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STREAMLINING THE DATA TRANSFORMATION PROCESS FOR CONSTRUCTION PROJECTS VIA BUILDING INFORMATION MODELING

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ABSTRACT

Information processing is critical to the successful development and execution of a construction project plan. Currently, Building Information Modeling (BIM) has been widely used in representing the physical and functional characteristics of design and construction. However, in order to use BIM effectively in construction project planning, more construction knowledge should be transformed and integrated. This paper proposes an activity-based modeling approach to process project information in an organized manner and proposes a Multi-Dimensional (MD) CAD model. The MD CAD model is composed of the MD CAD objects. The model can assist project planners in assessing information concerning the inter-relationships between schedule, cost, resources, and work areas. A computer implementation called MD-Construction Project Management Information System (MD-CPMIS) is presented to verify the feasibility of the proposed approach.

KEYWORDS

MD CAD model; Project planning; Building information modeling

1. INTRODUCTION

In construction project planning, information processing is perhaps the most challenging task faced by project teams. As a construction project increases in size or complexity, the efficiency and accuracy of information processing between different project participants have a tremendous impact on the successful development and execution of a construction project plan. The planning process requires the transformation of data into decisions and actions. Information required for the execution of a project needs to be extracted from design and construction data. This information is then processed to formulate project knowledge necessary for making appropriate decisions and actions.

In practice, the implementation of information processing by most project teams is substantially manually. The project team needs to study the 2D design drawings and contract documents, and investigate the site in order to further develop plans on budget, schedule, and so on. Furthermore, these project plans are generally created independently of one another. This respective approach becomes a heavy burden to the project team due to the tremendous amount of information that must be manually pieced together to integrate a comprehensive plan [1]. For example, it is still very difficult to integrate information from budget and schedule plan. Thus, it is hard to take account of both cost and schedule impact during the decision-making process.

Along with current development of computer technology, various research efforts attempt to develop innovative ways of processing project information. Embarking on advancements in data standards, CAD systems and information systems, many researchers have tried to streamline the information processing tasks by modeling and standardizing the information required for design, construction and operation of constructed facilities. The Building Information Modeling (BIM), with its data-rich digital representation, is a new approach to cataloging the physical and functional characteristics of design and construction [2,3]. However, to use BIM effectively in construction projects, the information processing between different participants in the construction process has to be more efficient [4]. In addition, more construction knowledge and project information should be implemented in BIM to assist project planners to effectively process construction documents into project plans.

This paper starts with analyzing the discrete processes undertaken within building construction in order to present the information of construction activities and specifications in the BIM model. These essential characteristics of the work items and building components are defined in the property sets of the proposed MD CAD objects [5]. These graphic objects are then utilized to create the MD CAD model, which will be further exported as a project database. In order to transform these project data into the information for project planning, this research employs an activity-based modeling approach as a mechanism of information transformation. In the transformation process, the scope hierarchy structure is availed to define the activity items in a consistent formation. This organized manner assists in integrating project information into a standard format for cost estimating, project scheduling and project control. Since the MD CAD objects are created based on work items, which contain the information related to the required resources including labor, machine, and material. These objects facilitate the process of quantity takeoff. In addition, the proposed MD CAD model system can assist project planners in assessing information concerning the inter-relationships between schedule, cost, resources and work areas.

In the first section of this paper, the development of Building Information Modeling (BIM) is elaborated. Next, the procedures of developing a MD CAD model system are described. Finally, a computer implementation MD-Construction Project Management Information System (MD-CPMIS) is presented to verify the feasibility of the proposed approach.

2. BUILDING INFORMATION MODELING

CAD systems have been widely used in the AEC industry and have evolved over the years. However, the CAD graphic documents often exclude information needed for effective project planning. The information that is sufficient for project designs is often insufficient to meet the requirements of project planning. In addition, information fragmentation within project documents has always been an obstacle to information sharing and exchange among different participants and different phases.

Building Information Modeling (BIM) is known as an innovative approach to modeling building information in a 3D object-oriented model. The purpose of BIM is to visualize the physical and functional characteristics of design and construction, so that the design intent and program can be easily understood and automatically evaluated via its digital representation. Currently, BIM has been recognized to be essential in AEC industry for its capabilities of managing, sharing and exchanging information among project participants throughout the project lifecycle. As a data-rich shared resource, BIM can lighten the load of re-gathering or re-formatting information, by classifying and standardizing design and planning information, which usually fragmentally exists in a variety of phases and aspects of a building project. Besides, the International Alliance for Interoperability (IAI) [6] is one of the initiatives for collaborative working in AEC industry. IAI has developed Industry Foundation Classes (IFC) as a standardized data structure for representing information used in BIM. Currently, the IFC data model has been widely adopted in the developments of BIM applications. The model defines an integrated schema to represent the main physical and logical building objects, including their characteristics and their inter-relationships in the form of a class hierarchy.

In the development of model-based information integrating systems, however, research efforts are still focused on the integration of design-related information instead of the actual requirement of information management in the construction phase [7]. From a project planning perspective, the ideal world would be the one in which an architect and a project contractor are able to exchange building information model data between their applications in a seamless fashion. Although the model schema of building product is now available, standards in construction management domain still need to be defined. The IFC hierarchy covers the core project information such as building elements, the geometric and material properties of building product, project costs, schedules and organizations. However, the current IFC is still incapable of providing sufficient information required by the construction activities [8]. Thus in facilitating project planning, more construction knowledge and project information should be implemented in BIM to effectively process construction documents into project plans. As a core of information integration for project planning, an ideal integrated BIM does not merely consist of physical components of a building. The information of construction and management activities linked to the relevant building components should be described as well. In addition, the relationships among the building components and activities are also crucial to an integrated BIM [9].

3. MD CAD MODEL

3.1. The framework of MD CAD model system

The proposed MD CAD model system will be developed as a computer system, which will focus on conducting project information and decision supports for project planning. The MD CAD model will be adopted as core project information repository, where initial project data from various design/contract documents will be retrieved and further transformed into the information required for the execution of the project.

The diagram in Fig. 1 shows the framework of the MD CAD model system. According to this diagram, the multidisciplinary data generated by various project participants is collected in pre-construction phase. These data are then used to create the MD CAD objects an IFC-based CAD system. The MD CAD model is composed of these MD CAD objects. In order to present the information of construction activities and specifications in the MD CAD model, this paper starts with analyzing the discrete processes undertaken within building construction. These essential characteristics of the work items and building components are defined in the property sets of the MD CAD objects. After the creation of the MD CAD model, the information described in the MD CAD model will be exported to a project database. Thus, all project-required work can be identified on the basis of collected work items in the MD CAD model.

In the model, even though the work items described in the MD objects can present the construction contents, they are still incapable of generating information on activity items. This limitation arises because the relationships between work items and activity are not established. Moreover, since the component-based modeling approach defines the components' structure in BIM model from the perspective of building design, the graphics objects used in BIM can only used to show the ultimate appearance of the designed building. In order to transform the project data into the information for project planning, this research proposes an activity-based modeling approach as a mechanism of information transformation. In this transformation mechanism, a scope hierarchy structure is established to define the activity items in a consistent formation. This organized manner will assist in integrating project information into a standard format for cost estimating, project scheduling and project control.

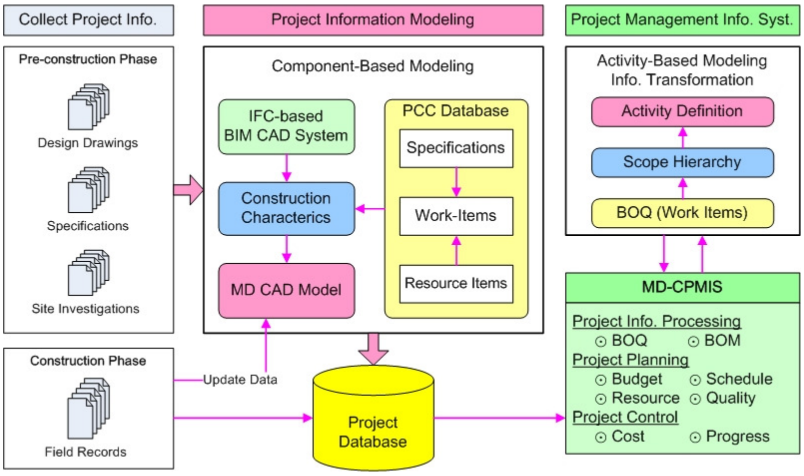

Figure 1. The framework of MD CAD model system

In the MD-CPMIS system, project information such as BOQ (Bill of Quantity), BOM (Bill of Materials), and resource requirements can be produced efficiently and accurately to support future budget and schedule planning. In addition, during the construction phase, the filed records are recorded in the MD-CPMIS to assist the project team in cost and schedule control. Based on the project performance evaluations, the project plans can be modified according to the performance indexes such as CPI (Cost Performance Index) and SPI (Schedule Performance Index).

3.2. The creation of MD CAD model

A MD CAD model is an extension of a BIM model, which incorporates multi-aspects of construction information required for project planning and management. The attributes of a MD CAD object are divided into geometric, containment hierarchy, and behavioral aspects. Figure 2 demonstrates the structure of a MD CAD object's attributes.

- In geometric aspect, the attributes include the coordinates, measurements, and physical relationships of a building component. This information is obtained from the BIM CAD system. The measurements information will be utilized as a reliable source in quantity estimation for a project. The physical relationships between building components can be used to generate an optimal sequence of construction, this sequence can be further served as a basis on scheduling [10].
- In the containment hierarchy, the MD CAD objects are classified into physical, spatial, and logical objects. The physical objects include all the basic building elements, such as slabs, columns, beams, walls, doors, windows, and etc. The spatial objects include spaces and zones. Generally, a space is bounded by several building elements, and a zone is consisted of spaces. Within the structure of logical objects, a building floor contains the physical and spatial objects, a building contains the building floors, a site contains the buildings, and a project contains the sites. This containment hierarchy defines the model structure of the MD CAD model.
- In behavioral aspects, the construction contents are described by the work items in an appropriate level in the containment hierarchy (as shown in Figure 3). The work items employed in this research are classified and encoded according to a hierarchical standard code. Based on the standard code of a work item, the information of the corresponding specification and resource items can be obtained. In this research, the Public Construction Master

Codes announced by the Public Construction Commission (PCC) in Taiwan [11] are adopted as a work item database. The PCC Master Codes are developed with reference to CSI MasterFormat of the United States. By applying the master codes of work items, the information of specifications and resource items in the PCC database may be applied in the MD CAD model. Moreover, project teams can establish their own construction information database and develop knowledge management system by using the PCC's codes.

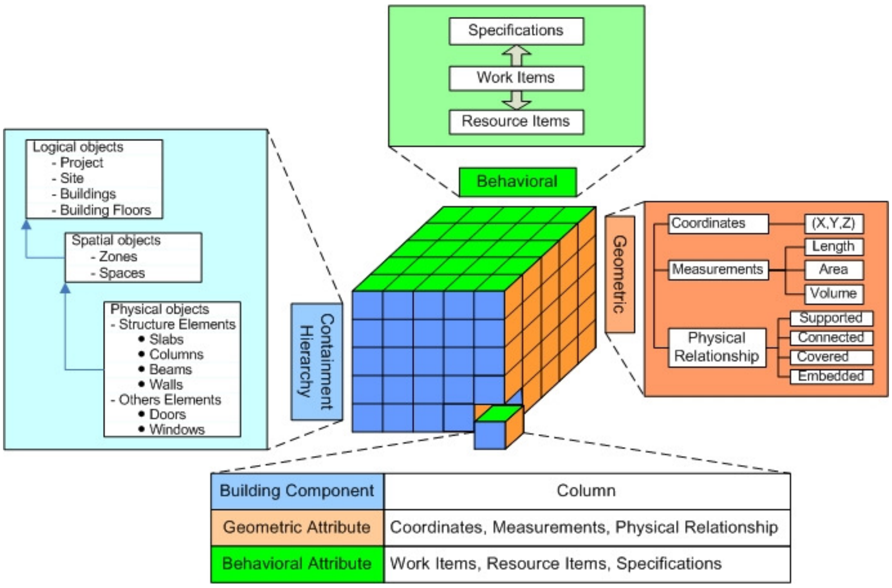

Figure 2. The structure of a MD CAD object's attributes

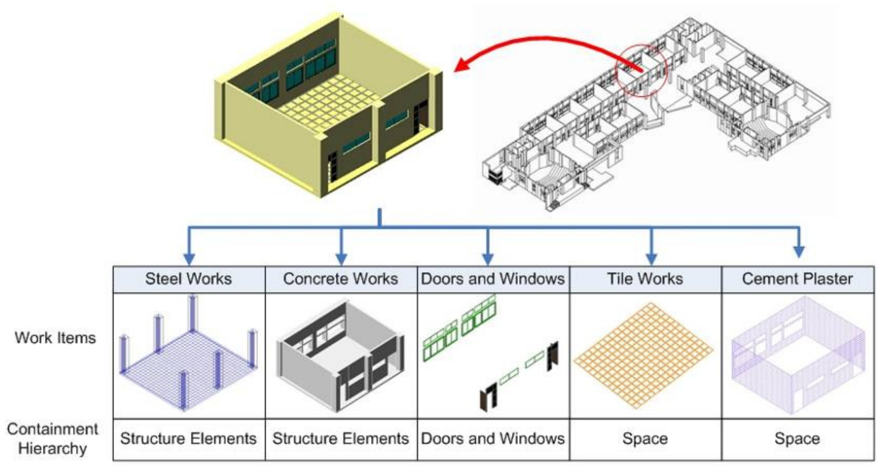

Figure 3. The analysis of construction contents

3.3. The information transformation

A common technique used to understand and organize complex tasks is to break the project-required work into smaller pieces (divide into subparts). In construction, this technique is applied in both planning and estimating. This step is accomplished by separating construction into its incremental parts. They are referred to as construction activities in this research. To create a construction plan, all of the activities necessary to accomplish the project are first identified. Activity descriptions should be concise and unambiguous. The description communicates the scope and location of the activity. In practice, activity items are seldom listed in the contract documents, but are necessary for evaluating requirements and developing project plans. At the most detailed level, each activity item is usually related to and performed by a crew. The planner develops the activity description by defining the type of effort required to construct a work item. To complete a work item, multiple activities may be necessary. Activity descriptions should be as complete and accurate as possible to lend credibility to the project planning and aid in later review and analysis.

In order to generate the information for project planning, this research proposes an activity-based modeling approach as an information transformation mechanism (as shown in Figure 4). All project-required work could be identified on the basis of collected work items in the MD CAD model. In order to define the activity items in a consistent format, a scope hierarchy structure, which is a hierarchical breakdown of the activity scope is established for this purpose. It provides a common, ordered hierarchy framework for summarizing information and for quantitative planning and management. Thus, the activity items could be consisted of the following levels of detail: element, space, zone, floor, building, site, and project, which are corresponding with the levels in MD CAD model structure. After the project-required work is analyzed and broken into the activity items, each activity item can then be quantified prior to project planning. As depicted in Figure 4, the activity items in 1F_structure_ engineering may include: 1F_Z1_Structure Steel Works, 1F_Z1_Structure Form works, and 1F_Concrete Pour Work. According to the work item breakdown analysis, the 03210_42001 Reinforcing Steel can be further divided into resource items such as materials (M0321042031 product, steel bar, SD28, fy=28kgf/mm2), labor (L7122090002 steel bar worker), and equipment (E3814005001 crane, 50~59t). Also, the Master Codes of the work items 03210 can be used to link the specification of Reinforcing Steel.

4. COMPUTER IMPLEMENTATION

This research applies the AutoCAD Architectural 2008 for the creation of the MD CAD model. In order to facilitate the process of creating project's MD CAD model, the prototype of the MD CAD objects are systematically saved in a MD Object Database. The diagram in Figure 5 demonstrates the development process of a MD CAD model. After the MD CAD model is created, the data collected by the MD CAD model will be exported to a database file, which will further be applied in the MD-CPMIS system to provide better information integration for project planning and control. There are five major sections in the MD-CPMIS system:

1. *General Information*: In this section, the general information of the project such as project name, project number, site address, construction date, and contract total cost is recorded.
2. *BOQ and BOM* (as shown in Figure 6): The quantity take-off is an important part of the cost estimate and schedule planning. In this section, based on the project database imported from the MD CAD model, project information such as BOQ (Bill of Quantity), BOM (Bill of Materials) and resource requirements can be efficiently and accurately produced. The activity items can be identified on the basis of the project-required work items. Descriptions are created to describe the scope and material requirement for each activity item. The unit cost for each activity item is developed as a direct cost with separate cost for the labor, equipment and material components. The number and detail of the listed activities will vary from job to job and will depend on the intended level of planning. This detailed review enables the planner to formulate a construction sequence and duration.

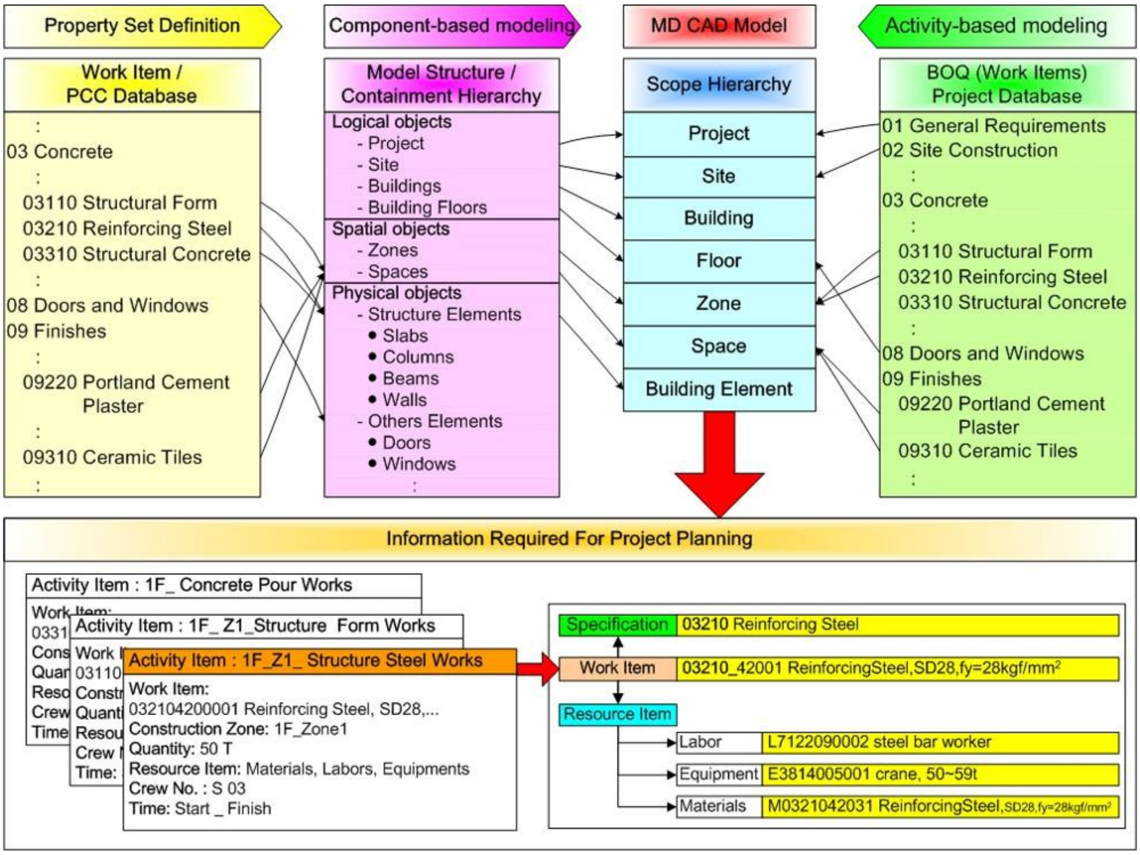

Figure 4. Activity-based modeling process.

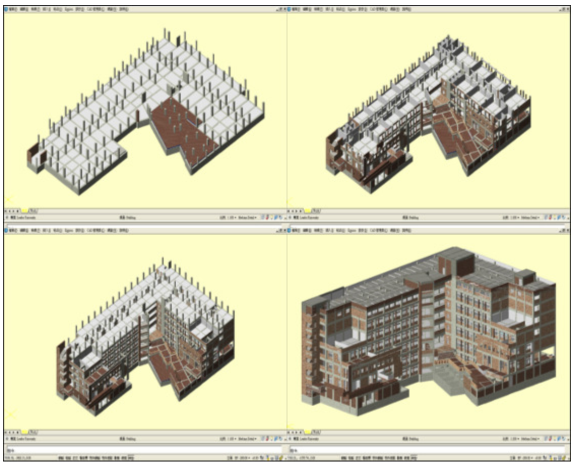

Figure 5. The development process of a MD CAD model

3. *Project Scheduling* (as shown in Figure 7): In project planning, the duration of an activity is estimated according to both the quantity of work to be done and the work production rate. The work production rates are determined based on the labor and equipment used to perform the task. The system supports the modification of the work production rate to allow a more flexible planning. MS Project is used for scheduling; and the outcome will then be transferred back to the system. In addition, information of the cash flow analysis is also provided in this section.
4. *Site Record*: The system is capable of generating the daily filed records for tracking the construction work. The information includes the completion of work items, resource consumption and cost.

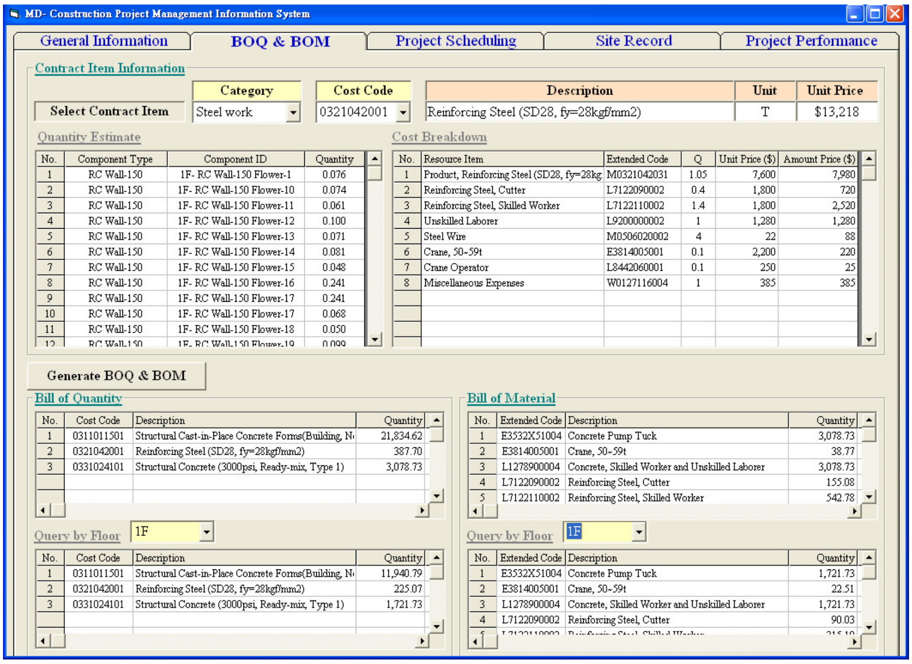

Figure 6. The *"BOQ and BOM"* section in MD-CPMIS.

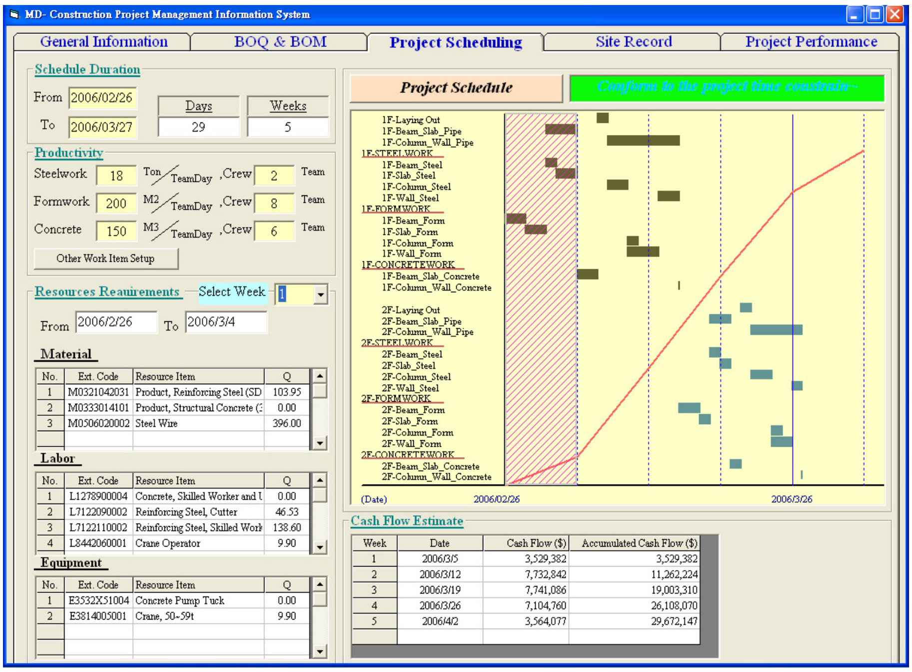

Figure 7. The *"Project Scheduling"* section in MD-CPMIS.

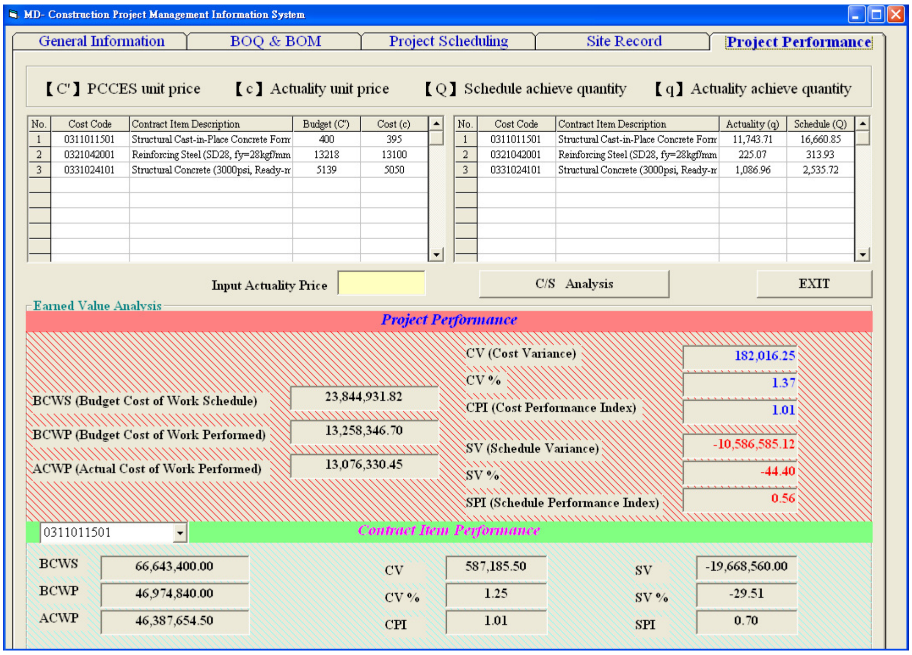

Figure 8. The *"Project Performance"* section in MD-CPMIS.

5. *Project Performance* (as shown in Figure 8): Effective planning requires continuous monitor so that the manager can make forecast and revise plans to maintain the proper course toward the objective. In this section, the data obtained from "Project Scheduling" and "Site Record", such as weekly scheduled completion, budgeted cost, actual completion, and actual cost, will be used in earned value analysis. The cost and schedule variances assist in evaluating and controlling project risk by measuring progress in monetary terms.

5. CONCLUSIONS

This paper presents a model-based system that employs MD CAD model to streamline information transformation for construction project planning. The MD CAD model consists of MD CAD objects, ensures the consistency and efficiency of information integration. In addition, extending the functionalities of BIM, this research proposes an activity-based modeling approach to define the activity items in a standard format for cost estimating, project scheduling, and project control. The MD-CPMIS system has demonstrated the efficiency and feasibility of the proposed approach in project planning and control. In the future, the results in this research will assist in developing an automating planning system.

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