A COMPUTER-BASED INFORMATION SYSTEM FOR ARCHITECTURAL DESIGN OFFICES

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ABSTRACT: Obtaining, handling and distributing information among participants in the building design process has become more difficult with increasing project complexity. In individual areas such as scheduling, estimating and drafting, it is possible to have access to computerized tools but it is clear that there is a gap in architects' offices regarding the integration of these tools into a unified system. Architects work closely with engineers, clients, suppliers, and public authorities. Managing the information flow among these participants may not be much of a problem in small offices. But the larger architectural offices face serious management-related problems in the design process because of the lack of an efficient information system. This paper presents a computer-based information system called ASAP that was developed to respond to the stated problem of large architectural offices. The conceptual framework as well as a description of the prototype are presented in this paper.

Keywords: Architectural office, office automation, information systems, information technology, relational database, software development.

INTRODUCTION

In building production, several participants undertaking various functions and having different purposes come together for a temporary and unique production activity and disband after finishing their work. These participants include entrepreneurs, designers, consultants, contractors/subcontractors, and material/equipment vendors. Educational institutions, information providers, research organizations, and software developers provide specific services to these participants.

The information flow among the participants must be smooth and speedy at all stages of the building production process in order to achieve the basic project objectives of economy, timeliness, and quality. In large and complex projects, a large number of participants are involved and several hierarchical levels are observed in the organization charts. The large volume of information recorded, organized, and delivered to the many participants requires the use of information technologies. The architect/engineer/contractor research community has recognized the enormous potential benefits that information technology offers and, thus, is pushing for greater use of information technology in the industry (Brauer and Fischer, 1994).

The idea of integrating the functional components of a construction organization and computer applications developed for construction is not new. Various research projects such as RATAS - Infrastructure for Computer Integrated Construction (Bjork, 1994), SPACE - Simultaneous Prototyping for an Integrated Construction Environment (Underwood and Alshawi, 1997), ICON - Intelligent Integration of Information in Construction (Brandon et al., 1994), COMMIT - Construction Modeling and Methodologies for Intelligent Information Integration (Rezgui et al., 1998), ATLAS - Architecture, Methodology and Tools for Large Scale Engineering (Bohms et al., 1994), COMBINE - Computer Models for the Building Industry in Europe (Dubois et al., 1995) and MITOS - Multi-phase Integrated Automation System for Construction (Kanoglu, 2000) that attempt to solve the integration problem can be found in literature. But none

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of these studies was specifically developed to deal with the design process in the construction project.

The type, the level of detail, the speed of flow, the time frame, and the format of the information required by every participant in the design process is different depending on the participant's function and purpose. The objective of this study is to develop a computer-based information system in response to the information handling problems of large architectural design offices.

PROBLEM DEFINITION

Since a considerable part of the construction market consists of constructors, the problems associated with the construction phase and construction companies are considered to be important and occupy a large portion of the research agenda. The problems related to the other stakeholders such as designers are often ignored. Indeed, recent research studies seem to focus on conceptual and practical models organizing the information flow among project stakeholders in the construction phase (e.g., Luiten and Tolman, 1997; Froese, 1996; Stumpf et al., 1996; and Rezgui et al., 1998). There are only few conceptual and practical models that were developed as a response to the needs in the design stage, such as those developed by Platt (1996) and Mokhtar et al. (1998). However, any comprehensive model specially designed for architectural offices could not be located in the literature.

As for the commercial software packages in the marketplace, it is possible to find some programs such as BillQuick, Portfolio, and Semaphore that offer limited solutions for architectural and engineering offices. These models provide standard operational level database functions but no management-related tools. Semaphore is the only one that can communicate with a project management software.

Architectural firms are affected by changes in the market conditions as much and as quickly as the construction companies. An organization may grow or contract when environmental circumstances dictate this kind of change. Though growing is considered to be a progression, the problems arising from this change generally become the starting point of the company's failure (Maxwell, 1997). If it is unpredicted, contraction is as agonizing as expansion, but the problems differ. The origin of the problems faced during growth is in the way growth progresses. Mostly, organizations respond almost as a reflex to increased demand. Although considered simple organizations, architectural offices have a complex nature due to the large number of participants that are involved in the design process. The relationships among these participants are also very complex because of the temporary nature of the project organization and the complexity of the projects undertaken. Indeed, every project is a temporary endeavor undertaken to create a unique product or service. This production can be qualified as custom-made. This kind of process that requires a multi-disciplinary approach including technical, social, economic, and financial constraints can be seen rarely in the context of industries other than the construction industry.

Like all companies, architectural offices have management-related problems at the company level too. In addition, every project undertaken brings another set of problems that must be solved in the context of that particular project. Also, architectural offices generally have principals who act as decision-makers for major design issues and decentralization of decision-making is generally not a preferred alternative. Given these circumstances, architectural offices have to make use of information systems and information technologies to successfully go through organizational changes especially when they are growing. Mostly, it is too late when the firm becomes aware of the need for IS/IT support. This paper aims to present a model designed to handle the information requirements of large architectural offices in response to this need that has not received much attention until now.

The objective of the study is to design a conceptual framework and develop a computerized model for recording, organizing and delivering information in an efficient way in order to provide effective management functions in large architectural offices. “ASAP” (**A**utomation **S**ystem for **A**rchitectural **P**ractices), an integrated computer-based information system, is the outcome.

A COMPUTER BASED INFORMATION SYSTEM FOR ARCHITECTURAL OFFICES

There are six functional components that constitute the software (*Figure 1*). These are organized in twelve modules. ASAP is the basic component of the model which undertakes the main information handling functions in design offices and includes seven internal modules. Five of the twelve modules are external modules including the Suppliers and Inputs Module (ASAP-SI), the Cost Estimating Module (ASAP-CE), the Standards and Specifications Module (ASAP-SS), the Scheduling Module (MS-Project), and the Library Module (AXIS) (Kanoglu, 1999). The external modules can work independently and they can be linked to ASAP. The Project Planning & Programming Module (MS Project) is the only commercially available software integrated to the model. AXIS, the Library Module has been designed and is maintained by the Construction Management Research Center at Istanbul Technical University. The remaining three modules have been developed as part of the ASAP development. Three of the external modules, Cost Estimating, Standards and Specifications, and Scheduling are reached from the Projects Module. That is why, the Main Menu presented in Figure 2 contains only nine modules. Descriptions of the twelve modules are presented in the following sections.

Projects Module

Every project is defined by its ID and name. For each project, information related to contracts, written/audio-visual/electronic messages and meeting minutes, the WBS for drawing sheets, income-expense values and payment plans related to clients and engineering offices, normal and overtime working hours of personnel, the list of engineering offices that design the subsystems, the process of legal approvals, legal documents and forms, bill of quantity and cost estimation information and construction related standards, regulations and codes can be accessed from this module.

Any type of file format (fax messages, drawing files, document files, work schedule files, scanned images, drawing files, etc.) can be linked to related projects and reached easily by the Projects Module. The progress of any of the projects listed in the Projects Module can be monitored by accessing this information in the related modules.

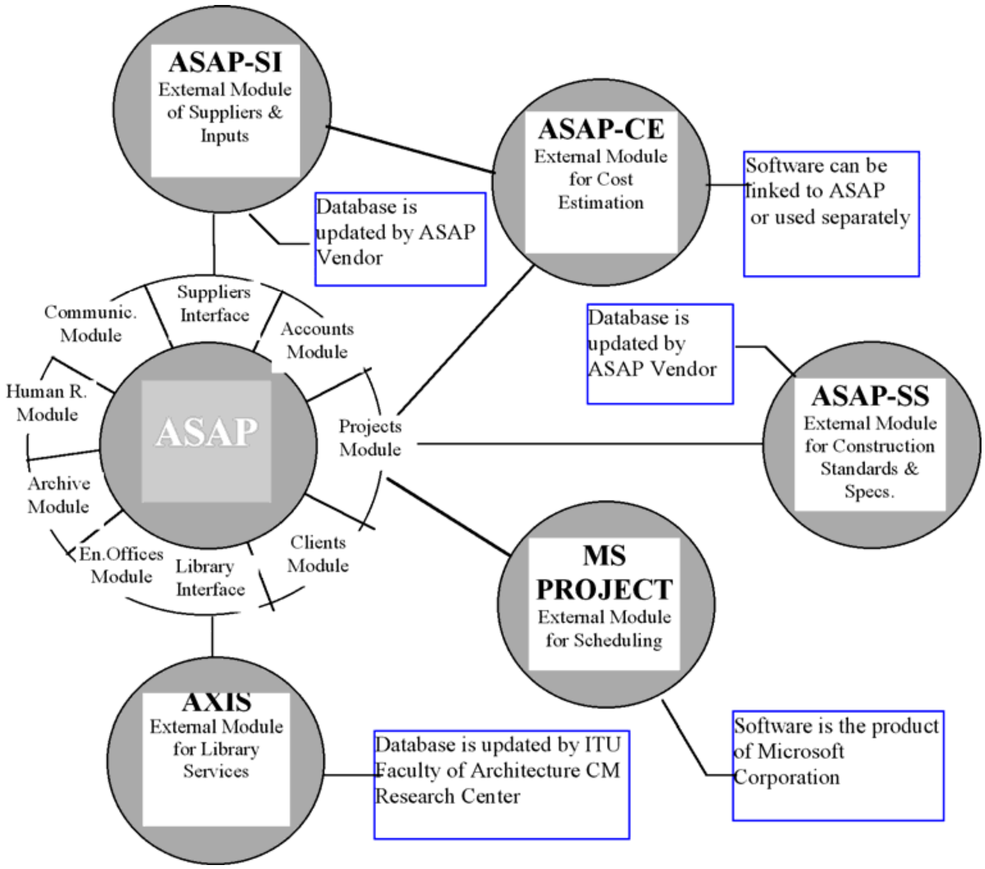

Figure 1: Conceptual structure of ASAP

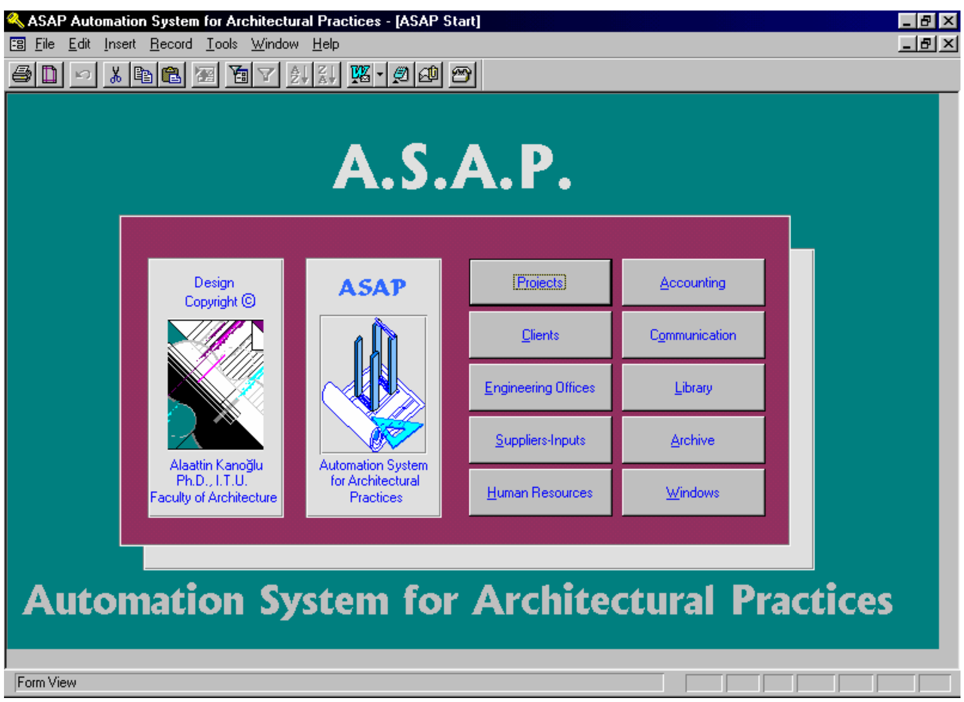

Figure 2: ASAP start screen and basic modules

Clients Module

Architectural offices may work with the same client in different projects. Sometimes these projects may be handled concurrently. In most situations monitoring the information on the basis of the selected client is required.

In this module, every client is defined by its ID and name. Projects, meeting minutes, income and expense records, payment plans recorded in related modules can be accessed for each and every client included in the Clients Module.

Engineering Offices Module

Architectural design offices organize and integrate design services for all subsystems. They identify the engineering offices that will provide design services for various building subsystems, contract with them, monitor their works, and integrate these subsystem designs into the overall design.

Architectural offices must cooperate with and coordinate the activities of at least three engineering offices, structural, electrical and mechanical. In some cases the number of participants increases when special subsystems (electronic, nuclear, environmental, etc.) are part of the building. All the administrative (bidding, preparing contracts and specifications, monitoring the process, providing communications, etc.) and management related (developing project, integrating subsystems, etc.) functions must be performed efficiently by the architectural design office. ASAP provides the database utilities to perform these functions.

Engineering design offices are defined by their ID and name. Projects delivered to these offices, meeting minutes, payment conditions and expense records are stored and can be accessed to monitor the relationship between the architect's office and each and every engineering office that is listed in the Engineering Offices Module.

Human Resources Module

The staff in a design office is composed of architects, engineers, draftsmen, technicians and administrative personnel. The staff should be organized in an effective way to achieve high productivity. Managers should consider the capabilities of the staff members when assigning tasks (creating, developing, drafting, etc.) to these individuals. Furthermore, each individual's workload must be planned ahead of time and when new assignments for the new projects are made, overloads must be avoided. Whenever necessary, a temporary workforce can be imported or subcontractors can be employed. Those decisions are made with relative ease if the impact of new projects is known with some certainty before starting the design. This type of analysis can be done by using activity based planning techniques like CPM. ASAP uses *MS Project* for this purpose in addition to its Personnel Module, which provides information related to the qualifications of the staff members.

Three different types of human resources (office personnel, labor and consultants) are defined by their ID and name. The hours that an employee worked are recorded by project and fees are calculated according to normal and overtime rates. Payment records can be accessed either in graphic or text format. An example of an individual's work record is presented in Figure 3.

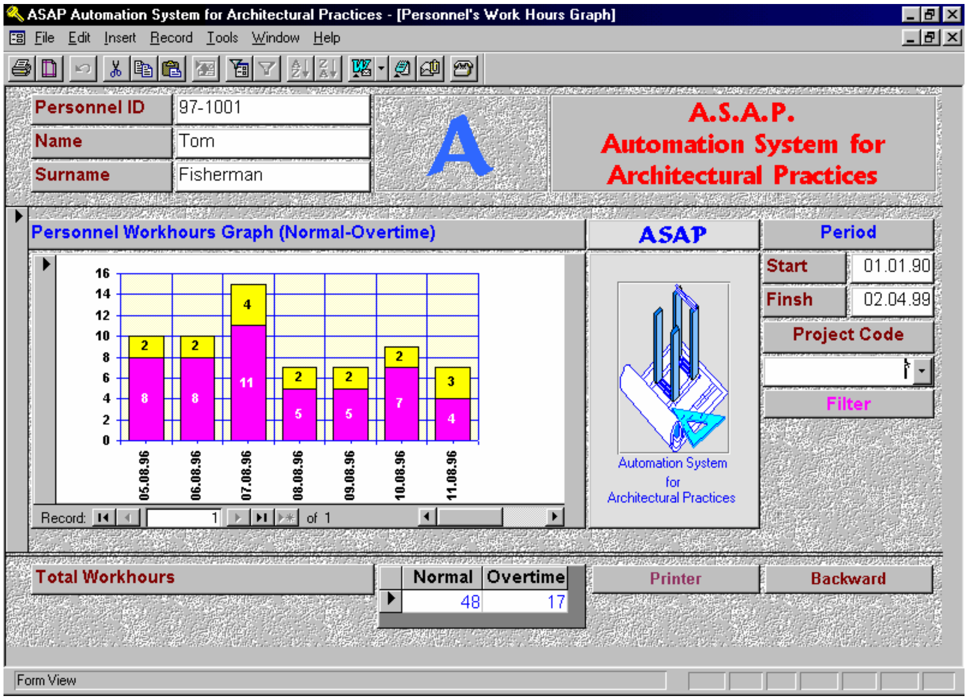

Figure 3: Personnel work hours graph (HR module)

Suppliers and Inputs Module

The supplier companies are defined by ID and name in this external module (ASAP-SI) and they are classified according to the input type (labor, material, equipment) they deal in. International standards (SfB) are used in this module for coding input items. A list of inputs supplied by individual companies or a list of companies that supply specific inputs can be produced using filter options. A sample list of input items in the equipment category can be seen in *Figure 4*. The inputs supplied by different companies and their unit prices are used by the Cost Estimating Module for creating alternative input tables. These tables are used to calculate alternative project costs. The unit prices must be updated periodically and the model allows the related database tables to be updated by the users of the model or by the software vendor of ASAP.

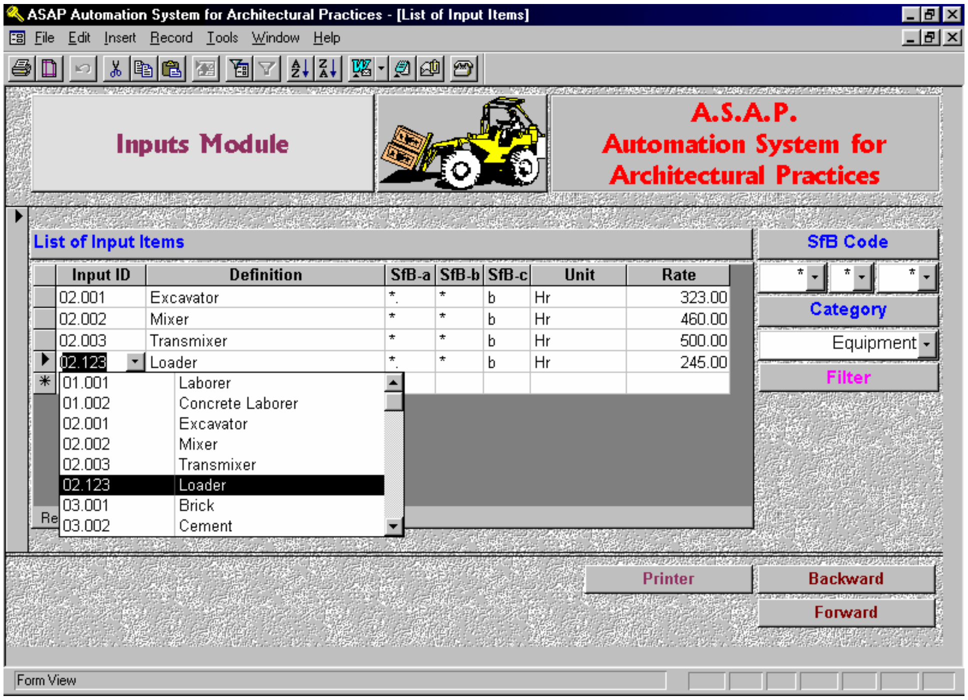

Figure 4: Input items information (ASAP-SI external module)

Accounting Module

Design offices provide services for a fee in order to earn money to survive and thrive. Consequently, cost estimating, cost planning and cost control functions are vital to the well being of the firm. It is very difficult for large design offices to identify the cost factors that affect their bottom line if they do not use the appropriate information technology tools.

In addition to the project level cost estimation function, the cost accounting system proposed in ASAP allows the analysis of cost factors by providing a user-defined cost code structure at the corporate level. All incomes and disbursements are defined according to a user-defined cost code structure. Customized reports can be obtained for each project by specifying client, date, and cost code.

Cost Estimating Module

The module (ASAP-CE) is one of the external modules integrated to ASAP. If desired it can be used independently. The module allows the user to define project take-off items at different stages of design. At the conceptual design stage take-off items can be defined in terms of amounts of building components. After completing detailed design, it is possible to define take-off items in terms of production items if desired. The user can choose one of these methods.

The module allows the user to define an unlimited number of *input tables* each composed of different combinations of material, manpower, and equipment items provided by different suppliers with different associated rates. The items are chosen from the periodically updated database in the Supplier Module that includes the data related to supplier companies and the input items provided by them. So, it is possible to make up alternative input sets organized in different *input tables.* By assigning alternative *input tables* to the current project, the client can be informed about the impacts of alternative input sets on project costs.

The user can also define an unlimited number of *production items/building components* (according to the preferred method of estimating) and calculate their unit prices by assigning input items and quantities they require. Thus, the unit prices of the *production items/building components* are automatically calculated based on the *input table* assigned to the project. When the user defines take-off items and their quantities in the project, the price of the item is automatically and immediately calculated and the project total cost is updated.

Quality Module

The quality of the constructed facility is planned at the design stage. Designers have to make decisions concerning the subsystems, components and materials such that these are compatible with the scope of the project. In order to make timely decisions, information about these items must be available, easily reachable, efficiently filtered and quickly retrievable. An information system including published specifications and standards can provide this kind of information.

All the general and local codes and regulations, construction specifications, and standards related to construction are organized in different databases in the Quality Module. This module can be expanded to include specifications published by ASTM, AIA, ASHRAE etc. (*Figure 5*).

Scheduling Module

Large design offices have to maintain a complex production process in which a large number of participants take part. In order to save time, coordination must be provided not only among these participants but also among the sub-processes of the projects. The time management tools used for planning and scheduling the activities in the construction phase can also be used in the design stage (Sanders, 1996). ASAP calls on *MS Project* for this purpose as an external module.

The scheduling of a project undertaken by an architectural practice can be conducted by considering the duration of and logical relationships between the design activities. Trying to solve the problem of assigning the limited manpower to the many projects is a multi-project planning activity. Although an extensive study is not necessary in small offices to solve the problem, sophisticated IT and planning tools may be required in large offices to deal with the concurrent design of many projects by a limited number of personnel and equipment. Various scheduling software can handle the duration, resources and costs in an integrated way. One of these general purpose and customizable software packages could be integrated into ASAP.

Integrating a commercially available software is a more reasonable solution than developing the module from scratch. The reasons and enabling technologies for using such packages are explained very clearly by Rao et al. (1997). There are also comprehensive models that define the architecture of construction-related software integration (e.g., Fischer and Kunz, 1995; Wu and Hadipriono, 1994; and Rao et al., 1997).

MS Project for Windows 98, a project management software, has been integrated to ASAP for management functions related to time, cost and resources in design offices. One of the major challenges of the study was to develop an *integration* beyond a *link* between these two components *(Figures 6 and 7).*

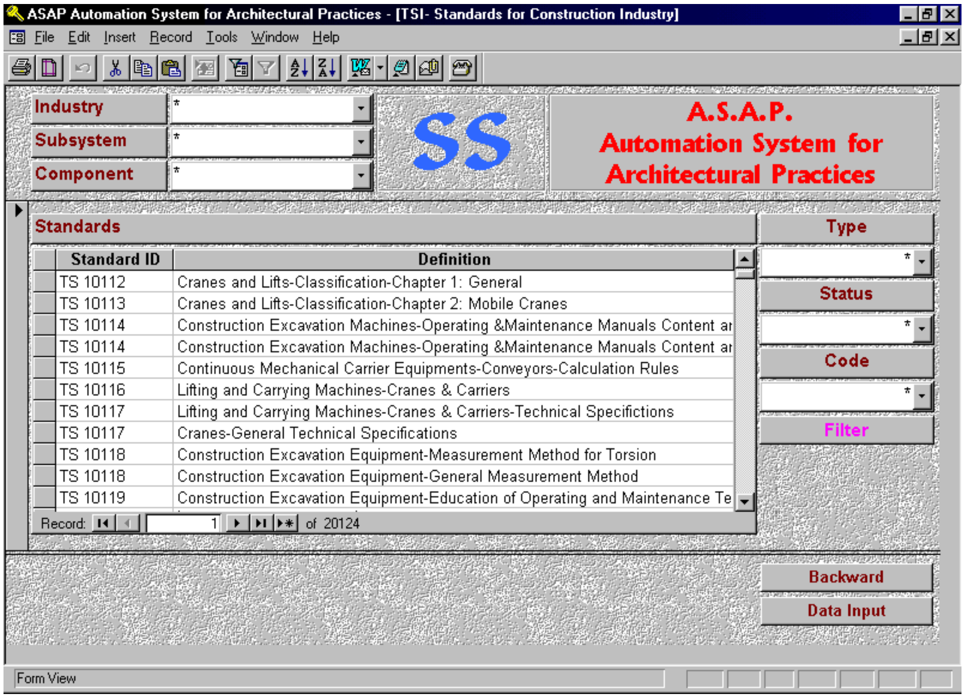

Figure 5: Information for construction standards (ASAP-SS external module link)

In order to determine the most appropriate project management software for this module, a software evaluation system developed by Berkoz et al. (1994) and Kanoglu (1997) was used and MS Project was found to be the most suitable among the software listed by Westney (1992) in the low-end category. The basic criterion used in the selection process was the software's capability of saving the information in MS Access format and providing easy integration to ASAP without using an interface.

The alternative solutions generated by what-if analysis on MS Project can be incorporated into different runs of ASAP. The outcomes can be analyzed and the alternative that generates optimum conditions can be selected. The module can handle the planning of engineering offices, human resources, equipment, time, and cost.

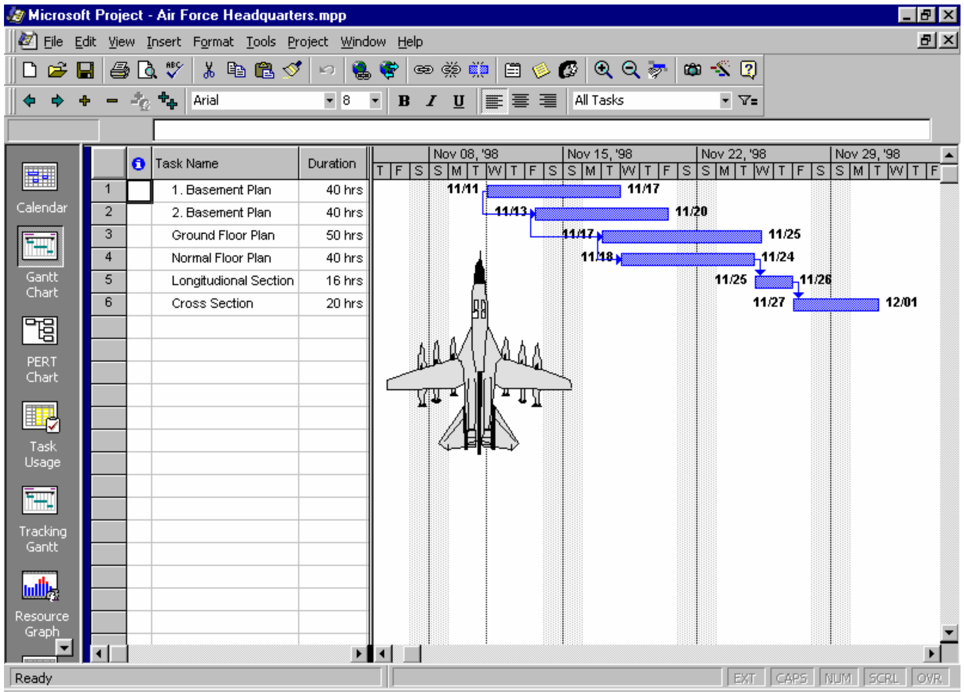

Figure 6: Sample project schedule in MS Project

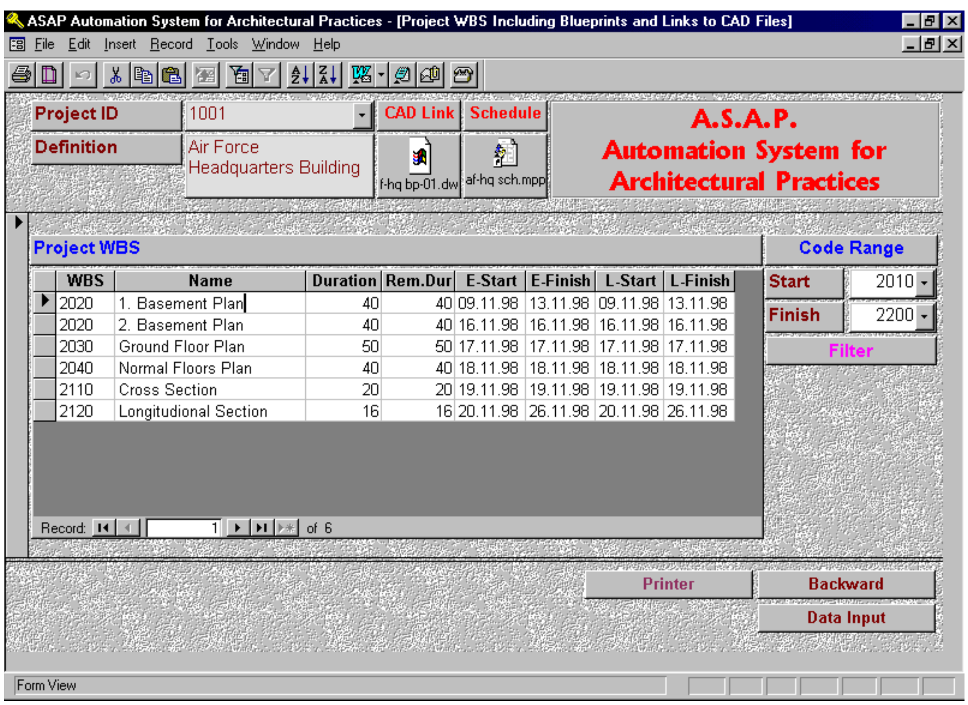

Figure 7: Sample project schedule in ASAP (MS Project external module)

Communications Module

An increase in the scale and complexity of production requires a larger number of participants and a more efficient communication among them. Because of the fragmented nature of the construction process, construction organizations have always searched for new ways to integrate both inter and intraorganizational functions (Nam and Tatum, 1992). As such, design offices also have to give up traditional communication tools and media and adopt modern means and electronic media. Especially architectural offices that work concurrently on a number of projects have to provide effective communication among interior (office personnel) and exterior (engineering offices, local authorities, clients, etc.) participants.

All kinds of messages and meeting minutes are recorded and stored in this module. The message files including fax or voice messages are linked to related fields and the database can be queried by parameters such as date, project, keyword, etc.

Library Module

Reference books and scholarly and trade journals are of great importance to an architectural office. The Library Module of ASAP consists of the Academic Information System (AXIS) that was developed as part of another project. AXIS is currently used by the members of the Faculty of Architecture at Istanbul Technical University (ITU). Thus, the database in the Library Module of ASAP includes updated contents of the holdings of both the firm’s library and the library of the Faculty of Architecture at ITU. The books and periodicals on the database can be searched by user-defined keywords and other parameters such as author, date, periodical code, publishing company, etc.

Archive module

After a project is completed, all the documents, minutes, legal deeds, drawings, etc. related to the project are archived. The original documents should be kept in good order and should be easily accessible when needed while copies can be stored electronically.

The Archive Module of ASAP contains electronic copies of the archival information for project documents including contracts, maps, urban plans, drawings and specifications that were used on the project. Information about documents can be accessed on a dedicated screen and a search can be conducted by category and subject.

THE STRUCTURE OF THE SOFTWARE MODEL

The software can be used on a personal computer but since its basic purpose is to solve the communication and information-handling problems, it is designed as a product that works on a network system. It works efficiently on a pentium-based network server connected to pentium-based terminals.

ASAP has been designed in relational database structure (*Figure 8*) and is open-ended for further development. At this stage it contains 35 tables, 261 forms, 107 queries, 32 reports, 238 macros. The size of the ASAP.mdb file is 14 Mbytes and total size of the software is 50 Mbytes including all the linked external modules except MS Project.

The software has been developed on *Access for Windows’95* database development software. The Content (ASAP.cnt) and Help (ASAP.hlp) files that were written initially in MS Word in rich text format (ASAP.rtf) were later compiled by using *MS Help Workshop Module* of *MS Access Developer Toolkit* and then linked to the related screens in the model.

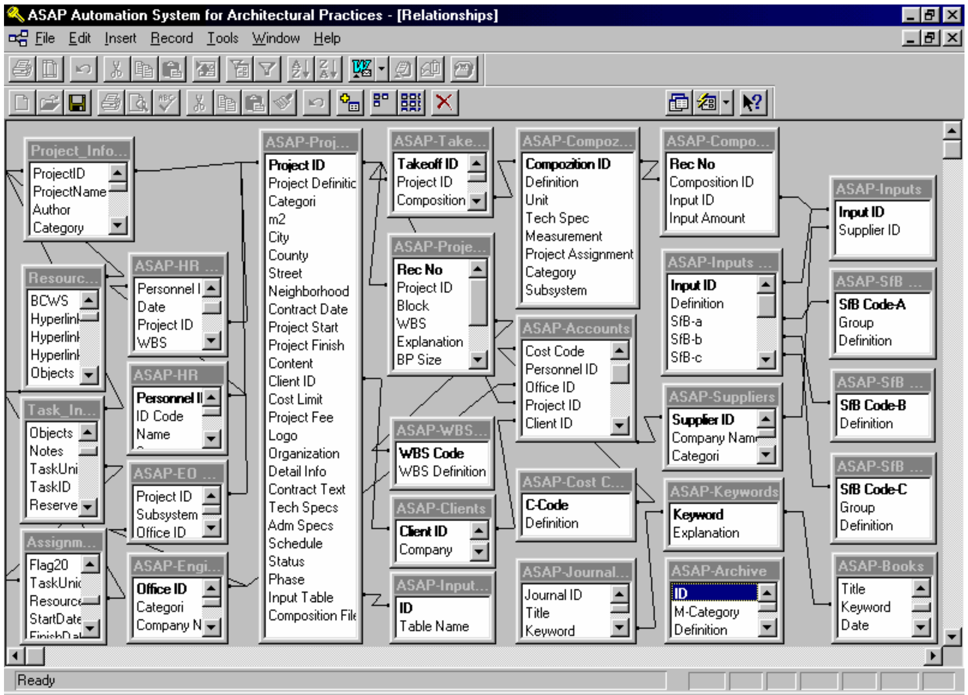

Figure 8: ASAP relational database structure

After developing all the modules of ASAP, the basic component of the model (ASAP.mdb), the Cost Estimation External Module (ASAP-CE.mdb), the Suppliers & Inputs External Module (ASAP-SI.mdb), the Standards & Specifications External Module (ASAP-SS.mdb), the Library Module of Academic Information System (AXIS.mdb), the Access Runtime Module (Access.exe) and the required driver files were converted into an automatically installable professional package by using *MS Access Developer Toolkit*.

Another structural aspect of the model is the integration of ASAP and MS Project. The relational database file created by MS Project and saved in (mdb) format consists of several tables. Four of them that are essential for the integration are:

- Project information (data related to projects),
- Task information (data related to activities),
- Resource information (data related to resources),
- Resource assignment information (data related to assignments of resources to tasks).

MS Project allows the files to be converted into MS Access database format (and saved as *MS Projects.mdb* file in our model). MS Access for Windows'95, the database development software that was used in developing ASAP, allows the developer to establish relationship with external applications in three ways: object linking, object embedding, dynamic data exchange. The four tables in this file are *linked* to the *ASAP.mdb* file. Thus, the project information is updated externally by MS Project and not by ASAP. Matching the related *Project ID* fields in the *ASAP.mdb* file and the *MS Projects.mdb* file is the next step. The integration of the respective ID information these database files is seen in *Figure 8*. The only action that should be taken by the user is to save the project files in *MSProjects.mdb* file by using the “save as” option in the MS Project menu after updating the project information and then to assign the ID of the project in MS Project to the *MS Project ID* field in the project information screen.

Since all users should not have access to all the information, user groups are created after defining users by User IDs and assigning them passwords. The users' access, read-write and modification rights for database objects (tables, queries, forms, reports and macros) are defined by using Access's built-in capabilities. How strict security is and what level of access is assigned to a member of the staff will depend on the organizational structure and administrative preferences of individual firms.

IMPLEMENTATION OF THE SYSTEM

ASAP was developed in response to the need expressed by a large architectural office in Istanbul. The firm is a well-established firm that undertakes international projects in cooperation with international partners. The team that contributed to the development of the model was composed of experienced architects including the principal of the firm. Thanks to the well-defined problem statement, the system analysis stage was completed in a short time compared to the planned schedule. The software was completed in six months including the testing of the independent modules. Implementation started after all the modules except the scheduling and the cost estimating modules were operational.

ASAP is currently being used on an experimental basis by 9 architectural offices. It was observed that large architectural design offices (more than 15 employees) used almost all the modules of ASAP while the medium and small offices never used some modules such as the scheduling, human resources, library, and archive modules. The principals of the large firms stated that they can monitor progress better at both project and corporate levels and that they can easily conduct long-term strategic planning by making use of the information provided by ASAP.

The Cost Estimating Module is of particular importance because it allows the designer to prepare alternative sets of inputs; the client and architect can then make decisions by comparing the building costs of different input sets. Another module that is of special importance is the Scheduling Module. The architectural offices that took part in the experiment demanded basic and advanced training in project planning and programming and strongly encouraged their management-related personnel to attend these courses.

The following recommendations were generated on the basis of the feedback obtained from the implementation of ASAP in these nine firms:

Recommendations Related to IS/IT Implementation:

- The principals of the architectural offices did not like delegating their decision making functions and sharing information that they deem sensitive. But they quickly found out that they need IS/IT to solve their problems. They found that changes in their traditional behavior are inevitable and that re-engineering many of the functions of the firm is unavoidable.
- Educating the personnel about the value of IS/IT and training them in the intricacies of ASAP implementation is vital for the success of the system.
- Many architectural offices are not run efficiently because of the lack of an information system and most of them are not aware of the basic reason of their problem. Some of them diagnose their problem but are not able to find the way out. They should forge alliances with research and consulting agencies in order to have access to the proper information system and this way continue to be competitive in the marketplace.
- At least one of the members of the firm should be an IS/IT expert in addition to the consulting help received from the outside in order to maintain the information system.

Recommendations Related to ASAP:

- The model was found to be practical and seemed to meet the expectations in general but the users also identified some shortcomings that need to be eliminated for the efficient use of the system.
- It was found that the standard report generated by the model could be expanded or preferably be converted into a customizable form.
- It was suggested that the relationship between the Scheduling Module (MS Project) and ASAP could be stronger. Integrating the resource and cost functions into the system was recommended in addition to integrating the functions related to project duration.
- It was suggested that the Suppliers and Inputs Database that is handled by the related external module (ASAP-SI) be updated by vendors on a monthly basis.
- It was pointed out that ASAP is an intranet application but that it could have been developed for use as a web-based management tool. The current version of ASAP was developed using Access for Windows 95 that did not allow an interface with web-based html screens. But Access for Windows 2000 that appeared after the development of ASAP allows such an interface. In other words, ASAP can be used as a web-based management tool with minor modifications after it has been upgraded to Access 2000.

CONCLUSION

Recent advances in information technologies make it possible to use new approaches like Concurrent Engineering (CE) and Total Involvement Engineering (TIE) in the design processes of building production. Information must be available at all times to decision makers who need to make decisions in an efficient and timely way in order to reach company objectives. This can be achieved by using contemporary information technologies. Yet, many design organizations that traditionally claim to have highly creative talents can hardly survive in the competitive market place because they lack adequate access to integrated information and as a result are short in managerial skills.

While a number of computer based models have been developed for construction companies, there is a lack of similar models developed in response to the problems of architectural and engineering design practices. Commercially available models emphasize the solution of operational level problems and the automation of transactions. The model presented in this paper is the first one that takes an integrated and holistic approach to the problem.

ASAP (Automation System for Architectural Practices) has been developed by considering not only an accounting perspective but the total process of design that takes place in an architectural office for every project. It is obvious that the design stage of the building production process involves vital activities that need to be coordinated by means of special management tools.

In addition to basic transactions and database functions provided by commercially available office automation software packages, ASAP provides new database utilities and managerial tools:

- A flexible cost estimation function based on current rates of input items provided by suppliers can be performed by means of a specially designed external module called ASAP-CE. Thus, the customers can simulate the impacts of alternative decisions on project cost by assigning user-defined input tables to projects.
- An effective planning and control function handles time, manpower, equipment (computers) and subcontractor (engineering offices)

assignments by making use of a commercially available project management software, MS Project.

- Comprehensive databases for standards, specifications, codes, and regulations related to construction are provided by the system.
- Additional databases for library services (documents, books and journals), archive services (projects, maps, architectural details, documents, and software), communication services (messages, meeting minutes, etc.), and project approval process and legal/technical documents are also provided by the system.

The ASAP system is currently being used by nine architectural offices for testing and refinement.

IT implementation is not just a technical enhancement but a managerial decision that involves re-engineering of organizational functions and operations. The traditional job design, work flow, reporting system, accounting procedures and control mechanisms are in need of being re-engineered on the basis of new possibilities created by IT. IT should be used not to automate old processes but to enable new ones (Ahmad et al., 1995).

Architects are continuously looking for more efficient ways of designing and drafting with computers. Architects should also look for ways to improve information systems, which are used for recording, processing, and updating, the information created or gathered through the design process. Handling the information and managing the information system requires that everyone’s access rights and responsibilities on the system be clearly defined. The personnel in the office must be trained in utilizing as well as contributing to the information system.

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