AN INTEGRATED MANAGEMENT INFORMATION SYSTEM FOR CONSTRUCTION PROJECTS

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ABSTRACT: Current research focus in the construction industry is directed at implementation of an effective information management based integrated system environment. Construction organizations are developing methodologies of integrating information technology in the work environment of their operations. All construction process improvement strategy is based on integration of effective project planning, monitoring and control techniques provided by an enterprise level of integration of all organizational parameters, functions, members and incorporated technologies. Creating an automated information system in computerized environments via networks using web-based technology enables top-level management to visualize various types planning information to support decision making. Based on the Donation Program which, began in 1997, ITU Campus Construction Projects have been multiplying due to the increased donations from volunteer companies and individuals. Istanbul Technical University's Project Management Center, established as a research institute center under ITU Rectorate with the main aim seeking efficient solutions in planning, executing and controlling all construction projects within the university campus. The university construction projects are financed through two separate funds. PMC is responsible of managing multiple projects financed through the funding bodies, State Budget and ITU Foundation. For this purpose PMC has undertaken a research project "An Integrated Automation System for ITU Campus Construction Projects". The objective of this project was to develop an integrated information management tool for effective management of multiple construction projects consisting of monitoring schedule, cost and funding components. This paper describes the model involving the integration of an automation system through decision support utilities for multi-project analysis using web-based technology. The system formulates a process for accumulating the data (all project related documents) in a multi-project environment for multi-task decisions to achieve completion of the multi-projects on time within budget. A review of similar systems available in other countries will be discussed in detail. The paper concludes with a discussion of how the proposed system contributes to the development of the construction industry.

KEYWORDS: Information technology, web-based project management, Internet, automation, Istanbul Technical University Project Management Center (ITU-PMC).

1. INTRODUCTION

As owners demand a life-cycle approach to their construction projects, the construction industry is challenged with capturing for future use the enormous amounts of information produced during a project's life. This approach demands that project information should be exchanged, shared, and managed effectively. In this new paradigm, information systems are the enabling mechanism. The recent developments in computer technology provide new opportunities for integration of information technology (IT) applications. With the recognition that improved communication has become essential to organisational changes, the building industry is already adopting computer-aided communication. This has led to a more effective usage of the large amounts of information and knowledge that have become

available electronically since the introduction of computer applications. Integration of computer applications implies communications between the applications. Luiten et al. (1997) points out that application integration is only possible when information and knowledge are available electronically and further automation is only economically feasible when information and knowledge input is automated.
IT comprises many techniques, methodologies and paradigms, which have considerable potential for improving the management of information within the construction industry. The vast topic of IT includes general artificial intelligence systems, knowledge-based systems, intelligent decision-support systems, and the ever-popular Internet, which are fields that are continually growing independently, but proportionately with each other. The ever-growing attention given to information resources suggests that better management of these resources become critical to project success. Dutton et al. (1996) present their views on future research concerning the Internet and knowledge-based systems for the construction industry. They emphasise the need for fast, efficient, peer-to-peer communications facilitating easy supply of information and knowledge when virtual teams through remote working require it.
Björk (1994) points out that, in establishing the infrastructure for data structuring and transfer standards for computer integrated construction (CIC) applications, digitised construction information services and changing patterns of organising projects become critical issues. Currently, construction companies are occupied with a variety of research and development efforts toward the improvement of transformation processes. Executives address the need for intelligent integration of information in supporting decision-making for effective management in all stages of design and construction.
In recent years, one of the most common topics in the construction industry is multi-project analysis and reporting. Changes in the economy have resulted in fewer mega-projects, allowing organisations to take on the challenge of managing their own projects more effectively. To meet this challenge, there is a need to establish management information systems for multi-projects programs. Krizel et al (1996) points out the one of the main problems encountered within the contractual approach used and experiences accumulated from the multiphase reconstruction projects of the Technological Institute building on the Northwestern University Campus in Evanston, Illinois was the strong need for effective management at all levels with continuos communication among all parties and the authority to render timely decisions.
The model and processes discussed in this paper aim to show the establishment and implementation of a management information system for executing multi-project programs and the integration of software packages to produce multi-task reports for top-management purposes of the Istanbul Technical University Rectorate throughout the construction projects' life cycles within the campus.

1.1 Information Technology in Construction

The exchange of information in computerised environments now covers new research areas in information modeling, such as computer-based documentation, the construction of information models, the development of product models and computer integration of design and construction knowledge. The major approaches to information modeling in construction are *data modeling, activity modeling, and product modeling.* Aquad et al (1993) suggests that data modeling allows the identification and modeling of information for a certain domain (for an exact construction work). Activity modeling is used to model processes such as design, procurement, estimating and planning, and data and materials flow between these processes. Product modeling can be considered as a sub-set of data modeling and can be used to model the components found in a particular product and their relationships (a building is an example

of a product). The product model contains information for all-life-cycle stages and for all participants in the building process. Björk et al. 1989 points out that product modeling builds on the strengths of integration. Classification (and coding) of building products, activities, and construction resources has proved its usability in practice; its division into categories and its terminology can be a basis for product models. The major standardisation effort in product modeling today is ISO-STEP, the international Standard for the Exchange of Product-model data (ISO/TC184, 1999) by the International Alliance for Interoperability throughout its Industrial Foundation Classes (IAI/IFC, 1999) and UN/EDIFACT (UN/EDIFACT, 1999). Eastman (1999) points out that the work in building product models beyond the need to develop the appropriate semantics for representing the building data needs to address the information flow issues arising from the current procedures of architecture, engineering and construction practice. Eastman (1999) offers scenarios common to building practice and an analysis of the information flow issues named Information Exchange Architectures. Gorlick and Froese (1999) developed a prototype distributing Computer Integrated Construction (CIC) system to model building product and process information using IAI standards. Ma and Chen (1999) proposed a model of collaborative environment for building construction project toward computerisation of total information based on the usage of LAN.

The increasing technical complexity of projects creates a demand for the integration of construction project information. The development and deployment of new construction industry software applications, improvements in network technology, the application of robotics to the building process, the development of new modeling methodologies and languages and the definition of standards for information exchange all create new opportunities for integration. Turk (1997) suggests that information technology has assisted the collaboration and coordination of many professionals. The nature of the construction industry is such that virtual teams are often brought together for projects before being broken apart again upon completion. The software applications used may also vary from one construction project to another. The organisations and individuals forming the team contribute to the project with their specific skills and resources, which may include legacy applications and data. The collaboration effort created by the team environment must therefore be carefully co-ordinated and managed.

The introduction of new communication technologies such as the World Wide Web (WWW) is creating unique opportunities for project teams to develop new coordination and communication strategies. Of particular interest is the capability of teams to interact remotely in a virtual team environment. Specifically, researchers are focusing on the capability of the World Wide Web to serve as a facilitator of remote team interaction. The decision to use the WWW as a project information center generates important issues regarding the amount and type of information to be placed on the pages. Coleman and Mroz (1997) suggest that as project management begins to move onto the Web, its functionality is evolving once again. The vision for a Web-based application is a project database intranet/internet server providing easy but secure access through distributed clients. These range from using the Web as a means to simply share project information to the creation of innovative redesign of the application to support a collaborative work team environment. Internet equips project management software with the ability to directly publish project management schedules and related reports to a web server, which offers tremendous benefits to organizations. These reports can be viewed through a regular web browser, which is virtually device independent and can be distributed to any part of the globe.

1.2 New Trends in Project/Construction Management – Application of Web Technology in Construction Management

As our society and businesses become more complex and distributed, there is a greater need to manage projects across time and space. The WWW and intranets now provide a less inexpensive way to transfer information and collaborate in a distributed manner, so it is no surprise that many users and vendors are looking at these infrastructures as a way to manage distributed projects. With the need for better information management and project control throughout the construction process, firms within the construction industry are embracing change in the form of Internet-based project web sites (also called project extranets) to communicate project in a fast, cost effective and efficient manner.

In the construction industry, project success relies heavily on timely transfer of information. The WWW provides new opportunities for the development of distributed systems. These systems can cross the organizational boundaries and provide a unique opportunity for teamwork and workflow automation among otherwise isolated entities. Some examples of the content of research conducted in this area is as follows:

Dikbas and Yitmen (1998) developed a model of approach showing an example of an integrated management information system in multi-project scheduling using a collaborative web-based project management tool for Eastern Mediterranean University's campus construction projects. The current research project concerning *Management Information Systems for Istanbul Technical University Construction Projects* involves decision-support utilities for communicating, organizing and managing project information using web-based technology and the network (Dikbas et al, 1999). Rojas (1999) developed a model called "Field Inspection Reporting System" of the Boulder Campus of the University of Colorado for reporting and implementation and evaluation of a web-centric system that supports inspection. Al-Reshaid and Kartam (1999) suggests a web-based Information delivery Intranet Site as a complimentary communication tool that would enhance the delivery and exchange of information on the Special Projects Administration (SPA) of the Ministry of Public Work in the State of Kuwait construction projects. Saad (1999) discusses a new interactive multimedia system that can be used by different project members to document and report progress in construction projects as well as a tool to analyze the progress and help predict the final project outcome. Ahmad and Nunoo (1999) present a model of data warehousing as an emerging database management technology to provide resource for decision making in the context of construction organizations.

2. DEFINITION OF THE CASE – ONLINE CONSTRUCTION MANAGEMENT SYSTEM

Based on the Donation Program which, began in 1997, ITU Campus Construction Projects have been multiplying due to the increased donations from volunteer companies and individuals. Reaching a total closed area of 200,000 m^2 and $80,000,000 value brings the need of an effective management of the construction investments of these multiple projects. Setting up a successful multi-project environment necessitates a comprehensive implementation plan. Multi-project management implies that data from many distinctly managed projects can be moved together for analysis and reporting purposes and that the resulting analysis can be rolled back to the individual projects. Organizations need better tools to access and analyze data across multiple-projects and report for an unlimited number of projects.

Different types of construction projects undertaken by the ITU Construction Works Office are continuing to expand. With new developments and additions to the main Ayazaga Campus, restoration projects of the historical buildings at the City Campuses, and the day to day maintenance of existing buildings, a serious need for the management of all construction related activities was recognised. This immediate need brought about the establishment of

the Project Management Center (PMC), a research and application center under the ITU Rectorate. PMC is responsible of managing multiple projects financed through several different funding bodies. Apart from the regular management activities involved in project management, such as budgeting, time management, cost management, and so forth, the most important factor in the management of campus construction projects involves the integration of such information in a format that can be transferred to the level of the Rector for effective decision-making. PMC, in cooperation with the ITU Information Systems Center, has developed an information system for this purpose.

In order to allow for the immediate transfer of previously manually kept information to a computer environment, and to minimize the time factor, the information system was initially designed as separate units. Before going into the details of the system, it is important to understand the nature of the projects, the involved university bodies, and the financial resources used in these projects.

The university construction projects are financed through two separate funds. The first fund consists of the share allocated for construction works in the State budget. These funds are forwarded to the university together with a spending plan from the Ministry of Finance. Therefore, the management of monies in this account must be in accordance with the spending plan set forth by the State. Although the Ministry allocates the monies in this account to specific projects, requests from the Rector to transfer funds between projects are usually approved. However, consideration must be given to the bureaucratic procedures involved in getting these approvals, and the fact that changes in government policy may render the approval process quite difficult, if not impossible.

The second funding body is the ITU Foundation. A large portion of the funds used for construction works through the Foundation, is an accumulation of donations. The university management is quite flexible in the utilisation of these resources, however, in some instances, the donator may set forth certain limitations to how their donation is to be utilised. The information system must also be responsive to such restrictions. In addition, some projects utilise fund from both resources mentioned above. PMC must ensure that the funds are utilised in accordance to specific restrictions.

Based on the source of financing, the projects can be broadly categorised as 3 different types. Type 1 projects are those that have been approved by The Higher Education Board of Turkey (YOK), and thereby have been allocated a specific share of State funds. The determination of the amount of financing, the expenditure and transfer of these funds are determined and controlled by the Ministry of Finance.

Type 2 projects are those that are Foundation projects in which financing is for the most part covered by donations. These financial resources can be quite flexible or project-specific, based on the request of the donator.

Type 3 projects constitute university projects that require urgent attention. Funding for such projects can be obtained through the general budget (State share), or the ITU Foundation Fund. Sometimes these projects are planned to utilise general budget resources but later are supported through donations, or vice-versa. The model therefore, not only takes into consideration these different categories of projects, but also holds a general nature enabling possible future sources of funding and project-types to be incorporated into the system.

In defining the projects, project information is expressed in two separate groups. The first group entails the common characteristics of the projects. The second group entails the project-specific information that varies from project to project. In terms of database organization, the first group uses one common table, while the second group uses a different table for each project. The aim here is to create a single project space by utilising one common table.

The definitions of resources have been done in a similar fashion. Regardless of the types of resources, they have been defined within a single table. While the details and restrictions are described for each resource, it is assumed that each project can utilise any of the resources if permitted by the restrictions defined for the resources.
In light of these principles, the 3 systems initially designed as separate modules is discussed below, followed by an explanation of how these modules were integrated.
The first system is the *construction works reports system* that enables all project-related documents (progress payments, photographs, weekly reports, meeting minutes, etc.) to be viewed in the web environment. The management module of this system allows data entered by the operators to be viewed, controlled and approved by authorized managers. Authorized users entering the system through the Web can view all projects undertaken by PMC by category. It is possible to access all documents concerning a project by simply selecting categories and entering the project involved. Documents retain their individual formats. Therefore, the system allows information created through the use of different applications to be viewed in the same environment.
The Donation System is designed ease administration of funds donated to the Foundation for construction works. Broadly, the system enables access to information concerning the donators, monies spent from each donation, and the creation of various reports that are needed by upper-level management. Similar to the Reporting System, this system also has a web-based interface. Data is entered by users and can be accessed by managers via any web browser.
The Construction Works state-funded budget projects system was initially developed under Visual Basic, and aims to automate the operations of The Construction Works Office, which is an administrative unit within the university. The system broadly aims to ease the administration of the financial management aspects of projects through budget reports, progress payments, and realistic financial forecasts.
At the stage of integrating the independently designed modules of the system, the initial step was the development of the web-based interface to be accessed by managers for support in their decision-making activities. Since the Construction Works state-funded budget system was the last module created, it was designed to allow integration with all other systems. The web interface allows direct administration of state-funded budget information, while databases from the other systems were appropriately linked to enable the use of all 3 systems on the same platform.
The proposed Online Reporting System integrates data extracted from the specific software packages (for example, software packages that are used independently for quantity surveying, schedules, budget and so forth) generating a variety of reports which become extremely important especially in decision-making at the multiple project level for the ITU Rectorate. The project management sub-modules were integrated to establish a decision-support system that minimizes the decision-making process of a human planner. This Online Construction Management Reporting System is a module of the research project “An Automated Decision-Support System Model for Construction Management Executives”. This case study is based on one of the working methods of the system modules “Online Construction Management Reporting System”. The integration of active databases and generating a variety of reports through Internet and project management tools that will interpret data automatically are the key research points.

3. OBJECTIVE OF THE STUDY

The aim of the proposed system presented in this paper is to establish a web-based management information system for multi-project programs through internet using active

databases for top-management multi-task reporting purposes throughout the construction project life-cycle. It is aimed to provide an easy and structured access to the information contained within project documentation and regulations involved in the construction project process. This kind of approach will enhance control procedures for problem recognition, combining data from different applications to evaluate performances in a multi-project environment. It is designed to assist a project manager in organizing, analyzing, modifying and reevaluating existing or needed spatial information within construction planning activities by implementing an effective process for managing multiple projects. The reporting system is capable of monitoring schedule, cost and funding components in a dynamic user-friendly environment for multi-task decisions.

4. PROPOSED MODEL AND METHOD

A LAN-based system that will provide a fast communication in information distribution and eliminate the unnecessary paper work is a primary necessity for the Online Construction Management Reporting System. The system modules enable managers and top-management easy access to data for different processing needs. The web-based schedule and cost control system provides a complete project overview, updated daily along with detailed reports. Data is password protected and available to project managers and top-management.

4.1 Report Development Methodology

The major steps in the development of the Online Construction Reporting System are as follows:

(a) Defining the structure of a progress reporting system to reflect actual projects status at any period
(b) Selecting the appropriate project management software packages to document project information including schedule, cost and contract administration
(c) Designing custom report formats
(d) Collection of field data from actual projects
(e) Recording the updated project data in the applications
(f) Producing the final report based on the updated data

4.2 Reporting System Structure and Display of the Project Information

Online Construction Reporting System is designed to be easy to use, to have access to all data and analysis procedures. The menu driven approach was designed with the assumption that the user might not have a strong computer background. The user needs to have the capability to direct the flow of information towards a desired goal.

In this model, the applications are integrated within the system through independent interfaces. Interfaces are instances of the same class for common applications; therefore, duplication of interface codes can be avoided. Each interface consists of three main functions. As displayed in **Figure 1**, (1) marks the application's specific component that allows access to the application database; (2) provides the most important function of the interface in that it allows each application to be used independently, as well as jointly, within a common format. For example, in an interface that is used for two different time planning applications, while (1) is specific to each application, (2) produces data that determines how time planning information will be stored in the system. Thereby, it filters the applications used for time planning. Part (3) of the interface saves accessed data on the system's database in order to avoid redundant repetition of the conversion processes during future queries. In multiple project environments, such as the one shown in **Figure 2**, each project is displayed through a different A-Type component. Each A-Type component is responsible for providing all information concerning the project it is linked with. For example, when the

user wants to access budget information concerning a specific project, the related A-Type component communicates with the B-Type component it is linked to in obtaining the desired information from the relevant application's database. The application (or version of the application) containing budget data may vary from one project to another. The system may therefore contain different versions of B-Type components to accommodate such differences. A-Type components are functionally capable of utilizing as many different B-Type components as necessary in gathering the required data. In order to provide fast access to previously converted data, B-Type components save status information on the system's database. If the status information shows that the converted data is still current, this data can be rapidly accessed through the system's database without going through the conversion process. B-Type components perform a status control on the data requested by the A-Type component. Based on this information, A-Type components either attain the required data from the system database, or wait for the B-Type components to perform the necessary conversions in forwarding the required data.

The main components of the Online Reporting System comprise the general information about the projects in both single and multi-project environments. Progress information includes a summary of the current status of the projects schedule, budget and expected completion date, report on the current progress this period (since last update to date), report on the cumulative progress to date (since the start of the project), report on the end forecast (expected time and cost at completion). From the main menu, the type of report based on the period as interim, annual or final is selected to reach the required formatted report. Reports are considered in two categories as both single and multi-project environment. The Reporting Section contains the Project Management Knowledge Areas for the progress documentation of the projects in a multi-layered process, with different levels of details about the project status. The total project information can be drawn from different applications and displayed into five categories as Project General Information, Scheduling-Cost Planning, Financial Planning, Custom Reports and Decision Analyzer. The user can reach the required formatted report of the project information from the list of the projects as single or multi-project. For example *Scheduling-Cost Planning Tool* comprises progress view in tabular and graphical format, *Gantt Chart*, of the active projects that are currently being worked on and also for proposed projects which have not been given approval to begin. Also the resource review in tabular and graphical format, *Histogram*, gives an idea about the resource progress, quantities and costs for each resource assignment. *Financial Planning Tool* comprises Budgeted Cost, Cost Baseline (Actual Cost and Projected Cost) and Progress Payments in tabular and graphical format, S-Curves. Budget status and variances column shows whether the project cost is within the planned limits. Each of these tools is required in order to generate a clear picture of the projects. When there is an approved change to the budget due to a change in project scope, the budget baseline should be updated to allow a true picture of the work being accomplished. **Figure 3** shows the Project General Information including project descriptions and contract documents. **Figure 4** shows the Multi-project Scheduling in the form of Gantt Chart together with the related resources review. **Figure 5** shows the Multi-project Cost Planning with a view of budget status and variances in tabular format and a view of S-Curves in graphical format.

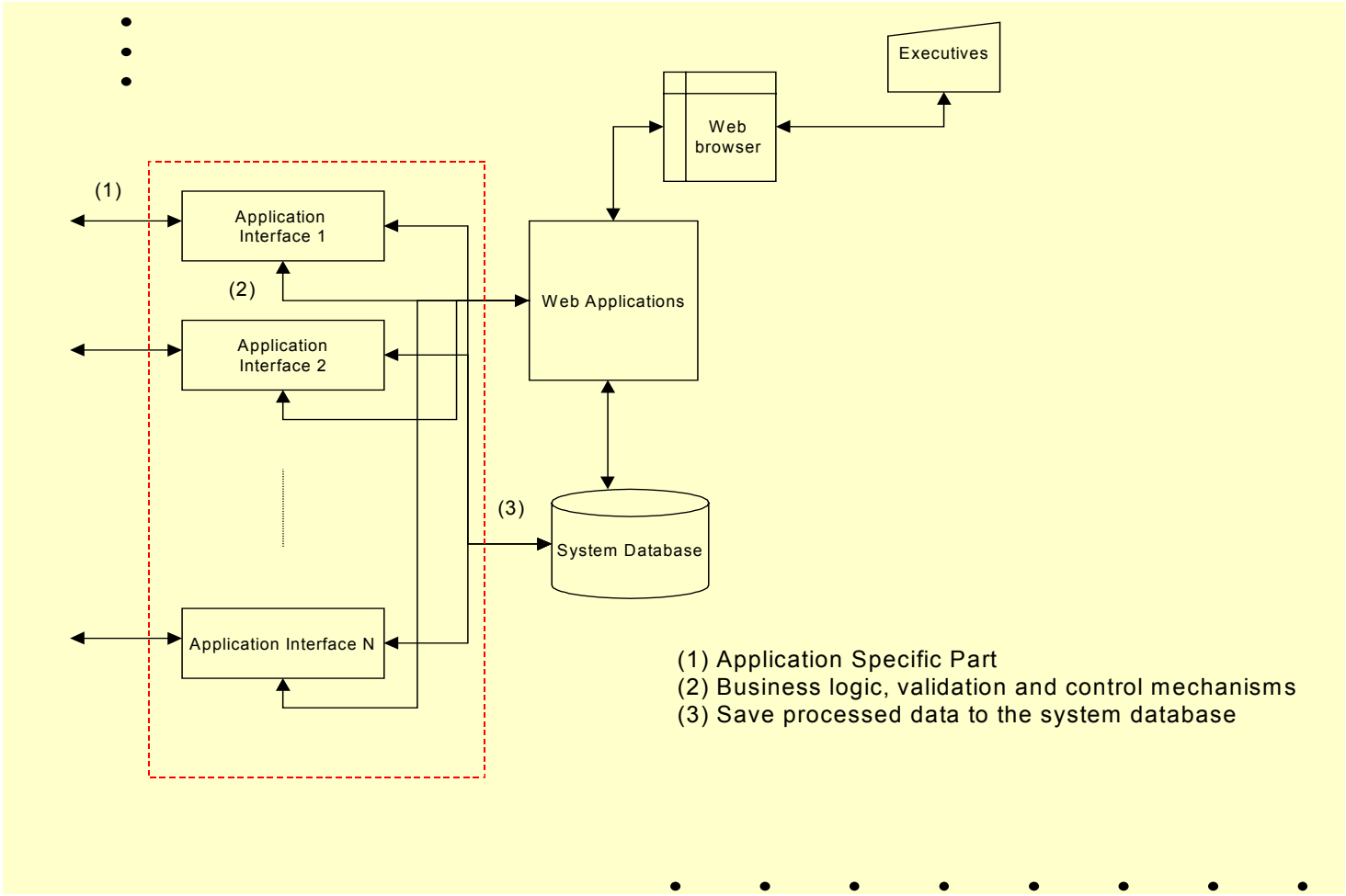

Figure 1. General Structure of the Proposed Model

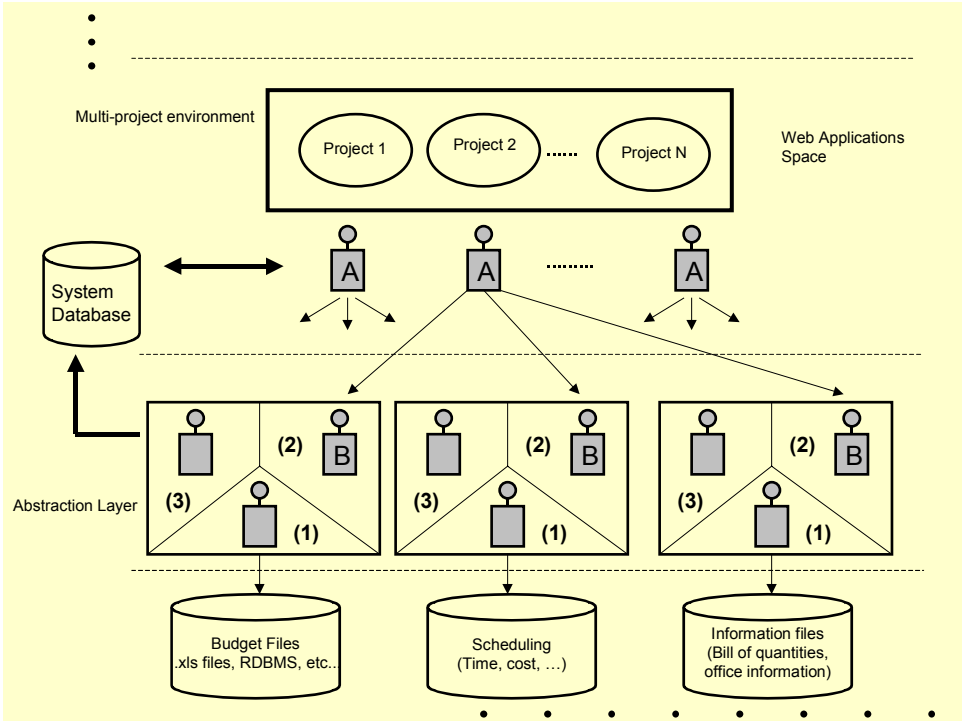

Figure 2. Operation System of the Model's Application Interfaces

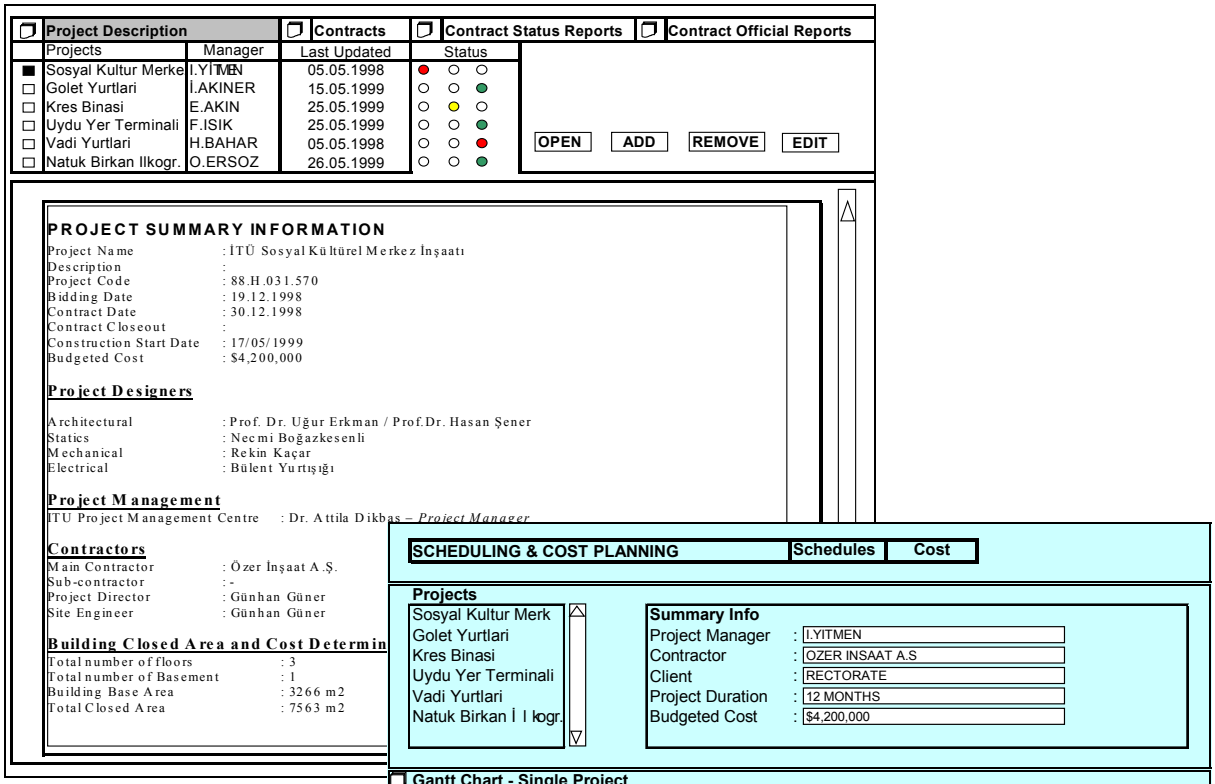

Figure 3. Project General Information

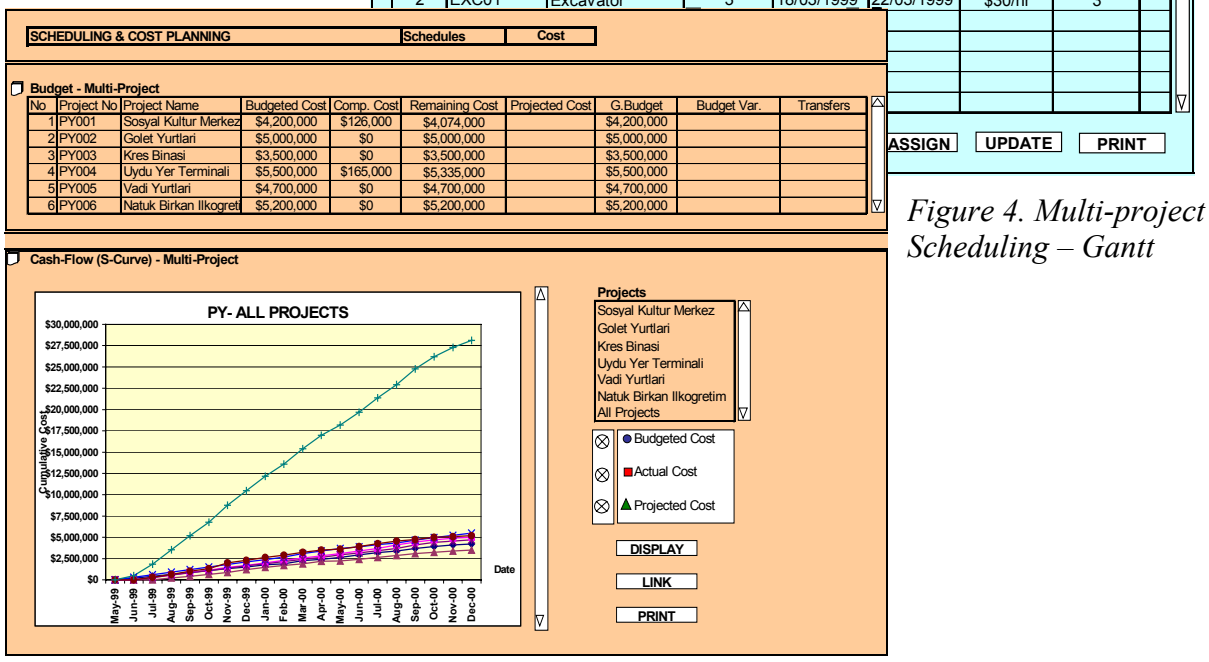

Figure 4. Multi-project Scheduling – Gantt

Figure 5. Multi-project Planning – S-Curves

5. DISCUSSION AND CONCLUSION

One of the most common topics nowadays in the construction industry is multi-project analysis and reporting. Top management needs to know in a timely and accurate manner, how is the project progressing, where they are currently in comparison to the initially set plans, whether deadlines are met, budgets are respected. This can be achieved by setting up a successful multi-project environment with a comprehensive implementation plan. Current research in information technology in construction management is directed towards the achievement of the functions in computer-based environments via networks using web-based technology. Creating an integrated automated information system for multi-project analysis and reporting enables top-level management to visualize various types of planning information to support decision making. The Online Reporting System aims to improve information accuracy and accessibility, to eliminate redundant files, to provide multi-locations access to information, to improve process efficiency since communication uses less time and fewer resources and to obtain accurate and timely information. The system formulates a process for calculating data from various software packages, accumulating this data in a multi-project environment and formatting this data to create integrated reports. The system is currently being successfully used in the management of ITU construction projects. Reports are effectively and rapidly being conveyed to management (in this case, the Rector) and tracked through the ITU network and Internet. The major benefit of the developed system is that it will reduce the existing uncertainties in the overall project control of the constructions in the university campus so that it is no more a hard task to achieve completion of the multi-projects on time within the budget. The proposed system will also contribute to the transfer of knowledge between theory and practice. Because of the degree of commitment is different between top management and site employees, online construction management will promote and support the use of good project management practices and will benchmark the quality of their service/product in order to integrate the systems.

The growing demand from industry proves that the proposed model fills a tremendous gap of information flow to upper level management in the construction industry. The Turkish construction sector is becoming aware of the efficiency benefits of this system, and approaching ITU-PMC for such customized solutions to their communication and decision-making needs. In turn, ITU-PMC is continually developing the sub-modules of the system (classification and coding structure of building product models, standardization process, and construction information documentation) in aims to offer industry an optimized system.

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