 |         |      |     |      |      |           | PEMS    |         |
|         |         | FAP0522 |         |      |     |      |      |           | PEMS    |         |
|         |         | FAP0523 |         |      |     |      |      |           | PEMS    |         |
|         |         | FAP0524 |         |      |     |      |      |           | PEMS    |         |
|         |         | FAP0525 |         |      |     |      |      |           | PEMS    |         |

**Figure 3.** Comparing FAM functions with representative practical systems

As a subject of analysis, building information modeling (BIM), product life-cycle management (PLM), project management information system (PMIS), and system work package (SWP) were selected in the CM, enterprise asset management system (EAMS) was selected in the AM, computer-aided facility management (CAFM) was selected in the FM, and manufacturing execution system, factory energy management system (FEMS), and HSSE management system (HSSEMS) were selected in the OM. As illustrated in Figure 3, the FBS of FAM proposed in this study shows the appropriateness of encompassing each management field.

As a case study, a case company in the manufacturing industry describes seven systems, including MES, equipment management system (EMS), utility monitoring system (UMS), safety and supply monitoring system (SSM), plant energy and environment management system (PEMS), integrated safety management system (ISM), and central monitoring system (CMS), for operating a smart factory. As shown in Figure 3, the OM part of the matrix indicates that the case company's systems can all be included in the proposed FBS.

Notably, the function of 'facility operation management (FA03)' requires BIM, PLM, and MES systems together, and the function of 'facility maintenance management (FA04)' requires EMS, UMS, SSM, and CAFM systems together. It indicates that integrating common information for those areas is an important issue. Further studies on how those systems share common information in different formats or different levels of detail (LoD) are currently being explored by the authors.

## 5. Conclusion

Facility asset management (FAM) is a key component to achieving smart factories. However, there is still no legitimate research on FAM focused on factory facilities. In this context, the functional breakdown structure (FBS) of FAM for smart factories was proposed in this paper.

The FBS has a hierarchical structure with three levels, including five functions in level 1, fourteen in level 2, and forty-one in level 3. In addition, the FBS verified the appropriateness through comparative analysis with international standards and practical systems of CM, AM, FM, and OM.

As a follow-up study, the property of each business function will be defined, and the properties will be utilized for publishing and sharing with namespaces.

## ACKNOWLEDGMENTS

This research was supported by the National Research Foundation of Korea (NRF), funded by the Ministry of Science and ICT (MSIT) (NRF-2021R1A2C1006997), and the Ministry of Education (MOE) (NRF-2021R1I1A1A01055223 and RS-2023-0024334713582110600001).

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