AN INTEGRATED DECISION-SUPPORT SYSTEM MODEL FOR CONSTRUCTION MANAGEMENT EXECUTIVES
Model for construction management executives

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Abstract

In recent years, with the increasing popularity of the World Wide Web, integrated data management tools have enabled organizations to automate their management information systems. The application of information technology (IT) in the construction industry mainly involves planning, monitoring, reporting and similar managerial functions that, in unison, support effective decision-making. Istanbul Technical University's Project Management Center (ITU-PMC), was established as a research institution under the ITU Rectorate, with the main aim of planning, executing and controlling all construction projects within the university campus. One of the initial activities undertaken by the ITU-PMC, in enabling an efficient and effective management system was a research project concerning *Management Information Systems for ITU Construction Projects*. The objective of this project was to develop an integrated data management tool including decision-support utilities for communicating, organizing and managing project information using web-based technology and the network. This paper describes the model that was developed to enable the effective management of ITU's campus construction projects. The model entails an automated system for the effective management of multiple construction projects, enabling efficient budget utilization by offering an elaborate decision-support system for executive managers.

Keywords: information technology (IT), management information systems (MIS), Internet, computer integrated construction (CIC), decision-support systems, web-based project management, Istanbul Technical University-Project Management Center (ITU-PMC).

1   Introduction

Compared with many other industries, the construction industry faces high levels of complexity, uncertainty, discontinuity, as well as many restrictions. The construction process involves a large number of participants, various forms of project organization, and the use of numerous different types of computer applications. These characteristics bring forth the need for intensive data exchange and information sharing based on the integration of various applications. This can be achieved through a more efficient utilization of information technology tools for the management of construction information processes. 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 emphasize 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 CIC applications, digitized construction information services and changing patterns of organizing 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.

Emerging object-oriented tools and environments offer new possibilities for the development of models for integrated management construction information systems.   The approaches discussed and the model presented in this paper aim to show how communication and decision-making in the construction industry can be improved by means of intelligent knowledge-based systems.

2   The role of distribution technology in construction information systems

Advances in information technology have created a wide range of research developments in construction. Some examples of the content of research conducted in this area is as follows:

Björk (1992 and 1993) proposes a model consisting of a conceptual model of spaces, space boundaries and enclosing structures and discusses the problems in the development of this model. Björk (1993) also presents suggestions for the integration of construction information at the document-level. Augenbroe (1993) discusses the design systems in a computer integrated manufacturing context for the construction of information models. Björk et al. (1995) present the

development of product models in information modeling, while Eastman (1993) discusses the computer integration of design and knowledge in construction.

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 organizations 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 coordinated and managed. Brown et al. (1996) points out that any integrated environment should provide a means by which the component objects contributed by organizations and application vendors can inter-operate in a seamless way.

IT researches proactively support the construction industry by offering an infrastructure for better-constructed facilities in less time and at lower costs. Researchers of this subject have suggested various methods for information integration in construction. These methods can be categorized as: communication between applications (achieved through specific software integrating a unique and invariant set of chosen applications); integration through geometry (often the case in commercial CAD packages where integration is based on and limited to geometrical information); knowledge-based interfaces (linking multiple applications and multiple databases); and integration through central project databases (holding all the information relating to a project according to a common conceptual model). Bohms et al. (1994) propose a model (namely, ATLAS) towards a computer-integrated system for large scale engineering projects. Dubois et al. (1995) developed a model (COMBINE) involving conceptual modeling approaches for HVAC and building design. Bjork (1994) presents the RATAS project, which sets an example for cooperation between industry and research towards computer integrated construction. Aouad et al. (1995) proposes the ICON model for effective building design and construction management. Effective management of construction projects depends on easy access to and control of data, especially data pertaining to cost and schedule control functions. Long recognizing the need to integrate these interrelated functions, researchers have proposed conceptual models towards this purpose. However, a functional design of an automated solution that would support the need for integrated cost and schedule control, as well as providing distributed access to data for different processing needs is generally lacking. In their data storage model, Abudayyeh and Rasdorf (1991) suggest how such an automated solution can be effectively designed and developed.

3   Web technology in project/construction management

The World Wide Web not only provides a means for information display and gathering and efficient accessibility to applications, but also grows to become a platform for design collaboration by increasing the flow of information between and within all computerized organizations. However, there is still a need for an environment in which planners can contextually visualize various types of planning information to better support their decision-making processes. Advances

in network computing are rapidly changing the way management functions are being performed. With the maturation of technologies, especially Internet-based technologies, concepts that have been proposed for Web-Based project management and software development are now realized. In recent years, a great deal of research has been carried out into the creation of integrated data management tools that enable organizations to automate systems towards product development by using web-based technology. 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.

Increased popularity of Internet technologies and applications nowadays offer new opportunities for the construction industry. Portable software modules commonly referred to as *plug-ins*, allow for the viewing and simple manipulation of data through a Web browser without requiring a commercial license of the original software application used in creating the data. These tools can be used to integrate heterogeneous distributed data from several sources on a single user's screen to support decision-making. Similarly, integrated project data management tools create a project environment based on web technology. Examples to some existing Web-based tools that are somewhat related to construction management are **MesaVista**, **WebProject (**Java-based) and **Spider**, which are collaborative project management environments designed for product development teams using Web technology for faster access to up-to-date information in their decision-making processes.

Such tools bring together the information produced by disjointed tools in an intelligent manner, on a common platform, accessible through a common interface--the web browser. Project management scheduling data can be viewed in a Java-enabled web browser and fit into overall engineering and managerial processes and organization workflow.

4   Overview of the case and problem definition

Istanbul Technical University started a donation program within the framework of the "Year-2001 Projects" which was conceptualized in 1997. The realization of numerous construction projects has been enabled as a result of the funds made available through this donation program. These projects, with a total closed area of approximately 30,000 m^2 and estimated valued of $50 Million, include dormitories, a student dining-hall, a student cultural center, a closed swimming pool, a child-care center, an elementary school, and miscellaneous renovation projects.

With such a rapid spurge of projects, a need was recognized for a system that would ensure the effective management of the donation funds in the construction of ITU's campus projects. With the main aim of enabling such management and decision-making tools, ITU-PMC initiated a research project that forms the basis of the model presented in this paper.

As a starting point, the availability of software packages relevant to construction/project management in the local market, and the suitability of these packages for integrated use was investigated. It was found that both locally

produced and foreign software packages are available and concurrently used in our country. Locally produced software packages offer the benefits of taking local conditions into consideration. Available foreign software packages can be collected under two categories; (1) those that are adapted to accommodate specific conditions in Turkey, (2) those that are generic for standard usage in any country, and not specific to Turkey.

Even though a large variety of project management software packages are currently being used in our country, when considered in an integrated environment, none of these packages are capable of complete and effective integration. They either become outdated during the duration required for adaptation, thereby losing the capability of dealing with recent changes; or the interfaces used within the applications are not capable of supporting fast and detailed transfers of information. Additionally, locally produced software packages are only capable of supporting single aspects of the construction management processes (such as only bill of quantities). The use of multiple applications in the same environment requires the use of multiple interfaces, which in most cases are only capable of transferring basic data between applications.

At the present time, it can be argued that a sufficiently effective system has not yet been developed to provide fast and accurate information transfer to upper-level management. ITU-PMC started to develop such Web-based MIS and decision-support tools with the aim of eliminating some of the deficiencies in the existing systems. The proposed system allows each participating organization to continue using the specific software packages they are accustomed to in planning and managing their projects. By integrating data extracted from these specific software packages (for example, software packages that are used independently for quantity surveying, schedules, budgets, and so forth) the system generates a variety of reports, which become extremely important especially in decision-making at the multiple project level. In the ITU context, the system has enabled the Rector to develop a variety of scenarios, based on project criteria and priorities, in establishing profitable and beneficial budget allocations in the realization of multiple campus construction projects.

5   Objectives of the study

The aim of the system described in the proposed model is to provide easy access to current information for upper-level management during analysis, decision-making, and control processes. The objectives of this project is to develop a decision-support system with multiple-criteria decision-making facilities for optimum distribution of the budget allocated for construction through donations and state funds, and to prioritize ongoing and upcoming campus projects.

The optimum model for such an integrated system, capable of performing the tasks explained in Part 4, is one that consists of a structure independent of its application components, but yet is capable of supporting each application within its system. In other words, the system must consist of an integrated network of application modules. In generating such a model, the following problems must be considered:

- There are numerous software packages that work under different systems and that do not have common interfaces.
- The above factor brings about the requirement for an enormous number of codes necessary to enable software integration.
- Rapid developments in the software industry continually render the systems outdated over very short time spans.
- Since different firms may be using different applications, the model would need to provide the required flexibility in accessing different combinations of applications.
- Considering that each client organization may have different versions of the same applications, and to ensure compatibility of new versions with previous versions of these applications, the system must have the capacity to support different versions of the software packages.

The model would need to have the following characteristics in order to offer effective solutions to the problems listed above:

- The program application can not be monolithic. The program must be adaptable to different operational systems, hardware, specific customer demands, and other such variables.
- The system must consist of independent components. Each component must have the capability of being easily installed into, or changed within, the system.
- The system must support the simultaneous use of different versions of the same applications.
- The system must be designed in a *chaotic* structure in order to support a variety of operation environments utilized by the component applications.

6   Proposed model and method

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 order to offer a more detailed understanding of the interface functions within this system, an example of a common construction management application is observed in the following sections. The area circled with a dotted

line in Figure 1 is circled similarly in all illustrations concerning this example case. This example represents any application requiring multi-project information, such as decision support systems, S-Curves, and so forth.
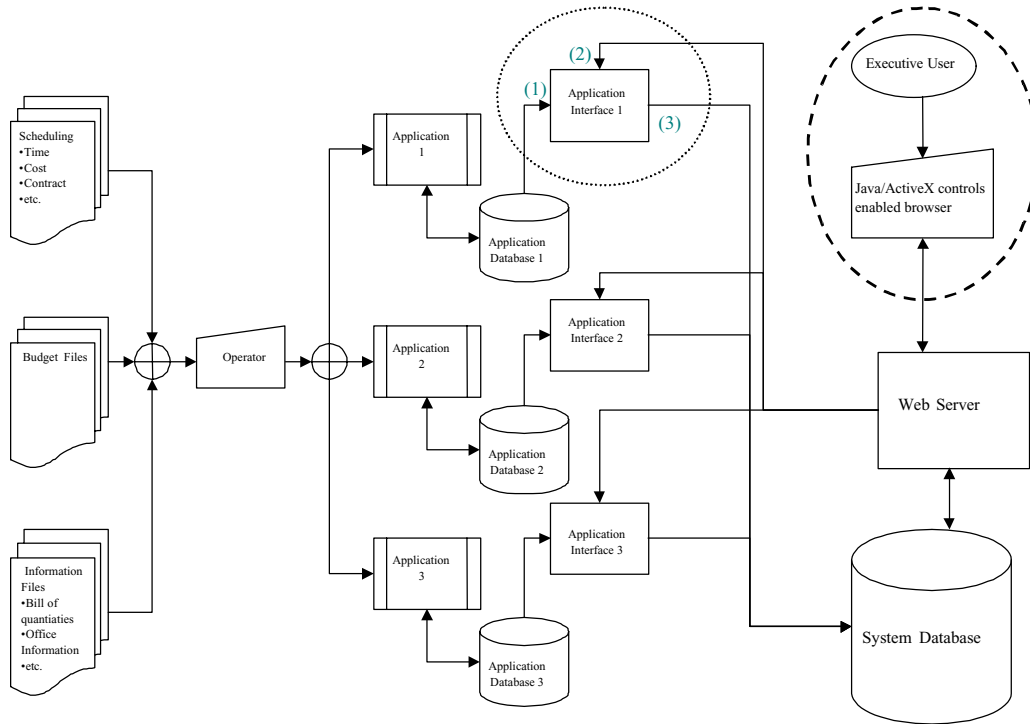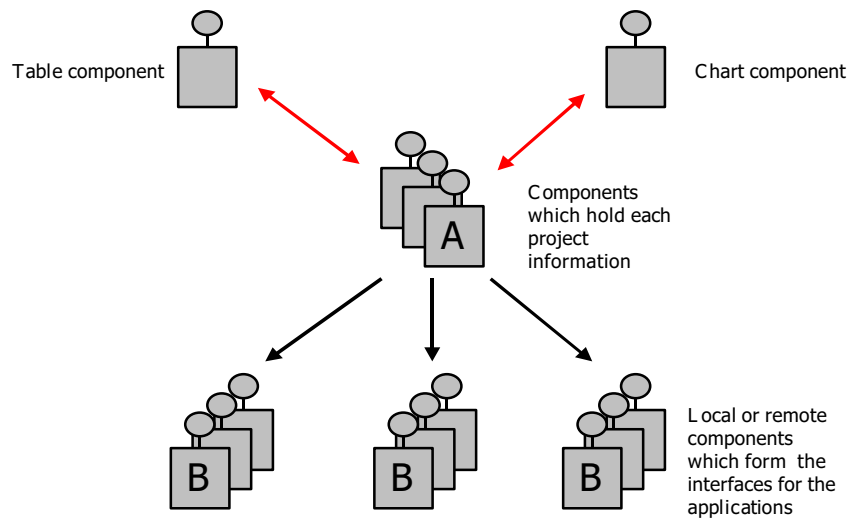

Fig. 1: General structure of the proposed model

Fig. 2: Relationship between interface components

7   Sample implementation

A user interface displaying multiple projects is an environment that consists of components that operate through different processes. The A-type components shown in Figure 2 are defined by the user application that provides the interface with application-specific data.   These components can be used in any user interface application. Figure 3 shows a sample user interface. The interface is capable of creating the S-Curve of multiple projects, and tabulating combined budget information. The application responsible for the creation of tables and charts attains all required information from respective A-Type components. Figure 2 displays the programming model within an application.

Each A-Type component is dynamically created and used to store the data of one specific project. Similarly, when its related project is not accessed, an A-Type component can be excluded from the process. A-Type components must have the capability of reading databases of different applications in collecting project data.   In achieving this function, A-Type components utilize B-Type components, which are responsible for converting data from various applications within the system into a pre-defined format. B-Type components are written specific to applications, and may support more than one application. However, the data format created for A-Type component utilization is standard.
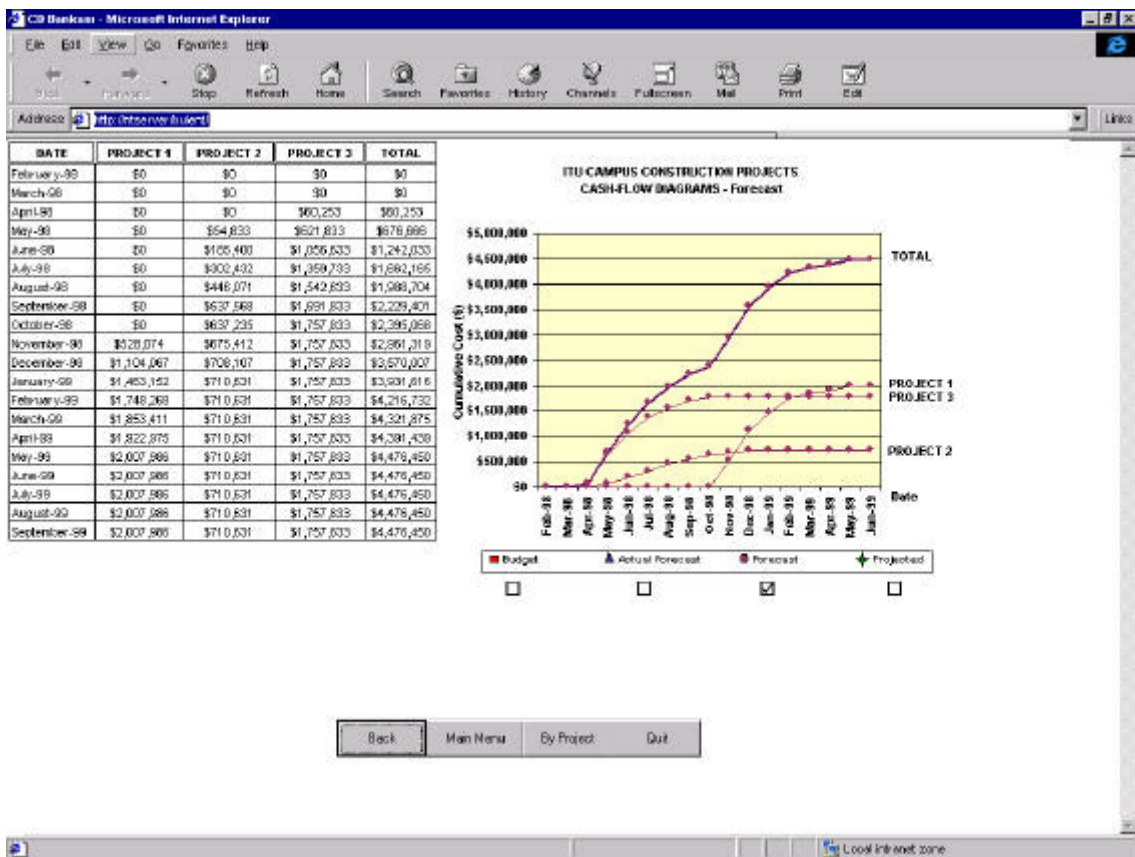

Fig. 3: A sample user interface

In multiple project environments, such as the one shown in Figure 4, 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.
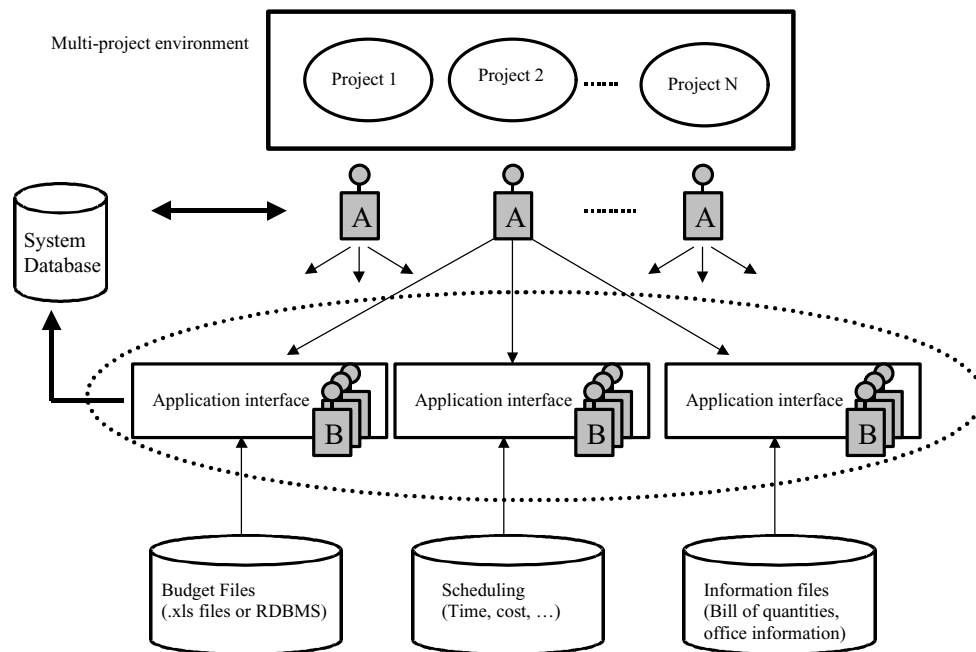

Fig. 4: The operation system of the model's application interfaces

A component-based approach is used in the application of this model. The aim here is to create a non-monolithic system with functions capable of supporting the addition and removal of components without requiring alterations to the general structure of the system itself. Therefore, a flexible system consisting of many components and interfaces required for internal communication within the system has been created in this model, as shown in Figure 5. Each component

is designed to perform a specific function independent of the others. Apart from the components that make up the system's mainframe and the ones that define the required links between the components, the system has a very dynamic structure.
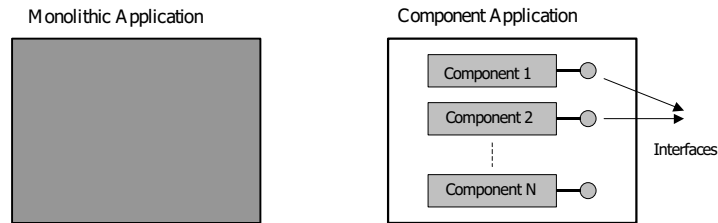

Fig. 5: Component-based application model

All of these interfaces are implemented as remote objects and placed in a component pool, as shown in Figure 6. There are two methods that can be used in this type of implementation. The first method is based on Microsoft's COM and DCOM approach. Objects can be implemented as ActiveX controls in order to be used in ASP scripts. The second method is to remain in the Java environment and to implement these objects as server objects. Even though these two approaches are similar in principle, a problem arises while implementing both methods simultaneously. Method 2 (Java-based technologies) is being used in this project. However, based on requirements brought forth by other platforms, either method can be used in future applications.
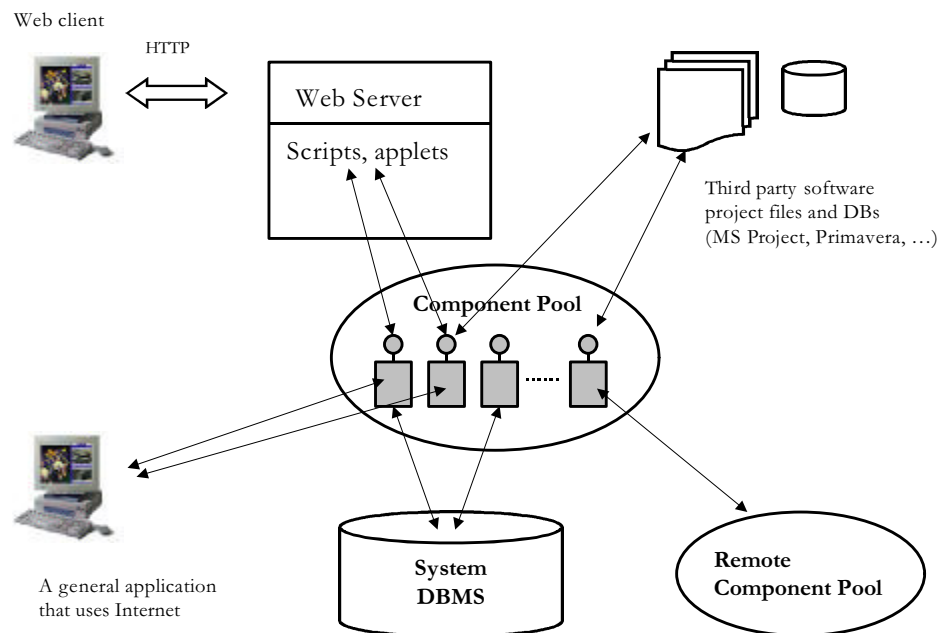

Fig. 6: General view of the entire system

Two types of clients can use component pools. (1) Web clients, (for example, Microsoft ASP scripts can create and use COM objects). (2) Java Applets can use remote objects by RMI (Remote Method Invocation). Another method of using these objects is by accessing them through general applications, which use Internet as the communication platform. All applications written in any language (Java, C++, Visual Basic, etc.) can access and use these objects. The appropriate client type is selected based on the type of the application needed. Internet technologies are rapidly merging. It is anticipated that in the near future, the main access to such objects will be through the web. However, the second type of client may offer more effective usage until certain performance problems have been overcome in the system. Regardless of the selected client, the data is processed in the same way because the components of the system remain the same.

The S-Curve and tabulation example mentioned previously confirms the project aims at the secondary level. The Java Applets/ActiveX controls create the necessary reporting environment.

The decision-support system at the third level is realized by the shaping of project data based on user input via A-Type components. The user is able to perform a variety of analyses based on different project priorities. These analyses can be saved and compared with previous analyses. The system thereby provides a flexible environment with a reporting system and a decision-support module enabling the user to access a variety of interfaces without changing the existing infrastructure of the system. One of the most beneficial aspects offered by the third level of this system is that it allows for executive managers to create and analyze a variety of scenarios concerning the execution and prioritization of projects based on self-entered subjective criteria and budget information.

8   Conclusion

The model presented in this paper proposes a solution to one of the most frequently discussed questions in today's construction management context—*how best to manage multiple projects*. Previously developed models (as discussed in parts 1-3 of this paper) accommodate general project management requirements. Although construction management and project management techniques have a great deal of overlap, the application of such a model for the construction sector poses several additional issues.

The main problem in developing integrated automated information systems for construction management purposes is that the large number of different software packages used in the construction sector render the integration process quite complicated. Generally very elaborate and specific applications are used for construction planning and management tasks such as quantity take-off/cost estimation, time scheduling/management, and cost/budget control. Additionally, the software packages used for these tasks are very likely to vary from one construction firm to another.

In general, the report formats used by executive managers and decision-makers are very similar, in that they contain the same type of information. The difficulty lies in formulating a process for collecting data from various software packages, accumulating this data in a multi-project environment, and formatting

this data to create integrated reports. When this process is considered in the Web-environment, interface requirements create further complications.

The system discussed in this paper has been tested and 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 the Internet. The system has enabled a more efficient use of the university's budgetary resources as well as faster and more effective decision-making in general.

Being Web-based, this automation system provides easy and rapid access to project information from anywhere, at any time, ensuring timely decision-making. The project team[i] is now working on software applications that will assist managers of construction firms in viewing the gain/loss ratios of their firms, and in decision-making during the bid-phase of construction projects.

8.1 Glossary of terms

Application Interface(s):   Application-specific program that integrates its application to the system with a standard interface.

System database: Relational Database Management System (RDBMS) that organizes all the data infrastructure of the system. It includes all the system data and holds all the data and status information provided by application interfaces.

9   References

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