THE STRATEGIC USE OF AN INFORMATION SYSTEM
IN SUPPORTING ARCHITECTURAL DESIGN DECISIONS
FOR A DESIGN FIRM

by

LIU, LU

Bachelor of Architecture
Tunghai University, Taichung, Taiwan
1977

Master of Architecture
University of Houston, Houston, Texas
1980

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Signature of the author__________________________ Liu, Lu
Department of Architecture
February 7, 1985

Certified by______________________________ Eric Dluhosch
Associate Professor of Building Technology
Thesis Supervisor

Accepted by______________________________ Julian Beinart
Departmental Committee for Graduate Students

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LIU, LU

Submitted to the Department of Architecture on February 7, 1985, in partial fulfillment of the requirements for the Degree of Master of Architecture.

ABSTRACT

This thesis is to illustrate how a computer-based information system for supporting decision making, that is a Decision Support System (DSS), can be utilized as a strategic tool in architectural design for a firm. The products of information technology have been designed around a wide spectrum of needs. Architects can immediately adopt the technology and use it as design tools. These tools are not just a productional convenience, but also bring about strategic advantages to a firm.

In this study, through the investigations on the current computer use in professional architectural design, a need is called out for DSS planning. Derived from the field of Management Information Systems, a method of strategic DSS planning is set forth, which is a top-down planning process from office strategy to data base requirements, with the emphasis on the most critical applications to the top management.

This method is applied through a three-phase planning process to a hypothetical office which represents a typical design firm. It is found in this study that the construction cost analysis for schematic design phase is the key operation for a DSS. This DSS can forge strong links between architectural design, project management, and office strategy in establishing a firm’s competence in the cost and quality control for a building.

Thesis supervisor: Eric Dluhosch
Title: Associate Professor of Building Technology
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The goal of this study is to investigate how a computer-based information system can be utilized as a strategic tool in supporting architectural design decisions for a medium-sized architectural firm.

DEFINITIONS

AN INFORMATION SYSTEM FOR SUPPORTING DECISION MAKING, that is, a DECISION SUPPORT SYSTEMS (DSS) is defined here as a system which links man, computer, and information together, for the purpose of supporting the human-decision making process through information retrieval, manipulation, analysis and display. We will examine three primary aspects of such a system:

1) Application. A DSS can provide decision-making support for users at all levels of managerial activity (i.e. strategic planning, management control and operational control) and for various office functions such as marketing, financing and production.
2) Function. A DSS assists end users in their decision processes with some or all of the following functions: interaction and display, decision modeling, statistics and manipulation, and data base management. The functions are independent of each other and can be selectively used.

3) Technical configuration. Typically, a full blown DSS requires technological building blocks organized into a data base management system, model management system (*), and dialogue management system. Several technological developments have made the DSS approach practicable. An interactive and user friendly computer environment allows nontechnical users to work at a terminal without needing specialized skill. Along with the advances in the development of graphic terminals, micro-computers, telecommunication networks, data-base management systems, specialized modeling and application languages, and application packages, information technology has offered a set of building blocks that can be combined to provide a particular system.

THE STRATEGIC USE OF A DSS FOR A FIRM. DSS can be used as a technological lever to build up a firm's strategic advantages.

Strategy is the pattern of missions, objectives, policies and significant resource utilization plans stated in such a way as to define what business the company is in or is to be in and the kind of company it is. (*)

Recognizing that information has a strategic impact implies a clear need to link DSS to business strategy and, especially, to ensure that business strategy is developed in the context of the new information technology environment.

GOALS

The primary goal of this study is to understand how a DSS can be used as a strategic tool in architectural design for a firm.

During the past three decades, innumerable systems have been computerized to improve efficiency in accounting and operational activities. In the past few years, DSS have come into their own and flourished in many companies. Now with the advent of the personal computer, computer-based assistance for all functions of the business is becoming widespread in a number of companies.

In the field of architectural design, presently, a proliferation of analytical models, graphic tools and design aids is occurring. Architects are concerned how this large variety of technical building blocks can be utilized into a DSS for assisting architectural design decision. Furthermore, the use of DSS should not be viewed basically as a production convenience, rather it should be seen as a top-level strategic concern. The study emphasizes the following goals:

1) To understand the context for DSS development in professional architectural design. Apparently, DSS development is still in the beginning stages for the profession. Yet, with numerous hardware and software tools in information technology for architectural design, the building blocks for DSS development have been prepared.

2) Based on the nature and issues of DSS development in professional architectural design, to identify the most appropriate method of strategic DSS planning.

3) Based on the method identified, to demonstrate step-by-step how to plan strategically for a DSS in an architectural firm.

SCOPE

The emphasis of this study is on systems analysis, that is,
bridging the gap between architects and DSS builders, analyzing user's needs, and identifying major systems requirements. The actual system development concerning detailed design and implementation issues is not included in this study.

Architectural design is viewed here as a function carried out by a design team of a firm, among other functions, such as accounting, personnel and marketing. In order to use a DSS for architectural design in a firm, the system should be linked to business strategy and management control. The direct users are members in architectural project team, and the indirect users include members of top management in an architectural design office of a medium-sized firm.

APPROACH & OVERVIEW

This study has three major parts corresponding to the three major goals emphasized in the following chapters.

Chapter I: Understanding the context for DSS development in architectural design by examining the use of computer-based tools. The investigation can be divided into three parts: 1) investigating the hardware/software building blocks of DSS for architectural design. 2) examining how they have been used in
architectural design. 3) understanding their strategic impact on architectural firms.

Chapter II: Identifying the most appropriate DSS planning process in response to the requirements of DSS development in architectural design. Six issues of computer use in the profession are identified, which reflect the need for strategic DSS planning. In response to this need, several concepts in the field of a Management Information System have been reviewed:

Critical Success Factors (CSF) (*) - to engage management's attention and ensure that the Information Systems meet the most critical business needs. CSF is the critical means that can successfully achieve the ends.

Prototype Design Strategy(*) - an adaptive design process, to allow management to quickly receive system results, to have something concrete for testing and refining as part of the development process. Prototype system, taking the essential features of a full blown systems, are built with an initial fundamental, yet not complete, set of functions.

The Extended CSFs Methodology (*) - Tying the above concepts together in a planning context is found particularly

(*) see chapter II.3 concepts in DSS planning and design
A method, adapted from the extended CSF, is established to fit the particular purpose of this study. The method can be viewed as a three-phase process: linking a DSS to the strategic needs of a firm, identifying prototype system, and identifying data base. Full explanations are in chapter II. (see Fig II.1)

Chapter III, IV and V: Demonstrating strategic DSS planning in architectural design for a hypothetical office that represents a typical mid-sized design firm in this country. The planning method is based on the three-phase process. Information is collected through interviews as well as literature surveys and observations.

Chapter III: Linking DSS to the firm's strategy. The key linking technique is the CSF approach which uses a top-down planning process. By analyzing the environment where design firms compete, the office strategy is shaped. In this study office strategy have been defined as building up the firm's competence in cost, time and quality control to maximize clients investment return. In response to this strategy, the goal and related CSFs of management and architectural design have been determined respectively, as well as their relationship. Among all the CSFs of architectural design, the operational goal of the DSS is identified as evaluation of
schematic design options to understand the cost and quality impacts across all subdivided tasks of a design team. The DSS goal not only reflects top management concern, but also represents operational needs at the implementation level.

Chapter IV: Identifying prototype system. In reference to a number of measures concerning the DSS goal, a set of critical decisions for schematic design is formed. Three distinct decision processes in cost evaluation during schematic design have been identified in this study. And construction cost analysis by building systems is chosen as the opportunity for a prototype system.

Chapter V: Identifying data base. In construction cost analysis, three distinctive decision events are identified. They are space analysis, building systems estimates, total building estimate. The required data base of each event has been defined respectively.
In the field of professional architectural design, there may only be a few systems which are built according to the DSS concept; yet the computer-based tools have been intensively utilized through various applications. Computer-based tools, the technological building blocks of DSS, are those hardware and software elements in information technology, which can facilitate the development of a specific DSS. For example, a DSS for police dispatching was built using technological elements such as a graphics routine package and a raster-scan color monitor.

This chapter aims at understanding the use of these tools in professional architectural design, which will serve as a base for identifying issues in the DSS development in the next chapter. The investigation focuses on answering the following questions: 1) what are the computer-based tools, the building blocks of DSS, in architectural design? 2) how are these tools used in architectural design? 3) what are their potential
impact on the strategic level for a firm?

The sources for this part of the study have been the Sweet's surveys by McGraw-Hill Information Company, and a series of articles from architectural journals. The topics dealt with in this chapter are:

I.1 Computer-based tools in architectural design.
I.2 Current computer applications
I.3 strategic impact on architectural firms

I.1 COMPUTER-BASED TOOLS IN ARCHITECTURAL DESIGN

The advancement of computer technology have not meant that DSS development has become an easy exercise. However, it now seems more useful to think of technology as a set of building blocks that can be combined to provide a particular system. These building blocks include hardware and software elements, which have the greatest amount of recent development. The building blocks mentioned below are by no means exhaustive, but they indicate fairly clearly that architects now have many tools tailored to their needs and convenience.

HARDWARE. General purpose time-sharing computer systems
permit nontechnical users to work at a terminal without specialized knowledge and skills. Users can have easy access to substantial computer power in an interactive mode. Graphic terminals provide effective means for presenting large volumes of data in a graphic format. Micro-computers provide personalized, inexpensive, and easily transported tools. Telecommunication networks extend the computer from number crunching and data processing to message sending and data sharing, as a result, they provide mutual access to information among decentralized organizational units. Computer Aided Design (CAD) systems, normally are available as a combined hardware and software package, based on either mini or micro computer technology. This systems allow architects to create, store, retrieval and manipulate graphic data files. Some offer the ability to associate non-graphic information with graphic elements. The systems automate the production of drawings with desirable productivity gains.

According to Sweet's survey, 1981, (*) (Fig I.1) there were 49% of design firms owning a mini or micro computers. With the availability of inexpensive micro computer, this figure has been predicted to grow rapidly. Whereas, the percentage of the firms having CAD is very low, due to its high price. Now, with the advent of micro-CAD, the situation may be changed.

Source: Mileaf M."Computer use in Architecture"  
Architectural Record,1982,June, pp.20

Figure I.1 Percentage of Equipment owners

<table>
<thead>
<tr>
<th>Application</th>
<th>Percent of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design analysis</td>
<td>1981 1982</td>
</tr>
<tr>
<td>Accounting</td>
<td>46 66</td>
</tr>
<tr>
<td>Spec writing</td>
<td>41 70</td>
</tr>
<tr>
<td>Cost estimating</td>
<td>31 62</td>
</tr>
<tr>
<td>Construction management reporting</td>
<td>21 51</td>
</tr>
<tr>
<td>Computer-aided design</td>
<td>12 23</td>
</tr>
<tr>
<td>Automated drawing</td>
<td>8 32</td>
</tr>
<tr>
<td>Product/equipment selection</td>
<td>5 27</td>
</tr>
</tbody>
</table>

Figure I.2 Percentage of Applications
SOFTWARE. Database management systems extend the range of information that can be collected, allow better access to existing data files, and allow answers to relatively complex queries. Application packages permit off-the-shelf installation of systems specially designed for particular types of application, such as cost estimation, energy performance evaluation, and specs writing packages. Application languages reduce development time particularly for complex models, such as spread sheet modeling languages.

Commercially available software packages are mostly designed for business applications. Seldom did computer vendors make a major marketing effort to develop software that is specifically directed towards architects. This is what led a lot of architectural firms to develop their own application software.

1.2 CURRENT COMPUTER APPLICATIONS

The major area of computer applications, according to the Sweet's survey of 1981, is at the level of design analysis (see Fig 1.2). This is due to the heavy influence of engineering analysis. Figure 1.2 shows that accounting is the major application; spec writing and cost estimating follow. Computer-aided design and automated drawing represent a relatively small application involvement in 1981, but major
growth is expected. In the process of architectural design, the major computer applications are as follows:

CONCEPTUAL MODELING. Application programs are available which permit architects to create a three dimensional, simplified block model of a building within a graphic computer system. Perspective and isometric views of the building can be shown, and the computation of shadow patterns produced by buildings can be incorporated. This calculation is not complex, but involves a great deal of data manipulation. These programs are valuable particularly as an effective marketing tool. Clients can be presented with alternative designs with views from various angles, at different hours of a day, and with different color schemes.

COMPUTER DRAFTING. Computer drafting capability normally is obtained through a CAD system. Most mini-based systems offer three-dimensional modeling capabilities and some offer the ability to associate non-graphic information with graphic elements. Currently, micro systems only have the capability to work in two-dimension and with smaller computer memory. Through CAD systems, a library of standard details and symbols can be easily developed to the standard of a firm. Hence, the efficiency in producing architectural drawings can be greatly improved.

SPEC WRITING. There are several options for architects to
automate their spec writing. Word processing, the ability to easily edit a text, is the most elementary way for spec writing. Original versions can be easily modified to produce finished copies. This method can be improved by adding database management capability, which allows users to create their own master spec files and to manipulate them. By searching and retrieving specifications from a master file, architects may compile the desirable specs for a particular job.

DOOR AND ROOM FINISH SCHEDULES. Programs are available that allow one to enter, store, update and print out information on room types, finishes, furnishing, and accessories. Thus reports are produced that can be continually updated through the course of a project.

DESIGN ANALYSIS. Energy performance programs are available that allow users to receive an estimate of energy consumption due to heating and cooling loads, lighting and other building services. In addition, lighting analysis is used to predict the natural and artificial light with an output of the value of intensity at particular points or surfaces in a room. Acoustic analysis can give reverberation times in a room, for various ceiling height and size of a room.

PREDESIGN ANALYSIS. Programs are written for calculating financial impact of a project. This is very useful in the
predesign stage. Programs in space projection are useful for architectural programming. For example, based on regularity of meeting scheduled times, programs can predict the number and size of conference room required.

COST ESTIMATION. By entering the building components and materials and their quantities of a building proposal into a computer, building cost estimates can be calculated. Estimation occurs in the early stages of a project and is continually refined as schematics become design development drawings. Therefore, several levels of computer programs are required. Many architectural and construction firms develop their own cost estimating programs rather than purchasing one. Often, firms have their own practices and methods of cost estimating that they wish to preserve, rather than adopting other's methods.

SPACE PLANNING. Computer programs take the requirements in functional and spatial relationships and create diagrammatic floor plans. The major purpose is to achieve space efficiency with minimal amount of circulation area. Computerized space planning can be also applied in the contexts of site planning.
1.3 STRATEGIC IMPACT ON ARCHITECTURAL FIRMS

The impact of information technology on different industries and services is far beyond common expectation. Initially, it is utilized for the effectiveness and efficiency of a task execution. Yet through the proper leverage of the technology, its potential impact has reached organizational and industrial levels.

This section will examine the strategic impact of computer-based tools on architectural firms. According to Sweet's survey, 1981, 75 percent of designers using computers thought that computers gave them a competitive edge and were looking for deeper involvement and broader applications. Up to now, the impact of these tools on architectural firms has not become explicitly evident. Yet, from the pioneer experiences in the field, a picture can be drawn on the ways that information technology (IT) influences a firm at the strategic level.

In this section, the framework of strategic impact analysis is based on "the three-level impact of information technology" (*) (Parson, 1983). According to Parson, IT could change the firm's execution of strategy in terms of the following

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(*)
Parson, Gregory L. "Information Technology: a New Competitive Weapon"
considerations: 1) adding unique features to product and service, 2) reducing overall cost, 3) identifying and creating market niches.

Information about the strategic impact has been mainly collected from two symposia (*) sponsored by the Architectural Record. Each symposium invited over twenty panelists most of whom were architects experienced in computer use from firms of varied size and a few of whom were computer consultants.

1.3.1 Adding Features to Product and Service in Architectural Design.

By using IT, architect's service to clients may be greatly improved. Reliability of the services can be enhanced through computerized project control and automated drafting. Besides, a computer's extremely fast computational power allows the architect to use more sophisticated quantitative analysis than he would consider in doing by hand. Hence, architects are provided with better insights and faster feedback in making design decisions. Due to this prompt feedback, architects may explore more design alternatives, of which the consequences can be compared on a quantifiable basis. Since IT allows

(*) Recorded in the two articles: "Round Table on Computers in Architecture" and "Round Table: Computer Use in the Small Architectural Firm". All the remarks of the architects in this section are from these two symposia.
architects to come up with more design alternatives and design analyses, their services tend to be more responsive and flexible to client's needs.

I.3.2 Reducing Overall Cost

Significant gains have been made in the areas of specs writing and schedule report generating, where a micro computer can well accomplish the job. For CAD systems, in the experiences of most architects, productivity comes in at a different level of repetition of a project, such as in hotel and apartment designs, where CAD systems can be used very efficiently. Other areas of high productivity are in interior design and space planning.

Initially, a lot of firms expected that the use of Computer Aided Design (CAD) will result in three to five times return on their annual costs - carrying costs and operating costs. To their surprise, they found that they seem to be operating on the same fee level as they would have manually. One firm expressed that they were promised enormous productivity gains and very fast pay-offs by using CAD, but later discovered that those figures were true only by using the system 100 percent of the time. Another firm with 25 employees justified the cost of CAD by aiming at a minimum of a two-to-one productivity gain by using CAD, and indeed eventually
realizing this performance level. Yet the firm found it was hard to maintain such a level of work load at all times.

1.3.3 Identifying and Creating Market Niches

IT can be used as a lever to extend services into related areas, such as project financial projections, architectural programming, space planning, and interior design. An interesting example is that of building facilities maintenance. Since architects may store the complete set of information on a building in the computer, they come to the realization that "We end up taking care of a building almost as custodians managing everything, when the building life cycle is completed".

A computer system can have a great impact on the marketing efforts of a firm. A 25-person firm in Chicago expressed that the reasons for them to have a sophisticated CAD system was because "The firm that beat us out had a computer which could transmit information directly back to the client's home office". After that the firm started taking a hard look at what a CAD system could do, not only in terms production savings, but also due to its competitive advantages.

It has been the experience of a few firms that clients started to request computer drafting services since they knew the
drawings would be technically prone to error and better controlled in terms of cost and time. It is likely that in the near future architects may face a market of computer-literate clients, who will demand electronically based products and services, as a matter of routine and as a normal process of professional service.

Furthermore, in the near future, market segmentation in architectural services may be less dependent on the size of a firm, but rather on the technological level of utilizing information technology. As predicted by the principle of a large firm (*) "small architect is, in the long run, going to be the bigger winner - with computers, he will be able to do more work with fewer people. If good data bases and standard details becomes available as software, he is going to be able to tackle very large projects". Yet, people from small firms are much more cautious on the competition issue.

(*) "Round Table on Computer in Architecture", pp 50.
CHAPTER II: IDENTIFICATION OF DSS PLANNING PROCESS

This chapter aims at identifying the most appropriate method of strategic DSS planning in response to the issues of computer use in professional architectural design. Six issues are presented, which call out a need for strategic DSS planning. From the field of Management Information Systems, a few concepts in DSS planning and design are reviewed. Based on these concepts, a method of DSS planning is formed. The topics discussed in this chapter are:

II.1 Issues of computer application in professional architectural design.
II.2 Need for strategic DSS planning.
II.3 Concepts in DSS planning and design.
II.4 A method of strategic DSS planning.

II.1 ISSUES OF COMPUTER APPLICATION IN PROFESSIONAL ARCHITECTURAL DESIGN

Although a great number of innovative applications occurs
throughout all architectural design phases, clear information about the kind of softwares that architects need has not yet been established. "No one really has any good idea what sort of software we need, one of the major problems for the profession is that the software does not really exist after those elementary applications such as word processing and specifications" (*), as expressed by one architect. Among the numerous software developments in the field, a number of issues can be observed.

PROGRAM VERSUS SYSTEM. The full strength of an information system has not yet been utilized by most of the architectural firms. A lot of ad hoc application programs have been created. In general, each program owns its own input and output data without sharing and transferring data among programs. In addition, programs are seldom functionally correlated in order to tackle a large task. Application programs which are not linked together into an overall coordinated information system are common phenomena for the firms.

STATIC VERSUS DYNAMIC. In dealing with complex, changing problems of architectural design, the process of information system design should be adaptive and evolving by coping with a fluid task situation. The conventional, structured design techniques for information system which emphasize on an

(*) quoted from "Round table:computer use in the small architectural firm"
exhaustive search so that complete requirements of a full
blown system may be determined. In this approach, the long
development time and the major data gathering efforts
required, make the process expensive and not responsive to
change. Common result is that problems have to be compromised
to fit the off-the-shelf programs, rather than make the
program adapt to a specific problem situation.

BIG VERSUS SMALL. Big, complex computerized models are
difficult for architects to understand and difficult to
manipulate, therefore they are not trusted. A growing
response to this problem is to utilize a library of small
models, which deal with a problem at a time rather than a
pre-packaged series of problems. Thus, it is left to the
decision-maker to integrate the modeling steps and activities
as a mental or manual process. Furthermore, models should be
easy to be manipulated so that a user can make them behave the
way he wants them to. For instance, a large energy model
with twenty input parameters makes the situation overly
complicated for end user to understand in terms of the impact
of each input parameter on the whole.

OPERATIONAL VERSUS STRATEGIC. Efficiency involves a narrowing
of focus and minimization of the time, cost, and effort
required to carry out a given activity. Effectiveness
involves identifying what should be done and ensuring that the
defined performance criterion is the relevant one. In the
architectural profession, computer applications start from the
direction of efficiency in automating labor-intensive work and
the desire to reduce manual errors. Gradually, the
applications extend in the direction of effectiveness in
supporting human decision-making, i.e., as judgemental tools.

Furthermore, computers and information technology have their
strategic influence on design firms. Information technology
can acts not only as a productive tool to improve efficiency
of routine work flow, but also as a competitive weapon to
affect the direction of business operations. Yet, information technology as a strategic tool is overlooked by
the majority of design firms.

ALL-INCLUSIVE VERSUS CRITICAL. To many architects, a complete
integrated database is thought to be the key to uplift the
profession into the era of information technology. This
integration can be viewed both vertically and horizontally. In
vertical integration, the computer's database is used in every
step of the job from marketing to final working drawings. In
horizontal integration, the computer is used all disciplines
in each phase of the design process. Both integrations have
not yet been fully realized, but present a research
task which will require enormous capital investment.

Nevertheless, by learning from business applications,
all-inclusive integration often is unnecessary and
uneconomical. The best policy is to focus on the most critical application rather than including all. Innumerable opportunities of computer applications in architectural design have been identified. Yet usually, only a few are critical to the needs of a firm. These critical applications should be the investment focus of the firm.

TECHNICAL VERSUS PLANNING. To the most interest of architects and design firms, the questions concerning computer applications have been how to effectively utilize information technology, and where to start with. Basically, these are planning issues rather than technical issues. Often, the emphasis in information system development has been placed on the technical side of selecting hardware and writing programs, and without careful investigations on the needs and the related decision processes of architects. As a result, there is often a good chance that computer involvement may bring about more expense than profit.

II.2 NEED FOR STRATEGIC DSS PLANNING

All the above issues point to the need for a strategic DSS planning method to meet the particular contexts in professional architectural design. Based on the issues identified, the method should address to the following
requirements as strategic DSS should be:

1) Able to meet the organizational contexts of professional architectural design, so as to provide a link to the business strategy and management of a firm.
2) Able to be responsive to the nature of decision making in architectural design, which is semi-structured and volatile.
3) Able to focus on the most critical area for DSS development.
4) Able to provide a pragmatic link from strategic planning to the major database requirements.
5) Able to subdivide a decision task into a group of decision components.
6) Able to insure DSS as an effective means to achieve the desired ends.

II.3 CONCEPTS IN DSS PLANNING AND DESIGN

Before identifying the appropriate DSS planning method, let us firstly review a few concepts related to information system planning and design in the field of Management Information Systems.

PROTOTYPING DESIGN STRATEGY. It is most appropriate to an
adaptive design process, which assumes that the final system must be evolved through usage and learning. Rather than focuses on functional specifications, the designer relies on a prototype system to find out quickly what is important to the user as opposed to what the designer thinks to be important. In other words, the method provides something concrete for the user to react to and test with, and further to allow the system to be easily modified and evolved. The prototype is a real system, not a mock-up or experiment. It provides the base for learning by using. Hence, prototyping design strategy can cope with the fluid situation of particular task environment.

CRITICAL SUCCESS FACTOR (CSF) APPROACH. John F. Rockart, 1979, developed the CSF approach as a means to understand directly the information requirements of the chief executive officer. He defines CSF's as "those few key areas where things must go right in order to successfully achieve goals or objectives". Since the goals of key decision makers form the basis for the CSF analysis, the methodology will directly strengthen goal-strategy linkage, from decision maker's needs to operational requirement for information systems. The approach is based on intensive interviewing process and workshop sessions, in order to elicit individual CSFs and consolidate them on the organizational level.

EXTENDED CSF METHODOLOGY. A strategic planning framework.
Derived from the CSF approach, John Henderson developed the extended CSF. There are two key characteristics for this methodology: 1) providing a context for the planning process through evaluation of the positions and needs of key decision-makers, 2) providing a pragmatic link from the conceptual design to the detailed design. Building upon the CSF approach, the proposed method provides the context for three products: critical information set, critical decision set, and critical assumption set. Each of the set requires various levels of information systems. Finally, these three sets of requirement provide an important insight into a strategic data model (see Fig II.1).

II.4 A METHOD OF STRATEGIC DSS PLANNING

Based on the extended CSF methodology, the method of strategic DSS planning in this study is formed. The method concentrates on the stream of DSS development, aiming at extracting the opportunity for prototyping a DSS and the related data base required. The method is comprised of three phases: 1) linking to the office strategy, 2) identifying prototype system, 3) defining database requirements.

1) Linking to the office strategy. The key technique is CSF approach in order to identify the most critical operational goal of DSS in response to office strategy. In dealing with
Figure II.1 A Strategic Planning Methodology
CASE INTERVIEW & OBSERVATION

TOP MANAGEMENT

MIDDLE MANAGEMENT

GOALS OF PROJECT MANAGEMENT

CSFs

PROJECT TEAM

PRIMARY GOAL OF ARCH. DESIGN

CSFs

GENERAL BACKGROUND INVESTIGATION & ANALYSIS

major competitive forces in architectural service

model of management

major tasks in three primary arch. design phases

major responsibilities of project architect and project designer

architectural design theory

LINKING TO OFFICE STRATEGY

OPERATIONAL GOAL OF DSS

CRITICAL MEASURES

CRITICAL DECISION SET

IDENTIFY DSS PROTOTYPE SYSTEM

OPPORTUNITY FOR PROTOTYPE SYSTEM

DECISION SCENARIOS

IDENTIFYING DATABASE

REQUIRED DATABASE

DECISION MAKER'S VIEW:
consolidate goals of key decision makers.

DECISION TASK'S VIEW:
based upon general heuristics in the profession, in conjunction with arch. design

Figure II.2, Strategic DSS Planning Method for Supporting Arch. Design

35
architectural design decisions, the organizational context involves three groups of participants: top management (office strategy); middle management (project management); and project team (architectural design). Their relationship is illustrated in Fig II.2.

2) Identifying prototype system. First, by identifying critical measures, the measures in monitoring the performance of an operational goal of a DSS, architects may have a concrete reference in listing the critical decision set, which is key decisions that greatly impact the successful execution of a task. Then, derived from the critical decision set, distinct opportunities for DSS and their priorities can be identified. The first priority will be the opportunity for a prototype system.

3) Identifying data base. The key technique is decision scenarios. Each decision scenario (*) represents a particular decision event and the questions which are recurringly asked by architects in formulating a decision. In answering these specific questions, a required data base can be defined.

(*) used by Rockart in "Engaging top management in information systems planning and development"
CHAPTER III IDENTIFICATION OF OPERATIONAL GOAL OF DSS

The purpose of this chapter is to identify the operational goals of a DSS in assisting architectural design activities for a firm. The process which utilizes the CSF approach is divided into four steps (see Fig II.2):

1) Office strategy. This step is to define the basic business direction of a firm and focus on the most crucial aspect to architectural design.

2) Goal and CSFs of project management. A goal is an operational transformation of a general mission. Critical Success Factors (CSFs) are the means to the goals, the key areas in which successful performance will lead to the achievement of the desired ends. Major concern of management in relation to architectural design is on project management, which emphasizes the efficient and effective use of office resources among all projects. This step is to identify the CSFs necessary to achieve the management goal.
3) Goal and CSFs of architectural design. Architectural design is viewed as operations broken down into schematic design, design development, and construction documents. This step is to define the most critical design activities in supporting the office strategy.

4) Operational goal of DSS. By examining the CSFs of architectural design and their relationship to the CSFs of project management, the DSS goal is identified.

In this study, owing to the limited time, the intensive interview as suggested by the CSF method has not been feasible. Therefore the study relies on general background investigations, instead of case interviews and observations. The topics discussed in this chapter are:

1) Office strategy related to architectural design
2) Goals and CSFs of project management.
3) Goals and CSFs of architectural design.
4) Operational goal of the DSS.

III-1 OFFICE STRATEGY RELATED TO ARCHITECTURAL DESIGN

This section will be investigating the general business strategies which directly relate to architectural design for a
mid-sized firm. This top management view will form a planning context to further extract lower level goals in management and architectural design.

The essence of formulating strategy of a company is by relating the company to its environment. Although the relevant environment may be very broad, due to various social as well as economic forces, the key aspect of a firm's environment is the industry in which a firm competes. From the analysis of M.E. Porter (1972, Competitive Strategy), the state of competition in an industry depends on five basic competitive forces (see Fig. III-1). Of those five forces, the most powerful competitive forces in the architectural service industry are rivalry between suppliers of construction related services (engineering consultant and contractor), substitution for architectural service, and client. The strategy of a firm will be based on a determination of the effects of these.

THE DESIGN FIRM AND THE CLIENT: The definition of architectural services, stated by a successful design firm principle, is nonprofessional and to the point "Anything that is necessary to get a building up." This firm has put this awareness into practice, being able to provide a broad range of services from project financing through construction. Similarly, many firms have experienced that for architects to be successful, they must be prepared to enter into many areas
POTENTIAL ENTRANTS

Threat of new entrants

SUPPLIERS

Bargaining power of suppliers

INDUSTRY COMPETITORS

rivalry among existing firms

Bargaining Power of buyer

BUYERS

Threat of substitute products of service

SUBSTITUTES


FIGURE III.1 Five Competitive Forces
mid-sized firm. This top management view will form a planning context to further extract lower level goals in management and architectural design.

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beyond design - feasibility, economics, financing, regulatory process, community involvement, program and contract management etc, in order to make a project work.

As a result, an architect should be actively involved in those "areas beyond design," or he or she will find himself relegated to a relatively minor role, or worse - an irrelevant factor when the owner considers a building project. Based upon this awareness, the critical strategy of a firm is to broaden its services to make a project financially viable in order to gain a client's trust and to ensure his commitment. This consideration can usually be taken care of in the predesign phase.

THE DESIGN FIRM AND ITS SUBSTITUTES: Today, almost every new facility must be rigorously budgeted and fitted into a firm's schedule. Frequently, corporate or governmental clients insist that the designers give an early guarantee as to completion date and cost. Besides, invariably all clients need someone who is accountable for cost and budgeting control of capital expenditures in a project. In this hard school of the real world, unfortunately many architects have failed to assume their responsibility. They have acted as artistic advisors to the construction industry, incapable of dealing with various factors such as the cost of building supplies in the contexts of a fluctuating economy. And because of this,
many owners have turned to construction consultants or package builders for the guarantee of performance in project time, cost and quality.

These burgeoning outside entrepreneurs clearly have been a threat to the architectural profession. Nevertheless, architects have held the most advantageous tool to counter this threat, that is, their design skills. Yet, improvement is needed in cost control disciplines for coping with design in all stages. As a result, a new look is needed at the design process itself, so that costly excursions in trial and error are not excused in the name of art.

As a result, many established architectural firms require their design services to have a leadership role in controlling building cost and quality, with the benefit that these services can easily incorporate their input into phases of construction, administration and management.

THE DESIGN FIRM, THE CONTRACTOR AND THE ENGINEERING CONSULTANTS. Buildings have become much more complex in the twentieth century and now require large-scale use of engineering services, never needed in the historic styles of architecture. And, architects, once the versatile renaissance men, are now losing ground as the professionals who head the building process.
Architects are overwhelmed with information needed for designing buildings; information supply has become information overload. Gradually, specialists have taken over specific building systems which only they could design. Thus architects saw the need to delegate the design of certain elements of the building to others and thus lost the total personal control of the design process. Today about 60% of the construction dollar is spent on building systems which are designed by engineers, not architects. Since the fifties, engineers and other consultants and technicians have emerged as an integral part of the design team. Architects no longer play a singular role; nevertheless, as a prime contractor to the building owner, architects should carry complete responsibility for all players on the team and for the promised performance of building.

THE DESIGN FIRM AND RIVALRY: The structural environment in which many architectural firms compete is an fragmented one, that is, an environment where no firm has a significant market share and thus would be able to strongly influence the outcome of its service industry. In general, fragmented industries are populated by a large number of small and medium-sized companies, privately held, with no power to shape industry-wide events. Architectural service fits right into

(*) Poter M.E. "Competitive Strategy" chapter 9, competitive strategy in fragmented industries.
The critical strategy for a firm to cope with this fragmented architectural service is overall differentiation of products and services. The purpose of such a differentiation is to create a high margin of production that could otherwise be easily achieved on basic products by normal design firms or new entrants into the architectural service industry.

CONCLUSION: OFFICE STRATEGY RELATED TO ARCHITECTURAL DESIGN. In general, for an established mid-sized firm specializing in commercial residential jobs, the typical strategy to position itself in the industry is an overall differentiation of products and services. Nevertheless, this differentiation does not imply narrowing down services and products to one particular building type and project size, rather, it means broadening service areas, so as to add extra services or product features which can directly contribute to the initiation and enhancement of a client's commitment to and trust in the architect. As identified previously, these value-added services are:

1) Feasibility study for the clients. In order to initiate and sustain a client's investment plan, the architect must analyze the market place, prepare economic and investment analyses, investigate financing alternatives, evaluate
ownership characteristics, establish site alternatives, determine building parameters and investigate code requirements. Most of these activities occur in the predesign phase, which is beyond the scope of this study.

2) Control of building cost, quality and time, for maximizing owner's investment return. The general concern of a building owner is to maximize his investment. Often, a cost reduction in construction does not necessarily result in a profit increase, when future rent and operational costs are taken into consideration. Besides, the concept of cost comprises capital costs and future costs. The elements of capital cost are land cost, construction cost, design fees and so on. Future costs, in turn, contain operational cost, real estate taxes, and financing. These definitions are, in fact, simple enough, but calculating total cost needs also to be based on the concept of the time value of money. As a result, the essence of cost control involves dynamic tradeoffs among cost, quality and time, with the ultimate intention being to maximize an owner's return on investment.

This strategy addresses each of the four competitive forces discussed above: 1) enhance the trust of clients. 2) respond to the threat from substitutes. 3) strengthen the leadership role and bargaining power for architects. 4) create a barrier to common competitors or new entrants. As a result, the office strategies related to architectural design is
identified as: to build up a firm's competence in controlling building costs, quality and time to maximize a client's investment return in order to gain a leadership role in the building process.

III.2 GOALS AND CSFs OF PROJECT MANAGEMENT

This section examines goals of project management and their CSFs necessary to achieve them. The overriding goal of project management is to assure efficient and effective use of office resources for all projects in order to achieve the cost, quality and time controls identified in the chapter on office strategy.

For the purpose of achieving this management goal, the process of project management in an office must be investigated. Based on the concept of an organization as a cybernetic system (Swinth, 1974) (\(\star\)), project management can be analyzed as three levels activities: policy level, control

\(\star\) Scott, Organizations, chapter 5 pp. 102-120. "Organizations as open systems".
level and operation level. In reference to these three levels, the required CSFs can be identified accordingly. The topics discussed in this section are: 1) management goal in response to office strategy, 2) a model of control as a cybernetic system, 3) a model of project management, 4) CSFs of management.

III.2.1 Management Goals in Response to the Office Strategy

In supporting office strategy, management's primary concern is to effectively and efficiently use office resources - mainly staff personnel of all the project teams. Normally, design firms are managed in a decentralized manner, where individual operations are small and autonomous. In order to coordinate and manage all these relatively independent project teams, a strong central supervision and performance-oriented compensation for personnel staff is needed.

Middle management represents this central supervision which links the strategic planning office with the project team. By means of this supervision managers assure resources are obtained and used effectively and efficiently in the accomplishment of an organization's objective.
III.2.2 A Model of Control as a Cybernetic System

According to Swinth, 1974, an organization can be viewed as a cybernetic system, which emphasizes the relationship among policy, control and operations centers (see Fig III.2).

The policy center of an organization sets its goals in response to office strategy. The control center, which is responsible for decisions at the middle-management level, designs a set of instructions or directions to the operation units, based upon standards prescribed by the goals. The operations center receives the raw materials and transforms them into output. The control center monitors the output of the operations center and compares it with the stated goals. This process may result in a modification of a previous set of directions. This feedback-controlled arrangement is goal-directed, that is, the behavior of the system is directed by the deviations of the current state from the stated goal. Such a control system relies heavily on mechanisms which can quickly measure performance, and detect problems in a timely fashion by identifying deviations of the actual from the planned, so that incentives and corrections can be created.

III.2.3 A Model of Project Management
Figure III.2 Organization as a Cybernetic System
Within the organizational context of the architectural office and based on the Cybernetic System, the management of all project teams can be illustrated (see Fig III.3). Managers at the policy center translate the contract stipulations into specific tasks to be accomplished and decide what percentage of the compensation defined by the contract will be realized as income when the work has been performed. In addition, they have to devise rules for assigning resources to each task. At the control level, each task is scheduled and provisions are made for allocation of resources in accordance with budgeting limitations and required technical expertise. Furthermore, this control plan should be constantly adapted in coping with the performance of the operation units. At the operations level, where the actual architectural design activities occur, the project progress should be recorded, periodically evaluated and feedback to the control center.

III.2.4 CSFs of Management

Based on the above analysis, the goal of management is to provide a central supervision of all projects to ensure that office resources are effectively utilized for building time, cost and quality control. The CSFs in achieving this goal are:
Business strategy: building cost, quality, and time control

Management goal: effective and efficient use of office resources to meet the strategy

POLICY: fee structure, strategy in project income and resources allocation

CONTROL: resource budget and schedule, performance standard

ARCHITECTURAL DESIGN AND PRODUCTION

Figure III.3 Model of Project Management
1) Fee Negotiation. To clients, policy of design fee negotiation should be restructured. The percentage of construction cost is the most common method of compensation, but does not give incentives for practitioners to be responsive to a client's needs. Rather this method gives a firm the incentive to spend the full budget.

2) Project Income Assignment. To various design phases and tasks, project income assignment should be adjusted to reflect an architect's efforts at building cost control.

3) Project Budgeting and Scheduling. Budget and schedule should reflect the best utilization of office resources and be refined progressively according to the performance of the project.

4) Evaluation of Project Team. Periodic performance evaluation of project team should be done to ensure a project will finish on time, within the budget and with the desired qualities.

III-3 GOALS AND CSFs OF ARCHITECTURAL DESIGN
Here, architectural design is viewed as a function of office operations and is broken into three phases: schematic design, design development and construction documents. First, the goal of architectural design is identified on the basis of the experience of practicing architects. Then, by analyzing the control process in coping with architectural design, the CSFs can be further defined. The topics dealt with in this section are: 1) architect's goals in response to the office strategically, 2) control process and schematic design, 3) identification of CSFs of architectural design.

III.3.1 Architect's Goals in Response to the Office Strategy

As stated by one architect, "the economic success of a project is generally determined in the first few weeks of preliminary design. After that, conceptual changes increase cost by costing delay." It is not always realized that about 90 percent of design man-hours are spent on work that can affect cost only about 7 percent plus or minus, while about 10 percent of design hours are spent on preliminary design.
decisions, which can affect costs 30 percent plus or minus.

(*) Often, sophisticated computer programs can be used to
save pennies by reducing the number of bolts used with
structural steel, while outdated rules of thumb on building
economy establish big line items, such as overall building
form and costs.

As stated by another architect, "You may be very surprised to
realize that during a typical schematic phase of the design
process, you are locking in somewhere between 60 and 70 % of
the cost of the typical project. By the time you are done with
your design development, you have locked in roughly another 20
%." (**) (see Fig III.4) As a result, schematic design is more
cost critical, and requires more analytic methods. With
project architects the major concern in schematic design are:

1) Project scheduling. Prepare a control schedule for the
project. Set up coordination procedures that will keep all
design professionals on a concurrent basis or will alert the
design team when they are not.

2) Quality design. Investigate design alternatives. Search
for best building configurations and determine major building
systems. Because this study is concerned with architectural

(*)
Swinburne, Herbert, "Design Cost Analysis"

(**)
Nielsen, Kris R. "Construction Cost Management"
Source: Nelsen, K. R. "Construction Cost Management," Exhibit no. 2

Figure III.4 The Cost "Lock-In" profile
design activities, quality and cost control during the schematic design phase will be the focus.

III.3.2 Control Process and Schematic Design

Control is an integral part of architectural design. In the early schematic design phase, an owner's investment objectives have been formulated into specific targets which can be attained through building. These targets include expected revenue, total budget, date of completion, level of building quality and space requirements. The typical process of design proceeds by evaluating a limited set of design options against the desired state and then by choosing a satisfying solution. The process will gain efficiency by adding a control program, as in (Fig III-5).

Architects should constantly refine their control program, as a goal oriented process for better design, rather than a restriction. Therefore, during the schematic phase, architects should explicitly transform their conceptual design into specific itemized targets for all disciplinary groups in the team. Meanwhile, constant refinement and evaluation are necessary to utilize the control mechanism as a design tool.
owner's investment objectives

GOALS: desired revenue, building cost, time, and quality

CONTROL POLICY: itemized budget, schedule, and performance standards

DESIGN OPTIONS

Figure III.5 Architectural Design and Control Process
III.3.3 CSFs of Architectural design

The goal of architectural design as identified above is to exercise cost and quality control over all discipline groups and integrate it with the schematic design process to maximize an owner's investment return. The following is a list of CSFs, critical for the project architect to achieve primary architectural design goal:

1) Budget and quality planning should be based on an owner's investment goals and should indicate realistic and itemized guidelines concerning cost and quality for various groups of a design team.

2) Evaluation of design options should be based on an architect's guidelines so as to identify the best plan, to deal with potential problems, and to further refine the original guidelines.

3) A construction market profile should define an accurate information base on the local construction market, which can effectively direct the budget planning.

4) A design team should be well coordinated and mechanism for communication should be clearly defined.
III.4 THE OPERATIONAL GOAL OF THE DSS

In this section some of the most important links between the CSFs of management and architectural design are mentioned. In each of the cases below, a CSF for architectural design is useful to management:

1) Market profile and policy for contract negotiation. Good knowledge base about local construction industry and other design professionals can greatly enhance the bargaining power in fee and contract negotiations.

2) Budget planning and manpower scheduling. A realistic budget for a project forms a sound base for office manpower scheduling.

3) Evaluation of design options and evaluation of the performance of design team. The evaluation of design options should be based on objective measures. This evaluation is both a design tool for selecting among various alternative choices and also is a monitoring tool for performance-oriented compensation of a design team.
The operational goal of the DSS is to evaluate design options to understand their cost and quality impacts for all sub-divided tasks. This goal was selected for the following reasons:

1) It reflects the design behaviors of architects during the schematic phase.

2) It corresponds to the strengths of a computer system.

3) The process will gradually force architects to formulate a set of guidelines, as evaluation criteria. As a result, the coordination among design professionals can be built on a more explicit basis.

4) The evaluation is set to maximize an owner's investment return, thereby gaining more trust and commitment from clients.

5) The process will have a direct impact on design activities and also be useful to the project team evaluation.

6) Evaluation, used as a monitoring tool to constantly refine the planned budget, will assist the process of budget planning.

7) In the long run it will have its full strategic impact.
CHAPTER IV: IDENTIFICATION OF PROTOTYPE SYSTEM

The purpose of this chapter is to identify the opportunity for a prototype system, which supports the operational goal defined above. A prototype system has the essential features of a finished system, yet does not have a complete set of functions. A prototype system is tested to illustrate what it can do with the expectation of adding more functions later. Such a system can be identified using the following steps:

1) Establish critical measures. The measures are the hard and soft data that decision makers use to monitor the performance of the operational goal for the DSS.

2) Generate a critical decision set. In reference to the critical measures, the critical decision set, generated from an architect's viewpoint is a list of important decisions that most impact the successful execution of the operational goal.

3) Identify prototype system. Critical decisions can be grouped and transformed into a series of distinctive decision
processes, which designate types of opportunities for DSS. The prototype system is identified through prioritizing these opportunities.

In this chapter, data being used for decision-making were collected through investigations and interviews, and also, through interviewing project designers and the project architects. Thus the priorities of a decision set were established. In addition, in order to understand the way architects exercise cost and quality analysis, an examination of architectural design theory is very helpful. The pieces of information that architects use in their daily design activities can thus be organized into a meaningful framework.

The topics dealt with in this chapter are:

IV.1) Architectural design theory
IV.2) Critical measures of the operational goal
IV.3) Critical decision set
IV.4) opportunity for prototype system

IV.1 ARCHITECTURAL DESIGN THEORY -Thematic Design Approach

The Thematic Design approach is an architectural design methodology that regulates a formal system according to a set of rules. This formal system is not arrived at through
personal intuition or speculation. Instead, it is derived from a 'theme', which is something basic in peoples' beliefs and values about living environments, i.e. governed by social conventions. Part of the process of formulating a theme is through the alternating interaction between space and material. In the realm of space, based on use and social-cultural convention, the major spatial elements and their relationship are defined. In the realm of material, bounded by technological and economic constraints, the technical systems for buildings are determined. Thus, a theme is formulated through the interaction between spatial system and its bounding technical system. (*)

The thematic approach is really applicable to professional architectural design. The pursuit of a theme may not be the goal of an architectural office, yet certainly, in most offices, architects have their own set of proven formulae or conventions, which result in a fixed set of spatial technical elements. Beyond that architectural design in an office is basically a process of selecting the best candidate among choices and matching space and material. Technical building systems conventionally can be subdivided into the following:

(*) Based on John Habraken's theory of Thematic Design, Amine Klam, in his thesis, examines the relationship between space and material.
Architectural building systems: roofing, exterior walls, partitions, wall finishes, floor finishes, ceiling finishes, specialties, fixed equipment, conveying systems.

Structural building systems: foundations, floor on grade, superstructure.

Mechanical/electrical systems: HVAC, plumbing electrical.

IV.2 CRITICAL MEASURES FOR THE OPERATIONAL GOAL

The operational goal of a DSS has been identified as cost evaluation for schematic design options to achieve satisfactory investment return for an owner. Critical measures should be determined to indicate the performance of a design in relation to an owner's investment goals. Typically, an owner's investment goal can be expressed as maximizing potential revenue and minimizing cost. In this study, the focus has been primarily on the building itself rather than on land and other indirect costs.

REVENUE. The revenue generated by a building can be analyzed in terms of rentable space and rent. The conventional measures of these items used by architects are as follows:

1) Rentable Space:
i) Areas by room functions. Areas assigned to the various room functions and any excessive space allocation should be recorded.

ii) Ratio of square feet net to square feet gross. This ratio is compared with ratios typical for that particular building type and if it is found excessive, further design studies are called for.

2) Future Rent: The potential rent of a building is determined by a number of factors other than the building itself. Yet the perceived quality of the building does influence future rent, and the criteria for building quality include such immeasurable factors as real use, image, and aesthetics. Assessing these factors are beyond the scope of this study, which is concerned with the measurable qualities of space and building systems in a design:

Space quality:

i) Room size, from generous to economical.

ii) Quality of room finishes and equipment.

iii) Special design features, such as atrium, green-house, or energy saving features.

Building systems quality: Including exterior wall, roofing, etc.
i) Dollars per square-foot of each building system, ranging from austere to luxury. Often, unit cost is in proportion to quality and complexity of an individual building system.

ii) Performance criteria: such as fire proofing, damp proofing, thermal resistance, etc.

COST: The components of cost are construction cost, life-cycle cost, and financing cost.

1) Construction Cost: initial cost by building systems.

i) Construction cost total and cost detail of each system. (see Fig IV.1)

ii) Total cost per square-foot (SF) and system cost per SF.

iii) Percentage of each system cost to cost total. Usually systems with high relative cost are superstructure, exterior walls and mechanical systems.

2) Life-Cycle Cost:

i) Operating cost: annual cost of energy consumption. Typically, roofing, exterior walls, glazing, building forms, building orientation, mechanical system, and electrical system are all interrelated in affecting operating cost.
## SCHEMATIC COST ESTIMATE NO. 1

<table>
<thead>
<tr>
<th>Description</th>
<th>Labor, $</th>
<th>Material, $</th>
<th>Total, $</th>
<th>$/sq ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations</td>
<td>75,161</td>
<td>47,227</td>
<td>122,388</td>
<td>0.50</td>
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<tr>
<td>Floors on grade</td>
<td>24,901</td>
<td>25,521</td>
<td>50,422</td>
<td>0.21</td>
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<td>Superstructure</td>
<td>1,065,591</td>
<td>2,025,629</td>
<td>3,091,220</td>
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<td>Roofing</td>
<td>25,747</td>
<td>29,627</td>
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<td>Exterior walls</td>
<td>832,462</td>
<td>1,487,491</td>
<td>2,319,953</td>
<td>9.51</td>
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<td>859,356</td>
<td>1,290,244</td>
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<td>154,211</td>
<td>324,349</td>
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<td>610,512</td>
<td>878,308</td>
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<td>Specialties</td>
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<td>342,785</td>
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<td>490,882</td>
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<td>244,279</td>
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## SCHEMATIC COST ESTIMATE NO. 1 WITH COST DETAILS OF BUILDING SYSTEMS

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<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Labor, $</th>
<th>Material, $</th>
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<td>Floor finishes</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramic tile</td>
<td>11000</td>
<td>sq ft</td>
<td>23,889</td>
<td>20,691</td>
<td>44,680</td>
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<td>sq ft</td>
<td>31,151</td>
<td>60,750</td>
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<td>Computer floor</td>
<td>10000</td>
<td>sq ft</td>
<td>27,830</td>
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<tr>
<td>Carpeting</td>
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<td>sq yd</td>
<td>52,953</td>
<td>186,504</td>
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<td>18,293</td>
</tr>
<tr>
<td>Marble Flooring</td>
<td>11000</td>
<td>sq ft</td>
<td>35,626</td>
<td>73,517</td>
<td>109,143</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>186,469</td>
<td>448,754</td>
<td>635,223</td>
</tr>
<tr>
<td>Ceiling finishes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plaster</td>
<td>22000</td>
<td>sq ft</td>
<td>46,189</td>
<td>14,087</td>
<td>60,276</td>
</tr>
<tr>
<td>Paint ceiling</td>
<td>26000</td>
<td>sq ft</td>
<td>14,387</td>
<td>2,775</td>
<td>17,162</td>
</tr>
<tr>
<td>Acoustical tile</td>
<td>198000</td>
<td>sq ft</td>
<td>109,562</td>
<td>137,349</td>
<td>246,911</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>170,138</td>
<td>154,211</td>
<td>324,349</td>
</tr>
<tr>
<td>Conveying systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cab allowance</td>
<td>7</td>
<td>each</td>
<td>12,193</td>
<td>32,139</td>
<td>44,332</td>
</tr>
<tr>
<td>Doors, guides, controls, etc.</td>
<td>1</td>
<td>LP SM</td>
<td>82,921</td>
<td>201,482</td>
<td>284,403</td>
</tr>
<tr>
<td>Elevator, medium speed</td>
<td>6</td>
<td>each</td>
<td>153,692</td>
<td>338,701</td>
<td>492,393</td>
</tr>
<tr>
<td>Freight elevator, electric</td>
<td>1</td>
<td>each</td>
<td>18,990</td>
<td>12,193</td>
<td>31,183</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>267,796</td>
<td>610,512</td>
<td>878,308</td>
</tr>
<tr>
<td>Specialties</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toilet partitions</td>
<td>1</td>
<td>LP SM</td>
<td>13,342</td>
<td>60,379</td>
<td>73,721</td>
</tr>
<tr>
<td>Toilet accessories</td>
<td>1</td>
<td>LP SM</td>
<td>2,600</td>
<td>3,900</td>
<td>6,500</td>
</tr>
<tr>
<td>Misc specialties</td>
<td>1</td>
<td>LP SM</td>
<td>100,000</td>
<td>180,000</td>
<td>280,000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>115,942</td>
<td>244,279</td>
<td>360,221</td>
</tr>
</tbody>
</table>

Figure IV.1 Sample of Schematic Cost Estimates

3) Financing Cost: Working hours for building design and construction. The longer the time span the higher the financing cost of the project. For each building system, labor and working hours should be noted, so that a total man-hour requirement can be obtained. This provides the base for scheduling the progress of a project.

IV.3 CRITICAL DECISION SET

The operational goal is to perform cost monitoring for achieving the owner's investment goals. Maximizing revenue and minimizing cost is the major concern for building owner. For architects, this concern is transformed into maximizing building performance and minimizing building cost. In other words, an architects' major responsibility at the schematic phase is to effectively utilize a budget for creating desirable building performance for the owner. Refering to the above critical measures of revenue and cost, the following list sets forth the critical decisions that architects are constantly confronted with during the schematic design phase of a project:
1) Can the area of rentable space be increased with a minimum of construction costs?

2) Does the cost distribution of building systems reflect the best utilization of budget? How can the problems in budget utilization be identified and corrections be made?

3) Can space and material quality be maintained by some less costly alternatives? Is the quality of space and material consistent with an owner's expectation? Is there any over-design of a particular building subsystems, unnecessarily complex details or specifications which are unfeasible for the existing budget?

4) Can systems and material selection take better advantage of the local construction market?

5) Will the chosen design option cause significant delay in design and construction?

6) How can the annual cost of energy consumption be reduced. For example, by changing the configuration, orientation, fenestration, or the material used for exterior enclosure and glazing?

7) Because the improvement of energy performance results in higher initial cost, will this cost be justified in the long run?
8) In order to maintain the same rate of investment return, how much rent must be raised to cover the increased construction cost?

IV.4 THE OPPORTUNITY FOR PROTOTYPE SYSTEM

Construction cost analysis: In current architectural practice, construction cost analysis is the most important of the three processes. There are two levels of cost analysis related to items (1), (2), (3), and (4) in the critical decision set: the macro level which is the estimate by building systems; the micro level which is a detailed estimate for each building system.

Operating cost analysis: This process is related to item (6) in the list of critical decisions above. The purpose of an operating cost analysis is to analyze the energy performance of a design option. This process allows users to determine building orientation and material, and to receive in return an estimate of energy consumption due to heating and cooling loads, lighting, and building services. Based on energy consumption estimates, operating costs can be defined. In addition, maintenance costs should be considered for material
selection for all building systems.

Total cost analysis: This process is related to items (5), (7), and (8) in the critical decision set. The purpose of this process is to evaluate construction cost, operating cost and financing cost on the basis of the time value of money. Architects know that the improvement of operating costs will raise construction cost. But knowing the direction of change is not enough. One must also know how much change is the total cost; furthermore, in order to maintain a certain level of rate of investment return, how much must the rent be raised to cover the cost increase? With such quantitative knowledge an intelligent decision can be made.
The purpose of this chapter is to identify the data base required for the prototype system mentioned above, so that the system may be more formally defined. A data base is generally defined as a collection of computer-stored data. Every organization maintains a collection of data that is used for the planning, control, and operation of that organization. This will be called as the internal database. Most organizations also use external data, that is data gathered and maintained by another organization. Internal and external data bases are important prerequisites for DSS because these data bases will contain some of the data relevant to the decisions supported by the DSS.

The process of defining required data base is based on the technique of a "decision scenario" (Rockard, 1981). Each decision scenario concerns a particular event and the questions which might be asked in formulating a decision. In decision scenarios, it becomes clear which questions would be answered by the new system and which would be left unanswered. In answering these questions, the relevant data base is
In this chapter, three decision scenarios are identified through the critical decision set. They are building space analysis, building systems estimates and total building estimate. Each scenario presents the particular activities in which architects perform construction cost analysis, and specific questions they asked.

V.1 Building space analysis  
V.2 Building systems estimates  
V.3 Total building estimate  

V.1 BUILDING SPACE ANALYSIS  

Description of decision events. During the design phase, architects tend to fix the floor plan as soon as possible. The building configuration needs to be examined for: 1) total area needed to achieve essential functions and relations; and 2) efficiency of the ratio of net to gross floor area. If the ratio is determined to be inefficient when compared to the ratio for a similar building type, the architect must revise his plans.
Decision Scenario: Space analysis

Questions asked by architects measure

1) Is there any excessive space floor area by room allocations related to the building program? function

2) Does space efficiency comply to floor area net to the owner's expectation? floor area gross

Data Base Required: Floor plans, with attributes of each room, such as size and function.

V.2 BUILDING SYSTEMS ESTIMATES

Description of decision events: Among all the building subsystems, the superstructure and exterior walls are the two systems that most impact the building form. They represent about 35% of the construction cost. (see Fig V.1) As a result, these two systems are an architect's primary concern during the schematic design phase.

1) Superstructure and Exterior Wall Analysis: During the process of exploring building configurations, architects study form in conjunction with an appropriate structural system. The superstructure is an inherent part of architectural form, and it is usually the architect rather than structural engineer, who selects the type of structural system and sets
THE ENGINEERS’ SHARE OF AVERAGE CONSTRUCTION COSTS
FOR A COLLEGE LIBRARY

(Site costs are excluded.)

<table>
<thead>
<tr>
<th>Building Systems</th>
<th>Costs</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofing</td>
<td>$1.22</td>
<td>1.9%</td>
</tr>
<tr>
<td>Exterior walls</td>
<td>8.58</td>
<td>13.4%</td>
</tr>
<tr>
<td>Partitions</td>
<td>2.96</td>
<td>4.6%</td>
</tr>
<tr>
<td>Wall finishes</td>
<td>1.06</td>
<td>1.7%</td>
</tr>
<tr>
<td>Floor finishes</td>
<td>1.48</td>
<td>2.3%</td>
</tr>
<tr>
<td>Ceiling finishes</td>
<td>1.98</td>
<td>3.1%</td>
</tr>
<tr>
<td>Specialties</td>
<td>2.26</td>
<td>3.5%</td>
</tr>
<tr>
<td>Fixed equipment</td>
<td>6.42</td>
<td>10.1%</td>
</tr>
<tr>
<td>Conveying systems</td>
<td>1.02</td>
<td>1.6%</td>
</tr>
<tr>
<td>Foundations</td>
<td>2.26</td>
<td>3.5%</td>
</tr>
<tr>
<td>Floors on grade</td>
<td>0.90</td>
<td>1.4%</td>
</tr>
<tr>
<td>Superstructure</td>
<td>13.54</td>
<td>21.2%</td>
</tr>
<tr>
<td>HVAC</td>
<td>10.22</td>
<td>16.0%</td>
</tr>
<tr>
<td>Plumbing</td>
<td>3.78</td>
<td>5.9%</td>
</tr>
<tr>
<td>Electrical</td>
<td>6.20</td>
<td>9.7%</td>
</tr>
</tbody>
</table>

Costs by Building Systems

<table>
<thead>
<tr>
<th>Design Disciplines</th>
<th>Costs</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$25.95</td>
<td></td>
<td>40.6%</td>
</tr>
<tr>
<td>$16.70</td>
<td></td>
<td>26.1%</td>
</tr>
<tr>
<td>$20.20</td>
<td></td>
<td>31.6%</td>
</tr>
</tbody>
</table>

Source: From "Design Cost Analysis", Swinburne, H.

Figure V.1 Cost Distribution by Building Systems
bay size and building height. The superstructure system consists of three subsystems: vertical support assemblies, primary and secondary framing assemblies and deck assemblies. The selection of subsystems should be based on the requirements set by building and should properly reflect the local construction market. The superstructure cost per square-foot of floor area is a useful measure to check if the cost exceeds that of a similar building. When architects want to reduce cost, they usually try to reduce bay size and building height; simplify building form; and compare their solution with other similar building.

Exterior walls are the most costly of all architectural subsystems. The area of the wall surface is a function of building perimeter and floor height. Therefore, an analysis can be made of the ratio of the area of the perimeter walls to the gross floor area of the building. If this ratio is found excessive, further design studies are suggested. The major factor involved in making a decision concerning the superstructure is floor-to-floor-height, which determines the area of the building skin. Thus, usually these two subsystems - superstructure and exterior wall - are considered together. The exterior walls consists of wall assembly, finish material, glazing, exterior door, backup material, and shading.

Other building systems. Other building systems, such as
roofing, foundations, electrical and mechanical systems only have a minor impact on building form. The measures used by architects usually are system cost per SF, cost details of each subsystem, and overall cost. In addition, unit prices of various materials should be noted, as an indicator of overall material quality.

In the schematic phase, architects seldom have information that is sufficiently detailed in the mechanical and electrical areas, other than broad concepts. Yet, as stated by a mechanical engineer: 'If you described the type of the building and the basic functional arrangements of the space, we could tell you within 3% what that load will be. Once that is known, that locks the basic amount of cost into the project, and there is very little that you can do about it.' As a result, dealing with this type of estimate, appropriate rules of thumb are very useful. (1)

Decision Scenario: Configuration, Superstructure, and exterior walls

<table>
<thead>
<tr>
<th>Question Asked</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) How can one make a more realistic estimation?</td>
<td></td>
</tr>
<tr>
<td>a) accurate information about the local construction market at bidding time.</td>
<td>cost index conversion factors</td>
</tr>
<tr>
<td>b) well predicted inflation rate.</td>
<td>inflation rate</td>
</tr>
<tr>
<td>2) Is the system cost higher than average?</td>
<td>system cost per SF</td>
</tr>
</tbody>
</table>

(1) Nielsen, K.R. "Construction Cost Management"
How can the cost be reduced without degrading the building quality excessively?

a) Are the decisions about space reasonable? and change of bay size or floor height, or reduce complexity in form possible?

b) Is the decision about building subsystems reasonable?
   i) Where can one start to cut down or to add on the cost?
   ii) Is there over-design or excessive complexity of detailing?
   iii) Does system quality comply to the performance criteria?
   iv) Does material quality match the owner's expectation?
   v) Does system selection take advantage of the local construction market?

Data Base Required:

1) floor plans, building sections.

2) A profile of the local construction market by building systems. This may be the biggest problem, for the large size of the data base and the needs for constant updating with the fast changing construction market of today. Yet, for the prototype system, the collection of data can begin with frequently used items. Beyond that, there are external data sources, which provide effective computerized cost data for several building types. By simple telephone-adapted Equipment (modem), firms can access these data with reasonably low cost.

3) Library of building systems. A collection of building
technical elements, frequently used among projects, is very useful for the selection of building systems. For example, files of superstructure elements includes items such as vertical support, primary and secondary framing, and deck; whereas, files of exterior walls include wall assembly, finish material, glazing, exterior doors. These data should link closely to that of the local construction market.

4) Cost Guidelines. Records of cost distributions for each building system and for various building types can be a good references for cost comparison. Derived from these records, office standards may be developed over time.

Decision scenarios on the other building system. This is similar to the decision scenario illustrated above. Yet, it can be much simpler in the initial development stage of the prototype system.

V.3 TOTAL BUILDING ESTIMATE

Descriptions of decision events. Based on input from the system estimates above, a final schematic estimate can be derived. The value of this estimate is in cost comparison, subsystem by subsystem. By comparing this estimate with the cost distribution, typical for a particular building type, architects may spot problems.
The strength of such a cost estimating process lies in the interplay between system estimates and the total building estimate. For example, in the overall building estimate, if the percentage of the total for the superstructure exceeds that of an average building, this condition is a warning indication that uneconomical decisions in the superstructure may cause a problem. Therefore, by going back to check the cost details of superstructure, architects may realize that by decreasing bay size and floor height, a substantial saving can be achieved. Or, by examining the floor finishes, for example, the marble flooring for all elevator lobbies, they may discover the reason for a high dollar cost per square foot. Although marble floors may be desired by the owner, the owner must be informed that such a level of quality for flooring is too high. One possible solution may be restricting marble flooring only to the first floor lobby. Therefore, such a cost analysis process must go back and forth between the macro and the micro levels, between the total building cost and subsystems costs. Thus, the architect should not be satisfied with only one design solution, even if the design seems aesthetically and functionally satisfactory. Exploring alternatives is a typical way of seeking not only better, but also more economical design solution for architects.

Decision Scenario: Total building estimate by building systems
Question Asked

1) Does the cost estimate exceed the budget?

2) Is there any economical imbalance in the building estimates?

3) Where might there be the problem?

Data Base Required: Cost distribution of a building by building systems should be collected for a wide range of projects from luxury to modest and for various building types. Thus, the comparison of identical cases can be made through a complete list of historical records.
CONCLUSION

The theme of the study is the planning process for DSS in architectural design, linking office strategy with project management emphasizing on a specific prototype system, i.e. schematic cost analysis. This top-down approach ensures that the systems not only contains the relevant data for architectural design purposes, but also provides the material for both project management and top strategic planning.

The future direction for the DSS development should not be heading toward enhancing its completeness, by adding sophisticated life-cycle analysis, but rather establishing its direct linkage to management on the strategy level. For example, in regard to the information requirements for cost evaluation mentioned above, there are three sets of information requirements which will greatly improve the efficiency of the DSS: the local construction profile, cost guidelines, and library of building systems. Among the three, the emphasis should put on the cost guidelines and the local construction profile, so that a system of budget planning can be developed. Furthermore, such budget planning can impact fee negotiation and manpower scheduling. Following in such a manner, the DSS will eventually grow and expand into an information system with real strategic impact.
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