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A CONCEPTUAL MODEL OF A PRODUCTIVITY INFORMATION MANAGEMENT SYSTEM FOR CONSTRUCTION PROJECTS

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ABSTRACT

Although there have been many researches on construction productivity issues, researches focused on productivity management using managing productivity information have rarely been carried out. This paper suggests a conceptual model for a productivity information management system. The characteristics of productivity information are classified and the concept of a data warehouse is applied to the proposed system. For the implementation of the system, multi-dimensional productivity data models are presented. One assumption made during the study is that legacy databases exist so that the source data for this system can be extracted. The proposed system would be useful in two respects; (1) the project management team can use this system in managing project-related productivity (2) the accumulated productivity information in this system can be used for planning future projects. Some examples of each of these cases are described. In future, further research on the computerization of the proposed system is required.

KEYWORDS

Productivity Information, Information Management System, Data Warehouse, Data Modeling

1. INTRODUCTION

The construction industry in Korea is significant as it occupies almost 10% of the Korean GDP. However, the productivity of the Korean construction industry has declined over the last 10years. Considering the importance of the construction industry to the national economy, some effort should be taken towards productivity improvement through a systematic management of productivity information.

For productivity management, the productivity cycle (the cyclic process of measurement, evaluation, planning, and improvement) should be well recognized (Shin, 1992). However, it seems that prior researches on productivity have been focused primarily on the measurement of productivity or the method of productivity improvement, while few concerns have been given to cyclic productivity management based on productivity information.

Effective project management requires appropriate information at each phase. Productivity information, collected during the construction phase and used during the engineering phase such as scheduling and budgeting, is one of the important information, which is necessary for successful project management. Nonetheless, neither systematic management methods nor computerized systems for productivity information have been developed. For this reason, the performances of projects have not been properly accumulated and productivity information has not been effectively utilized during the engineering phases.

The objective of this paper is to present a conceptual model for a productivity information management system. This will be accomplished after first reviewing concepts and characteristics of construction productivity information. The method of construction productivity information management will be discussed based on these characteristics. Then a conceptual model for a Construction Productivity Information Management System will be suggested. Fundamentally this model adopts the concept of a data warehouse from which multi-dimensional data modeling will be conducted accordingly. Finally, the usefulness of productivity information will be discussed. One assumption is made that legacy systems or databases exist so that the source data for this system can be extracted.

2. CONCEPT OF PRODUCTIVITY INFORMATION

At the outset, the concept of productivity information must be established. A definition of productivity may vary according to the point of view, but basically it means the ratio of output to input. In other hand, information can be defined as a set of data processed and combined in accordance with a certain purpose. From these, the concept of productivity information in this research can be defined as the combination of data - data which are the result of processed input and output data and data which are additionally attached to explain that result. The purpose of combining all these data is to utilize the information in decision-making at the engineering phase and in productivity management at the construction phase. This concept of productivity information can be expressed as follows:

Productivity Information = F (d_i, d_o, d_1, d_2, …,d_n)

F ; processing and combining data

d_i ; input data

d_o ; output data

d_1, …, d_n; additional, explanatory data

3. METHOD OF PRODUCTIVITY INFORMATION MANAGEMENT

3.1 Characteristics of Productivity Information

Data are resources that produce the information, which is required in the course of project execution and business administration. Therefore, information management means managing the data as well as the information. (Lee, 1995) The characteristics of productivity information can be summarized as follows; (1) To be perfect information, additional data are required in addition to the input and output data. (2) In order to utilize the information properly in evaluating productivity improvement and in decision-making at the engineering phase, productivity information must be accumulated and a time-series analysis of that information must be possible. (3) It is efficient to manage the productivity information separately from any other legacy systems or transaction processing systems, since the productivity information is not for transaction processing but for productivity management. (4) Since productivity information is a set of data provided by legacy systems, the productivity information management system can be possibly integrated with those legacy systems.

3.2 Legacy Systems

The legacy systems, or transaction processing systems, are information systems that collect, process and store the data routinely generated in the course of everyday operations. (Seo, 2000) Accounting systems, schedule management systems, quality management systems, budget management systems, cost management systems, or integrated project management systems are some examples of legacy systems that are used in the construction industry to process routine tasks. These are computerized systems that handle the typical tasks that were previously done manually. The important factors in these systems are accuracy, promptness and transaction cost, and in order to achieve this, well-designed relational databases are widely used.

3.3 Data Warehouse

(Chang et al, 2000, Cho et al, 1999, Kimball et al, 1998, Kimball, 1996). Dr. Inmon (1993) defined the data warehouse as a subject-oriented, integrated, time-variant and non-volatile database that supports decision-making.

According to this definition, the characteristics of the data warehouse are summarized as follows; (1) Subject-oriented means that information is constructed not based on the tasks but based on the subjects. (2) Integrated means that data collected from different locations or stored in different systems are to be combined together. (3) Time-variant means that the data stored in the data warehouse has a time-record so that a time-series analysis of these data is possible. (4) Non-volatile means that the data in a category are accumulated and are not renewed frequently.

A data mart is a subset of a data warehouse in which a summarized or highly focused portion of the organization's data is placed in a separated database for specific users. A data mart typically focuses on a single subject area or line of business, so it usually can be constructed more rapidly and at lower cost than an enterprise-wide data warehouse. (Laudon et al, 2001) Therefore, the characteristics of data mart are very similar to those of data warehouse. As data warehouse or data mart normally uses multi-dimensional data modeling, they have another characteristic that multi-dimensional analysis of information is possible.

3.4 Method of Productivity Information Management

Productivity information management has specific subjects, i.e., it is not for daily transaction processing or routine tasks but for productivity management at construction phase or for decision-making related to productivity at engineering phase. From the characteristics of the productivity information and the data warehouse reviewed above, it can be recognized that data warehouse can be well adopted as a method of productivity information management.

4. CONCEPTUAL MODEL OF A PRODUCTIVITY INFORMATION MANAGEMENT SYSTEM

4.1 Productivity Data

The productivity information in this paper mainly focused on labor productivity, since direct labor constitutes a high percentage of the total cost of a project (an average of 15%, with a fairly wide range, depending on the type of project and the location) (Clark et al, 1997) Labor productivity is normally calculated as a ratio of output work-done quantity to input Man-Hour, and this data can be extracted from daily job reports. In addition to this, additional data that explains circumstances affecting input or output is required.

In order to establish a productivity data mart, productivity-related data are classified into (1)fact data that are the object of evaluation and (2) dimension data that explain the fact data. The fact data are classified into output, input, execution and planning data. The dimension data are classified into within-project and inter-project data. Each data can be classified again into additive, semi-additive and non-additive data. Table 1 shows the classified productivity data that are considered as important by experienced construction engineers.

Table 1: Classification of Productivity Data

Classification		Additive	Semi-additive	Non-additive
Fact Data	Output Data	Quantity of work done, Amount of work done		
	Input Data	No. of Labor, Cost, Working Hour		
	Execution Data	Equipment Delay, Material Delay	Foreman Ratio, Skilled Labor Ratio	
	Planning Data	No. of RFI, No. of Design Change		Work Method, Site Layout Plan, Suitability of Material, Suitability of Equipment
Dimension Data	Within-Project Data	Trade, Time Period, Part, Work Zone, Contract, etc.		
	Inter-Project Data	Trade, Location, Project Type, Project Size, Project Condition, Project Duration, etc.		

Table 2 shows the details of these productivity data. The source data means the data extracted from the legacy databases and transferred to the productivity information management system or the construction productivity data warehouse.

Table 2: Details of Productivity Data

Classification	Data	Code	Type Of Data	Unit	Source
Output Data	Quantity of works done	Qty_Work	N	m^2,m^3, ton, etc.	Daily job report file
	Amount of work done	Amnt_Work	N	$	Cost File
Input Data	Number of labor for works	Nos_Man	N	Man	Daily job report file
	Time consumed for works	Work_Hr	N	Hour	Daily job report file
	Cost for works	Cost_Work	N	$	Cost File
Execution Data	Time delay due to equipment	E_Delay	N	Hour	Daily job report file
	Time delay due to material	M_Delay	N	Hour	Daily job report file
	Ratio of foreman to labor	Foreman_R	N	N/A	Daily job report file
	Ratio of skilled labor to labor	Skilled_R	N	N/A	Daily job report file
Plan Data	Number of RFI issued	Nos_RFI	N	No.	Design control file
	Number of design changes	Nos_Change	N	No.	Design control file
	Work method for each trade	Method	Vari.	N/A	Work plan file
	Site layout plan	Layout	D	N/A	Site layout plan
	Work sequence	Sequence	Vari.	N/A	Work schedule file
	Suitability of material	M_Prop	Vari.	N/A	Material file
	Suitability of equipment or tool	E_Prop	Vari.	N/A	Equipment file
Within-Project Data	Trades of work	Trade	T	N/A	Daily job report file
	Part of work	Part_Work	T	N/A	Daily job report file
	Time period	Time	T	N/A	Daily job report file
	Zone	Zone	T	N/A	Daily job report file
	Contractor or sub-contractor	Contract	T	N/A	Project file
Inter-projects Data	Project location	Pj_Location	T	N/A	Project file
	Type of project	Pj_Type	T	N/A	Project file
	Size of project	Pj_Size	N	$	Project file
	Condition of project	Pj-Condition	T	N/A	Project file
	Duration of project	Pj-Duration	N	Day	Project file

Type of Data: N; Numeric, Vari; Various, D; Drawing, T: Text

4.2 Multi-Dimensional Data Modeling

In order to describe the data warehouse of productivity information, multi-dimensional data modeling is used. A fact table and dimensional tables comprise a multi-dimensional data model. A fact table, located at the center of a multi-dimensional data model, contains the data that we are to analyze. Dimension tables, located around the fact table contain the data that are to explain the fact data. All the data, mentioned in Table 2 above or shown in the fact tables and the dimensional tables presented at the following multi-dimensional data models, are to be extracted from the source systems or legacy systems.

The productivity data warehouse in this research comprises 'measured productivity data mart', 'execution-related data mart', 'plan-related data mart' and 'inter-projects data mart'.

Measured productivity data mart

The measured productivity data mart provides the measured productivity with various dimensions for analysis. The productivity information from this data mart is to compare the target productivity with the actual productivity at the evaluation stage of the productivity cycle. Figure 1 presents the multi-dimensional data model for this data mart. An example of information possibly provided by this data mart is; the 'productivity' of formwork for columns at zone 1 by contractor A during last month.

Execution-related data mart

The execution-related data mart is to check if any mistakes were made during the construction execution, when the measured productivity is lower than the planned productivity. This data mart uses the same dimensions as the measured productivity data mart. Figure 2 presents the multi-dimensional data model for this data mart. An example of information provided by this data mart is; 'time delay due to equipment', 'time delay due to material', 'ratio of foreman to labor' or 'ratio of skilled labor to labor' of formwork for slab at zone 1 by contractor A during last month.

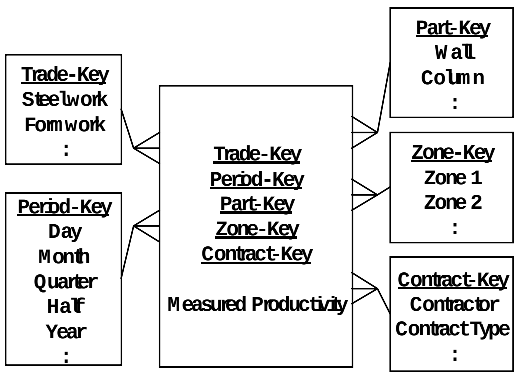

Figure 1: Multi-dimensional data model for measured productivity data mart

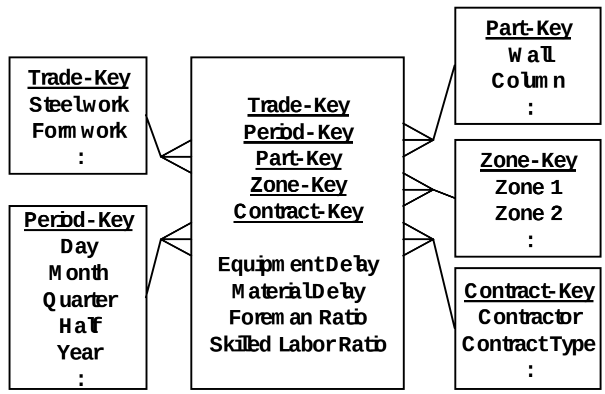

Figure 2: Multi-dimensional data model for execution-related data mart

Plan-related data mart

The plan-related data mart is to check if any mistakes were made during the construction planning, when the measured productivity is lower than the planned productivity. This data mart uses the same dimensions as the measured productivity data mart or the execution-related data mart. Figure 3 presents the multi-dimensional data model for this data mart. An example of information provided by this data mart is; 'number of RFI issued', 'number of design changes', 'work method for that trade', 'site layout plan', 'work sequence', 'suitability of material' or 'suitability of equipment or tool' of formwork for slab at zone 1 by contractor A during last month.

Inter-projects data mart

The inter-projects data mart is for comparing the productivity of different projects or to forecast the productivity of a project based on the productivity information of other similar projects. In this case, various combinations of dimensions can be made for analysis. Figure 4 presents the multi-dimensional data model for this data mart. An example of information provided by this data mart is; 'productivity' of RC work for an office building project at the downtown area of A city with the project amount of around $10mil.

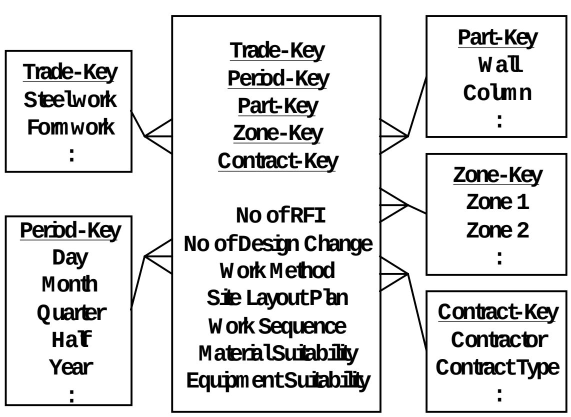

Figure 3: Multi-dimensional data model for plan-related data mart

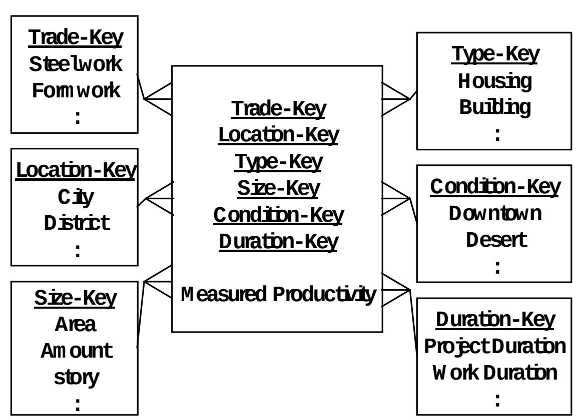

Figure 4: Multi-dimensional data model for inter-project data mart

4.3 Conceptual Model of Productivity Management System

Based on the data models presented above and the concept of data warehouse technology, the conceptual model of the productivity management system is presented as Figure 5. As mentioned above, the legacy systems or the transaction processing systems are assumed to exist.

Utilizing and customizing proper IT tools can accomplish extraction, transformation and loading of the data from the legacy systems to the data warehouse. Browsing and reporting are the way of information representation to the users, or they can be called user interface. These areas of highly technical subject are not the scope of this research, and the solutions for these technical matters are to be provided by IT specialists once the conceptual model of the system is built.

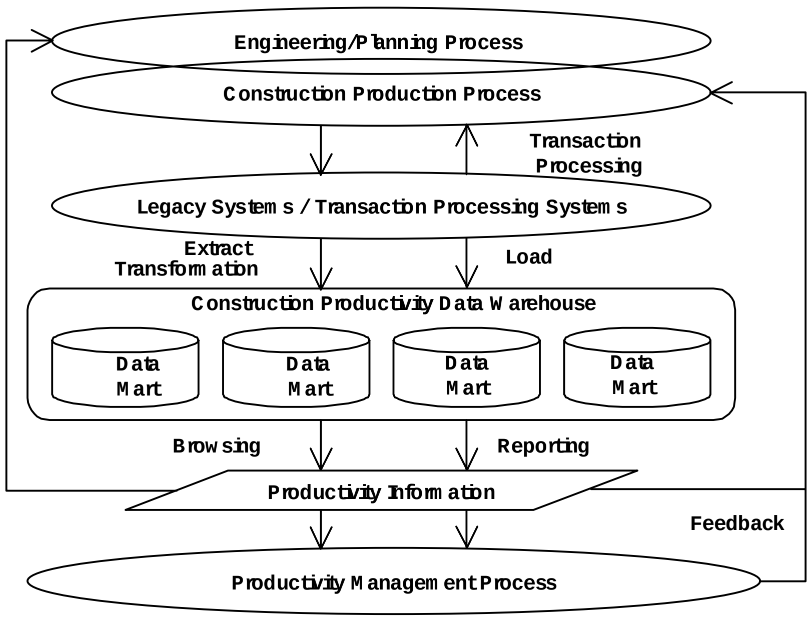

Figure 5: Conceptual model of productivity management system

5. UTILIZATION OF CONSTRUCTION PRODUCTIVITY INFORMATION

5.1 For Productivity Management

Setting up the target productivity
Using the inter-project data mart and analyzing the project conditions of similar projects executed in the past, the target productivity for preparing a project can be set up. Establishing the target productivity for a certain trade or a field organization, etc. is required when a new project is ready so that the productivity management of the project is implemented.

Evaluating the actual productivity
Using the measured productivity data mart and comparing the measured and the target productivity, the actual productivity accomplished under certain conditions can be evaluated. Evaluation of the productivity is the first step of productivity management and productivity improvement efforts. When the measured productivity is lower than the target productivity, the reason must be investigated and some measures must be taken to improve the productivity.

Evaluating the execution-related mistakes
When the actual productivity is lower than the planned or the target productivity, the reasons may be the delay of equipment, the delay of material, lower foreman ratio, lower skilled labor ratio, etc. Using the execution-related data

mart, any execution-related mistakes such as those mentioned above can be reviewed and proper actions can be taken to remedy the lowered productivity.

Evaluating the plan-related mistakes

When the actual productivity is lower than the planned or the targeted productivity, the reasons may be the number of RFI, the number of design changes, the work method, the site layout plan, the work sequence, the material suitability, the equipment suitability, etc. Using the plan-related data mart, any plan-related mistakes such as those mentioned above can be reviewed and proper actions can be taken to remedy the lowered productivity.

5.2 For Project Planning or Engineering

During the project planning phases or engineering phases, basic productivity information or base productivity, which is the productivity expected under normal or average conditions, is necessary for cost estimation, work duration estimation, budgeting, scheduling, resource planning, work method selection, man loading planning, etc. It is known that the best way to get this base productivity information is to use historical data on the company's past project. (Clark et al, 1997) Using the inter-project data mart and analyzing the project conditions of similar projects executed in the past, the required productivity information can be utilized for these engineering activities. Also, the productivity trend analyses such as time series analyses can be implemented in order to diagnose the competitiveness of an organization.

6. CONCLUSIONS

A conceptual model for a productivity management system and some examples of utilization of productivity information are presented. This system is based on the productivity data that will be effectively provided by the data warehouse or the data mart technology. This system will be able to collect, process, store and utilize the productivity data so that productivity information required for productivity management during the construction and engineering phases.

The proposed system would be useful in two respects; (1) the project management team can use this system for managing project-related productivity (2) the accumulated productivity information in this system can be used for planning future projects.

This research is mainly limited to conceptual exploration and further researches on the computerization of the proposed system are in progress.

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