Engineering Information Classification System

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Abstract: A good information classification and coding system is of great advantage to management. However, until now there has been no such a system for engineering management. MasterFormat is widely accepted as a construction information system but is not applicable to engineering work. This paper presents an engineering information classification system for engineering management that has a faceted and hierarchical structure that can flexibly classify information from facility to resource levels, such as construction information classification systems. The six digit coding system for products and functional tasks assists in project cost data collection and schedule planning. A design project was used as an example; the application can be broadened to incorporate the profit center practice and align a consulting firm's business strategy.

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Introduction

Knowledge work demands better information management in terms of data needs, collection, and analysis as well as information transfer and interpretation. The numerical or alphanumeric designations of work items can simply convey work information and knowledge and store them in a database. A good classification and coding system will provide planning and feedback information for better project or organization decision making.

Engineering work is one kind of knowledge work. In construction, MasterFormat (CSI 1995) is widely used as an information classification system (ICS) but is not applicable to engineering work. Until now there has been no ICS or coding system for engineering work, which perhaps is less tangible and more difficult to categorize and standardize than construction operations.

Kang and Paulson (1997) suggested a construction information classification system (CICS) with five facets of classification, including facility, space, element, operation, and resource. Rad (1999) showed three bases for the work breakdown structure (WBS): deliverable oriented, schedule oriented, and resource oriented. Hanlon and Sanvido (1995) established a construction information model to classify constructability information and facilitate improvement of processes and products.

This paper establishes an engineering information classification system (EICS) for engineering work. Engineering design has a high level influence on construction project performance. From the starting point of the supply chain, it is also necessary to develop an EICS to facilitate information sharing throughout the planning, design, construction, and maintenance phases of a construction project.

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EICS

To achieve a fit between the designed EICS and the project situation and thus achieve better results (Miles and Snow 1994), this study adopts a systematic process by considering the work unit, WBS, and coding. The developed EICS is shown in Fig. 1. At the top, the EICS divides engineering information into two units: the market unit, which includes three levels of the EICS as a WBS: construction type, life cycle, and product or service, and the process unit, which contains the function and task levels: The six digit coding system allows individual users to specify the project number. The design theories are explained in the next section.

Work Units

Designing an information system requires an understanding of work grouping, which can refer to organizational design theories. The basic building block for organizational design is the clustering of related work activity in a work unit (Tatum 1986); individuals are then grouped into work units to perform specific tasks.

There are two basic types of work units, as shown in Fig. 2: work process and market (Simons 2000). Function is the most basic organizational component in the work process unit. Effi-

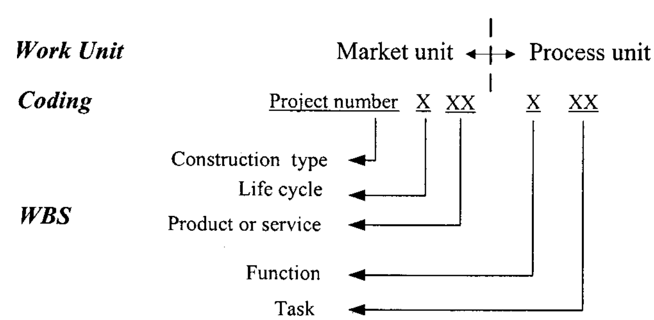

Fig. 1. EICS

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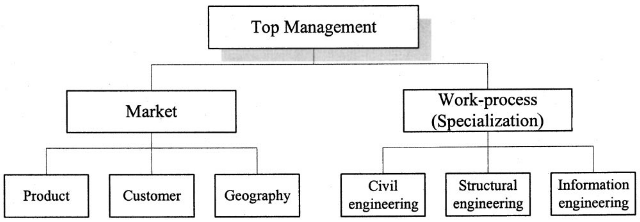

Fig. 2. Two types of work units

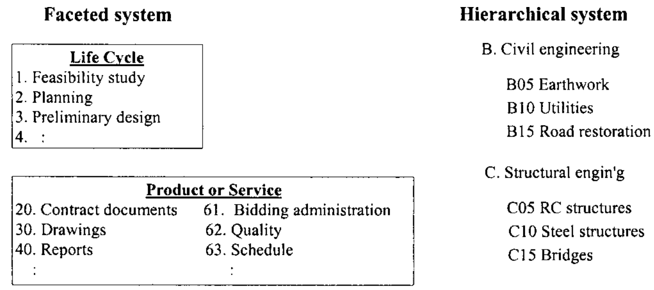

Fig. 4. Combining two systems to classify information

ciencies can be gained by specialization in the function (Mintzberg 1979). Market-focused work units are normally clustered by product, customer, or geography. Firms choose to organize by product for creating economies of scale or scope or by increasing return on management (Simons 2000). Since engineering jobs usually belong to a work process unit, the market concept is less familiar to engineers.

These two units suggest complementary views of the engineering product and process. The market unit perspective coincides with the way owners or users look at design: the functional tasks are components that a designer incorporates into the work of an engineering project. This arrangement is similar to MasterFormat, which includes construction products and activities (CSI 1995).

The sequence of the two EICS units follows the theory of work-unit design. The theory indicates that any firm, whatever its structure, is a market-focused entity when taken as a whole. At the lowest organizational level, all activities are grouped by function to allow specialization (Tatum 1986); that is, the upper work units are market focused, and the lower work units are work process focused.

EICS as Work Breakdown Structure

The EICS is a kind of work breakdown structure (WBS), of which Fig. 3 is an example. A WBS is the logical method for dividing a project into small, manageable components and always focuses on a product or process (Mansuy 1991). The upper-level items are generally the final products, such as reports, and the lower-level items are functional tasks to complete the products, such as drainage analysis. When using a deliverable-oriented WBS that arranges activities at lower levels, an analysis of the project's schedule and cost would be more meaningful (Rad 1999). The EICS has been designed with the idea, as can be seen in Fig. 3, that tasks are at the lowest level.

There are three bases for a WBS: deliverable oriented, schedule oriented, and resource oriented (Rad 1999). A WBS could have several bases if needed. In this study, the EICS combines the three bases to classify all information about the engineering work. The three orientations correspond to an engineering project's output, process, and input. The EICS's product level is derived from a deliverable WBS, the task at the lowest level can be schedule oriented, and the function (plus man-hours) corresponds to the resource. With the three orientations built into the EICS, information collected can display different perspectives, and management control can be exerted at the output, process, or input stage (Merchant 1982).

Coding System

After the WBS defines the work content, it needs a coding system to make the information classification complete. A coding system is a powerful tool for information filing and retrieval. An ICS should be capable of linking to any product classification or coding system; this flexibility will ensure usefulness in any discipline (Hanlon and Sanvido 1995).

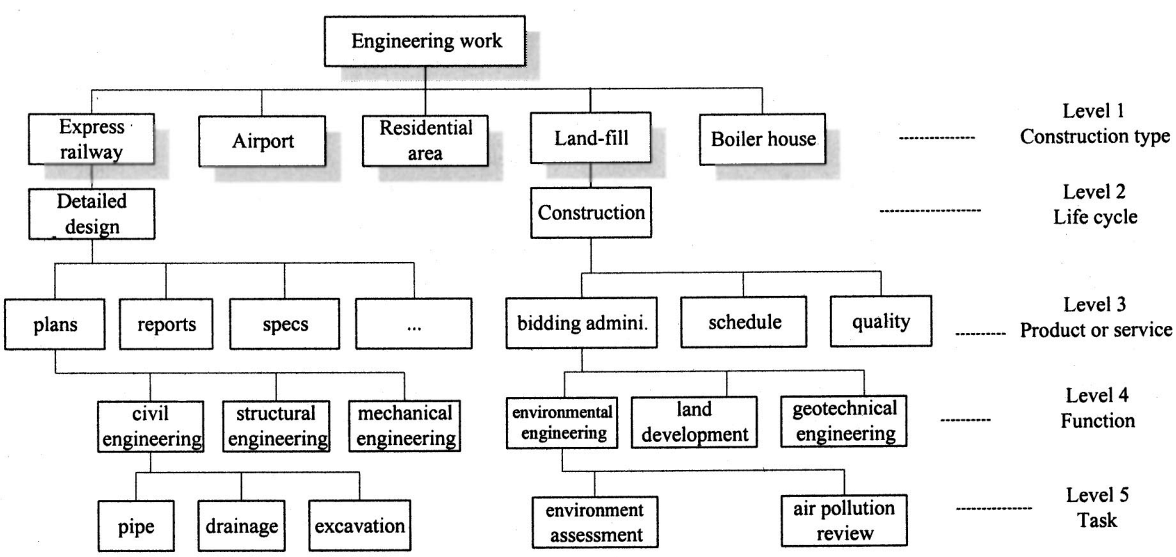

Fig. 3. WBS of EICS

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Table 1. Life Cycle Category

Category	Description
1. Life cycle	Feasibility study, planning, preliminary design, detailed design, construction, decommission, etc.

The coding system of EICS includes six digits: the first three digits address the market unit, and the second three denote the technical elements. All digits use decimal numbers except the function (or fourth) digit, which is a letter of the alphabet.

A project number will be given at the beginning of an engineering project and will include the engineering project's construction type. Since a construction type is often project specific and already implied in the project number, it does not take any digits in the EICS coding system. Incorporating construction type into the EICS will enhance the linkage with a CICS to become an integrated ICS.

Generally the structure of information classification is made up of hierarchical or faceted systems (Kang and Paulson 1998). A hierarchical structure fixes upper-level items with lower-level items. This arrangement links an upper-level item with its lower-level items easily, but the lower-level items have to be identified for all upper-level items in advance. In contrast, a faceted structure allows flexibility, in which an upper-level item may choose its lower-level items. But this choice needs judgment on the linkage between levels.

The products or services of most engineering work are usually similar, such as reports or site supervision. If a classification scheme has a hierarchical structure, the scheme must contain a large number of similar items to be classified repeatedly by different engineering projects. While a faceted system would be desirable for engineering work, it may comprise too many facets; thus, this research combines hierarchical and faceted coding structures.

The EICS adopts a combined system for consulting work that includes planning, design, site supervision, and construction management projects and takes advantage of the faceted structure to obtain a better class of products and services. On the other hand, the classification scheme of functional tasks has a hierarchical structure. Each function will have its own tasks; that is, tasks are not independent of their functions. Fig. 4 shows the combined systems incorporating four level categories.

The categories helping the coding system for the four levels are searched and shown in Tables 1 to 4. The life cycle in Table 1 consists of a construction project's phases from feasibility study to decommission. The product category in Table 2 includes contract documents, drawings, reports, and so forth, and each category contains more detailed deliverables. In Table 3, consultants also provide services other than products through management and construction supervision types of projects; each type has its service areas. Finally, in Table 4 the technical activities are performed within various functions and tasks. Function refers to engineering disciplines, and the tasks under each function can be identified with a certain degree of detail.

Fig. 5 shows two examples of how to use the coding system. For a certain facility, preparing a utility report on a preliminary design can be coded as 340B15, while the 561C00 code means bidding for an administration service performed as structural engineering during the construction stage.

Table 2. Product Category

Category	Description
20. Contract documents	Conditions of contract, specifications, construction methods, schedules, etc.
30. Drawings	Design drawings, construction drawings, as-built drawings, etc.
40. Reports	Alternative study, maintenance report, monthly report, etc.
50. Calculations	Analysis calculations, quantity calculations, cost estimates, etc.
60. Others	License, user's manual, etc.

Table 3. Service Category

Management type projects	Construction supervision projects
61. Bidding administration	71. Construction techniques
62. Quality	72. Construction administration
63. Cost/financial	73. Safety and environmental protection
64. Schedule	74. Design change handling
65. Technical support	75. Contract dispute handling
66. Implementation management	

Table 4. Function and Task Categories

Function	Task
A. Administration	Personnel, accounting, procurement, etc.
B. Civil engineering	Earthwork, utilities, road restoration, etc.
C. Structural engineering	RC structures, steel structures, bridges, etc.
D. Geotechnical engineering	Foundation, piling, dewatering, etc.
P. Electrical engineering	Power system, illumination, weak power, etc.

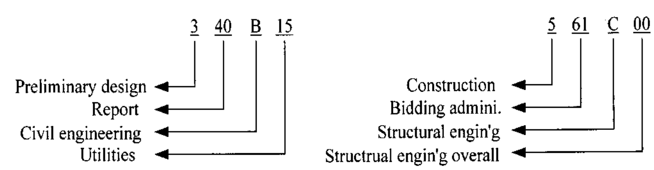

Fig. 5. Two coding examples

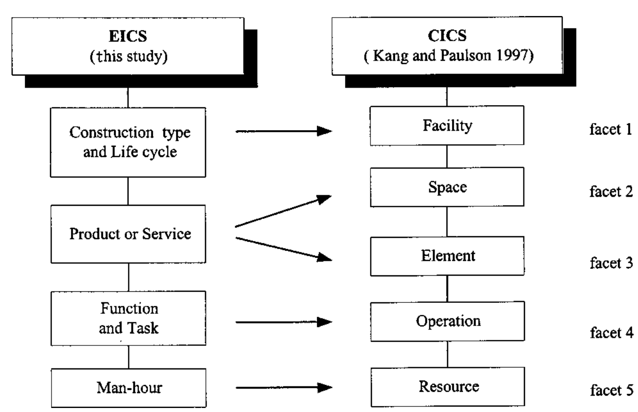

Fig. 6. EICS compared to CICS

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Table 5. Comparison of Three ICSs

Function	MasterFormat	CICS (Kang and Paulson 1997)	EICS
Structure	Hierarchy	Facet	Facet and Hierarchy
Notation	Decimal system	Mixed system	Mixed system
Classes	16 divisions	Five facets	Four facets
Level of classification	Four levels	Facility, space, element, operation, and resource	Life cycle, product or service, function, task, and man-hour
Application of system	Applicable to construction works	Applicable to civil works	Applicable to engineering work

Relationship with CICS

MasterFormat is widely used as a CICS by the construction industry (CSI 1995). Trying to overcome some information classification difficulty associated with MasterFormat, Kang and Paulson (1997) proposed a CICS with five facets: facility, space, element, operation, and resource. EICS is compared with CICS and MasterFormat in the next section.

Comparing EICS with CICS

It is meaningful to compare an engineering ICS to a construction ICS (Fig. 6). Eventually all engineering work involves constructing, modifying, or maintaining a facility. The construction type and life cycle in the EICS are implied at the facility level in the CICS. The engineering-generated products or services are prepared for a facility, but they are neither independent nor final results. This characteristics is similar to those of space and element in relation to the facility. Functions and tasks of engineering work correspond to construction operations. When allocated to tasks, the man-hour is the major resource for engineering work, but is only one of the resources in construction.

Comparing Three ICSs

Three ICSs are compared in Table 5, in terms of structure, notation, classes, level of classification, and application. MasterFormat uses a hierarchical coding structure and decimal system; it consists of 16 divisions and four levels. The CICS suggested by Kang and Paulson (1997) uses a five-facet system with a mixed notation. For notation, a mixed system is made up of a numeral and a letter of alphabet. Both CICSs are applicable to construction work. The EICS is quite compatible with the other two systems in structure, notation, class, and levels, as shown in Table 5; it has great potential to be linked to the CICS.

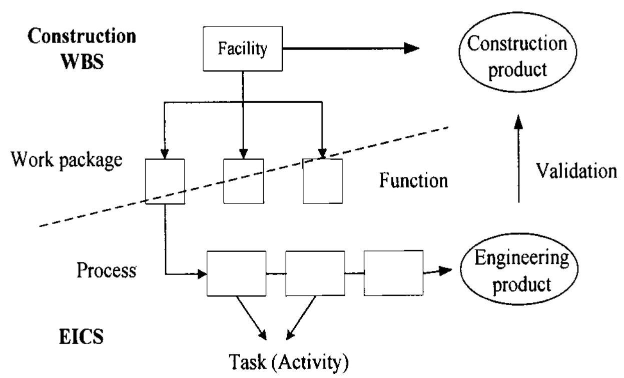

Fig. 7. Conceptual linkage of EICS and CICS

King and Paulson (1997) stated that most classification systems have difficulty classifying working information from the facility level to the operation level, but the EICS in this study can incorporate information from an engineering project's products at levels of engineering work as processes. A facility can be traced by the engineering project number. The project's upper management pays attention to products or service areas, and operational engineers specialize in functional tasks. These operations and amounts of time can be recorded periodically in employee timesheets to gather working information.

Linking EICS with CICS

The conceptual linkage model for a CICS and an EICS is shown in Fig. 7. The construction WBS vertically classifies information from a facility at a certain level of detail called a work package or cost center. The cost center's characteristics are equivalent to the function of an EICS. Up to this level, the classified information is mostly static, while down from this level, the engineering design process transforms static into dynamic information and integrates it into products through a series of tasks. The engineering products are to meet the requirements of a facility as the construction product. This feedback provides validation for the engineering design (Dym and Little 2000).

Halpin et al. (1987) stated that most detailed work packages used by the contractors are not the same as those used by the designer. This implies that beyond the summary levels of the

Table 6. Man-Hour Distribution to Products

Second, third digits	Product description	Planned hours	Actual hours	Variance
10	Project management	5,557.0	2,190.5	−2,190.5
12	Meeting	728.0	160.0	568.0
13	Quality assurance	—	89.0	−89.0
21	Project execution plan	—	154.0	−154.0
25	Construction plan	394.0	288.0	106.0
26	Specifications	—	1,719.0	−1,719.0
27	Contract conditions	3,231.0	507.5	2,723.5
30	Other proposals	394.0	66.0	328.0
33	Monthly report	841.0	0.0	841.0
35	Other reports	2,094.0	5,886.5	−3,792.5
36	Analysis calculations	2,730.0	2,973.0	−243.0
37	Quantity calculations	2,168.0	506.5	1,661.5
38	Budget	1,116.0	2,242.0	−1,126.0
41	Design drawings	35,499.0	24,721.5	10,777.5
45	CAD drawings	12,048.0	9,041.0	3,007.0
56	License	—	204.0	−204.0
60	Other documents	—	185.0	−185.0
Total		66,800.0	50,933.5	15,866.5

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Table 7. Man-Hour Distribution to Functions

Fourth digit	Function	Planned hours	Actual hours	Variance
B	Civil engineering	7,000.0	5,009.5	1,990.5
C	Structural engineering	12,608.0	6,773.0	5,835.0
D	Architectural engineering	10,950.0	3,758.0	7,192.0
E	Geotechnical engineering	4,729.0	3,959.5	769.5
F	Surveying engineering	—	10.0	−10.0
H	Transportation engineering	859.0	342.5	516.5
I	Railroad engineering	9,310.0	11,544.0	−2,234.0
M	Material engineering	183.0	85.5	97.5
N	Environmental engineering	219.0	150.5	68.5
P	Electrical engineering	7,904.0	7,703.0	201.0
Q	Mechanical engineering	4,965.0	3,531.5	1,433.5
R	Mechanical and electrical equipment	343.0	21.0	322.0
S	Environmental control	7,248.0	7,019.0	229.0
T	Information engineering	482.0	1,026.5	−544.5
Total		66,800.0	50.933.5	15,866.5

WBS, the package definition during engineering will differ from that used during construction; that is, the work packages or the tasks below the dotted line in Fig. 7 defined for engineering will be function oriented and focus on products such as drawings. During construction, work packages at these and lower levels will focus on facility and component.

McFadden and Hoffer (1991) presented a similar approach to identify information models. The major functions of the organization are identified, each of these functions is then divided into a group of processes, and each process, is in turn, divided into a set of activities. Business functions are a broad group of closely related activities and decisions that contribute to a product or service life cycle, and business processes are decision-related activities that occur within a function.

Application of EICS

The EICS can be applied to engineering management. Cost management is an apparent application that is illustrated in the next section with a design project. In schedule management, the products and functional tasks can be used to represent milestones and schedule activities, respectively. In a broader view, the EICS brings in the profit center concept in addition to the cost center. Consulting firms can find more business information and knowledge from analyzing the relationships among the EICS, the owners, and other factors.

Cost and Schedule Management

The EICS is also a cost system; the EICS structure allows flexibility to reflect cost information from different aspects and at different levels. The database for the EICS can provide planned and actual man-hours for products and functional tasks, and the man-hour data can be transferred into cost for cost planning and control.

A case study of a subway design project was used to record man-hours according to the EICS; The project members were asked to code their hours monthly for one year and accumulated over 50,000 man-hours.

Tables 6 and 7 show man-hour distributions to products (the second and third digits) and functions (the fourth digit), respectively. The planned and actual hours (66,800.0 versus 50,933.5) are the same for these two aspects; the variance is a saving of 15,866.5 h. The distribution in Table 7 can be better understood by examining Fig. 8. In Table 6, project management, meeting, and quality assurance are supporting activities consuming the indirect cost of the project; project management takes 4.3% (2,190.5/50,933.5) of total man-hours.

Table 6 contains some blanks in the planned hours column, such as ''Specifications.'' The number of hours was not estimated at the budgeting stage; the actual 1,719 h were accumulated for specifications and can be referenced for future projects. Also at a lower level than digits 5 and 6, the 1,719 h consist of spending by individual functional tasks in Table 8.

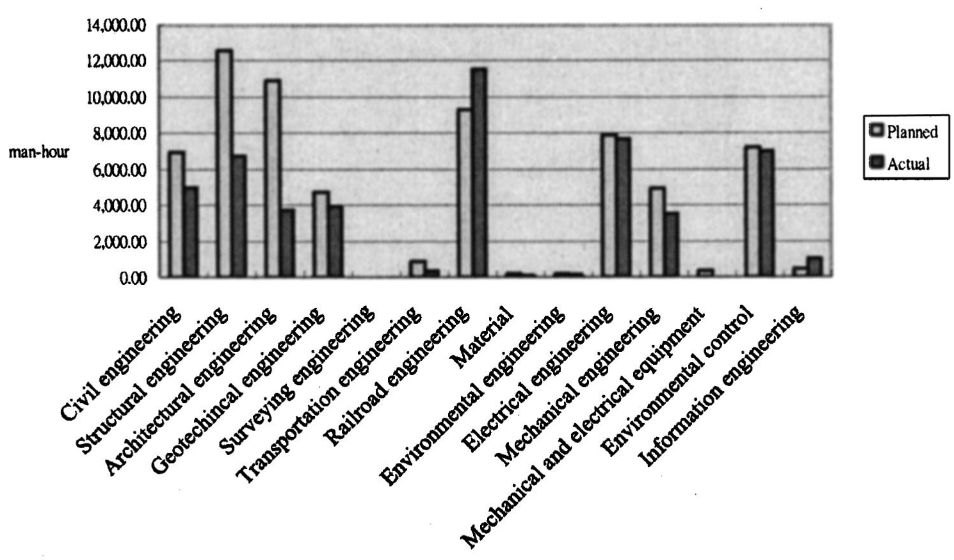

Fig. 8. Man-hour distribution to functions

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Table 8. Actual Hours of Specifications

4, 5, and 6 Digits	Specifications functions	Hours
C00	Structural engineering	642.5
C05	Mechanical workshop structure	74.0
I00	Railroad engineering	579.5
Q00	Mechanical engineering	44.0
Q05	Water supply system	16.5
Q20	Fire fighting system	70.5
S00	Environmental control	32.0
S10	Environment monitoring	30.0
S15	Power system	79.0
S25	Exhaust fumes system	8.0
S35	HVAC	143.0
Total		1,719.0

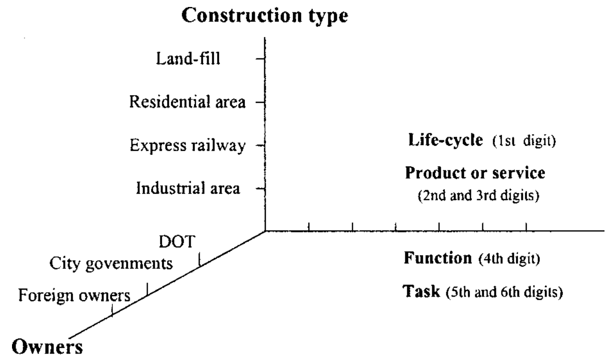

Fig. 10. Expanded project information

The EICS can help with schedule planning as well. Products and functional tasks in the EICS correspond to deliverables and activities in a schedule. As shown in Fig. 9, a product can be scheduled to deliver on a certain date (the triangles). Under this milestone, minor milestones (the diamonds) can be established for subproducts, or related tasks will proceed during a certain period.

When a project begins, one can make a list of relevant products and functional tasks from the EICS database for budgeting and schedule planning. Based on historical data, one knows the number of man-hours needed for selected products and functional tasks. The manpower loading schedule or cost curve can be easily drawn. During the project, the actual man-hours spent can be compared with those planned so as to control cost and schedule.

Cost Center and Profit Center

The financial structures generally have two common configurations of accountability: the cost center and the profit center. A cost center represents a narrow span of work-unit accountability encountered in most firms. Typically managers of cost centers, such as project managers, are accountable only for their project's level of spending, that is, project costs. Nevertheless, a profit center manager has a broader span of accountability than does a cost center manager. Managers of profit centers are accountable not only for costs, but also for revenues and net profits.

The proposed EICS makes use of the product classification to bring in the idea of revenues and net profits. For instance, after completing a report, a consultant could make an invoice to the owner for revenue. Revenue minus functional task cost equals net profit. The market is a good mechanism of control (Ouchi 1979); in a rapidly changing market, project managers should be able to respond quickly to what the market demands. Managers can make decisions effectively only if they have both cost and revenue information.

Application for Consulting Firms

For an engineering project, one probably can find the man-hours spent or the cost ratios of individual functions or tasks. However, a project with the same work content may have distinctive complexity or cost as a result of different construction types or owners, so to expand project information to locate profitability and align business strategy, one can analyze construction types, owners, and other variables in addition to the levels of the EICS.

The 3D view in Fig. 10 illustrates this idea. On the horizontal axis one can flexibly choose life cycle, product or service, or function (and task) of the EICS as the unit of analysis, and at the same time gather information about the facility and owners. From data mining and statistical analysis, one could identify the relationships between the degrees of work difficulty, project profits, and different construction types and owners. The results may reveal some business patterns and relations that were ignored before and suggest new business directions (Feelders et al. 2000).

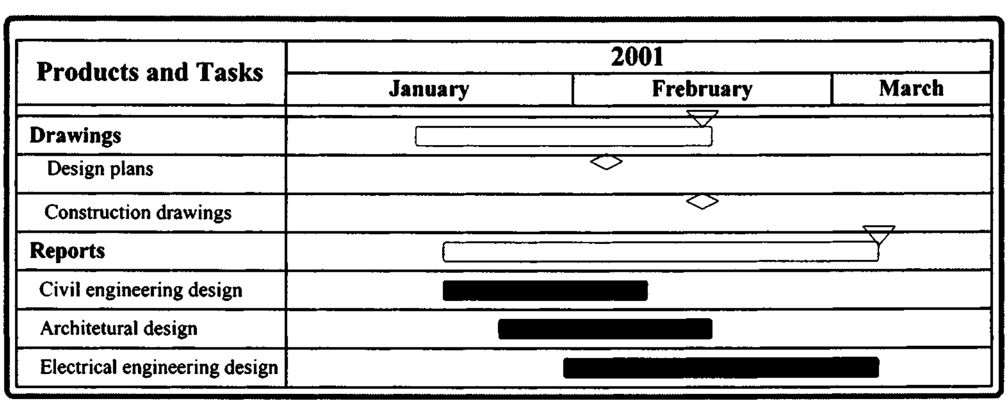

Fig. 9. Schedule of products and tasks

Conclusion

This study proposes an ICS with a faceted and hierarchical coding structure for engineering work. The EICS consists of construction type, life cycle, product or service, function, task, and man-hour levels. These levels can be mapped to appropriate construction classifications, such as facility, space, element, operation, and resources of a CICS. Two types of ICSs were compared, and the result indicates that they are compatible and that linkage between them is possible.

The EICS incorporates the theory of market and work-process units based on organizational design and also considers WBS principles and the system view. It further brings in profit center practice in addition to the cost center, which is what traditional cost systems did not offer. Using these theories as a foundation makes the EICS applicable in many areas, such as cost/schedule management and business strategy identification. Further, the EICS can improve coordination of information for design, construction, and management. One can extract desired information from different levels and perspectives. The EICS can also be the foundation of information and knowledge management for owners, consulting firms, and contractors at an earlier stage of the construction life cycle.

References

Construction Specifications Institute (CSI). (1995). *MasterFormat: Master list of numbers and titles for the construction industry*, Alexandria, Va.

Dym, C. L., and Little, P. (2000). *Engineering design: A project-based introduction*, Wiley, New York.

Feelders, A., Daniels, H., and Holsheimer, M. (2000). ''Methodological and practical aspects of data mining.'' *Inf. & Manage.*, 37, 271–281.

Halpin, D. W., Escalona, A. L., and Szmurlo, P. M. (1987). ''Work packaging for project control.'' *Rep. to the Construction Industry Institute*, Univ. of Texas at Austin, Austin, Tex.

Hanlon, E. J., and Sanvido, V. E. (1995). ''Constructability information classification scheme.'' *J. Constr. Eng. Manage.*, 121(4), 337–345.

Kang, L. S., and Paulson, B. C. (1997). ''Adaptability of information classification systems for civil works.'' *J. Constr. Eng. Manage.*, 123(4), 419–426.

Kang, L. S., and Paulson, B. C. (1998). ''Information management to integrate cost and schedule for civil engineering projects.'' *J. Constr. Eng. Manage.*, 124(5), 381–389.

Mansuy, J. (1991). ''Work breakdown structure: A simple tool for complex jobs.'' *Cost Eng.*, 33(12), 15–18.

McFadden, F. R., and Hoffer, J. A. (1991). *Database management*, 3rd Ed., Benjamin/Cummings Publishing Co., Redwood City, Calif.

Merchant, K. A. (1982). ''The control function of management.'' *Sloan Management Review*, Summer, 43–55.

Miles, R. E., and Snow, C. C. (1994). *Fit, misfit, and the hall of fame*, Free Press, New York.

Mintzberg, H. (1979). *The structuring of organizations*, Prentice-Hall, Englewood Cliffs, N.J.

Ouchi, W. G. (1979). ''A conceptual framework for the design of organizational control mechanisms.'' *Manage. Sci., September,* 833–847.

Rad, P. F. (1999). ''Advocating a deliverable-oriented work breakdown structure.'' *Cost Eng.*, 41(12), 35–39.

Simons, R. (2000). *Performance measurement and control systems for implementing strategy*, Prentice-Hall, Upper Saddle River, N.J.

Tatum, C. B. (1986). ''Designing project organizations: An expanded process.'' *J. Constr. Eng. Manage.*, 112(2), 259–272.

J. Constr. Eng. Manage., 2003, 129(4): 454-460