Issues and Needs for Standard Classifications for Facility Management in Smart Manufacturing

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Abstract –

As construction projects become larger and more complicated, the importance of information sharing among various project participants throughout the entire life-cycle of a facility is ever-increasing. Establishment of standard classification system is the most fundamental task for systematic and efficient management of construction information. In recent years, technology advancement of smart manufacturing, which is for intelligent factories supported by ICT combined with existing manufacturing technology, is becoming a key issue.

However, due to the lack of information exchange (IE) standards for the management of smart manufacturing's construction and operation, it is very limited for various construction participants to generate and share information by using the standards. In addition, each standard classification should be used in a combined manner in order to improve information processing efficiency.

Standard classification requires a variety of facets such as facility, space, element, and work section. The purpose of this study is to propose a physical breakdown structure (PBS) that best reflects distinct characteristics of smart manufacturing. Firstly, the influencing factors for defining PBS were identified. A methodology for creating the facility classification suitable for smart manufacturing was then developed. Finally, cost breakdown structure (CBS) and work breakdown structure (WBS) were developed by combining the PBS and other standard classifications. This case-study of CBS and WBS formulation were used as a validation for the proposed methodology. The concept of "flexible WBS" by Jung and Woo [6] were utilized in this case study as well, in order to accommodate the managerial requirements of an owner organization from the display industry.

Keywords –

Standard classifications; Smart manufacturing; Facility management; Information exchange

1 Introduction

Recently, as part of the fourth industrial revolution, technology development and standardization of smart factories that can optimize relevant management by sharing and utilizing all production information and knowledge in real time based on ICT has become a key issue in the manufacturing industry. Planning, design, production, distribution, and sales could be conducted at lower cost and reduce time through the development of technology and standardization [9]. In addition, it is possible to build a next-generation factory that actively responds to new environments such as productivity improvement, energy saving, implementation of people-oriented working environment, and personalized manufacturing [9].

A lot of standards have been developed for standardized information exchange (IE) among the various components of the manufacturing process. However, due to the lack of information exchange standards for construction and operation management of smart factories, it is very limited for various construction participants to generate and share information by using the standards. Therefore, a great deal of effort is required to rework the data for the operation and maintenance (O&M) phase.

In an effort to develop standard classifications for airport projects, Jung et al. [2] pointed out that "the issues of information exchange could be discussed from various perspectives including level of detail (LOD), diversity of various facets, and business requirements".

The purpose of this study is to develop a physical breakdown structure (PBS) that best reflects distinct characteristics of smart manufacturing. Firstly, the influencing factors for defining PBS were identified. A methodology for creating the facility classification suitable for smart manufacturing was then developed. Finally, cost breakdown structure (CBS) and work breakdown structure (WBS) were developed by combining the PBS and other standard classifications.

This case-study of CBS and WBS formulation were used as a validation for the proposed methodology.

2 Needs for Standard Classifications in Smart Factory

There are two types of standards for smart manufacturing. One is directly related to manufacturing and the other one is indirectly related to manufacturing process [8]. Lee et al. [9] summarizes current ISO standard activities as listed in Table 1 based on KATS [7].

Table 1 International Organization for Standardization for smart manufacturing [7] [9]

IEC/SEG 7	- Smart manufacturing
IEC TC 65	- Industrial process measurement, control and automation
ISO TC 184/SC 4	- Industrial data
ISO TC 184/SC 5	- Interoperability, integration, and architecture for enterprise systems and automation applications
ISO/IEC JTC 1/WG 9	- Big data
ISO/IEC JTC 1/WG 10	- Internet of things
oneM2M	- Standards for M2M and the Internet of Things
IEEE P2413	- Standard for an Architectural Framework for the Internet of Things

These standards have been developed by ISO mainly in the fields of IoT, big data, cloud computing, security CPS, M2M, etc. For example, most of ISO TC 184/SC 4 is the series of representation and information exchange for product data (ISO 10303). IEC TC 65 mainly covers standards for industrial cable, wired and wireless network, and system integration [9].

However, due to the lack of information exchange (IE) standards for construction and operation of smart factories, it is very limited for various construction participants to generate and share information by using the standards. Therefore, the establishment of a standard classification for construction information exchange will contribute not only to realization of data-centric factory construction management but also to the improvement of managerial effectiveness.

From the owner's perspective, standard classifications enables to collect standardized information from many construction participants, like designers, engineers, contractors, operators, etc. This also allows new construction participants to share information automatically.

3 Standard Classification and Numbering System (SCNS)

Like the smart manufacturing, the construction industry has been using international standards for a long time. For example, MasterFormat [10], Uniclass [12], OmniClass [11], etc. In particular, information exchange through the standard classifications is a very important factor in terms of managerial effectiveness and information consistency, as there are many participants, including owners, designers, engineers, contractors and operators in factory construction projects.

In the early stage, this study attempted to use existing international standards for factory construction projects. However, existing international standards cannot adequately reflect the characteristics of the factory. Among the various classification facets, the facet that best reflects characteristics of factory is 'facility'. However, it is difficult to classify 'facility' according to existing construction standards, because the level of 'facility' classification is too high to present a special-purpose building to a factory. It is also difficult to define an equipment or a system as a part of a 'facility' classification in the existing construction standard classifications.

In order to solve this problem, a 'facility' classification of owner's perspective is developed, known as physical breakdown structure (PBS) in practice, which reflects characteristics of smart manufacturing for systematic and efficient management and utilization of construction information on factory.

As shown in Table 2, PBS is developed by the concept of standard for classification and numbering system (SCNS) [3]. SCNS consists of standard classifications (CLN) and project numbering system (PNS).

Establishment of CLN and PNS is the most fundamental task. It forms a framework for all related project management tasks, such as scope management, design management, process control, cost control, quality control [4].

There are many different facets in CLN that satisfies general requirements. ISO [1] recommended facility facet, space facet, element facet, work section facet, material facet, construction aids facet, management

Table 2 SCNS - Standard Classification and Numbering System [3]

L I	Level II	Level III	Remarks
Standard Classification and Numbering System (SCNS)	Standard Classifications (CLN) *	(CLF) Facility Facet	e.g. Building, Airport
		(CLS) Space Facet	e.g. Office, Bed room
		(CLE) Element Facet	e.g. Column, Beam
		(CLW) Work Section Facet	e.g. Steel structure
		(CLM) Construction Material/Assembly Facet	e.g. Re-bar, Concrete
		(CLA) Construction Aid Facet	e.g. Wood form, Crane
		(CLG) Management Facet	e.g. Cost, Contracting
		(CLP) Attribute and Property Facet	e.g. Heat transmission
	Project Numbering Systems (PNS)	(GBS) Geometry Breakdown Structure **	Multi-facet for 3D design
		(WBS) Work Breakdown Structure	Multi-facet for scheduling
		(CBS) Cost Breakdown Structure	Multi-facet for cost
		(EBS) Equipment Breakdown Structure	Multi-facet for procurement
		(OBS) Organization Breakdown Structure	Multi-facet for stakeholders
		(RBS) Risk Breakdown Structure	Multi-facet for risk
		(MBS) Measurement Breakdown Structure	Multi-facet for estimating
		(SBS) Specifications Breakdown Structure	Multi-facet for specs
		(DBS) Drawing Breakdown Structure	Multi-facet for drawings
		(PBS) Physical Breakdown Structure	Single facet
		(FBS) Functional Breakdown Structure	Single facet

* Eight facets defined by ISO [1], ** Patented by Myongji University [5]

facet, and attribute facet as the top level categories. In addition, combining these facets could be used as a PNS for specific purposes (e.g. cost, scheduling, etc.) [3]. Therefore, the continuous development of standard classifications for other facets in smart factory would be able to expand the influence for extensive application in practice.

As discussed previously, PNS has a structure that combines several different CLNs. As shown in Table 2, most of PNSs are 'multi-facet'. For example, CBS can be defined by combining CLF with CLW of CLN. However, PBS and FBS are 'single facet' and PBS can be defined as a 'facility' classification, which is CLF. Therefore, CBS also can be defined as a combination of PBS and FBS in this study.

4 Physical Breakdown Structure (PBS)

The proposed PBS of a factory construction project in the display industry has three-level structure as shown in Figure 1. The first level has eight categories. There are 'project general (000), panel equipment (100), module equipment (200), fab common facility (300), utility (400), electric power facility (500), architecture/civil (600), and trunkline (700)'.

The second level of 'project general (100)' has 'planning (010), site acquisition (020), licensing/permission (030), project/production management (050), and indirect cost/others (090)', which includes general items to perform the project. 'Panel equipment (100)' includes several panel-related production equipment, and 'module equipment (200)' includes module-related production equipment. 'Fab common facility (300)' includes several common items for fabrication buildings, and 'utility (400)' includes utility-related equipment. Items belonging to the second level of 'panel equipment (100) and module equipment (200)' are not open to the public at the display company's request.

'Fab common facility (300)' has 'CR (310) and FA (320)' as the second level, which are facilities that common includes 'panel equipment (100) and module equipment (200)'. 'Utility (400)' includes 'gas (410), chemical (420), water (430), vacuum (440), emission (450), waste (460), and air (470)', which are utility equipment. 'Electric power facility (500)' includes 'electrical facility (510), distribution facility (520), and generating facility (530)'. 'Architecture/civil (600)' has 'infrastructure (610), stock (620), storage (630), auxiliary building (640), and temporary facility (680)', which includes general buildings. Finally, the second level of 'trunkline' includes 'system wiring (710),

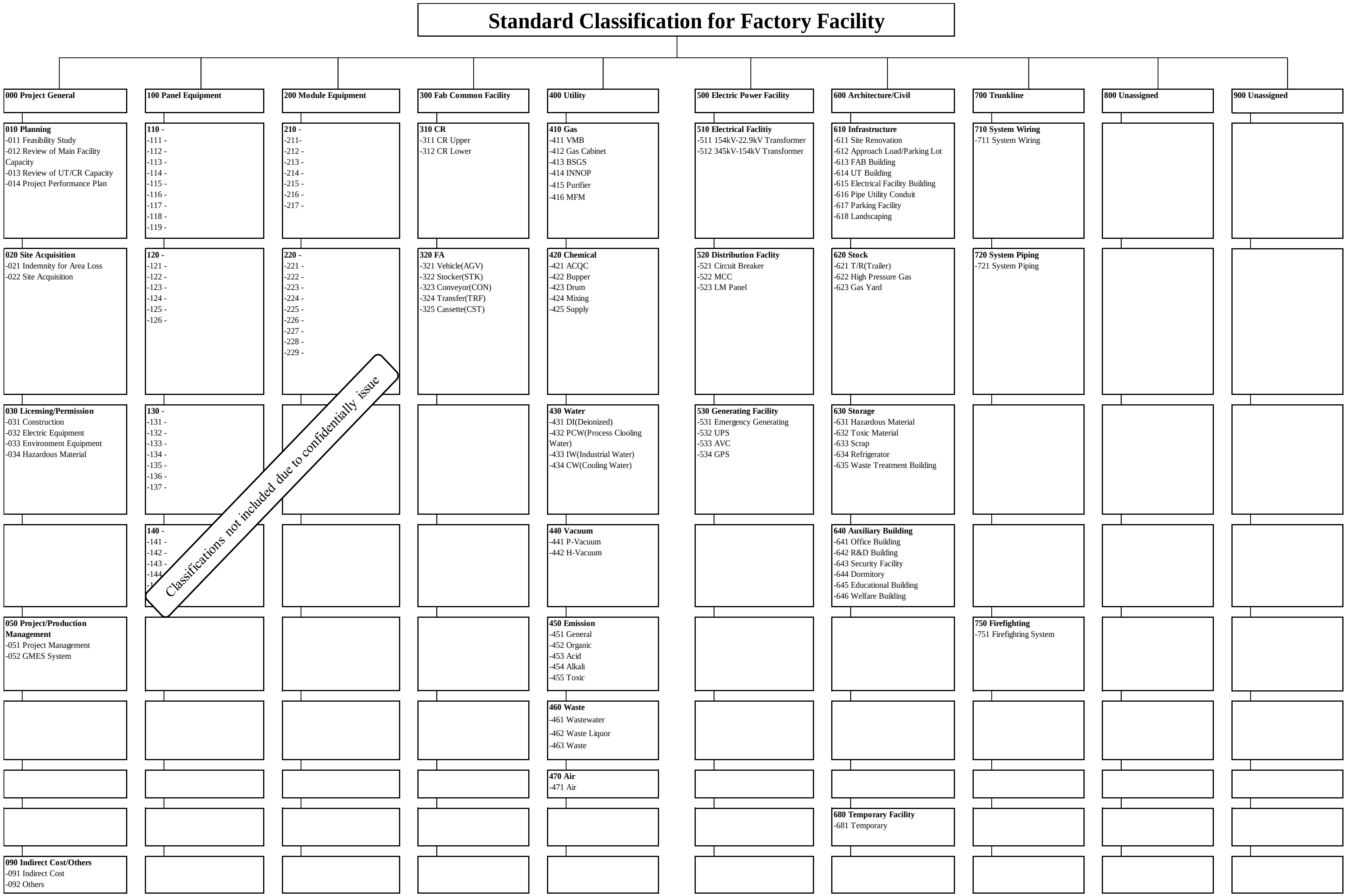


Figure 1. PBS Structure for Factory Facility

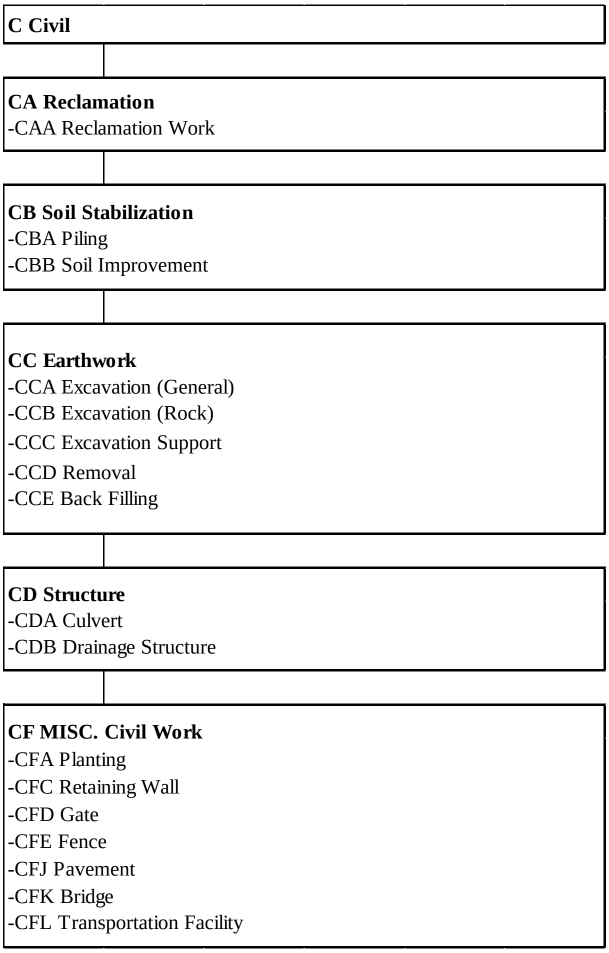


Figure 2. Part of PBS

system piping (720), and firefighting (750)'.

For example, Figure 2 shows the category of 'architecture/civil (600)'. 'Infrastructure (610)' includes 'site renovation (611), approach load/parking lot (612), fabrication building (613), utility building (614), electrical facility building (615), pipe utility conduit (616), parking facility (617), and landscaping (618)', which are infrastructures. 'Stock (620)' has 'trailer (621), high pressure gas (622), and gas yard (623)'. 'Storage (630)' includes 'hazardous material (631), toxic material (632), scrap (633), refrigerator (634), and waste treatment building (635)'. 'Auxiliary building (640)' includes 'office building (641), R&D building (642), security facility (643), dormitory (644), educational building (645), and welfare building (646)'. Finally, 'temporary facility (680)' includes 'temporary (681)'.

As a result, this category has five sub-categories in level 2 and twenty three items in level 3. In this way, PBS is defined that including a total of 8 categories in level 1, 31 sub-categories in level 2, and 125 items in level 3.

The proposed 'facility' classification in this study shows unique characteristics that cannot be found in existing construction codes. More specifically, 'project general (000)' are the general factors to perform a project. (700)' are defined with the factors for machines and 'Panel equipment (100), module equipment (200), utility (400), electric power facility (500), and trunkline systems rather than facilities. Because unlike general buildings, these factors are essential for supporting managerial tasks such as cost, scheduling, and operating in the factory construction project.

5 Case-Study

Due to the characteristics of factory construction, each standard classification of different technical fields should be used in a combined manner in order to improve information processing efficiency of construction participants according to share necessary information on entire related technical fields, such as civil, architecture, machinery, electricity, instrumentation, and communication.

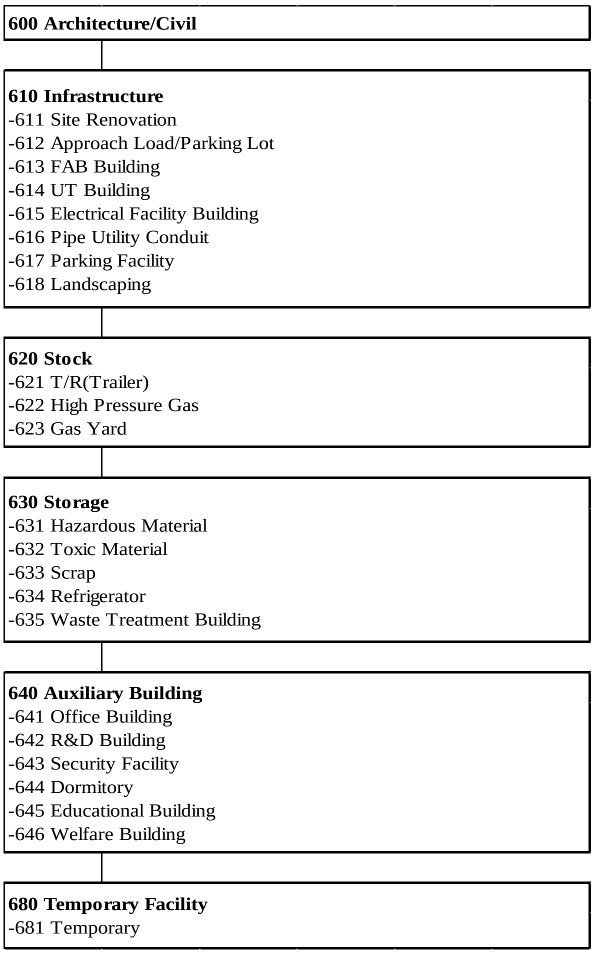


Figure 3. Part of FBS

Table 3 Criteria for combining PBS and FBS

PBS Division		**FBS01**		**PBS01**	**PBS02**	**PBS03**	**PBS Division**		**FBS01**		**PBS01**	**PBS02**	**PBS03**
000	Project General	L	Planning		●		400	Utility	D	Design	●		
		K	Consulting		●				M	Mechanical Equipment		●	
									E	Electrical Equipment		●	
100	Panel Equipment	D	Design	●					S	Commissioning		●	
		M	Mechanical Equipment			●							
		E	Electrical Equipment			●	500	Electric Power Facility	D	Design	●		
		S	Commissioning			●			E	Electrical Equipment	●		
200	Module Equiepment	D	Design	●			600	Architecture/Civil	D	Design	●		
		M	Mechanical Equipment			●			G	Temporary		●	
		E	Electrical Equipment			●			C	Civil			●
		S	Commissioning			●			A	Architecture			●
									M	Mechanical Equipment			●
300	FAB Common Facility	D	Design		●				E	Electrical Equipment			●
		A	Architecture			●			N	Automatic Control			●
		M	Mechanical Equipment			●			T	ICT			●
		E	Electrical Equipment			●							
		N	Automatic Control			●	700	Trunkline	D	Design	●		
		S	Commissioning			●			M	Mechanical Equipment	●		
									E	Electrical Equipment	●		

A case study of cost breakdown structure (CBS) structure is introduced by combining PBS and functional breakdown structure (FBS) at a display factory in this chapter.

Like PBS, FBS also has three-level structure. The first level has 12 categories. There are ‘architecture (A), civil (C), design (D), electrical equipment (E), temporary (G), consulting (K), planning (L), mechanical equipment (M), automatic control (N), contract (P), commissioning (S), and ICT (T)’.

For example, Figure 3 shows the category of ‘Civil Engineering (C)’. This category has 5 sub-categories. These include ‘reclamation (CA), soil stabilization (CB), earthwork (CC), structure (CD), and MISC. civil work (CF). ‘Reclamation (CA)’ includes ‘reclamation work (CAA)’. ‘Soil stabilization (CB)’ includes ‘piling (CBA) and soil improvement (CBB)’. ‘Earthwork’ includes ‘excavation (general) (CCA), excavation (rock) (CCB), excavation support (CCC), removal (CCD), and back filling (CCE)’. ‘Structure’ includes ‘culvert (CDA) and drainage structure (CDB)’. Finally, ‘MISC. civil work (CF)’ includes ‘planting (CFA), retaining wall (CFC), gate (CFD), fence (CFF), pavement (CFJ), bridge (CFK), and transportation facility (CFL)’.

As a result, this category has 5 sub-categories in level 2 and 17 items in level 3. In this way, FBS is defined that including a total of 12 categories in level 1, 45 sub-categories in level 2, and 130 items in level 3. If looking at the components of FBS, it also could define as a ‘work section’ classification.

In this case study, it has one specialty in CBS. When combining PBS and FBS, the FBS is combined at level 3, but PBS is combined at different level according to managerial objectives of owner. The criteria for combing PBS and FBS is shown in Table 3. In this table, level 1 is used as code ‘01’, level 2 is code ‘02’, and level 3 is code ‘03’.

Items of ‘project general (000)’ are combined PBS02 with the work items about ‘planning (L) and consulting (K)’. Items of ‘panel equipment (100) and module equipment (200)’ are combined PBS01 with the work items about ‘design (D)’, and PBS03 with the work items about ‘mechanical equipment (M), electrical equipment (E), and commissioning (S)’. Items of ‘fab Common facility (300)’ are combined PBS02 with the work items about ‘design (D)’, and PBS03 with the work items about ‘architecture (A), mechanical equipment (M), electrical equipment (E), automatic control (N), and commissioning (S)’. Items of ‘utility (400)’ are combined PBS01 with the work items about ‘design (D)’, and PBS02 with the work items about ‘mechanical equipment (M), electrical equipment (E), and commissioning (S)’.

Items of ‘electric power facility (500) and trunkline (700)’ are combined PBS01 with the work items about ‘design (D) and electric equipment (E)’. In addition, items of ‘trunkline (700)’ are combined PBS01 with the work items about ‘mechanical equipment (M)’. Finally,

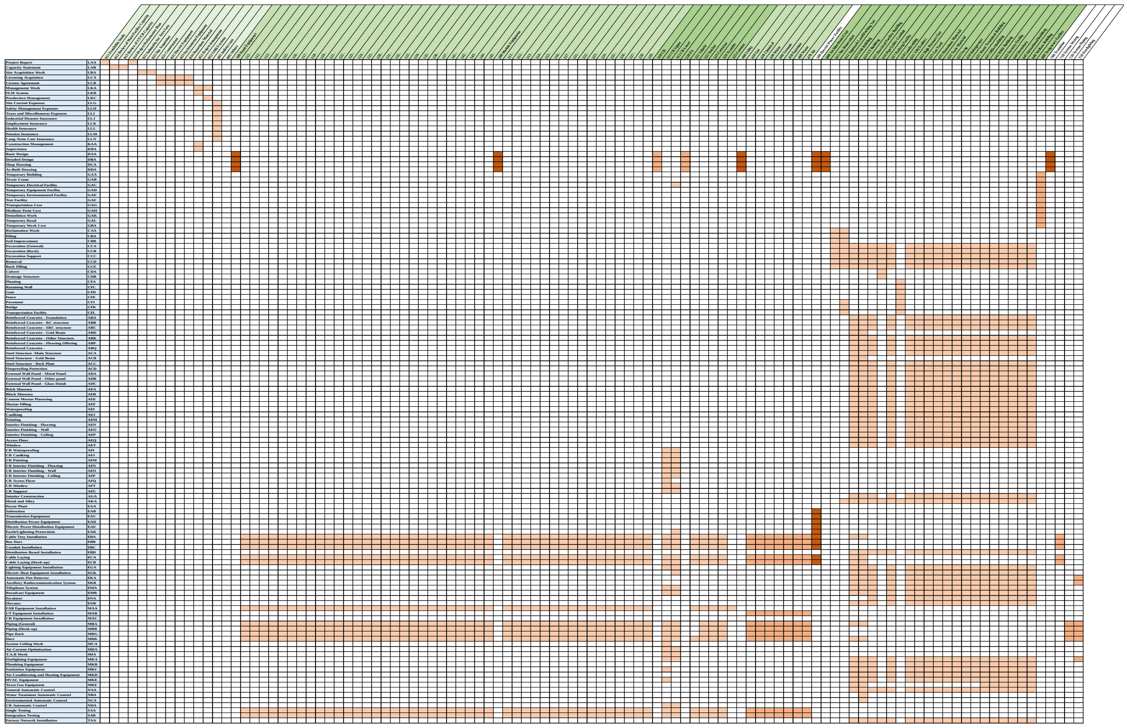


Figure 4. Matrix combining PBS and FBS

items of 'architecture/civil (600)' are combined PBS01 with the work items about 'design (D)', PBS02 with the work items about 'temporary (G)', and PBS03 with the work items about 'civil (C), architecture (A), mechanical equipment (M), electrical equipment (E), automatic control (N) and ICT (T)'.

As shown in Figure 3, different CBS packages (cell) may have different levels in terms of combining a PBS with a FBS. The rationale behind having different levels is to accommodate the different importance of managerial requirement for a specific from the owner's perspective. In other words, the concept of "flexible work breakdown structure (WBS)" is used in this research [6]. Due to the characteristics of the display factory in this case, 'panel equipment (100) and module equipment (200)' are very important parts. On the other hand, 'electric power facility (500) and trunkline (700)' are supporting function throughout the entire project.

In this way, a total of 1,709 Items for CBS are identified by combining PBS and FBS. It is represented by a matrix as shown in Figure 4. In this figure, a darkest cell is the combination of PBS01 and FBS03, dark cell is the combination of PBS02 and FBS03, and the lightest cell is the combination of PBS03 and FBS03.

The main objective of this case study is to develop criteria for managerial effectiveness of project cost on the owner's perspective in the preliminary stage. In other words, it is to develop a standard CBS, which proposed in this study.

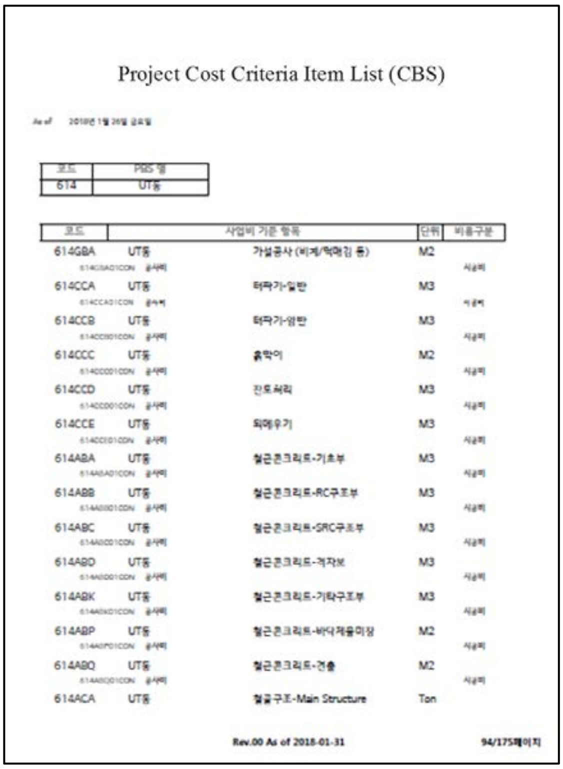
The case-study firstly defined FBS, which covers an entire life-cycle of smart factory construction based on the existing data of the display company. And each FBS was assigned standard code. CBS is developed by combining PBS and FBS with standard codes. This study used a relational data-base (RDB) system to create a list of CBS items through established relationship between each standard classification (Fig. 5). Therefore, historical data will be connected with the CBS items and it is possible to manage automatically and systematically. Standards codes can also be used to automatically information exchange (IE) among many different organizations [2].

6 Conclusions

Due to the lack of standard classifications for construction and operation management of smart factories, it is very limited for various construction participants to generate and share information by using the standards. This requires a great deal of effort to rework the data for the operational phase.

The purpose of this study is to develop a standard classification that could improve the effectiveness of information exchange among construction participants, and for systematic and efficient management and utilization of construction information for factory construction projects.

As firstly, PBS which is a standard classification for 'facility' facet that best reflects the characteristics of smart manufacturing has been proposed in this study.



Project Cost Criteria Item List (CBS)

코드	PBS 명
614	UT동

코드		사업비 기준 항목	단위	비용구분
614GBA	UT동	가설공사 (비계/낙하물 등)	M2	
614CCA	UT동	터파기-일반	M3	
614CCB	UT동	터파기-암반	M3	
614CCC	UT동	흙막이	M2	
614CCD	UT동	잔토처리	M3	
614CCE	UT동	되메우기	M3	
614ABA	UT동	철근콘크리트-기초부	M3	
614ABB	UT동	철근콘크리트-RC구조부	M3	
614ABC	UT동	철근콘크리트-SRC구조부	M3	
614ABD	UT동	철근콘크리트-격자보	M3	
614ABK	UT동	철근콘크리트-기타구조부	M3	
614ABP	UT동	철근콘크리트-바닥재물미장	M2	
614ABQ	UT동	철근콘크리트-견출	M2	
614ACA	UT동	철골구조-Main Structure	Ton	

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Figure 5. Example of CBS Criteria Items List

The proposed PBS is verified through a case-study in the display industry. It could be seen that the CBS constructed through the combination of PBS and FBS best reflects the characteristics of the factory.

Although the smart manufacturing industry has been utilizing many well-established standards for a long time, standards for factory facilities have not been actively reviewed. In this context, the issues proposed in this study will contribute to the development of smart manufacturing industry.

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