A BIM-Based Approach to Reusing Construction Firm's Management Information

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Abstract

Nowadays most construction firms have begun to use information management systems in their business to work more efficiently. At the same time, a lot of management information is being accumulated and some of the information can be reused to support the decision-making. Up to now, the information has not been reused so effectively in construction firms as expected. This paper introduces a new approach to reusing construction firm's management information, which is based on BIM (Building Information Modeling) technology. In the paper, the current approaches are reviewed at first, and then the framework of the new approach is described. Next, the key issues of the new approach are clarified. Finally, a use case of the new approach is demonstrated. It is concluded that the new approach can be used in construction firms to better reuse the accumulated management information.

Keywords: Information resources, reuse, BIM, IFC

Introduction

Nowadays most construction firms are using information management systems as management tools and more and more information is being accumulated in the systems over time, related to productive information on elements such as labor, machine, and material and so on, and covering aspects such as schedule, cost, quality, etc. (Rujirayyanyong 2006) Just as the term "information explosion" indicates, huge amount of information thus may be accumulated in the system, because each project leaves several gigabytes of information after completion, while a moderate large construction firm have hundreds of projects in China each year. The information of reuse value is referred to as information resources in the context of this study and it is expected that by making full use of information resources, the ability of decision-making could be improved, which thus enhances the competitiveness of construction firms.

There exist two approaches to reusing information resources. One approach is to manage the major information (e.g., engineering documents) and make it easy to query. For example, Tserng (2004) analyzed five phases of knowledge management, i.e. knowledge collection, knowledge extraction, knowledge storage; knowledge sharing and knowledge update, and developed a system to support information reuse. The other approach is to extract useful information to build data warehouse and excavate potential knowledge by using data mining techniques. For example, Soibelman (2004) conducted schedule delay analysis using decision tree method and artificial neural network method to analyze the information accumulated in enterprise databases. Some construction firms hired management consulting firms to implement Business Intelligence (BI here after for short) tools for them in China. However, the existing approaches are still not convenient and efficient for construction firms to use.

There are mainly two reasons for this. One is that the huge amount of the accumulated information prevents the users from extracting the right information easily and generating valuable information through handling the information. The other is that the existing

information does not include that of the relationship among various information items explicitly.

BIM (Building Information Modeling) technology makes it possible to express the relationship of various information items explicitly so that the various information items in the lifecycle of construction projects can be shared easily. In the study, the classification and identification of information resource items were carried out so that only information resources are extracted for storage from the information management systems and BIM technology was used to represent the information resources in order to simplify the extraction of information resources for analyzing. A new approach based on BIM technology was formulated in order to reuse information resources more efficiently and effectively, and a prototype system was developed to verify it. This paper is intended to present the approach in an integrated way.

A New Conceptual Framework for Reusing Construction Firm's Information Resources

Though investigations against senior managers in construction firms, it is estimated that only about 10 percent of the accumulated information in construction firms' information management systems can be regarded as information recourses in the sense that they can be reused in future. So it is necessary to extract information resources firstly from the information management systems of construction firms to make efficient use of them. Accordingly, a conceptual framework is established for reusing construction firm's information resources, as shown in Figure 1 (Ma 2009).

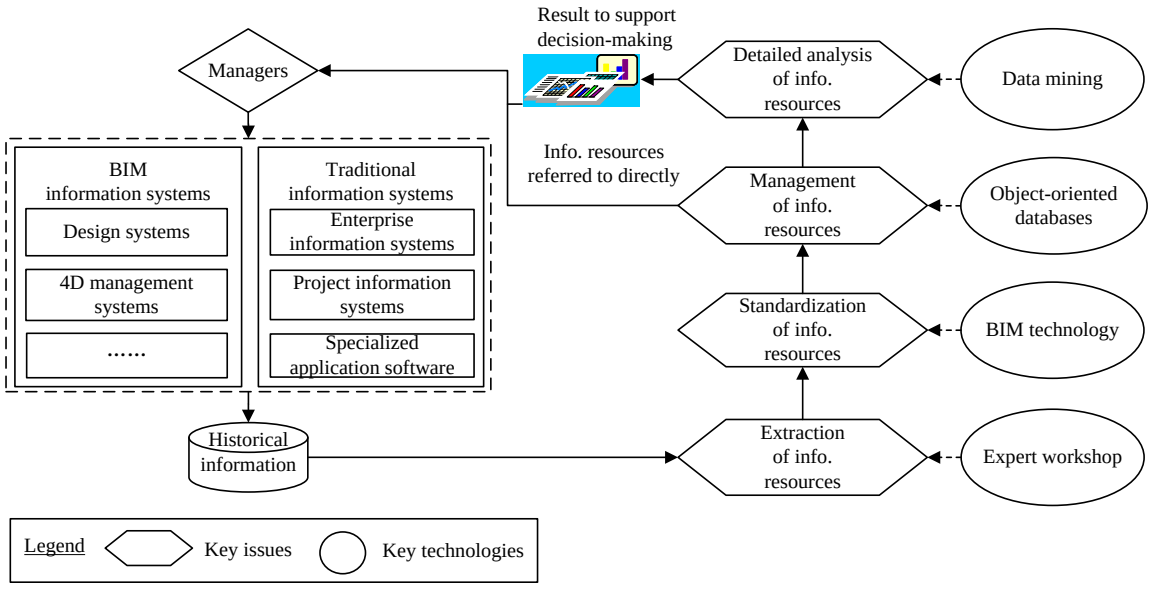

Figure 1 Conceptual framework for reusing construction firm's information resources (Ma 2009)

According to the framework, information resources need to be extracted from the information management systems after a project is completed. The information resources then should be standardized and added to a dedicated system for information reuse; just like reusable spare parts that are removed from used cars and stored in the warehouse. Whenever the support for decision-making is needed, the managers can then analyze the information resources by using the dedicated system. This framework reduces the quantity of information stored in the database of the dedicated system so that the information resources could be reused efficiently.

In order to implement the framework, several key techniques need to be used to clarify the key issues; for example, expert workshop is used for identifying the information resource items, BIM technology is used for the representation of information resources, an object-oriented database management system is used for managing them, and data mining technology is used for extracting knowledge to support the manager's decision-making.

Research on the Key Issues

Classification and Identification of Information Resource Items

While the classification and identification of information resource items is the basis of the new approach, it is very difficult to carry out the work because it not only involves many aspects of the management of construction firms, but also depends on the experience of the managers. An experienced manager knows what kind of information resources could be reused in his decision-making. In addition, the classification and identification has to be systematic, so that the information resource could be extracted from information management systems without losing the valuable ones.

Hence, the procedure for the classification and identification of information resource items is formulated and implemented in the study as shown in Figure 2. As Step 1, the major decision-making processes in construction firms were summarized based on extensive literature review. As a result, the decision-making processes are divided into two parts, project level processes and enterprise level processes; the former includes 5 project stages such as bidding and contract-signing, and the latter includes 8 functional management categories such as planning and production. As Step 2 and Step 3, the information resource items that are required in the processes and their usage were summarized. Thus totally 63 information resource items were proposed, among which, 37 items are related to project-level management and the rest are related to the firm-level management. Then a questionnaire form was formulated for use in next step. In Step 4, a workshop was held and 5 experts from top construction firms in China were invited to discuss and fill in the questionnaire form to evaluate the reusability of the information resource items. The reusability of the information resource items was divided into three levels, i.e. A-level, B-level and C-level, where A-level corresponds to the largest reusability, B-level to the medium one and C level to the smallest one. As an example, Table 1 shows the information resource items of A-level and B-level reusability.

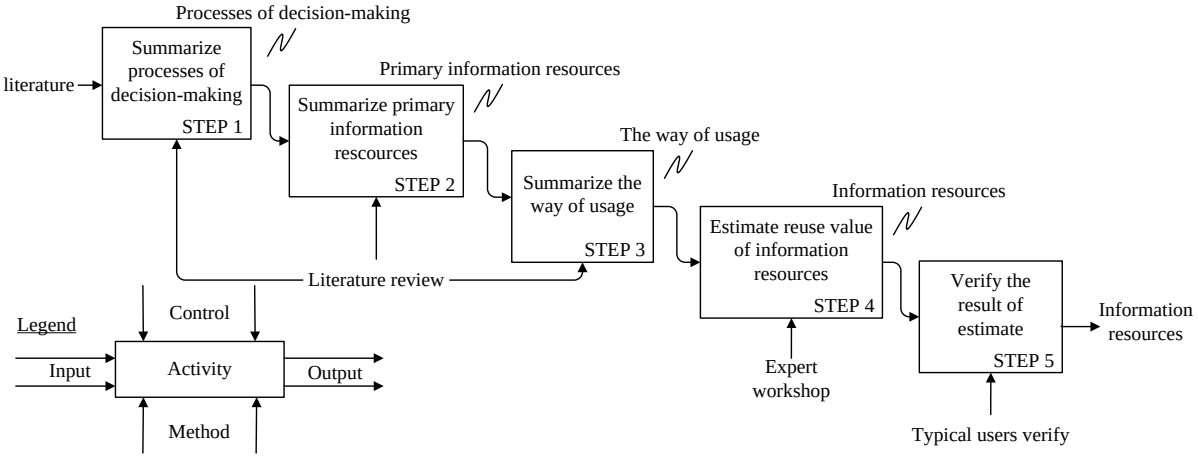

Figure 2 Procedure for the classification and identification of information resource items (Lu 2011)

The evaluation results on information resource items were verified by holding a meeting in a construction firm which had implemented information management systems successfully for several years. Ten high-level managers including the general manager attended the meeting and were asked to evaluate the reusability of the information resource items independently. As a result of comparison, the evaluation was in agreement with that given by the experts. Thus it is concluded that the result of classification and identification of information resource items is applicable for extracting the information resources from information management systems of construction firms (Ma 2010b).

Code	Information resource items	Reusability level	Code	Information resource items	Reusability level
1	Project bidding detail	A	16	Cost accounting record	A
2	Certificate info.	A	17	Design documents	B
3	Cooperation record	A	18	Abstract info. of bidding	B
4	Cost planning detail	A	19	Abstract info. of contract	B
5	Actual schedule detail	A	20	Contract documents	B
6	Material procurement record	A	21	Abstract info. of constr. Planning	B
7	Direct cost record	A	22	Material planning detail	B
8	Indirect cost record	A	23	Equipment planning detail	B
9	Annual plan	A	24	Labor planning detail	B
10	Project contract info.	A	25	Labor work record	B
11	Project cost info.	A	26	Equipment procurement/rent record	B
12	Construction method	A	27	Quality inspection record	B
13	Material procurement record	A	28	Employee performance info	B
14	Cash flows record	A	29	Deployment of staffs recorded	B
15	Income and expenditure records	A			

Table 1 Partial information resource items (Ma 2010b)

Representation of Information Resources

In order to manage the information resources that are extracted from existing information management systems, it is better to define a neural format for storing them. In recent years, with the development of BIM technology, the IFC standard has been recognized as a mainstream data standard. The study adopts the IFC standard as the storing format of information resources. There are three reasons for doing this. First, because of the direct or indirect relationship between the construction firms' information and the building products, it facilitates future integration of the information resources with the design information. Second, the IFC standard, which is object-oriented, contributes to classifying and storing information resources semantically and thus can make it more convenient for the construction firms to retrieve information resources that they want than using other representation method. Finally, the IFC standard contributes to better sharing and exchange of information resources since it does not change with information management systems.

However, the IFC standard has not been used in the field of construction management up to now, except for a few aspects such as schedule management and cost estimating. Hence, in order to use the IFC standard in this approach, it has to be expanded.

In the study, the expansion of the IFC standard was carried out for representing the information resource items of A-level reusability. Object-oriented analysis method was used and eleven classes including labour and organizations were identified. By examining the IFC standard, it was found that only three categories of information related to “data records”, “drawings” and “the relationship with drawings” need to be defined as expansions. The hierarchical structure of existing and expanded entities about the above-mentioned categories is shown in Figure 3. In the structure, two entities related to drawing are in the resource layer, so they do not inherit from IfcRoot (Ma 2010a).

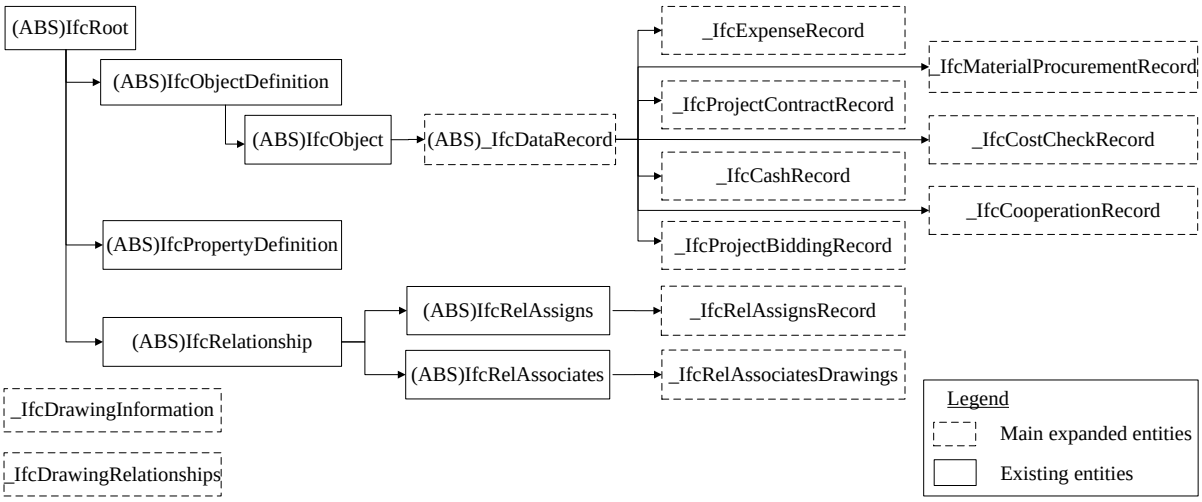

Figure 3 The hierarchical structure of existing and expanded IFC entities related to “data records”, “drawings” and “the relationship with drawings” (Ma 2010a)

Thus, the IFC-based model of information resources is formulated as shown in Figure. 4. The expanded entities are properly arranged into the domain layer, interoperability layer, core layer and resource layer in the IFC standard respectively. Based on the model, the information resources are supposed to be extracted from the information management systems of a construction firm and transformed to IFCXML files before they are imported into the prototype system in this study. The way to extract information resources depends on the information management systems that the construction firm uses. A mapping between the information items in the information management systems and the information resource items needs to be established by an engineer and a script program needs to be developed based on the mapping in order to extract the information resources from the information management systems. Next, the mapping between the information resource items and the IFC entities’ data member needs to be established by the engineer who has the knowledge of the IFC standard. Then the mapping can be established in the dedicated system for reusing the information resources by utilizing the functions provided in the system.

It deserves to note that the quality and consistency of information resources depend on both that of the information in the original information management systems and the quality of the two mappings established by the engineer in the construction firm. While the former is out of control of this study, the latter can be controlled if the construction firm can find an engineer who knows or can learn the information items involved in the information management systems, information resource items and the IFC standard well. The control of the latter is not a problem, since it needs the engineer to do only once in short period as long as the information management systems is not changed and it is not difficult for him to master those knowledge.

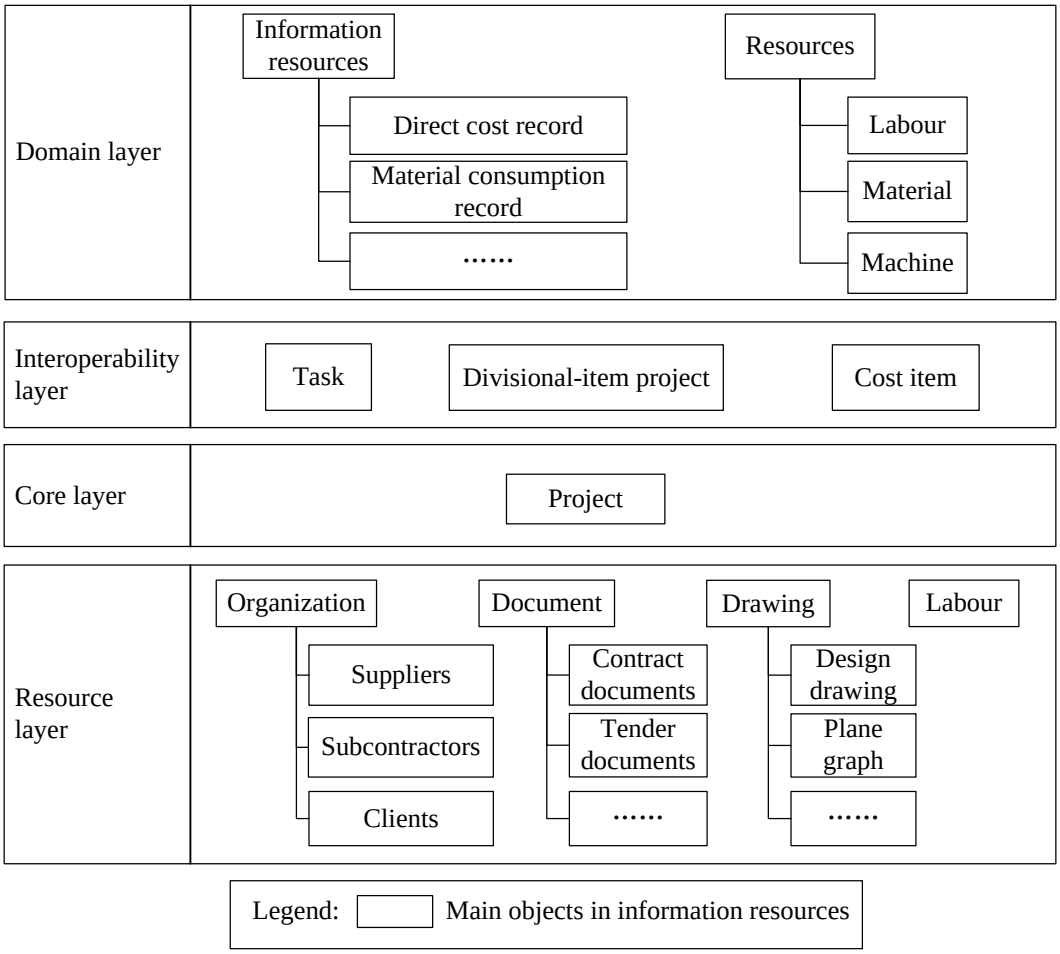

Figure 4 Information resources model based on the IFC standard (Lu 2011)

When making use of the information resources stored in the system, an inverse process needs to be carried out. Since the combination of information resource items may be needed in many cases of decision-making, the mapping between the data member of IFC entities and the process of decision-making support need to be established in advance before the data are used for the analysis to support decision-making. The process of obtaining the data of information resources for decision-making is shown in Figure 5, where the main IFC entity represents IFC entity whose attributive data can be use directly, while the basic IFC entity represents that whose attributive data have to be obtained through relation entities before being used.

Management of Information Resources

Since vast amount of information are anticipated to be in such a system in order to make use of information resources in construction firms, it is necessary to adopt an efficient database management system. Traditionally, relational databases (RDB) management systems are used to manage data in information systems (Demian 2006). Considering that the IFC data are object-oriented, it was expected that object-oriented database (OODB) management system are more efficient than the traditional RDB management system. To verify it, comparisons were carried out by using an OODB management system, Versant Object Database 8 (Versant 2011), and a relational database, SQL Server 2005, respectively.

The comparison was carried out in the following way, i.e., establishing databases for simple data (e.g. a single IFC entity), combined data (a relation entities is used for combining two IFC entities) and complex data (more relational entities are used for linking more IFC entities), and then manipulating the databases by inserting information and retrieving information up to 100000 times. The results are shown in Figure 6. It is clear that in most cases, the OODB management system showed much higher performance than the RDB management system (Ma 2011). Hence, the Versant Object Database 8 was used in the development of the prototype of the dedicated system for information reuse (the prototype system hereafter) in this study.

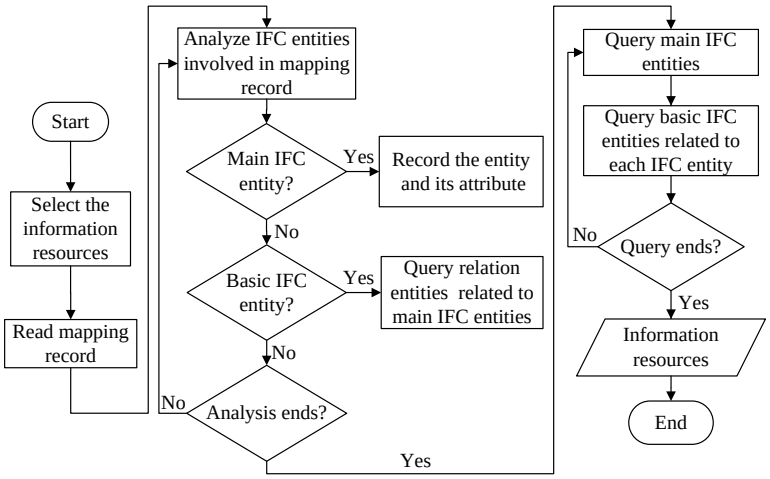

Figure 5 The process of obtaining the data of information resources (Lu 2011)

Reuse of Information Resources

Through investigations it is concluded that the statistical analysis method can satisfy construction firms' daily needs for supporting decision-making in most cases. So the prototype system that was developed in the study provides only the basic analysis functions, i.e. graphical representation and multiple linear regression analysis. Besides, to satisfy users' need for complicated analysis, the prototype system facilitates outputting information resources in the form of XLS, CSV and ARFF files so that users can make in-depth analysis with dedicated software such as BI tools.

Prototype System

Introduction to the Prototype System

Based on the above-mentioned research, the author et al. developed a prototype system called the Information Resources Reuse System for Construction Firms (InfoReuse for short) by using C# language and Versant Object Database 8. Figure 7 shows the system model.

The system has two types of users, i.e. information managers and information analysts. The former are supposed to be an engineer in the construction firm who know information resource items and the IFC standard and are responsible for importing information resources from the information management systems. In addition, they are responsible for setting departments, users and user rights, maintaining information resources, decision-making processes and analytical models, and setting the mapping of IFC entities, etc. in the system. The latter can browse, search, use and output information resources that they want by using the system.

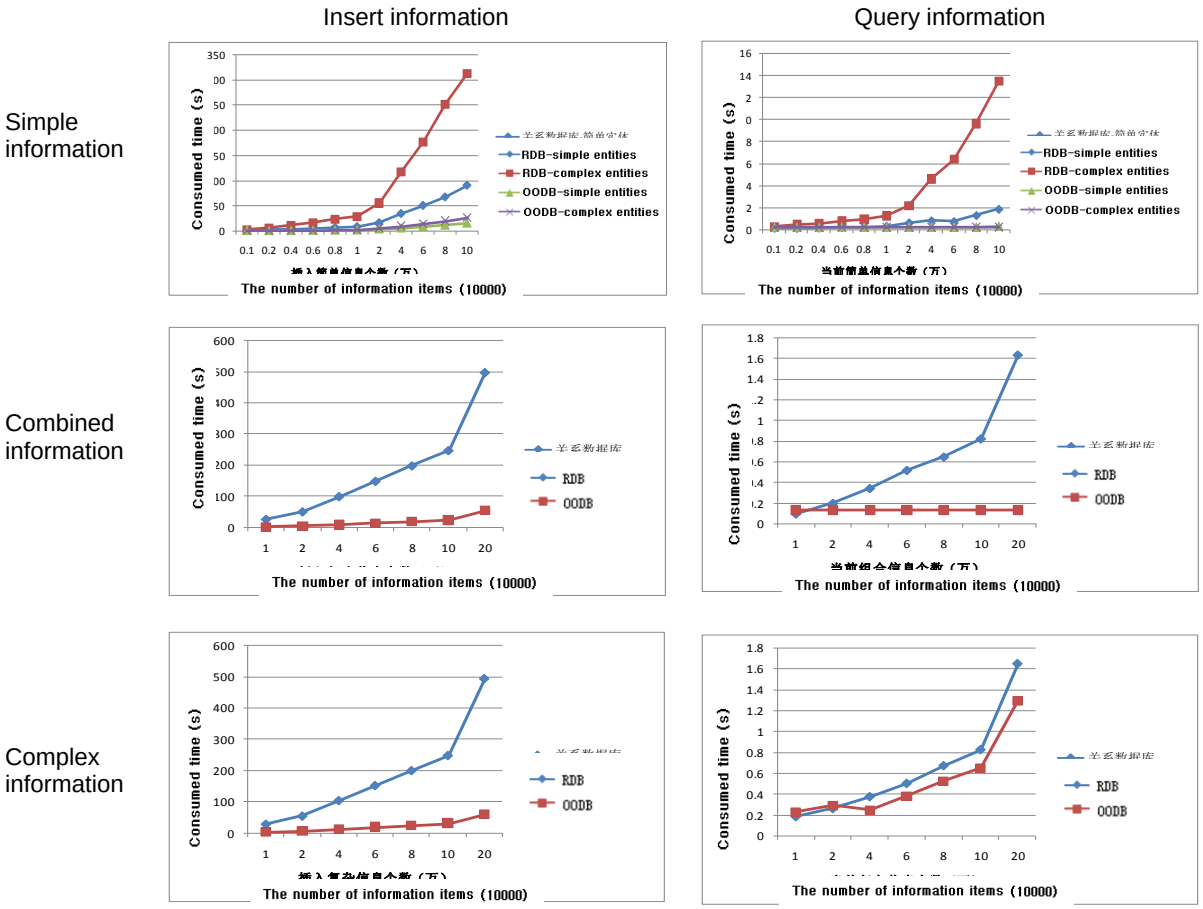

Figure 6 Comparison of OODB and RDB for the efficiency of manipulating IFC data (Ma 2011)

Using the System for Case Studies

In the study, a construction firm that has used an ERP system for about 8 years was selected to test the prototype system. The extracted information resources cover project information, suppliers, material, WBS, material purchase records, cost records and enterprise cost records etc. There are about 5000 information resource instances from 21 projects. The size of IFCXML files is about 10MB involving 30,000 IFC entities. The imported information resources are then used it to predict project cost, to assist in material purchase and so on. For example, the information resources of wood-based panel factory projects were used to predict the cost of a planned project. It was found that the construction cost of a wood-based panel factory project mainly depends on the output of the factory and duration of the project. Based on this feature, the cost of the planned project was predicted by using multiple linear regression analysis method. Due to the shortage of similar data, the system could not be validated by predicting a new case. However, when the results were explained to two senior managers of the same construction firm and they valued the findings very much.

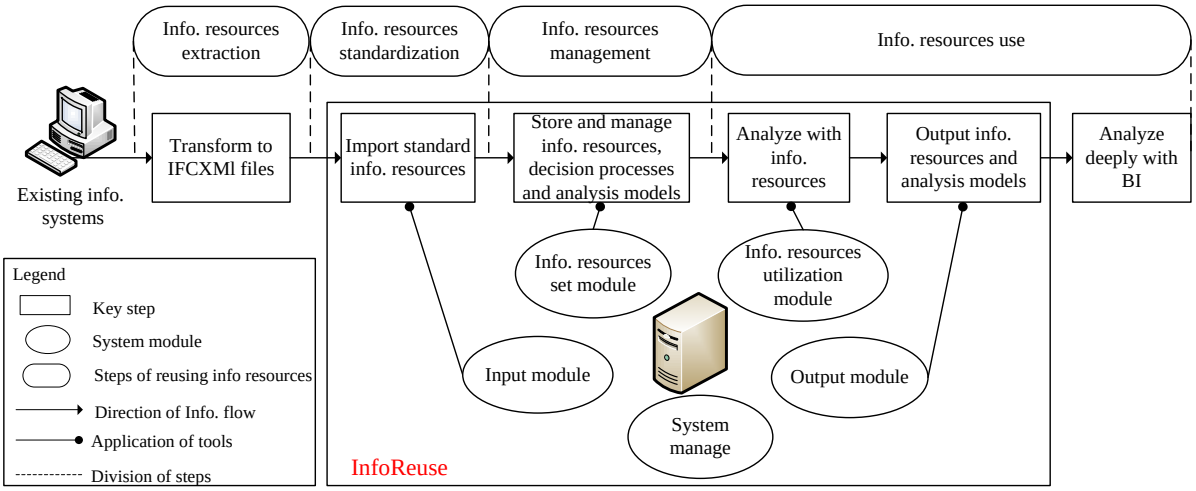

Figure 7 System model of InfoReuse (Lu 2011)

Conclusions

A new approach for reusing information resources in construction firms was established based on BIM technology in the study. To verify the approach, the related key issues were clarified by using key techniques and a prototype system was developed and applied. The following summarizes the findings.

(1) This paper reviews the previous undertakings of this study, i.e. the classification and identification of information resource items based on literature review and an expert workshop, the representation of information resources based on the IFC standard, and managing the information resources by using object-oriented database management system. These works has laid a sound foundation for the new approach.

(2) The new approach proposed in this study, which is based on BIM technology can help to achieve higher efficiency of managing and reusing information resources than traditional approaches in order to support the decision-making of construction firms.

(3) As the contribution to the body of knowledge, the integrated use of identification of information resources based on pre-defined items, representing them by using the IFC standard and managing the them represented by using object-oriented database management system provides a more efficient approach for making full use of information resources of construction firms.

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