

# Development of a Support Tool for Cost and Schedule Integration Management at Program Level

H. J. Yang, R. Z. Jin, I. J. Park, C. T. Hyun

**Abstract**—Government has promoted development of megaproject to revitalize urban regions. However, many problem such as large-scale budget investment and increase in the incomplete elements of project schedule management have happened. In particular, as the project management information system (PMIS) is meant for managing a single project centering on the construction phase, there is a limitation in the management of program-scale businesses like megaprojects. Thus, a program management information system (PgMIS) that includes program level management technologies is needed to manage multiple projects.

In this study, a support tool was developed for managing the cost and schedule information occurring in the construction phase, at the program level. In addition, a case study on the developed support tool was conducted to verify the usability of the system. With the use of the developed support tool program, construction managers can monitor the progress of the entire project and individual subprojects in real time.

**Keywords**—Cost-Schedule Integration Management, Supporting Tool, UI, WBS, CBS, introduce PgMIS (Program Management Information System), PMIS (Project Management Information System).

## I. INTRODUCTION

WITH the recent horizontal development overload in urban areas, urban regeneration and reconstruction projects have been undertaken in the direction of high density and complexity. In addition, megaprojects for urban reactivation have been expanded to apply to government-led municipal- and civil-development projects, and the importance of program unit businesses like megaprojects has been highlighted [1].

However, there is a lack of skills and experience of managing large business like a business dealing with units of program; whereas, there are many difficulties in doing business due to the factors such as costs for large-scale project and construction, prolonged period of business and construction, lack of existing data and complicated relations of involved subjects.

The ongoing project, 'the Three-Dimensional-and-Complex Space Development for Urban Regeneration', aims at incorporating and managing each of the business costs and the business schedules throughout the whole working process so as to accomplish the entire project's efficient operation.

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This project would be carried out in the field of program unit business, which has the goal for revitalization of urban areas.

In connection with this, to improve the inefficient business processes between the project participants, to maximize the business efficiency, to manage the business information occurring in the entire construction phase, and to provide administrative support through the promotion of a paperless environment, a project management information system (PMIS) is being operated [2]. PMIS, however, has limitations in supporting program unit businesses like megaprojects, which require management in the entire business phase, because it can manage only the construction phase of a single project. Accordingly, understanding of and approaches towards single project management as well as program level management that is efficient in administering multiple projects and programs are required [3]. Considering these characteristics, it is necessary to construct a program management information system (PgMIS), which can be used to efficiently manage depending on the cost inputted on a large-scale over a long period.

In this study, support tools for PgMIS were developed for the efficient management of the construction cost and schedule, centering on the construction phase for program management (to manage multiple projects simultaneously), and the results can be used for the management of the project cost and schedule. Such support tools were developed to maximize the cost-schedule Integration Management in all the phases of program unit construction projects, through application to an actual cost-schedule support case.

## II. LITERATURE REVIEW

### A. Comparison of PMIS and PgMIS

Project Management Body of Knowledge (PMBOK) of Project Management Institute (PMI) defined project management (PM) as "the application of knowledge, skills, tools, and techniques to project activities in order to meet the project requirements"[4]. Program management (PgM), on the other hand, is defined as "the centralized and coordinated management of a program to achieve the program's strategic objectives and benefits"[5].

PgMP also defined the relationship between PM and PgM. PgM is the act of creating and managing multiple projects, most of which are usually related to one another. A project may or may not be part of a program, but a program will always have projects [5]. Both PM and PgM require management technologies (i.e., PMIS or PgMIS) that are appropriate to the characteristics of each, through the differentiation of the technologies included in the system. A comparison of PMIS

and PgMIS is shown in Fig. 1.

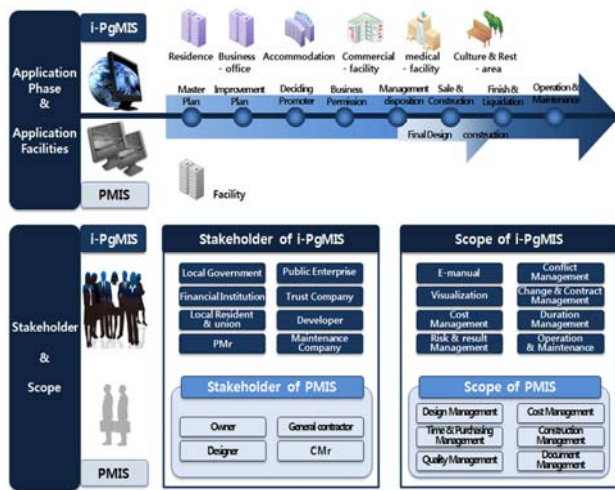


Fig. 1 Differences between PMIS and PgMIS

PMIS consists of the tools and techniques used to gather, integrate, and disseminate the outputs of the other project management processes. It is used to support all aspects of the project from initiating through closing and generally includes both manual and automated systems [4].

On the other hand, The PgMIS can manage several projects being simultaneously progressed at once, and can generate. PgMIS manage each project through PMIS System connection

### B. Integration Cost and Schedule

There are many management targets in the construction industry, and much effort is required for the planning and management of these targets. Thus, a proper management system is an essential element in this course[6].

As it is difficult, however, to link account items between the cost and schedule, the integrated management of such items is not easy. Purposes of incorporating business costs and schedules are the following: to predict the project's final construction cost and completion date as soon as possible; to estimate construction progress rate through pre-existing condition execution, and to increase the accuracy of funding spend. Accordingly, for cost-schedule Integration Management, it is most important to efficiently connect the cost breakdown structure (CBS) and work breakdown structure (WBS)[6].

The available cost-schedule integration information system for the real-time record track analysis of the project cost and progress suitable for business purposes makes it possible to share construction information and to help execute project control at the level of input cost assessment [7]. Accordingly, it can be said that to manage the program cost and schedule, total management is required. This study focused on how to manage the cost and schedule data occurring in the construction phase at the program level.

### C. BS(Breakdown Structure)

#### 1. Cost Breakdown Structure(CBS)

According to Blanchard and Fabrycky (1998) [8], The work breakdown structure(WBS) defined that CBS constitutes a functional breakdown of costs, and for the life cycle cost of a product, the entire life cycle could be considered and identified in CBS. This includes the research and development, production and construction, operation and system support, and retirement and disposal costs. Moreover, Lee et al. (2007)[9] and Le et al. (2009) [10] largely classified CBS into initial costs (construction cost), O&M costs (repair cost), and disposal costs (residual value) in their studies, which were related to life cycle cost (LCC) analysis. Further, most of the past studies on the integration of the project cost and schedule came up with a CBS that considers only the cost in the construction phase[11][12][13].

As identified in various researches, the cost items included within CBS differ depending on the characteristics of the research. This study focused on the management of the construction phase of individual projects at the program level.

#### 2. Work Breakdown Structure(WBS)

PMBOK (3rd edition) defined WBS as “a deliverable-oriented hierarchical structure of the works to be executed by the project team to attain the project objectives and to come up with the required deliverables. The WBS defines the total scope of the project.”[14].

In addition, as WBS defines and constitutes the entire work range through the BS, centering on the work output, a project element [15], there have been many attempts to establish a schedule BS and to utilize it for efficient communication in the construction phase[16].

In this study, PgM control points were established based on the process information, which serves as the standard for measuring a project's progress among the WBS components implemented in a construction management business.

#### D. User Interface(UI)

Interface management is the systematic control of all the communications supporting the process operation [17]. The user interface delivers complex tasks with help of the mutual support from computer. It also provides a variety of information according to the progress of program. This is the user interface (UI), which is defined as a channel for delivering a point of contact between humans and systems, or information between the users and each system[18].

Kim et al. (2004) [19] stated that the consideration of the usability and user in the design of the Web application fulfills an important role in the success or failure of the system. The utilization of a UI providing information on the cost and schedule is effective in the construction of an information management system like PMIS, and elevating the usability of the technologies included within the PMIS is considered even more important.

### III. COST-SCHEDULE INTEGRATION MANAGEMENT LINK MODULE

#### A. Development of PgMIS's Link UI for Construction Phase Support

Throughout the entire business, to manage the program units of detailed activities in the construction phase is very complicated. Therefore, along with a process to categorize activities, it is necessary to promote the accuracy of working process and to minimize unnecessary elements.

The program work breakdown structure (PWBS) is the program level WBS, and the project-related components of the PWBS, will be further decomposed to create a WBS for each constituent project[20].

PgMIS presents the project cost comprehensively, and based on it, the CBS standard model, a cost classification system based on 48 cost items suitable for cost-schedule Integration Management, was configured. CBS items help identify the cost in the cost items by level, and supports cost-schedule Integration Management by setting the control account. A component at the lowest level of a PWBS is called program package. A program package is a management interface between PM and PgM. Technically speaking, a program package is a management control point where the program manager's control ends and a project manager's control begins. This will typically correspond to the first or second level in the WBS of each constituent project[21].

In general, individual projects have different PMIS applied to correspondent projects, because different contractors manage each of them. Due to each different project has different elements of PMIS, the detailed elements of PMIS, which are linked to PgMIS, are also different.

Fig. 2 shows the BS of the factors configuring the entire program, and the grouped activities were set as a program package. The management scopes of the PgMIS and PMIS are shown in Fig. 2.

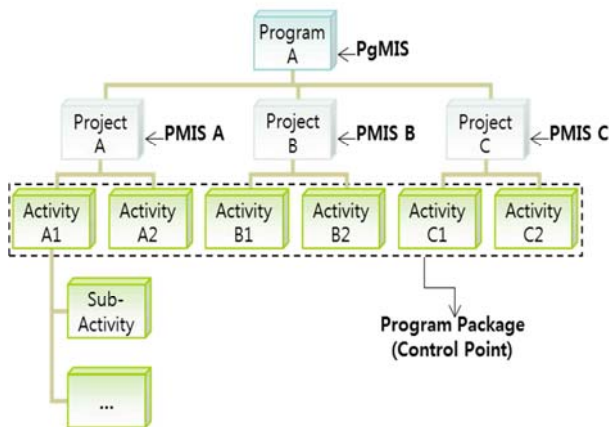


Fig. 2 Sample program package for cost-schedule Integration Management at the program level

#### B. Establishment of Program Package for Cost-Schedule Integration Management

In this study, for checking the construction progress rate more conveniently, I set Program Package into the WBS and it is the common standard of measuring construction progress rate. Also, I allocated CBS, which consisted of construction costs, depending on each activity in WBS.

Fig. 3 shows the schematized program package set on a single project among the various projects comprising the program. In Fig. 3, the program package is presented as civil engineering work, construction work, landscaping work, electric work, utility work etc. by WBS, which can be changed by the users according to the project characteristics.

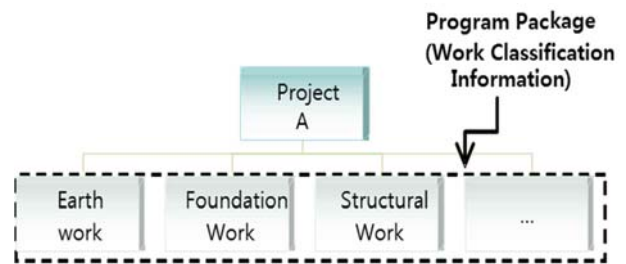


Fig. 3 Program Package for Integration of Cost Schedule

#### C. Method for Cost-Schedule Integration Management of Construction Phase at a Program level

In general, data regarding the construction cost and schedule are created by linking the details of each activity in the cost-schedule Integration Management's WBS to CBS. Linkage is not easy, however, because each activity and each cost elements does not exactly match each other.

Accordingly, an operation for connecting the cost and schedule is required. As shown in Fig. 4, the costs separated from multiple items in the CBS are grouped into activities in the WBS.

Before proceeding with a project, the contractor has to come up with detailed schedule and execution plans for the project. The owner carries out the construction work based on such plans, after examining the feasibility of the planned schedule.

As such, the plan serves as an important basis for the management of the construction progress, providing owners with baseline data on whether the construction work is implemented within the planned construction schedule and cost.

As this study focused on cost-schedule management at the program level from the point of view of the owner, the relation between the CBS and WBS, or that between a construction cost item from the CBS and the detailed activities(a WBS subproject) into which it is inputted, had to be clarified. Based on this, the efficiency of the PM can be enhanced through a prearranged progress schedule presenting the details of the construction cost distribution according to the schedule plan.

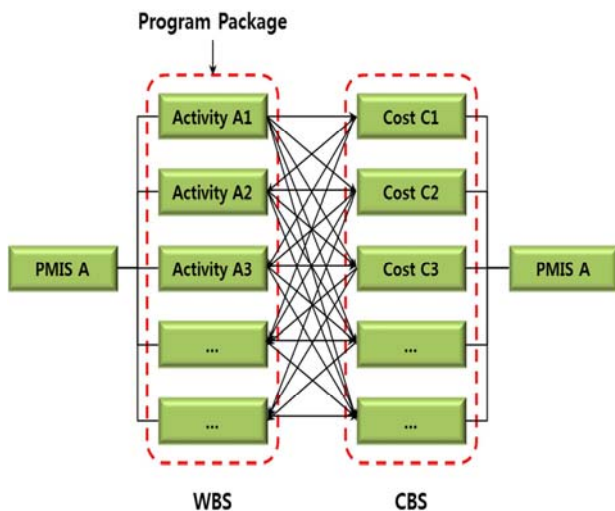


Fig. 4 Information Link between WBS and CBS

#### IV. LINKED UI OF PMIS AND PGMIS AND CASE VERIFICATION

Based on the contents described in chapter III, a UI for cost-schedule Integration Management in the construction phase at the program level was developed. The cost-schedule Integration Management support tool mainly consists of four major functions (refer to ① in Fig. 5). For the Integration Management UI, there is the Integration Management function, which monitors the entire business at a higher level, and for the Activity, Planning, and Execution Management UI. There are the Activity, Planning, and Execution Management functions, which will enable the users to carry out operations regarding the cost and schedule. Below are the detailed descriptions of these functions.

##### A. Figures and Tables PgMIS Cost-Schedule Integration Management Supporting UI

###### 1. Integration Management UI

In the Integration Management UI, the users can check the final cost and schedule progress (i.e., progress against plan [progress], execution of the plan [execution], etc.). As the Integration Management UI provides the definitive output, it is considered more useful to the managers monitoring the business at a higher level rather than to the staffs in charge of inputting the actual information.

Fig. 5 shows the Integration Management UI. In Fig. 5 ① indicates Integration, Activity, Planning, Execution Tool that are supported within the Integration Management UI for business costs and schedules. The subprojects making up the program are displayed in tap form, as in ② Data regarding the progress of the project appear in the form of a bar chart, as in ③ and ④, which appear when the corresponding project is clicked (i.e., project A). Data regarding the progress against the project plan also appear in the form of a bar chart, as in ③, and the detailed progress of each activity within the project is displayed in bar chart ④. The data included in ④ pertain to the progress against the plan for each activity, whether or not to start the

construction work at a certain point in time, etc. As an icon for selecting the project cost or progress (%), ⑤ provides the function of deciding whether to display the information on each project as cost or progress (%). ⑥ represents the revision and document management functions.

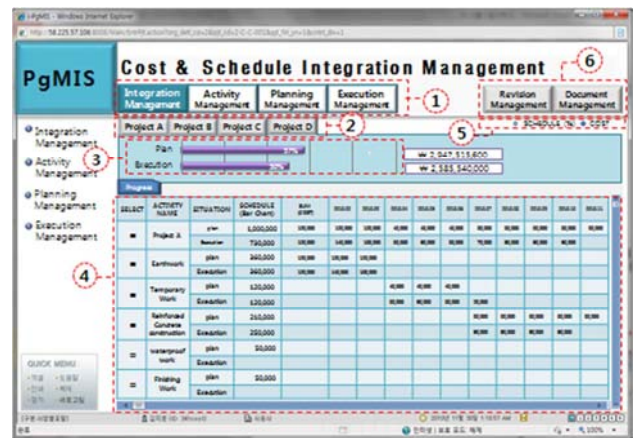


Fig. 5 Integration Management UI

###### 2. Activity Management

In Activity Management UI, the user shows the summary of cost and schedule of each project's activities through Planning Management and Execution Management. This summary is to perform the cost-schedule Integration Management of construction phase with regard to program units. ⑦ in Fig. 6 is the screen showing the list of the activities for managing projects.

Here, the users can add or delete activities. On the right side of the screen, activity period information (i.e., planned schedule) for each activity is provided in ⑧, activity cost information (i.e., planned construction cost) in ⑨, and a memo function on the applicable activities in ⑩.

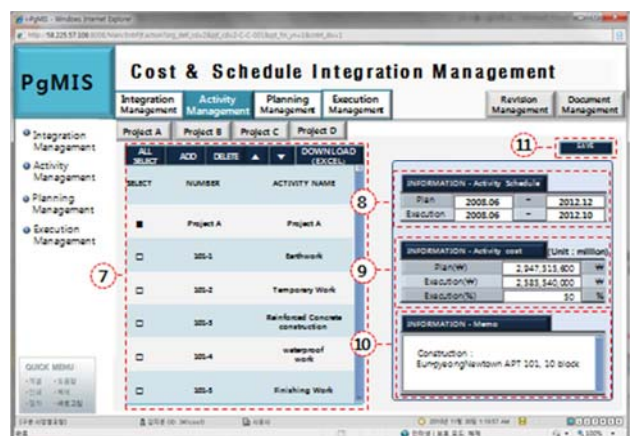


Fig. 6 Activity Management UI

###### 3. Planning Management

In Planning Management UI, the user is to set a plan on each activity in detail. Fig. 7 represents the Planning Management

UI. Each activity's cost and schedule, which are set up in the Planning Management UI, are reflected on Activity UI explained earlier with Fig. 8(i.e., starting date, end date, construction cost, etc.).

A sample UI for establishing the detailed plan for each activity is shown in ⑫ in Fig. 7. Here, the users can establish a detailed plan of how to set up monthly progress within the period in which the applicable activity is planned, and the expected cost.

Thereby, the content of the Planning Management UI is linked to the Integration Management window.

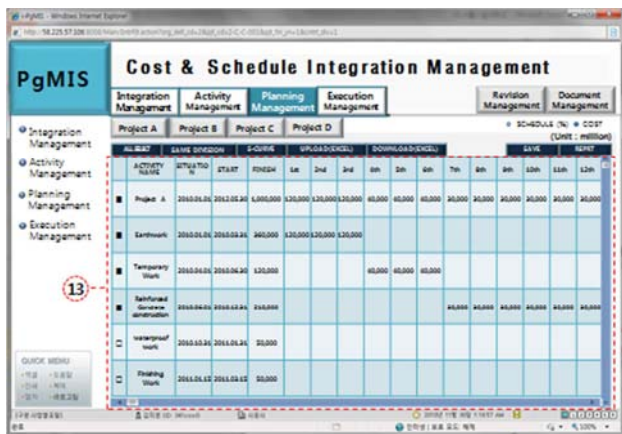


Fig. 7 Planning Management UI

#### 4. Execution Management

The Execution Management UI was configured so that the users can input the progress execution cost according to the construction progress schedule. The schedule plan and execution progress in Fig. 7 and 8 are planned for the same period. For example, the plan and execution progress is configured as a weekly unit, where "1st" means one week, and as a monthly unit, where "1st" means one month. The monthly execution progress was inputted in Fig. 8. In addition, ⑬ in Fig. 8 represents the cost planned for each cycle, and ⑭ shows the cost executed in each period. The users can input the progress (%) or cost of the activities according to the construction progress by pressing the buttons (same as ⑮ in Fig. 7) on the upper right part of the screen in ⑯.

As a result, the inputted progress by activity in Fig. 8 appears in the Integration Management UI, as shown in Fig. 5. Accordingly, program managers can figure out the entire construction progress through Fig. 5, and can check the progress of each project and that of the activities included within the project.

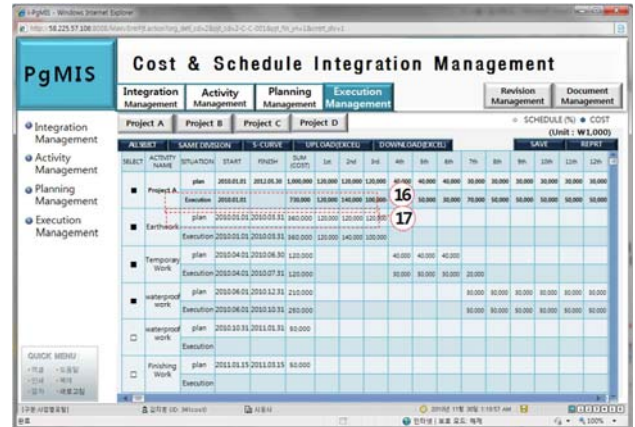


Fig. 8 Executing Management UI

### B. Case Application & Verification :System Connectivity verification through the E New-Town Project

#### 1. Overview of the E New Town Project Used for the Case Study

In this study, a PF project of the central commercial district in a new-town urban-development area was selected as a case application target area. The target area that was designated as a restricted development area (green belt) was the underdeveloped region in Seoul, where an urban regeneration and maintenance project was recently carried out.

According to characteristics of the cases whose size of mega project, I verified the systematic linkage by applying the developed supporting tool. It aims at managing effectively and systematically the construction period as well as the construction cost in the matter of the construction phase.

The business overview of this project is shown in Table 1.

TABLE I  
BUSINESS OVERVIEW OF NEW TOWN

Content	Detailed
Site	79-15 BL. 10(101dong), Jingwan-Dong, Eunpyeong-Gu, Seoul, Korea of south
Duration	06.01.2009 – 10.31.2012(48 months)
Major building use	Residence
Use Zone/district	General Commercial district, first type District Unit planned zone, Special planned zon
Scale	31 Floor
Structure	Structure Reinforced Rahmen concrete
Lot area	2,136m <sup>2</sup>
Building area	32,243m <sup>2</sup>
Totalarea	32,243m <sup>2</sup>
Construction cost	₩32,153,203,874 (32,153,203,874 won)

## 2. System Connectivity Verification through a Case Study

The system connectivity was verified through the selection of the structures used as residential facilities among new-town projects, in the four major UI functions for cost-schedule Integration Management in the construction phase at the program level.

To identify the system connectivity verification progress alone, the database (DB) used for verification was applied by correcting and presuming the actual DB specifications of WBS and CBS in a real new-town project.

In this study, verification was carried out in the order of the inputting of each activity, schedule, and plan.

### A) Planning Management

The Planning Management UI helps to establish a detailed cost-schedule plan for each activity in a new-town project. In the new-town project that was used for the case study herein, a construction cost plan was established within six months, from July 2009 to December 2012.

In the figure, we can see the costs and schedules on planning period of each construction's activities. Execution Management(Fig. 9) is shown to be associated with the information of estimated costs and schedules upon Activity Management(Fig. 10).

For reference, there was a one-year buffer time before the start of the construction work for the adjustment of the construction in the new-town project.

The UI in which the cost and schedule of each activity are planned is shown in Fig. 9.

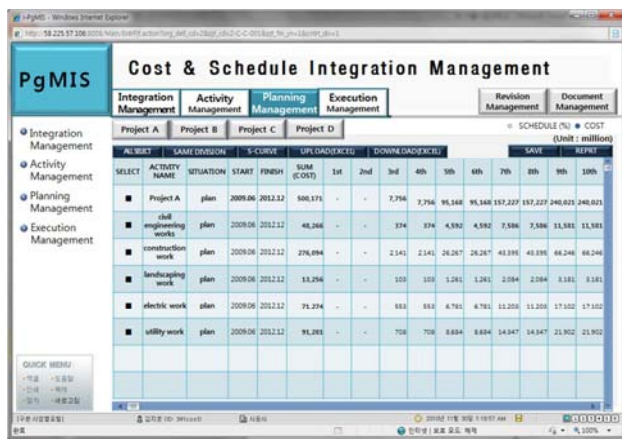


Fig. 9 Planning Management UI (Example)

### B) Executing Management

In the Execution Management UI, the Activity and Planning Management data are linked. The planned and proceeded schedules of each activity, and the execution information, are identified in Fig. 10.

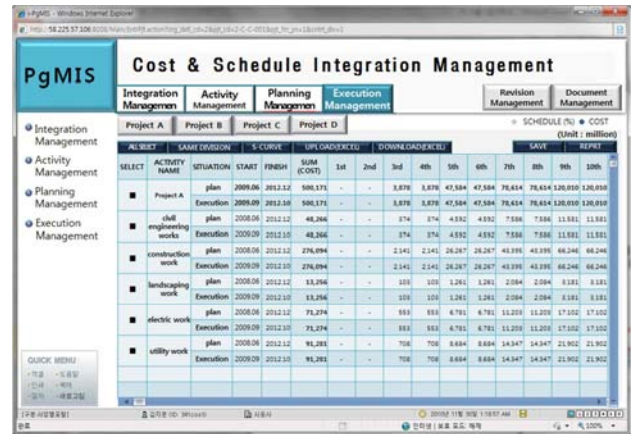


Fig. 10 Executing Management UI(Example)

### C) Activity Management

Through Activity Management UI, practitioners can check the work types that are included in 10 Block, 101 Building of E New Town Business. Here, we know that data of New Town Business is already input through Planning Management and Execution Management. Through the summarized Activity Management, we can verify that the activities of New Town Business are Civil Engineering Work, Construction Work, Landscaping Work, Electric Work and Utility Work.

A sample Activity Management UI applying the aforementioned new-town project case is shown in Fig. 11.

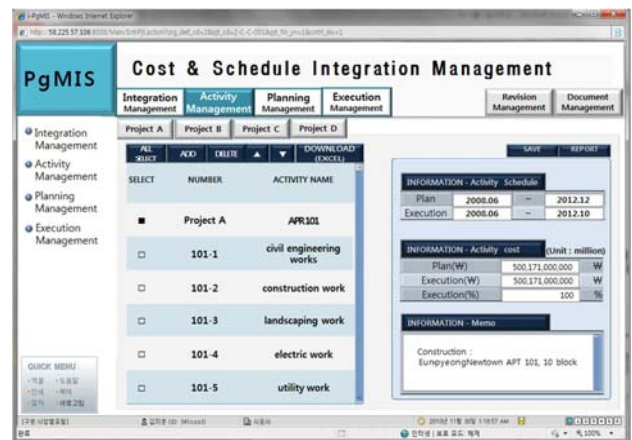


Fig. 11 Activity Management UI(Example)

### D) Integration Management

Integration Management is the UI, which can be checked by the manager through the history of new town project. Thus, it becomes the key of Integration Management for cost and schedule for verifying its linkage with integration system dealing with cost and schedule. The data regarding the planned and proceeded cost and schedule of the configured activities are linked in each UI. The data regarding the activity, cost, and schedule of the new-town application case are supported in the form of a bar chart, which can be used for monitoring the construction business status.

In preparation for unexpected risk against practical cases, I left buffer schedule, but there was no specificity regarding the buffer schedule. Instead, I could see that there was a reduction of business duration for about two months in comparison with the initially expected period of construction. The monthly execution amount of each activity can be checked in the "101-building" execution details, and the total project period and work expenses for each activity were identified.

The cost and schedule of each activity were planned at schedule intervals, and the details of the executed construction cost and schedule were the same as those of the plan. Accordingly, it was found that cost-schedule Integration Management in the construction phase can be accomplished through the developed UI.

Fig. 12 shows a case application of the Integration Management.

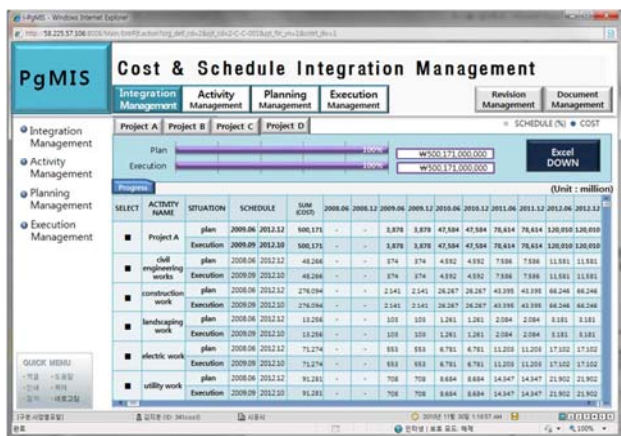


Fig.12 Integration Management UI(Example)

## V. CONCLUSION

With the activation of megaprojects, invigoration of urban economies and rearrangement of infrastructures have been actively promoted for the regeneration of urban areas. It has been difficult to conduct business operations, however, due to the lack of large-scale construction management technologies and other multidimensional issues, including long-term project periods, excessive business expenses, and conflict of interest between the shareholders. Thus, a management system for supporting the program management technology through the organic connection of the management technologies at the program level is required.

In this study, a support tool was developed to efficiently manage the cost and schedule information occurring in the construction phase at the program level, centering on the construction management in the construction phase for the development of technologies for managing the program. In addition, excellent system connectivity and cost-schedule integration were verified via the E new town project case verification of the support tool.

The following is a summary of the research results:

- 1) The difference between program management and project management was determined by reviewing the past related studies, and the cost-schedule Integration Management process in the construction phase was presented.
- 2) To efficiently manage the cost and schedule information in the construction phase at the program level, the program package was set as activities in the work breakdown structure, a standard for construction progress.
- 3) A method for connecting cost and schedule information was suggested for the management of the program package.
- 4) Based on the aforementioned process, a user interface (UI) for cost-schedule integration in the construction phase was developed.
- 5) Considering the users, an Integration Management UI for the managers monitoring the entire business at a higher level as well as Activity, Planning, and Execution management UI for the staffs in charge of the actual operations were presented.
- 6) Lastly, through verification of the system connectivity of the cost-schedule support tool, where a new-town project case was applied, the suitability and reliability of the integrated cost-schedule UI for the management of the program-level construction cost and schedule were proven.

Since in this paper, the case of E New Town Business is the only target of systematic verification, especially in term of already invented supporting tool; in order to secure the reliability of PgMIS system, it is necessary of continuous verification of many cases. Moreover, it can be considered that we would be in need of applying and verifying not only limited cases in construction phase, but also cases in the entire project.

It is expected that efficient construction management can be achieved through the utilization of the developed support tool for cost-schedule integration because the management of the cost and schedule linked to the system is carried out by program manager in real time. In addition, the progress of the entire project can be measured, and the progress of the subprojects can be monitored more closely, thereby helping manage the schedule. In particular, with excellent compatibility with Excel, information management will become easy, and the problems of information and document duplication in the existing business operations will disappear.

It is expected that the integrated cost-schedule UI will be established and used as an optimal support tool not only for construction cost-schedule Integration Management in project unit businesses but also for the efficient management of the cost and schedule in program level projects carried out on a large-scale.

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