A Study of the Role of Information Systems on Existing Building Delivery Methods: Towards Better Coordination and Flexibility for the Integration of New Systems and Products

by

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Abstract

This thesis is concerned with the opportunity for architects to reinvent current design methods, by looking at current trends in building delivery methods, such as fast-track methods, and recent innovations in information systems technology, such as database technology. Two case studies are presented as examples of companies using fast-track delivery methods and information technology, as a way of responding to client's demand for speedy delivery of a project. The firms used for the case study are Goody Clancy &Associates and Herzog-Hart Corporation. Case Studies are used to examine the evolution of computer systems use in each firm, and consequent outcomes in each organization. The cases also contain interviews with individuals from each organization, in order to gain insight into current methods of practice. The thesis then discusses current ideas in management concepts, recent developments in computer technology, and their application for reinventing the design process.

Thesis Supervisor: Eric Dluhosch
Title: Senior Lecturer and Professor Emeritus

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To whomever may read this thesis in the future, thank you for your interest in this material, and please read on!

The designer then becomes a designer of generating systems- each capable of generating many objects- rather than a designer of individual objects.

-Christopher Alexander

Table of Contents

List of Figures

Chapter 1

Introduction- In search of New Opportunities

The premise of this thesis is, given the circumstances of current professional practice what opportunities exist for new design methods. The current environment of professional practice is one of speedy methods of building delivery, and various new uses of computer technology offering the promise of greater efficiency. Speedy delivery refers to methods of fast-track construction, while computer technology refers to recent developments in information systems technology (IT).

The thesis begins by exploring some of the current methods of project delivery, in order to familiarize the reader with fast-track projects. Another purpose for starting with delivery methods is to show the diminishing role of the architect on the faster delivery methods. In traditional design-bid-build delivery method the architect represented the client and was put in the position of leader on a project, that is ,in relation to other parties such as contractors and engineering professionals. However, in newly developed delivery methods the architect can no longer claim leadership on a project. In other words, the changing role of the architect in fast-track delivery methods begins to raise the issues regarding the need for a new design method, one that may either put the architect in a position of leadership on a project, or one that better aides in a teamwork approach to design and construction.

Fast-track methods are known for being coordination intensive. Some firms have looked to IT as a means of linking parties on a project together, electronically. Through the use of IT organizations desire to make their reaction time to project contingencies shorter, thereby facilitating faster construction. The role of IT in fast-track and its various applications are discussed in the thesis. However, IT offers new possibilities in communication and document creation, as well as a method for storing and retrieving information of various kinds. The new possibilities in computer technology is what interests the author, in terms of how current developments in IT may lend themselves to the design and construction process.

The current difficulty with computer technology and its development is that it is happening in so many places at once. That is, computer magazines offer one type of source for recent developments in computer hardware by manufacturers, yet there are numerous efforts by private individuals and organizations to develop computer systems catered to their specific needs, Case 2 in chapter 3 is an example of such an organization. In Case 1 and Case 2 two firms that participate in the construction industry are presented. Their approach to computer technology use is explained , and issues raised by the new uses of the computer are explored through interviews with members of each organization. Also, covered in the interviews are issues pertaining to the climate created by fast-track delivery methods in construction.

Changes in delivery methods in conjunction with the capabilities of new computer technology, as a means for exploring new methods for design, is the focus of the this thesis. The issues relating to these changes are discussed, and explored, with the Conclusion offering some of the authors personal opinions on the current developments in the areas covered in this thesis.

Chapter 2

A Description of Building Delivery Methods, Information Systems, and Flexibility.

2.1 Building Delivery Methods and their Evolution, in Response to Owner's Requirements.

2.1.1 Design-Bid-Build

The traditional model for the building delivery process is the design-bid-build delivery method (see figure 2-1). In the design-bid-build delivery method the project progresses in a linear sequence. The advantages of the design-bid-build delivery method is in its clear division of responsibilities and liabilities . In design-bid-build the architect's role is as the owners representative. This means that the architect's responsibilities, although not contractual, include construction administration. In the past two to three decades, liability insurance carriers and legal advisors have dissuaded architects from involvement in the construction process in order to reduce their

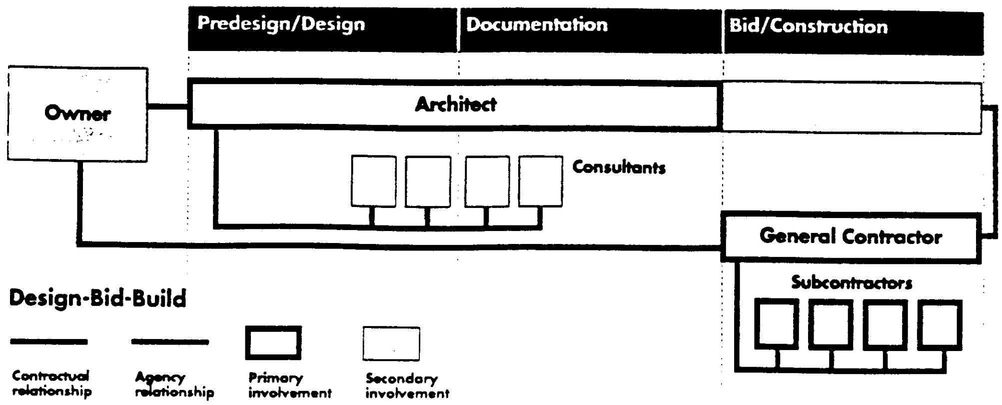

Figure 2-1: Diagram of Design-Bid-Build, where Architect provides construction administration services.

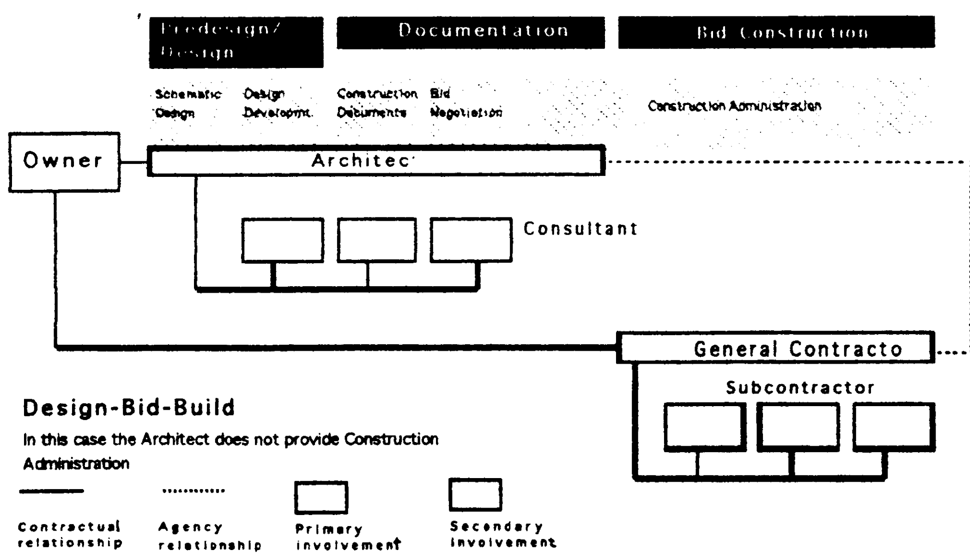

Figure 2-2: Diagram of Design-Bid-Build, where Architect does not provide construction administration services.

exposure to professional liability claims. Consequently, an increasing number of architects and firms withdrew from providing services beyond the completion of construction documents.[1] The outcome of this practice has led to the relative absence of the architect from the construction scene. This relationship is shown in figure 2-2. The architect in this relationship facilitates the interpretation of the construction documents during the construction phase, but does not provide any construction administration service to the owner. The most common form of construction contracting for design-bid-build involves competitive bidding for a single construction contract (see figure 2-3).[2] With the emergence of design-build, fast-tracked, bridging, etc., delivery methods clients complain that design-bid-build is inefficient and slow.[3]

2.1.2 Speedy Delivery

In Total Quality Management(TQM) it is said,"the best way to satisfy customers is to deliver a high-quality product at a low price when the customer wants it".[4] In response to the failure of older delivery methods and to satisfy owner's requirements for speed of construction without paying premium price, new delivery methods

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[1] [1],p.3

[2] [3],p.I-1-6

[3] In this thesis the term "client" is substituted with the term "owner", except where otherwise noted.[1],p.30

[4] [5],p.40.

have been developed.[5] These delivery methods can be categorized by the type of contractual agreement used by owners for each type of project. The basic types of contractual relationships are identified as Multiple Prime, Construction Management(CM), Design-Build, and Owner Builder.[6] Each type of contract is illustrated in figures 2-4 through 2-7. In the multiple prime contract the owner divides the work into separate packages. These packages are then contracted separately to various contractors ,e.g., plumbing, mechanical, electrical, site, etc., with each contractor entering into a separate contractual relationship with the owner (see figure 2-4). This method of contracting is used in phased construction, here contracts are awarded sequentially as construction occurs.[7] Fast-tracked construction is used where time is critical to the completion of a project.[8] In the Multiple Prime Contract the architect prepares separate sets of construction documents, or packages, for each contract. For example, construction on the foundation package may proceed prior to the completion of the total building design. This leads to an overlap in the scheduling of the sequence of construction (see figure 2-8). For this reason fast-tracked projects are coordination intensive, because the lines of responsibility and liability may blur as multiple work on a project proceeds

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[5] [1]p. 34

[6] [3]pp.I-1-6 to I-1-8

[7] Or fast-tracked construction.

[8] [3]p.I-1-7

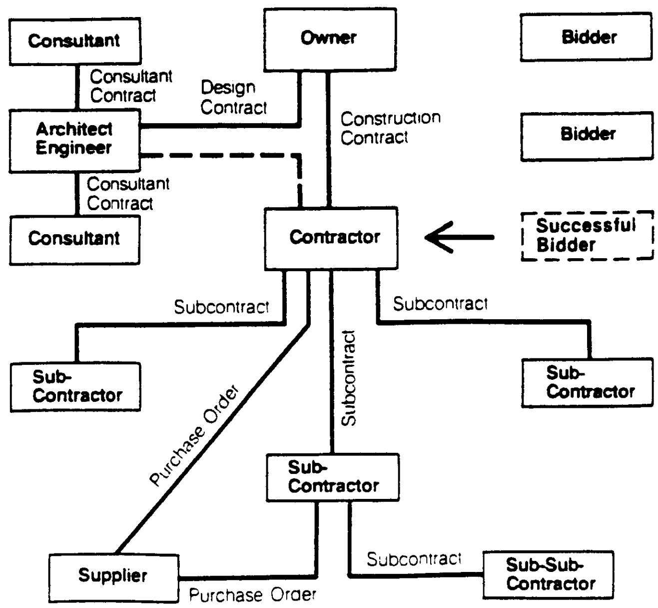

Figure 2-3: Contractual relationships in a competitively bid Single Contract.

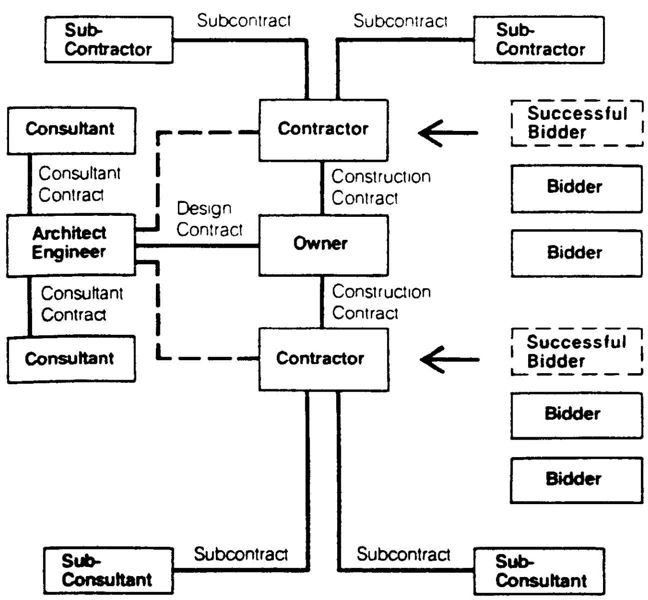

Figure 2-4: Contractual relationships in a Multiple-Prime Contract.

concurrently. As a rule, the designer has to clearly define the scope of work within each construction package for each contractor. Packages typically represent the phases of work to be done on the project.

2.1.3 Construction Administration

In order to address coordination problems in a prime contract project, owners usually seek the services of a construction manager (CM). The CM represents the owner by administering and overseeing the process of construction. In administering the project the CM's role includes the evaluation of bids and the awarding of all or parts of the contracts for the project (see figure 2-5).[9] Generally, the CM does not participate in the direct construction of the project. For this reason many general contractors, in order to avoid the liability issues associated with the construction process, have been drawn into providing CM services. With the GC as CM the services rendered by the construction manager include those services traditionally associated with a contractor, such as "estimating, scheduling, constructability reviews, and procurement of long lead times".[10] By providing these services during the preconstruction phase CMs are better able to serve owners, and architects benefit from the CMs valuable construction expertise.[11]

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[9] [3],p.I-1-7

[10] [1],p.30

[11] [1]p.30

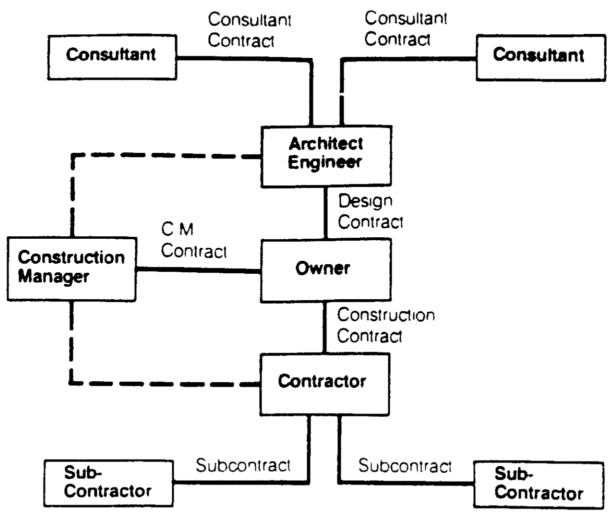

Figure 2-5: Contractual relationships when a Construction Manager is used on a project.

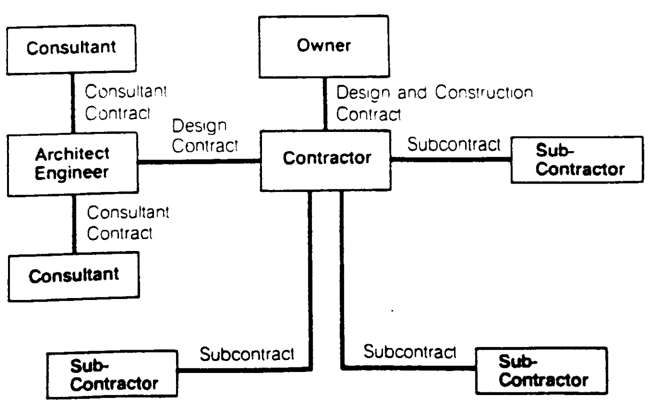

Figure 2-6: Contractual relationships in a Design-Build project.

A CM who does not provide construction services may be viewed as a CM-Advisor(see figure 2-9). Whereas a CM who provides construction services is viewed as the CM-Constructor (see figure 2-10 and appendix A).[12] The choice between the two is whether an owner prefers to have a single source provider of design and construction, e.g., CM-Constructor, or checks and balances offered by separate contracts for design and construction,e.g., CM-Advisor. Some other delivery methods, as defined by their contractual relationship between the owner and the participants on a project are Design-Build, Owner-Builder, and Bridging (see figures 2-11 , 2-12 , 2-13). In Design-Build the owner contracts with one party for design and construction work. Most Owner Builders are developers who have in-house personnel to supervise projects. As depicted in figure 2-12, owner builders hire sub-contractors directly. In the case there is no staff available in-house, for design and engineering work, such services are contracted outside the company. Bridging has come into existence in order to address the issue of quality design. It is generally recognized that architectural design offices tend to have the best designers. Therefore, these firms typically get featured in design magazines for excellence in design. Whereas architectural/engineering (A&E) firms offer owners better one source service and tighter coordination in terms of project management services, but are less recognized for the quality of their design work.[13] Bridging offers owners the opportunity to have one source service of the design/builder combined with the services of an architect or firm.

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[12][1]1,p.31

[13][4],p.38

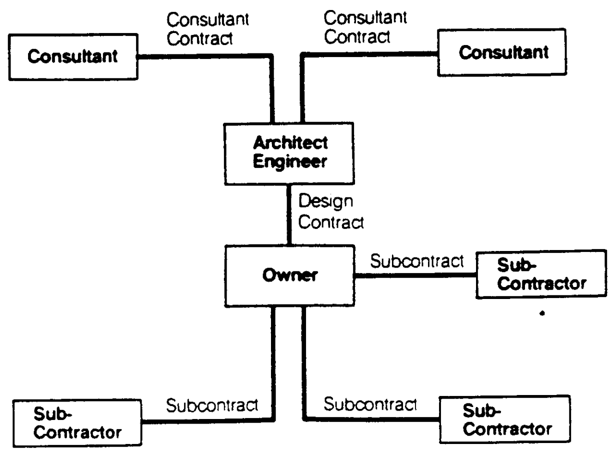

Figure 2-7: Contractual relationships in a Owner/Builder project.

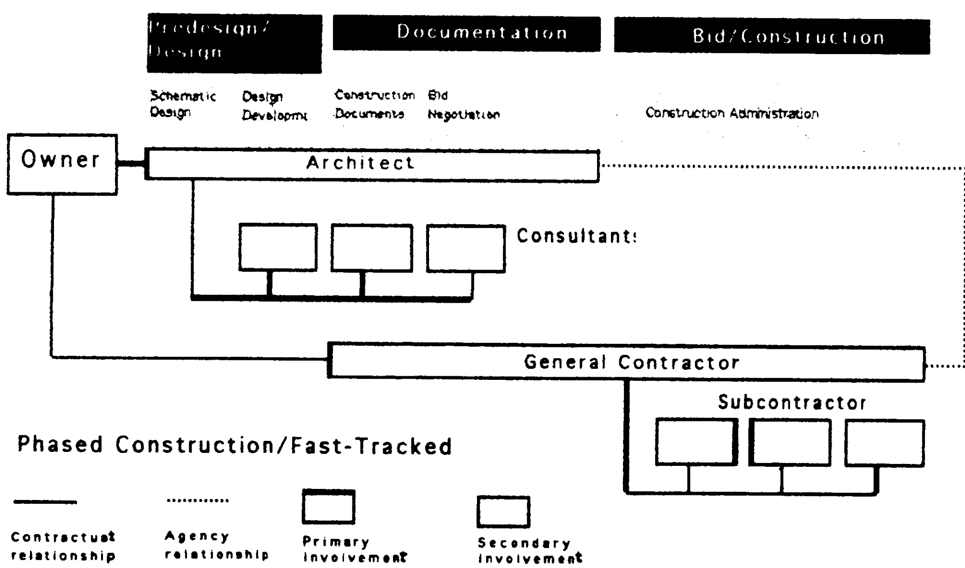

Figure 2-8: Diagram of Phased Construction/Fast-tracked project delivery process.

2.1.4 Architect's Role in Current Delivery Methods

The development of different delivery methods is a consequence of trying to better satisfying owner's requirements. These improvements include faster delivery of the building, higher quality construction, and higher quality design. The previous section briefly discussed how each delivery method attempts to address all or some of these owner requirements. The list of delivery methods presented here is not exhaustive, and it can be said that the construction industry is ever looking for a delivery method which satisfies the maximum of owner's requirements. The goals of faster delivery of the building and higher quality of construction have been met by more recent delivery methods, especially as projects increase in complexity. However, the issue of the quality of design of a building still presents problems. This is especially true of multidisciplinary firms.[14] The one source service that these type of firms provide addresses owners demands for efficiency and speed, i.e, multidisciplinary firms focus on "owner-driven design and process".[15] Unfortunately, these firms cannot consistently show that such attempts at efficiency have produced greater satisfaction in regards to quality of design.[16] In response to the need for better quality design, multi-disciplinary firms have developed a variety of ways to work with architectural designers. The options range from having well known independent designers become

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[14]The multi-disciplinary firm is described as a firm which combines multiple professional services,e.g., Architectural Engineering(A/E), Engineering Architectural(E/A), Architectural Engineering Construction(AEC),etc.

[15][4],p.38

[16][4],p.38

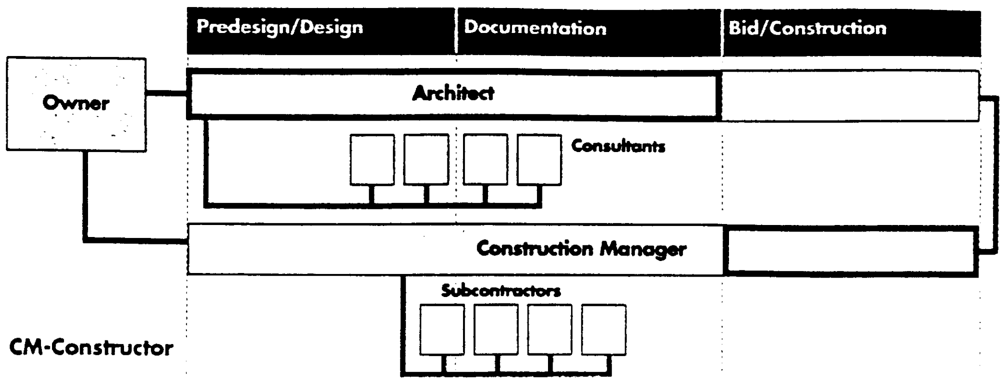

Figure 2-9: CM-Constructor project delivery process.

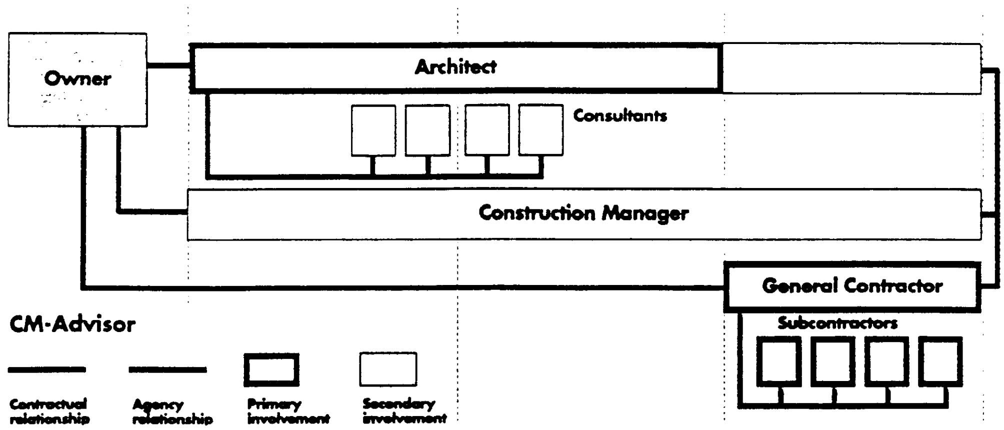

Figure 2-10: CM-Advisor project delivery process.

partners in an established A/E firm,e.g., Helmut Jahn at Murphy Jahn, to working on projects as a team with architectural firms (see figure 2-10).[17] These examples represent a specialized case as opposed to the norm. The norm being where the management in the multi-disciplinary firm is made up of engineering professionals. Most multi-disciplinary firms do not tend to attract highly talented architectural designers .This has been attributed to the focus of these firms on quality of construction and quick delivery of the project, over a concern for the esthetics of the project's design.[18]

Architects have moved from a position of being a part of the construction process in the design-bid-build delivery process, to that of being in-house designers in some of the more recently developed building delivery methods, or acting as a specialist design firm in joint project ventures. Generally, owners are aware of the value of good design. However, the question remains whether architects can capture a more active role in the construction project beyond that of a designer, especially in regards to the current building delivery methods discussed above. As a rule these require multi-discipline project teams for their execution. As quoted in Architectural Record:

[17] An established A/E firm collaborating with a popular (but usually smaller) design firm.

[18] [4],p.37

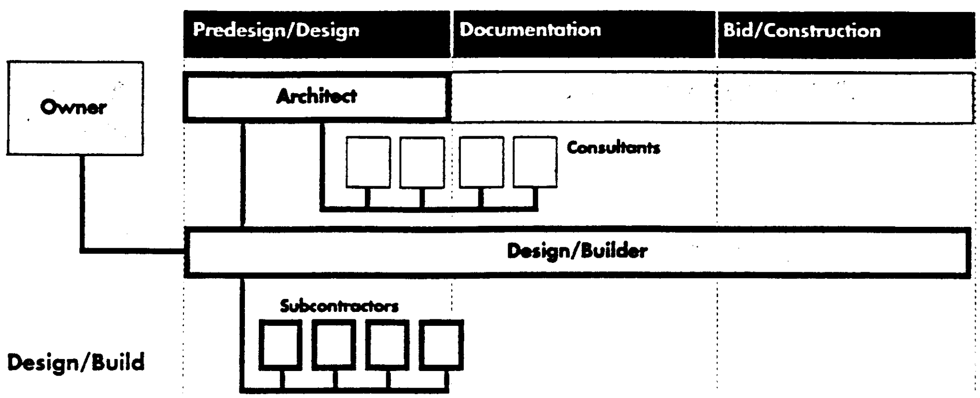

Figure 2-11: Design-Build project delivery process.

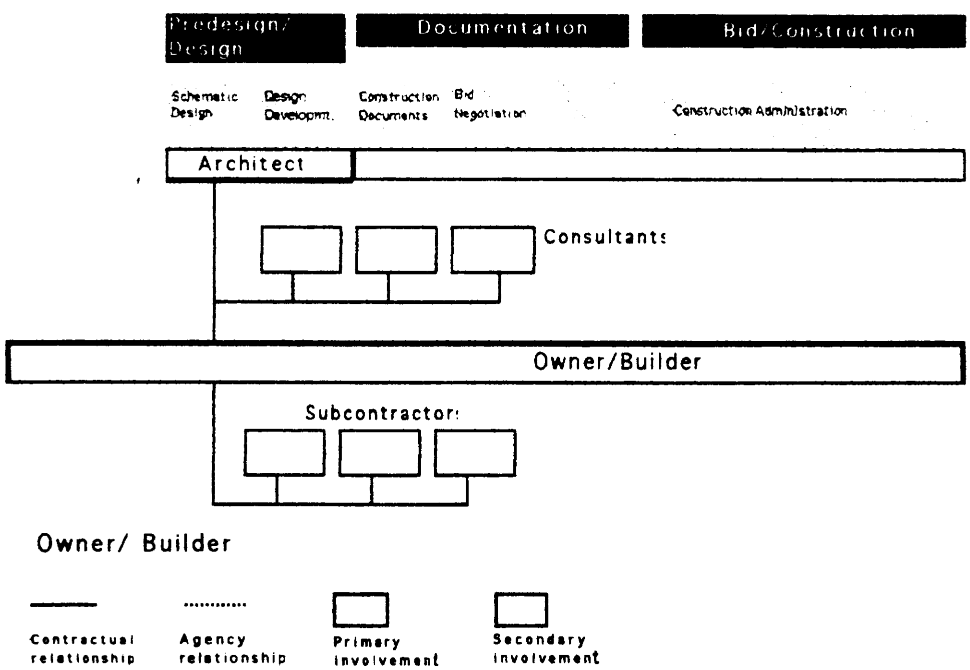

Figure 2-12: Owner/Builder project delivery process.

> There is a close relationship between the degree of responsibility architects accept for the fulfillment of their designs, and the social and economic status of architects in the community or society in which they practice.[19]

2.2 Information Systems

2.2.1 Links between Strategy, Technology, and the Organization

An Information System (IS) is generally defined as a collection of computer hardware and software organized towards specific work applications. For example, figure 2-14 shows a generic diagram of an electronic banking system without integration. When multiple systems are integrated to work together in an organization then they are considered Composite Information Systems (CIS)(see figure 2-15).[20] This diagram shows the relationship between the strategic, technical, and organizational issues associated with CIS systems. Briefly, a company's decision to integrate their various computer systems into one overall linked information system is based on issues related to strategic advantages offered by IS, computer technology applications, and the organization's ability to assimilate new processes required by technological changes. Information technology may be considered the computer systems that make up

[19] [4],p.35

[20] Composite information systems is category of information systems(IS). In this thesis the generic term information systems will include CIS systems[19].p.6

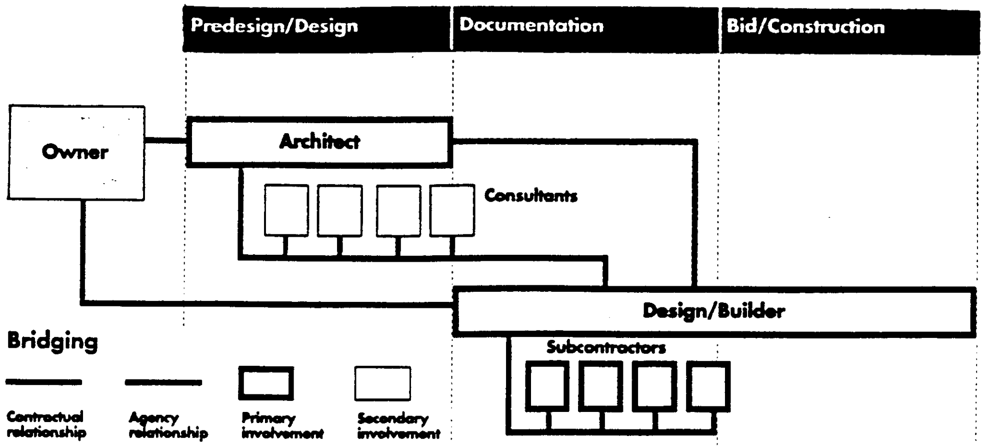

Figure 2-13: Bridging project delivery process.

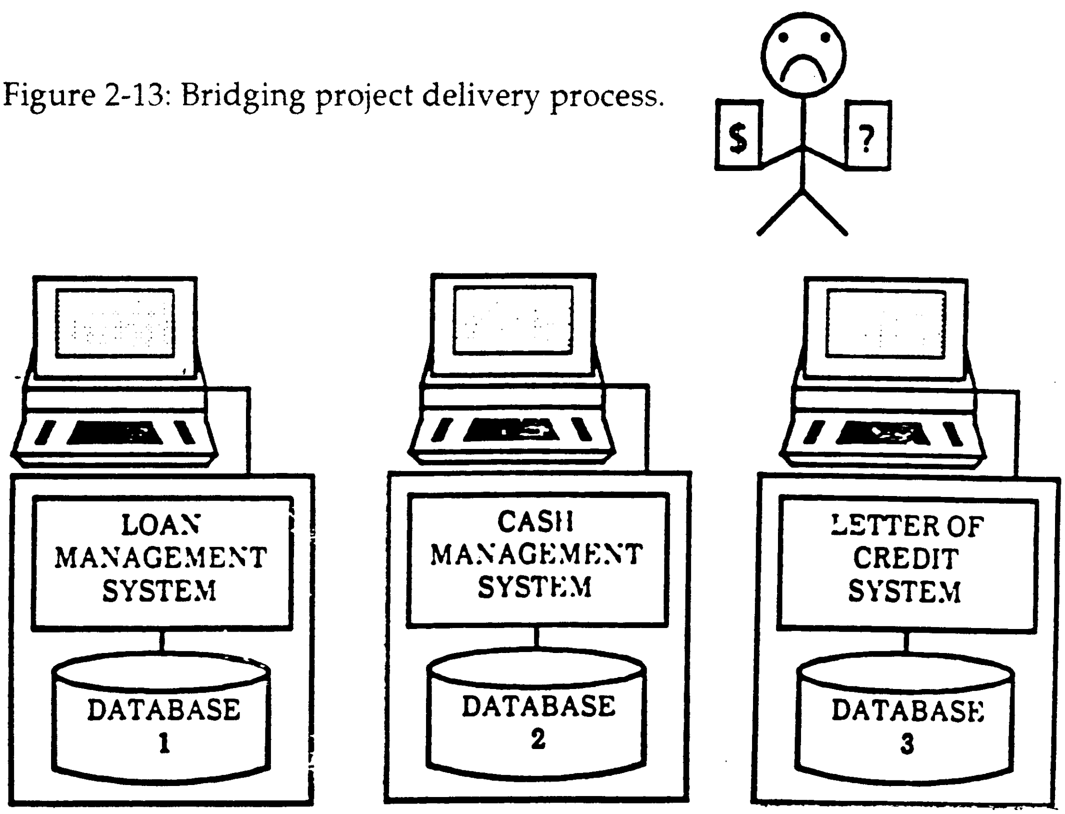

Figure 2-14: Electronic Banking system without links between systems.

IS.[21] In terms of business strategy IT can be considered "broadly to encompass the information that businesses create and the use as well as a wide spectrum of increasingly convergent and linked technologies that process the information".[22] The "linked technologies that process information" are the computer, software, and devices based on the microchip.

2.2.2 Facilitating Faster Communication

Computers, printers, fax-modems, and other peripheral devices linked in a network which facilitate communication between these devices collectively make up Information Technology. This constitutes the hardware side of IT. The instructions that tell the various hardware what to do is considered the software.[23] Software is made up of written sets of instructions in computer language. Computer languages range from machine language level instructions to the higher level languages like C and C++.[24] Computer languages are based on sets of algorithmic instruction.[25] The ability of computers to communicate with each other and with

[21] For an additional definition of IT see the succeeding section.

[22] [20],p.149

[23] [16],p.3

[24] C and C++ are known in computer programming as high-level languages. "These languages allow programmers to express algorithms in a much more compact way, using more powerful statements that are somewhat closer to human language"[18]. p. 5

[25] [18],preface.

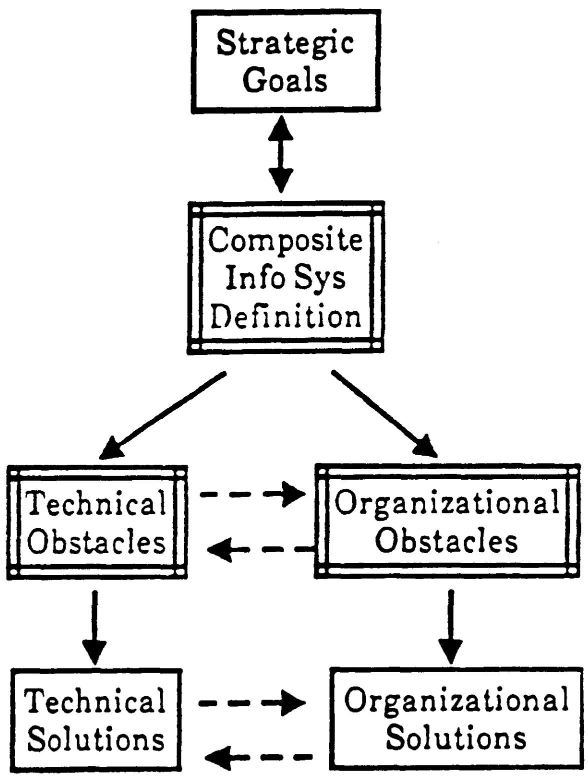

Figure 2-15: Chart of organizational issues associated with Composite Information Systems(CIS).

peripheral devices has revolutionized the way we do business.[26] Data stored in one computer can easily be retrieved and worked on by a user at another computer terminal. For the construction industry this ease of data transfer has proved invaluable for faster delivery of the building. The following is an account of a project which used IT.

> In Texas,where speed is apparently as valued as size, the Department of Criminal Justice recently designed and constructed 32 new prisons for 10,700 prisoners in less than six months (see figure 2-16)... Though standardized design elements, industrialized building techniques, and expedited approvals all contributed to the extraordinary speedy completion, the electronic integration of data dramatically shortened the design phase. CAD drawing and specification files were developed, reviewed by CMs and owners , and updated in real time (participants could view changes on-screen over the network rather than wait for prints). Plotting and distribution of documents also took place over a computer network.E-mail,cellular phones,and laptop computers enhanced response time(by avoiding phone tag). Charles Thomson reports that a dimensional discrepancy was discovered in structural steel that was already fabricated and on site. In less than two hours a remedy was e-mailed to all 24 sites.[27]

In using IT to instantly respond to construction problems it is evident that the time required for informed deliberation of a problem is inadequate. However, the argument for the use of IT for immediate response purposes is predicated on the ability to either have

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[26] [17],p.70

[27] [1],p.32

individuals with extensive knowledge of construction on a project, or a computer database used to capture precedent construction information that can be used in making decisions quickly (Also see Chapter 3 Case 2).

2.2.3 Proliferation of PCs and Software

The revolution in IT is attributable to the development of the personal computer (PC). By being low in cost, relative to traditional computer systems, PCs have lowered the price barrier traditionally associated with computer technology without significant loss of computational power. Most PCs today rival the computational power associated with the large mainframes of the past. For example, in 1941 the Mark I was switched on by Harvard University, one of the earliest experimental mainframe computers, it was approximately 51 feet in length and took more than one hour to perform a single calculation.[28] In 1991, laptop computers used by students at Harvard Business School ran at more than one million instructions per second.[29] This computational power is supported with a variety of software that increasingly facilitate ease of use of the PC. Therefore, you don't have to be a computer scientist to use the PC, which was the case with mainframes. The outcome of the low price of the PC has led to greater accessibility to a wide variety of users. Low cost and high performance has made the PC ubiquitous in the business world. The PC has broadened the range of services a professional can provide to a customer. Reference is made to the

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[28] [16] p.4

[29] [16] p.4

ability of architects to provide the owner with the special services usually associated with GCs and engineers.

Quantity take-off, project scheduling, and estimating software make it possible for the designer to provide such services. The ability for architects to provide these services has led to the debate of whether architects should assume the additional responsibilities associated with the GC-Advisor.[30] Structural analysis software also offer architects the ability to analyze the structural integrity of their designs. This is a service the designer conventionally procures from a structural engineer. This is not to say that GCs and structural engineering services should necessarily be provided by the architect. Rather, this is to show the possibilities offered by personal computers and the expanding range of available software.

With the development of CAD packages, which contain architectural libraries of plans and elevations, architects face the issue of potential owners and others designing their own projects. In fact, some developers already offer such services. That is, customers come into their showrooms and work with a "computer draftsman" to design their homes. The Japanese do this routinely in home design for prefabrication. Available Software that allows users to "design" their own building projects, thereby giving them control of their projects, poses an additional challenge to the design professional. With the aid of the PC, owners are also able to produce their own plans for construction. Once a GC is chosen the plans may be further refined for construction, leaving the architect out of the picture.

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[30] [1],p.35

The challenge for the designer is to offer a service that the owner can feel adds value to their project. This is not an easy task as the idea of a "good design" is qualitative in nature. However, the following should help to articulate what designers understand about design:

> It has been pointed out that MacDonald's quality is as legitimate as Harrods'; it has also been noted that an amateur orchestral rendition might be as note perfect as that of a professional symphony orchestra, but is unlikely to equate with it on qualitative terms.[31]

As we approach the end of the century, designers will have to find a way to systematically produce designs that are distinctive and of good quality as a contribution to a project. The ability for the non-professional to "design", further raises this issue of what the contribution of the architect is to be in a project? In what way is the architectural designer to produce work which will give the owner a sense of control over the design process, as well as make owner's feel catered to by the design process. In other words, making owners feel as if they are in control of the creation of their projects. The general criticism against designers is that they impart their own idiosyncratic notions into a project, which results in owner's general dissatisfaction with design services. Thus, the designer must adequately address the concerns of the owner in designing the project, as well as anticipate possible needs not originally indicated by the owner. The ability for the designer to consistently produce good quality designs that address

[31] The name MacDonald's refers to the popular U.S. Fast-food chain McDonald's, and the quote is taken from an English publication. The author assumes MacDonald's to be the spelling for this fast-food chain in England. Harrods' is a large retail store in London, England. Probably the equivalent of a Saks Fifth Avenue here in the United States.[7],p.147

owner's stated, and anticipated, needs will give value to professional design's contribution to a project.

2.3 Anticipating Owner's Requirements

2.3.1 Identifying the Customer[32]

The starting point for any construction project is the desire to build by the owner. "It is the owner who initiates the project and secures funding for the design, construction, and subsequent operation of the completed project".[33] Yet often, the owner may not be the final occupant of the building. As defined by the Construction Specification Institute (CSI) the term "owner" is generic. It is generic in so far as the "owner" may be the government, an organization, a club etc. Those who occupy the building, or interact with it on a day to day basis, may be termed the users. For the designer the users' satisfaction with the building should be just as valuable as that of the owner. Owners benefit from the value users give to their buildings. These benefits may be in the form of full occupancy of their buildings, longer rental agreements, premium rental prices, etc. Beyond the immediate users of the building are those who interact

[32]The term customer refers to "whoever uses the product of your work" or "the person or group who receives the work you do".[5] p.41

[33][3],pI-1-6

with the building in other ways, such as members of the community where the building is built. Community includes even local governments and beyond.

The context in which the building has been placed may be identified as society at large. The owner, user , and society are all "customers" of the building product, and as such "owners" of the building. The challenge for the designer is his/her ability to produce a building which addresses the needs of all these groups. A good example of this idea is exhibited in the designs of two Frank Lloyd Wright buildings. The "Imperial Hotel", in Japan, and "Fallingwater"(Figure 2-16, 2-17). The following is a comment by Bruce Brooks Pfeiffer and David Larkin in their book *Frank Lloyd Wright the Masterworks* on the "Imperial Hotel";

> Frank Lloyd Wright gave to Japan an edifice that respected and honored its culture, but he also made it a safe and durable building that used the best modern technology and his own engineering skills.[34]

The "Fallingwater" project has become a national treasure to the United States. It not only fulfilled its owners needs, but became a national landmark as well. The status of landmark may possibly be the highest praise a society could give a building. Quality of design is exhibited in "Fallingwater" by the manner in which the architect used various resources. The house is well integrated with the landscape, uses local materials, and incorporates the latest (at the time of construction) ideas in construction technology. Falling Water is

[34] The Imperial Hotel "withstood one of the worst earthquakes in recorded history, on September 1,1923". Many Japanese sought refuge from the quake in the hotel.[12],p119.

exceptional in that the architect not only fulfilled the requirements for a weekend house, which is what "Fallingwater" was originally meant to be, but a "special place" to retreat to. This was the way it was described by its owners. The architect fulfilled an anticipated requirement.[35]

2.3.2 Designing for a Moving Target

During a time when architects like Frank Lloyd Wright(FLW) practiced architecture, societal changes were fairly infrequent. This is to say that society was not going through "rapid change" as it is today.[36] Prof. Shoji Shiba describes "rapid change" as follows:

> changes of customer requirements, technology, staff requirements, the communities around you, the monetary system, and the international geopolitical situation- and such change is frequently unforeseeable.[37]

Unlike today, in traditional process of design the "factors of change" described above were viewed as more or less infrequent. [38] Unfortunately, designers today must take into account as part of their

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[35] [12] p.155

[36] [5],p.37.

[37] [5],p.37

[38] Traditional Process of design refers to the five phases in architectural practice- schematic design,design development,construction documents,bidding negotiation,construction administration. These five phases reflect the sequential process of a design-bid-build project. In this process the design is completed and further refined towards the completion of the construction documents.

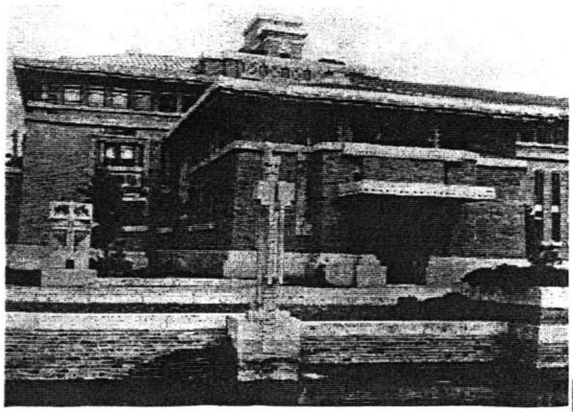

Figure 2-16: Imperial Hotel

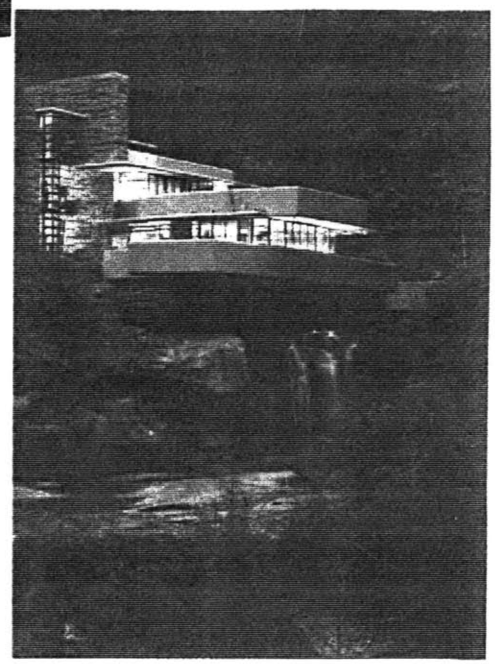

Figure 2-17: Fallingwater

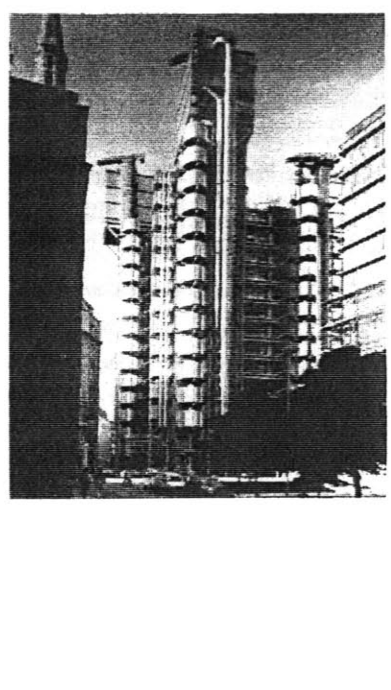

Figure 2-18: Lloyd's of London

"normal" practice these rapid changes in society. A case in point is the construction of the Lloyd's of London building by Sir Richard Rogers, which took eight years to complete from commission to occupancy. Eight years is not unusual for a project of this scope. However, in comparison to current Fast-Track projects, which are as short as six months to a year in duration, eight years is an eternity. The following account of the Lloyd's of London project illustrates the changes that occurred within the eight year span of the project:

> Market conditions and expectations changed radically over that period, requiring massive adaptations to occupational configuration, allowances for computers, consequent electrical and air conditioning loads, and so on... While critical acclaim was being offered by the pundits, however , appraisals of qualitative worth deeply divided opinion among the new occupants, prompting plans for further change.[39]

Fortunately in the case of Lloyd's of London, the designers were able to respond quickly to changes as they occurred(Figure 2-17).

We may consider two strategies for addressing design for a society in a state of rapid change. The first would require the ability to design and build the building within a shorter overall time span. Yet this may not address possible future uses of the building. The second would require the ability to anticipate future user needs. In turn, anticipating user needs requires the ability to respond as quickly as they change. This is a major challenge facing the architectural design industry, as we

[39] [7],p.148

approach the new millennium and thus requires that we develop new design methods for such a rapidly changing society.

2.3.3 Flexibility in the Design Process

How does one go about developing a design methodology for a rapidly changing society? It is interesting to search for an answer in the development of modern architecture. During its early inception in the late 1800's and early 1900's architectural designers were in search of new methods for design. The new methods were required in order to produce work that was expressive of contemporary society and technology during the turn of the century. The technology of industrialization was changing the way people lived. Designers of the Modern Movement recognized the need for designs which would reflect the societal and technological changes occurring during their time. It would appear that designers face a similar situation today at the end of the twentieth century. There is a similar need for new design methods that produces work that is contemporaneous to the way we are living, or will be living and interacting with technology. It is the conviction of the author that a design method for contemporary society will have to be inherently flexible. However, the requirement of "inherent flexibility" for a design methodology needs to be further clarified. In a reader for his course *Architectural Technology and Form* Prof. Eric Dluhosch defines flexibility as:

> the ability to adapt to various wishes and needs of the end user. Provision for flexibility must be made already in the initial planning / design phases. It should be possible to accommodate flexibility without necessarily having to change the basic system, or its elements.[40]

Rapid changes in computer technology and society will to a large extent govern the environment in which the designer must work. In order to address these rapid changes new design methods with inherent flexibility will be required. In other words the designer will have to design for flexibility.

The ability of designers to adapt to rapid change in the future to a great extent is based on their ability to manage information. That is, information on new products, technologies, and social trends. The ability to acquire information on new products and computer technology is facilitated through the use of information systems technology (IT). For example, a library database used to catalogue and retrieve information as it may be required would easily facilitate faster response to a given situation. Yet, if provisions for flexibility are implemented through the use of computer technology for handling standard information types, like product data, then more time can be spent by a designer exploring societal issues.

However, the ability to correctly predict human behavior is not easy, but can be determined through a standardized approach to gathering user requirements. In his book *Architectural Systems* Mr. Ehrenkrantz suggests the use of an Activities Location Chart to

[40]Systems here refers to Building Systems.[15] n.Pag.

ACTIVITIES LOCATION CHART

	Living Room	Dining Room	Bedroom	Kitchen	Bathroom	Foyer	Utility Area	Private Garden
RECEPTION								
Activities								
Entry and exit				•		•		
Visiting						•		
Delivery				•		•		
Collection						•		
Servicing						•		
Furniture, appliances, and equipment								
Telephone				•		•		
Storage								
Closet						•	•	
SLEEPING AND DRESSING								
Activities								
Sleeping			•					
Making love			•					
Dressing			•					
Undressing			•					
Storing clothes			•					
Studying	•	•	•					
Furniture, appliances, and equipment								
Beds	•		•					
Chairs	•		•					
Table								
Dressing table			•	•				
Mirror			•	•				
Storage								
Closet			•					
Drawers			•					
Shelves			•	•				
PERSONAL CARE								
Activities								
Washing				•	•			
Bathing					•			
Excreting					•			
Making up			•		•			
Brushing hair			•		•			
Setting hair			•		•			
Cleaning teeth					•			
Taking medicine			•		•			
Manicuring			•		•			
Exercising	•		•		•			•
Cleaning shoes				•		•	•	
Brushing clothes			•		•	•		
Pressing clothes				•			•	
Washing clothes				•			•	
Furniture, appliances, and equipment								
Toilet					•			
Lavatory					•			
Bathtub					•			
Shower					•		•	
Urinal								
Bidet					•			
Exhaust fan					•		•	
Water heater				•	•		•	
Storage								
Medicine cabinet				•	•		•	
Towel racks					•			
Coat hooks				•		•	•	
SERVICE AND UTILITIES								
Activities								
Washing things				•			•	
Drying					•		•	•
Ironing	•			•			•	
Mending	•			•				
Cleaning	•	•	•	•	•	•	•	
Collecting rubbish				•			•	
SERVICE AND UTILITIES *(cont.)*								
Collecting dirty clothes			•		•			
Sorting							•	
Storing linen			•				•	
Storing clothes			•			•		
Maintaining appliances				•	•		•	
Arranging flowers	•	•					•	
Repairs and renovations	•	•	•	•	•	•	•	
Disposing of garbage				•			•	
Furniture, appliances, and equipment								
Garbage disposal				•				
Dishwasher				•				
Washing machine				•	•		•	
Dryer				•	•		•	
Laundry tray				•	•		•	
Floor drain				•	•		•	
Furnace				•			•	
A/C filter							•	
H. V. C. terminal						•	•	
Fuse box				•		•	•	
Ironing board							•	
Sink				•			•	
Storage								
Linen closet				•		•	•	
Tool closet				•			•	•
Broom closet				•		•	•	
Shelves				•			•	
Drawers				•		•	•	
FOOD PREPARATION								
Activities								
Preparing food and drink	•	•		•				•
Cooking				•				•
Washing up				•			•	
Storing food				•				
Storing drink	•	•		•				
Refuse disposal				•			•	
Supervising kids	•	•		•		•	•	•
Furniture, appliances, and equipment								
Range				•				
Hood fans				•				
Refrigerator				•			•	
Kitchen sink				•				
Garbage disposal				•				
Exhaust fan				•			•	
Work top		•		•			•	
Chair or stool		•		•			•	
Telephone				•				
Storage								
Food closets				•				
Shelves				•				
Garbage bin				•			•	
Utensil closet		•		•				
EATING AND DRINKING								
Activities								
Eating		•		•				•
Drinking	•	•						•
Laying table		•						
Serving	•	•						•
Clearing away	•	•						•
Socializing	•	•						•
Parties	•	•						•
Furniture, appliances, and equipment								
Table	•	•		•				•
Chairs	•	•		•				•
Storage								
Drawers	•	•		•				
Closet	•	•		•				

Figure 2-16: Activities Location Chart used to systematically determine user requirements.

catalogue user requirements (figure 2-19). The Activities Location Chart is used as a checklist in the initial planning of a design in order to determine the distribution of activities within a project.[41] Such information when gathered over time and stored in a database may be analyzed through statistical methods for trends, which can be anticipated and designed for. Also, a Support/ Infill approach may be taken in designing for societal flexibility, based on the work of Prof. John Habraken. Where an outer container is designed ,e.g., structural elements, for long term use with minor modifications required over the duration of its life, and infill systems developed ,e.g., wall panel systems, for regular modification on a short term basis as user requirements may change. Using IT a standard plan of supporting elements may be easily updated with changes in infill element design. Currently, Prof. Habraken uses this approach of integrating IT with Support/ Infill systems design in his professional practice to address changes in user requirements as they may occur.

Through the use of computer technology designers may ultimately find the ability to keep pace with rapid change. By automating standardized tasks through computer technology, less time will be spent by the designer processing information. As the computer to a great extent will facilitate information processing and analysis. This may give the designer more freedom to do creative work in the future.

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[41] [6] p.37

Chapter 3

Information Systems and Speedy Delivery in Professional Practice

3.1 Case Studies

The Case Studies presented in this section are used to present two key issues: first- current attempts to deploy Information Technology in a firm, second- to highlight current attempts by firms in responding to client requirements for speedy delivery, quality of product, and low cost of construction.

The two firms discussed are Goody Clancy & Associates and Herzog-Hart Corporation(HH). Goody Clancy & Associates is a Boston, Massachusetts firm that specializes in providing clients with architectural design services, as well as planning and urban design services.[42] Their efforts to integrate the computer into their design process and utilize the capabilities of IT drew the author to this firm as a case study for this thesis.

[42]Goody Clancy is the shortened form of the name of this firm. The shortened firm name will be used interchangeably with the firm's full name of Goody Clancy & Associates.

Herzog-Hart Corporation is an architectural engineering (A/E) firm based in Boston, Massachusetts. HH provides facilities design and engineering services to their clients. They provide plant development, design, and construction services to the pharmaceutical, biotechnology, and chemical industries. However, in terms of building design work HH designs buildings that house labs and lab facilities for the pharmaceutical companies. In an attempt to meet client demands, HH has reinvented their organizational structure to support IT throughout the company's processes. HH's approach to process reinvention, based on innovations in IT to meet client needs, interested the author to use this firm as a case study for this thesis.

3.1.1 Case I- Goody Clancy & Associates

Evolution of Computer Use at Goody Clancy

The use of computer aided design and drafting (CAD) software was introduced into Goody Clancy in the early 1980's.[43] Commercially available CAD software of this period was designed primarily with the engineering professional in mind, and not the architectural professional.[44] Consequently, the architects of Goody Clancy were not comfortable working with the newly introduced CAD system except those in the firm who were technically proficient in the use of the computer. However, at that time the number of those in the office proficient in the use of a computer system was small. In other words,

[43]Over the years computer aided design and drafting(CADD) makers have dropped "drafting" from the name of their software. CADD software is generally known today as computer aided design (CAD) software. The author chooses the current name for CAD systems.

[44] [21]p. 11

this early CAD system required a high degree of technical knowledge in computing on the part of it's users.

Also, at that time manual methods of drafting and design were the norm in Goody Clancy. Yet, it was recognized that CAD software handled repetitive manual drafting tasks more efficiently. Thus, the work performed by means of CAD was strictly drafting.

The commercial CAD software chosen by Goody Clancy was Autodesk's AutoCAD, which was one of the first commercially available software packages for the PC. AutoCAD became widely used by firms who could not invest in expensive computer workstations, which during that early period were considered high-end CAD systems. Later, software developers brought to market third-party software for AutoCAD. Third-party software is software developed by a vendor, i.e., a company not associated with the making of the host software, and designed to work with a popular brand-name computer program.[45] In the case of Goody Clancy, Auto-Architect was the third party software purchased to work with AutoCAD. Auto-Architect facilitated the addition of height and other architecturally based information to the firm's computer drawings.[46] This led to the ability to generate 3-dimensional models of building proposals.The influx of young architectural graduates in the early 1990's, introduced a new spirit of computer use in the firm. Graduates of architectural programs that advocated computer literacy, which included MIT and Harvard, introduced the use of 3-dimensional models to ongoing projects within the firm

[45] AutoCAD is considered stand alone software. It can be operated on a computer without a host software. Third-party software is not stand alone, and needs the host software in order to work.

[46] [21]p.10

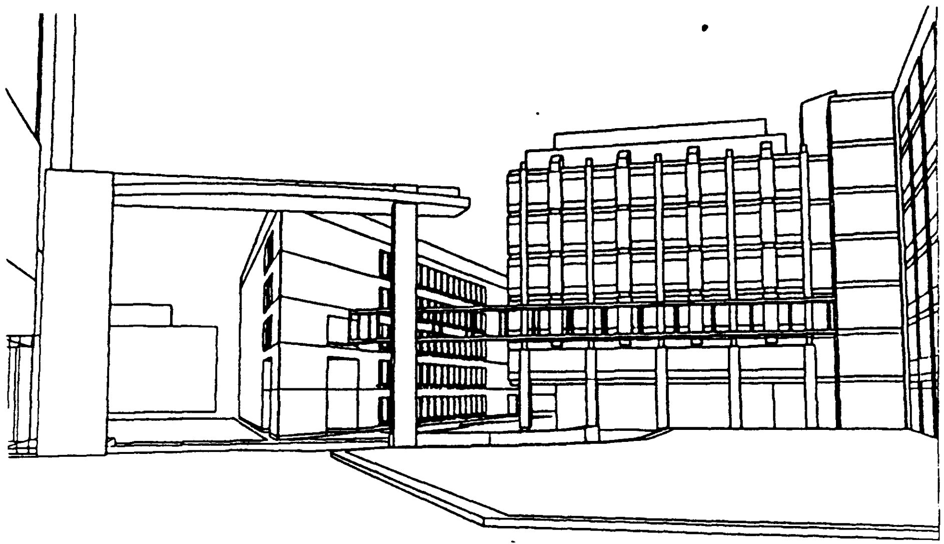

Figure 3-1: 3-dimensional model created by computer using AutoCAD.

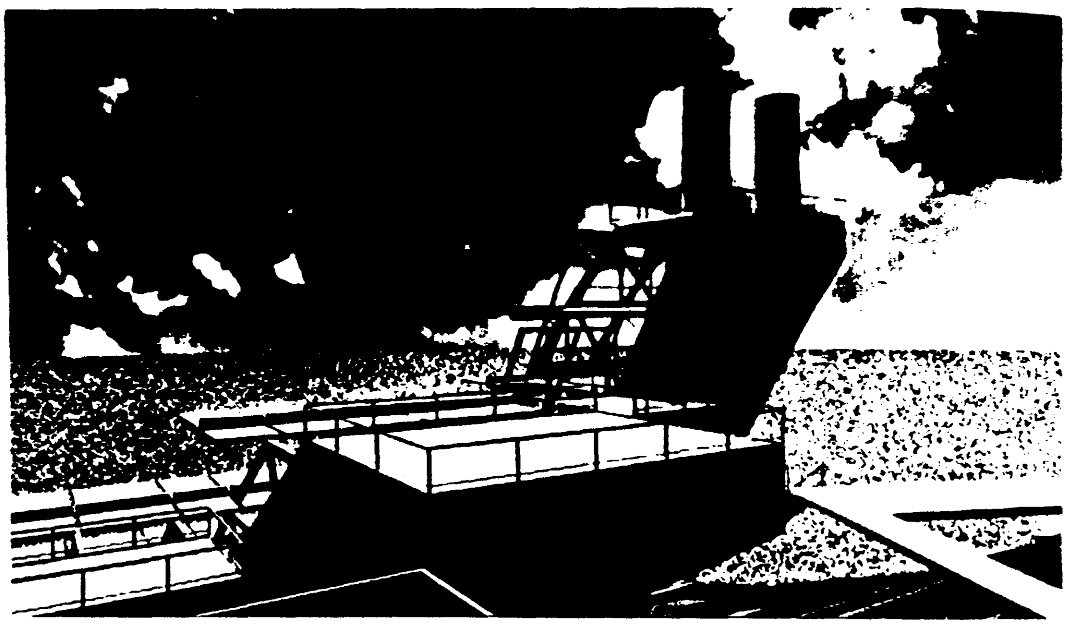

Figure 3-2: Rendering created with AutoCAD and 3-d Studio, showing photorealistic qualities of computer images.

(figure 3-1).[47] During this time as well, a 3-dimensional rendering software by AutoDesk was introduced in the firm, called 3d Studio. 3d Studio produces photorealistic renderings of 3-dimensional objects (figure 3.2). This led the more experienced professional architects in the firm to become interested in the new uses of CAD, as demonstrated by the younger architectural graduates.[48]

Eventually, Goody Clancy's senior designers started to use 3-dimensional models during preliminary design. The major advantages of using 3-dimensional drawings was in the speed and number of viewpoints that could be generated of a project(figure 3.3). By and large, 3-dimensional models were printed as Wireframes on paper.[49] These Wireframes of multiple viewpoints of the project would be used by the designer to render and develop various design schemes. Design schemes produced in this manner with computer rendered 3-dimensional models are then presented to clients and project team members for review. This, was done in order to get earlyfeedback on the validity of a design idea. Another direct benefit was the ability to view a 3-dimensional model in less time than was formerly spent on producing drawings by hand to see the building from different perspectives. The 3-dimensional model is also useful during the production of construction documents as details of a design may be produced and looked at as a 3-dimensional model in order to

[47] 3-dimensional models are 3-dimensional drawings created with a CAD program. CAD packages produce three types of 3-dimensional images: wireframes-these are 3-dimensional line drawings, surface objects- these are wireframes with surface information,e.g., shaded squares, shaded circles, shaded triangles,etc., and solid objects- these are 3-dimensional primitive forms,e.g., cubes, spheres, tetrahedrons, torus,etc(also see figure 3-2).

[48] [21]p.11

[49] Wireframe drawings are line drawings of 3-dimensional models(figure 3.3).

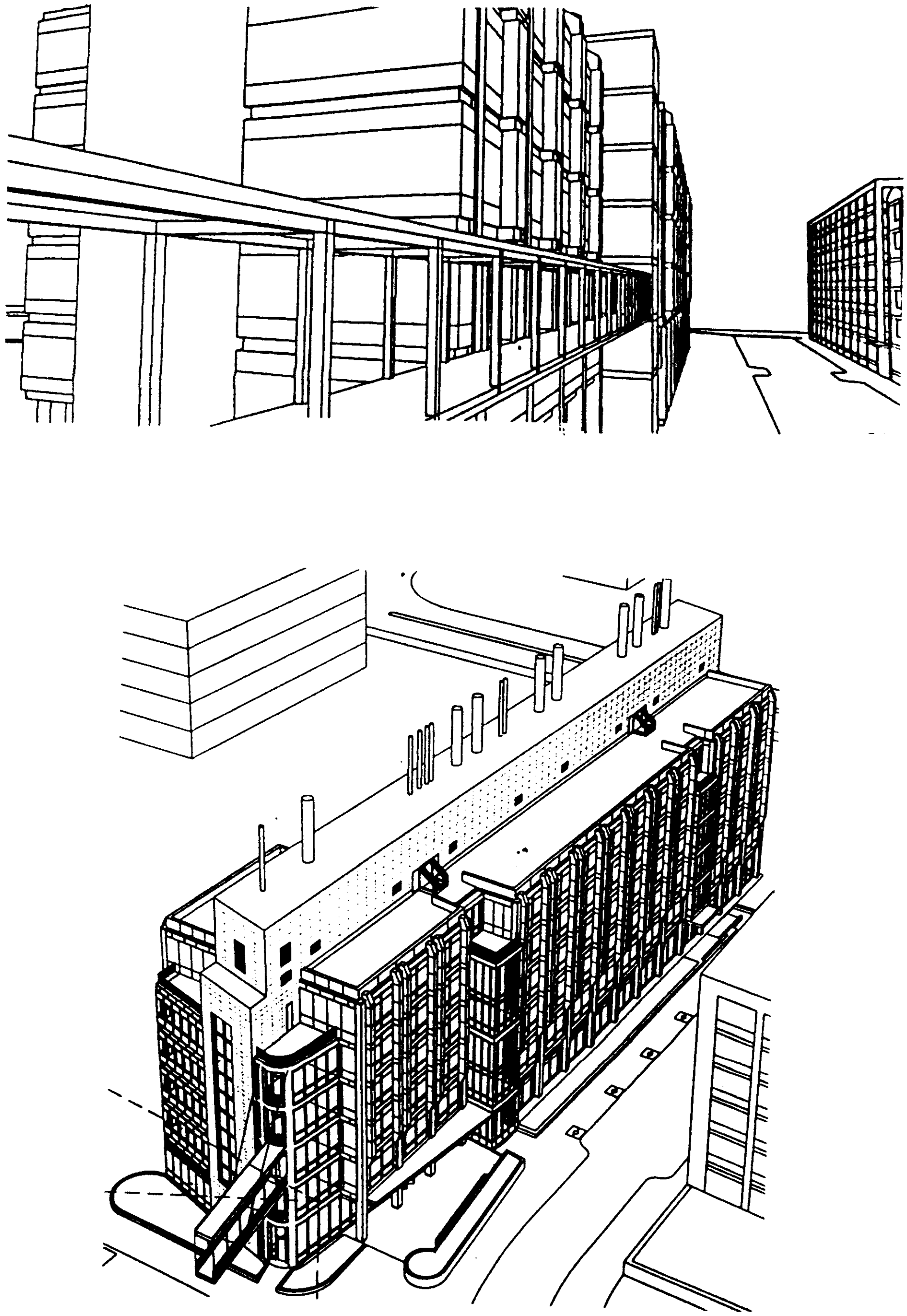

Figure 3-3: Multiple views of the MIT Biology Building created in AutoCAD.

assess it for possible methods of construction. Future applications of 3-dimensional modeling at Goody Clancy include viewing a design proposal in the context of it's proposed site, and selecting finishing material for interior design work.

Interview with Geoffrey Wooding, Project Architect, Goody Clancy & Associates

The following interview was conducted to gain insight into the issues facing architects on fast-track projects, in comparison to traditional delivery methods. Mr. Geoffrey Wooding is currently a project architect and designer for Goody Clancy & Associates. He acted as project architect on a number of Goody Clancy projects including two recent building projects on the MIT campus, namely the Biology building (Building 68) and the addition to the Whitehead Institute (figures 3-3, 3-4). Mr. Wooding has experience working with design-bid-build and fast-track delivery methods. The following is a summary of Mr. Woodings responses to questions regarding the issues facing the designer in a fast-track project.

Owner's trade-off decisions

Owners are increasingly turning to fast-track delivery methods. There is hardly a project today that does not incorporate fast-track methods in one way or another. Owners are increasingly faced with high interest rates from lending institutions. High interest rates and the uncertainties involved when interest rates fluctuate between high and low, cause owners to want to capture a fixed rate for the duration of their project.For this reason the owner is faced with making a trade-off

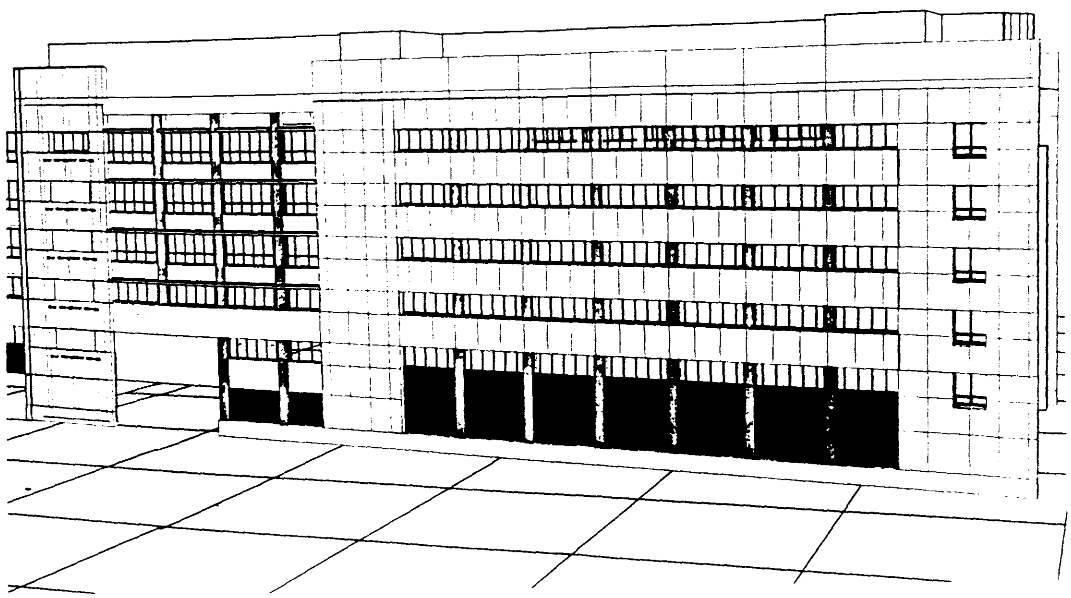

Figure 3-4: Diagram of MIT's Whitehead Institute addition created in AutoCAD.

between design-bid-build and fast-track methods of delivery. Design-bid-build's advantages are in the use of the competitive bidding process on a completed set of construction drawings. This is where general contractors (GCs) are asked to submit bid proposals for the project, which are in the form of cost in order to complete construction. Typically, fast-track projects are higher in cost than design-bid-build projects. In the fast-track method bids are based on partially completed design development drawings, which have far less detail than completed construction documents. The GC reviews the drawings and submits a "guaranteed maximum price" for completion of the project.[50]

In Mr. Wooding's opinion, and due to the lack of detail in design development drawings, the "guaranteed maximum price" estimate is really more of an educated guess by the GC, based on his/her prior construction experience. However, the complexity of projects today make each project extremely singular. Therefore, prices may vary greatly from one project to another. In other words as Mr. Wooding puts it, the guaranteed maximum price has in effect turned into a guaranteed minimum price. In his opinion the expected cost savings associated with fast-track methods, due to speed of construction, are offset by cost overruns associated with inaccurate "guaranteed maximum price" estimates. The owner is faced with the choice of a higher price for speedy delivery of the project, or a higher price in interest rates with design-bid-build.

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[50] Guaranteed maximum price is the estimated price for completing a project. Essentially, the contractor offers this price as the maximum which the owner has to pay for a given project.

General Contractor Leveraging Prices

The General Contractor (GC) is constantly trying to "leverage" the price of a construction "package" through their sub-contractors.[51] GC leveraging occurs when, in an attempt to provide the owner with a competitive bid, the GC might underestimate the cost of construction. Mr. Wooding suggests that this is possibly the reason behind GC's constant attempts at lowering costs on a project. A "lump sum" is provided by the GC for the completion of a "package" through the sub-contractor.[52] When the "guaranteed maximum price", estimated by the GC is not a sufficient amount for completion of the project, the GC often resort to trying to get the sub-contractor to lower their prices for a given "package". Mr. Wooding terms this as "leveraging prices through the sub-contractor".

The Package

There is a difference between the architect's conception of what constitutes a "package" , and the GC's perception of what it should be. Architect's view packages in terms of assemblies of functional systems. For example, a wall is viewed by an architect as sheltering the interior from the exterior. The elements or components that make up the wall support it in the act of sheltering the interior, i.e., the components of a wall may consist of windows, exterior fenestration material, waterproofing, insulation, etc. In this sense a wall is made up of these sub-units, or components, and the whole performs as a system to

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[51] The term "package" is described in section 2..1.2 in chapter 2.

[52] "Lump sum" is a total price given by a contractor for the completion of a construction "package".

provide shelter against the exterior environment. Architects create drawings "packages"with this concept in mind.

The GC prefers to view the "package" in terms of the breakdown of construction work. That is, various sub-contractors perform specific functions on a project, e.g., plumbing work is done by plumbers, carpentry work by carpenters, steel work by steel workers, etc., which requires the GC to break down the project into work to be done by each specific sub-contractor. In the GC's opinion his/her task would be made easier if the project as a whole was viewed in this way by the architect as well.

Design Process Modified

The pace of a fast-track project requires the architect to keep up with construction work as it proceeds in the field. Mr. Wooding views the "driving of a project schedule" by the pace of construction work at the site as the "demand of the construction process". In other words, there is a constant demand by the construction process for the delivery of "packages", once construction begins. Consequently, architects are continuously pressed to design and detail "packages" as quickly as possible to keep up with the rate of construction on the site. Additionally, the speed of fast-track projects does not allow for much iteration on a design. In other words, it is difficult to arrive at a fully developed design solution in fast-track projects, prior to construction work, unlike, in design-bid-build, where a design goes through successive stages of refinement from schematic design to a completed construction drawing set. In Mr. Woodings opinion, the fast-track process makes it extremely difficult for the designer to have an overall picture of the project prior to the onset of construction.

Design Changes by GC

Mr.Wooding mentioned that quite often a fast-track project will approach 50 percent completion, with 80 percent of the budget already used. In such a situation, and when a client becomes aware of the escalating price of the project, he/she may decide to look for areas in the scope of work to lower costs. Typically, the GC may suggest design changes to be made on specific parts of the project, thereby lowering costs. For example, the owner may be told by the GC that specific portions of the design require the expensive use of material and construction methods, and can be achieved for a lower cost if substituted with a less expensive alternative. According to Mr.Wooding, these GC driven changes often do not coordinate well with the aesthetic intentions of the overall project. One of the outcomes when a project has a considerable amount of GC driven changes is that the owner begins to identify cost overruns with the design work of the architect. Consequently, the architect runs the risk of loosing control over the execution of his/her design work.

Intertwined nature of fast-track

Once the GC or any party is contracted on a fast-track project they are "tied in", that is to say, the costs associated with replacing a party already on a fast-track project is very high. Since it is imperative to complete a fast-track project on schedule, loss of time due to a project participant having too be replaced is to be avoided.

Mr.Wooding raised this issue in reference to contractors who performed their work poorly during a project. In contrast to fast-track, in traditional design-bid-build there is an opportunity for the replacement of contractors whose work is poorly executed. The reason for this is that speed is not as much an issue as it is with fast-track. Poor execution refers to a variety of scenarios, such as poor workmanship, inability to meet with scheduled deadlines, inability to provide sufficient resources to complete work, and so on.

The Ideal Client

Depending on the client, on a fast-track project, the architect may either have a prominent role throughout construction, or the architect may be relegated to merely answering questions pertaining to construction drawings. According to Mr.Wooding, the ideal client understands the need for good design and supports the architect throughout the course of the project. Whereas, a less ideal client is one who's primary purpose for construction is to produce a low-cost building, without any real concern for its design.

MIT proved to be an ideal client for Mr.Wooding. The Institute clearly understood the need for good design and when cost concerns arose on projects, the Institute did not hold the designer responsible for cost overruns. According to Mr.Wooding, MIT accepted the views of all the key parties on a project and took action in a manner that was fair to all participants.

Systems

Mr.Wooding is finding himself increasingly using catalogued items, such as the exterior metal wall system used in MIT's Biology Building, as opposed to designing custom pieces to be assembled on site. The reason behind the use of catalogued items is due to the requirement in fast-track projects to design in a manner that facilitates faster assembly. Mr.Wooding found it fairly easy to apply an existing manufacturer's catalogue system of component parts to the Biology Building project with technical support from the manufacturer. Thus, Mr.Wooding found no difficulty in using "off-the-shelf" manufacturer's system products. His opinion is that manufacturers will increasingly work with designers in the use of such systems for fast-track projects.

Computer Technology

On the issue of computer technology, Mr.Wooding described what he termed the "flexibility of the drawing versus actual technical constraints". In other words, good drawings do not necessarily mean good construction possibilities, especially in regards to photorealistic computer images. In his experience, the photorealistic drawings produced by his firm's computers often seduce clients into thinking the renderings represent the final project. Mr. Wooding's opinion is that care should be taken in the manner that computer images are used during design, such that clients do not become fixed on the photorealistic representation of an immature design idea.

Mr. Wooding also feels that computer representation also affect the way the profession views viable projects. Construction engineering technology has reached a point where through the use of computer analysis, there is confidence that if a phenomenon can be calculated then it can be built. His fear is that projects that are environmentally harmful may be falsely represented as viable by use of computer simulation.

3.1.2 Case-2 Herzog-Hart Corporation

Development of IT in Herzog-Hart

Reengineering

About four years ago Herzog-Hart Corp.(HH) reengineered their company. Reengineering was necessitated by a highly competitive marketplace and the ability to respond to changing owner requirements. Owners demanded quality at lower costs. For example, clients were no longer satisfied with fast-tracked delivery methods that had taken beyond six months to deliver a facility. Yet, owners did not wish to pay a premium for the benefits of even faster delivery. For this reason, HH sought to reinvent the process used to deliver a building. The requirements of the new process were the ability to be responsive to market pressures as well as fully utilize current technology with minimum delivery time. The traditional mode for plant design had to be reinvented as well, since plant design was based on the design-bid-build delivery model, which HH considered as inefficient in terms of transferring information on a project(see figure 3-5).[53] Multifunctional project teams were to be used, which required the elimination of the

[53] Plant design refers to the design and engineering of chemical processing plants.

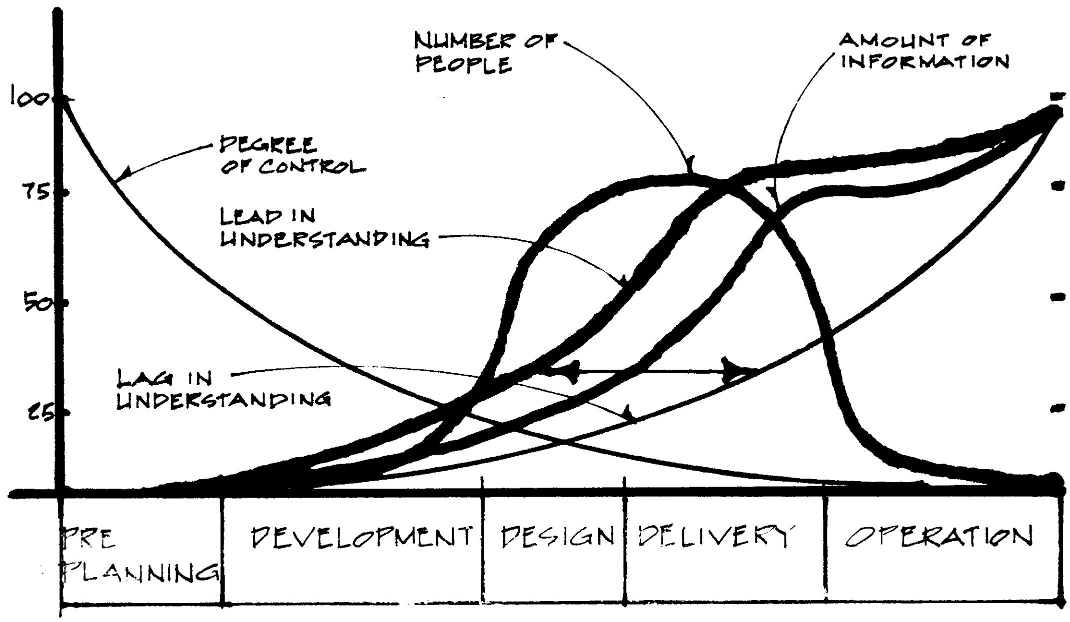

Figure 3-5: Chart showing the generation of information on a project.

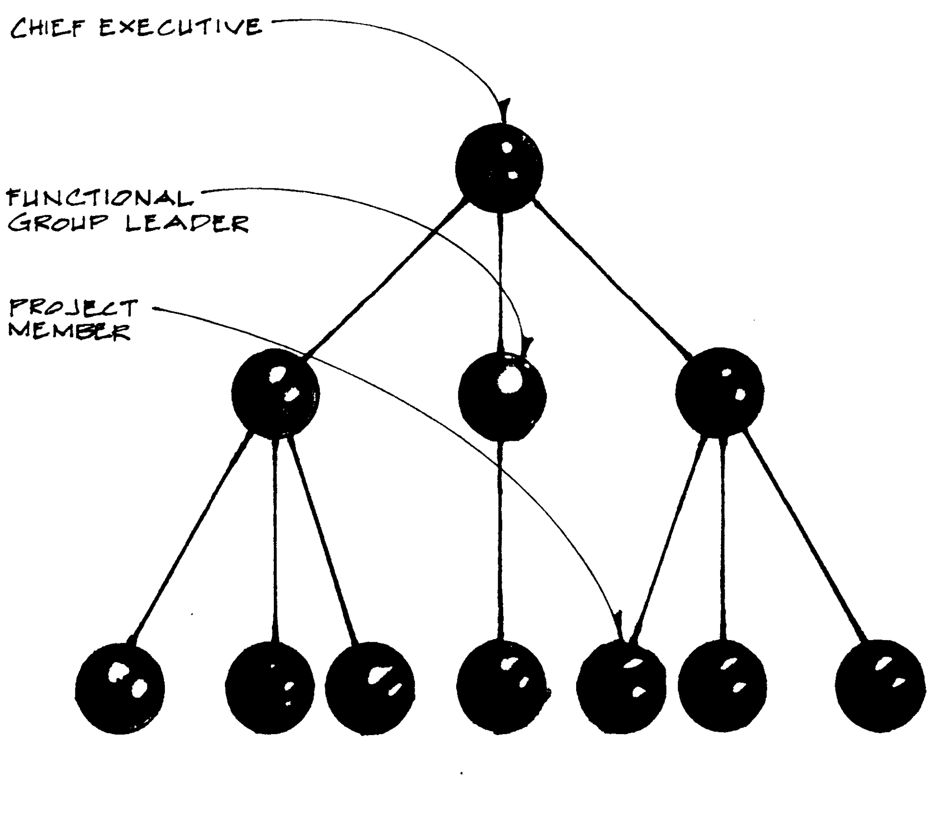

Figure 3-6: Functional hierarchy.

traditional functional hierarchies within the firm(see figure 3-6). It should also be noted that in the design-bid-build project there occurs a lag between the amount of information generated on the project and the understanding of that information by the organization conducting the work. In other words, the understanding of the information generated on a project cannot be used to mitigate unforseen contingencies. This is shown in figure 3-5 as the lag in understanding. In reinventing their company, HH sought to develop a lead in understanding, which would perform the same function as generating the knowledge of building a project prior to it's actual construction(figure 3-7). In other words, HH sought a process that provided actual construction understanding, prior to erection, which is termed *a priori* design and construction.

Programming Language Used as a Paradigm

HH felt that recent developments in IT during the early 1990's, did provide a reasonable framework for reinventing their company, particularly with respect to ideas from computer programming, such as object-oriented concepts.[54] Also, recent developments in the sharing and transfer of data between computers showed great promise for linking and sharing files within the company. Some examples of these new IT developments were object-oriented databases, CAD 3-dimensional modelling, and electronic data interchange (EDI).[55]

[54] Object-oriented concepts are discussed in chapter 4.

[55] Databases and EDI are discussed in chapter 4. This chapter will go into detail on CAD modelling.

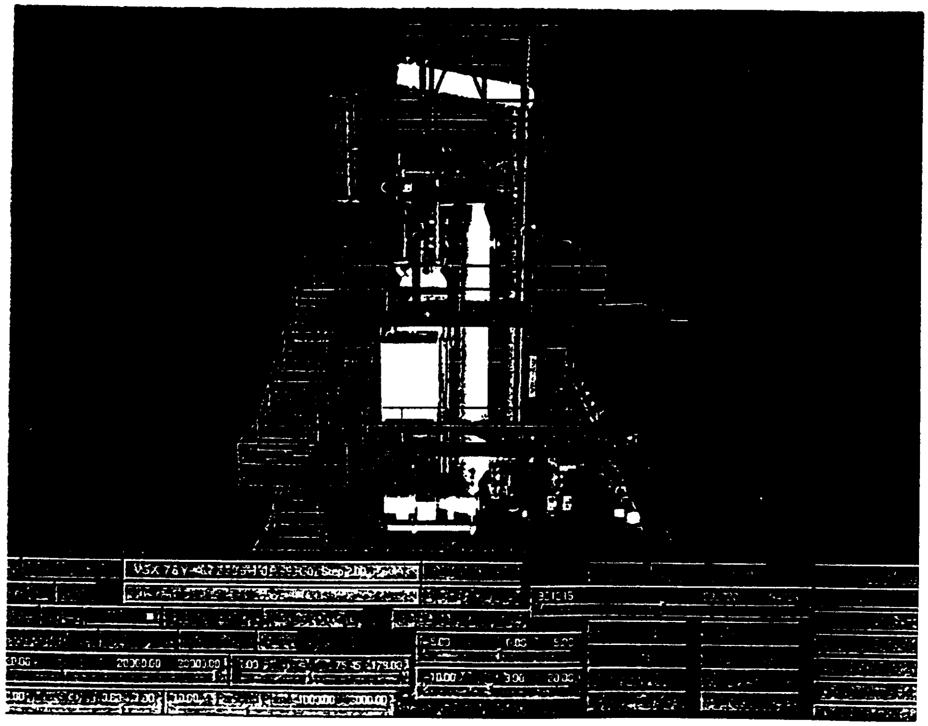

Figure 3-7: ProjectVISUALIZER screen showing a chemical plant design.

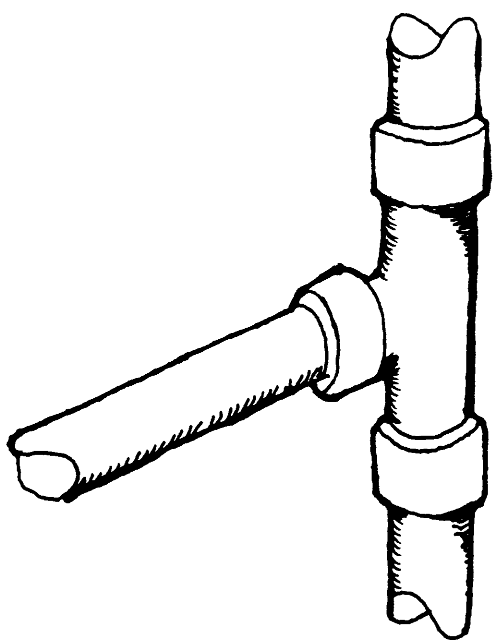

Figure 3-8: An object/component, in this case a pipe.

In addition HH included the capabilities of a 3-dimensional CAD Modeler (3-D modeler) in their new IT system.[56] Using CAD's 3-dimensional modelling capabilities, 3-dimensional drawings of component parts for a facility were created and stored in HH's computer system,e.g., different sized pipes, I-beams, flanges, etc. Based on object-oriented concepts these 3-dimensional drawings of component pieces were designated as elemental objects. The development of the idea of having components and their systems represented as objects were based on an effort by HH to change the traditional language used to describe construction.

According to Mr. Don Hall, in an attempt to effectively manage information through innovation, HH changed the language that they use to describe the pieces of construction, i.e., "projects are composed of components, which are essentially objects".[57] Objects can be further disaggregated into elemental objects. Elemental objects are the lowest information piece. Below the elemental piece are construction materials. The elemental object represents a specific component(see figure 3-8), such as a pipe fitting. At the bottom of the chart in figure 3-9 one can see a schematic the various levels of objects down to the component.

Components become aggregated into control objects. Control objects define an area or center of work activity,e.g., Bay "AI", Bay "A2",etc.

[56] A 3-D modeler is essentially a CAD program that is capable of producing 3-dimensional primitives.

[57]The term objects is borrowed from the field of object oriented programming. Most of the following terms developed by HH are heavily influenced by programming language. Mr. Hall, chairman of HH, explained that language from outside construction was used in order to create new terms for their reinvented process. Their goal was using words which would help workers to rethink the construction process[25],p31

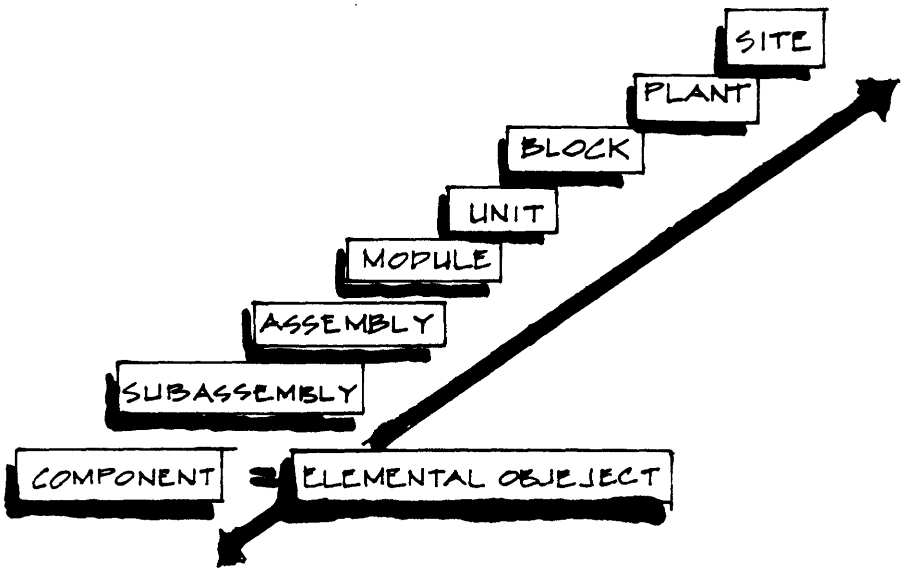

Figure 3-9: Diagram of various object levels.

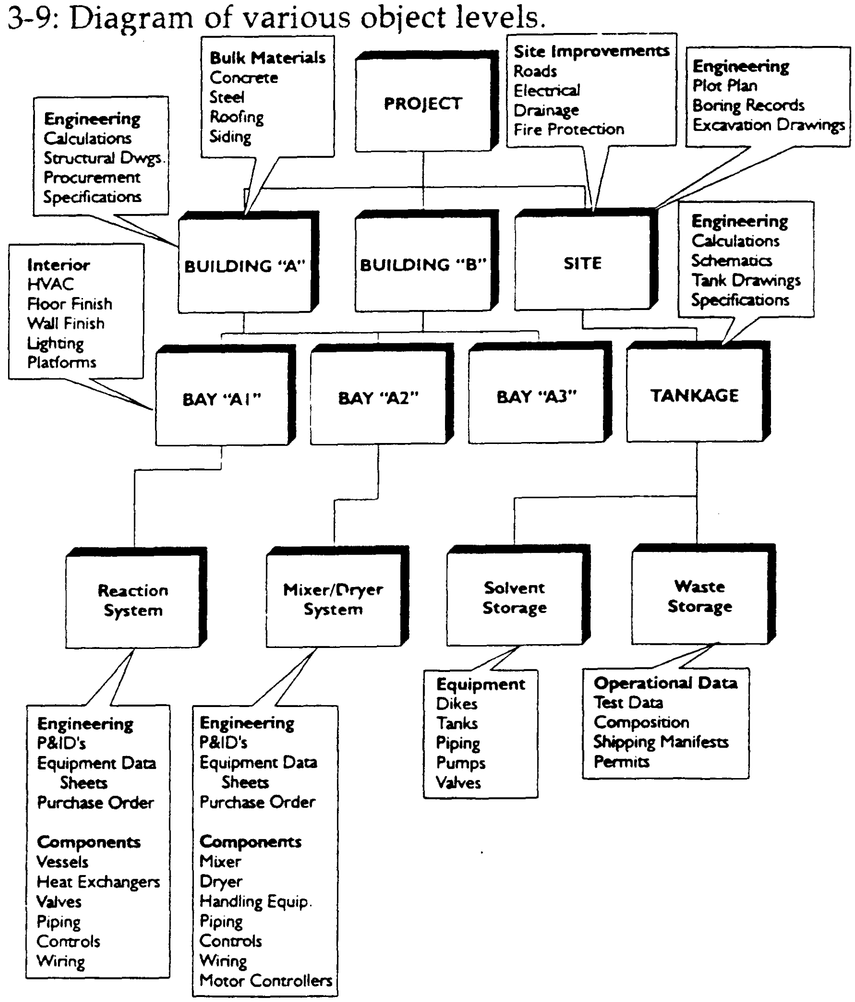

Figure 3-10: Work Breakdown Structure(WBS) of objects.

The basis for the creation of these terms was the "work package". [58] The work package describes the work to be done,e.g., interior work, engineering, bulk materials, etc(see figure 3-10). The relationship between the work package and the elemental object is by means of technical data, which references the work package with the object through the use of work package numbers. Therefore, the order of the work to be accomplished for each object can be tracked by means of the work package number(see figure 3-11). The order or sequence of a project's construction is described not in terms of phases but by stages. As the 3-D model is created, this information can be stored in a database for later retrieval. In essence the creation of the 3-D model is the equivalent to constructing the facility electronically.

3-Dimensional Modelling and Project Management System

HH's information technology system is a composite system(figure 3-12).[59] It links separate computer systems together into one overall system. In this way data is shared and translated between all computer systems in the office. In figure 3-12 the ProjectVISUALIZER system is shown. It consists of some traditional CAD capabilities as well as Project Management(PM) capabilities. The CAD capabilities of the system are primarily 3-dimensional. Yet, the system can also print out traditional 2-D drawings. In the ProjectVISUALIZER system, 3-dimensional objects are stored in a database. A simulation of the construction sequence of a project can be determined through the

[58] The work package refers to the description of the packaging of work in fast-tracked projects.

[59] See Chapter 2

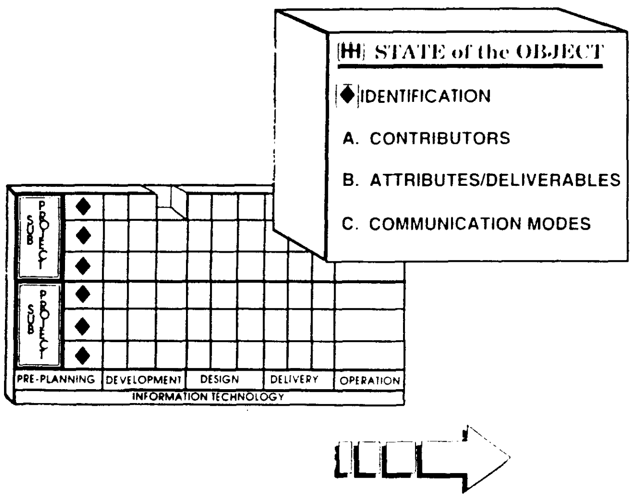

Figure 3-11: This diagram shows the method for keeping track of a work package in HH's construction process.

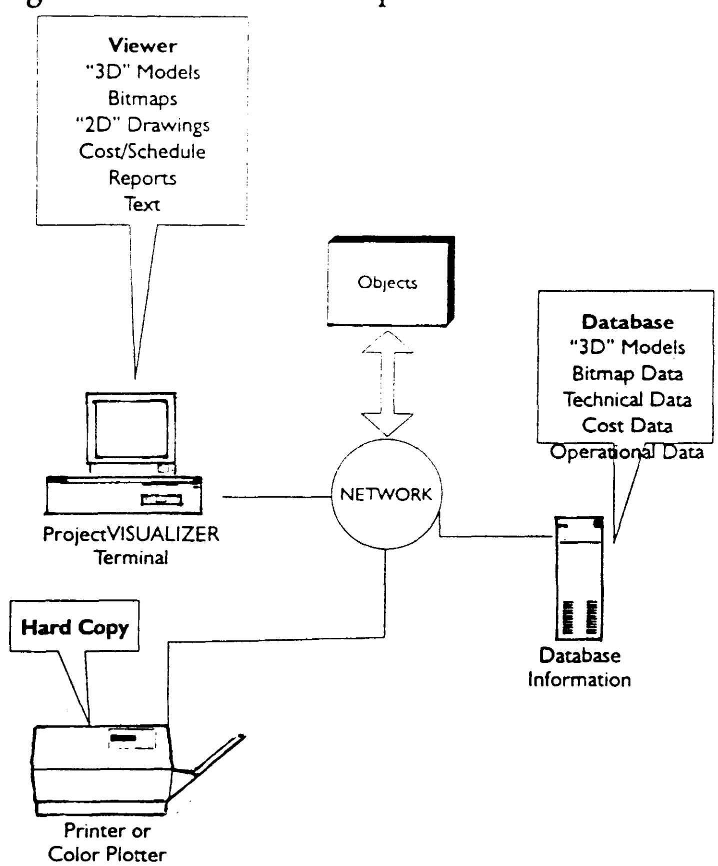

Figure 3-12: Schematic of the ProjectVISUALIZER computer system.

assembly of objects in the system. The 3-dimensional capabilities of the system are primarily used for viewing graphically the progress of a project. The list bellow summarizes the system's capabilities.

PM capabilities of the system include a model for the breakdown of work, i.e., the Work Breakdown Structure(WBS) and the Critical Path method(CPM). The WBS and CPM network processors have been traditionally used by project managers "to define and integrate the information about the scope, time, and the cost of projects".[60] The system developed by HH is thus considered to be a complete project management system. The following is a list of its capabilities:

- Cost Schedule Control System, including:

  -WBS display system, which integrates and displays WBS information

  -Critical path schedule processor, which displays critical path method(CPM) diagrams for project scheduling purposes.

  -Cost processor, which summarizes and displays information at various levels of the WBS and does earned value calculations.

  -Resource processor, which relates information to the schedule processor and displays resource requirements and usage.

- Document Management System, including:

  -Document retrieval software

  -Scanning and optical character recognition (OCR) and/or photo CD capabilities

[60][25],p.30

-Document storage

-Word processing

- Three-Dimensional(3D) CADD System, including:

  -Three-dimensional object modelling

  -Access to database with stored objects

  -Linkages to stored graphic and non-graphic attributes

  -Plant "walk through" capabilities

- Object scheduling system that establishes object schedule requirements

- Three-dimensional status system (ProjectVISUALIZER), which allows the project manager to review object activity status and attributes in a model format.[61]

The 3-D model is also used to provide clients with facility maintenance information. This is the same as life-time costing for the upkeep and general maintenance of the facility.

[61] [25],p.34

Interview with Mr. Don Hall and Joe Morray of Herzog-Hart

This section is based on a discussion the author had with Mr. Don Hall, HH chairman, and Mr. Joe Morray, HH senior vice-president. The discussion was conducted in order to get an insight into the issues that faced them in the reinvention of their company.

Innovations and Challenges

According to Mr. Morray, innovation in general is driven by the client. The client's requirements challenge the service provider to find new ways of satisfying their customers. For HH these new ways have been facilitated to a great extent by recent advances in computer and information systems technology. In order to satisfy clients, HH attempts to anticipate and respond to owner requirements. For example, the ProjectVISUALIZER system has helped HH to be flexible in responding to client's demands during a fast-track project. Clients can be linked into HH's computer system via Internet, and can view the progress of their projects on-line.[62] This allows clients to be involved in each phase of the project, and gives HH immediate feedback on their efforts on the project.

The quest to further anticipate client needs has led HH to provide specific "facilities development" services. That is, HH wishes to offer clients project programming services. Mr. Hall and Mr. Morray view this as helping clients to create strategic plans for the future construction and development of their facilities. Mr. Morray mentioned that 80 percent of the time when clients come to them with a program, a good deal of design time is spent in the interpretation of the program. In order to speed up the process of delivery, HH feels that

[62] The Internet is explained in Chapter 4.

there is a need to be involved in their client's strategic planning for future facilities, in order to reduce the interpretation time associated with design development. If anything, future facilities may be modeled in the computer, and retrieved when they are needed for construction.

The ProjectVISUALIZER database maintains a library of parts (figure 3-12). The ability to retrieve historical design information for use in a new project has drastically reduced the time required for design. Elemental objects once produced, need not be redrawn. Objects are stored and catalogued in the database until needed. Currently, HH can provide a client with a variety of design proposals for a plant in three months, down from six months in the past. Standard design elements can be reconfigured in a variety of ways in order to come up with new plant designs. However, such a recombination of parts requires the reliance on modular coordination and off-the-shelf components, along with the ability to use a systems approach to design and construction.[63]

According to Mr.Morray, the ability for clients to currently tie into HH's computer system, gives clients a feeling of being personally catered to. Mr. Morray compares this to the perception of control felt by clients when they were able to see workers in traditional drafting rooms. Viewing these draftsmen at work gave the client the impression that the firm was working hard on the client's behalf. However, some clients are still uncomfortable with current computer technology and prefer standard sets of drawings. Mr. Morray mentioned that he noticed discomfort with computer technology in his older clients, and attributed their discomfort to a lack of exposure to the use of the computer. One of the concerns that HH faces, when dealing with

[63] Systems approach is discussed in chapter 5.

clients, is the fear of overwhelming them with new computer technology. Both gentlemen mentioned how some clients were surprised by the firm's technological capabilities, such as the ProductVISUALIZER system, video conferencing, and animated video simulations of construction. They explained that some clients come to them expecting printed sets of construction drawings, and unfortunately become perplexed by the variety of computer technology being used at HH. For these clients HH does provide paper-based construction documents. The firm feels that generally it is ten years ahead of its clients in terms of computer-aided technology. For this reason some clients are presented with a video presentation of a 3-dimensional model of their project as opposed to having them view it directly on a computer screen. Increasingly, HH is using their ProductVISUALIZER system as a tool to better communicate their designs to clients. This is also one of the reasons why they have a video editing room on the office premises.

Another application of video presentations at HH is their use in project meetings. Instead of distributing project reports that are filled with Gantt charts and CPM schedules, HH hands each meeting participant a video. This video contains animated construction sequence models. The animations are created on the computer, using the system described above, and are voice-narrated to identify the pertinent issues that will be raised in the project meeting. Project meeting participation has improved dramatically, due to the use of this video technology. Mr. Morray said that prior to the use of videos for project review, less than half of the people at project meetings actively participated in discussions. With the inception of videos almost everyone in a project meeting does actively participate in discussions.

HH has an office in Mobile, Alabama, as well as an affiliate office in England. Models are created in Boston and are sent to these sites over the Internet, via modem. Project reviews are conducted via teleconferencing. This mode of communication facilitates quick response to problems that may occur even in remote locations.

From pictures to CAD files

Some of HH's projects require renovations of existing chemical plant facilities. Performing surveys of existing rooms to gather data on existing site conditions often takes days and weeks. Due to the many pipes obstructing easy access to the taking of clear measurements, such site surveys are easier to do with the aid of Photogrammetry. Photogrammetry uses photographic technology with traditional surveyor's tools to locate objects 3-dimensionally in space. Two dimensions are gathered for each object encountered on a site to be measured. Subsequently, the object's location is also measured from a selected third point of reference. The information is recorded and used in their offices to generate existing site condition drawings. The author encountered the use of this device in a movie company's special effects stage set in the summer of 1994. In the movies it is used to keep track of objects in space, so that when images are combined on film for special effects purposes, their location in space can be accurately determined. In other words, photogrammetry, like the other technologies mentioned so far, are applications of technologies that already exist in other industries, and are now applied to the construction industry.

HH in Summary

In the attempt to fully utilize computer technology and in order to facilitate innovation in their design-engineering-construction processes, HH discovered the need to change their organizations thinking. This was the reason for the need to find new ways of communicating the project within the firm. In its attempt to innovate the design-engineering-construction process the company has come up with some maxims of the "HH way"(see appendix B). Although HH has been relatively successful at implementing these systems, it has taken a toll on their workforce. The drive in the organization to give more decision making responsibilities has driven out a good deal of workers. According to the senior vice president, HH has experienced a 50 percent turnover rate since the inception of reengineering. One of the reasons behind the high rate of turnover of employees was due to the abrupt way the reengineering program was introduced. The management of the firm did not attempt to phase in new innovations gradually. This did not give workers an opportunity to adjust to the rapid changes occurring in the firm.

The author spoke with a recently retired Project Manager from HH, Mr. Al Badger, who complained how hectic the construction industry had become. According to Mr. Badger , the pace of work at HH and other firms he had previously worked in, did impact on his decision to retire. Mr. Badger had approximately 20 years experience in the construction industry. However, Mr. Badger did also say that some of his younger colleagues find the current pace of construction projects challenging.

Although, HH is not a typical architectural design firm, the author suspects that HH might represent the practice of tomorrow.

A case in point is how Goody Clancy & Associates is currently discovering the possible uses 3-D models. That is, Goody Clancy's use of the 3-D model is primarily for presentation purposes, whereas HH's use of the 3-D model is based on the ability to represent data that can be used in construction simulation. Yet these cases were not presented primarily as a comparison of what constitutes "good practice". They were presented in order to look at different approaches of the uses of computer technology in professional practice.

The major distinction between these two firms is the motivation for their exploration into computer technology use. In general, an architectural firm's focus is on the esthetics of its projects, this reason may be behind the focus on the visualization capabilities of CAD systems in Goody Clancy. The A/E firms focus is on the quality and speedy delivery of the product, for this reason the concern in A/E firms is in efficient construction administration. Thus, HH does provide facility design services, as well as engineering and construction administration work, but the focus is not primarily on the esthetics of the plant design. The opinion of the author is that there must be a middle ground between these two types of firms. The challenge the industry faces is finding that middle ground.

3.2 Conclusion

The cases presented offer us insights into how two very different firms are dealing with project delivery issues and computer technology in the construction industry. Both firms are increasingly using IT to support their processes. However, the approach to dealing with changes in computer technology and client demands are quite different.

It may be argued that Goody Clancy's approach to change in the uses of IT and delivery process is reactive. That is, from a look at their method of current practice, no effort has been made by management to reinvent their existing approach to design. If anything, and based on the views expressed by Mr.Wooding, Goody Clancy is still trying to conduct their practice based on the traditional model of design-bid-build. From the account of the evolution of CAD in their practice it would appear that they take a "wait-and-see" approach to technological innovation in computer-aided practice. In other words, new technology is not specifically sought out, but only used because of the need to remain competitive. Mr.Wooding did acknowledge that part of the reason for transferring files to contractors electronically was because of the specific requests by the GC for Goody Clancy to do so.

Another issue of interest with regard to Goody Clancy is their design approach. Based on the comments of Mr.Wooding, it would appear that designer's practice in his office still is based with design-bid-build in mind. Yet, unfortunately they are increasingly faced with projects that are fast-tracked. This is expressed in the frustration articulated by Mr.Wooding, that it was not possible to complete a full set of construction drawings, as well as the failure of the architect to have the whole picture of the project merely by using electronically produced design development drawings. Traditionally the architect's position on project was primary because he/she was the only one on the project who had the full vision of the project. Fast-track projects have takenthe ability of such a vision away from the designer. If anything, this may suggest that designers will have to search for new methods of designing in tandem with speedy delivery methods, possibly by means of computer technology , in order to regain the advantage of being the keeper of the overall vision on a project.

Based on the interviews, it may be argued that HH took a proactive approach to IT and delivery method issues. That is, an effort was made to look for new computer technology that would help them to respond more rapidly to client demands. The firm thus took a systematic approach to the reengineering of their organizational processes. The firm's management has maintained an open mind to change and felt that this is a necessary adjustment it must make to survive rivalry from competitors. Technically speaking, their ProjectVISION system is successful, in that it achieves a total integration of all their internal computer systems, as well as allowing clients to be linked with HH. However, their approach to reinvetion was primarily technologically focused. Based on the employee turnover rate after reengineering, it may also be argued that not much consideration was given to worker's ability to make a smooth transition to the reinvented HH. The concern to satisfy clients and use technology throughout the organization effectively penalized the people within the firm, who would run the system.

The author does not suggest that either firm's approach is correct. Rather that each case raises issues which are pertinent to professional practice, by offering two perspectives in dealing with computer technology and speedy delivery methods.

Chapter 4

Reinventing Professional Practice

4.1 Ideas in Management and Technology

The two proceeding chapters described the current circumstances in which design professionals practice. The two case studies in the previous chapter may be considered exemplary of how firms are responding to the market forces that affect professional practice today. In response to market forces, firms have looked to new methods of management, currently available computer technology, and reinvention of their design/delivery process. This chapter discusses some of the latest advances in each of these areas.

4.1.1 Managing Change

One of the key issues discussed in both cases is the need for better management and coordination of information. Better management of information facilitates quicker response to unanticipated problems. Therefore, the ability to capture knowledge and quickly distribute it within an organization is as important as the tools for distribution of information. The firm of Herzog-Hart understood this, which is why they reengineered their company.

Reengineering as a management philosophy was used by HH to breakdown the hierarchical structure of their organization. The reinvented organization focused on project teams that were multidisciplinary in make-up. That is, engineers from the different functional groups within the firm were on a project basis deployed as a team, as opposed to the former practice, where projects had to be channeled through various functional departments on their way to completion. Goody Clancy &Associates, like most architectural design firms, uses project teams on their projects. However, the issue is not whether a firm uses project teams or not, but how they are used and the structure within the organization that supports these teams. The goal in creating project teams is to facilitate a quicker response by a company to market pressures, unanticipated problems, and to provide greater flexibility. This goal is best achieved within an organization that provides project teams with the autonomy required to make decisions directly related to their tasks on a project, without having to go through middle management in order to get approval from those at the top of the organization. In other words providing workers with greater decision making responsibilities.

Various developments in management techniques address concerns relating to worker empowerment and better access to information, for decision-making purposes. Reengineering focuses on "intra-organizational" restructuring, reinventing the organization from within. In the construction industry, where separate parties join together to execute a project, partnering has been developed for "inter-organizational" communication and coordination. This is where communication and coordination occur across separate companies. Partnering may be described as the application of Quality Management(QM) principles to the construction industry.[64] Another

[64] Quality Management(QM) is a set of standardized tools for assuring quality in a process and the output of that process. QM comes from the principles use in Total Quality Management(TQM), which is discussed later in this chapter.

management philosophy, which shares some common themes with Reengineering is Total Quality Management (TQM). TQM, known in Japan as Total Quality Control(TQC), has its origins in the Japanese manufacturing companies. These management techniques focus on the ability to manage information and people in a time of rapid change.

4.1.1.1 Organizational Change/ Reengineering

Reengineering concerns itself with business "processes". The premise of Reengineering is that industrialized methods of business focused on efficiency and control of work, where industrialized methods of business are the traditional approach to business management based on concepts of efficiency and control. Efficiency and control were achieved by breaking work down into simple "tasks", and having managers supervise the workers who performed each task, with managers over those managers, and layers of management occurring till the very top of an organization. This is a description of Adam Smith's idea regarding the division of labor for industrial work[Hammer, 1993 #26].[65] Reengineering's premise is that in technologically advanced societies the method of conducting business can no longer be based on an "industrialized model" of production, which may also described as an "assembly line model" of work. New technology that is based on the computer requires new methods of doing business. Therefore, in Reengineering work tasks are reunified into "coherent business processes".[66]

The tool that enables Reengineering to occur is information technology(IT). Workers who have computers can be linked to a

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[65] [26],p.2

[66] [26] ,p.2

database that houses the information required to perform work. A clearer understanding of Reengineering is achieved through a discussion of its principles, which are as follows:

- *Organize around outcomes, not tasks.* Here the idea is to make one person responsible for a specific process. The work is organized around the attainment of a specific objective. Responsibility for a specific process is given to one person. Some companies have modified this principle by making a single team responsible for a process. For example, HH used to have projects move from functional group to functional group within their company. That is, the design group will design the plant, then it would go to the structural and engineering department, and through each functional group until completion. In other words a sequential progression of work from department to department. After reengineering, a team within HH would see a project through from start to completion, with various team members coming and leaving the team as required by the project. The goal of this principle is to streamline work activities by having a specific person or group responsible for all the tasks required to achieve a specific objective.

- *Have those who use the output of the process perform the process.* Typically, companies organize their departments into specialized groups. For example, purchasing is a specialized group often found in companies.[67] Purchasing departments have the responsibility of handling all outside purchases for a company. In this principle a function such as purchasing would be handled by the group or individual making the purchase, using a computer database outfitted with an expert system that can track and update all purchases on a project, for later review.[68] This avoids the time and cost delays associated with processing approvals and making purchases through a purchasing department. In other words, streamlining a process by allowing the individual/group to perform all the necessary functions required to perform their work.

- *Subsume information-processing work into the real work that produces the information.* This principle has to do with the processing of information. Certain departments within a company exist for the sole purpose of processing information. The accounts payable department found in most organizations is an example. Accounts payable departments gather information from purchasing and other departments like billing in order to process the data for review. This informs a company of its performance, i.e, whether profits are being made or not. Using computer

[67] In some construction companies the purchasing department is known as the procurement department.

[68] see glossary Appendix E

databases, information gathered on a specific project in terms of billable hours, material purchases, and the like can easily be produced for analysis. In essence, IT can store and retrieve the data in a manner that is suitable for a group to perform the necessary actions required by the information produced. This alleviates the current trend of information travelling through a department to middle managers and finally down to those who require the information to do their work. HH's attempt at reinventing their project information on a purchase order model is geared towards fulfillment of this principle.

- *Treat geographically dispersed resources as though they were centralized.* Resources such as people, material, equipment, etc., may be dispersed between different locations. This is where a company has operations in many locations. Resources become specific to a particular location, with material purchases and uses of resources localized to each site. Using IT, this principle suggests linking all resources through a shared database in order to take advantage of economy of scale. Material purchases may be substantially lower in price, based on bulk purchases, or people can be deployed where needed the most. In this way a company may have units that are deployed locally, but also have the ability to access the parent company's resources as required.

- *Link parallel activities instead of integrating their results.* In a product development project activities often occur in different departments without any communication between the departments. For example, the concurrent development activities between a product design group and a mechanical design group on the same product development project. This often leads to rework, once both development efforts are combined for testing. In order to avoid this situation, this principle suggests linkages between separate development activities. These linkages can be achieved through a shared database, communications networks, and teleconferencing. In HH, the use of a 3-D model informs all groups associated with a project of the status of another groups' activities on the same project. As the model is regularly updated each time design work is done to it.

- *Put the decision point where the work is performed, and build control into the process.* People who do the work should be able to make decisions required by their work, as opposed to a situation where a manager would supervise a worker and make the decisions for that worker. Here, the ability for a worker to have access to information will give him/her the power to make decisions. As mentioned previously, expert systems can provide necessary information in a manner that can be quickly understood by the user, as well as make for faster responses to potential problems. This also alleviates the need for management supervision of day-to-day work, Leaving management with time to focus on long term initiatives, such as performance evaluation of workers on projects, etc. Finally, managers can facilitate in the start-up and closing-out of projects.

- *Capture information once and at the source.* Here the focus is on the ability for everyone in an organization to have access to the same information through IT. In other words, information need only be gathered once. Different departments need not repeat the gathering of similar data already acquired by another department. Only a search for that entry is required in the database for the information to be retrieved. This avoids redundant work in an organization.[69]

A word often repeated with regard to Reengineering is "starting over". This means breaking with the "past" and moving into the "new", where the "past" is the traditional way of doing business, and the "new" is a reinvented company that fully utilizes current computer technological breakthroughs throughout it's organizational processes, even though reengineering has become synonymous with those companies who have scaled back their organization through massive lay-offs. It is important to distinguish between the conception of

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69 [27] pp. 108-112

reengineering as described by it's creators, and popular misconceptions. Some companies have successfully reengineered their processes with remarkable results and with corresponding yields in market performance, while other companies have met with disastrous consequences, typically due to cutting back too many workers too quickly. For example, "businesses like Ford Motor Company and Mutual Benefit Life Insurance have reengineered their processes and achieved competitive leadership as a result. Ford has reengineered its accounts payable processes, and Mutual Benefit Life, its processing of applications for insurance".[70] However, the following account describes an example of where reengineering did not lead to market advantage,

> Detroit automakers are catching up with Japanese rivals on quality and cost. Supplier networks have been reconstituted, product-development processes redesigned, and manufacturing processes reengineered. However, the cheerful headlines heralding Detroit's comeback miss the deeper story- among the losses have been hundreds of thousands of jobs, 20-some percentage points of market share in the United States , and any hope of US automakers beating Japanese rivals in the booming Asian markets anytime soon.[71]

As in the use of any other tool, an intelligent application of these principles is required. A common sense approach should always be taken when attempting to apply any principle. As such, the key concepts that should be remembered in Reengineering are the use of IT and organization of "work tasks" into "processes". The ability for a company to sensibly achieve "reinvention" through the integration of "processes" and IT is reengineering.

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[70] [27] p. 105

[71] [44] p.126

4.1.1.2 Partnering

Partnering is a method of team building on a project. It is a non-contractual agreement between all parties on a project, where all parties agree in pooling resources, i.e., in allying to exploit opportunities, and in linking systems to improve the ability to compete without adding capacity in terms of overall resource use.[72] "While the contract establishes the legal relationship, the partnering process attempts to establish working relationships among the parties (called stakeholders) through a mutually-developed, formal strategy of commitment and communication".[73] Partnering's goal is the establishment of "good faith" in a project, between all participating parties. The key elements of partnering, as described by the document *Partnering a Concept for Success* are as follows:

- *Commitment* - Commitment to partnering must come from the top management. The jointly developed Partnership character is not a contract, but a symbol of commitment.

- *Equity* - All stakeholders' interests are considered in creating mutual goals and there is commitment to satisfying each stakeholder's requirements for a successful project by utilizing win/win thinking.

- *Trust* - Teamwork is not possible where there is cynicism about others' motives. Through the development of personal relationships and communication about each stakeholder's risks and goals, there is better understanding. With understanding comes trust and with trust comes the possibility for a synergistic relationship.

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72 [35] p. 43

73 [34] p. 2

- *Development of Mutual Goals/ Objectives* - At a Partnering Workshop the stakeholders identify all respective goals for the project in which their interests overlap. These jointly-developed and mutually agreed to goals may include achieving value engineering savings, meeting the financial goals of each party, limiting cost growth, limiting review periods for contract submittals, early completion, no lost time because of injuries, minimizing paperwork generated for the purpose of case building or posturing, no litigation, or other goals specific to the nature of the project.

- *Implementation* - Stakeholders together develop strategies for implementing their mutual goals and the mechanisms for solving problems.

- *Continuous Evaluation* - in order to ensure implementation, the stakeholders agree to plan for periodic joint evaluation based on the mutually agreed to goals- to ensure the plan is proceeding as intended and that all stakeholders are carrying their share of the load.

- *Timely Responsiveness* - Timely communication and decision making not only save money, but also can keep a problem from growing into a dispute. In the partnering workshop the stakeholders develop mechanisms for encouraging rapid issue resolution, including the escalation of unresolved issues to the next level of management.[74]

In a public-sector project, i.e., a project funded by the government, such as the Central Artery/Tunnel project in Boston, Massachusetts a partnering agreement is entered into upon the completion of the bidding process and prior to construction. Representatives from the top management of the owner's and successful bidders' organizations meet for an initial Partnering workshop. In this meeting, which is held off site (possibly, in a hotel conference room), a commitment to

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[74] [34] p. 2

Partnering is established between all stakeholders. With the goals of each stakeholder expressed and unified into a single project goal, which may be the completion of the overall project on schedule without the need for litigation between parties. The top management of each stakeholding company then has the responsibility of educating their organizations about Partnering. Key players from each stakeholder's organization, which are people who have decision making authority and are responsible for contract performance, will subsequently participate in their respective Partnering workshops. After the initial workshop, periodic meetings are agreed upon by participants over the duration of the project. These meetings are used for periodic evaluation of project goals and reenforcement of the relationships built in the initial Partnering workshop. A firm is sometimes retained as a facilitator in the initial Partnering workshop, and subsequent meetings. The role of the facilitator is to act as a neutral third party who helps in conflict resolution as they may arise, especially for parties new to Partnering. A facilitator is useful in the beginning of a project, where stakeholders are unfamiliar with each other and have not established any trust. However, the successful facilitator is working their way out of a job, once trust is established between stakeholders, communication can occur with participants having respect for each others viewpoint.[75] When trust and mutual respect are established the services of the facilitator is no longer required. In some cases problems may arise that cannot be resolved by lower management. When this is the case, such conflicts are "escalated" to a higher level of management, where upper management attempts to expeditiously come up with a resolution to the specific problem.

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[75] [35] p. 47

The idea of Partnering is not a new one. The traditional terms to describe what we now know as Partnering are "retainer arrangements", "evergreen", or "sole-source contracting activities".[76] Originally, Partnering was developed in private-sector projects, where Partnering is a long term agreement between the owner and construction firm. In this case Partnering aligns the goals of the two parties for a project, or over a series of projects.[77] Partnering in the private sector is typically used on large scale design-build projects ,e.g., DuPont has maintained a long term relationship with the construction firm of Flour-Daniel Inc., of Irvine, California, in the construction of numerous chemical plants.[78] In a private-sector project, a Partnering agreement is often initiated prior to a formal contractual agreement.

Partnering became widely viewed as a method for handling public sector projects when the Mobile District of the US Army Corps of Engineers pioneered the use of Partnering in a public sector project,e.g., the Oliver Lock and Dam project, in Tuscaloosa, Alabama.[79] The US Army Corps of Engineers turned to Partnering as a way of avoiding costs associated with "final resolution of all administrative problems and financial responsibilities".[80] The time taken to resolve these issues were typically two to three times the amount of time spent in actual

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[76] [32] p. 25

[77] [32] p. 25

[78] [32] p. 26

[79] [35] p. 44

[80] [35] p. 44

field work.[81] Using partnering they were able to save $600,000 in the early resolution of disputes that might have gone into litigation, on the Oliver Lock project.[82] Additional cost savings were also achieved by contractor-initiated cost reduction proposals. Consequently, the Corps of Engineers has used partnering on many of its other projects,i.e., three other projects in the Mobile area which involved NASA, the Air Force, and other contractors.[83] For this reason, other government agencies have since used partnering on their projects,e.g., Department of Energy, Arizona Department of Transportation. Currently, Partnering is being used by the Massachusetts Highway Commission(MHC) in the Central Artery/Tunnel project, in Boston, Massachusetts. Unlike in design-build Partnerships, public-sector Partnerships run for the duration of a single project, due to public-sector projects being competitively bid in order to get the lowest price, and to avoid the development of collusive practices between an owner's representative and a specific contractor.

The key concern of Partnering is early conflict resolution through better communication. This reduces participant's fears of exposure to litigation, and fosters cooperation on a project as members realize that they share common goals for quality of construction, timely completion, and quality of product . It should be noted that Partnering does not emphasize the need for IT, but as a method of inter -company coordination, it does support the use of information systems.[84]

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81 [35] p. 45

82 [35] p.45

83 [35] p. 45

84 Appendix C contains copies of partnering agreement forms.

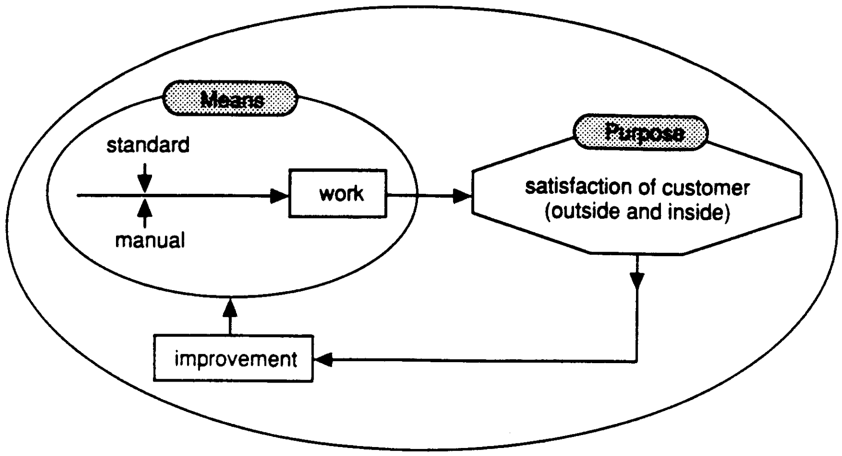

Figure 4-1: Diagram of the Market-in Concept.

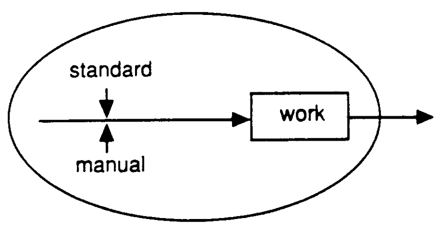

Figure 4-2: Diagram of the Market-out Concept.

4.1.1.3 Total Quality Management (TQM)

Total Quality Management (TQM) is described as a "thought revolution", a way of changing the thinking of management.[85] Where the focus of management is on a "market-in" concept of business (figure 4.1). The "market-in" concept is defined as the need for a company to have a customer's viewpoint, where everyone in a company sees themselves as users of the product produced by the organization. The "market-in" concept also refers to a situation where customer's needs drive the product development activities of a company, as opposed to the "market-out" concept, which focuses on a companies internal standards, irrespective of customer needs(figure 4.2). The need for a customer focus is exhibited in some of the basic concepts of TQM, primarily the "four fitnesses" or "quality levels"(figure 4.3).

The "four fitnesses" correspond with the four periods of the evolution of quality in the history of Japanese industry, or rather, the four eras of Japanese TQM.[86] The development of the "four fitnesses" is also know as the "evolution of Quality Methods".[87] By means of the concept of "fitnesses", TQM is concerned with the changing definitions of quality over time. For this reason a discussion of each fitness is appropriate, in order to arrive at the current definition of quality.

In the 1950's, Japanese industry viewed a concern for quality as an obstacle to mass production, as the goal of the industry was to rapidly

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[85] "Thought Revolution" is from the definition given to students of TQM by Prof. Shoji Shiba, Adjunct Professor at the Sloan School of Management, in his course Total Quality Management(15.766).

[86] [5] p. 18

[87] [5] p.18

rebuild the country's commercial infrastructure, after World War II, in order to achieve a measure of quality some of the more progressive companies used statistical quality control(SQC).[88] This was the basis for the quality method known as Fitness to Standard. Fitness to Standard defines quality as a measure of deviation from a standard. In other words, the closer a product performs as specified, the higher the quality of that product. In Fitness to Standard the ability to avoid defects is the focus of ensuring quality. Here, a product that performs as per designers' intentions is considered as good in quality. In order to determine the performance of a product, inspection of the product of manufacturing is required. "To achieve Fitness to Standard, managers and engineers define each manufacturing task, record those tasks as standard practices in manuals, and define inspection procedures to enforce the standard practices".[89]Typically, statistical methods are employed in the evaluation of Fitness to Standard. For example, in the 1950's W.E. Deming, an American quality expert, brought the concept of statistical quality control (SQC) to Japan.[90] This heralded the use of "quality methods" in Japanese manufacturing.

Fitness to Standard has two weaknesses: an inspection-oriented attitude, and weak consideration of the market/customer. An inspection-oriented attitude implies that quality can be attained through inspection. This is where inspection of the output of manufacturing occurs, and defective or low quality items are

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[89] [5] p. 4

[90] [5] p. 17

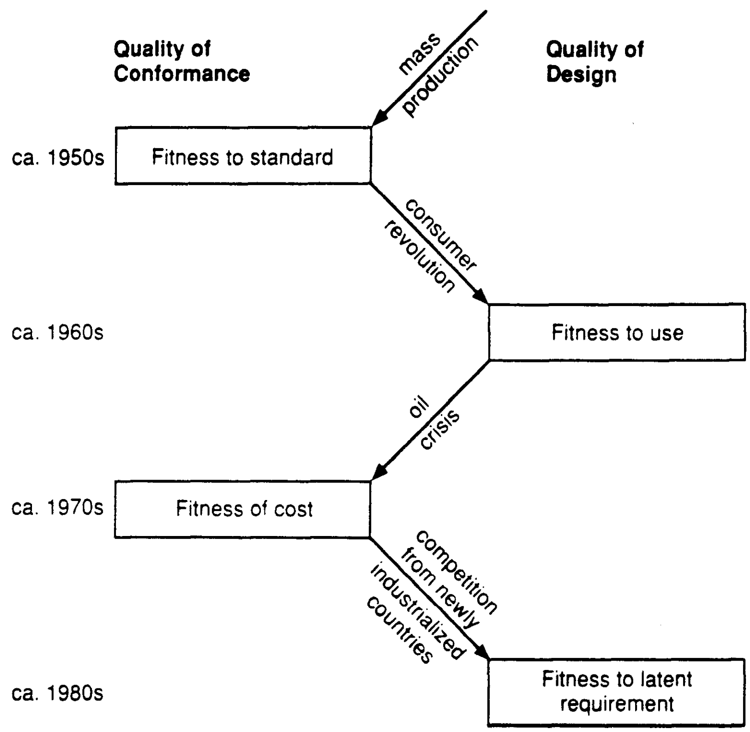

Figure 4.3: Diagram showing the four "Fitnesses".

discarded.[91] Inspection in such cases is carried out by those who are not part of the production process. This often leads to an adversarial relationship between those whose work is being inspected, and the inspectors. Fitness to Standard's focus on production standards and inspection directs people to a focus on the designer's specification for a product, as prescribed in manuals, as opposed to the ability of a product to satisfy a customer need.

However, the basis for competition in Japan in the 1960's was no longer the amount of "usable units" produced, since the country generally was thriving economically and people enjoyed a higher standard of living.[92] Rather, as the Japanese costumer no longer had an urgent need to replace essential goods, manufacturers started to produce a variety of products,e.g., televisions, washing machines, cameras, etc.[93] This led to the rise of the "consumer" and the concept of "market".[94] This led to the development of Fitness to Use, which is the ability to "totalize all functions". Essentially, the customer is free to use the product in anyway he or she chooses? In Fitness to Use the product is adapted to the customer's needs. A good example of Fitness to Use is described in the following account, which was the experience of a Japanese appliance maker:

> A major appliance company made a new washing machine. However, there were many complaints about it from the customers living in rural areas. The company sent its engineers to the field to observe. They found that

[91] [5] p. 5

[92] [5] p.6

[93] [5] p. 17

[94][5] p.17

> farmers were using the machines to wash the dirt off potatoes. Although such use wasn't prohibited by the manual, the machines weren't designed for such dense loads, and they would often break. When the manufacturer realized the use to which customers were actually putting the machines, the machine was redesigned to tolerate potato washing, and the machines returned to normal reliability. [95]

This is not to say the producer's standards are not important. Rather, that in Fitness to Use the real needs of the customer are the focus of production.[96] Fitness to Use, like Fitness to Standard, requires inspection. For this reason the adversarial relationship between the inspector and the inspected still remain. Further, the ability for a company to assure performance of the product in all circumstances requires rigorous inspection. That is, a narrower limit of acceptable products that do not deviate from the standard is required(figures 4-4). Since any manufacturing process will have deviations from the standard, extreme cases of deviation require rework or disposal. Therefore, in Fitness to Use higher quality translates into higher cost of production and a higher price for the product. In order to achieve Fitness to Use, market research and close functional divisions within a company are required.The oil crisis of the early 1970's required an approach to manufacturing that lowered the cost of production, but not the quality of the product. As Japanese manufacturers found their companies competing in foreign markets in order to acquire foreign revenue for the purchase of oil, since "nearly 100 percent of domestic oil for consumption is imported" in Japan.[97] This led to the

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[96] [5] p. 6

[97] [5]p.17

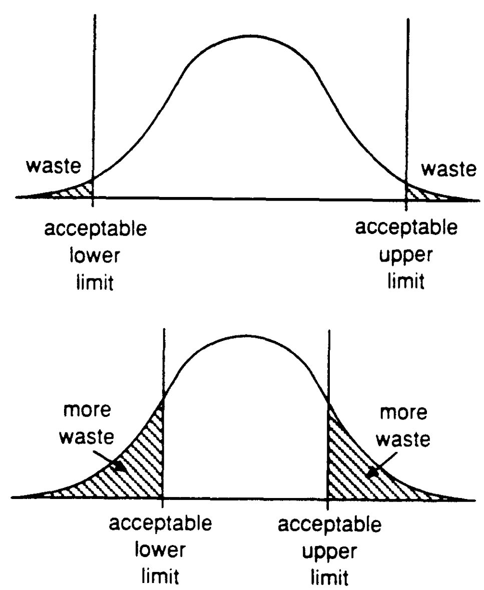

Figure 4-4: Statistical variation in product characteristics.

development of Fitness to Cost,which is concerned with "building quality in", as opposed "inspecting quality in".[98] Fitness to Cost means making better quality products at a lower cost, which is accomplished by reducing the variability of the production process (figure 4-5). When the variability of the process is reduced, all products produced fall within the inspection standards.[99] Consequently, there is a reduction in waste as a by product of the process. The goal in using this fitness is to have "100 percent quality without culling".[100] This requires a change in the process of the production system, as constant feedback and correction is needed in each stage of the process to achieve this level of quality (figure 4-6)[Shiba, 1993 #5].[101] Here control is not limited to the output of the production process, but to the process itself. As described in the book *A New American TQM* the modern methods for accomplishing this shift are

-using statistical quality control(SQC)

-monitoring the process in addition to output

-providing for feedback at each step, whereby every line worker notices the work of his or her predecessor, and can ensure that mistakes are corrected immediately

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98 [5] p. 7

99 Variability of the process refers to the variance from given standards, or specifications, set for a manufacturing process.

100 [5] p.8

101 [5] p. 9

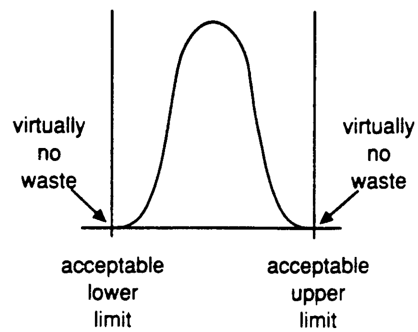

Figure 4.5: Result of reduced variability in a production process.

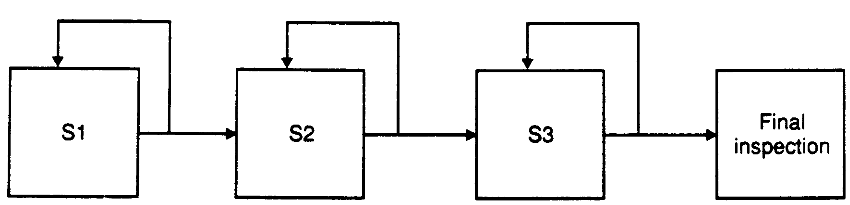

Figure 4.6: Diagram showing feedback at each step of a production process

- instituting line worker participation in the design and improvement of the production process, to make it continuously more reliable.[102]

TQM offers standardized tools for continuous improvement, e.g., quality circles, 7 quality control (QC) steps, 7 QC tools(figure 4-7). [103] These tools are mass taught to workers in a company in order to give them the ability to carry out improvements in the process of production. The weakness of Fitness to Cost is that others can copy these management methods with relative ease. In the case of Japan, it's technology and management methods had spread to other parts of Asia. In the 1980's countries who had cheaper labor were able to implement the same techniques and produce lower priced goods, which posed a serious threat to Japanese manufacturers,e.g., Korea, Singapore, Taiwan, and Hong Kong.[104]

The threat of competition led to the development of Fitness to Latent Requirement. Fitness to Latent Requirement is the ability to anticipate customer's needs, before they themselves become aware of those needs. In this "fitness" a company differentiates itself from competitors by being the first to come to market with an innovative product. For example, the Sony Walkman may be considered a product consumers did not know they needed. However, as soon as the Walkman was available many uses were found, such as people jogging with it, kids playing their music on it, people commuting on the subway with it, etc.

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102 [5] p. 9

103 These tools are not discussed in this thesis as they are specifically geared to management of workers in manufacturing processes, which is not the purpose of this discussion of TQM. If the reader has further interest in this and other TQM topics not covered here, the author refers the reader to the book A New American TQM, which is listed in the bibliography.

104 [5] p.17

However, some weaknesses still remain in this "fitness", such as the inability to accurately forecast human behavior, since it is always changing. In other words, " These weaknesses arise not from the companies' current processes for product and production process design, but from the variable speed and appropriateness of improvement and change".[105] A company's inability to keep up with improvements as quickly as it's competitors, may lead to failure in the market, which in turn might force the company to go out of business.

In TQM the concept of quality changes as societal needs find new expression.[106] With each succeeding change in the development of a "fitness" the concept of quality evolved. This is described as "revolutionary changes in how people thought about quality", by Prof. Shiba in *A New American TQM* .[107] Subsequent changes in the evolution of quality required a corresponding development in tools used for assessing quality (Figure 4-7). The development in tools are also known in TQM as the "evolution of methodology".[108]The changes between fitnesses are characterized by a shift in the concept of what drives quality. For example,

- From Fitness to Standard to Fitness to Use : shift to the concept of market
- From Fitness to Use to Fitness of Cost : shift to the concept that price is set in the market

[105] [5] p. 12

[106] [5] p. 16

[107] [5] p. 18

[108] [5] p.18

- From Fitness of Cost to Fitness to Latent Requirement : shift to the concept of continuous change in market need and thus the continuous shortening of product development cycles.[109]

The tools that are relevant to this thesis are those used for Fitness to Latent Requirement. In Fitness to Latent Requirement the ability of a product to have a certain"design value" distinguishes it from other products. The standardized tools used in this "fitness" are Quality Function Deployment (QFD) and the 7 management and planning tools.[110] The 7 management tools are not restricted to use by management, but are for use by people at all levels of a company. QFD is designed to provide a common understanding between those in marketing, engineering, and management. "QFD is a systematic process that helps identify customer desires and deploy them throughout all functions and activities of the corporation, remaining faithful to the voice of the customer".[111] QFD's focus is on the use of multifunctional teams to solve problems, and it combines four of the management tools of TQM to focus on the customer,e.g., affinity diagram(KJ method), relation diagram, tree diagram, and matrix diagram(appendix D). A key component of QFD is the use of large displays, these are on paper and range from a few feet in dimension to as large as 5 feet by 15 feet in length. The tools of QFD are House of Quality, the four management tools of TQM described above, Pugh concept selection process, and Taguchi's system of quality

109 [5] p.18

110 [5]p.20

111 [8] p. 60

engineering.[112] A modification of QFD titled Enhanced QFD (EQFD) builds on the principles of QFD and makes it relevant to complex products that are conceptually dynamic. "EQFD is an extensive corporate capability that integrates the corporation holistically with a concentrated focus on customer satisfaction".[113] In other words, EQFD focuses on standardized methods for developing complex products that require regular changes based on customer needs.

QFD's focus is on product development and design. Whereas the 7 management tools focus on translating customer information, which is typically qualitative, into quantitative data to be used by a company in understanding the customer's voice(Figure 4-8). The voice of the customer is the information gathered from customers through surveys with regard to the quality of a product.

TQM puts great emphasis on the ability to acquire customer information. For this reason a definition of the customer is required. Customers are generally defined as anyone who receives the product of your work.[114] Customers are divided into internal and expanded, where the internal customers are those within the company, and the expanded customers are the clients, users, society, industry, planet, etc. The distinction made between the client and the user is the following: the client procures the good or service, and the user is one

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[112] Due to space limitations these specific tools are not discussed in this thesis. Rather a discussion of their application will occur. The reader is referred to Prof. Clausing's book Total Quality Development for detailed discussion of these tools. The book is included in the bibliography.

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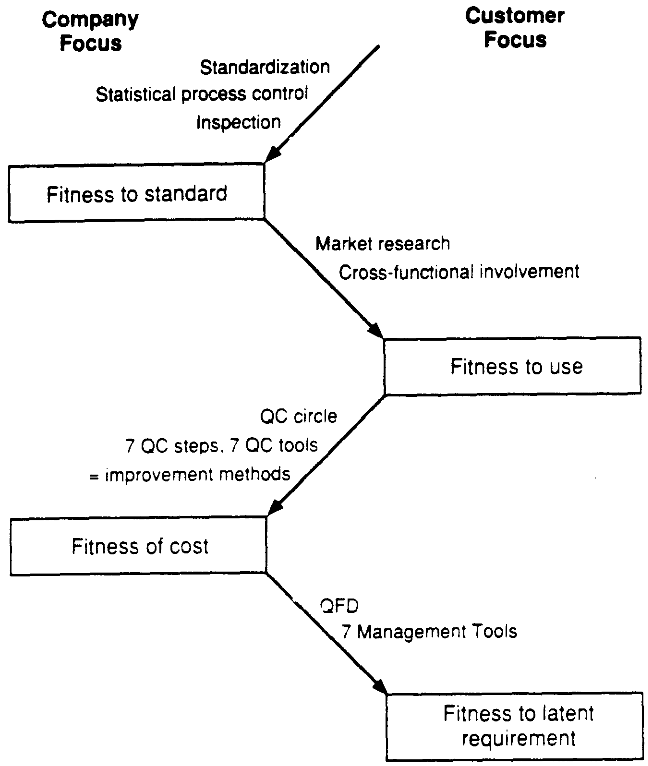

The Evolution of Methodology

The Tools and Steps of Quality Control

The 7 QC Tools

1. Check sheet*
2. Pareto diagram
3. Cause-and-effect diagram
4. Graphs/Stratification
5. Control charts
6. Histogram
7. Scatter diagram

The 7 QC Steps

1. Select theme
2. Collect and analyze data
3. Analyze causes
4. Plan and implement solution
5. Evaluate effects
6. Standardize solution
7. Reflect on process (and next problem)

Figure 4-7: The Evolution of Methodology and the Tools and Steps of Quality Control who uses the product. The need for a market-in concept and an understanding of the customer is predicated on rapid societal change (this is discussed in chapter one). Briefly, societal change is described as changes in economy, attitude, technology, etc. In an attempt to continuously keep pace with societal change TQM offers tools for "continuous improvement". The model for this is exhibited in the WV model (figure 4-9), and its name is derived from the shape of the model. The WV model represents the process for systematic improvement through problem solving. It identifies three types of improvement: Process control, reactive improvement, proactive improvement, where it identifies the activities required as you move from thought to experience. It is basically a feed back loop. Information gathered at the end of the system is fed back in. There are three types of data identified by the model: Data 1-"qualitative data used to design a product or make other business direction choices", Data 2- falls between data 1 and data 2 using both language and numbers for reactive improvement, Data 3" quantitative data used to control the process".

Process control is where you have a process in place and want to make sure that all products produced by that process do not deviate from a standard. "For example, you have a standard bill paying process (S); you use, or , do, it (D) to decide which bills are valid to pay and when to pay them; you take data and evaluate or check(C) the results to make sure you are maximizing your cash position without paying so late that you incur payment penalties; and you act (A) to return to the standard process if it has gotten out of kilter and you are paying incorrectly, too

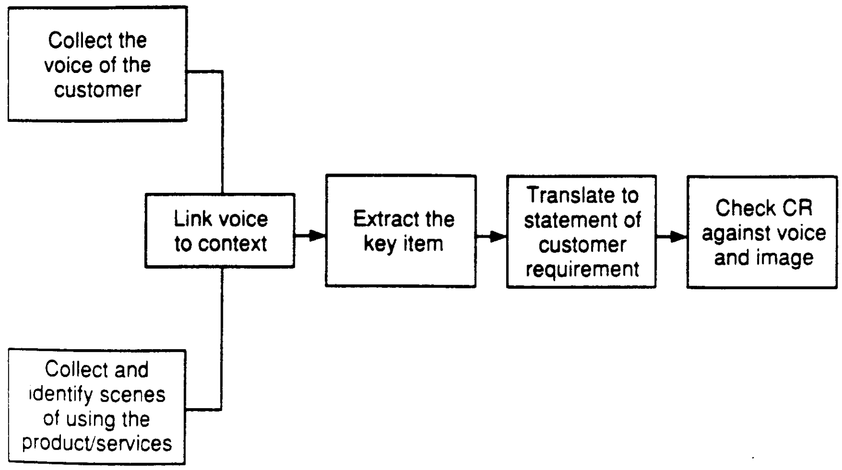

Figure 4-8: Transforming the Voice of the Customer into Customer Requirements.

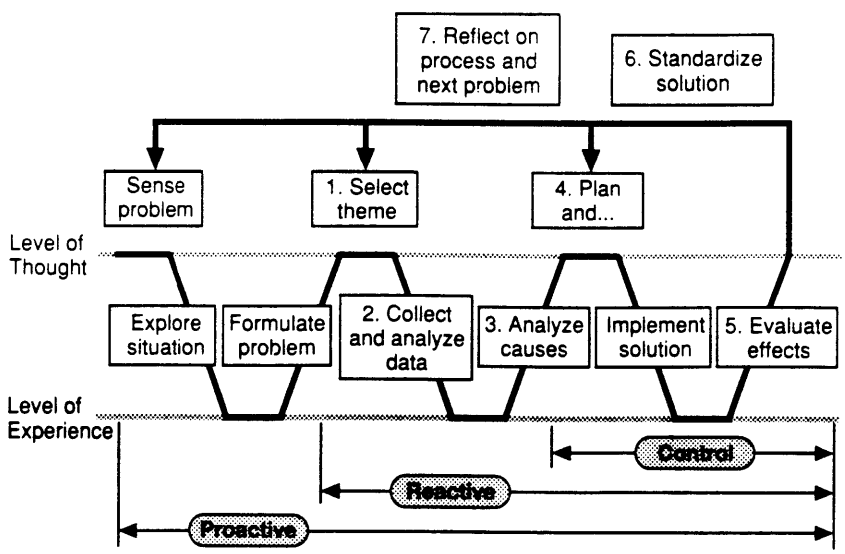

Figure 4-9: The WV model

soon or too late".[115] This cycle, is known in TQM as the SDCA (standard,do,check,act) cycle(figure 4-10).[116] The "reactive improvement" portion of the WV model, as described in *A New American TQM* , is as follows:

1. Select a theme (a specific improvement, such as "decrease after-shipment bugs reported in product X")

2. Collect and analyze data(to discover what types of bugs occur most often).

3. Analyze causes (to discover the root cause of the most frequent type of bug).

4. Plan and implement solution (to prevent the root cause from recurring).

5. Evaluate effects (to check the new data to make sure the solution worked).

6. Standardize solution (to permanently replace the old process with the improved process)

7. Reflect on process and the next problem (to consider how the problem-solving process could have been better executed and decide which problem to work on next, such as the next most frequent type of bug from step 2).[117]

"These steps, known as the 7 QC steps or 7 steps, are TQM's standard methodology for improving a weak process".[118] This is also known as the "reactive improvement" approach to problem

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115 [5] p.51

116 [5] pp. 56-57

117 [5] p.53

118 [5] p.53

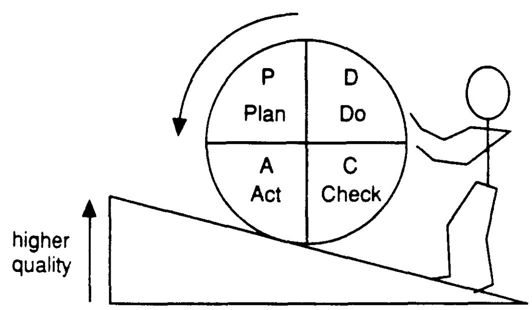

Figure 4-10: The PDCA cycle.

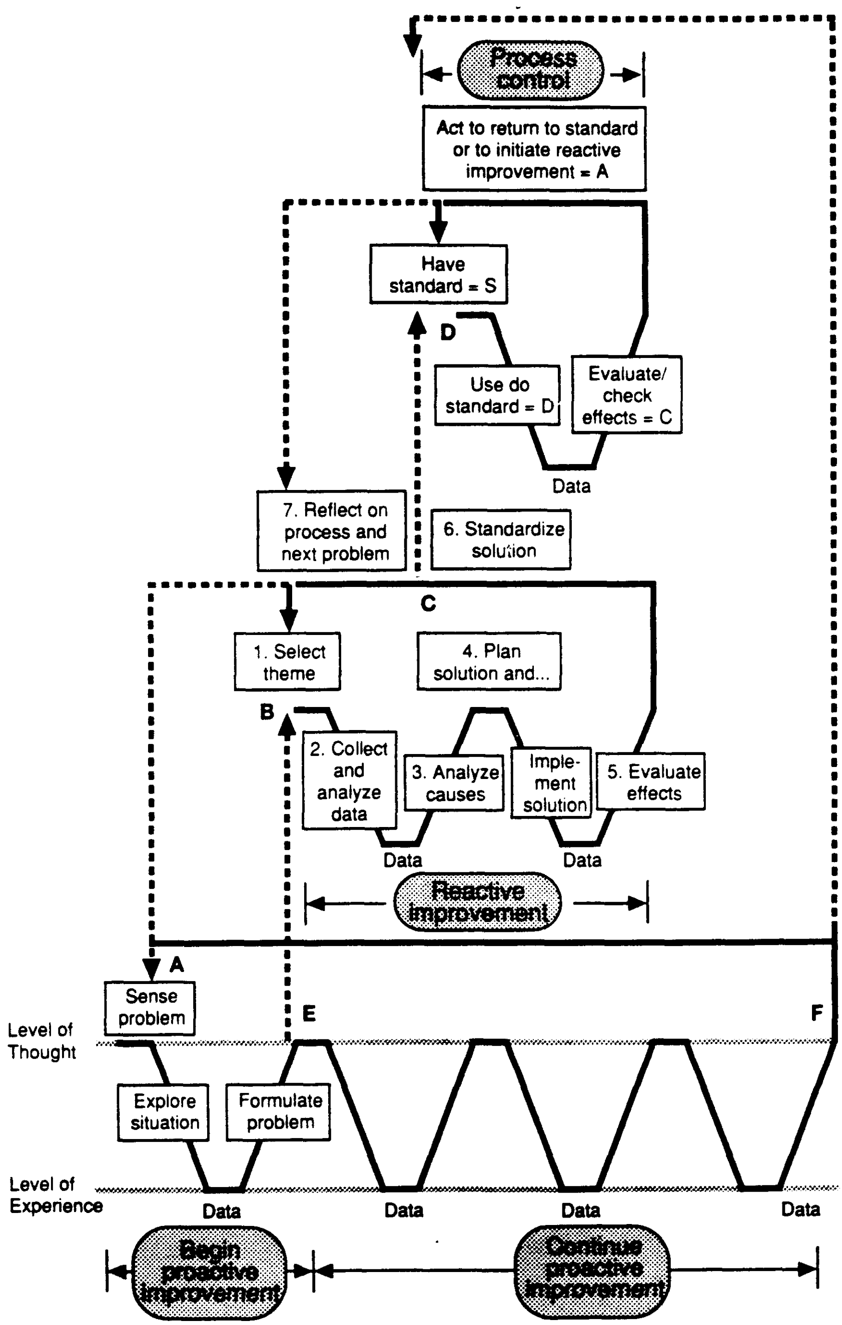

Figure 4-11: The Expanded WV model

solving, as it responds to already identified weaknesses. The methodology for "proactive improvement", addresses the case where a problem is generally sensed. For example, a company might want to embark on a product development initiative, which would require the gathering of customer data to ascertain customer wants. Or, a company may not be sure which process to improve internally. Two things can occur in this situation; After generally appraising the problem, the company can begin the use of the 7 QC steps, or the 7 management and planning tools with QFD. The overall improvement process as shown in the WV model can be described as PDCA (plan-do-check-add)(figure 4-11), that is, implicit in the WV model is the idea of iteration, i.e., "making improvements in a step-by-step fashion and repeating the improvement cycle many times".[119] In this regard TQM views the WV model as applicable to all problem solving efforts (figure 4-12).As mentioned previously, QFD is concerned with the development of new products. Figure 4-13 is a diagram of a typical product development process, showing the key to a successful project development process is the ability to produce concepts, and in particular, winning concepts that would prove successful in the open market. In order to produce design concepts that will lead to successful products, QFD relies on the customers voice to drive development activities. The idea being that customer driven products fulfill a need, which is articulated through customer surveys. A QFD development process is described bellow:

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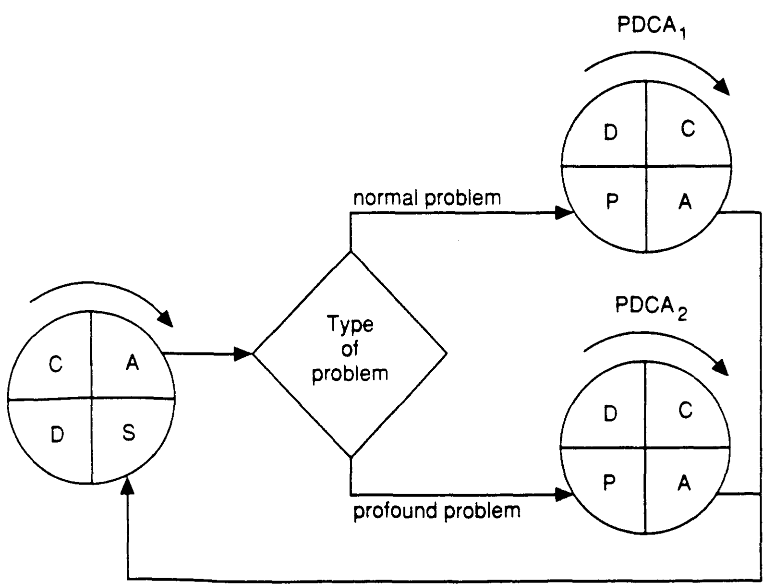

Figure 4-12: PDCA for Incremental and Breakthrough Improvements.

Define the problem- The tool used to do this is the KJ method, it is a method for gathering and analyzing qualitative data.[120] Through the use of the KJ method, customer surveys are analyzed andthe concept of the idea for development is defined, based on customer requirements. The multidisciplinary team visits the environment, e.g., market, home, hospital, etc., where the product is to be used- this is termed "swimming with the fish", then subsequently develops questionnaires based on the initial visit, the questionnaires are called "Kano Questionnaires". The questionnaires are distributed to all customers. When returned they are "scrubbed". Scrubbing is the process of changing the customers voices to the language of report. Or rather lowering the abstraction level of customer comments (figure 4-14). The development team then uses these "customer voices" to specifically define the problem using the KJ method. The KJ method uses a chart, which displays to all members of the product development team customer's requirements gathered from questionnaires, and its primary function is as a tool for building consensus on defining the goal of product development. Each member of the team participates in the development of the chart. In this way the identified problem, which is also the goal of the development activity, is arrived at by the participation of all. The KJ method helps in overcoming traditional differences amongst individuals from different disciplines within a company by building consensus on a project.

House of Quality - the house of quality is a relationship matrix. Simply described, it is used to translate customer requirements into corporate goals. In other words it is used for benchmarking. Customer requirements are compared against metrics, or standards of

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[120] A Japanese anthropologist by the name of Jiro Kawakita invented the KJ method in the 1950's, and the initials "KJ" are from the initials of his name.[5] p. 153

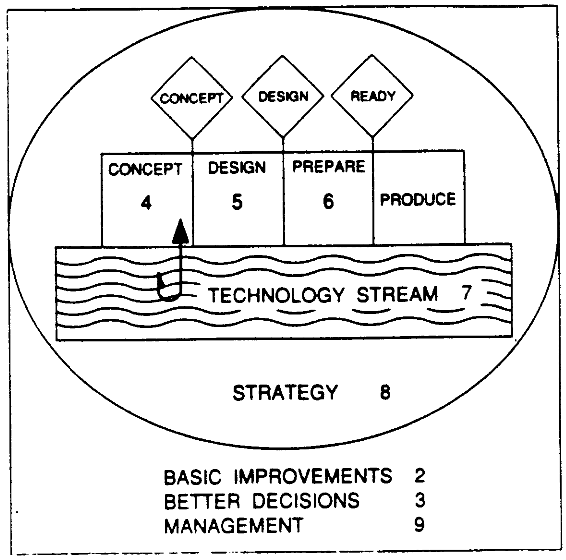


Figure 4-13: Product Development Process.

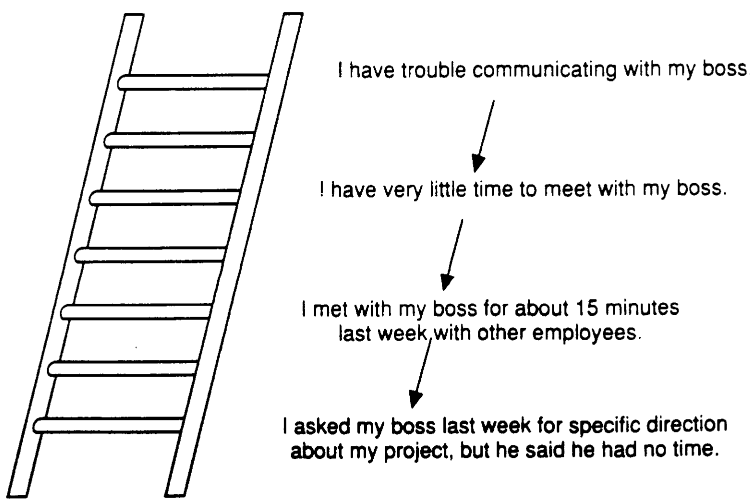
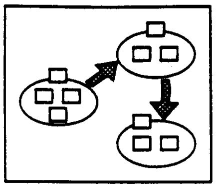


Figure 4-14: The Ladder of Abstraction

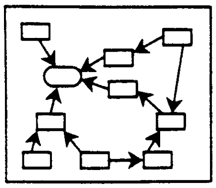
measurement developed by the team, using tree diagrams (figure 4-15). The "house of quality" is used to develop metrics for measuring customer requirements and also the design of experiments, which will be used in the product development activities. Figure 4-16 shows a schematic of the use of the "house of quality" for developing the different processes for the creation of a product. In QFD, customer information used in one development activity is also used in all subsequent development work,e.g., process planning, operations planning, etc . These planning activities can occur in parallel. This is called "concurrent engineering".

Pugh Concept Selection - QFD emphasizes teamwork, as such design work is by consensus with each member of the product development team contributing to the development of the concept for the product. A successful product is benchmarked and made the datum, and through iteration concepts contributed by the multi-functional team is rated against the datum, the goal being to arrive at a concept that is better than the datum. Various systems of ranking are used to pick a winning concept. In using a multi-functional team for this process, the idea is to come up with a viable concept as opposed to the traditional way, where a design team designs a product that is sent to the engineering department of a company, only to be redesigned by engineering and so on. By having all members of each functional group on the product development team, a quick assessment of the viability of a concept can be made during its initial conception.

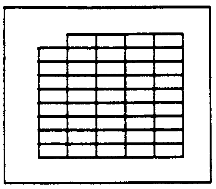
Taguchi's system of quality engineering - This system is geared to produce "products that go beyond mere feasibility to work well under actual conditions of use, maintaining performance close to ideal



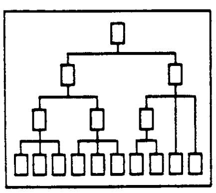
Affinity diagram (KJ method).[7] A tool that structures detailed data into more general conclusions. Used for providing initial structure in problem exploration. Often structures answers to "what?" questions, e.g., "what is going on in a complex situation?"



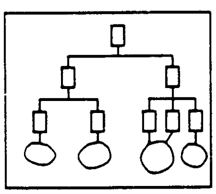
Relations diagram. A network of cause-and-effect relations. Often used to trace through answers to "why?" questions, e.g., "why is 'what's happening' happening?" A relations diagram is used when the situation is too complex for use of an Ishikawa diagram.



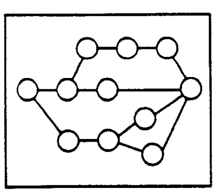
Matrix diagram. For relating multiple alternatives to multiple consequences of each. Often used to answer "which?" questions, e.g., "which things do we have to do to satisfy the customer's requirements?"



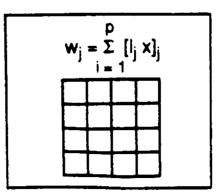
Tree diagram. A tool often used to relate means to ends, which in turn are means to more general ends. Often used to structure answers to "how?" questions, e.g., "how do we do the things that we have chosen to do?"



PDPC diagram (process decision program chart). A diagram of the flow of alternative possibilities and countermeasures for each. Often used to design responses to possible setbacks — answers to "what if?" questions?



Arrow diagram. A simplified PERT chart, used for scheduling events and identifying bottlenecks ("critical paths"). Answers "when?" questions, e.g., "when do we have to do the things we have chosen to do?"



Matrix data analysis. Mathematical analysis of numerical data arranged as matrices, e.g., "where in the data do we find various patterns?" There are many methods, often called multivariate analysis, including cluster, multiple regressions, and principle component analysis.

Figure 4-15: The 7 Management and Planning Tools.

customer satisfaction even under adverse conditions".[121] This system of quality engineering is named after Dr. Genichi Taguchi. This is a system of quality engineering using robust design as described above .[122] Robust design is geared towards satisfying customers' need for a robust product. The four activities that make up this system of quality engineering are described in Prof. Don Clausing's book *Total Quality Development* , and are described as follows:

> 1. Product parameter design, the systematic optimization of the robustness of the product design.
>
> 2. Tolerance design, to select the economical precision levels around the nominal (target) design values.
>
> 3.Process parameter design, the systematic optimization of the most important. production processes so that they will inherently produce more consistent products.

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121 [8] p. 76

122 [8] p. 76

Customer Requirements: 1st level	2d level	3d level	Priority	Measure the bend radius of the inner edge	Measure length of inner edge body contact in four wear positions	Count the number of adjustable parameters	Measure the maximum belt length	Measure the maximum belt length	Measure height of upward step that can be made without impacting basket	Measure length of largest stride that can be made without impacting basket	Measure height of bottom above knee of wearer	Measure distance from stripping motion start point to outer edge	Measure distance from stripping motion start point to top	Measure width of basket relative to width of wearer	Measure distance from top of basket to shoulder
Quality Metrics: 1st level				Measure how well basket can be adjusted to fit the worker					Test if basket facilitates body motions during fishing						
Quality Metrics: 2d level				Measure how well basket fits against body		Measure how adjustable basket attachment is			Measure how the basket affects walking			Test if the basket accomodates stripping motion			
Basket prevents line problems	The line moves only when desired	Line placed in the basket stays there until cast	4												
Basket prevents line problems	The line moves only when desired	The line is stationary in the basket	6												
Basket prevents line problems	When required line comes out of the basket	Line is cast without drag	1												
Basket prevents line problems	When required line comes out of the basket	Basket naturally gathers folds line in the bottom	5												
Basket prevents line problems	When required line comes out of the basket	Line in the basket is tangle-free	3												
Basket prevents line problems	Accomodates casting, stripping movement	The basket does not hamper arm or leg	2						⊙	⊙	△	△	△	△	△
Basket prevents line problems	Accomodates casting, stripping movement	The basket is adjustable to body position	7	○	△	⊙	⊙	⊙							
Effectiveness				○	⊙	⊙	○	○	⊙	⊙	△	○	○	△	△
Feasibility				⊙	⊙	⊙	⊙	⊙	○	○	⊙	⊙	⊙	⊙	⊙
Measurement plan															
Technical Benchmarking Evaluation		Orvis													
Technical Benchmarking Evaluation		LL Bean													
Technical Benchmarking Evaluation		Surfcaster													
Technical Benchmarking Evaluation		Other													
		Target value													

⊙ = high ○ = medium △ = low (blank) = none

Figure 4-16: Stripping Basket Example of House of Quality Schematic.

4. On-line quality control, prudent intervention on the factory floor to further improve production consistency.[123]

Taguchi's system of quality engineering heavily relies on statistical methods for achieving a high level of process performance. In QFD the development processes can be divided into two types. There is the development that creates "incremental" developments based on already established technologies and then there are the "innovative" developments that creates new technologies for future use. The first may be described as efforts belonging to developmental research, where new products are developed from existing technology. The latter may be viewed as belonging to basic research, whichidentifies new frontiers and pushes the boundaries of existing technology to invent something new (figure 4-17). QFD describes technology development as a "technology stream" that feeds into an existing product development program. The advantages of a technology stream are: "to enable time for creativity, to provide a creative environment, to develop flexible(robust) technologies that can be used in several products"(figure 4-18).[124] QFD identifies the need for a separate organization dedicated to development of new technology, such as an academic institution, or a non-for-profit technology development research group. Having a separate organization for the development of technology avoids schedule uncertainties associated with "invention

[123] [8] p. 77

[124] [8] p. 319

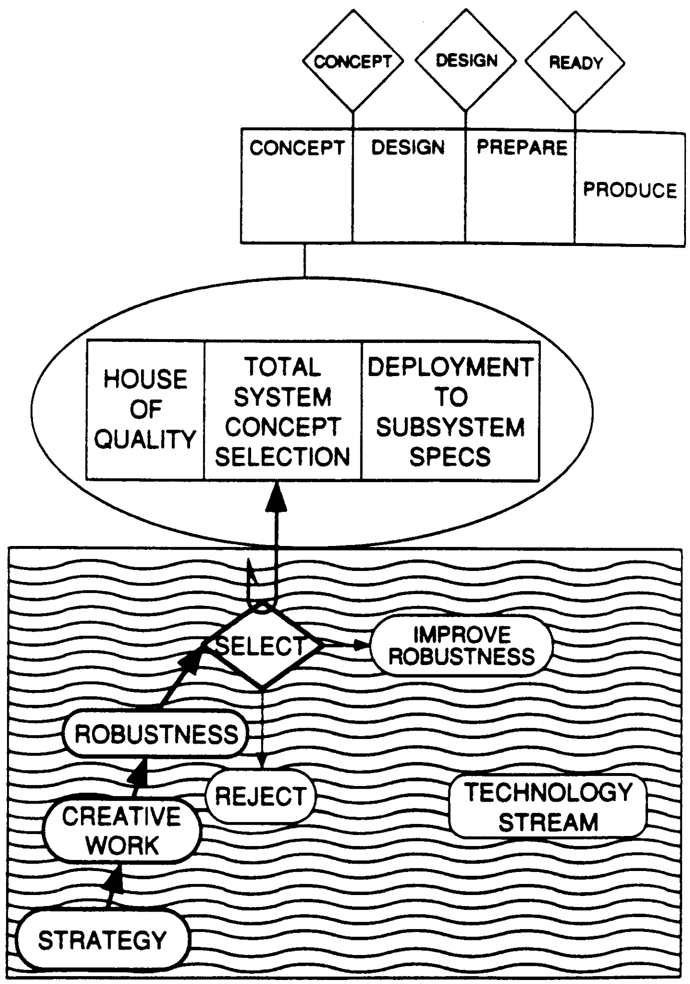

Figure 4-17: Diagram of Technology development.

uncertainty during the concept phase, and robustness uncertainty during the production preparation phase".[125] QFD identifies four steps in the technology development process: technology strategy, creative work, robustness development, and selection and transfer. The technology strategy guides development activities towards those technologies that are most needed.

Creative work has three components: definition of needs, invention and concept selection. The tools for creative work are the House of Quality and Pugh Concept Selection Matrix.

In creative work a wider range of customers are considered in order to develop flexible technologies that have a wide application for various product development programs. Robustness development is the early appraisal of a new technology for application to a specific development project. Early appraisal reduces the need for rework when the technology is applied to a product development program. In other words, robustness assures the maturity of a technology by testing its ability to meet performance specifications prior to use. The benefits of early assessment of whether a technology is robust or not are: enabling of quick time to market, flexibility, customer satisfaction, and low costs.[126] After a new technology is mature and superior to those which already exist it is eligible for transfer into a product development program.

[125][8] p. 318

[126][8] p. 329

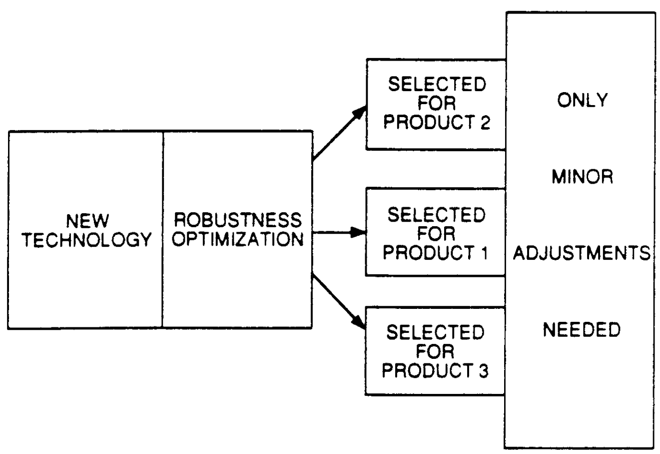

Figure 4-18: Flexible applications of robust technology.

TQM's concern is with the definition of quality as defined by the customer, and its development is a response to satisfying changes in customer requirements. As such, TQM offers a variety of tools for the transfer of customer needs to all aspects of the company process. The key concept in TQM is the systematic approach to problem solving, which is applied to all levels of production. TQM has many tools which are used for a variety of applications, such as corporate strategy, societal networking, and total participation of members within an organization in continuous improvement work. The author's selection was based on those that seem to be the most useful to the design professional. TQM, like partnering, does not emphasize the need for IT. Yet, as a process which requires the acquisition and dissemination of information in an organization, it does provide a social structure for the use of IT.

4.2 Recent Developments in Information Technology (IT)

Goody Clancy and Herzog Hart exhibited some current uses of IT in professional practice. Mainly, the use of computers for the transfer of data and sharing of information. The desire to facilitate the transfer of information has led to numerous developments in IT, which offer greater "connectivity" within and between organizations. "Connectivity" refers to the electronic links between organizations. The management concepts mentioned in the previous section address the need and uses of information in an organization. This section focuses on the computer based tools that facilitate the transfer of information. Briefly, developments in IT have focused in three key areas: database technology, data-transfer, and networks. Networking may be further divided into intra-organizational networks ,e.g., Local Area Networks(LAN), and inter-organizational networks,e.g., Wide

Area Networks(WAN). Currently, due to a rise in computer use by individuals, the most popular example of a WAN is the Internet. The Internet will be treated separately from the general discussion of WANs, as the Internet is a special case of a WAN.

4.2.1 Database Technology

In his book, *Introduction to Object-Oriented Databases* , Won Kim describes five generations of database systems development. They are first generation-file systems, second generation- hierarchical systems, third generation-CODASYL systems, fourth generation- relational databases, and fifth generation- extended relational databases and object oriented databases . The second and third generation database systems basically offer the same features and are treated together, and referred to as hierarchical databases. The following section briefly describes each generation of database systems. This in order to familiarize the reader with where developments in this technology have come from and are heading.

The first generation of databases were file systems. The primary use of a file system was the collection and storage of data. These "systems" came into wide usage in the late 1950's and early 1960's, as organizations increasingly began storing data in computers.[127] Typically, file systems were developed with specific applications in mind. That is, within an organization different business units would develop different "computer applications" specific to their departments. For example, in an organization the payroll department would have a system that was specific to its functions. Whereas the

[127] [16] p.8

accounting department in the same organization would have a filing system specific to a accounting functions.

The second and third generation of database systems introduced hierarchical database systems. These systems "realized the sharing of an integrated database among many users within an application environment".[128] These were developed in the late 1960s and early 1970s. The hierarchical database is controlled through the use of a software package called a database management system (DBMS). Data is stored in the database in a manner that allows other "application programs" to access the same data element from one source. Where the application programs operate from computers anywhere in an organization. It operates by having the application program function on top of the hierarchical database, and communicating with the DBMS to access information stored in the database. The hierarchical database offered organizations one central source for data entry and retrieval, reducing the redundancy associated with different departments collecting the same data, and improving data integrity since information is only entered into the system once. However, the weakness associated with hierarchical databases was lack of flexibility. In order to access information on these systems one had to go through layers of menus. That is, due to this system's hierarchical structure, navigating to access information is a tedious exercise, as there might be many layers on top of the information sought.

The fourth generation of databases were developed to address the method of querying the system for data. These systems are called relational databases, and were developed around the early 1980s. This database system uses software called "query optimizer" in order to

[128] [40], p.1

optimize the plan for executing any given query in the database. Previously, in the hierarchical database system a programmer would have to program a "navigational retrieval path" for accessing the database. The retrieval path is the plan the computer uses to navigate the system for queried information. However, in the "relational database" the navigation is automated through the use of the "query optimizer". The "optimizer" searches the database for the best way to access information requested by a user, by making use of appropriate access methods available in the system.[129] Relational database systems also use DBMS for instructions. Some examples of some commercially available relational DBMSs are Oracle Corporation's ORACLE for management of large databases on mainframe computers, and Borland International's Paradox for personal databases on microcomputers.[130] The weakness of this system is in its data model. The data model is the information type for which the database system is designed. For example, all the databases mentioned thus far, are a further development of file retrieval systems, which are based on applications such as accounts payable, accounts receivable, order processing, and inventory control.[131] These systems may be collectively called conventional database systems, and will be termed as such for the remainder of this thesis. The focus of these applications is in data entry. Typically, these applications are queried for information about the company. For these applications the proportion of use geared towards data entry is higher than that geared towards data reading.[132] These

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129 [40], p.2

130 [6] p. 8

131 [38] p.57

132 [38] p.57

types of applications are described as "data collection applications".[133] However, there are other types of applications that are used to examine the relationship between data and it's content. These applications require large volumes of data for which the relational database is not suitable. The type of applications in question are described as "information analysis applications".[134]

The fifth generation of database technology, developed in the mid to late 1980s, addresses the concerns raised in managing "information analysis applications". Examples of "information analysis applications" are feature-based CAD/CAM, production planning, network planning, financial engineering applications, multi-media, etc.[135] Two primary database systems have been developed for handling such applications: extended relational databases, and object-oriented databases. Proponents of extended relational databases offer this system as having the capability of handling all types of data. Yet, the extended relational database relies on the same data model as conventional database systems. For this reason it is argued that this system is still better suited to "data collection applications".[136] An example of an extended relational database technology is POSTGRES.

In the case of object-oriented databases the data model is different from those of traditional systems. The datamodel for an object-oriented database is an "object-oriented" data model. The phrase "object-oriented" comes from the concepts of object-oriented programming.

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133 [38] p.57

134 [38] p.57

135 [38] p.57

136 [38] p.57

Examples of object-oriented programming languages are C++, Smalltalk, Objective C, Eifel, and Common LISP Object Systems (CLOS). Briefly, the "object-oriented approach to programming is based on the concepts encapsulation and extensibility".[137] In object-oriented programming data is identified as "objects". "Objects" are encapsulated when they have attached to them information which describes their operation and behavior. The information which describes the operation on the object is known as the "data", and the information which describes the behavior of the object is known as the "code". For example, an object is defined as a shape, let us say a square. The data of the square describes it's dimensions, and the program describing it's behavior is called Display-shape, which tells the system to display the object on the computer screen. Extensibility is the ability to extend a system without introducing change to it.[138] The concept of extensibility uses the idea of behavioral extension and inheritance. In the example of the square above, a behavioral extension may be a program describing the rotation of the object. Let us say we want a specialized case, where a triangle has the same behavior as our square. Object-oriented programming allows us to create a special case of the triangle that has the behavioral properties of the square; this is called inheritance. This is useful in the operation of large systems made up of smaller modules, or objects. Object-oriented databases use data models that capture these object characteristics. In other words, "a data model is a logical organization of the real-world objects(entities), constraints on them, and relationships among objects... An object-oriented database is a collection of objects whose behavior and state, and relationships are defined in accordance with object oriented data

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137 [40] p.9

138 [40] p.9

model".[139] Apple Computers HYPERCARD, Macintosh and MacDraw are examples of object-oriented user interface applications.[140]

Both fifth generation database systems offer viable solutions to the handling of complex data types. Yet their suitability to a specific application type dictates their use. Originally, databases were developed for handling spreadsheet type data, where the primary operation was storage and retrieval. Currently, with the development of object-oriented databases new possibilities in the storage and retrieval of graphic data is on the horizon. Firms like Herzog -hart already use such systems for "what if" scenarios. Where different design schemes are accessed through the use of simulation applications. However, object-oriented databases can offer us new possibilities in regards to the creation of construction documents. Documents can now be multi-media presentations. Where text and animated graphics can be used to communicate the construction of a design. The possibilities are numerous, yet innovation should be based on an understanding of the capabilities of the technology.

4.2.2 Local Area Networks(LANs) and Wide Area Networks (WANs)

LANs

Computer hardware and software that are linked to each other and other peripheral devices ,e.g., modems, cellular telephones, fax machines, printers, etc., in order to exchange and share information make up a "network". Geographically close computers linked in this manner form a Local Area Network(LAN). An example of a LAN is

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139 [40] p.9

140 [40] p.8

MIT's Department of Architecture Computer Resource Lab(CRL). Also, most companies use a LAN to connect their computers. Recent developments in office computing have focused on the management of documents transmitted across "networks". The sharing of files over "networks" has raised the issue of how computer users may manage the flow of information to their PCs. The issue is, 80 percent of a corporations information is in document form stored on workers PC's, and not in the form of structured database records.[141] Typically, the information stored on PCs in an office are not easily retrieved, because of the hierarchical structure of the file systems on PCs. Also, the ad hoc nature of individuals different filing methods further exacerbates the ability to easily find information stored on a workers PC. The terminology for the recent developments in document management for the PC is the "new document-computing model".[142] The "new document-computing model" is an application of object-oriented concepts to PC file management. Where documents become objects that carry information about their origin, identity, and executable code, which contains instructions for the manipulation of the document. Searches on such a system can be made in a variety of ways. For example, development of new "query tools"(software dedicated to finding specified information by the user) can look up word associations. So that if a user types in the word tooth, citations would be found for molar,incisor,etc. An example of a company developing this technology is Xerox PARC (Palo Alto Research Center). Multi-media documents are the best example of documents that would require this approach to document management. In a multi-media document, textual data is incorporated with graphic data. A document

141 [39] p.91

142 [39] p.91

may be assembled by providing links to other sources,i.e., if a user clicks on a graphic on the document, the graphic may pop-up to show a video presentation. The idea being to provide users with greater flexibility in document creation. Other applications developers, such as Microsoft and Apple, have focused on developing better methods for the creation and retrieval of documents on the PC. These capabilities will be built directly into future versions of both companies' operating systems(OS). Most of these developments have been heralded by the use of graphical user interfaces(GUI) on PCs. An example of a GUI is Apples icon based desktop,and Microsoft's Windows.

WANs

"Networks" that link computers over geographically distant locations are Wide Area Networks (WAN). Networks can be classified by ownership as either public, private, or value- added.[143] When communication occurs between organizations this is known as electronic data interchange (EDI). Communication between organizations is facilitated through inter-organizational systems(IOS). A description of each type of "network" classification follows:

"Public networks are communication systems provided and regulated by companies that are licensed and regulated by state and federal governments to transport data and voice communication traffic belonging to others".[144] These companies are also known as common carriers. Examples of common carriers are American Telephone and Telegraph (AT&T), MCI, and Western Union. These companies provide "public lines" and "leased lines". "Public lines" are also

143 [16] p.7

144 [16]p.7

known as "dial-up lines", since users can access them by dialing a publicly available telephone number through the use of a modem.[145] "Public lines" are subject to a higher error rate in the transmission of data and handle low volumes of data transmission, than "leased lines". The appeal of "public lines" to home PC users is in the low cost to use them. Corporations typically use "leased lines", with dedicated communications lines that can transmit both data and voice information. "Leased lines" are also more secure than "public lines".

Private networks are developed and managed by a consortium of companies, i.e., Sears Corporation, IBM, DEC, and General Electric maintain a private network and sell excess "network" capacity to other companies.[146] Such large companies generate large volumes of data and voice transmissions, which justify the costs associated with having their own "networks". Also, sometimes security issues dictate the requirement for a private network. "In the 1980's very small aperture terminal satellites, called VSATS were introduced, which allowed small to medium sized companies to develop their own private WANs more cheaply than by leasing dedicated lines from the telephone company".[147] The additional advantage of these satellite systems is their ability to transmit the full spectrum of motion video and graphics at a reasonable cost to the use.[148] An example of a company using such a system is Frito-Lay, Inc. They use the system to support the transmission of detailed sales data from 10,000 route sales

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[145] [16]p.7

[146] [16]p.7

[147] [16]p.7

[148] [16]p.7

people to corporate headquarters, where the information is analyzed against competitors and market information. Correlated data is then sent back to salespeople in colored graphic form for their use.[149]

"Value-added networks(VANS) provide special communication and network management services over leased lines from common carriers. Tymnet and Telenet are examples of two companies that provide value-added network services. Companies rely on the services of value-added networks in order to avoid the management and maintenance of a long distance communication system, which can be complex and expensive to operate. The services provided by value-added network companies are:

1. Efficient data transmission with improved routing, error control, and efficiency.

2. Capability for interconnecting computers and terminals with dissimilar transmission protocols and speed.

3. Network management and maintenance services.[150]

Currently, standards are being developed for the exchange of data between organizations. The development of standards relate to current trends in electronic data interchange(EDI). EDI may also be defined as, " the use of computer and communications technology to support the information exchange needed to carry out day-to-day business activities".[151] The information exchange between companies is conducted through the use of "electronic documents". In essence

149 [16]p.7

150 [16]p.7

151 [37]p.1

"electronic documents" automate the traditional paper flows between companies, i.e., companies' reliance on postal agencies and courier companies for the transfer of invoices and purchase order forms, which can be substituted through the use of IT. However, electronic document transfer occurs within an organization, this was mentioned in our discussion of LANs. With companies having the capability of transferring documents internally, external transfer of documents would mean extending their information systems beyond the company boundaries. Linking their internal systems with the business and information systems of other organizations.[152] Three steps are required for companies to enter into an IT linkage that supports document transfer. They are,

> 1. Each organization must replace the manual interpretation of incoming documents with computer software.
>
> 2. The two organizations must replace the functions of the postal service with an agreement on a telecommunications link.
>
> 3. The two organizations must establish the terms and conditions governing electronically placed orders and agree on the operational details of an electronic link.[153]

After the agreement of the procedural details companies must focus on the management of organizational relationships that are mediated by electronic links.[154] However, over the past twenty years professional standards organizations working with common carriers, network

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[152] [37]p.2

[153] [37]p.3

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vendors, and companies purchasing network services have worked together to develop guidelines and standards to ensure interconnectivity of networks all over the world.[155] These standards are known as network protocols. The most recent protocol, called Integrated Service Digital Network(ISDN), specifies the standards for transmitting voice, data, graphics, and video over the same transmission channel.[156] Currently, ISDN is widely used over the Internet for the transfer of multi-media documents.

4.2.3 The Internet and the Web

The INTERNET is a computer networking experiment that was originally set up by the United States Government. In the mid to late 1960s the US Government recognized the potential in computer networks for supporting research and development (R&D) activities for academic and military purposes. The ARPANET was to be the precursor of the INTERNET. Funded by the US Advanced Research Projects Agency(ARPA), the ARPANET was established on January 2, 1969. One of the main development initiatives of the ARPANET project was the creation of a network that was not susceptible to failure if portions of it were physically damaged. This also tied in with efforts to produce a network that allowed nodes to be added and removed with minimal impact to overall service. As well as the need for the network to support all manufacturers computers. This led to the development of a standard network protocol to be used by all computer manufacturers. In other words, if a manufacturer wanted their computer to talk over the network, they had to subscribe to the use of ARPANET's network protocol.

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155 [37]p. 8

156 [16]p.6

The development of "packet switching" technology supported the then new protocol. "Packet switching" is a way for many different network segments to share a common transmission line. In packet switching networks data to be transmitted is broken up into sets of "packets" that contain source and destination information. These packets are routed by dedicated network components called "packet-switching nodes" to their destination. Upon arrival to it's destination a packet's source and destination information is removed, and the original data is reassembled into its original form. The advantages offered by packet switching are: many packets can flow through the same network and all arrive at their destination, and packets can circulate the network from one machine to another until they find their destination. The circulation of a packet through the network from machine to machine is called "routing".

In the 1970s ARPANET developed a new communications protocol to provide reliable and simple network communications. This new protocol is the Transmission Control Protocol/Internet Protocol(TCP/IP). Around the same time researchers at Xerox Palo Alto Research Center(PARC) were developing packet switching technology that may be used in coaxial cables. This is the sort of cable used to connect television sets to an aerial antenna, or VCR. Using the coaxial cable as a transmission cable Xerox PARC ultimately developed EtherNet local area networks, and in the mid 1980's Apple Computer's products, such as the Macintosh and its line of printers, were shipped to customers with EtherNet capabilities (Apple was the first PC maker to provide network capabilities in a commercially sold PC).

ARPA eventually became known as DARPA. DARPA encouraged the educational community to use it's networks. The University of

California at Berkeley, with the help of Cambridge based Bolt Baranek and Newman(BBN), developed a low cost implementation of TCP/IP.[157] Berkeley's efforts led to the support of TCP/IP by the Unix operating system, which was widely used in the academic community. Also, Berkley's version of UNIX provided additional improvements such as, File Transfer Protocol(ftp), remote login and file copy operations(rsh and rcp), intercomputer electronic mail(e-mail).

Between the early 1980's to the present the Internet went through a variety of administrative changes. Currently, it is under the administration of the National Science Foundation(NSF). President Bush's signing of the High Performance Computing Act into law, in 1991, led to the creation of the National Research and Education Network (NREN). The NREN, supported by researchers and a variety of organizations, is currently what is known as the INTERNET.

In 1990 researchers at the European Laboratory for Particle Physics(CERN is the French acronym) set up the "Web". The Web can be considered as one of the channels on the worldwide Internet. The worldwide Internet is the network linking all countries, who have networks already installed, together. The "Web" was originally intended for use by high-energy physicists who wanted to stay abreast of the progress of each others work.[158] Rather, the Web has become increasingly popular amongst personal computer users, businesses, governments, universities, and other organizations. For example, the number of Web servers- computers that handle requests for Web documents, rose from 130 in mid-1993 to an estimated figure of 10,000

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158 [41]p. 11

currently.[159] An account of the idea behind the creation of the Web follows;

> The idea was that one physics team might create a Web document, or "page", of text using an article or set of data, noting somewhere within the text the existence of, say, a corresponding graphic set up as a separate page in the system. After starting up a program to browse for Web pages, a user could find and read the text and then retrieve the graphic by clicking on the "link" to it (the link, in the form of a word, phrase, or icon, would be highlighted).[160]

In essence a Web page is a multi-media document. Navigation in the Web is supported by the use of browser programs. Browsers are designed to be intuitive to a computer user. That is, very little direction is required for their use. A browser program is really a graphical user interface (GUI). Examples of popular GUIs are Mosaic and Netscape.

The significance of the Web is in its rapid growth. The ease of use, facilitated by the browser programs, has made the Web very accessible to a wide variety of users. Unfortunately, the popularity of the Web has made it difficult for users to navigate it as freely as they wish. The equivalent of traffic jambs frequently occur on the Web. With the result that users frequently have difficulty in accessing information from a located site. Therefore, efforts are being made to better manage the flow of traffic on the Web. Such an effort is being organized at MIT's Laboratory for Computer Science(LCS). A group of software, electronics, and communications companies have formed the World Wide Web Consortium (W3C), which is headquartered at MIT's

[159] [41]p. 12

[160] [41]p. 11

LCS.[161] Some of the companies involved are IBM, Digital Equipment, Hewlett- Packard, MCI, Microsoft. Security and development of better protocol standards are also an issue to be addressed by W3C.

Currently, a wide host of activities occur on the Web. From the purchase of goods and services, to the exchange of film and video files by professional animators, and even dating services that introduce people through the use of their Web pages. Some architectural offices advertise on the Web, and link images of their firms work to their Web page. If the Web does not become a victim of its own popularity, and disappear in a few years, then this technology may replace current communications technology.

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[161][41]p. 13

Chapter 5

Conclusion- Opportunities For Design Innovation

5.1 A Brief Word on Reinvention

Current advances in computer technology coupled with process reinvention methods, offered through the use of current management concepts, open up new opportunities for rethinking the design process. Herzog-Hart(HH) Corporation exemplifies this idea in the manner in which they went about reinventing of their process. However, reinvention based on computer technology does not come easy. There are issues relating to the cost of new computer systems to be considered, as well as the manner in which new systems may be integrated with existing processes to allow workers time to acclimate to new systems. Fortunately, there is a great deal of documentation relating to the topic of reinvention of processes and the uses of new computer technology to accomplish change in an organization, this is especially the case in the business sector.

5.1.1 Systems Approach

This thesis offers a "systems approach" to design as the design methodology appropriate to current management and information systems. Prof. Dluhosch defines a "systems approach" as, " the utilization of management systems, or an orderly manner of management procedure, applied to an inter-disciplinary team in order to define, analyze, and realize the development of buildings and building projects".[162] The "systems approach" to design is not new and has been around since the 1960's. Advocates for this design approach include Ezra Ehrenkrantz, principle of Ehrenkrantz Eckstut Associates in New York, who uses this method in professional practice, and Christopher Alexander, a noted Professor of Architecture at the University of California, Berkley.

A "systems approach" to design is not the norm in professional architectural design practice, and has traditionally been viewed as a specialized method of design. The "systems approach" is typically viewed as being rigid and not flexible to creative manipulation on the part of the user, due to use of standard components, or a kit-of-parts. [163] However, it must be stated that a "systems approach" is not merely about the rejuggling and assembly of standard pieces, but about the process for assemblage.

Although, the author offers the "system approach" in this thesis, Prof. Bill Mitchell, Dean of the School of Architecture at MIT, offers the possibility of current technologies such as CAD/CAM in being able to

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[162] This definition is from an informal lecture note by Prof. Dluhosch. Inter-disciplinary team refers to multidisciplinary teams.

[163] A "systems approach" is very much what Herzog-Hart Corporation executed and is executing in their company, although they are not familiar with the concept.

offer additional component flexibility, through the ability to manufacture components as required for custom fitting.[164]

5.1.2 Obstacles to Change

The primary obstacles to design process innovation is the imagination. New and radical thinking of the uses and applications of computer technology is required for reinvention. One has to look beyond current applications of computer technology and look to rethink the way processes are organized and function, and innovatively apply computer technology to such processes.

Another, difficulty in reinventing a process is the current context for reinvention. For example, in the construction industry , the hardware or tools used for daily work are lacking in sophistication. That is, compared to current advances in computer technology, construction hardware is lagging well behind. By construction hardware we refer to the tools encountered in day-to-day construction. This is not to say that these tools inhibit reinvention, rather that current methods and practice are rooted in the tools we use. In other words, new methodologies would require new tools, in order to break any links associating a tool with a conventional practice.

5.2 Projecting our Understanding

The following short sketches are derived from the trends the author identifies as possible given current management concepts and computer technology, these are : new modes of operation, faster feedback facilitated by IT, and new ways of transferring data.

164 Computer Aided Design and Manufacturing(CAD/CAM).

5.2.1 Project Development

Based on the concepts of Partnering and TQD the future may hold the possibility of "design by committee". This is where design is developed by a multidisciplined team as described in the section on TQD. The possible argument for a multidisciplined design team is that in the schematic design phase all parties can contribute to the validity of a proposal, thereby avoiding the need to spend time on revisions during construction, due to poorly conceived construction details that cannot be built. However, an argument against this approach is that design by committee does not lead to distinctive or innovative designs. However, this argument can be countered by the fact that most building types are standardized by regulatory requirements. That is, an office building type is predefined by zoning and building code requirements. Therefore, time spent reinventing such a building type, or attempting through design to change the program of the office building, might not be time well spent. For example, in the Herzog-Hart's (HH) case, a chemical plant facility is well defined. Using information technology (IT) they store components of a chemical plant in their computer system, and reassemble pieces as required by each new project. With standard design types a design committee could reasonably assemble a project through the use of IT. In the "design by committee" method the architect's role will be to facilitate the design activities. In other words the architect will guide the group in producing design concepts.

While some designers might choose to participate in committee design, others may select producing innovative new concepts in design. Using IT, architects can specialize in developing building designs and new products. Not that this is not currently done.

However, using a system like Herzog- Hart's ProjectVisualizer a designer can produce computer 3-D model representations of unbuilt projects that have all the data required for construction. These 3-D models may be used to revise regulatory standards used above or for developing new ones. Or the 3-D models could be sold the same way kit-home plans are currently sold.

5.2.2 Immediate Feedback

Immediate feedback refers to the ability to use IT to link with other computer systems. In the HH case it was mentioned that clients are already tied into their computer system. Extending this idea of linkage it might be possible for firms in the future to be able to link into local building departments, or other agencies concerned with standards compliance. With such a link a building proposal could be sent to the building department for analysis, where they in turn run the project through a code compliance software. After which they send back the results of testing to the architect.

5.2.3 Changing the Drawing

In chapter 4 the "electronic document" was discussed. Something similar to the electronic document exists today. These are the Web pages on the Internet, which combine text, graphic, voice, and video information. With current innovations in document transfer over the Internet, especially on the Web, it is possible to think of a new construction document for the future. The construction document of the future would be a multimedia document with text,video, drawings, and voice. This document will be transferred over the Internet. Each party on the project would be able to access the information they require about the project. If the contractor needs drawings, he/she can download such information. If special instruction is required for a certain type of detail, the architect can include an instruction video as part of the document. The video clip can be later transferred to a video cassette. The possibilities continue, with the only limitation being the imagination.

Opportunities

The sketches in the last few paragraphs are meant to suggest the possibilities given the technologies we have today. The author does not suggest anyone of these scenarios will be the future of practice. Partnering may be here to stay, or may be gone tomorrow. However, it is the responsibility of the designer to be proactive about the direction in which the construction industry is going. If partnering is to be increasingly used then the designer should seek ways of using this trend to his/her advantage. Whether it is by developing new standards for building performance, or working to facilitate the transfer of design knowledge on a project.

It is also a fact that the Internet is growing and a lot of data is being transferred over the wire. For example, " there are 18,000 'host' computers around the globe serving up an estimated 3.5 million documents on the World Wide Web, according to Carnegie-Mellon's Center for Machine Translation. Roughly 6,000 more documents are being added daily".[165] In the past three years use of the Internet has grown geometrically. Currently, there are a variety of transactions occurring on the Web. There is the purchase of goods and services, exchange of e-mail, and the transfer of data. There is the possibility that future modes of electronic document transfer might be based on

[165] [42]p79

the Web page system. However, there is currently the opportunity for designers to seek out ways of employing this medium as a mode of transferring design knowledge.

In summary, the tools for reinventing architectural practice exist. Through a careful study of currently available technology and practice, new possibilities for practice can be found. The case of HH shows the results of reinvention of a process. The design professional can learn from the example of HH and search for other opportunities for reinvention.

5.3 Technology Elite

Most of the discussion in this thesis has centered on the U.S. construction industry. The US is considered a technologically advanced society. Most of the technological developments mentioned in this thesis are readily available in the US. This gives the US a sizable advantage in the use of new technology. Those countries who are able to share information with the US, in this case electronically, benefit from their relationship with the US. That is, those countries that have the facilities to tie into the US electronically have access to the developments in technology occurring here in the US. The authors concern is what happens to those countries that cannot be tied into the electronic network of the US. Marshall van Alstyne in his working paper Communication Network and the Rise of the Information Elite describes how an information elite arises in information networks.

Mr. Alstyne describes how each node in a network has but so many channels to communicate with.[166] Each node selects with whom it will exchange information. In Mr. Alstyne's model the basis for communication access is the ability to exchange information. In other words, a node-A will link one of its channels with a node-B, if node-B has access to information node-A wants. Node-A will continue to link up with other sources until all it's channels for communication are used up.

Using Mr.Alstyne's model it is safe to say that if a country has no information that is valuable to another , then communications links will not be set up. Also, a node may select how much information it decides to exchange. In other words a country like the US may do the same.

It is apparent that communications technology will have a great influence on the way we will live in the future. In fact, IT is currently changing the way we work. As design professionals it is not only important for us to develop new modes of practice for our profession. It is also important for us to identify those areas which might need to be remedied in our society. If communication is to become a commodity of exchange then we are faced with the responsibility of letting all have access to it. Although some may say that this has nothing to do with design and architecture. The author would argue that egalitarian motives were behind the early modernists efforts in producing a design method-Modernism, and that would ultimately lead to sociatal change. The designers of today have a similar

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[166] A node in a network is the point at which a computer or other communications device is connected.

make an impact on society by exploring the "new" in computer technology.

5.4 Conclusion

Architects have the opportunity to explore new possibilities in design, in a manner similar to architect's in the modern movement. That is, a search for a design method that is in "sync" with society is currently required. The means for developing this methodology is possibly through the creative application of computer technology in order to generate systems for design.

Unfortunately, the current use of the computer in architectural practice is as a glamorous presentation tool, without any further substance to the images viewed on the computer terminal display, such as having pictures linked with data. Current methods of computer application in architectural practice may be viewed as conventional, and do not take advantage of the broader capabilities of the computer. Architects, as part of their overall strategy to regain a position of prominence on the construction team, should be at the forefront of computer technology use, as it will increasingly, and already is, impact on the way we practice. This is not to say that one should irresponsibly buy into all new computer technology, but rather a designer should explore the new frontier of possibilities that are now available through IT today.

Appendix A

Risks and Responsibilities in Alternative Project-Delivery Methods

Design-bid-build

• *Predesign:* Architect typically offers predesign services such as programming and site selection.

• *Design:* Architect and consultants provide full design services including construction-cost estimates and schedules. Architect is liable for design efficacy and code compliance.

• *Bid/construction:* Contractor is responsible for construction cost, quality, and schedule. Architect, in consulting role, interprets documents and accepts or rejects construction as complying or not complying with documents.

CM-constructor

• *Predesign:* May be handled by the architect or the CM or both. Sometimes architects are hired by or through the CM.

• *Design:* The CM may assume all or part of the scheduling and cost-estimating tasks. CM advises on constructibility and cost of design elements. If a GMP is set, architect typically must design to meet CM's cost estimates. Architect remains responsible for design efficacy. If fast-tracked, the CM assists in dividing the documents into separately bidable packages.

• *Construction:* CM acts as general contractor. Subcontracts may be negotiated or bid. Architect offers typical observation and interpretive services.

CM-advisor

• *Predesign:* CM may offer many of the predesign services typically supplied by the architect.

• *Design:* The CM may assume all or part of the scheduling and cost-estimating tasks. CM advises on constructibility and cost of design elements. CM can't set a GMP because it is not contractually able to enforce. Architect remains responsible for design efficacy.

• *Bid/construction:* Projects can be fast-tracked, but owner is responsible for coordination of separate construction contracts. CM may offer GC-type services, but as a consultant to the owner. More typically, owner will hire a separate GC. CMs may assume some of architect's typical observation and payment-evaluation duties.

Design/build

• *Predesign:* The design/build entity may put together a variety of experts to address predesign needs.

• *Design:* The architect is hired by the design/build entity, which typically interprets owners needs for designers. In-house "build" experts typically take on schedule, cost, constructibility, and quality-assurance tasks. Design/build entity assumes liability for design efficacy.

• *Construction:* Architects may interpret documents, but most other tasks assumed by design/build entity. Projects are typically fast-tracked.

Bridging

• *Predesign:* May be done by owner's architect, a separate entity, or a program manager.

• *Design/bid:* Owner's architect prepares a detailed scope of work and design. Design/builder completes documents, negotiates price, and builds. Owner's architect is responsible for documents it prepares, but design/builder is responsible for technical efficacy as well as price and schedule.

• *Construction:* Owner's architect acts as agent, interpreting documents. *J. S. R.*

Appendix B

Herzog-Hart Method ™

- Break projects down into manageable "chunks" that are easily understood.
- Collect upstream input during creation from downstream users of information.
- Package information in ways most meaningful to the users.
- Provide direct access to project information; eliminate 'middlemen'; reduce 'transaction costs'.
- Create an environment that encourages, empowers, enables, and enlivens the project community.
- Train and simulate beforehand whenever possible.
- Rely on those closest to the work to do the right thing.
- " The work of a project then becomes the PROGRESSIVE INFORMATIONALIZATION of COMMUNICATION about each object to allow its SELECTIVE COMPLETION and enactment in both the virtual and physical worlds.

Appendix C

Partnership Forms

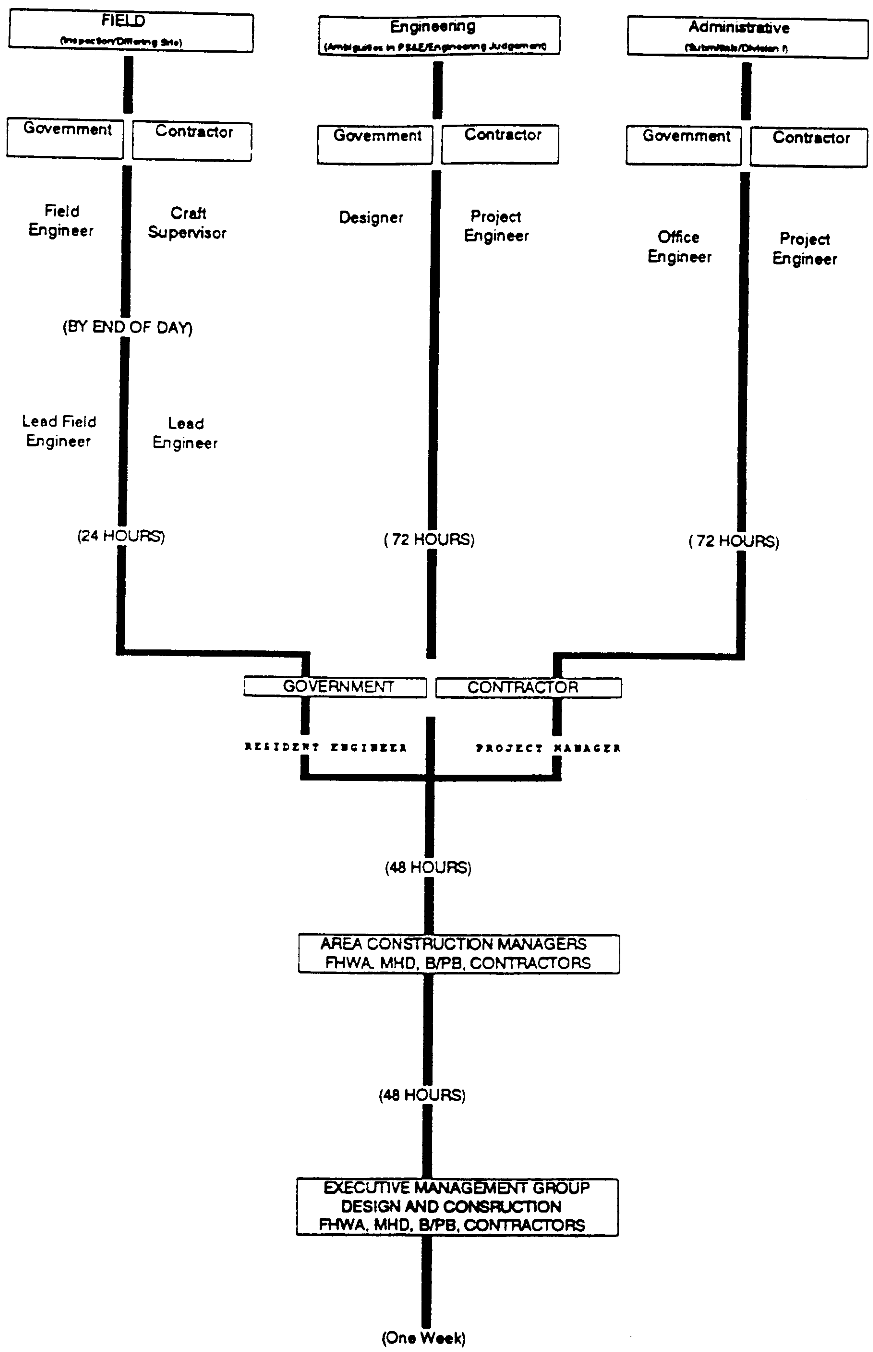
Partnering

The Department and the Management Consultant intend to encourage the foundation of a cohesive partnership with the Contractor and its subcontractors. This partnership will be structured to draw on the strengths of each organization to identify and achieve reciprocal goals. The objectives include; effective and efficient Contract performance; and completion within budget, on schedule, and in accordance with the plans and specifications.

This Partnership will be bilateral in makeup, and participation will be totally voluntary. Any cost associated with effectuating this partnership will be agreed to by both parties and will be shared equally with no change in Contract price. To implement this partnership initiative, it is anticipated that the Contractor's proposed on-site representative and the Department's Authorized Representative will attend a partnership development seminar at the earliest opportunity immediately after award. This will be followed by a team-building workshop to be attended by the Contractor's key on-site staff and Department personnel. Follow-up workshops will be held periodically throughout the duration of the Contract as agreed to by the Contractor and the Department's Authorized Representative.

An integral aspect of partnering is the issue resolution of issues in a timely, professional and non-adversarial manner. Alternative dispute resolution methodologies will be encouraged in preference to the more formal mechanism of Subsection 7.16 Disputes. These alternatives will assist in promoting and maintaining an amicable working relationship to preserve the partnership. Alternative dispute resolution in this context is intended to be a voluntary, non-binding procedure available for use by the parties to this Contract to resolve any issues that may arise during performance.

Sample Issue Resolution Model



Sample Partnering Agreement

VENT BUILDING NO. 6
C04A3

PARTNERING AGREEMENT

We the undersigned agree that our task is to construct a Quality Building we can all be Proud of on Time and on Budget.

We will do this by:

- Understanding the "Other Person's" Issues
- Making Everyone's Effort Satisfying
- Communicating Honestly
- Having no Injuries
- Exploring All Options to Reduce Cost
- Developing Mutual Trust and Respect
- Solving Problems at Field Level
- Meeting or Exceeding the Spirit of Project Affirmative Action Goals
- Having No Law Suits

Sample Action Plan

ACTION PLAN

Team 3

Brian Williams, KPAC
Mike Huie, KPAC
Steve Covert, KPAC
Greg Doyle, FHWA
Fred Read, B/PB
Jeanne Packard, B/PB
Steve Demos, MHD

New Project Milestones

GROUP III - MILESTONES AND CHANGES

Focus - Oper Date Oct 1995

1. Cofferdam - KPAC will prepare a plan to get the cofferdam work going by the <u>end of next week.</u> -where-why-how

2. Milestones -

A. B/PB will give dates showing when follow-on contractors must have a place to work. - <u>next week.</u>

B. KPAC will analyze dates and present options on how to meet those dates. <u>respond with conceptual options in two weeks.</u>

C. Working group will review options and determine the options to follow. <u>Working group meets concurrent with (B).</u>

D. Working group will try to identify areas where follow-on contractors may be able to start early.

3. Joint effort to provide timely funding for changes.

4. Standardize rates and review change/negotiation process.

The Who: Mike Huie/Kieth Sibley will select six to eight people.
Fred Read/Brian Williams will get involved to get the right people from up above involved.

. . Sample Problem Solving Format

PARTNERSHIP
PROBLEM SOLVING WORKSHOP ISSUE:

STATEMENT OF ISSUE/PROBLEM:

ISSUE/PROBLEM/OPPORTUNITY TO BE RESOLVED

CONTRACTOR'S VIEWPOINT (TO BE COMPLETED BY PROJECT AUTH REP) (AR)	B/PB VIEWPOINT (TO BE COMPLETED BY CONTRACTOR'S AUTHORIZED REP)
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

CONTRACTOR'S A.R. GOAL(S)/OBJ(S) FOR THIS ISSUE:	PROJECT'S A.R. GOAL(S)/OBJECTIVE(S) FOR THIS ISSUE:
1.	1.
2	2.
3.	3.
4.	4.

REFERENCE MATERIAL:	REFERENCE MATERIAL:
1. ____	1. ____
2 ____	2. ____
3. ____	3. ____
4. ____	4. ____

CONTRACTOR'S A.R. INIT. DATE:	PROJECT'S A.R. INIT. DATE:

Sample Partnering Evaluation

CO4A2
Partnership Evaluation

October 26, 1993

Item No.	Item	Weight	Rating	Score	Comments	N/A
I.	Resolution Time Lines	4				
II.	Issues To EMG	6				
III.	Unresolved Claims	7				
IV.	Safety	6				
V.	VE Savings/Program	4				
VI.	AA/EEO Goals	3				
VII.	Schedule	7				
VIII.	Communication on Changes	8				
IX.	Resolution of Changes	6				
X.	Nurturing Partnering	5				
Total Score						

SDC____ FHWA____ MHD____

SUB____ B/PB____ KPAC____

Score:

1. Unsatisfactory, immediate improvement is necessary
2. Satisfactory but needs lots of improvement
3. Satisfactory but we can do better
4. Satisfactory
5. Excellent

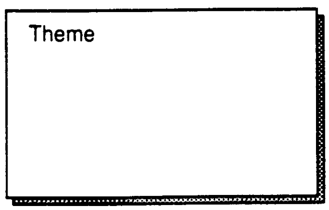
Additional Comments: ____________

E-1

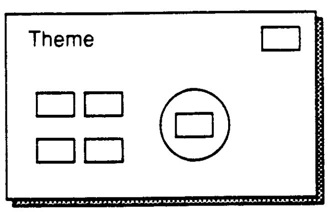
Appendix D

KJ Method

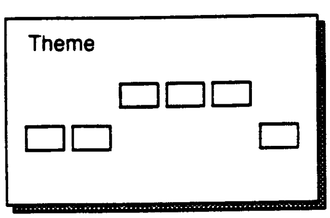
The steps of the KJ method are described below as adapted for use in the field of quality improvement.



1. ***Agree on a topic.*** Begin with careful consideration and team agreement on the appropriate topic to be considered. For a 7-step reactive improvement activity, the "theme" is much more sharply focused and usually calls for numeric data, for example, "Reduce the percentage of line items delivered after promise date by 30 percent in four months." The "theme" to formulate a problem using the KJ method is fairly broad and calls for subjective language (rather than numerical) data, for example, "What do our customers dislike about our service?" In many other types of discussions or arguments, an entire meeting may be held without precise agreement on the topic being discussed.



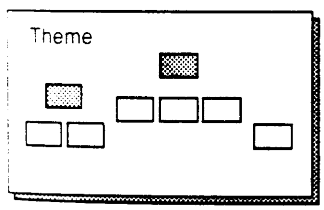
2. ***Write and understand the data.*** Next, each member of the team writes down several facts they know about the theme (you can use ideas also). Each fact is written on a separate label. Writing the facts makes them explicit so they can be examined by all team members. Then, one by one, each fact or idea on its label is clarified (in writing), using the rules of semantics (discussed shortly), until all members of the team understand what is meant by each item written by the team members.



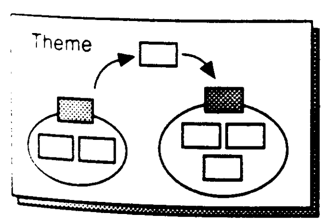
3. ***Group similar data.*** The team then works together to group facts that intuition says are similar to each other. Writing high-quality facts is difficult, although people new to this tool often don't recognize the difficulty. Grouping facts is also difficult, since people new to the tool find it easier to group by logical classification.

Such people ask, "Should grouping be done individually or collectively? What if people get in a loop, making and breaking the same groups?" The question is indicative of a two-valued mentality that needs to change to multi-valued thinking. The answer to the question is that each label has different distances from the others in the group of labels. Speaking is logical. Skilled users of the tool try to create an image in their heads. Intuition is image; they look at alternative grouping by physically moving the labels back and forth.

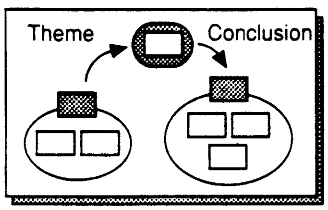
There is surprisingly little need for oral discussion, which in any case would be logical rather than intuitive. Shoji Shiba says, "Verbal statements such as 'I don't like this label to be part of this group' are counterproductive debate. Don't think with the brain — think with the hand. Listen to the facts — this is the voice of the customer. There is no methodology for hearing the facts. Skill must be gained through practice and experience." There is no right answer; there are just better ways. Consider how videos would show something — they would explain work by showing an image of a person sweeping a floor, a person standing at an assembly line, or a person sitting at a desk.



4. Title groups. The groups of similar facts are then given titles that express the same meaning or image of the group of facts, but at the next higher level of abstraction. Again the principles of semantics are used to refine titles. Grouping and titling continues until a hierarchy of no more than five groups exists.



5. Lay out groups and show relationship among groups. The group hierarchies are then laid out on the page to show clearly the internal structure of the groups and the relationship among the groups.



6. Vote on the most important low-level issues and draw conclusions. Once the team has reached a common understanding of the individual facts, their grouping and hierarchy, and the relationship among the groups, the team votes on the most important low-level facts (one must think of action in specific, not abstract, terms). From the important low-level facts a conclusion is drawn. Finally, the team decides what next steps are appropriate, given the outcome of the KJ.

Appendix E

Glossary of Computer Terms

Glossary of Terms

Alphanumeric Refers to both alphabetic characters (letters) and numbers. Often, the term also includes special characters (such as the @ or # signs).

Analog Information represented by an output signal that varies continually according to input. See *digital*.

Application software Software layer closest to the user, composed of one or more computer programs written in an appropriate programming language.

Arithmetic and Logic Unit (ALIA) Major component of the Central Processing Unit (CPU), used for calculations and comparisons while programs are running.

Assembly language Program language consisting of special combinations of digits and characters to express instructions to the computer. A very efficient language for the computer, assembly code does not have to be translated as much as "higher level" languages like FORTRAN and COBOL (see). An example of an assembly code instruction is STOW 2048 in register A. This instruction would store the contents of memory location 2048 in register A.

Bandwidth Range of frequencies carried over a transmission medium, measured in cycles/second or hertz (Hz).

Baseband Signal transmitted over entire bandwidth of medium (only one signal can be transmitted at a time).

BASIC Simple programming language often used by beginners. BASIC employs English phrases and sentences to express computer instruction. For example, the instruction, A = "HELLO"; PRINT A, would print the word, HELLO.

Binary numeric form A form of storing computer instructions and data in a series of 0 and 1 digits. For example, the letter Y might be expressed as 0101 1001.

Bits per second (bps) Units used to describe transmission speed. Large rates may be specified in Kbps (kilobits per second = 1,000 bps), Mbps (megabits per second = million bps), Gbps (gigabits per second = billion bps).

Bridge Connection between two similar types of networks, such as two Token-Ring networks from IBM.

Broadband Multiple signals transmitted over a medium (where medium is divided into subchannels).

Burst A set of characters grouped for data transmission.

Bursty Refers to activity that comes in bursts (as in transmission traffic associated with electronic mail) rather than in a steady stream.

Bus topology LAN architecture where all nodes are linearly attached to a "backbone" circuit.

Byte Amount of memory space needed to store eight binary digits (0 and 1 digits). These binary digits can be used to represent one character. For example, the letter Y might be expressed as 0101 1001. The size of a computer's memory is often measured in Kilobytes (KB or K), where one Kilobyte is equal to 1,024 bytes. Other terms include Megabyte (MB)—approximately one million bytes—and Gigabyte (GB)—approximately one billion bytes.

Card reader Input device that reads punched cards into the computer.

Cathode ray tube (CRT) Video display technology used in monochrome and color displays.

CD-ROM Secondary storage device based on optical disk technology (see Optical disks). CD-ROM stands for Compact Disk Read Only Medium. A single CD-ROM can hold about 550 million bytes of data—the equivalent of over 1,500 standard double-density, double-sided diskettes.

Central Processing Unit (CPU) Heart of a computer system; contains electronic circuits that manage and control all other hardware components and carry out detailed sequences of instructions.

Character printer Printer that prints one character at a time; frequently slower and cheaper than other types of printers.

Circuit switch Specialized computer that establishes a continuous dedicated path, in a network.

Circuit Switching Telecommunications transmission technique in which individual circuits are interconnected through successive exchanges to establish a continuous end-to-end transmission in each direction. See *packet switching*.

Coaxial cable (coax) Shielded copper wire used in LANs.

COBOL Programming language often used in business applications; uses rigid data descriptors and is often called "self-documenting." By a wide margin, the most often-used language for traditional, large, business software applications such as payroll and accounting programs. A COBOL instruction might look like SORT PERS REC BY ID NO BY SOC SEC NO BY SALARY which would sort the personnel record by three fields: (1) employee ID#, (2) employee social security #, and (3) salary.

Common Carriers U.S. and Canadian legal term for telephone companies; these provide public data transmission services through end-to-end connection across a telecommunications network.

Computer output to microfilm (com) Output device that allows direct transfer of computer information to microfilm or microfiche.

Computer-generated voice Output device that synthesizes the human voice.

Connectivity Refers to the need to interconnect computer systems of varying sizes and designs in order to provide access to and integration of corporate databases. Also, the degree to which equipment may be connected for the purpose of communications or file transfer. Computers exhibiting connectivity are compatible on the data-transfer level: they can pass data back and forth electronically.

Continuous Stream Refers to telecommunications techniques that transmit data in an unbroken analog or digital stream. See *packets*.

Cooperative processing Refers to link between microcomputers, minicomputers, and mainframes. The goal is "transparency" for the user, who does not need to worry about where the data are stored or where the calculations are performed. See *transparency*.

Corporate Data Warehouses Generic label referring to large databases built to centralize corporate data so that managers can extract and present subsets of information in a manner relevant to a particular task.

CSMA/CD (Carrier Sense Multiple Access with Collision Detection) Protocol for LAN specifying method for handling network traffic.

Data Integration Efforts to ensure that data generated in one part of an organization is available to and can be accessed through electronic systems used by other parts of the organization. See *connectivity*.

Databases Collections of data arranged according to a predetermined structure; in computer science, collections of data stored electronically, accessible to a computer, and structured according to rules maintained by a *database management system (DBMS)*. In corporate information systems, databases maintain and organize data that can be accessed by multiple software applications, in contrast to having each application maintain its own, customized collection of data.

Database management systems (DBMS) Software products that provide functions for orderly storage and retrieval of data (DBASE III is an example). The three database models are network, hierarchical, and relational. The trend is toward relational models.

Decision support systems Software application combining data processing with quantitative modeling and a user-friendly interface to support decision making.

Desktop Icons Symbols used to represent application programs or system commands on computer systems which use a *graphical user interface* (see). System users run complex commands by selecting the icon with a pointing device such as a *mouse* (see).

Dial-up Lines Telecommunications lines along which terminals, workstations, or other computers have access to a computer system through the use of *modems* (see).

Digital Representation of information by combinations of discrete binary units (e.g. 0s and 1s), as contrasted to representation by a continuously changing function or signal (e.g., a continuously varying voltage waveform) referred to as *analog* (see).

Digital signal Discrete signal consisting of electrical pulses like those produced by terminals, computers, and other types of data processing equipment.

Digital signals The 0 and 1 electrical currents (see *binary numeric form*) used in the computer to carry out instructions.

Digitize To convert a continuous variable or analog signal into digital form. This is often accomplished by sampling the input many times a second and assigning each sample a digital value. The result converts an analog value into a stream of numbers (which can be represented digitally in the 0s and 1s of base 2).

Digitizer Input device (also called a graphics tablet) that consists of a flat surface. A user draws on the surface with a special stylus and the tablet senses the location of the stylus.

Disk Operating System (DOS) System software that manages the physical components of the hardware and the conversion of program instructions into processing language for a microcomputer. Called a "disk" operating system because it is physically maintained on a disk device, it can be contrasted to early microcomputer tape operating systems (TOS) that were maintained on magnetic cassette tapes. Two popular disk operating systems use MS-DOS, developed and sold by Microsoft, and PC-DOS, developed and sold by IBM.

Disk packs Secondary storage devices used on mainframe and minicomputers. A series of hard disks is rotated around a drum, and read/write heads are quickly positioned over the appropriate "tracks."

Distributed Computer Processing Processing data at different physical locations in a system that shares computing tasks among several interconnected but geographically separate computers (i.e., "distributed"). Processing usually involves microcomputers or minicomputers. Systems are categorized by their management system (centralized or decentralized) and by hardware/software (geographically centralized or distributed).

Electronic data interchange Network application that directly links different organizations for communications and information exchange.

Error Transmission errors occur when the received data stream differs from the transmitted data stream. Sources of errors include background noise, distortion, crosstalk, echoes, and fading.

Ethernet Local area network product designed by Xerox Corp. and adopted by many hardware vendors (such as DEC); employs bus topology, CSMA/CD protocol, coaxial cable, and has transmission speeds up to 10 Mbps.

Evolution In computer systems design, a system that develops slowing, using existing features and programming code to make small incremental changes in system characteristics. A computer system that is modified by building on itself. See *revolution*.

Expert systems Computer programs that use stored information (such as pre-specified judgmental rules expressed in if-then format) to draw conclusions about a particular case. Expert systems differ from *databases* that merely call up stored information and present it to the user unchanged. Databases retain data and information about the structure of information needed by the *database management system*. Expert systems include a "rule" base in addition to a "data" base. The system uses the rule base to draw inferences about patterns in data it subsequently encounters. Expert systems have been used to troubleshoot defects in machines, analyze oil well samples, and diagnose diseases.

Facts The database and rule base of an *expert system* are sometimes referred to in combination as a *knowledge base*. Facts are included in the rule base as "if-then" rules: e.g., if your car has run out of gas, then it won't start. See *heuristics*.

Fiber optics Thin glass thread that carries light signal, rather than electrical signal, used in LANs.

Fiber optic cable Cables used for data transmission using laser-generated pulses of light. Fiber optic cables offer a transmission medium of enormously greater capacity than traditional copper cable at two orders of magnitude smaller size in a format impervious to electrical interference and requiring less amplification over distance.

File management The process of assigning and recognizing labels associated with data files, facilitating access to data stored in those files. In corporate information systems, the practice by which each corporate software application maintained its own files of data, customized for that applications use. This practice gave rise to problems of redundancy and data definition which were later treated by the advent of *databases* and *database management systems* (see).

Floppy disks Secondary storage devices used by most personal computers. Most floppy disks are 5¼ inch or 3½ inch.

FORTRAN Programming language often used in scientific applications. Its name is short for "formula translation." A FORTRAN instruction might look like AREA=3.14159 * (RADIUS **2) which would calculate the area of a circle given the value of its radius.

Front-end processor Specialized computer that, when attached to a mainframe central processing unit (CPU), handles communications, and administrative tasks for CPU.

Gateway Connection between two different types of networks, such as between an Ethernet installation and the Dow Jones News Service.

Geosynchronous rotation The orbit of a communications satellite where the satellite remains stationary with respect to its ground station.

Graphical user interfaces Computer interface that uses *desktop icons* (see) for communicating between the computer user and the computer control program. A computer using a text- or character-based interface processes commands that are typed as collections of words on a "command line" following a "system prompt." For example, a user wishing to see a list of files on the screen of an MS-DOS computer can type the command word DIR after the system prompt (e.g., C>). The computer would then display a directory, or list, of the files on disk drive C. A graphical user interface, or GUI, uses pictorial symbols and a pointing device to process commands. Using a GUI-based machine (such as the Apple Macintosh or a machine running Microsoft Windows), a user would use a *mouse* (see) to select a picture of a disk drive on the computer's display screen, and the system would show the list of files on that drive.

Graphics tablet See *digitizer*.

Hard disks Secondary storage devices used with some microcomputers. Storage is on a rigid plate of aluminum.

Hardware Physical component of a system, including terminals, printers, disk drives, network transmission media, and the permanent instructions that control their inner workings and interplay. (Note: the permanent instructions are frequently referred to as Firmware.)

Hertz (Hz) Measure of the frequency of a communication channel in cycles per second.

Heuristics "Rules of good judgment" arising from trial-and-error experience. Heuristic rules are part of an *expert system's* rule base in addition to more precise "if-then" rules known as *facts*. For example, if your car won't start, a heuristic rule might be: maybe it's a good idea to check to see if the gas tank is full.

Hierarchical In early *database management systems*, refers to structures that organized data hierarchically. This arrangement made a database very efficient for answering questions for which it was originally designed to answer, but extremely inflexible for answering questions not anticipated by data base designers. See *relational database management systems*.

Hypertext Approach in computer-assisted text retrieval that allows a reader to skip immediately to cross-referenced material by selecting linked text; users can thus navigate text-based material unencumbered by the traditional linear arrangement of text on the printed page. The links between individual data elements for a network structure that is even more flexible than the table structures in *relational database management systems* (see).

Impact method Printing method in which characters are created by a device actually touching (impacting) the paper. Daisy wheel and dot matrix printers are examples.

Infrastructure Refers to the characteristics and components of an information system's "architecture," including the types of *hardware* and *software* employed, and the types of communications arrangements involved. In corporate information systems, infrastructure refers to the integrated configuration of computer systems used to support an organization.

Input/Output (I/O) devices Devices that transfer data into and out of the computer.

Input/output control unit Responsible for the orderly management of data flow into and out of the computer.

Integrated Services Digital Network (ISDN) Digital transmission network that integrates voice, data, and other services over a common transmission medium. The aim is to allow any communications device—telephone, facsimile, video or computer—access to the network through a standard wall socket and to transmit digital information to other devices similarly connected.

Instructions Orders given to a computer by a software program application.

Intel 8086, 80286, 80386 microprocessor chips Produced by the Intel Corporation, these chips are the heart of many microcomputers on the market today. The 80386 is the newest and fastest chip, and it is instrumental in IBM's new Personal System/2 architecture. See *microprocessor chip*.

Interorganizational system Computer systems that, by providing computer *hardware* and *software* for building communications pathways for business transactions and information, provide a channel and linkage between separate companies that had not existed beforehand.

Joystick Input device that allows data and/or commands to be entered without typing used most often for computer games. Technologically compatible with a mouse (see *mouse*), it consists of a vertical lever which can be moved in a circular direction and a set of push buttons.

Key-to-disk Input mechanism for placing data directly onto a disk pack.

Key-to-tape Input mechanism for placing data directly onto a magnetic tape.

Knowledge base management systems Specialized *database* designed to manage both data items measuring events (e.g., *facts*) and data items used for reasoning or inference (e.g., "facts about facts"—rules and *heuristics*).

Knowledge engineering Formal process of interviewing experts and designing *knowledge bases* associated with designing and constructing *expert systems* (see).

Knowledge base The collection of data (facts), rules, and heuristics used as the basis for information retrieval and inference generation in an *expert system* (see).

Leased lines (private lines) Dedicated line provided by a common carrier on a leased basis.

Light pen Input device allowing user to draw directly on a computer screen; a light-sensitive rod shows position with respect to the screen, and the input is converted to (0,1) binary data.

Line printer Moderately fast printer that prints one line at a time.

Liquid crystal display (LCD) Output technology that requires very little energy; often used in laptop computers.

Local area network (LAN) Network connecting devices in same department, building, or surrounding buildings.

Machine language Detailed sequences of instructions in a computer, normally in binary (0,1) form. The sequence 1000000000000000000001000 might mean "load the value of memory location 2048 into register A."

Magnetic storage Secondary storage concept based on a form of magnetic recording technology, similar to the technology used for recording on a cassette tape or video tape. Included are floppy and hard disks as well as magnetic tapes. Compare with *optical storage*, which is used in newer CD-ROM technology. (See *CD-ROM*.)

Magnetic tapes Secondary storage devices used on mainframe and minicomputers. Much as with audio technology, data are recorded and retrieved from moving tapes.

Main control unit Major component of the Central Processing Unit (CPU); supervises the programs and operations of the computer.

Main memory Computer's memory that is always immediately available; contains both Random Access Memory (RAM) and Read Only Memory (ROM).

Mainframes Large computers often used by large business units or companies for centralized information processing.

Management support systems Class of information systems dedicated to providing information support for managers. MSS typically comprise a collection of subsystems that support information collection, measurement, analysis, and communication. MSS applications are often built around a central database fed by a *corporate data warehouse* (see).

Manufacturing Automation Protocol (MAP) Protocol developed by General Motors to standardize manufacturing floor communications between different vendor equipment.

Memory Computer's data storage containing numbers or text. Memory is often described as a file cabinet with drawers; the data reside in files within the drawers of the file cabinet.

Microcomputers The smallest computer systems, usually controlled by individuals and small functional units. Personal computers are the most commonly used microcomputers.

Microprocessor chip A single integrated circuit in a very small package. These chips contain the CPU for a microcomputer (see *Central Processing Unit*).

Microwave Any electromagnetic wave in the radio frequency spectrum above 890 megahertz. In telecommunications, a transmission technique using microwaves to carry voice and data traffic between transmitters and receivers placed atop towers or buildings.

Minicomputers Medium-sized computers, usually servicing more than one user and controlled by a large functional area or a small, data-intensive group.

Modem Communications device for connecting computers to telephone lines; the name is a contraction of "modulate-demodulate." The unit at the transmission end of the telephone line modulates the digital data stream from the computer into an analog signal (normally consisting of a changing frequency wave audible to humans as a series of very fast-paced beeps). The unit at the receiving end of the line demodulates the analog signal into a digital signal (e.g., a series of 0s and 1s) for the use of the receiving computer.

Monochrome display Video display unit with one color output.

Mouse Input device that allows data and/or commands to be entered without typing. Consists of a small plastic box with roller balls or a light source. Converts directional movements to electrical signals when rolled on a flat surface.

Multitasking Refers to a single processing unit of a computer being shared by many programs. Multitasking computers can have more than one task or "job" being run at a given time; the operating system manages the sharing of the computer's resources between the tasks. This sharing makes for a more expedient use of the resources, but it also requires some overhead.

Multiplexers Hardware device used to place signals into subchannels in broadband systems.

Network System of hardware and software that allows multiple devices or users to share data and programs, which are transmitted over a variety of media.

Network protocols Standards associated with successfully implementing computer-assisted communications across a telecommunications network. Individual protocols cover the representation of data, physical system connections to a network, circuit switching characteristics, packet construction, packet switching characteristics, and other topics.

Node Device connected to a network, such as a PC, modem, terminal, or computer.

Nonimpact method A printing method in which characters are created by a device that does not actually touch ("impact") the paper. Laser printers, thermal printers, and ink-jet printers (which spray the ink on the paper) are examples.

Open architectures Computer system architectures in which *hardware* does not depend on proprietary *software* provided by the hardware manufacturer in order to function properly.

Operating system System software that manages execution of one or multiple programs in the computer. The operating system is also responsible for the management and sharing of computer hardware among multiple users.

Optical character reader (OCR) Input device that can be used to scan a pattern and convert it to digital data.

Optical storage Secondary storage techniques based on laser technology; CD-ROM is an example of an optical storage device. See *magnetic storage*.

Optical disks Secondary storage devices whose technology is based on laser disks; finely focused laser beams are used to write and retrieve data from spinning disks.

Output devices Device used to receive and deliver data processed by a computer system. Typically a printer, for example, for printed output.

Packet Unit of data consisting of address, data, and return address; one method of sending data or voice over a network.

Packet Switching Method of routing data, or a message, from transmitter to receiver which splits the message into small units or "packets." The splitting may be done either at the transmission terminal or at an exchange, and each packet includes the "address" of the message's destination. Packet switching can then use different routes for the various parts of a message to enhance the telecommunications network's efficiency.

Paddle Input device that allows data and/or commands to be entered without typing. Used most often for computer games. Technologically compatible with a *mouse* (see).

Page printer Fast printer that prints one page at a time.

Parallel processing Use of a single microcomputer to perform more than one series of tasks at the same time by sharing resources. The Intel 80386 multiprocessor chip makes parallel processing available in IBM's Personal System/2 units.

PBX (Private Branch Exchange) Name for privately owned voice switch most commonly used for telephone system.

Personal Computer (see Microcomputer) Computer system designed to be used by one person, typically based on a *microprocessor chip* (see) and sized to fit at, on, or near a desk.

Plotter Output device that consists of a computer-controlled drawing machine used to produce graphic output on paper.

Portability The ease with which software written for one computer can be moved to another computer.

Printer Output device that prints readable alphanumeric characters on paper.

Private WAN A *Wide-Area Network (WAN)* designed, built, and maintained by a private company whose primary business is not telecommunications. Private WANS are typically built by organizations that have a high volume of transmission traffic and have elected not to use the public WAN—i.e., the networks maintained by common carriers.

Processing speed Computer measurement for speed of handling instructions. Newer technologies (such as Intel's 80386 microcomputer chip) dramatically increase processing speeds.

Program Set of instructions for the computer.

Programming language Set of words, symbols, and syntax that a programmer uses to communicate with a computer.

Proprietary architectures Computer *hardware* designs that function only when using *software* provided by the hardware manufacturer; computers that are restricted to proprietary *operating systems*. See *open architecture*.

Protocol Guidelines or standards that insure compatibility between networks, systems, or applications.

Public network Hardware and software communication systems provided by companies licensed and regulated the state and federal governments to transport data and voice communication traffic belonging to others.

Public lines (dial-up lines) Network facilities provided by a common carrier where more than one user shares the same channel.

Pull-down menus Menus, often used in a *graphical user interface (GUI)*, that expand on-screen after they have been triggered from a set of initial choices. "Pull-down" comes from the screen design development that led to an initial line of menu items being displayed across the top of a computer screen display, with subchoices appearing below an initial choice once it had been selected. By using a pointing device such as a *mouse* to select menu items, the user is pulling the submenu down from the top menu line.

Radio Communication medium using electrical waves in space, normally employing frequencies above 20,000 cycles.

Random Access Memory (RAM) Main storage that is erased when the computer is turned off or accidentally loses power. RAM is used for running software application programs. The size of the RAM determines the size of programs that can be run on the computer.

Read Only Memory (ROM) Main storage that is not erased when the computer is turned off or accidentally loses power. ROM is used for basic instructions that run devices like printers. In most computers, ROM instructions are stored when the machine is manufactured and cannot be altered by the user.

Relational database management systems Database organized to maintain equal accessibility to all of its data items; enables the construction of multiple relationships between data items for answering questions unanticipated by the system's designers. A relational database operates by building tables of information that relate data items to one another according to well-understood relationships. The table-based approach contrasts markedly with the hierarchical approach used by earlier database management systems (see *hierarchical*).

Revolution In computer systems design, a system that is redesigned by discarding existing program code and starting again from scratch using new systems design concepts and programming routines. The new systems may use a completely different systems architecture, as in the case where a series of applications are rewritten from the ground up so that they are capable of sharing data; revolutionary change means that the constraints inherent in existing applications no longer apply.

RGB display Color output device that combines the three primary colors: red, green, and blue.

Ring topology Network architecture where each node is connected to the next in a closed ring.

Satellite Object or vehicle orbiting, or intended to orbit, the earth, moon, or other celestial body. Telecommunications satellites mount circuits, called transponders, that redirect transmissions received from one point of the earth's surface to another.

Secondary storage Devices that supplement main memory by providing permanent storage of great capacity. Floppy disks, hard disks, and CD-ROM devices are examples.

Software Set of instructions that enables a computer to produce information, control machines and equipment, play games, and so forth.

Spreadsheets Software products that provide data manipulation and calculation capabilities in a grid filled in by the user. A set of commands provides easy calculations and references to "cells," where numbers—and sometimes text—can be stored. LOTUS 1-2-3 is an example.

Star topology Network architecture where all nodes are connected to one central processing device.

Supercomputers Specialized mainframe computers designed for faster processing than general purpose mainframes. The term is often applied to the largest and fastest computers currently available, although processing speed benchmarks consistently become inaccurate as technology evolves.

System software Computer's software layer closest to the hardware. Manages the computer's physical components and supervises the application software that is running on the computer.

Systems Network Arcnitecture (SNA) IBM's overall approach to integrated systems, including hardware, software, and network specifications.

Sytek Manufacturer of broadband local area networks.

Terminal Input/output device connected to a computer by a network or a dedicated line.

Terrestrial microwave Transmission medium providing communication between two ground stations antenna.

Token passing Protocol for a LAN in which a small message, or token, is passed between nodes to handle network access by multiple users.

Token ring network Local area network offered by IBM which uses ring topology, token-passing protocol, *twisted-pair* medium, and speeds up to 4 Mbps.

Tools Used in the context of software engineering, software tools are programs used to construct other programs, either by assisting in the process of writing program code (so-called Computer Assisted Software Engineering, or CASE, tools), or by providing "generic" applications such as spreadsheets or word processing that can be combined into customized configurations. Viewed in a business sense, for example, a spreadsheet is a software tool for building mathematical models representing important business relationships.

Touch screen Input device that uses a screen with either a pressure-sensitive surface or beams of infrared light. The user touches the screen to indicate responses and commands.

Transmission media Physical components (wires, cables, and their associated connectors) over which telecommunications systems transport communications traffic.

Transparency *Cooperative processing* (see) concept. A user does not need to know where data are stored or calculations are performed: whether in the microcomputer, in a minicomputer, or in a mainframe is "transparent" to the user.

Twisted pair Inexpensive wire used in LANs consisting of two twisted wires in a minimally protected coating; used to connect telephones to wall jacks.

Ultra High Frequency (UHF) Band of radio frequency between 300 and 3000 Megahertz (MHz).

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