BUSINESS BREAKDOWN STRUCTURE FOR CONSTRUCTION MANAGEMENT AND WEB-BASED APPLICATION SYSTEM

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SUMMARY: The process for construction management (CM) includes much specialized information for the management of time, cost, and quality throughout the project life cycle. Accordingly, a standardized code system, such as a business breakdown structure (BBS) for classifying each CM business, is necessary for efficient information management of detailed CM tasks. The BBS for CM proposed in this study can make it possible to systematically classify documentary information, references, and management tasks that evolve from all the phases of a construction project. The organized BBS for CM consists in total of ten classification tables including the classifications for form of information, management subjects, and eight tables by the CM function. Because each CM task is processed by management information for a work on the construction site, it is also necessary to connect a BBS code with a work breakdown structure (WBS) code. This study suggests a method to integrate the two code systems and it can have applicability in facilitating the retrieval and management of information for CM processes. To verify the applicability of the BBS for CM, this study included a prototype web-based system including the integration between BBS and WBS codes and a new approach to use BBS and WBS in a 4D CAD system.

KEYWORDS: business breakdown structure (BBS), construction management (CM), construction information classification system (CICS), work breakdown structure (WBS), 4D CAD.

1. INTRODUCTION

It is important to standardize the administrative information for an effective performance of each construction management (CM) process. The business breakdown structure (BBS) for CM is one of the breakdown structures for classifying CM information generated from each CM process, and it could be a useful tool for the standardization of various administrative information for a construction project. The process of CM includes many specialized information for management of time, cost, and quality throughout the project life cycle. The BBS is a standardized code system to classify those CM tasks for efficient management of information generated from detailed CM processes.

A work breakdown structure (WBS) is a representative code system and most construction projects have a unique WBS code system, however the WBS is focused on the work operations. On the other hand, BBS code is classified and focused for the business information, such as time scheduling, cost management, quality management and resource management, that is generated through the whole CM duration of a project. For

example, time scheduling tasks can be classified by critical path analysis, network diagramming and progress control process. BBS code classifies those detailed management information for each CM task as a standard breakdown structure so that project manager can manage and reuse those information through project duration. Accordingly, WBS code is necessary for managing construction operation information in the construction phase, on the other hand, BBS code is necessary for classifying business information for each CM task through the whole project duration. The organized BBS code in this study consists in total of ten classification tables including the classifications for form of information, management subjects, and eight tables by the CM function.

For the study, Masterformat (CSI/CSC, 1988) and Uniclass (CPIC, 1997) in the existing classification systems were examined to verify the adaptability of the classification codes. And the classification tables that can be applied to the practical processes of CM were organized on the basis of analysis with actual references (CMAA, 1993; CMAA, 1990; Fisk, 1980) including the regulations and guides, etc. Engineering information classification system (Chang, 2003) is the other related work that classifies information for engineering management using a facet and hierarchical structure from facility to resource levels. This research attempts to include engineering tasks code within a construction classification system, but it cannot cover the classified items for the detailed tasks for CM. Also it is difficult to classify task information by each CM process in current classification systems because they put the applicability of the classified items to the construction operations.

Finally, this study suggests a practical application method of the classification tables and a prototype of a web-based CM system to evaluate the adaptability of the organized CM BBS system. And this study proposes a new approach to link BBS and WBS codes with 4D CAD system in the future work section because 4D CAD is one of the representative tool for visualizing CM information.

An approach to link information classification system to 4D CAD was attempted in 4D/VR construction processes simulation research (Dawood, 2002). Information classification system is also applied to the lean enterprise web-based information system (LEWIS) to integrate various database for drawings, CAD file and specifications (Dawood, 2003). Prototype web-based construction project management (Chan, 2004) is another research related web-based CM system and the research presents a conceptual model of a metadata-based information system for data exchanges among web-based documents for CM. Those approaches for web-based CM are generally focused on the real time information exchanges and visualization of construction data, however, this research is focused on the classification of administrative information for each CM task and the application of the classification system to web-based CM tool linked with WBS.

2. NECESSITY OF BBS AND WBS

Recently construction managers recognize the necessity of a systematic business information management for CM tasks as well as operation data management for construction work processes. Especially, business information management is a more important tool because CM scope is being extended to the life cycle of a project from the planning phase to the maintenance phase. If project manager cannot use a standard code system as the BBS in life cycle management of a project, it is difficult to reuse historical project information and to systematically manage CM information by a project phase because the enormous amount of project data are stored and managed separately by a makeshift code system of each project.

In other words, because CM task generates large amounts of information and frequently requires the exchange of information among related subjects, a standardized information classification system for each management task should be developed for the efficient exchange and management of project data. Such a classification system makes it possible to systematically classify documentary information, references, and management items that evolve through all the phases of a construction project. Consequently, the standardized classification system as the BBS has its applicability in facilitating the retrieval of management information generated on the construction site.

And for the more effective information management, it can be helpful for a project manager to group the construction information into two categories such as construction work information and management task information. To manage the information originated in the management task separately from the information for the construction work can be useful for an information classification system because the characteristics between two kinds of information are quite different. For example, the classified items for the construction work such as earthwork or formwork for a pier have uniqueness in the project. In contrast, the classified items for the

management task such as critical path analysis or quality management can be used as common items for both of earthwork and formwork.

But two categories need to be linked throughout the project life cycle for an integrated construction management. For example, there might be a pier item in a construction work breakdown and the network drawing item in a management task breakdown. To represent the network diagram for the pier, the two categories should be connected by their codes. This study suggests a methodology to link such two kinds of construction information by a web-based system and 4D CAD system.

If the detailed items for the two kinds of information are classified in one classification system as in Masterformat or Uniclass, it is difficult to classify detailed tasks for the management process because the number of classified items is limited in hierarchical coding system. And the system may have an artificial classification without a consistency and mnemonics in the coding system.

The existing construction information classification systems (CICSs) are focused on the practical construction work breakdown information. On the other hand, because the BBS is focused on the classification of management tasks, the standardization of CM business and the rationalization of management procedure can be easier by the BBS. The BBS suggested in the study is a separate classification system from the general work breakdown classifications, and it can be a new concept for construction information classification system in the professional construction management field.

3. EXAMINATION OF THE EXISTING CLASSIFICATION SYSTEMS

Currently, Masterformat and Uniclass are the representative classification systems equipped with the classification codes that can be used as a BBS for CM. Thus, this chapter examines the structure and applicability of the classification code systems in Masterformat and Uniclass for the management tasks.

3.1 Classification codes in Masterformat

The Masterformat that is widely being used as a work section classification in North America, having a focus on architectural works, consists of 16 specification divisions and a section for bidding requirements and contract forms (Kang and Paulson, 1997). In particular, Division 1 for general requirements and the section for bidding requirements are expected to be applicable as a BBS for CM. Table 1 represents the main classification items for CM in Masterformat.

TABLE 1: Masterformat Codes for CM Tasks (CSI/CSC, 1988)

Division 0 – Bidding requirements, contracts forms, and conditions of the contract	Division 1 – General requirements	
00010 Pre-bid information	01010 Summary of work	01100 Special project procedures
00100 Instruction to bidders	01020 Allowances	01200 Project meetings
00200 Information available to bidders	01025 Measurements and payment	01300 Submittals
00300 Bid forms	01030 Alternates/alternatives	01400 Quality control
00400 Supplements to bid forms	01035 Modification procedures	01500 Construction facilities and
00500 Agreement forms	01040 Coordination	temporary controls
00600 Bonds and certificates	01050 Field engineering	01600 Material and equipment
00700 General conditions	01060 Regulatory requirements	01650 Facility startup
00800 Supplementary conditions	01070 Identification systems	01700 Contract closeout
00900 Addenda	01090 References	01800 Maintenance

The section for bidding requirements in Table 1 classifies the documents needed in the procurement phase into 10 categories (00010 Pre-bid information - 00900 Addenda), and then subdivides subcategories into detailed items. This section has a practical application in classifying bidding documents. General requirements in Division 1, corresponding to the general rules of specifications, classifies the general information in the construction phase into 19 categories (01010 Summary of work – 01800 Maintenance), and then subdivides

subcategories into detailed items. Accordingly, this division is expected for classifying management information and documents in the construction phase.

Those codes in Masterformat, however, can be partially applied not to classification of numerous information generated through the project life cycle but to classification of the information during the procurement and construction phases. And Masterformat has its limitation in practical application with the lack of the codes in detailed items for each CM task. That is, it was analyzed that the classification codes in Masterformat could be applied only to partial classification of information, not to general classification of information throughout the CM business. However, those partial classification codes in Masterformat were also considered in organizing BBS items for CM in this study.

3.2 Classification codes in Uniclass

Uniclass is a classification system developed to supersede the construction index/samarbetskommitten for byggnadsfragor (CI/SfB), which is one of the existing classification systems (Kang and Paulson, 2000). By including CM items in the table of *C Management*, unlike other information classification systems for construction projects, it is expected that Uniclass can be utilized for such objectives as planning and management of a project in the construction industry. Table 2 represents categories and sub-items of the structure of *C Management* table in Uniclass.

TABLE 2: Uniclass Codes for CM Tasks (CPIC, 1997)

C1 Management theory systems and activities	C4 Specialist areas of management
C11 Corporate strategy	C41 Management of office services
C12 Quality management	C42 Marketing, selling
C13 Security, industrial espionage, trade secrets	C43 Research and development
C14 Objective setting	C44 Finance and accounting, business economics
C15 Decision making	C45 Personnel management and industrial relations
C16 Problem solving	C46 Management of computing, information technology
C17 Coordination	**C5/C9 Management of construction activities/project management**
C18 Appraisal, assessment	C50 General techniques/information
C19 Other	C61 Inception/procurement
C2 Management personnel	C62 Feasibility
C21 Top management, directors, partners	C63 Outline proposals/program preparation
C22 Other levels of management	C64 Scheme design/costing
C3 Type of business/organization	C65 Detail design/costing
C31 Organizations by scale and location	C66 Production information
C32 Private enterprises	C67 Bills of quantities
C33 Mixed enterprises and partnerships	C68 Tender action
C34 Government and related organizations	C71 Construction preparation/project planning
C35 Public enterprises	C72 Construction operation on site
C36 Non-profit-making organizations, charities	C73 Completion
C37 Industrial and commercial associations	C81 Occupation/facilities management
C38 Construction industry	C83 Feedback
C39 Other types of organization	C84 Refurbishment and recommitment
	C91 Decommissioning
	C92 Demolition etc.
	C93 Redevelopment

Because *C1* to *C4* items in *C Management* classify management theories, activities, management personnel, type of business and organization respectively, the items are expected to be applicable mainly for CM in the head

office of a construction company. In contrast, *C5* to *C9* items are expected to be applicable with priority given to a construction site, as classifying the information related to the project management according to the process of a project. But in spite of this application, *C5* to *C9* items have difficulty in classifying directly information generated from the detailed tasks of CM because the classified items are too generally grouped by their concepts.

That is, the classified items in *C Management* are not sufficient to apply to information that comes from implementation of CM tasks with input/output information such as detailed task items and related documents. For example, although the item of *C722 Time Controls* can be used as a definition for the term, 'time management', it is difficult to use it for classifying the detailed tasks such as 'master scheduling' and 'evaluating project schedules' for the time management. Therefore, this study organizes a BBS for CM, including the detailed business items, on the basis of analysis of the detailed contents such as regulations and guides (CMAA, 1993; Fisk, 1980) related to the CM business.

The table of *A Form of Information* in Uniclass, classifying form of information, may be used in combination with the code items of other classification tables to indicate both form and subject of each information. Table 3 shows categories of *A* classification table.

TABLE 3: Table A of Uniclass (CPIC, 1997)

Code	Description
A1	General reference works
A2	Legislation, legal documents
A3	National and international standards
A4	Other rules, recommendations
A5	Standard specifications
A6	Standard contracts
A9	Types of medium

The code items of *A* table can be used in combination with the code items in *C Management* table and the classification tables for work breakdown structure. The WBS can consist of seven tables from *E Construction Entities* to *K Work Sections* in Uniclass. For example, *C505 Risk Analysis and Management: A18 Reports* means a code for representing risk analysis and management report, and *P22 Concrete, General: A5 Specifications* can be considered as a code for concrete standard specification.

Also, because *A* table includes classified items for the storing type of information, the item of *A9 Types of Medium* can represent in which type each information is stored through the combination of codes. For example, *C652 Working Drawing: A981 CD-ROM* represents the working drawing saved in CD-ROM. As above, the classification table for the form of information should be included in CM BBS for various type of information management. This study suggests a CM BBS considering the management of construction processes based on the analysis of existing CICSs.

3.3 Differences of BBS comparing with existing CICSs

In the background of the study, there is no any common and detailed code system for classifying CM tasks in the construction industry. Masterformat, Uniclass and CI/SfB systems are widely used as a construction information classification system (Kang and Paulson, 1998), however, they are focused on classifying a general construction information and a work breakdown information for the facilities, elements and operations on the construction site.

Though they have classification codes for CM tasks, the codes are just limited in the tasks for contract process or conceptual and basic management process as in Masterformat. And even if the codes for management tasks in Uniclass have more detailed codes, it is not easy to apply the codes to a practical construction project because it left out several tasks in the detailed level of CM. Those items give weight to theoretical and academic classification of project management field as shown in Table 2.

The BBS is not for integrating or updating the existing systems because the characteristics of classified items in BBS are different with those systems. Those systems are for general and overall information classification

systems for a construction project, however, the BBS is for classifying only management tasks for a construction project. Accordingly, the BBS is designed to manage the information generated from CM field, and it can be more effective for the classification of CM tasks to use the BBS rather than the existing systems, which are focused on overall construction work information including the detailed breakdown structure. The BBS is one of new classification system if the scope of information management is considered in only construction management field.

4. ORGANIZATION OF BBS FOR CM

4.1 Structure of BBS

The organized BBS for CM in the study consists in total of ten classification tables with two groups including the classification of information form, the classification for management subjects, and eight classification tables by the business for CM. Also, it includes an auxiliary code system for considering a construction phase and for representing a principal participant related to a CM business, such as owner, contractor, designer and construction manager (CMr).

The first group of the BBS has two tables such as *A Form of Information* for classifying the form and the storing medium of information and *B Management Subjects* as an all-inclusive classification for theory and general information of CM. Those tables in the first group can be used for controlling management information by a construction company unit rather than a project unit. The second group has eight classification tables by the business for CM such as *C Project Management*, *D Contract Management*, *E Time Management*, *F Progress Management*, *G Cost Management*, *H Resource Management*, *I Quality Management*, and *J Safety Management*. Accordingly, those tables in the second group can be used for controlling management information by each project unit. Fig. 1 schematizes the general applicability of the BBS with *A/J* tables and the auxiliary code systems proposed in this study.
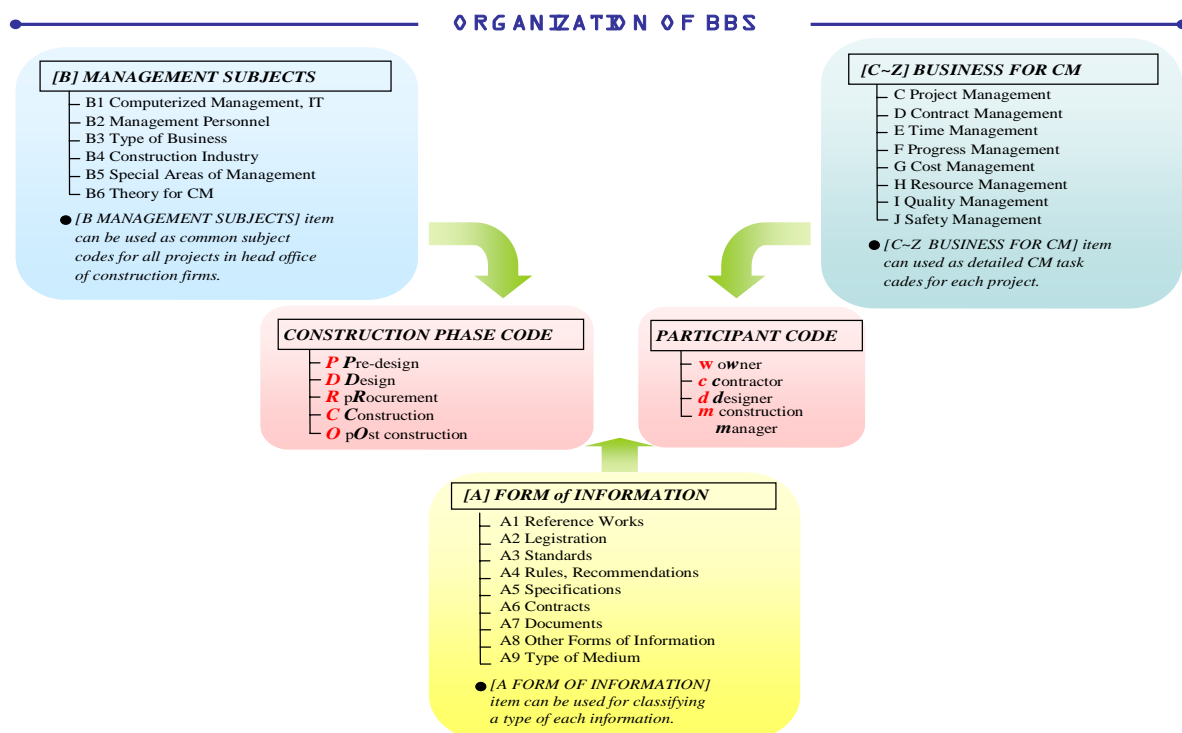

FIG. 1: Organization of all facets in BBS

4.2 Classification for Form of Information

The classification table for information form (Table 4) has similar codes and structure with *A Form of Information* of Uniclass (CPIC, 1997), but it reflects the actual conditions of construction information. Particularly, in comparison with the Uniclass *A* table, the detailed items in *A2*, *A3*, *A5* and *A6* were modified in priority. *A7* and *A8* items were also added to this classification table. This classification table was composed of two sublevels but Table 4 illustrates total categories in the first level and partial items in the second level. The classified items in Table 4 were organized for representing a kind of form of individual information and a storage medium of the information generated from CM tasks.

TABLE 4: Classification Codes for A Form of Information

A1 General reference works	A3 National and international standards	A7 Documents
A11 Dictionaries, encyclopedias	A31 National standards	A71 Official documents
1 Dictionaries	A32 Other national standards	A72 Private documents
2 Encyclopedias	A33 ISO standards	A73 Other documents
A12 Guides, directories	A34 Organization standards	A74 Work reports
1 Guides	1 Domestic organization standards	**A8 Other forms of information**
2 Directories	2 Other national and multinational	A81 Other forms of information
A13 Catalogues	organization standards	**A9 Types of medium**
A14 Surveys	3 International organization standards	A91 Books
A15 Statistics	A35 De facto standards	A92 Journals
A16 Price books	A39 Other standards	A93 Pamphlets, leaflets, unbound
A17 Learning materials, textbooks	**A4 Other rules, recommendations**	printed material
A18 Reports	**A5 Specifications**	A94 Drawings
A19 Other	A51 General specifications	A95 Photographic information
A2 Legislation, legal documents	A52 Special specifications	A96 Microfiche, microfilm
A21 Constitutional law	A53 Project specifications	A97 Video, films
A22 Legislation	A54 Explanatory documents	A98 Media accessed via a computer
A23 Ordinance	A55 Guides	1 Optical discs, CD-ROM,DVD
A24 Regulation	A56 Design drawings	2 Magnetic disks, floppy disks
A25 Rule	**A6 Contracts**	3 Magnetic tape
A26 International legislation	A61 Standard contracts	4 Online information, Internet information
A27 Judicial reports	A62 Government supply contracts	A99 Other special forms
A28 Patents, licenses, copyright	A63 Non-government supply contracts	1 Models
A29 Other legislation, legal documents		9 Other

4.3 Classification for Management Subjects

The classification table for *B Management Subjects* (Table 5, Table A in Appendix) is made up six categories labeled *B1* to *B6*. *B1* to *B4* items in *B* table have similar codes with *C1* to *C4* items in *C Management* of Uniclass (CPIC, 1997). Those categories were organized to classify information for general management subjects of a construction company. *B4 Construction Industry* is the classification for contractual relationship and participants in a construction project. Also, as *B6 Theory for CM* divides the disciplines of CM field into nine sub-items from *B61 Project Management* to *B69 Risk Management*, it is applicable to library classification related to the theories of CM. The classification table for management subjects suggested in Table 5 has two sublevels, but the classification items for more detailed sublevels may be added in practical applications. The detailed items for sub-level are classified in Table A of appendix.

TABLE 5: Classification Codes for B Management Subjects

B1 Management of computing information technology (IT)	B2 Management personnel	B4 Construction industry	B5 Specialist areas of management	B6 Theory for CM (subject disciplines)
B11 Computerized process of CM	B21 Top management, directors, partners	B41 Contractual relationship	B51 Management of office services	B61 Project management
B12 Business process reengineering (BPR)	B29 Other levels of management	B42 Contractual entities	B52 Marketing /selling	B62 Schedule management
B13 Concurrent engineering for construction project	**B3 Type of business/organization**	B43 Contractors	B53 Research and development	B63 Progress management B64 Cost management
B14 Hardware for computer application	B31 Organizations by scale and location	B44 Designers /consultants	B54 Finance and accounting, business economics	B65 Resource management
B15 Software for CM	B32 Private enterprises	B45 Management consultants		B66 Quality management
B16 Application of Internet	B33 Mixed enterprises and partnerships	B46 Services engineering designer/consultant	B55 Personnel management and industrial relations	B67 Safety management
B17 Electronic document management	B34 Government and related organizations	B47 Other technical consultants	B56 Equipment management	B68 Facility management B69 Risk management
B18 Electronic commerce system	B35 Public enterprises	B48 Legal/financial consultants	B57 Productivity management	
B19 Other construction IT	B36 Non-profit-making organizations, charities	B49 Manufacturers, suppliers, other		
	B37 Industrial and commercial associations			
	B39 Other types of organization			

4.4 Classification for CM business

The classification for CM business (Table 6, Table B in Appendix) is made up of eight main classification tables from *C Project Management* to *J Safety Management*. *C5* to *C9* items of Uniclass divide management tasks and required information into general classification items according to the process of a project. However, as in Table 6, this study proposes separate classification tables classified by eight management tasks such as project, contract, time, progress, cost, resource, quality, and safety managements.

TABLE 6: Classification Codes for Business of CM

C Project management	D Contract management	E Time management	F Progress management
C1 Feasibility study	D1 Bid management	E1 Schedule plan	F1 Monitoring schedule compliance
C2 Project organization	D2 Contract management	E2 Schedule management	F2 Earned value management
C3 Management information systems	D3 Submittals	E3 Suspension/resumption of work	F3 Historical data management
C4 Project meetings	D4 Claim/dispute management	E9 Other	F4 Delayed activity management
C5 Document management	D5 Modification procedures		F5 Time extensions
C6 Construction facilities and temporary controls	D6 Completion		F9 Other
C7 Risk management	D9 Other		
C9 Other			

The main categories in each table consist of the principal business by management task, and sublevels consist of detailed task items according to the each principal business. Table 6 covers two sublevels and partial items in

sublevels, but more detailed items may be added in practical applications. The detailed items for sub-level are classified in Table B of appendix.

4.5 Auxiliary code system

The proposed classification tables illustrate only part of the detailed items as a tentative classification system. In project management, various types of information could be repetitively produced with the similar type through the project life cycle. For example, information for a schedule network can be for a design schedule network in the design phase and for a construction schedule network in the construction phase. The same information items generated repetitively from each phase of a project, such as pre-design, design, procurement, construction, and post construction phases, were represented with a unified code to avoid an enormous code system. Accordingly, this study includes the codes for five construction phases as in Table 7, such as (P) Pre-design phase, (D) Design phase, (R) procuRement phase, (C) Construction phase, and (O) pOst construction phase, in order to discriminate the information generated repetitively according to the each phase of a project. Also, four participant codes, such as (w) owner, (c) contractor, (d) designer and (m) CMr, were added to represent the relationship of the participants for each type of information in a project. Table 7 shows an auxiliary code system and the organization of codes considering mnemonics.

TABLE 7: Auxiliary Code Systems

Construction phase codes	Participant codes
(P) *P*re-design	[w] o*w*ner
(D) *D*esign	[c] *c*ontractor
(R) p*R*ocurement	[d] *d*esigner
(C) *C*onstruction	[m] c*m*r
(O) p*O*st construction	

4.6 Description of requirements needed in BBS

The users of this system may be confused by some similar items. To prevent that, some additional requirements or descriptions of each table are described in this section. For example, *A2 Legislation* in Table 4 is classified with official legislations or legal documents published by a public institution or government. On the other hand, *A4 Other Rules* means a rule or a recommendation published by industry bodies, and *A71 Official Documents* includes an official notice and a government paper except for a kind of legislation. *B612 MIS* in Table 5 is for classifying documents information for general management information system (MIS) theory. In contrast, *B613 PMIS* item means MIS information for a professional construction project. That is, the library classification for MIS theory based on the management engineering is possible in *B612*, and the MIS tasks for project management on the construction site are classified in *B613*.

Generally, the information management has different characteristics by a target of management and the scope of application. Accordingly, because a class and a type of necessary information for the main office of a construction company are dissimilar with them of a project unit on the construction site, it may be helpful to keep the classification table separately for those two categories.

Though several items are repeated in Table 5 and Table 6, the requirements of the items in each table have different views in their application. The items in Table 5 can be used for classifying management subjects and references by the theoretical approach of construction management field. Accordingly those items are applicable to group or filter various materials, such as books, documents and construction reports, in a company head office. Also when the head office needs to systematically manage construction documents that are generated from many construction projects, project manager can file the information by management subjects such as *B62 Schedule Management* and *B64 Cost Management*. This information classified for the head office can be useful for a similar project in the future.

On the other hand, though Table 6 includes some similar items in Table 5, the items in Table 6 should use for a project unit on the construction site. Accordingly the *E/J* codes in Table 6 consist of detailed items for each management field of construction operations. If this requirement applies to Table 5 and Table 6, *B614 Contract Management* in Table 5 can be used for grouping documents information generated from the contract process of

all projects that are being progressed by the company. And *D Contract Management* in Table 6 can be used for classifying the detailed information related to the contract business with owner for a project that is being progressed on the construction site.

Considering that a construction main office needs to separately manage the summarized information from the detailed information based on each project unit, this approach for the requirements of various information will be helpful for standardizing and computerizing management tasks.

5. APPLICABILITY OF CM BBS

5.1 Applicability of A Form of Information

A Form of Information table is quite useful for confirming the form and the storage medium of individual information with the link to the *B/J* items within the BBS. That is, if this classification table is utilized for organizing a database of the integrated retrieval program for construction data, the organized database will make it possible to confirm which form the information has and to search information according to its form. Especially, if *A* classification table is used with its WBS code classified by work item, a *WBS code : A94* code can represent that it is a design drawing document for the work item of the WBS code.

Also, if a contractor needs the information for a judicial report related to a claim, it could be obtained by searching the code with *B6143 : A27*. Therefore, this classification table will make it easy to get the necessary materials by the form of information, such as *A18 Reports*, *A17 Textbooks*, *A27 Judicial Reports* and by the storing medium of information such as *A97 Video, Films* and *A984 Internet Information*.

5.2 Applicability of B Management Subjects

B Management Subjects table is composed of six categories. First, *B1 Management of Computing, Information Technology* can classify the information of materials for construction information technology, because recently the computer application including the Internet is rapidly spread throughout the construction industry. *B2 Management Personnel* makes it possible to classify and combine the information for each employee through the classification of management executives by their position. Also, *B3 Type of Business Organization* and *B4 Construction Industry* are applicable to the classification of the information about other organizations related to construction industry by the form of organization. In particular, because the *B4* code divides authorities and companies related to the construction industry according to their function, those codes may be useful to the organization of a database and the retrieval of information for construction companies. Classifying the general management tasks of a construction company by their functions, *B5 Specialist Areas of Management* can be applied to manage wholly the different information generated from each function. And *B6 Theory for CM* enables the application to the classification of a library and a document related to CM by subdividing CM theories into nine items according to their function.

5.3 Applicability of *C/J* classifications by each CM business

C/J classification tables by each CM business were developed to classify information generated from each project. In other words, the detailed codes of each classification table concern to the documents and the output materials needed in each CM task by a project unit. So those codes enable output materials from the construction site to distinguish by a task or a management field, such as project management, contract management, and time management. Accordingly, it is possible to confirm not only the source of each data item but also inversely the documents and data required according to the field of management and the substance of the individual task.

The individual tasks classified by the management field can be overlapped through the each project phase. Thus, in this study, those overlapping task items were not classified repeatedly by the each project phase in order to prevent the classification code system from becoming enormous. But those repetitive tasks can be distinguished in combination with five construction phase codes such as P, D, R, C, and O as shown in Table 7. For example, *(P) : C42* represents the progress meeting of the pre-design phase and *(D) : C42* is that of the design phase and *(C) : C42* is that of the construction phase. Also, the project participant subject codes of Table 7 can be used to distinguish a producer or a responsible person for the information with the link to the code in the CM BBS. For example, *I21 : c* code shows that the producer of a quality management plan is a contractor and *I412 : m* shows that an inspection report was written by CMr.

6. A PROTOTYPE OF WEB-BASED BBS SYSTEM FOR CM

In order to materialize the applicable method of the BBS for CM, this chapter suggests a prototype of web-based 'integrated construction information management system' (iCIMS) on the basis of the proposed classification tables in this study. The iCIMS can be a tool to synthetically collect and manage the information generated from both the head office and the construction site. That is, as a concept to integrate a MIS of a head office and a project management information system (PMIS) of a construction site unit, iCIMS enables remote clients to manage and retrieve the information from the head office or the construction site through the Internet. The script language for web design and the Java language may be used for a web-based program of construction schedule management. In addition, if software for representing a construction process diagram is linked to iCIMS, it is possible to show the input/control/output/mechanism (ICOM) of an information item by each construction process.

The prototype in the study is not a completely organized web site but an explanatory tool to demonstrate the necessity and applicability of CM BBS. It is explained by nine pictures for illustrating the main functions of the system. Fig. 2 ~ 8 illustrate PMIS by a project unit and Fig. 9 ~ 10 are examples of MIS for the head office.

6.1 For the link BBS with PMIS

Fig. 2 is the first screen of the prototype system. In the upper-left frame of the screen, a database that may be the PMIS for a project or the MIS for the head office should be selected according to the need of the manager. For the case where PMIS was chosen, Fig. 2 displays that a project currently in progress has connected to the relevant database. If a user knows the BBS code of a specific item, the information can be directly retrieved in the lower-left frame using its BBS code. But in opposite case, the user can search necessary information by clicking an appropriate classification item on the pull-down menu of the lower- right frame. The code system in the pull-down menu consists of the classification tables (*C/J*) by the applicable CM business to manage the information by a project unit. The user can select a code for A9 *Types of Medium* to distinguish the storage form of information and two auxiliary codes for representing a project phase and a participant subject. Fig. 2 shows that user has chosen *E Time Management* as a code for the CM business, *A984 Internet Information* as a storage medium code, and *(C) Construction Phase* and *(m) CMr* as codes for a project phase and a participant subject, respectively.

FIG. 2: Input Data of Basic Information for Construction Management

6.2 For the link BBS with CM process

Fig. 3 is the result of search menu chosen in Fig. 2. As user had chosen *E Time Management* as a BBS code, screen was connected immediately to BBS tree diagram for the *E* code. The upper-right and lower-right frames in Fig. 3 show diagrams for the time management process generated from IDEF (Integration Definition), which is one of typical software for drawing process diagrams. In the upper-left frame, the name of the chosen project can be confirmed, and then the user can select the information about the project phase for *E Time Management* task according to the five construction phases. If user clicks a classification code on the BBS tree diagram in the upper-right frame, the CM process diagram for the code appears in the lower-right frame.
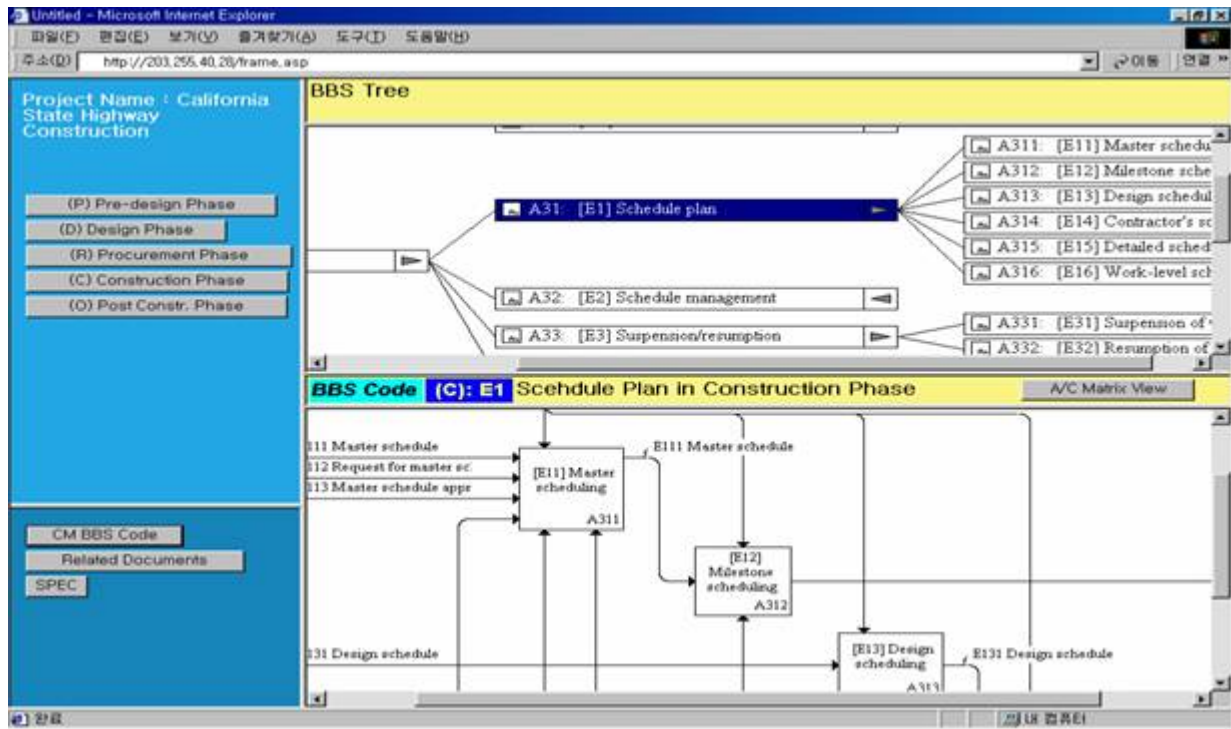

FIG. 3: Construction Process Diagram

Because Fig. 3 is a case of choosing *(C) Construction Phase* and *E1 Schedule Plan*, the lower-right frame displays the detailed processes for time management in the construction phase. If the user clicks the 'Activities/concepts (A/C) matrix view' menu item, the information matrix for representing ICOM materials of *E1* code will be shown as in Fig. 4.

Fig. 4 is the result of clicking the 'A/C matrix view' icon in the middle-right frame of Fig. 3. The frame represents the task items for the *(C) : E1 (m)* code, which a CM task is concerned for the schedule plan in the construction phase, and the ICOM information by each task item. If the user selects an output information item on the A/C matrix screen and clicks the 'document view' menu, the screen is connected to the picture where the user can draw up and transmit the relevant document.
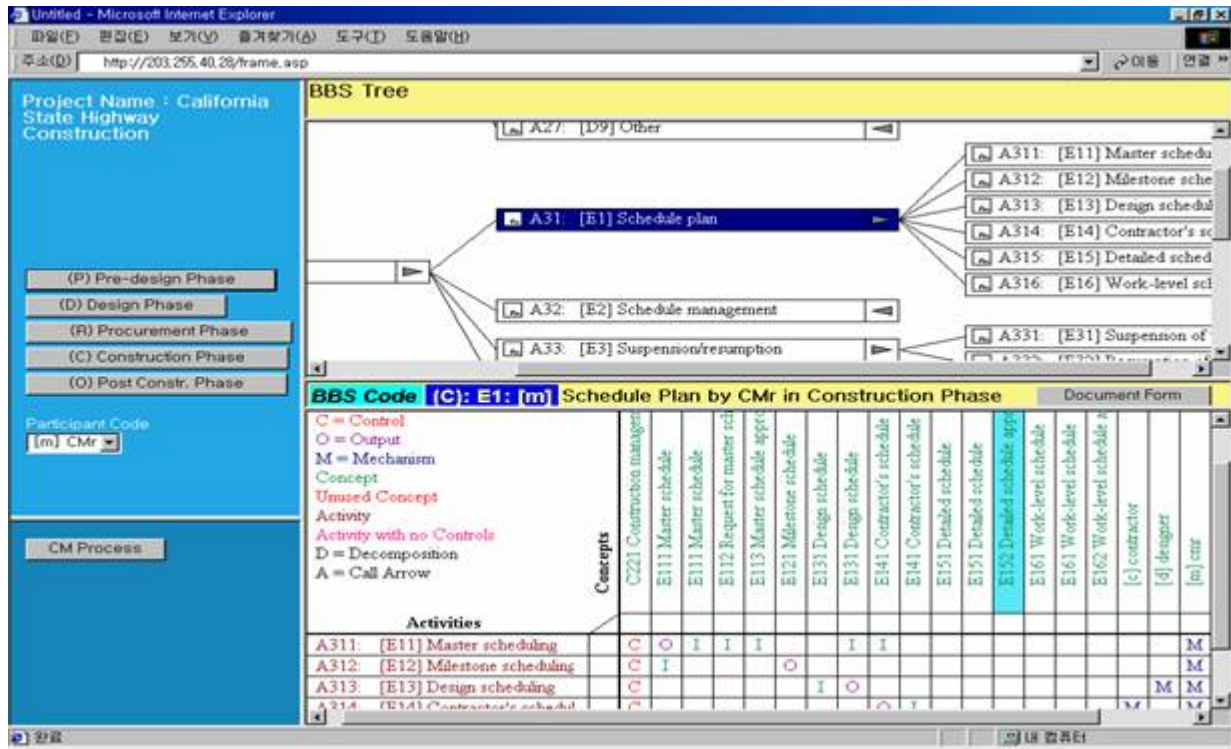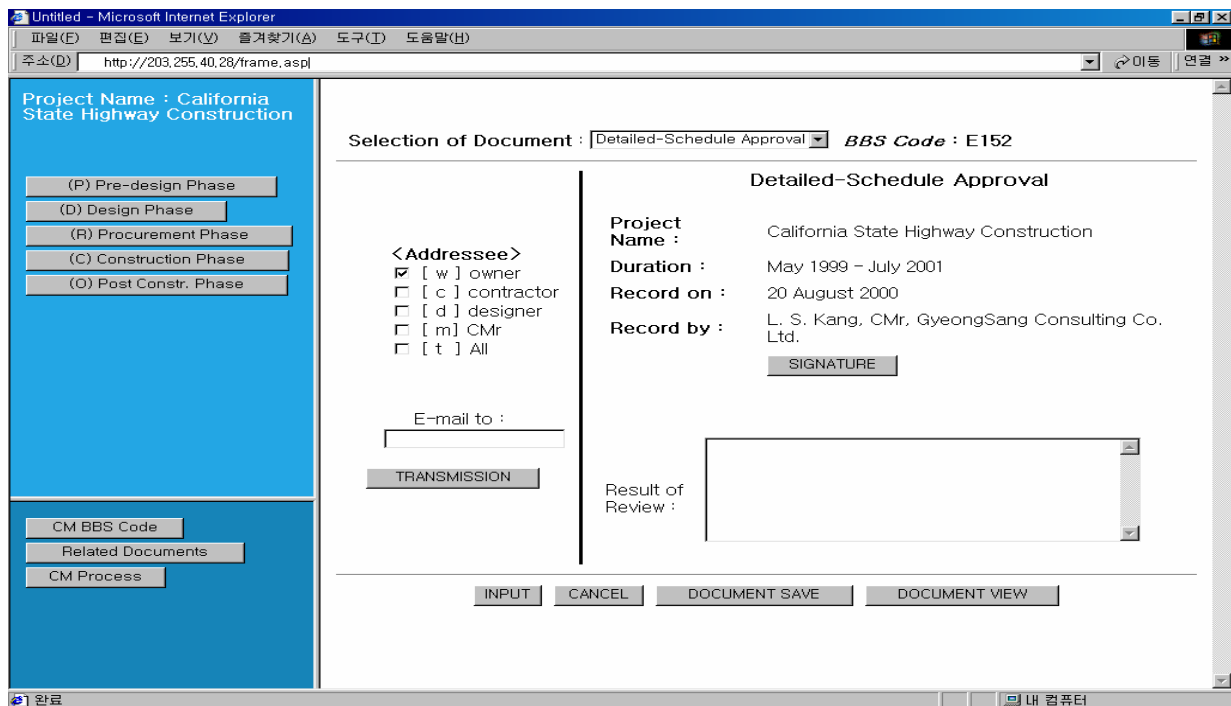
FIG. 4: Activity/Contents Matrix View

FIG. 5: Document for Detail-Schedule Approval

If the code of *E152 Detailed-schedule Approval* is selected in Fig. 4, the documents for the detailed-schedule approval connect with the item to forward them to an addressee as in Fig.5. As the result of clicking the 'SPEC' menu in the lower-left frame of Fig. 3 for displaying the related specification item, Fig. 6 connects regulations in the specification of the code *(C) : E1* for the schedule plan in the construction phase to the lower-right frame.
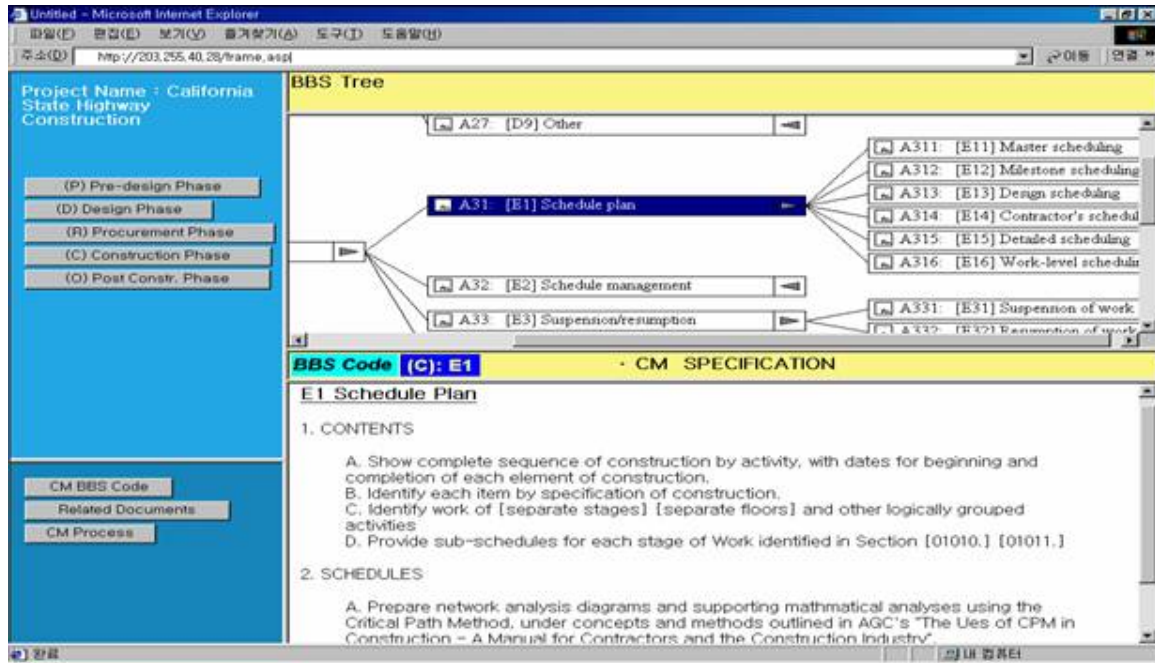
FIG. 6: Specification Code View by CM BBS Code

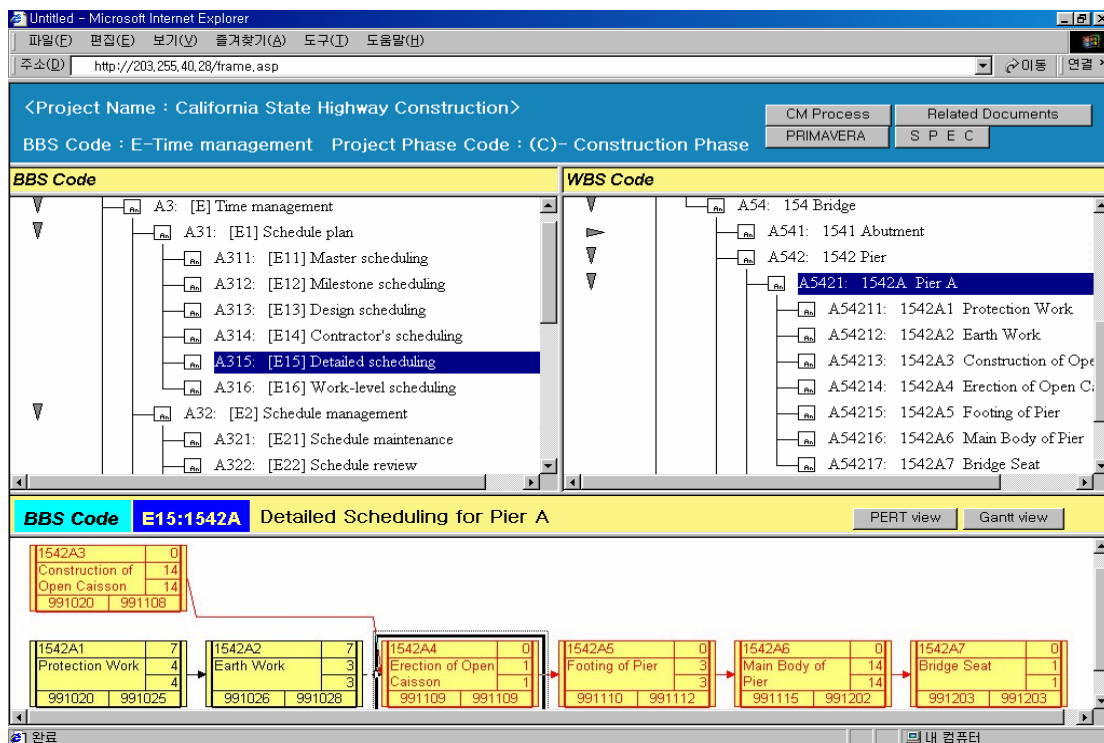## 6.3 For the link BBS with WBS

FIG. 7: Link of CM BBS Code with WBS Code

Fig. 7 is the result of choosing the 'CM BBS code' item in the lower-left frame of Fig. 3. In the case that the relevant BBS code is a task in the construction phase, the BBS code is automatically linked with the WBS code as in Fig. 7. This link makes it possible to get the information of the CM BBS according to the WBS level in the construction phase. In the example of the *E15 : 1542A* code, once the user selects *E15 Detailed Scheduling* as a BBS code and *1542A Pier A* as a WBS code, a detailed schedule network for *1542A Pier A* can be represented

by clicking 'PRIMAVERA' menu for the connection with the scheduling software. Consequently, Fig. 7 displays the detailed schedule network for the pier A to the lower frame.

Fig. 8 links a resource diagram for the pier A to the lower frame by selecting *H53 Resource Leveling* as a BBS code and *1542A Pier A* as a WBS code. The WBS code is for classifying a work item such as facility, element or work section, and the BBS code is for classifying management information of the work item. Accordingly, it is necessary to link the WBS code with the BBS code for an integrated information management between construction work information and management information.
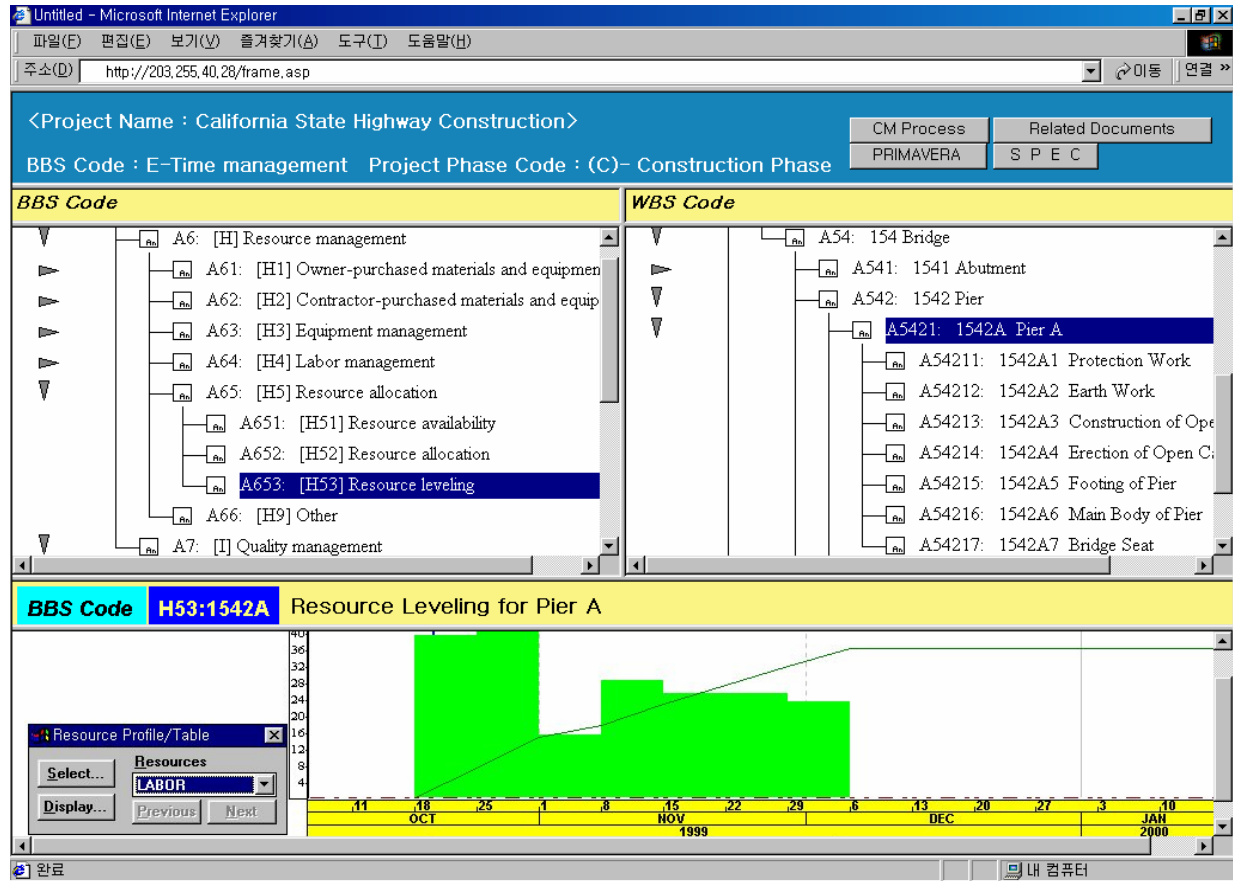

FIG. 8: Link of CM BBS Code with Schedule Management S/W

Fig. 7 and Fig. 8 illustrate an example to link the WBS code with the BBS code. By such an integration of two code systems, the construction operation information during the construction phase can be directly connected to the detailed CM tasks such as time scheduling and cost estimating. That is, an integrated code as in *H53 : 1542A* code of Fig. 8 can represent the resource leveling task for pier A work.

6.4 For the link BBS with MIS

As a case of choosing the MIS for the head office in Fig. 2, Fig. 9 enables a project manager in the head office to search general information by each BBS code based on the company unit. The MIS for a head office consists of the items, such as *B Management Subjects*, *A Form of Information* and *A9 Types of Medium*, to manage summarized information from each construction project as in Fig. 9.
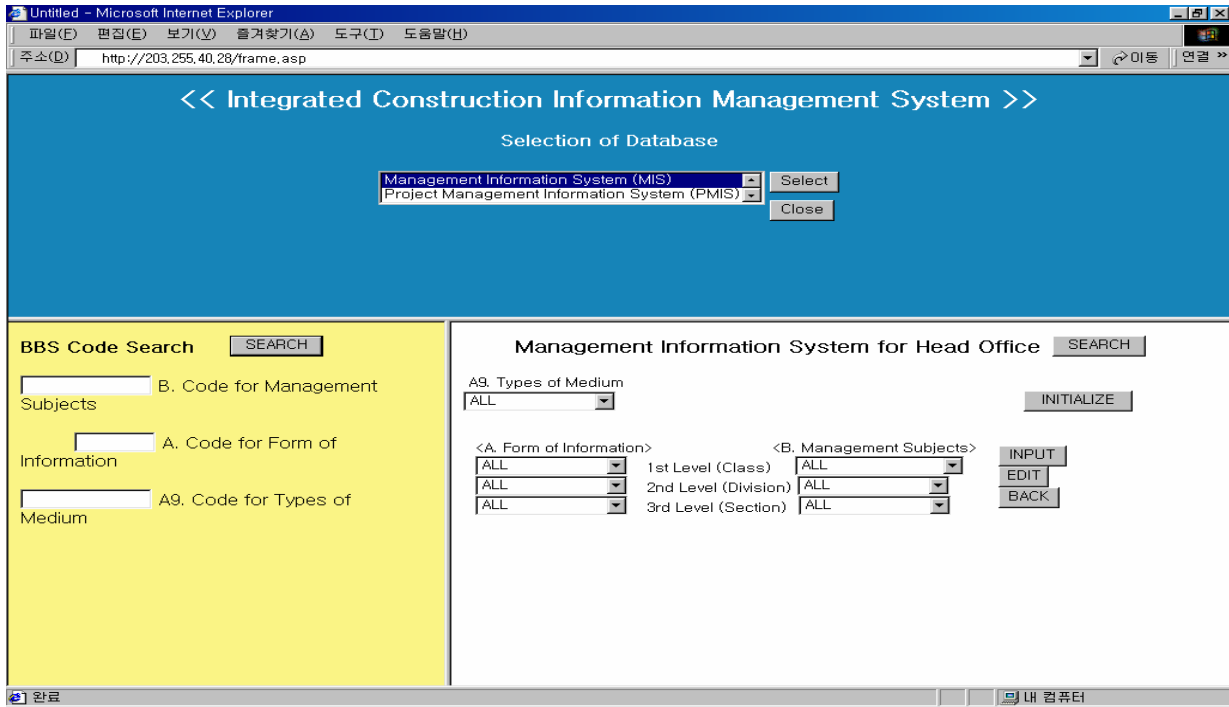
FIG. 9: Management Information System for Head Office

As the result of choosing 'All' for *A9 Types of Medium*, and *B641 LCC Analysis* for *B Management Subjects* in Fig. 9, Fig. 10 displays all the data related to life cycle cost (LCC) analysis. In Fig. 10, if the user chooses *A984 Internet Information* code for the type of medium, the screen can connect to the web page with relevant materials. And if *A94 Drawings* for the type of medium and *A31 National Standard* for the form of information in the BBS code, and *1542A Pier A* in the WBS code are selected in Fig. 9, the user can collect the national standard items with drawings for a bridge pier in Fig. 10.
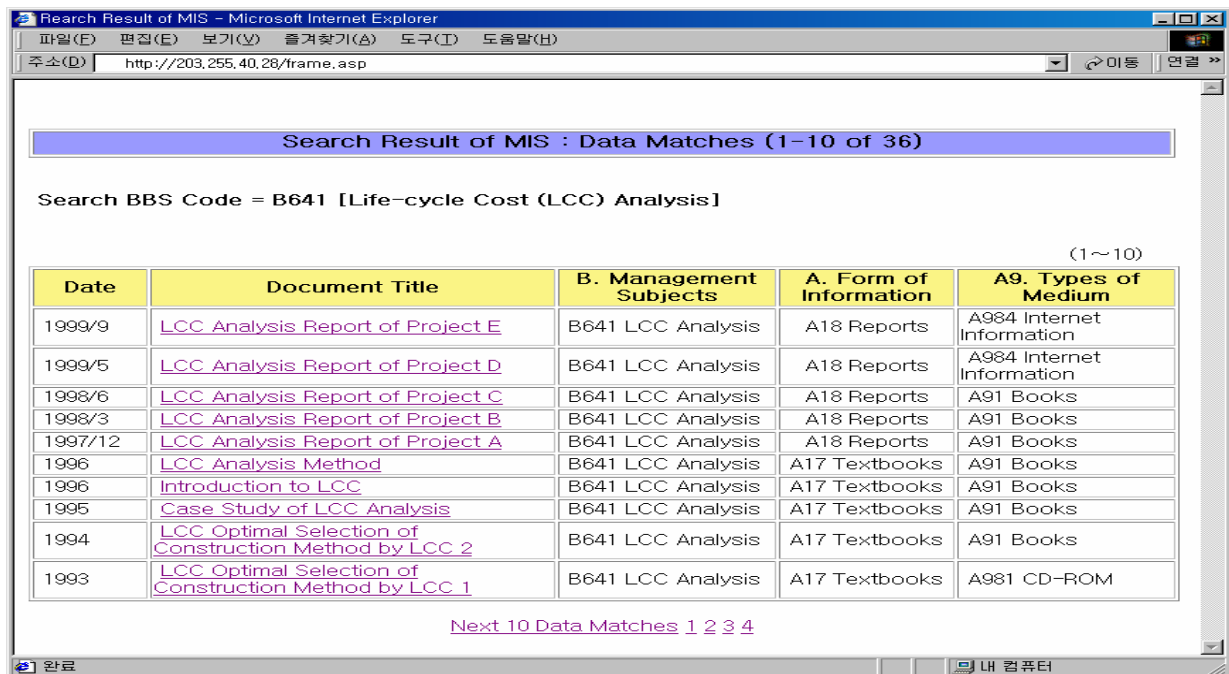

FIG. 10: Search Results of MIS

6.5 Examination of iCIMS

Since the study is focused on classifying each code of BBS and verifying the appropriateness of the organized structure of BBS, the computerized system using the Internet is introduced just to verify the applicability of an integrated code system between BBS and WBS codes. Recently several companies with an interest in electronic commerce system are developing document management systems based on the Internet. But those systems are literally limited on the document management and they are focused on the remote exchanging system of documents. Accordingly they are not a suitable system to link the BBS for management information with the WBS for construction work information because those systems work separately from the information classification system.

iCIMS, a web-based system suggested in the study, is a prototype to illustrate the applicability of BBS and the usefulness of construction information management by the link of BBS and WBS. A standardized information management system can be an especially useful tool when the construction project is executed by many kinds of participants. With the increasing opportunity for various construction consortia to work together on major projects, the BBS and iCIMS can be used as an information center of various management tasks that are progressed by several contractors. In those projects, the construction information throughout the project life cycle needs to be collected with a unified coding system like BBS to avoid overlapping a task among contractors. If an owner uses the BBS and iCIMS, it can be used for classifying detailed contract management tasks and for facilitating the ordering processes by a standardized classification system and a web-based system with the same coding system.

7. FUTURE WORKS - APPLICABILITY OF BBS AND WBS FOR 4D CAD SYSTEM

Recently various kinds of information technology (IT) tool are being introduced in the CM field. A systematic information management is one of prerequisite processes for developing a computerized CM system by using IT tools. 4D CAD system is a representative tool for visualizing construction schedule data. 4D CAD system for the construction management task is to visualize the completed appearance of 3D objects in drawings linked with construction schedule. Because 4D system includes schedule and drawings information, database of 4D system consists of various kinds of information. Accordingly, the successful information management in 4D system is an important factor to serve user's convenience and to simplify link environment between construction schedule and drawings. To make a 4D simulation object in current 4D systems, users should repeat link work for schedule and drawings data because those data are generated by activity code and drawings code respectively. And then those data need to be linked to simulate 4D object in additional link process (Kang, 2004).

iCIMS is a kind of web-based tool for managing construction project. If iCIMS includes a time scheduling function and it can be linked by 4D CAD system, the BBS and WBS codes will be a useful tool for integrating 4D object in 4D database. That is, if there is a common code system that can be used in both schedule and drawings data, such as a standard WBS, in 4D system, the link process can be simplified, because all data in 4D system is generated by a common WBS code. BBS code can also support to classify the CM outputs from 4D simulation by information type or management subject. This study proposes a standard code system as WBS to be stored as a library file within 4D system in advance and all functionalities of the 4D system to be operated in reference to the common code in the library. To configure schedule information in schedule management module, schedule data is created directly in reference to the pre-defined WBS code and activity list.

In terms of drawings data configuration, too, drawings object data corresponding to system-provided WBS codes are stored in advance. As both schedule and drawings data are stored in reference to common WBS codes, they are mapped to each other automatically in 4D simulation. Fig. 11 shows data interface scheme utilizing common WBS code.
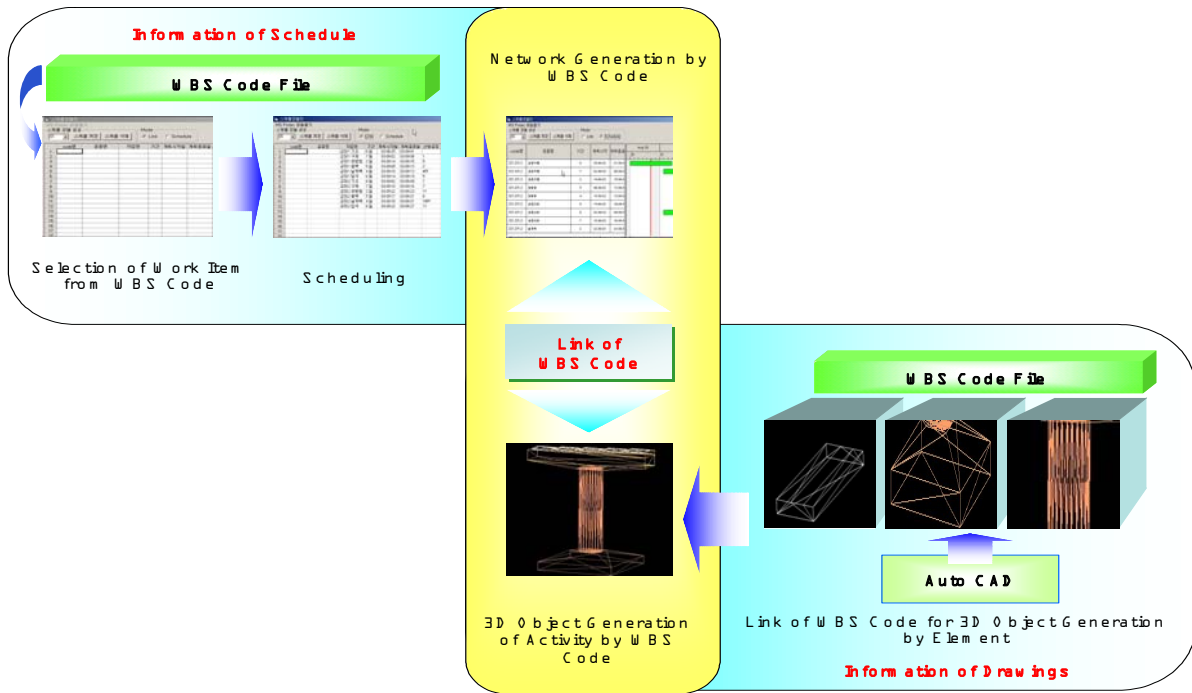
FIG. 11: Integrated Information Management in 4D Link Procedure by Using Common WBS Code

The bottom line functionality of 4D system is to simulate planned vs actual progress of construction facilities in 3D by interfacing construction schedule and drawings data. A proper code structure that can be used to manage such data is necessary for systematic information management and it could be an information center in 4D database. Utilizing WBS as an information center can improve usability of 4D system functions to a great extent. For example, 4D simulation can be performed at various levels from element level consisting of operations to space level consisting of elements or facility level, according to code level hierarchy of WBS. Namely, as described in Fig. 12, schedule data can be mapped to individual WBS codes and to which corresponding 3D objects are mapped as well. As this enables 4D simulation aligned to a specific user needs by classifying work size per management level, construction schedule management function of 4D system can be greatly enhanced.
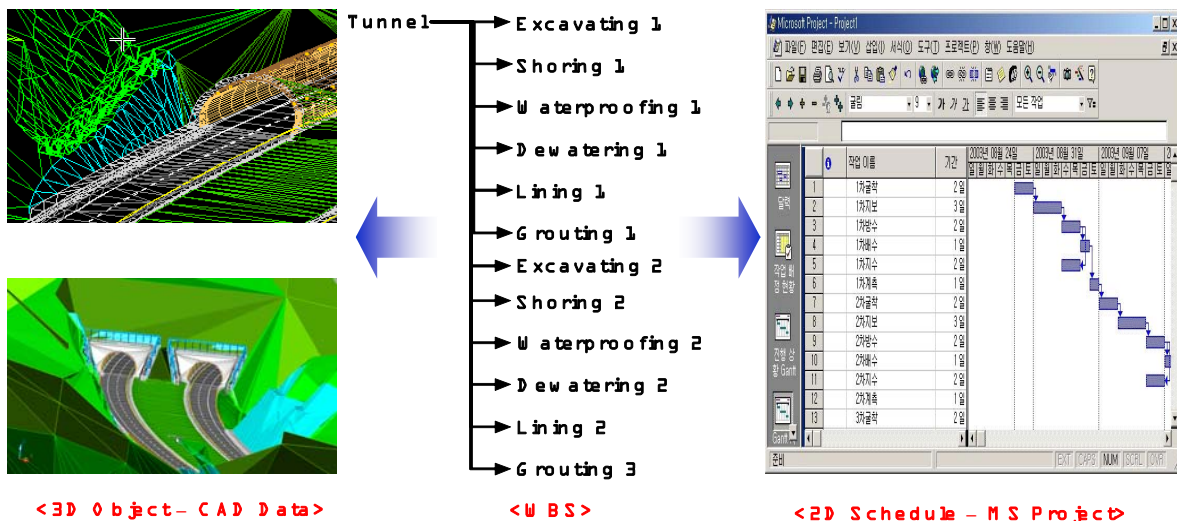

FIG. 12: Mapping Between Schedule Data and 3D Object by WBS Code

This study suggests a possibility for the future study that BBS and WBS are used as an information center for all inputs and outputs of 4D system. Considering that both BBS and WBS are classification code systems for

representing information in CM fields including time scheduling function and that 4D system is one of typical tools for visualizing CM outputs, the link of BBS and WBS with 4D database can be an available tool to improve 4D functions. If BBS and WBS codes are used for a common information code, all discrete functions of 4D systems can be referenced to the code as their key fields so that all data stored in 4D system could be managed per activity level. This new approach is worth continuing research for improving performance of current 4D systems significantly.

8. CONCLUSIONS

Considering that the characteristics of administrative information are different with them of construction work information and that it is difficult to apply a special classification system for the detailed CM tasks in the construction industry, the BBS suggested in the study can be a new approach for classifying CM information.

Because the classification items in the *A Form of Information* table can be used for classifying relevant information according to its form and type of storage medium, the classified items can be applicable to construction CALS (continuous acquisition and life-cycle support) including an electronic documents exchange system. Eight classification subjects according to the function of management task, as in the classification for CM business, have applicability in processing and searching data generated from the construction site by a project unit. Also, the combination with two kinds of auxiliary code systems enables the BBS system to have structural simplicity and clear mnemonics in the code system.

The practical applicability of the study is verified by demonstrating an applicable methodology of the BBS with a prototype web-based system. The iCIMS proposes an integrated method, between BBS and WBS codes, for connecting the work information generated from the each construction site with the management information of the work. In such a system, it makes possible management tasks in each process to be directly linked to the documents information needed at the tasks. And various management information produced from schedule and cost management tasks can be directly connected with each element or operation in WBS. Those functions enable a project manager to integrate the process or schedule information with the construction work information and to improve the efficiency of construction document management.

In line with the recent trend of IT tool application in construction industry, most large construction projects are controlled by a project management information system (PMIS). The recent PMIS needs a real time function and a web-based management function as in the iCIMS. It is necessary to use a systematic information classification system such as BBS and WBS for the PMIS with those functions. 4D CAD aided schedule control tools are being developed by several organizations and 4D system is expected to be an up-to-date tool for transformation of numeric schedule data into visual information. However, usability and applicability of 4D system is greatly influenced by 4D engine configuration and efficiency of internal data management. While improved system configuration approaches to address such issues are in great demand, this research proposed a new approach to enhancing 4D information management by BBS and WBS codes that can be used as an information center.

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APPENDIX. DETAILED CLASSIFICATION TABLES FOR BBS

TABLE A: Classification Codes for B Management Subjects

B1 to B4 Items	B4 Items (*continued*)	B5 Items	B6 to B9 Items
B1 Management of computing, information technology (IT)	B42 Contractual entities 1 Owner	**B5 Specialist areas of management**	**B6 Theory for CM (subject disciplines)**

B11 Computerized process of CM	2 Contractors
	  3 Subcontractors
		B51 Management of office services	B61 Project management
			  1 Feasibility study

B12 Business process reengineering (BPR)	B43 Contractors
	  1 General contractors
		1 Switchboard services
		  2 Reception services
			2 Management information system (MIS)

B13 Concurrent engineering for construction project	2 Specialty contractors B44 Designers/consultants	3 Commissionaire, security services	3 Project management information system (PMIS)

B14 Hardware for computer application	1 Civil/structural
	  2 Architectural
		4 Secretarial services
		  5 Mail management
			4 Contract management
			    1 Types of contract

B15 Software for CM	3 Landscape	6 Reprography	2 Bid management
B16 Application of Internet	4 Plant	7 Records management	3 Claim
B17 Electronic document management	9 Other B45 Management	9 Other B52 Marketing, selling	4 Dispute 5 Tender
B18 Electronic commerce system	consultants	1 General marketing activities	9 Other

B19 Other construction IT	1 Project managers
	  2 Construction managers
		2 Marketing concepts and systems	B62 Schedule management
			  1 Critical path method

	9 Other	3 Promotion	2 Program evaluation and review technique (PERT)
B2 Management personnel	B46 Services engineering	4 Sales management	3 Line of balance (LOB)
B21 Top management, directors, partners	Designers/consultants	5 Social marketing	4 Graphic evaluation and review technique (GERT)
1 President	1 Electrical engineers	6 International marketing	9 Other
2 Chairman	2 Telecommunications engineers	7 Marketing by type of product	B63 Progress management
3 Chief executive	3 Mechanical engineers	B53 Research and development	1 Progress analysis
4 Managing director	4 Public health engineers	1 Research	2 Earned value management (EVM)
5 Partner	5 Acoustic engineers	2 Testing	
6 Other executive director	9 Other	3 Development	9 Other
7 Non-executive director	B47 Other technical consultants	4 Results of research	B64 Cost management
B29 Other levels of management	1 Town and country planners	B54 Finance and accounting, business economics	1 Life-cycle cost (LCC)
B3 Type of business/organization	2 Building control officers	1 Financial world	2 Value engineering (VE)
B31 Organizations by scale and location	3 Geographic information system (GIS) engineers and land surveyors	2 Financial management	3 Cash flow analysis
1 International		3 Accounting, auditing	4 Trade-off study
2 Multinational		4 Business economics	5 Quantity surveying
3 National		B55 Personnel management and industrial relations	9 Other
4 Regional organizations	4 Quantity surveyors, cost engineers	1 Personnel management theory and systems	B65 Resource management 1 Resource allocation
5 Local organizations			2 Resource levelling
B32 Private enterprises			9 Other
B33 Mixed enterprises and	5 Health/safety/		B66 Quality management

partnerships	environmental consultants	2 Recruitment and selection	1 Quality planning
B34 Government and related organizations	6 Transportation planners	3 Training	2 Total quality management (TQM)
B35 Public enterprises	7 Design audit consultants	4 Employee communication	3 Quality control
B36 Non-profit-making organizations, charities	9 Other	5 Industrial relations	4 Quality assurance
B37 Industrial and commercial associations	B48 Legal/financial consultants	6 Conditions of employment	9 Other
B39 Other types of organization	1 Legal consultants	7 Remuneration	B67 Safety management
	2 Financial consultants	8 Working conditions, nature of work	1 Safety planning
B4 Construction industry	3 Insurance consultants	9 Other personnel management issues	9 Other
B41 Contractual relationship	4 Other	B56 Equipment management	B68 Facility management
1 Conventional lump sum contract	B49 Manufacturers, suppliers, other	B57 Productivity management	B69 Risk management
2 Design and build	1 Manufacturers		1 Risk analysis
3 Consulting contract	2 Distributors		2 Risk management
4 Consulting and build	3 Importers		3 Risk breakdown structure
	4 Other		

TABLE B: Classification Codes for Business of CM

C Project management	**D Contract management**	**E Time management**	**F Progress management**
C1 Feasibility study	**D1 Bid management**	**E1 Schedule plan**	**F1 Monitoring schedule compliance**
C11 Benefit analysis	D11 Invitation to bid	E11 Master scheduling	F11 Progress rate analysis
C12 Financial review	D12 Advertisement for bids	1 Master schedule	1 Construction progress "S" curve
C13 Appraisals	D13 Pre-qualification	2 Request for master schedule acceptance	2 Progress rate analysis report
C14 Surveys and structural implications of site	1 Pre-qualification forms	3 Master schedule approval	
C15 Energy strategies	D14 Instructions to bidders	E12 Milestone scheduling	F12 Progress record
C2 Project organization	D15 Bidding	1 Milestone schedule	1 Inspector's daily record of work progress
C21 Project team organization	1 Bid forms	E13 Design scheduling	2 Inspector's weekly progress report
C22 Construction management plan	2 Supplements to bid forms	E14 Contractor's scheduling	F13 Estimated vs. actual
C23 Project process manual	D16 Bid evaluation	1 Contractor's schedule	
C24 Staffing plan	D17 Negotiation	E15 Detailed scheduling	
C3 Management information systems	**D2 Contract management**	1 Detailed schedule	**F2 Earned value management**
C31 PMIS	D21 Contract	2 Detailed schedule approval	F21 Based on cost
C32 Electronic MIS	1 Notice of award	E16 Work-level scheduling	F22 Based on work-done value
C4 Project meetings	2 Agreement forms	1 Work-level schedule	F23 C/SCSC analysis
C41 Conference	3 General conditions	2 Work-level schedule approval	
C42 Progress meeting	4 Supplementary conditions		**F3 Historical data management**
C43 Regular meeting	5 Addenda		
	6 Notice to proceed		
	D22 Summary of work		

C44 Special meeting	D23 Contract closeout	**E2 Schedule management**	**F4 Delayed activity management**
C5 Document management	**D3 Submittals**	E21 Schedule maintenance	F41 Analysis of delayed activities
C51 Document control system	D31 Permits, bonds, insurance	1 Schedule maintenance report	F42 Recovery schedules
C52 Document distribution	D32 Shop drawings	E22 Schedule review	1 Remaining schedule review
C53 Record management	D33 Submittal management	E23 Float	2 Recovery program
1 Daily work report	1 Submittal log	E24 Schedule of values	
2 Progress photo	D39 Other submittals	E25 Schedule revision	**F5 Time extensions**
3 Record drawings	**D4 Claim/dispute management**	1 Revised schedule	F51 Time extension request
4 Record keeping	**D5 Modification procedures**		1 Construction time extension reason and recommendations
9 Other	D51 Change Orders	**E3 Suspension/resumption of work**	F52 Time impact analysis
C6 Construction facilities and temporary controls	D52 Instructions	E31 Suspension of work	1 Time impact analysis report
C61 Site mobilization	D53 Field orders	1 Notice of suspension of work	F53 Time impact evaluation
C62 Utilization plan	D54 Directives	E32 Resumption of work	**F9 Other**
C63 Environmental considerations	**D6 Completion**	1 Notice of resumption of work	
C64 On-site facility plan	D61 Beneficial occupancy	**E9 Other**	
C7 Risk management	D62 Substantial completion		
C71 Risk evaluation	D63 Final completion		
C72 Assignment of risk	**D9 Other**		
C9 Other			