Framework to Assess a Facility's Ability to Accommodate Change: Application to Renovated Buildings

by

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B.Sc. in Civil and Environmental Engineering, Tufts University, 1997

Submitted to the Department of Civil and Environmental Engineering in partial fulfillment of the requirements for the degree of

Master of Science in Civil and Environmental Engineering

At the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 1999

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Abstract

An assessment framework that presents the critical attributes that influence the accommodation of change within a building, specifically focusing on the renovation and reuse of existing low to mid-rise buildings, is developed. Unlike past studies on building renovation and reuse, this research moves away from the exogenous factors (e.g., building location, social and community issues, building age, or building deterioration) and instead concentrates on the physical engineering systems within a building that influence the feasibility of renovation and reuse. In order to develop this framework, detailed information was gathered about building renovation and reuse through literature, construction site visits, and interviews with industry professionals.

A sample of 45 general building renovation case studies was examined according to two dimensions, a set of building systems and a set of changes which they experience over time. The building systems used include the structural system, the exterior enclosure system, the services system, and the interior finish system. The changes, which they experience, were broken down into three main categories: function, capacity, and flow. These dimensions were used to examine 26 out of the 45 general case studies in detail to obtain the empirical data with which the framework was developed.

The examination of these case studies and the development of the assessment framework show that a movement towards accepting and incorporating new methods, techniques, and design alternatives within the construction industry is growing. More owners and developers are changing their overall outlook on the cost associated with building design, construction, and renovation from a concentration on initial costs to a broader encompassment of a building's lifecycle costs. This change in thought has incited a movement towards incorporating capabilities to accommodate change within building designs. However, to complete this movement the complex interactions and dependencies among the building systems and the changes that they experience, which through this research have been shown to exist, must be addressed and simplified.

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Acknowledgements

I would like to express my gratitude to: my parents Chris and Ann, Beth, my brother Michael, and my sister Elizabeth for their love, encouragement and support; my roommates, Eric, John, Josh, and Ethan for putting up with me and my constant complaining; Professor Sarah Slaughter for her inspiration and guidance; all of the professionals within the construction industry with whom I spoke for allowing me to visit their various construction projects and for taking the time to help me with this research; and the National Science Foundation for their funding of this research.

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1 Introduction and Problem Statement

1.1 Background

The construction industry has traditionally been seen as slow to accept change and incorporate innovation. This applies not only to the products and equipment but also to new methods and techniques as well as new design alternatives. This research addresses the apparent reluctance within the construction industry to accept and incorporate new methods, techniques and design alternatives by providing a systematic approach in which to assess design and technology innovations. A major problem in today's building construction industry and its building stock is the inability to efficiently accommodate changes and future needs, resulting in the onset of functional obsolescence. By incorporating new methods and techniques of designing and constructing such buildings, which acknowledge the importance of building flexibility and incorporate capabilities to accept change, the effects of this problem could perhaps be decreased.

1.1.1 Buildings vs. Other Forms of Infrastructure

The foundation and lifeline of the United States of America is the nation's infrastructure. To ensure that this nation continues to grow and prosper from within, this infrastructure must be managed and maintained properly. An emphasis has already been placed on the importance of designing, building, and maintaining infrastructure in order to ensure that it can serve its intended purpose for an extended lifetime (often explicitly 50 to 100 years) (Slaughter, 1997). Most forms of infrastructure, including bridges, highways, tunnels, and offshore platforms, have incorporated this ideology. Although these structures currently do not explicitly incorporate this emphasis on long term functionality into their design and construction, it has become a major current objective that they do so. These structures are generally designed and constructed to provide safe and sufficient use for the public over a long lifecycle; in a sense, they are considered as permanent additions to the built environment.

Research has been performed to devise methods that can be used to assess the levels of deterioration as well as the overall obsolescence associated with such infrastructure (Lee and Aktan, 1997; Lemer, 1996). That research displays the importance of designing maintainable structures that are capable of providing efficient service over a long lifecycle. A facility's initial capabilities (e.g. the durability of materials, and the flexibility of mechanical equipment), and how the facility is maintained, influence the likelihood or timing of the onset of obsolescence (Lemer, 1996). However, infrastructure designers and managers have largely neglected the impact of this obsolescence. In fact, "across the nation, bridges have been restricted or closed because they cannot safely carry the increasingly heavy loads of vehicles.... The U. S. General Accounting Office concluded in 1991 that about 40% of the nation's bridges were deficient" (Lemer, 1996, pg. 153).

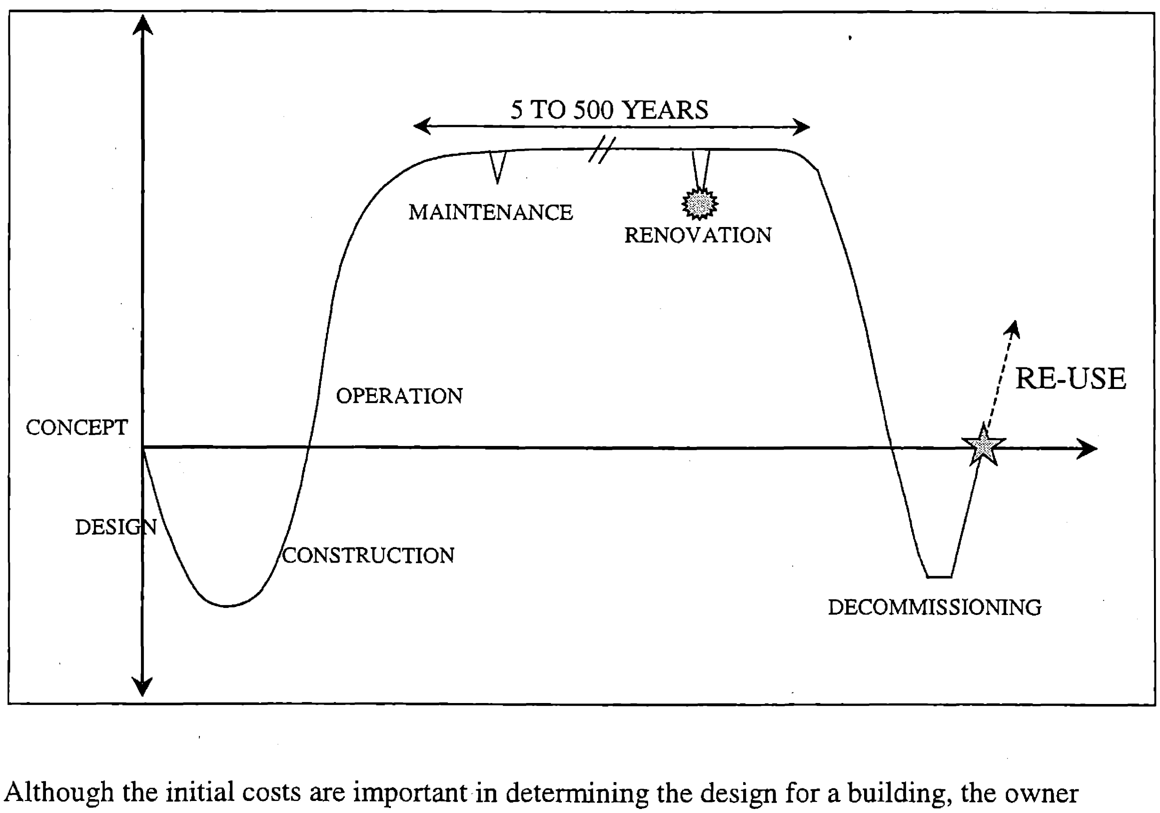
While increasing research focuses on bridges and other elements of the transportation infrastructure and their potential obsolescence, similar problems have occurred in another member of the infrastructure group, namely buildings. However, unlike the other parts of the infrastructure (e.g., highways, bridges, and offshore platforms), little emphasis has been made to ensure that buildings are designed, constructed and maintained in order to provide useful service over a long lifecycle. Older buildings that were initially designed to accommodate one usage can no longer suit that use and therefore are becoming obsolete (e.g., the loads placed on the floor slabs have increased due to an increase in the size of equipment, an increase in the amount of traffic within the building, or an increase in the need for mechanical HVAC units). Due to their initial design, these obsolete structures are incapable of accommodating the necessary changes that would once again allow them to function efficiently, whether for the original or a new usage class. By planning ahead and incorporating the flexibility necessary to allow such maintenance or such required changes to be performed, the lifecycle and useable service life of these buildings would increase, as would the associated savings.

1.1.2 Initial vs. Lifecycle Costs in the Building Construction Industry

Incorporating flexibility into the initial design and construction of a built facility is generally perceived to increase initial costs (Slaughter, 1998; Lewis/Trussell Interview, 1997). However, the overall lifecycle costs associated with operating, maintaining and renovating a building could decrease dramatically. It is often design approaches rather than simply bigger or thicker components that most effectively increase capacity to accommodate change. Therefore, incorporating flexibility may not significantly increase the initial costs as traditionally expected.

Within the construction industry, an emphasis has traditionally been placed on minimizing the initial costs associated with the design and construction of buildings. The common trend has been to design and build a building to the least initial cost while still meeting and maintaining the particular usage requirements for the building. For instance, office buildings can be designed and built to meet the minimum requirements in floor loads. While this approach can potentially save the owner money in the short run, it can cost them more money in the long run, such as when the building becomes obsolete for the particular use for which it was initially designed, or cannot accommodate emerging new requirements. By emphasizing minimizing the initial costs of constructing a new building, the owner often receives a false sense that he/she is saving money. Speculatively, if the owner had instead placed a larger emphasis on the overall lifecycle costs during the overall design and organization of the building, they might have saved more money over time. The costs associated with the design and construction of a building are just the beginning to a lifetime of different costs that a building owner must endure with a building, as shown in Figure 1.1.

Figure 1.1 – Building LifeCycle Costs (Slaughter, 1997)



Although the initial costs are important in determining the design for a building, the owner should also consider the longer term costs associated with maintaining that building and renovating it as particular systems or the entire building begins to become obsolete for its initial usage class. By planning ahead and incorporating the capability to accommodate future change within the building itself, the owner could decrease the lifecycle costs with only a small 1-3% increase in initial costs (Lewis interview, 1997; Kiell, 1992). For example, an owner could specify an office building with higher floor to floor heights and increased capacity for structural loads so that the building could suit research and development use, or other possible uses without having to incur major structural reinforcement down the line.

Building needs and usage requirements, as well as typical working environments, change frequently and often drastically, and can lead to a building's functional obsolescence much earlier than initially expected (Patterson, 1998; Iselin, ed., 1993; Kiell, 1992). By planning ahead and incorporating possible future changes within the initial design and construction of new buildings, it should be possible to create a defense to building obsolescence and its associated costs.

1.1.3 Building Construction in the 1980s to 1990s

In the 1980s, the real estate market and the construction industry in the United States experienced a major boom in the construction of commercial space (Kiell, 1992). Corporations and companies concentrated their time and money on creating new, larger and more complex facilities to help promote their industrial enterprises. The construction of these new commercial and industrial structures quickly gained public attention and captured the headlines throughout the U.S. However, while these new complex structures were gaining the headlines, smaller less complex renovation projects were also becoming prominent in the real estate market and the construction industry. Many owners began to take advantage of the characteristics which older structures possessed. They removed themselves from the traditional 'demolish and rebuild' theory of the late 1960s to early 1970s, and embraced a new era of reuse and adaptation of existing structures (Kiell, 1992; Lion, 1982).

As the 'demolish and rebuild' theory had done in the 1960s, this new theory of reuse began its own era in the 1980s. While new construction activity eventually evened out in the late 1980s, renovation continued to grow. "In fact, according to Cahners Economics in their publication *Building Design & Construction*, in 1989, inflation-adjusted spending on commercial reconstruction rose 5.9 percent in contrast to a drop of 2.8 percent in new office construction and a slight rise of 1.6 percent for new industrial construction" (Kiell, 1992, pg. 11).

"In fact, the rehabilitation of existing structures has become such an important issue that over the past decade in the United States, more than half of the total construction budget has gone to some form of renovation, remodeling, or reutilization of existing buildings" (Lee and Aktan, 1997, pg. 1). In many regions, particularly urban areas, renovation is becoming the more economical form of construction. Existing structures are no longer seen as disposable objects but instead are seen as valuable assets. The importance of existing buildings as assets, which can help promote the future growth and prosperity of metropolitan areas, has influenced many owners, developers and others to maintain and beautify existing structures (Lee and Aktan, 1997; Stewart, 1997; Poskanzer, 1996-97).

What truly is influencing many owners, developers and others to purchase older structures or hold onto their own structures and adapt them for future use? The renovation movement has been ignited primarily by several economic and social factors that arose during the 1980s (Poskanzer, 1996-97; Lion, 1982; Kiell, 1992). During this time, building costs increased. Materials, labor and design costs have increased, thus making cost a very important issue with regards to construction. Renovation has the potential to provide savings in these costs compared to new construction (Poskanzer, 1996-97; Lion, 1982; Kiell, 1992). Another factor is the fact that rehabilitation generally entails a much shorter construction schedule than new construction. More construction time equals a loss in revenues during that time (Poskanzer, 1996-97; Lion, 1982; Kiell, 1992). This increase in building costs is paralleled by an increase in the strictness of financing parameters offered by most of the lending institutions. Therefore, renovation projects often present lower construction costs than new construction projects (Poskanzer, 1996-97; Lion, 1982; Kiell, 1992). "With economy less of a factor in bygone days, many older buildings tended to be over-designed and have sound frames", thus promoting their capability for adaptation for other uses (Lion, 1982, pg. 2).

The increasing complexity which new construction now incorporates has also become an important factor. The incorporation of several new building codes for federal, state, as well as local authorities have made the entire construction process a much more difficult task to complete (Kiell, 1992; Bordass and Leaman, 1997). Another factor which has effected the decision for renovation over new construction is the increased sense of historic preservation within the U.S. Buildings are now being considered reminders of our nation's past that must be maintained and restored to continue to preserve our national heritage (Poskanzer, 1996-97; Lion, 1982; Kiell, 1992). Despite all of these previously mentioned factors, one of the main reasons for renovating a facility is simply a required upgrade of the facility to meet the tenants' needs.

In many regions, renovation projects can promote social issues and increase the sense of community within the environment. "By finding fresh uses [for these buildings], decay can be halted and whole neighborhoods rejuvenated while at the same time maintaining a sense of time and place" (Eley, 1984, pg. 3). In addition to these changes, the historic preservation of existing buildings became an important issue in many regions. This resulted in the prevention of the demolition of certain structures and thus promoted their creative reuse.

While the economic and social factors are very prominent considerations associated with renovation projects, there are many other reasons why many owners, developers, and others have decided to renovate. For instance in 1991, *Building Operating Management* magazine produced a survey in which they asked readers for their primary reasons for renovation. The results of this survey are shown in the table below.

Table 1.1 – Primary Reasons for Building Renovation (Mathew Kiell, 1992)

Reasons to Renovate	Proportion of Sample*
Modernization	62.4%
Conversion to New Use	30.3%
Energy Conservation	18.9%
Code Compliance	14.7%
Tenant Change	14.2%
Other Reasons	8.2%

*Note: Respondents could select multiple reasons, so the total proportion is greater than 100%

These reasons help explain why renovation and refurbishment has become such a popular method of construction over the past decade as well as why it is so important that buildings are designed to incorporate capabilities to accommodate future change and thus ease the renovation process.

1.1.4 Renovation within the Construction Industry

In studying the renovation of existing buildings, it is important to specify what exactly 'renovation' means. "Renovation, or refurbishment, is the hard-headed business of making use of what is usable in the aging building stock; the skillful adaptation of a building shell (which is valuable in its own right and not due to any historic mystique) to a new, or an updated, version of its existing use" (Marsh, 1983, pg. 3). While many people think of renovation as the conservation of a historical building, that is not always true. Few structures are worthy of such architectural merit. However, several structures are capable of and useful for renovation and reuse. Renovation simply is the "good management of the building stock of a country, a company or a building owner to ensure that the initial investment in 'bricks and mortar' are not squandered prematurely" (Marsh, 1983, pg. 3).

Renovation may actually reduce risks as well as initial costs. It can and has been argued that the construction of a new structure incorporates greater risks than renovations of older structures, because the older structures have already proven that they can withstand the associated development risks. "In sense, an existing building has a track record that makes the risks clearer and more predictable" (Kiell, 1992, pg. 15).

Yet, renovation projects are not always as easy as some professionals may say, and often times they too incorporate several risks that must be considered and analyzed prior to the work. The designers for the renovation of an older building must design around the constraints that the structure and other systems impose. "Refurbishment presents a fascinating array of snags which are novel to the designer who has previously concentrated on new work" (Marsh, 1983, pg. 1). These uncertainties and snags may make a renovation project much more unpredictable than a new project, thus increasing the associated risks (and often the associated costs). Due to this diversity of problems and the uniqueness of each renovation project, it is impossible to offer a single design approach or solution. However, it is possible to ease the renovation process by providing a systematic approach to assess the existing capabilities of a building to accommodate changes and incorporating flexibility within a building's design, thus providing it with the capabilities necessary to accommodate future changes.

1.2 Research Objective

This research focuses on the analysis of the reuse or renovation of existing buildings. In order to determine if a building can feasibly be renovated and reused, it is important to determine the particular characteristics within the building that permit renovation and reuse to be performed easily and that produce a good facility for the owner/occupant. The purpose of this analysis is to determine the critical aspects within a building's four main systems (e.g., the structural system, the exterior enclosure system, the services systems, and the interior finish system) which influence the feasibility of renovation and building reuse. The data for this research was empirically derived through site visits on renovation projects within the Boston Area, personal and telephone interviews with professionals associated with renovation projects throughout the United States, and through journal article reviews. The data obtained were with regards to a building's ability to accommodate changes in function, capacity, and flow, as well as the components within and interactions between the four building systems that aid the building's flexibility. The data were verified through interviews and interactions with professionals within the construction industry (e.g., owners, developers, owner/developers, contractors, and architects) who have had experience with numerous renovation projects.

The first stage of this research entailed the determination and analysis of the theory that buildings should be designed and constructed with capabilities to incorporate future change. In order to analyze the ability of facilities to accommodate change, the facilities were divided into the four commonly used building systems as stated above. These systems and their individual components were determined to be applicable to all forms of buildings and therefore relevant for the purpose of this research. Nearly all of the nation's building stock at one point in time undergoes some form of change. For the purpose of this research, such changes were categorized into three robust change categories: function, capacity, and flow. These change categories were analyzed according to their applicability to the building construction industry as well as their relevance to this research. Through this analysis, these change categories were further divided into more specific subcategories that better represented the types of changes that commonly are experienced by buildings. The building systems and the change categories were then used to analyze the case studies used for this research.

After establishing the relevance of these two dimensions of building system and change categories, the next stage of this research analyzed 46 case studies. The case studies consisted of renovation projects which are currently progressing or which have recently been completed within several different regions of the United States. Due to the availability of current projects within Massachusetts, a majority of the case studies are within the Boston area. The case studies were first analyzed to determine particular trends in usage class. Specific changes in usage, whether it is for the same or a new usage, were recorded. Through this analysis, a large trend towards office use was prominent. Upon determining the specific trends in usage class, 26 of the case studies were examined in more detail. Empirical data were obtained from these cases using the two dimensions of building system and change categories. Using this empirical data, critical aspects were determined for each building system, which influence each system's capability to accommodate the specific change criteria.

Within the final stage, a design framework was developed, based upon the data, which identifies the critical attributes of each building system that influence the accommodation of specific categories of change. This framework can be used as a diagnostic tool by professionals to help them in their decisions on the feasibility of building renovation. This framework is also intended to serve as the foundation for a future tool that can be applied directly to the design and construction of new facilities. Ultimately, this framework is intended to provide designers, owners, and construction professionals with approaches to incorporate flexibility within the building's design while at the same time presenting the associated costs and benefits for doing so.

1.3 Thesis Organization

Chapter 2 describes past research that has been performed on building reuse and renovation. It explains how significant work has been performed regarding determining the exogenous factors (e.g., location, social community issues, and building deterioration) that influence the decision on renovation feasibility. It concludes by stating how this research moves away from the exogenous factors and concentrates on the physical aspects within a building, namely the physical engineering systems that influence the reuse decision.

Chapter 3 presents the design framework that was constructed using the relevant data obtained. Also within this chapter are the definitions for the building systems and the change categories.

Chapter 4 explains the methodology that was used to perform this research. This chapter explores the collection of data, relevance of that data and the methods that were used to analyze and compile that data.

Chapter 5 provides the results of the analyses. This chapter specifies the relevance of these results and their applicability to the building construction industry, and building renovation and reuse.

In Chapter 6, the results of the proposed research are summarized and possible future research stemming from this research is proposed and suggested.

2 Background Literature on Building Renovation and Reuse

2.1 Buildings as an Asset

The adaptive reuse of older buildings is a growing trend, not only in retail, but also for private companies, schools, government agencies and health care providers. "Renovation and rehabilitation of older buildings offer viable, cost effective solutions to clients needs and at the same time preserves parts of our past" (Poskanzer, 1997, pg. 60). These older buildings have gradually become very attractive due to the improving economy as well as the increased availability of federal and private financing programs. Within many urban areas, these factors, coupled with the growing economics of renovation, are causing older buildings as well as new buildings to be identified and viewed as valuable assets (Lee and Aktan, 1997). Many owners, developers, and others are beginning to recognize that these structures can help promote the future growth and prosperity of metropolitan areas, and therefore are working towards maintaining and reusing them.

As an asset, a building must be evaluated on the basis of a defined need and its ability to meet that need as well as potential future needs. As explained by Kevin Stewart (1997), three potential extensions can be applied to this statement: "1) while potential needs may not change, the ability of the building to meet that need is diminished; 2) while the ability of the building has not necessarily changed the needs or requirements for the building have changed; and 3) given that the needs have changed as well as the ability of the building to meet those changes has diminished, the building must be reevaluated." There are three possible outcomes to this dilemma: 1) the building can be disposed of or sold at salvage value; 2) the building can be fixed up or renovated to meet the new need; and 3) nothing could be done.

In order to explain this train of thought one can think of an automobile (Stewart, 1997). Most automobiles are bought with the thought that they would last for a finite period of time and provide a variety of services over that time. However, often before that particular time is reached, three scenarios may have occurred with the car: 1) the car may be too old and broken down to meet the owner's needs; 2) although the car is capable to meet the needs, the owner has changed his or her needs; or 3) the owner's needs have changed and the car is too old and broken down to meet those new needs. For each of these scenarios the owner has three possible solutions. The owner can decide to keep the car and fix it so that it meets his or her needs, sell or destroy the car and buy a new car that meets the needs, or sell or destroy the car and use some other form of transportation. In this analogy, the car is the asset in question. However, the same train of thought is applicable to buildings and therefore similar emphasis and attention to maintenance practices and reusability can be applied to building design and construction.

2.2 Planning and Design for Assessing the Feasibility of Building Renovation and Reuse

The view of buildings as assets has led to an increased interest in sustaining building market values and thus in building maintenance and reuse. This increased interest has sparked several research projects on building maintenance and renovation over the past two decades. Many of these projects have concentrated on determining the important characteristics which influence the feasibility of building renovation and reuse, as well as those characteristics which help prolong a building's useful service life. The basis for a majority of these studies concentrates around factors such as building location, building age, building appearance, and site condition assessment, all of which will be referred from this point on as exogenous factors.

2.2.1 Urban Planning

One of the more important exogenous factors that have been considered for building renovation feasibility entails the urban planning of a building (Poskanzer, 1996-97). While urban planning is generally a very broad area within building construction, for the purpose of building renovation and reuse it has commonly been broken down into two main categories: building location and social and community issues. Both of these categories have been examined over the past couple of decades and their relevance to building renovation and reuse as well as new construction has been proven to be important.

2.2.1.1 Location

Building location has been determined as one of the more critical factors which influence the feasibility of building renovation and reuse as well as new construction. The location of a building has been shown to strongly influence the choice of new use for that building (Niskala, 1982). Often the particular location or neighborhood that an existing building is in can help expedite necessary approvals and dissuade any local opposition because of this view. Such buildings are often perceived as neighbors that are going through hard times, and the adaptive reuse of them is perceived as the building's as well as the neighborhood's savoir (Poskanzer, 1996-97). Furthermore, certain locations of existing buildings that are vacant can often lead to reasonable prices and thus offer the greatest real estate appreciation.

Several aspects of a building's location have been considered to be important in determining the feasibility of renovating a building, such as the building's accessibility to public infrastructure, appearance of the surrounding buildings, and atmosphere within the surrounding neighborhood (Lion, 1982; Gann and Barlow, 1996; Niskala, 1982; Stewart, 1997). Each of these studies concluded that a building's location and proximity to the previously mentioned amenities is critical in determining the overall feasibility of renovating and reusing a particular building. They also stressed that in order to examine this factor, accurate site investigations and surveys should be conducted and examined.

2.2.1.2 Social and Community Issues

The social and community issues which building renovation and reuse often encounter are another important factor that must be considered prior to making the decision to renovate (Poskanzer, 1996-97; Lion, 1982; Niskala, 1982; "Buildings", 1996). Such factors are critical to the 19 standards that the ASTM developed for determining the functionality of office buildings ("Building", 1996). It is important that the renovation of a building for the same or new usage class is compatible with the functional and architectural objectives of the local community in which it is located. Such community and social acceptance is a critical issue in insuring that such a project runs smoothly. A large proportion of these studies have shown that the renovation of an existing structure often displays a reinvestment into the community, and thus has the potential to stimulate neighborhood pride and further development (Marsh, 1983; Poskanzer, 1996-97; Niskala, 1982; Iselin and Lemer, ed., 1993). Renovation has also been found to preserve the past while promoting future economic growth within such communities. Furthermore, building renovation has proved to be a major form of environmental improvement, as it replaces the "tear down and rebuild" attitudes of the past with an attitude for recycling (Poskanzer, 1996-97).

2.2.2 Building Age and Appearance

Recent research has determined that a building's age and its overall appearance also contribute to the decision making process for reuse (Poskanzer, 1996-97; Gann and Barlow, 1996; Lee and Aktan, 1997). The practical and aesthetic consideration of the finished building should balance the functional and economic aspects of new use with the conflicting aesthetics of the original building (Poskanzer, 1996-97). Such factors have been used to categorize buildings in effort to determine their feasibility for potential reuse (Gann and Barlow, 1996). Building age has also been used as a determining factor within frameworks for determining and examining levels of building deterioration (Lee and Aktan, 1997). Through such studies, it was concluded that building deterioration is in fact strongly correlated to building age as well as other factors.

2.2.3 Building Deterioration

The issue of building deterioration and its effects on the overall feasibility associated with building renovation and reuse had become the basis for several research programs. Most of this research has focused on the different construction materials and building systems that were used to complete a facility.

2.2.3.1 Construction Materials

The materials used to construct a facility (e.g., structural material and cladding type) and the level of deterioration which they have experienced or are intended to experience over time is one of the main factors of recent deterioration analyses (Poskanzer, 1996-97; Lion, 1982; Lee and Aktan, 1997). Before determining to renovate an existing structure, it is important to perform a critical assessment of the building, including an investigation of the different building materials used to comprise the structural system, the exterior enclosure (especially the roofing), and the services systems (Poskanzer, 1996-97). Certain aspects of a building, such as windows (deteriorated, visually objectionable, energy inefficient), insulation (deteriorated, may not conform to modern standards), structural stability (damage deterioration of structural materials), and services (deterioration, leaks) should all be investigated and assessed (Lion, 1982).

Additional research has developed a set of models that specifically help describe building deterioration. The models, which have been developed, consist of a set of parameters (Building Age, Building Materials, Occupancy Class, Cladding Type, and Building Maintenance) coupled with a set of deterioration scales (No Deterioration – Slight Deterioration – Moderate Deterioration – Severe Deterioration) (Lee and Aktan, 1997). These models thus provide a platform for investors and developers to access information on the building stock. By determining the amount of material deterioration and its relevant possibility of failure, one can predict the feasibility of renovating a building as well as determine the extent to which repairs must be made aside from any alterations.

2.2.3.2 Building Systems

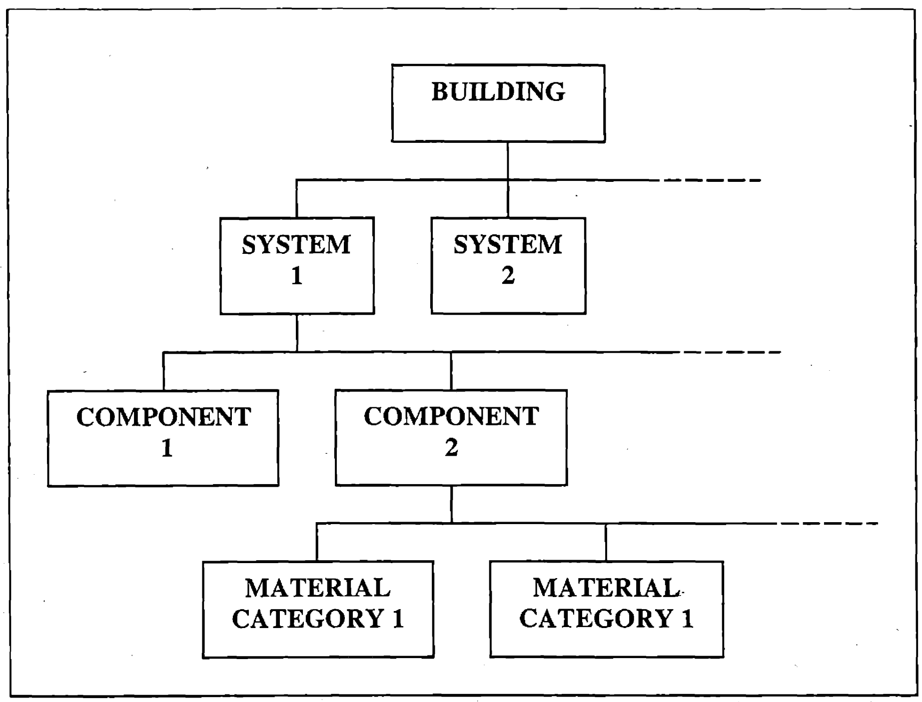
In order to examine and determine the amount or levels of deterioration that a building may possess, most of the past research has divided a building into more defined components or building systems. The deterioration within these systems are then measured and used to determine the feasibility and potential for future reuse or renovation of the building or of particular parts or systems within the building.

For instance, in a recent study on the conversion of low class office buildings for reuse as badly needed residential flats, a list of factors was developed for measuring the ease of conversion (Gann and Barlow, 1996). These factors included the following systems: Building Structure (type of materials/framing used), Building Envelope (type of materials/siding used, size and number of windows) and Building Services (often the most expensive and tedious or labor intensive aspect of building renovation/conversion). Other studies have also separated buildings into similar building systems (Lion, 1982). These building systems are:

1. Structural system – Foundation and the Structural framing
2. Enclosure System – exterior walls, exterior openings, exterior finishes, roofing and sheet metal, and weatherproofing and insulation
3. Interior Finish System – interior partitions, interior openings, interior finishes (often governed by the installation, etc. of services)
4. Services Systems – safety and security, comfort trades (heating, air conditioning, ventilation, plumbing, sprinklers, electric, vertical transportation.

Similar studies have organized such building systems within a hierarchy that divides them into their individual components and even further into materials categories (Uzarski and Burley, 1997). This hierarchy was then used as a building tool for managing building assets. The materials categories recognize that components made of different materials can have different performance histories requiring different maintenance and rehabilitation actions and frequencies. An example of this hierarchy is shown below in Figure 2.1.

Figure 2.1 – Building Hierarchy (Uzarski and Burley, 1997)



2.2.4 Building Obsolescence

Building obsolescence has become a main concern and problem within the building construction industry. "Anecdotal evidence suggests that the problem with facility obsolescence is substantial" (Iselin and Lemer, ed., 1993). While the traditional "demolish and rebuild" theory has been the solution to this problem in the past, renovation and reuse has now become the primary solution for dealing with obsolescence. However, renovation and reuse of buildings does not always present the least complicated and least expensive solution to this problem. Therefore, several forms of research have attacked the issue of building obsolescence in efforts to determine how to either slow its onset or completely avoid it. The method that is proposed and presented within this research involves the incorporation of capabilities within buildings to accommodate future change.

2.2.4.1 What is it?

The standard dictionary definition for obsolescence is "a condition of being antiquated, old-fashioned, or out of date" (Lemer, 1996). An obsolete item is not necessarily broken, worn out or otherwise dysfunctional, although these conditions may underscore its obsolescence. In most cases, things that are obsolete continue to function but at levels below contemporary standards.

Within building construction, obsolescence reflects the changed expectations regarding the shelter, function, comfort, profitability, or other dimensions of performance that a facility is expected to provide (Iselin and Lemer, ed., 1993). Obsolescence often motivates the need to overhaul, renovate or sometimes demolish a facility that no longer provides satisfactory service. "Obsolescence is not a matter of design alone but must be considered within the context of a facility's entire lifecycle, from initial planning through operations and maintenance" (Iselin and Lemer, ed., 1993).

2.2.4.2 Why does it occur?

There are several factors that have been determined to cause obsolescence. A facility's initial capabilities (e.g., durability of materials and flexibility of mechanical equipment) and how it is maintained influence the likelihood or timing of the onset of obsolescence. Over time, the quality of service declines from its initial level as a facility exhibits the results of normal wear, poor craftsmanship or materials, unlikely events, aging or some combination of such factors. Although a facility or piece of equipment within that facility may function adequately in basic terms, because it is old, antiquated or out of date, its service is simply unacceptable to its owners and users, thus forcing it into obsolescence.

While all of these factors have been attributed to the onset of building obsolescence, four main factors can cause obsolescence (Lemer, 1996; Iselin and Lemer, ed., 1993).

1. *Functional Factors* – those that are related to the uses a building or spaces within the building are expected to serve, including regulatory changes that impose new requirements on facilities;
2. *Technological Factors* –Technological changes that influence the scope or levels of service which a facility is expected to provide thus affecting the efficiency and service offered by the existing installed technology compared to new and improved alternatives;
3. *Economic Factors* – Economic or social changes in the markets within a region that can substantially alter the demands placed on the facilities and thus affect the cost of continuing to use an existing building, subsystem or component compared with the expense of substituting some alternative; and
4. *Social, Legal, Political or Cultural Factors* – The broad influence of social goals, political agendas, changing lifestyles (regulatory factors – ADA, etc.), and simply changes in values or behavior of the people that use or own the facilities can similarly alter the demands– however, these are more difficult to foresee.

The impacts of obsolescence can result in lost efficiency, rising costs, reduced output and declining morale, thus promoting the importance for developing methods for preventing obsolescence or avoiding it entirely.

2.2.4.3 Design Service Life vs. Physical Life of Buildings

One of the main misconceptions within the building construction market and industry, and one of the main reasons why building obsolescence is commonly encountered at an unexpected early time, is the failure to distinguish between design service life and physical life. Design service life has been defined as the length of time that a building, subsystems or component is designed to provide at least an acceptable minimum level of shelter or service as defined by the owner (15-30 years) (Iselin and Lemer, ed., 1993). Physical life, on the other hand, is defined as the actual time that it takes for a building, subsystem or component to wear out or fail, or the time period after which a facility can no longer perform its function because increasing physical deterioration has rendered it useless (Iselin and Lemer, ed., 1993). Elements that reach the end of their physical life must be repaired, replaced, refitted or abandoned in order to function, while elements that have reached the end of their service life can continue to function and may or may not have to be replaced or refitted.

2.2.4.4 How to Avoid/Prevent Obsolescence?

The primary incentive to avoid obsolescence is the cost incurred when the effort is made to update a facility or when the user or owner loses operating efficiency owing to facility performance (Iselin and Lemer, ed., 1993). "Minimizing the impact of obsolescence – that is, minimizing its costs through actions in planning and programming; design; construction; operations; maintenance; and renewal; and retrofit or reuse – is accomplished by anticipating changes, accommodating changes or both" (Iselin and Lemer, ed., 1993). Facilities can be programmed, designed, and operated to be robust to be able to accommodate change without substantial loss of performance capability. Such facilities can improve their ability to forestall or avoid obsolescence by assuring that design guidelines and criteria are based on the latest available information and provide for future change in technology and practice. Facilities can also improve this ability by making flexibility an explicit design goal and appropriately using design details or integrated building systems that enhance flexibility or adaptability.

In order to attack the issue of premature building obsolescence, it has been determined that owners, designers, and constructors must institute actions in planning, programming, design, construction, operations, maintenance, and renewal, retrofit or reuse of a facility that minimize the impact of obsolescence by anticipating change or that accommodate changes that cause obsolescence before the costs of obsolescence become substantial. While it is nearly impossible to foresee changes that will occur over the service life of a facility, the thoughtful planning and programming of a facility can do much to avoid early obsolescence, both for new construction or substantial reconstruction, by striving to assure that a facility's design is "robust." Robust, in this usage, means that the facility is capable of accommodating change without substantial loss of performance capability (Iselin and Lemer, ed., 1993).

Several attempts have already been made in the past towards devising methods in which building obsolescence can be controlled or avoided. For instance, Architect Richard Rodgers has made accommodation of changes a basic element of his design philosophy: "I believe that many architects misjudge the private needs of buildings. The rate of change in society – and you can pick the computer or whatever you want as a symbol – makes long-term prediction impossible and inflexible building unreasonable. A set of offices today might be an art gallery tomorrow. A perfume factory may switch to making electronics. What we can do – and this is the key to much of my work – is to design buildings that allow for change, so that they can extend their useful lives. …" (Iselin and Lemer, ed., 1993). He does so by separating the services from a building's useable space, making the services very accessible and organizing the building so that it does not have to close when the services are being renewed.

2.2.5 Building Flexibility

While the blame for defects within buildings is often placed on the materials and its obsolescence, too often it is actually the use or misuse of the material that is the cause. Typical engineering design faults within building construction include:

1. The lack of full appreciation of structural stability and robustness, omission of tying, lateral restraints, etc;
2. Inadequate attention to structural joints and connections;
3. The production of complex and practically unbuildable details;
4. Inadequate supervision of construction; and/or
5. The addition of insulation (or other environmental alterations) to the existing building without appreciation of the consequences (Smith and Moore, 1992).

Meanwhile, the users of these buildings also make poor decisions that cause defects and problems within built facilities. Some common user faults include:

1. Overloading of the building;
2. Alterations without structural design checks;
3. Lack of maintenance; and/or
4. Lack of inspection (Smith and Moore, 1992).

By incorporating flexibility within the initial designs of a building, the amount of incidents in which such faults occur could be decreased.

2.2.5.1 What is it?

Past research has defined flexibility as the ability to readily accommodate changed uses, more intense uses and new service systems (Iselin and Lemer, ed., 1993). For the purpose of this research, flexibility within buildings is defined as the interactions within and among building systems that influence the capacity of built facilities to accommodate change over the long term (Slaughter, 1997). This definition explicitly includes the nature of the building systems and the specification of the different types of changes that built facilities commonly experience over time.

Within the building construction industry, "A flexible facility is one that in the ideal world, the operations could change overnight. A flexible facility is a building that understands the work environment is a work in progress, and it will always be a work in progress. It's designed to adapt and accommodate continuing changes" (Patterson, 1998, pg. 39). Experience shows that flexibility or adaptability to change, no matter how it is achieved, is a valuable characteristic that helps to delay or avoid obsolescence.

2.2.5.2 Why is it important in today's construction market?

In today's market place, most business environments encounter fast-paced technologically driven changes. In order to meet these changes and allow these businesses to function efficiently and prosperously, flexibility must be incorporated into all aspects of their business plan. This includes flexibility within the building that houses their offices and operations. "Today's tenants need what they need when they need it – Now. Downtime means money down the drain and today's businesses won't stand for it… When you talk flexible building, you just can't pinpoint it. You have to be in a position to make your building do whatever it can for your clients that are sitting in it. If that's one day an enclosed office space with plush carpeting and window offices, that's one thing; but on the next day, if you want to knock down those walls and you want to put partitioned offices out there so everyone can now enjoy the windows, you need to be able to do that" (Patterson, 1998, pg. 38, 41). In order to achieve this goal, flexibility should be made an explicit design goal for all building construction projects.

2.2.6 Problems Associated with Building Renovation and Reuse

A renovation project is often subject to a number of diverse constraints: physical, dimensional, design considerations, building codes and insurance requirements (Gann and Barlow, 1996). Through several research projects, the most common technical limits to building conversion have been determined. These limits are shown in Table 2.1 on the following page.

Table 2.1 – Technical Limits to Conversion (Gann and Barlow, 1996)

Limit Area	Limiting Factor
Site	Orientation
	External Noise Source
	Car Parking and Amenities
	External Access
Size	Total Floor Area
	Height
	Depth of Building
	Floor Shape
	Grids
	Floor to Ceiling Height
Structure	Penetration for Services
Envelope	Cladding
Services	Installation of Services to Individual Units
Acoustic Separation	Floors and Partitions
	Flanking Transmission
Fire Protection	Means of Escape
	Access for Fire Brigade
	Fire Detection and Alarms
	Preventing Spread of Flames

While many professionals argue that these limits are unavoidable due to the economic/financial burden that is commonly misconceived to be associated with avoiding them, past research has shown that it is in fact possible to design flexible buildings with respect to those limits. Several attempts have been made which involve specific building characteristics as well as methods of design that provide flexibility within a building so that it can accommodate future changes more easily and thus extend its useful life. For example, the provision of large column free areas give maximum flexibility in moving partitions, and 24 to 30 foot column spacing continue to provide such areas, without excessive increases in structural costs (Iselin and Lemer, ed., 1993). Another example is the segregation of services from user-occupied space. This reduces constraints on the user space, but more importantly facilitates modification and updating of services through the use of raised access flooring, interstitial ceiling space, floor to floor distances of 15-16 feet, or through clustering services together in bays, canyons, and/or central points (Patterson, 1998). Another method that has become common, especially within office buildings, is the concept of modularity (Kendall, 1994; Patterson, 1998). This concept, in which changeable, moveable and de-mountable enclosure and partitioning systems are used to define the layouts of the interiors of such buildings, increases the building's capabilities to change. Projects with considerable site constraints have incorporated the construction of extra structure, foundation and unfinished enclosed space to allow for future expansion and change. Although this method may increase the initial costs, it also offers substantial reductions in lifecycle costs associated with obsolescence and future renovation or reuse.

Through incorporating such designs and methods within a built facility, the problems commonly associated with building renovation can be reduced or avoided all together. The research presented within this paper attempts to expand on these previous attempts, as it proposes a design framework that can be used to help determine the critical aspects within a building that allows buildings to accommodate future change and thus allows conversion to occur more easily.

2.3 Relevance to this Research

The thought process used for this research involved using past research on building renovation and reuse as a filter from which the research would flow. Therefore, the issues previously described regarding urban planning, building age, building appearance and deterioration are considered as inputs for this filter. From this filter, this research attacks the issues regarding building obsolescence. Rather than concentrate on the building as a whole, which past research programs have done, this research instead concentrates on the individual building systems and components that comprise a building. It attacks the issue of obsolescence through analysis of these systems and their inherent capabilities to accommodate necessary changes over time. Through these analyses, the research determined a set of critical attributes for each of the building systems which should be considered in order to increase the flexibility which a built facility possesses and thus allow the facility to adapt to changes over time. Furthermore, this research explores the different trends in usage class changes, as well as the interactions that exist between the different building systems as they undergo the required changes to meet these trends in usage change.

The issue of urban planning largely relates to the changes in usage class, which are evident within a large majority of building renovation projects. A building's location has commonly been thought to restrict the type of usage class that a building might be used for, largely due to local zoning and building codes. However, oftentimes renovating a rundown facility and introducing a new usage for that dilapidated building could help revitalize a dying neighborhood. By incorporating dynamic building usages within these neighborhoods, new opportunities, demands and needs for usage shifts could be created. Through analyzing several case studies, this research shows that such shifts in usage class exist and that they can in fact impact neighborhoods and communities in positive ways.

Past research has concentrated on building age and appearance at the broad scope, namely taking the entire building as a whole. However, it fails to investigate building age at a more detailed level, for instance within each of the building systems. The age and conditions of the individual systems that comprise a building are important factors for determining the levels of renovation required for making reuse feasible. Therefore, this research concentrates on the individual building systems within a built facility and the changes which they endure over time.

Past research has used a common breakdown of building systems within a building for analysis purposes (Figure 2.1). This breakdown hierarchy begins with the building as a whole, which breaks down to the main building systems, which break down to their individual components, which finally are broken into their different materials. Yet this ideal hierarchy which has used in the past fails to incorporate the interactions which may exist between the different systems and their components. Through the analyses performed, this research shows that such interactions do exist, and determines what they are and where they occur.

While the factors previously described within this chapter are very important and certainly must be addressed when considering whether or not to pursue the renovation of an existing building, they do not fall within the bounds of this research. This research assumes that such exogenous factors have already been assessed, and instead concentrates on the physical aspects, or the "bones and guts", of a building which also determine the feasibility of renovation and rehabilitation. Furthermore, while this research can apply to nearly every type of building design, from small residential family housing to skyscrapers, it primarily concentrates at this stage on mid to low rise buildings.

3 Presentation of the Design Framework

3.1 Purpose of the Framework

The intent behind creating a design framework was to develop a systematic means for owners, developers, designers, and constructors to assess the capacity of a built facility to accommodate specific types of changes over the long term. The first step taken to create this framework involved the development of a theory on how buildings are capable of accepting change and successfully adapting to that change. This theory incorporates the common breakdown of a building into its four main building systems: the structural system, the exterior enclosure system, the services system, and the interior finish system. In order to study these systems and determine how they respond to certain types of change that may occur over the lifetime of a building, a set of change criteria were developed. The four building systems and the set of change criteria were used as two dimensions within which the sample of building renovation projects was examined. These dimensions were used to examine the case studies and gather empirical data regarding changes within the particular systems as well as shifts or changes in usage class. Based upon this theoretical approach and the empirical data obtained, the critical attributes which influence a building's capability to respond to the specific categories of change were determined for each of the building systems. These attributes were then organized within a matrix to serve as the framework.

3.2 Definitions of Building Systems Analyzed

For the purpose of this research, each building was divided into four primary building systems. These four systems are the structural system, the exterior enclosure system, the services system and the interior finish system. Each of these systems consists of particular components that ultimately work together to produce a sound building which fulfills its intended use and provides a comfortable environment. The structural system, as shown in Figure 3.1, consists of the foundation, the columns, the beams, the floors, and the soil beneath the building – essentially the components that make up both the substructure and superstructure of the building. The enclosure system, which is shown in Figure 3.2, includes the roof, the walls, the cladding and any openings, such as windows and doors. Figure 3.3 displays the services system which includes such building components as the heating system, cooling system, energy system, water/plumbing system, sewer system, electrical system, telecommunication system, fire safety system and security system. The interior finish system includes the finished floors, walls, ceilings, doors, and windows as well as the acoustics within the interior of the building, as shown in Figure 3.4.

Figure 3.1 – Structural System and Components

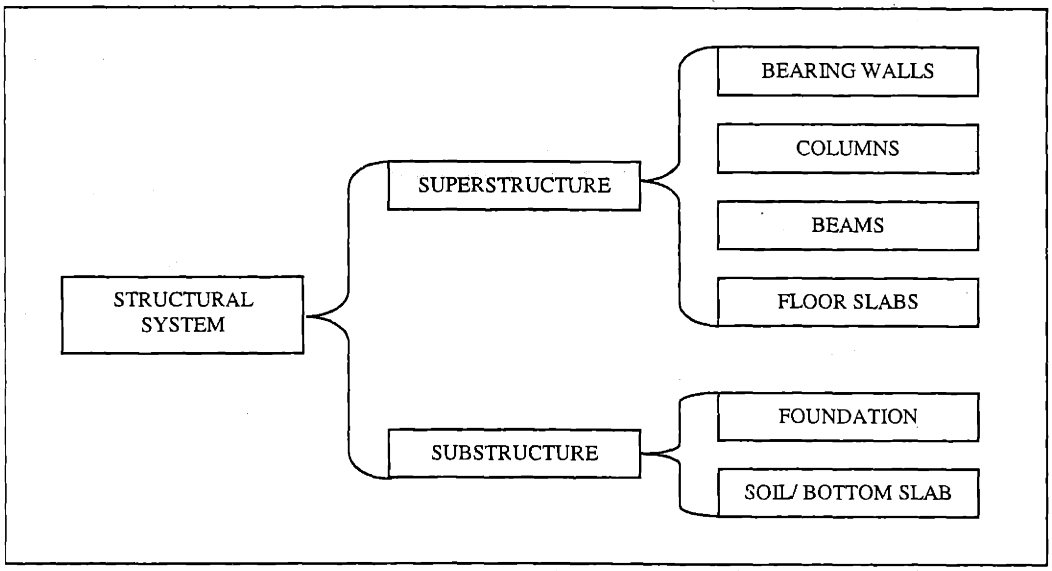


Figure 3.2 – Exterior Enclosure System and Components

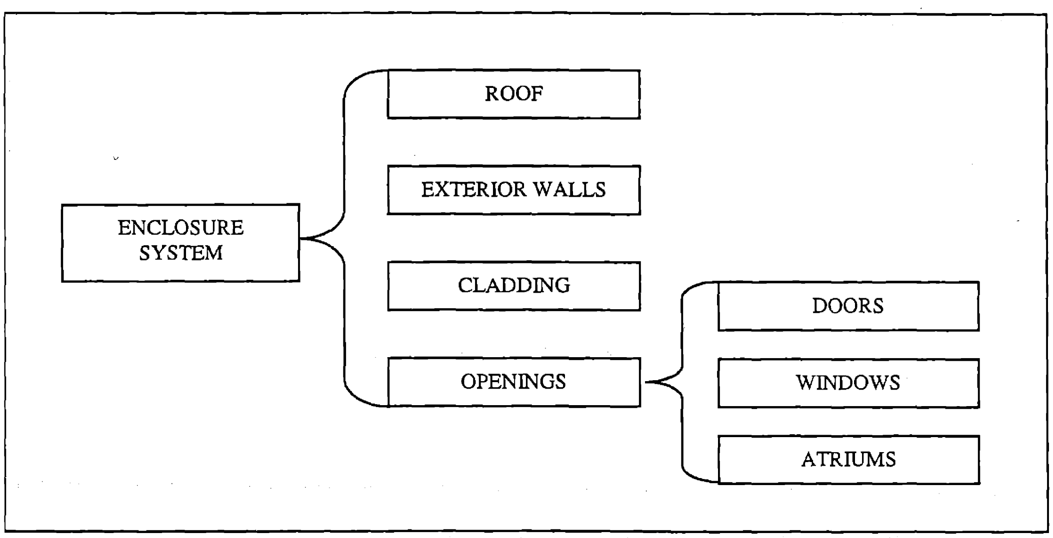


Figure 3.3 – Service System and Components

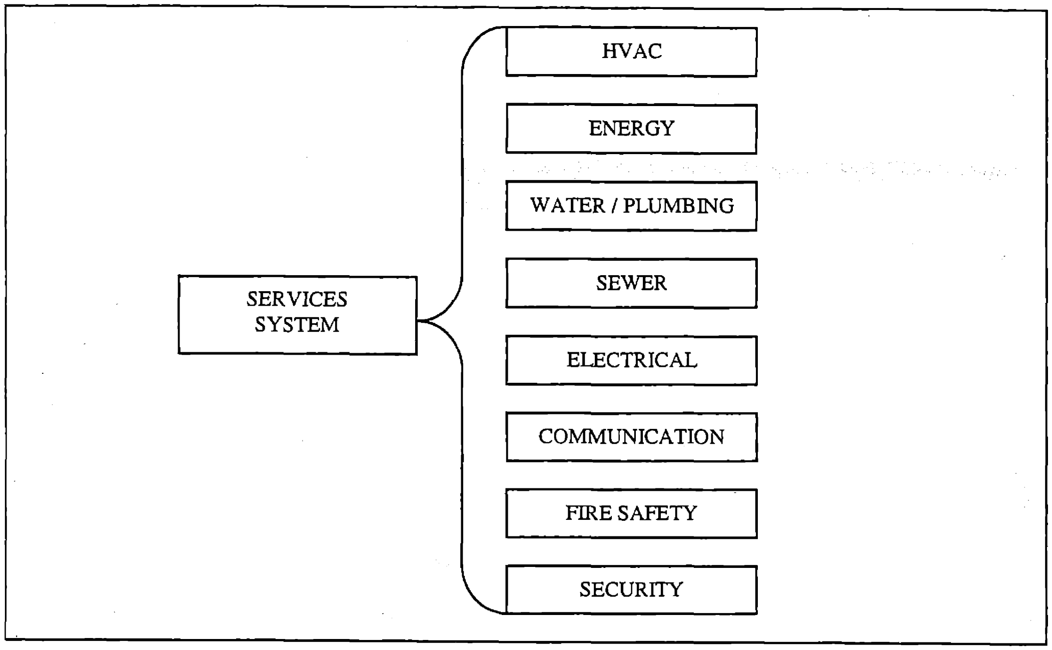
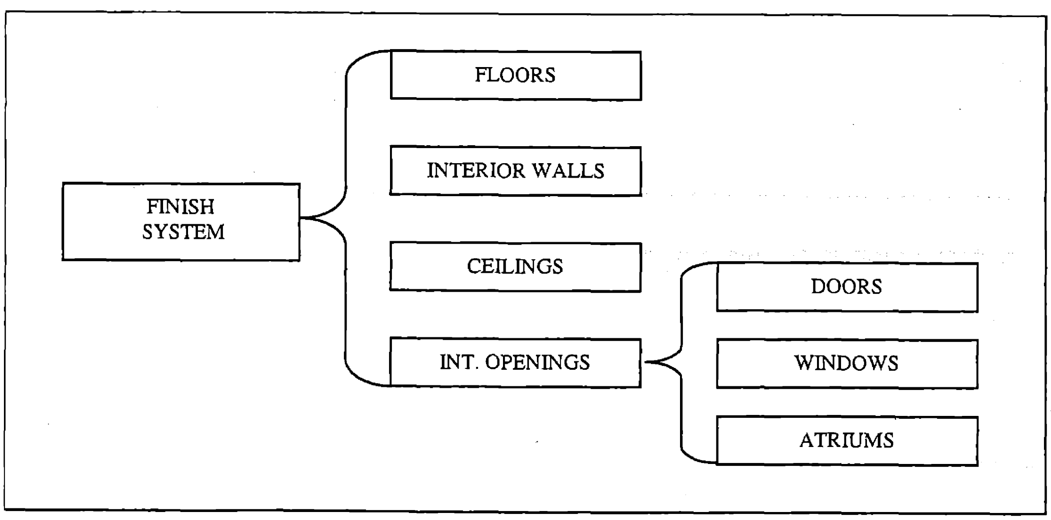


Figure 3.4 – Interior Finish System and Components



3.3 Definitions of Change Categories Used

During the actual life of a built facility, several different types of changes can be expected to occur. Most changes are caused by the factors listed below in Table 3.1.

Table 3.1 – Common Factors Which Cause Change in Buildings (Iselin and Lemer, ed., 1993).

Change Factors
The adoption of new standards and codes
Rising performance expectations
Major technological changes
Major changes in functional requirements
Major organizational changes
Shifts in property values
Poor maintenance or abuse of systems
Aesthetic shifts

While past research performed on building renovation and reuse has commonly classified such changes in the categories of function, economics, and technology, this research focuses on the physical systems and their capability to accommodate change rather than the causes of those changes.

For the purpose of this research, these changes which built facilities/buildings undergo, have been broken down into three main categories of change: function, capacity, and flow. Functions refer to the set of activities or components within a building which achieve a specific objective. They can be performed by the building itself (e.g., provide shelter) or with respect to human activities (e.g., transportation, manufacturing, and housing) (Slaughter, 1997). Capacity refers to the ability of a building, its systems, and their components, to meet certain performance requirements (Slaughter, 1997). Flow can be characterized as the building, its systems, and their components' interactions with the surrounding environment and its usage population. The flows can relate to climatic conditions (e.g., the circulation of air conditioning throughout a building) or to the movement of people and/or things (e.g., the movement of people from one floor to the next within a building) (Slaughter, 1997).

Each of the three change categories was broken into specific subcategories for analysis purposes. Changes in function include three main categories: 1) the upgrade of existing functions; 2) the incorporation of new functions within existing facilities; and 3) the modification of existing facilities to accommodate different functions or usage. The upgrade of existing functions generally entails the modification a set of existing activities or components to allow them to continue to achieve the same objective. For example, replacing single paned wood framed windows with double paned metal framed windows still achieves the same function (i.e., providing light and air), but the new window has additional attributes which may offer different benefits (e.g., lower maintenance costs, decreased air infiltration, and improved energy efficiency) (Slaughter, 1997). Incorporating new functions, on the other hand, refers to the addition of an activity or component that achieves a new objective in addition to those which already exist (Slaughter, 1997). For example, adding a passenger elevator within a school building might introduce an objective that was not previously met. Meanwhile, the modification for a new usage refers to the modification of a building, its systems, and/or their components to meet a totally new set of objectives (Slaughter, 1997). This change category provides clarification of the set of expected functions with respect to predictability and also provides specificity with regards to the change requirements from one usage to another.

Changes in capacity are separated into two categories: 1) The ability of a facility to meet certain performance criteria in loads or conditions, and 2) changes in the overall volume of the facility. Changes in loads and conditions can occur due to changes within the usage characteristics of a building, changes in the building codes, and changes in the surrounding environment (climatic and other) which effect the existing building. Changes in volume capacity generally refer to the provision or construction of additional useable space to allow the usage requirements of the building to be better met.

Changes in flow can be categorized as either: 1) changes in the surrounding environment, or 2) changes in the passage, movement or arrangement of people or things within a building space. Environmental flow changes commonly entail changes in climatic conditions with respect to air, heat, light, humidity, and others. Changes in the flow of people and things simply entail the management of people and things within a building.

All of the definitions for the change categories and subcategories are provided within Table 3.2 on the following page. For each of the change categories listed in Table 3.2, a set of measures were determined and used when analyzing the building cases. These analysis measures are listed within Table 3.3.

Table 3.2 – Definitions of Categories of Change

CHANGES IN FUNCTION:	**Relates to the set of activities or components that work together to achieve a specific objective.**
UPGRADE	The upgrade of existing facilities to meet the requirements of the building's usage class whether it remains the same or is new. (e.g., Improve the HVAC)
NEW FUNCTIONS	The incorporation of new functions within existing facilities to meet the requirements of the building's usage class. (e.g., Add air conditioning)
MODIFICATION	The modification of an existing facility to meet the requirements of and accommodate a different usage class. (e.g., Add bathrooms , etc., to change an office building into an apartment complex)
CHANGES IN CAPACITY:	**Relates to the ability of a facility to meet certain performance requirements.**
LOADS/CONDITIONS	The ability of a facility to meet certain performance criteria in loads and conditions for a particular usage class. (e.g., Changes in seismic requirements)
VOLUME	The incorporation of changes in overall building, or in system volume within a facility to meet the requirements of the particular usage class. (e.g., Add atriums or floors)
CHANGES IN FLOW:	**Relates to the interactions between a facility and the surrounding environment and its usage population.**
ENVIRONMENT	The incorporation of changes in the surrounding or internal environment within a building facility. (e.g., Enhancing of ventilation through mechanical systems, windows or both)
PEOPLE/THINGS	The incorporation of changes in the passage, movement or organization of people and objects within or around a building's space. (e.g., The installation of a new internal stairway)

Within the three general change categories, the exogenous changes which a building might experience (e.g., economic, aesthetic) were delimited. By examining the degree to which each of the four building systems can accommodate these three changes, the overall building flexibility was measured. The empirical data obtained through the analysis of the 45 case studies indicate that the characteristics of the four main systems (i.e., structural, enclosure, services, and interior finish) of a building establish the degree to which the existing systems can accommodate flexibility for the building as a whole. The results of this analysis were then used to create the foundation for the lifecycle design framework.

Table 3.3 – Analysis Measures used for each Change Subcategory

Change Category	Change Subcategory	Analysis Measure
Function	Upgrade of Existing Functions	*None*
		Repair
		Repair and Upgrade
		Upgrade
	Incorporating New Functions	*# New Functions*
	Modification for New Usage	*None*
		Minor
		Major
Capacity	Loads/Conditions	*None*
		Yes
	Volume	*None*
		Small
		Large
Flow	Environment	*None*
		Yes
	People/Things	*None*
		Yes

3.4 Design Framework

Using data collected from actual renovation projects, the framework presented in Table 3.5 was empirically derived. This framework can be used as a diagnostic tool to assess the capacity of a building to accommodate specific changes in requirements. The framework is a matrix with two dimensions, the four main building systems on the horizontal axis and the change categories on the vertical axis. These change categories were mapped for each of the four building systems. Using this mapping, and analyzing 26 detailed building renovation case studies, empirical data was gathered for developing the framework. The body of this framework consisting of the cells within it, displaying the empirically derived attributes within each building system that are critical for accommodating each of the respective change subcategories. All of these attributes were determined to be critical for allowing the particular changes to occur within the building for the renovation projects examined. By incorporating them into the framework, it is intended to provide designers, owners, and constructors with a starting point to consider prior to designing and building.

3.4.1 Mapping of the Change Categories to the Building Systems

The mapping of the change categories and subcategories to the four different building systems was critical for determining the relevance of this design framework. Therefore, it was important to ensure that the changes do in fact map with the building systems in a realistic and clear way. The mapping for each of the four building systems is explained in Table 3.4.

Table 3.4 – Building Systems vs. Change Categories Matrix: Definitions of each Change for the Respective Building Systems

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**	Any repair, reinforcement etc. of existing structural system for a similar use of the building	Any repair, washing, or upgrading of the existing building façade: including the walls and any windows or doors	Any repair, reuse or upgrade of existing services; replacement of existing outdated services with new ones	Any repair, reinforcement etc. of existing finishwork; existing walls repainted, replastered etc.
	Incorporating New Functions	Addition of new floors, areas, or any other structures that would require new structural members	Addition of new exterior - panels, atriums, etc. - that was not part of the existing exterior	Any addition of an entirely new service that was not included in the exiting building (e.g., A/C)	Installation of entirely new finishwork - new walls, etc.
	Modification For Different Usage	Any modification, reinforcement , of existing structural system to meet new building usage	Any repair, upgrade of the existing façade to meet the needs of the new building usage	Any repair, reuse or reworking of existing services or parts thereof to meet new building usage needs	Any repair, reuse or reworking of existing finishwork to meet new usage needs
CAPACITY	**Loads/ Conditions**	Changes to meet new loads or structural conditions	Changes in any load or condition which the exterior must support (e.g., Load bearing to non-load bearing panels)	Any changes in the amount of power or amount of connections for a service	Changes in any load or condition which the interior walls, etc. must support (e.g., Load bearing to non-load bearing walls)
	Volume	Changes resulting in overall changes in the volume of the building's space	Changes which result in overall changes in the volume of the building's space	Changes which result in overall changes in the volume of particular services	Changes which result in overall changes in the volume of the building's space
FLOW	**Environment**	Changes effecting overall environment within and around the building	Changes effecting overall environment within and around the building	Changes effecting overall environment within and around the building	Changes effecting overall environment within and around the building
	People / Things	Changes effecting overall movement or arrangement of people and things (furniture, etc.)	Changes effecting overall movement or arrangement of people and things (furniture, etc.)	Changes effecting overall movement or arrangement of people and things (furniture, etc.)	Changes effecting overall movement or arrangement of people and things (furniture, etc.)

3.4.1.1 The Structural System

All three of the main change categories and their respective subcategories map to the structural system of a building. The upgrade of existing functions within a building's structural system is simply the requirement of a higher functionality of the existing function. For instance, a change in building codes for higher load capacities due to certain equipment would require the upgrade of the current structural system to meet the loads (Figure 3.5). The incorporation of new functions within the structural system of a building could entail the addition of new structural members to accomplish new objectives, such as seismic dampers (Figure 3.6). The modification of the structural system for a different building usage, on the other hand, entails the reworking or upgrade of the existing building as well as the incorporation of any new structural members or functions that are required to meet the new building usage (Figure 3.7). While such changes could fit within the first two change subcategories defined, it was considered that all changes required to meet an overall change in building usage should be kept together for research purposes. This allows specificity to be made with regards to the change requirements from one usage to another and hence enhances the clarification of the set of expected functions that result from such changes in building usage.

Figure 3.5 – Example for Upgrade of Existing Functions for the Structural System: Wrapping of Structural Columns

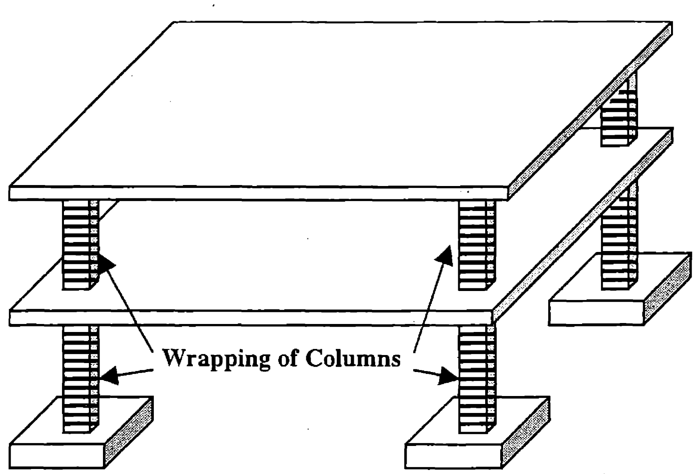


Figure 3.6 – Example for Incorporating New Functions for the Structural System: Installation of Seismic Dampers

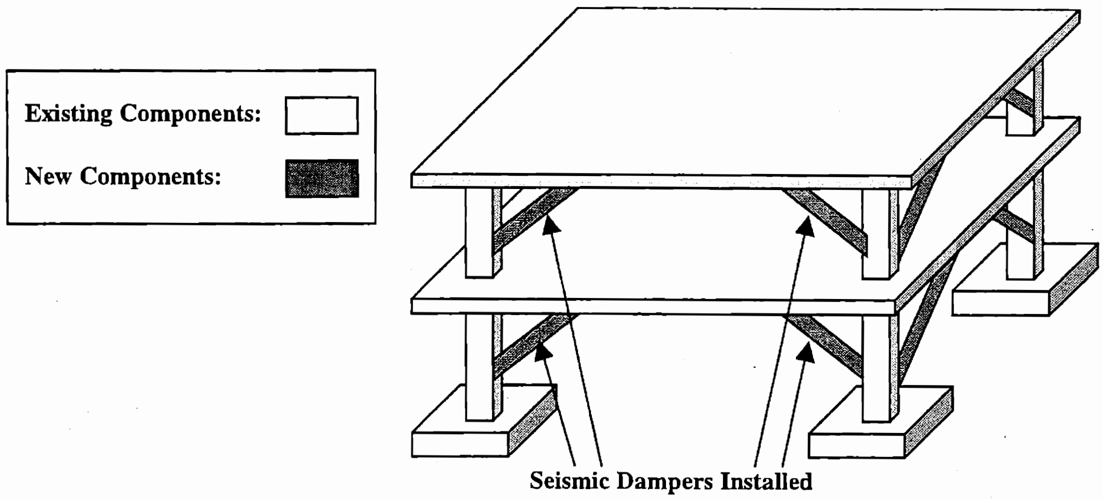
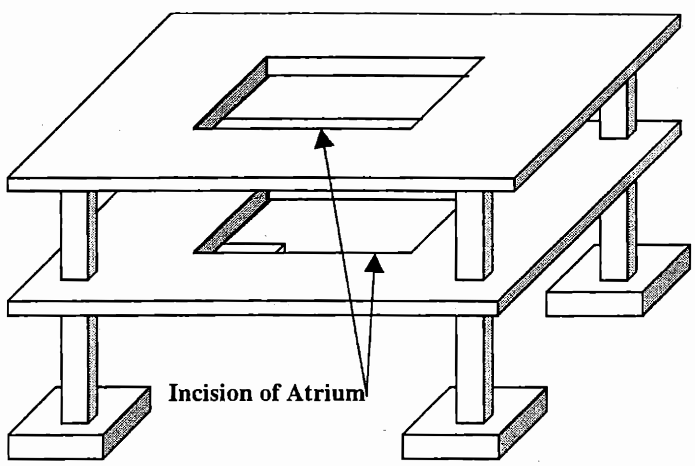


Figure 3.7 – Example for Modification for New Usage for the Structural System: Construction/Incision of Atrium within Building



With regards to changes in capacity, changes in loads and conditions within a structural system refer to any changes which are required due to a change within the loads or structural conditions which a building may experience (Figure 3.8). Changes in volume refer to changes in the volume of the structural system (e.g., the addition of extra floors), as well as changes that result in the building's volume due to modifications or upgrades of the existing building structure (e.g., the incision of large shaft openings in the floor slabs of a building effect the overall volume of the building) (Figure 3.9).

Figure 3.8 - Changes in Loads/Conditions for the Structural System

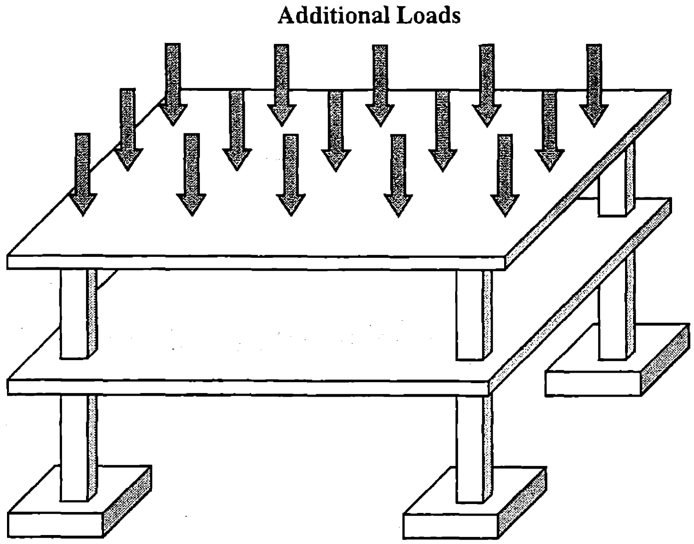
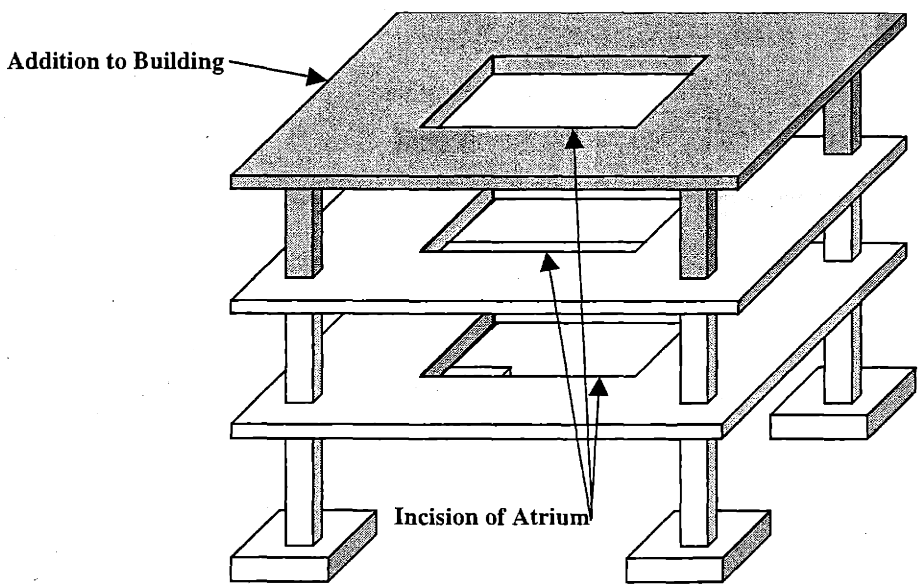


Figure 3.9 – Examples for Changes in Volume for the Structural System: Construction of an Addition and an Atrium



Changes in environmental flow, with regards to the structural system, generally refer to changes caused by site constraints or other building issues. While such changes in environmental flow are not prevalent for structural systems, changes in the flow of people and things are. Such changes in flow can be separated into two main categories: vertical flow, and horizontal flow. Changes in vertical flow involve issues regarding maintaining the stability and continuity of the structural floors while changing the flow of people and things (e.g., construction of utility shafts, new stairwells, and elevator shafts). Horizontal flow involves issues regarding the particular type of structural system (e.g., a masonry bearing wall system makes it hard to construct new openings such as doorways to change the flow within a building).

3.4.1.2 The Exterior Enclosure System

All three of the main change categories and their respective subcategories map to the exterior enclosure system of a building. The upgrade of the exterior enclosure refers to upgrade of the existing building façade including repair, washing and replacement of the walls, windows, doors, or the roof to meet the requirements of a higher function (Figure 3.10). The incorporation of a new function pertains to the addition of a new exterior or parts thereof, which continue to fulfill existing objectives while at the same time introducing a new functional objective. For example replacing existing fixed windows with operable windows still allows light to infiltrate the building but also provides a new mechanism for ventilation and the provision of outside air into the working space (Figure 3.11). The modification of an exterior entails any reworking of the exterior and its components to meet the requirements of a new building usage. For example, the reworking of a warehouse or manufacturing building with small windows to an office building with large open windows (e.g., 270 Albany Street, Cambridge, Massachusetts, see Appendix B) (Figure 3.12).

Figure 3.10 – Example of Upgrade of Existing Functions for the Exterior Enclosure System

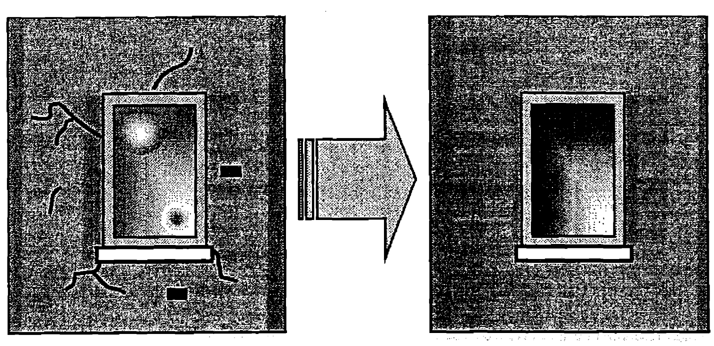


Figure 3.11 – Example of Incorporating New Functions for the Exterior Enclosure System: Replacement of Fixed Window with an Operable Window

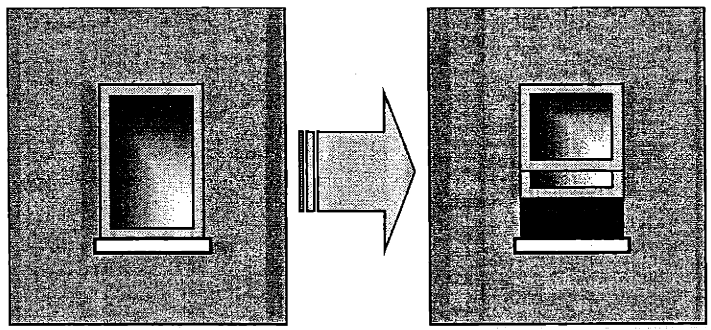
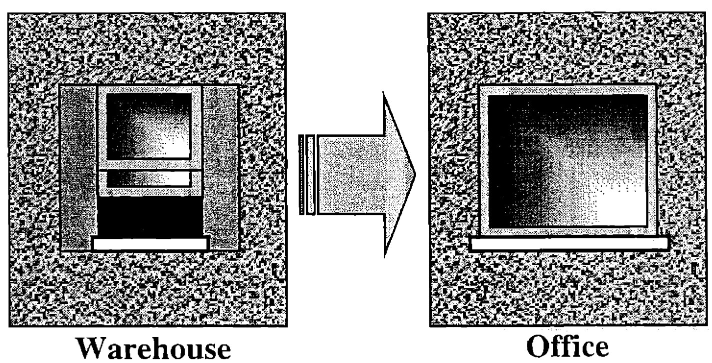
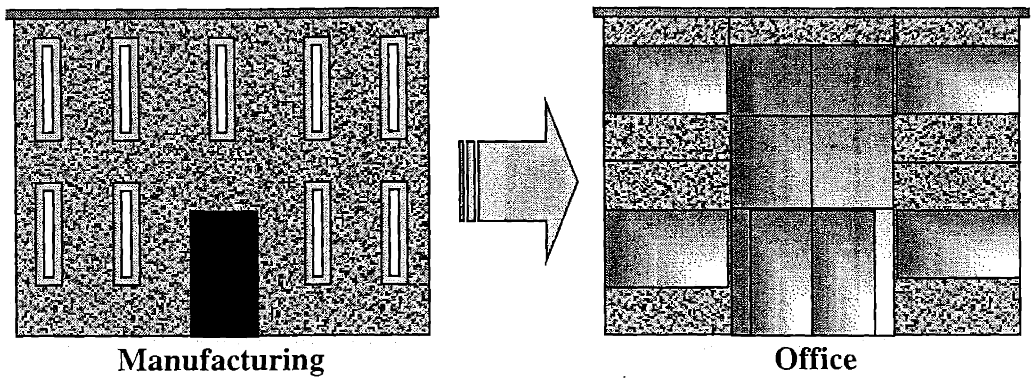


Figure 3.12 – Example of Modification for a New Usage for the Exterior Enclosure System: Change in Window Size from Warehouse Use to meet Office Use



Changes in capacity with respect to loads and conditions for the exterior enclosure system generally entails two main issues. The first incorporates the conditions of the exterior. The condition of the exterior refers to any deterioration, pitting, or other damage that might affect the overall stability or the appearance of the exterior enclosure. The conditions of the exterior generally result in changes in the loads which the exterior either supports or places on the building as the exterior requires modification and/or replacement of parts or all of the exterior systems to repair them. For example the replacement of an existing precast concrete panel exterior used for a manufacturing building with a new precast concrete paneled and glass curtain wall system to meet an office usage class (Figure 3.13). A change in volume capacity of the exterior enclosure system simply refers to a change in the overall volume of the exterior. For example, the addition of a new floor on top of a building or a new entrance lobby to the front of a building entails an increase in the volume of exterior to enclose it.

Figure 3.13 – Example of Changes in Loads and Conditions for the Exterior Enclosure System: Manufacturing to Office Building



A change in environmental flow with respect to the exterior enclosure refers to a change to the exterior enclosure, which alters the climatic conditions within a building. For instance, the replacement of fixed windows with operable windows allows the ventilation of air inside and the infiltration of air from outside a building (Figure 3.11). Similarly, a change in the flow of people and things entails a change to the exterior enclosure system that modifies the flow of people and/or things into and within a building. For example, the construction of a second entrance to a building which did not previously have one (e.g., 28 State Street, Boston, Massachusetts, see Appendix B).

3.4.1.3 The Services System

All three of the main change categories and their respective subcategories map to the services system of a building. The upgrade of existing functions within the services system entails the repair, reuse, and or replacement of existing services that have become obsolete for the particular objectives, which they fulfill. For example, old rotary telephones are replaced by touch tone telephones which are then replaced by wireless telephones. The incorporation of new functions with respect to the services system entails the addition of a new service within a building which originally was not required to meet the buildings usage but has since become necessary, for instance, the incorporation of a passenger elevator within an office or academic building to meet the Americans with Disabilities Act regulations. The modification of the services systems to meet a new building usage entails the repair and upgrade of existing services as well as the addition of new services within a building to meet the new usage. It is considered that such repair, upgrade and additions to the services system would not have taken place had the building's usage not changed. For example, when a manufacturing building is renovated to meet usage as a residential building, the existing electrical, plumbing and sprinkler systems must be upgraded and/or replaced, and a new HVAC system must be installed (e.g., Worthington Place, Cambridge, Massachusetts, see Appendix B).

Changes in capacity for the services system differ slightly from those within the other building systems. Changes in loads and conditions entail changes in the power, size, and amount of distribution means for the various service equipment and systems, such as enhancing an old telephone wire network to a larger fiber optic cable network. Changes in volume also entail changes in the size and distribution of the service systems within a building. For example, an increase in the amount of available outlets for computer and electrical equipment within an office building to meet required usage needs.

Changes in flow within the services system are interesting. Changes in environmental flow entail changes within the services system, such as the repair or upgrade of existing services and/or the addition of new services, which change the overall climatic conditions within and around a building (e.g., the incorporation of a new HVAC system within an office building). Changes in the flow of people and things, on the other hand, refer to changes in the services system, which modify the flow of people and things within and around a building. For example, the incorporation of a new passenger elevator within a building enhances the flow of people and things from on floor to the others.

3.4.1.4 The Interior Finish System

All three of the main change categories and their respective subcategories also map to the interior finish system of a building. The upgrade of existing functions within the interior finish system entails any repair, replacement, and reuse of the existing finishwork within a building (e.g., the rebuilding, replastering, and repainting of existing interior walls to form private rooms or the replacement of existing flooring or rugs with new materials). The incorporation of new functions entails changes to the interior finish such as the modification of an open office building plan to a more private enclosed office plan through the construction of new interior rooms and partitions. The modification of the interior finish system entails any repair, reuse, or reworking of the existing finishwork as well as the addition of new finishwork to meet the requirements of a new building usage (e.g., the adaptation of an open manufacturing space into numerous private apartment complexes, such as at Worthington Place, Cambridge, Massachusetts, see Appendix B).

Changes in capacity for the interior finish system resembled those defined for the structural and exterior enclosure systems. Changes in loads and conditions refer to any changes in the conditions of the existing interior walls, and other finish component and the respective changes in the loads which they might support and carry (e.g., changing flooring material to better take increased foot traffic within a building). Changes in volume entail changes to the interior finish system, which result in changes to the overall volume of the building. For example, the construction of new utility shaft areas, mechanical rooms, conference rooms, and private offices within the center of an office building, where none previously existed, changes the overall useful space for remaining office space and requires changes in the interior finish system.

Changes in flow are particularly interesting with regards to the interior finish system. Changes in environmental flow entail changes to the interior finish system, which effect the overall climatic conditions within a building such as the flow of air and light into and within a building. For instance, the modification of an open floor plan to a maze of private apartments changes the environmental flow within a building. Such a modification also effects the flow of people and things within a building. Changes in the flow of people and things with respect to the interior finish system entails similar changes to the finish system which modifies or adjusts the flow of people and things into, within, and around a building.

3.4.2 The Framework

The framework which is presented in Table 3.5 serves as a diagnostic tool for assessing the capacity of a building's four main systems to accommodate specific categories of change overtime. The framework displays the empirically derived attributes within each of the building systems that are critical for accommodating each of the respective change subcategories listed. This empirical data was obtained through detailed analyses performed on 26 case studies involving buildings that experienced extensive or emergency renovations. Through these analyses, the critical attributes, which require consideration before, during and after renovation of the building in question occurred, were determined and recorded. These attributes were then organized together and placed within the respective cells of the matrix shown in Table 3.5.

This framework functions as a starting point, which owners, designers, and constructors can refer to prior to proceeding with a renovation project. By using this framework as a reference, these professionals will be able to identify and therefore consider the necessary attributes which have been shown to influence renovation and its overall feasibility in past renovation projects.

Each of the attributes listed within the matrix possesses different yet similar definitions, depending on the building system that they apply to. For most of these attributes, the initially designed characteristics of the building system and the current and future conditions for which the system must operate must be compared and analyzed to predict the level of renovation required and thus the feasibility of pursuing that renovation. For example, when upgrading existing functions within the structural system of a building, it is important to consider the load capacity of the building's structure. This entails not only looking at what loads and conditions that the building must support in the future, but also entails an in-depth analysis of the loads and conditions which the building was originally designed to meet, as well as the loads and conditions which it currently carries. All of the definitions for these attributes are shown within Appendix C.

While this framework displays the attributes within each building system which are critical for allowing a building to accommodate each of the respective change categories over time, it does not display the interesting links which appeared to exist among the building systems as well as the change categories. While examining the building renovation project case studies, several interactions and linkages appeared to exist amongst the different building systems and the respective change subcategories. These linkages are listed with the attribute definitions found in Appendix C, and are further discussed in Chapter 5 of this thesis.

Table 3.5 – Summary Table of Systems by Change Category, Where Each Cell Displays a Specification of the Particular System Characteristic that is Critical to Accommodating the Respective Change Subcategory.

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**	LOAD CAPACITY BUILDING CODES SYSTEM TYPE	LOAD CAPACITY SYSTEM TYPE PERFORMANCE REQUIREMENTS SPECIAL REQUIREMENTS	LOAD CAPACITY SYSTEM TYPE PERFORMANCE REQUIREMENTS	SYSTEM TYPE SPECIAL REQUIREMENTS SPATIAL DIMENSIONS PERFORMANCE REQUIREMENTS BUILDING CODES
	Incorporating New Functions	LOAD CAPACITY PERFORMANCE REQUIREMENTS SPECIAL REQUIREMENTS BUILDING CODES SPATIAL DIMENSIONS	LOAD CAPACITY PERFORMANCE REQUIREMENTS SPATIAL DIMENSIONS	BUILDING CODES LOAD CAPACITY PERFORMANCE REQUIREMENTS SYSTEM TYPES	SPATIAL DIMENSIONS BUILDING CODES PERFORMANCE REQUIREMENTS
	Modification for New Usage	LOAD CAPACITY PERFORMANCE REQUIREMENTS SYSTEM TYPES SITE/BUILDING ISSUES	LOAD CAPACITY PERFORMANCE REQUIREMENTS SPECIAL REQUIREMENTS	LOAD CAPACITY SYSTEM TYPES PERFORMANCE REQUIREMENTS	BUILDING CODES PERFORMANCE REQUIREMENTS SPATIAL DIMENSIONS
CAPACITY	**Loads / Conditions**	LOAD CAPACITY BUILDING CODES SYSTEM TYPE	LOAD CAPACITY BUILDING CODES SYSTEM TYPE PERFORMANCE REQUIREMENTS	LOAD CAPACITY BUILDING CODES PERFORMANCE REQUIREMENTS SYSTEM TYPE	LOAD CAPACITY
	Volume	LOAD CAPACITY BUILDING CODES SITE/BUILDING ISSUES SPATIAL DIMENSIONS PERFORMANCE REQUIREMENTS	LOAD CAPACITY SPATIAL DIMENSIONS	LOAD CAPACITY SPATIAL DIMENSIONS PERFORMANCE REQUIREMENTS BUILDING CODES	SPATIAL DIMENSIONS PERFORMANCE REQUIREMENTS
FLOW	**Environment**	LOAD CAPACITY SITE/BUILDING ISSUES PERFORMANCE REQUIREMENTS	SPECIAL REQUIREMENTS PERFORMANCE REQUIREMENTS	BUILDING CODES PERFORMANCE REQUIREMENTS	PERFORMANCE REQUIREMENTS SPATIAL DIMENSIONS SITE/BUILDING ISSUES
	People / Things	LOAD CAPACITY SYSTEM TYPE PERFORMANCE REQUIREMENTS SPATIAL DIMENSIONS	PERFORMANCE REQUIREMENTS	PERFORMANCE REQUIREMENTS SYSTEMS TYPES SPATIAL DIMENSIONS	PERFORMANCE REQUIREMENTS SITE/BUILDING ISSUES SPATIAL DIMENSIONS

4 Methodology

4.1 Sources of Data

The objective of researching building renovation projects was to develop a design framework that could be used as a diagnostic tool to assess the capacity of an existing building to accommodate change and to incorporate flexibility within building design and construction. The main objective behind the data collection that was performed for this research was to develop theory with respect to empirical evidence. The development of this theory and the construction of the design framework required that information regarding construction and design practices, methods and materials be collected, analyzed and incorporated within the framework.

4.1.1 Data Collection

The data collection method that was used for this research consisted of two main steps. First, a literature review was conducted on the building construction industry, primarily concentrating on building renovation and reuse. Through this literature review, a comprehensive set of general case studies were found. Second, the research examined a select group of these case studies in detail to test the theories presented in the previous chapters of this thesis, and obtain the empirical data necessary to construct the design framework. This step also entailed site observations, and interviews with professionals directly involved in building renovation and reuse.

The literature review performed for this research involved the examination of engineering and construction reference books, journal articles, and newspaper articles. Through this literature research, a general list of 45 case studies was obtained for the purpose of this research. These case studies primarily consisted of current ongoing or recently completed construction projects within the Boston metropolitan area and several other regions throughout the United States and Canada that involved significant renovation or rehabilitation of occupied buildings. These construction and/or renovation projects excluded small interior finish renewal projects, and focused particularly on modification of at least two systems (structure, exterior enclosure, services, or interior finish), or complex reworking of one specific system, and often conversion to a new usage category.

4.1.1.1 General Cases (45 buildings)

The examination of journal articles and newspaper articles resulted in the compilation of a set of 45 different projects. All of the projects studied are located within North America (43 within the United States, 1 within Canada) with the exception of one that is located in Germany. Out of these projects, 42 projects involved the renovation of a building for the same usage or a new usage and three projects involved the construction of new buildings. Out of the case studies used for this research, 21 projects are located in the state of Massachusetts, with 16 of them within the Boston metropolitan area (including Boston, Cambridge, Charlestown and Watertown).

The three new construction projects included within this research were: Abbott Laboratories in Las Colinas, Texas; Toyota Motor Corp. Parts Center in Ontario, California; and the U.S. Federal Courthouse in Phoenix, Arizona (Appendix A for information on these buildings). While these projects are not renovation projects, they were included within this research because they are prime examples of design and construction projects that incorporate future changes. Abbott Laboratories was designed as a mix use facility which would allow the company the flexibility to quickly change the facility from office to manufacturing space over the first couple of years or the building's entire lifecycle. Toyota's warehouse building was designed and constructed to include amenities that would lower costs for maintenance, operations and insurance, and hence save the company money in the long run. The U.S. Federal Courthouse, on the other hand, incorporated a unique passive cooling system, which over the lifecycle of the building will result in energy cost savings.

Information was collected for each of the case studies researched using the data collection forms that are presented in Appendices A and B. This project data form was used once for each renovation project researched. It contains the basic project data, such as the project name, location, owner, contractor and architect names, start and completion dates (where available), past and future building usage class, past and future building systems within the building, and any special concerns which the project might have entailed (e.g., historic preservation or incorporation of flexibility within the design to meet future building facility needs). The complete listing of these general case studies, their location, and the reference from which they were obtained are shown in Table 4.1 on the following pages.

Table 4.1 – List of General Building Case Studies Used

#	PROJECT NAME	LOCATION	REFERENCE
1	Abbott Laboratories	Las Colinas, TX	Watkins-Miller, Elaine. (1996). "On the Pulse of Change." *Buildings*, 90(9, Sept.).
2	270 Albany Street*	Cambridge, MA	Rose, Joe. (1998). Phone and Site Interviews. Sienna Construction Co., Boston, MA, (January – August).
3	Building 16, MIT*	Cambridge, MA	Design and Construction Services, Physical Plant, MIT. (1994). "Buildings 16 and 56 Evaluation Study, MIT."
4	Building N42, MIT*	Cambridge, MA	McKennan, John. (1997). Phone and Site Interviews. Turner Construction Special Projects, Boston, MA. (Oct.).
5	Building 314*	Indianapolis, IN	Watkins-Miller, Elaine. (1998). "Building 314, Eli Lilly lab space discovers success." *Buildings*, (April), 36-40.
6	Charles River Business Center	Watertown, MA	Miara, Jim. (1998). "O'Neill wins Watertown Arsenal bid." *Boston Business Journal,* 18(5, March 13-19), 1,48.
7	Citicorp Tower*	Manhattan, NY	Morgenstern, Joe. (1995). "The Fifty-Nine-Story Crisis." *The New Yorker*, (May 25), 87-95.
8	DEC Headquarters*	Maynard, MA	Miara, Jim. (1998). "Massive DEC Headquarters to return as Class A space." *Boston Business Journal,* (April 3-9), 8.
9	Federal Office Building*	Norfolk, VA	Sawyer, Tom. (1997). "Recladding: No Longer Red in the Face." *Engineering News Record*, (May 26), 33-36.
10	75 Federal Street	Boston, MA	Lane, Bill. (1998). "Turning historical into high-tech." *Boston Business Journal,* (January 16-22), 29, 32.
11	Fitzpatrick Family Group Hotel	Manhattan, NY	"Pulse: New York." (1997). *Engineering News Record*, (October 27), 58.
12	Fort Point Channel Warehouses	Boston, MA	Brown, Diana. (1997). "Converting warehouses into premium offices." *Boston Business Journal,* (October 17-23).
13	GE Vapor Lamp Company	Hoboken, NJ	Wright, Andrew G.. (1997). "Hazardous Waste: Artists' dream space vanishes in a quicksilver twinkling." *Engineering News Record*, (September 1), 18.
14	Globe Department Store*	Waukegan, IL	Vangen, Clara M.W.. (1998). "College of Lake County Lakeshore Campus." *Buildings*, (April), 50-51.
15	Grand Central Station*	New York, NY	Rasmussen, Eric. (1997). "The Rebirth of a Station." *Civil Engineering*, (October), 54-57.
16	Hingham Shipyard	Hingham, MA	Salemi, Tom. (1998). "Reaction is mixed to revitalization plan for shipyard." *Boston Business Journal,* (January 23-29) 5.
17	Hood Business Park	Charlestown, MA	Babson, Jennifer and Richard Kindleberger. (1998). "Lots & Blocks: Hood Business Park." *The Boston Sunday Globe*, (January 11). "Pulse: Massachusetts." (1998). *Engineering News Record*, (April 6), 71.
18	Iowa State University Office*	Ames, Iowa	"Floors: Truss should squelch shaking." (1998). *Engineering News Record*, (June 15), 33.
19	K. Wayne Smith Building*	Dublin, OH	Watkins-Miller, Elaine. (1997). "K. Wayne Smith Building, OCLC writes a new page for warehouse, changing it to a multi-use facility." *Buildings*, (April), 56-58.

Table 4.1 (Cont.): List of General Building Case Studies Used

#	PROJECT NAME	LOCATION	REFERENCE
20	Lafayette Corporate Center*	Boston, MA	Lawlor, Patrick. (1998). "Behind the transformation of downtown's Lafayette Place." *Boston Business Journal, Real Estate Quarterly,* (January 23-29) 3, 15.
21	Liberty Tree Building*	Boston, MA	Martinelli, Scott. (1997). Phone and Site Interviews. Shawmut Design and Construction Co., Boston, MA. (Nov. 1997 – March 1998).
22	Mass. Museum of Contemporary Art	North Adams, MA	"MASS MoCA, Massachusetts Museum of Contemporary Art." (1998) Pamphlet.
23	Mount Auburn Hospital*	Cambridge, MA	Brenneman, Kristina. (1998). "Cambridge hospitals undergo $84M in renovations." Boston Business Journal, (January 16-22), 5.
24	705 Mount Auburn Street*	Cambridge, MA	Hubbard, Kim. (1997). Phone and Site Interviews. Kennedy and Rossi, Inc., Lexington, MA. (Dec. 1997 – March 1998).
25	Navy Pier	Chicago, IL	Patterson, Maureen. (1997). "Navy Pier, Precast concrete, space frame technology used in reconstruction." *Buildings*, (April), 68.
26	New Bedford Aquarium	New Bedford, MA	Bushnell, Davis. (1997). "New Bedford awaits ocean science center." *The Boston Globe*, (November 1).
			"Pulse: Massachusetts." (1997). *Engineering News Record*, (October 20), 81.
27	New York Life Building*	Kansas City, MO	Patterson, Maureen. (1997). "New York Life Building, Historical renovation marries state-of-the art environmental technologies with exquisite architecture of ages past." *Buildings*, (April), 52-54.
28	Nukeland	Kalkar, Germany	"Construction Week: Nukeland, Powerplant flop to be converted into an amusement park." (1996). *Engineering News Record*, (June 3), 7.
29	Philadelphia Naval Base*	Philadelphia, PA	Loomis, Gary W., and Dave P. Knepper. (1996). "Recasting a Foundry." *Civil Engineering*, (May), 14A-16A.
30	Polaroid Building*	Cambridge, MA	Thomas, Hillary. (1998). Phone and Site Interviews. Spaulding and Slye, Inc., Boston, MA. (Feb. – July).
31	Rush - St. Luke's Medical*	Chicago, IL	McManamy, Rob. (1997). "Fancy Footwork Finds Space for $42-Million Research Facility." *Engineering News Record*, (August 11), 32.
			"News: Engineers raise the roof at congested Chicago site." (1997). *Civil Engineering*, (July), 21.
32	Sage Hall*	Ithaca, NY	Angelo, William J.. (1997). "Adaptive Reuse: Exoskeleton saves historic façade for new school building." *Engineering News Record*, (October 27), 22-24.
33	266 Second Avenue*	Waltham, MA	Muller, Scott . (1997). Phone and Site Interviews. John Moriarty and Associates, Boston, MA. (Dec.).
34	Standard Life Tower*	Calgary, Alberta	Monroe, Linda K.. (1998). "The Standard Life Tower, Contemporary technologies update a tires, 1970s structure." *Buildings*, (April), 52-53.

Table 4.1 (Cont.): List of General Building Case Studies Used

#	PROJECT NAME	LOCATION	REFERENCE
35	28 State Street*	Boston, MA	Patterson, Maureen. (1998). "28 State St., Sleek high-rise opens a window to history nearby." *Buildings*, (April), 44-46.
36	255 State Street*	Boston, MA	"On Spec: Work starts at 255 State Street." (1998). *The Boston Globe*, (January), E-1. Kliener, Peter. (1998). Phone and Site Interviews. Schwartz Silver Architects, Boston, MA. (Jan. – Oct.).
37	Stop and Shop Building	Boston, MA	*The Boston Informer*. (1997). (33/34; Fall).
38	Toyota Motor Corp. Parts Center	Ontario, CA	Rosenbaum, David B.. (1997). "Toyota spends a little more to save a lot on big warehouse." *Engineering News Record*, (February 24), 13.
39	Trump International Hotel and Tower	New York, NY	"Trump International Hotel and Tower." (1998). *http://www.sunshinegroup.com/trump.html.*
40	Two Tequesta Point Condominiums	Miami, FL	Post, Nadine M.. (1998). "Engineer's troubles spur reviews, and repairs at condo." *Engineering News Record*, (June 8), 14-15.
41	Union Station*	Seattle, WA	"Seattle's Union Station marked for new life as development hub." (1997). *Engineering News Record*, (October 13), 20.
42	Union Station – 2	Kansas City, MO	"Museum rolls into train station." (1998). *Engineering News Record*, (April 27), 17.
43	U.S. Courthouse/Federal building	Pheonix, AZ	Raman, Mahadev, and Bein, Hogan and Sheldon. (1996). "Visualizing the Flow." *Civil Engineering*, (June), 43-45.
44	Washington Junior High School	Duluth, MN	"News: Defunct schoolhouse gets a new life." (1997). *Civil Engineering*, (July), 20.
45	Worthington Place*	Cambridge, MA	Russell, Dick. (1997). Phone and Site Interviews. Worthington Place, Cambridge, MA.

* Note: Cases which were studied in more detail

4.1.1.2 Detailed Cases (26 buildings)

Out of the 45 general case studies, 26 cases were examined further in more detail. This set of detailed case studies and their locations are represented in Table 4.2. The buildings associated with these cases were each examined in detail with regards to the project data sheets described in Section 4.1.1.1. Their particular usage class, their building systems, and any changes that were experienced through their renovation were determined. For each case study, the building's past and future usage class was determined. The past building systems (e.g. the type of structural system in the building, such as concrete, steel framed, or masonry) and the changes that were made to them to allow the building to meet its renovated use were also identified. Along with this information, any special concerns regarding the building and its renovation, including the acknowledgement and incorporation of expected changes, were explored.

Table 4.2 – List of Detailed Case Studies Used

#	PROJECT NAME	LOCATION
1	270 Albany Street	Cambridge, MA
2	Building 16, MIT	Cambridge, MA
3	Building N42, MIT	Cambridge, MA
4	Building 314	Indianapolis, IN
5	Citicorp Tower	Manhattan, NY
6	DEC Headquarters	Maynard, MA
7	Federal Office Building	Norfolk, VA
8	Globe Department Store	Waukegan, IL
9	Grand Central Station	New York, NY
10	Iowa State University Office	Ames, Iowa
11	K. Wayne Smith Building	Dublin, OH
12	Lafayette Corporate Center	Boston, MA
13	Liberty Tree Building	Boston, MA
14	Mount Auburn Hospital	Cambridge, MA
15	705 Mount Auburn Street	Cambridge, MA
16	New York Life Building	Kansas City, MO
17	Philadelphia Naval Base	Philadelphia, PA
18	Polaroid Building	Cambridge, MA
19	Rush - St. Luke's Medical	Chicago, IL
20	Sage Hall	Ithaca, NY
21	266 Second Avenue	Waltham, MA
22	Standard Life Tower	Calgary, Alberta
23	28 State Street	Boston, MA
24	255 State Street	Boston, MA
25	Union Station	Seattle, WA
26	Worthington Place	Cambridge, MA

** Note the references from which these cases were obtained are shown in Table 4.1*

All of this information was then organized according to the change categories defined within Chapter 3. The purpose of this analysis was to identify trends, links, and interactions between and among the four building systems and the change categories. These organized matrices, with the building systems on the horizontal axis and the change categories on the vertical axis, were created for each of the 26 detailed case studies and can be found within Appendix B. The trends, links, and interactions are presented in Chapter 5.

4.2 Relevance of Data Collection

To ensure that the framework accurately represents issues within the construction industry and is as representative as possible, data was obtained from case studies and then validated through interviews with professionals within the construction industry. The determination of the case studies used to provide this data, as well as the determination of the list of professionals who verified it, was made based on several different factors which are outlined within this section.

4.2.1 Determination of Site Cases Used

The site cases for this research were chosen based on the availability of information. This availability stems from two main factors. First, this research concentrated on renovation projects which involved substantial reworking of several of the four building systems, or the difficult and risky reworking of one of the building systems (e.g., the Citicorp Building project or the Federal Office Building project; see Appendix B). Such projects have been recognized either nationally or locally through journal, magazine, or newspaper articles due to the level of renovation required, the risk undertaken, or the success/failure that was experienced, and therefore information regarding them was readily available. Second, approximately 47% of the general case studies (21 out of the 45 projects) and 50% of the detailed case studies (13 out of the 26 projects) are located within the state of Massachusetts, with a large concentration within the areas in and around the city of Boston. These cases provided an easy source for information through local articles as well as through personal interviews and site visits.

4.2.2 Selection of Professional Contacts

Despite numerous site visits and article references, some of the required data on the projects researched was incomplete or required validation. For the purpose of filling in these voids and validating the results that were obtained through the analyses on the general and detailed case studies and analysis, a set of professionals within the building construction industry was interviewed (Table 4.3).

Table 4.3 – List of Professional Contacts

#	COMPANY NAME	CONTACT NAME	CONTACT'S LOCATION	TYPE OF COMPANY
1	Cathartes Group of Boston	Richard Graf	Boston, MA (phone)	Owner / Developer
2	MIT – Real Estate	Phil Trussell	Cambridge, MA (phone / personal interview)	Owner / Developer
3	MIT – Real Estate	Peter Lewis	Cambridge, MA (phone / personal interview)	Owner / Developer
4	Shawmut Design and Construction	Tim Hurdelbrink	Boston, MA (phone / personal interview)	Construction Management / General Contractor
5	Gastinger Walker Harden Architects	Kevin Harden	Kansas City, MO (phone)	Architect
6	Legat Architects Inc.	Arthur Del Muro	Chicago, IL (phone)	Architect
7	Schwartz Silver Architects	Peter Kliener	Boston, MA (phone / personal interview)	Architect
8	National Development of New England	Bryan Clancy	Newton Lower Falls, MA (phone)	Developer
9	National Development of New England	John Onufrak	Newton Lower Falls, MA (phone)	Developer
10	Massachusetts Port Authority	Christopher Gordon	East Boston, MA (phone)	Developer
11	Kennedy and Rossi Inc.	John Kennedy	Lexington, MA (phone / personal interview)	Construction Management / General Contractor

This list consists of professionals within architecture firms, general contracting / construction management firms, development firms and owners primarily from the Boston metropolitan area, but also including three professionals from elsewhere in the United States. The professionals on the list were chosen due to their individual experiences with the detailed case studies used within this research and/or their experiences with building renovation and reuse within the building construction industry. These professionals were used as contacts to determine the accuracy and relevance of the data that was obtained from other sources and organized within the framework that is presented in this report. These contacts were also used to see if and how the framework might differ within different geographic regions.

4.3 Validity, Reliability, and Representativeness of Data

The main goal of this research is not to prove a hypothesis, but instead is to develop a theory regarding the incorporation of change within building design. This is an area of research that has been discussed before; however this discussion has never been followed up with actual data collection before. The purpose of this research is to provide a diagnostic tool which can be used by owners, developers and designers to determine what factors should be considered prior to renovation or design work, as well as a foundation from which future research can be performed.

4.3.1 Validity and Reliability of the Data

The research approach which was used for collecting data provided an effective means for addressing the issues of validity and reliability of construction and renovation processes used to develop the design framework as a reasonably good approximation of reality. Empirical data was collected from three main sources: literature, site visits, and interviews. This data was then used to develop a design framework, which was incorporated into a design packet. This packet was sent to several professionals within the construction industry for their review. Follow-up interviews with these professionals on the packet reinforced the validity of the data collected. These reviews allowed the framework, and the data that was used to develop it, to be cross-checked and tested to ensure that it represented reality as accurately as possible. Through each of these measures, the empirically gathered information, and therefore the design framework, can be considered valid and reliable within the context of renovated buildings.

4.3.2 Representativeness of the Data

While the data collected in this research were valid and reliable, it was also important that it be representative as well. Therefore, three main factors were used to insure the representativeness of the data that was used for this research: Location, the Type of Design/Construction Company, and Building Type. The case studies that were used, and hence the data that was obtained, involved predominantly Massachusetts based projects. However, the sample of case studies does include several other projects that are located within other geographic regions of the United States (e.g., central U.S.). This geographic diversity was used to ensure that the data which was collected was representative of building construction throughout much of the U.S. and was not restricted solely to construction within the state of Massachusetts.

This emphasis on geographic diversity was also included within the selection of the professional contacts that were used to validate the data. While most of the interviewed professionals are located within Massachusetts, they also have experience with building construction and renovation projects in several different regions of the U.S. They also present diversity in the type of firm which the represent, since the firm types include architecture firms, general contracting / construction management firms, and development firms as well as owners. By using such a diverse list of professional contacts to review the data that was obtained, the representativeness of the data was evaluated and found to be adequate.

The third factor that was used to ensure the representativeness of the data was the type of building projects that were used. Although the majority of the projects are offices, the sample as a whole provided examples of several different building types. These buildings include light manufacturing, industrial, warehouse, institutional, retail, research and development, residential and office usage. The high proportion of office buildings that were included within the research sample can be attributed largely to the amount of projects from Massachusetts that were used for this report; 15 out of 21 general case studies and 9 out of 13 detailed case studies that were located in Massachusetts were offices. Despite this high number of office buildings, the overall sample pool can be considered representative of the mid-sized occupied buildings in the U.S.

5 Presentation of Results

5.1 General Results

As explained within the Methodology Chapter, this research involved the detailed examination of 26 projects from a pool of 45 general case studies. Through this detailed examination, several interesting trends and interactions have been determined for the building systems studied as well as the change categories that they have experienced. These trends and interactions will be presented in this chapter.

The analysis performed on the data obtained from the case studies first began with a general overlook of the entire detailed case study sample. The 26 detailed case studies were examined to determine the general counts of projects experiencing the respective change categories. These case studies were then explored in more detail as the counts were further broken down to incorporate the individual change subcategories within the change categories. Using the counts that were taken from these case studies, frequencies, representing the percentage of the sample that was studied which experienced change within the respective change subcategory, were determined. While these detailed counts were initially made for the sample of 26 cases as a whole, counts and frequencies were also made after breaking the sample down according to whether they incorporated renovation to meet the same usage or renovation to meet a new and different usage. By breaking the case studies according to this organization, a comparison of renovation to same and different usage class within buildings could be made.

Through the count and frequency analysis, the case studies appeared to present several interesting patterns and trends within their renovation for the same as well as different usage classes. Each of these patterns and trends were examined. The first involved the links and interactions that became apparent not only within and among the four building systems but also within and among the respective change subcategories that they experienced. These links and interactions were determined and examined. Flowing from these apparent links within the building systems and change categories appeared an interesting cascade in building system changes. This cascade was then followed by another cascade in building usage that appeared in the case studies. Through analyzing all of these links, interactions, and trends and the resulting cascades in changes important information regarding the renovation of existing buildings was obtained, which in turn can be used to enhance building flexibility and make renovation easier.

5.1.1 Whole Sample

The 26 detailed case studies were examined according to their building systems and the experiences with the change categories (Chapter 3). By making a general count of the projects that had experienced the respective change categories, some interesting trends and characteristics began to appear. Table 5.1 displays the counts that were made for the entire 26 case studies examined.

Table 5.1 - General count of Buildings in the Sample (26) Which Experienced the Respective Changes

	Structural	Enclosure	Services	Finish	Any
Changes in Function	*19*	*22*	*21*	*21*	*26*
Changes in Capacity	*19*	14	*20*	14	*25*
Changes in Flow	16	14	16	*18*	*24*
# with Change in at least one of the categories	*19*	*22*	*23*	*23*	

The results of this count show several trends within the building projects analyzed. As shown in the far right column of Table 5.1, all 26 buildings experienced change in function for at least one of the four main building systems. 25 out of the 26 buildings studied experienced changes in capacity and 24 out of 26 experienced change in flow for at least one of their building systems. The table also shows that functional changes experienced by the buildings studied were more or less consistent across the board for all of the building systems.

As expected, the Table shows that changes in capacity were substantially higher for the structural and service systems than they were for the remaining systems. The high number for the service systems can be attributed to the rapid increases in technological changes within buildings and their increased incorporation within today's building. These increases within the service capacity could also in part contribute to the high amount of projects experiencing changes in structural capacity. Increases in services are often involve increases or variances in overall loads applied to the structure, through the incorporation of new, larger equipment, the incision of larger shaft spaces within structural floors, or other required structural modifications.

Within the changes in flow category, the interior finish system presents the highest amount of buildings that experienced changes. It is expected that renovation will involve the reorganization of the interior finish space and hence change the overall flow of people and things, and thus the interior environment within a building. While the number in this area is high, as expected, the number of projects whose exterior enclosure system experienced changes in flow is substantially lower than expected. It is generally perceived that renovation of an exterior is performed to enhance a building's appearance and make the building more pleasing and welcoming to the public. In a sense, such changes reinvent the environmental flow around the building as well as the flow of people into and out of the building. However, according to the results presented in the table, it appears that most projects are "expanding the bubble but are refraining from actually opening it", as they show a high amount of upgrade of existing function and incorporating new functions for the exterior enclosure system.

Looking at the building systems, at least 19 of the buildings studied experienced some form of change within the structural system, 22 experienced change within the enclosure system, and 23 experienced changes for both the services and interior finish systems. It is interesting to see that while traditionally one would expect to see a high number of changes within the services and interior finish systems, we also see that a large number of buildings also incorporated changes within the structural and exterior enclosure systems as well. The high amount of changes in the structural system is definitely intriguing. This could be attributed to possible skewness in the sample; however, this issue of representativeness is covered within the methodology section of the report. This could also resemble an issue within building renovation that has been ignored in the past and therefore is a valid issue for further research.

Another fact to note is that none of the systems, and none of the change categories resulted in a null set of data. A change of some aspect was experienced in all of these categories.

While Table 5.1 presents a general count of the building systems and the changes that were experienced, these counts can be further broken down and examined according to the individual change subcategories. The results of such an analysis are presented in Table 5.2. Taking the counts, which are represented within this table, and comparing them with the entire sample of detailed case studies, frequencies were determined. These frequencies, which are shown in Table 5.3, represent the percentage of the sample which was studied (26 projects) which experienced change in the respective change categories. These frequencies are graphically represented by Figures 5.1, 5.2, and 5.3. Figure 5.1 represents the percentage of the building cases that experienced changes in function (Upgrade of existing functions, the incorporation of new functions, and modification for different usage). Figure 5.2 represents the percentage that experienced changes in capacity (Loads/conditions and volume). The percentage that experienced changes in flow (Environment and people/things) is represented within Figure 5.3.

Table 5.2 – The Numbers of Buildings in the Sample (26) which Experienced the Respective Changes

Changes in Function				
	Structural	**Enclosure**	**Services**	**Finish**
Upgrade	5	18	10	9
New Functions	7	9	10	5
Modification (out of 26)	13	11	13	13
Changes in Capacity				
	Structural	**Enclosure**	**Services**	**Finish**
Loads/Conditions	12	10	18	2
Volume	10	7	17	13
Changes in Flow				
	Structural	**Enclosure**	**Services**	**Finish**
Environment	12	14	13	14
People/Things	10	3	5	13

Table 5.3 – The Percentage of the Sample (26) Which Experienced the Respective Changes

Changes in Function				
	Structural	Enclosure	Services	Finish
Upgrade	19%	69%	38%	35%
New Functions	27%	35%	38%	19%
Modification (out of 26)	50%	42%	50%	50%
Changes in Capacity				
	Structural	Enclosure	Services	Finish
Loads/Conditions	46%	38%	69%	8%
Volume	38%	27%	65%	50%
Changes in Flow				
	Structural	Enclosure	Services	Finish
Environment	46%	54%	50%	54%
People/Things	38%	12%	19%	50%

Figure 5.1 – Changes in Function: Upgrade, New Functions, and Modification for the Entire Case Study Sample

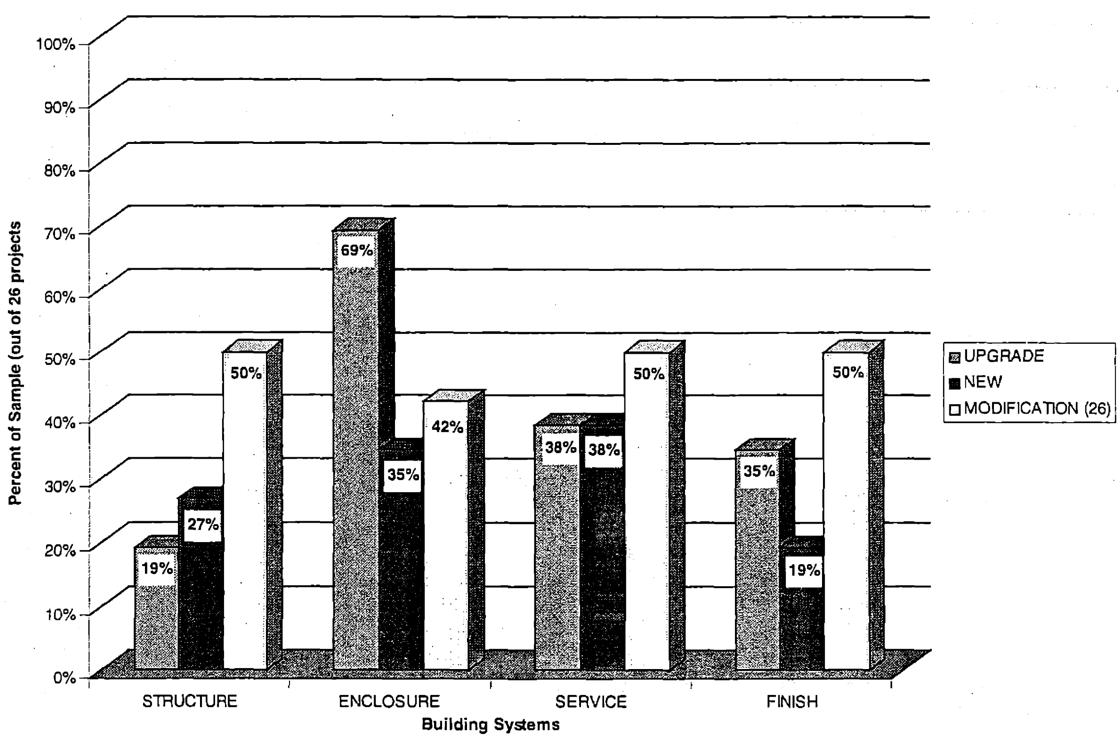


Figure 5.2 – Changes in Capacity: Loads/Conditions and Volume for the Entire Case Study Sample

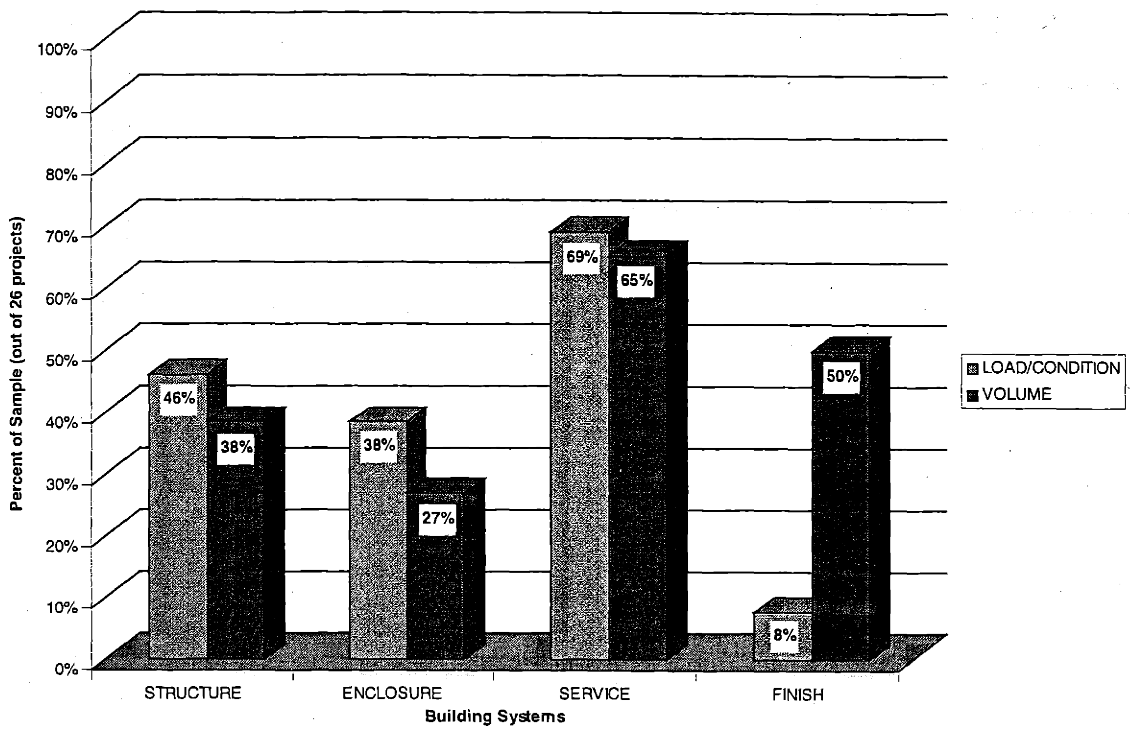
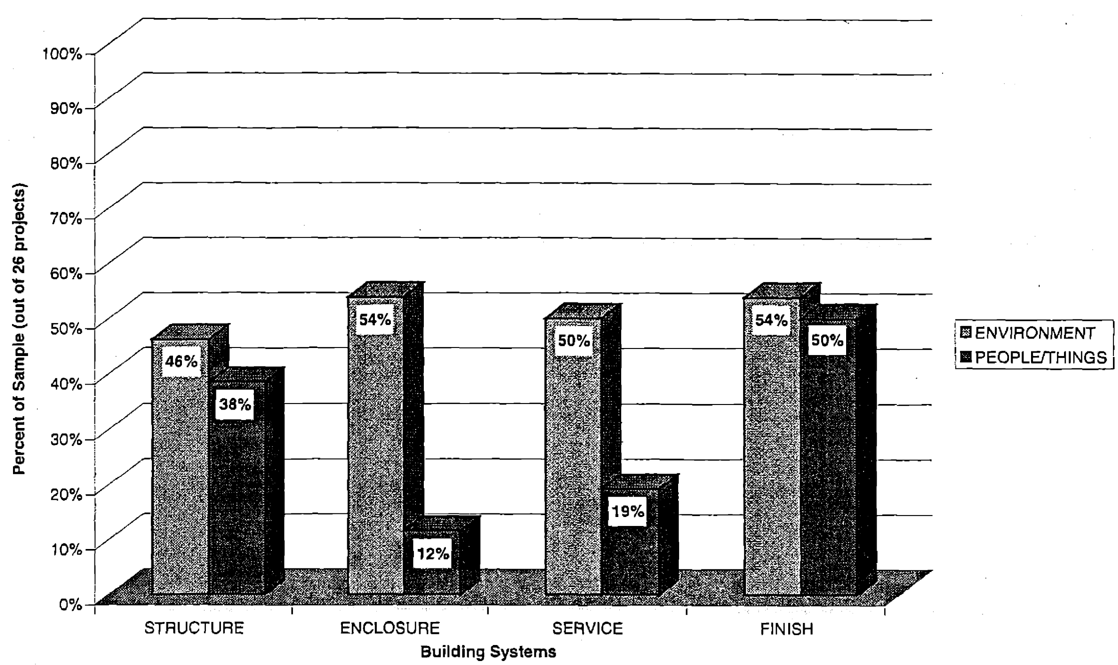


Figure 5.3 – Changes in Flow: Environment and People/Things for the Entire Case Study Sample



Upon analyzing the results presented in the Tables 5.2, and 5.3, and represented in Figures 5.1, 5.2, and 5.3, several general trends in the sample become evident. As shown in Figure 5.1, approximately half of the projects studied presented modification of the structural, service and interior finish systems. This figure also shows that the majority of the projects experienced an upgrade of the exterior enclosure system. Figure 5.2 shows that a majority of the projects experienced changes in loads/conditions and volume capacity within the services systems. This figure also shows that a majority of the projects presented changes in volume capacity for the interior finish system. Meanwhile, Figure 5.3 reveals that a majority of the projects present changes in the environmental flow around the building through changes within the exterior enclosure, services and interior finish systems. This figure also displays that a majority of the projects exhibit changes in the flow of people and things within the interior finish system, as well as an interestingly high percentage of changes in the flow of people and things within the structural system.

5.1.2 Sample Displaying Renovation for the Same Usage Class

The group of 26 building projects presented two general end usage classes for which they were renovated. Therefore, the entire sample of 26 projects was broken down into these two groups, namely those that were renovated to meet the same usage requirements and those that were renovated to meet new and different usage requirements. Out of the 26 projects, 11 projects were renovated for the same usage, while the remaining 15 projects were renovated for a different usage.

The 11 projects that were renovated for the same usage were examined in the same manner as the entire sample of 26, as explained in Section 5.1.1. The individual building systems that made up these projects were examined according to the change subcategories. A count was made for the numbers of these cases that experienced each of the respective change categories as shown in Table 5.4. These counts were then used to calculate the frequencies that are shown in Table 5.5. These frequencies represent the percentage of the 11 case studies examined that experienced each of the respective change subcategories. These frequencies are graphically represented within Figures 5.4, 5.5, and 5.6. Figure 5.4 provides the percentages of the 11 same usage projects that experienced changes in function (Upgrade of existing functions, the incorporation of new functions, and modification for different usage). Figure 5.5 represents the percentage that experienced changes in capacity (Loads/conditions and volume). The percentage that experienced changes in flow (Environment and people/things) is represented within Figure 5.6.

Table 5.4 – The Numbers of Buildings in the Sample Displaying Renovation for the Same Usage (11) which Experienced the Respective Changes

Changes in Function				
	Structural	**Enclosure**	**Services**	**Finish**
Upgrade	4	6	7	7
New Functions	3	5	3	4
Modification	0	0	0	0
Changes in Capacity				
	Structural	**Enclosure**	**Services**	**Finish**
Loads/Conditions	5	3	6	1
Volume	2	2	5	4
Changes in Flow				
	Structural	**Enclosure**	**Services**	**Finish**
Environment	4	3	4	5
People/Things	1	1	3	3

Table 5.5 – The Percentage of the Sample Displaying Renovation for the Same Usage (11) which Experienced the Respective Changes

Changes in Function				
	Structural	**Enclosure**	**Services**	**Finish**
Upgrade	36%	55%	64%	64%
New Functions	27%	45%	27%	36%
Modification	0%	0%	0%	0%
Changes in Capacity				
	Structural	**Enclosure**	**Services**	**Finish**
Loads/Conditions	45%	27%	55%	9%
Volume	18%	18%	45%	36%
Changes in Flow				
	Structural	**Enclosure**	**Services**	**Finish**
Environment	36%	27%	36%	45%
People/Things	9%	9%	27%	27%

Figure 5.4 – Changes in Function: Upgrade and New Functions Same Usage
(Note: No Modification changes were experienced by buildings renovated for the same usage)

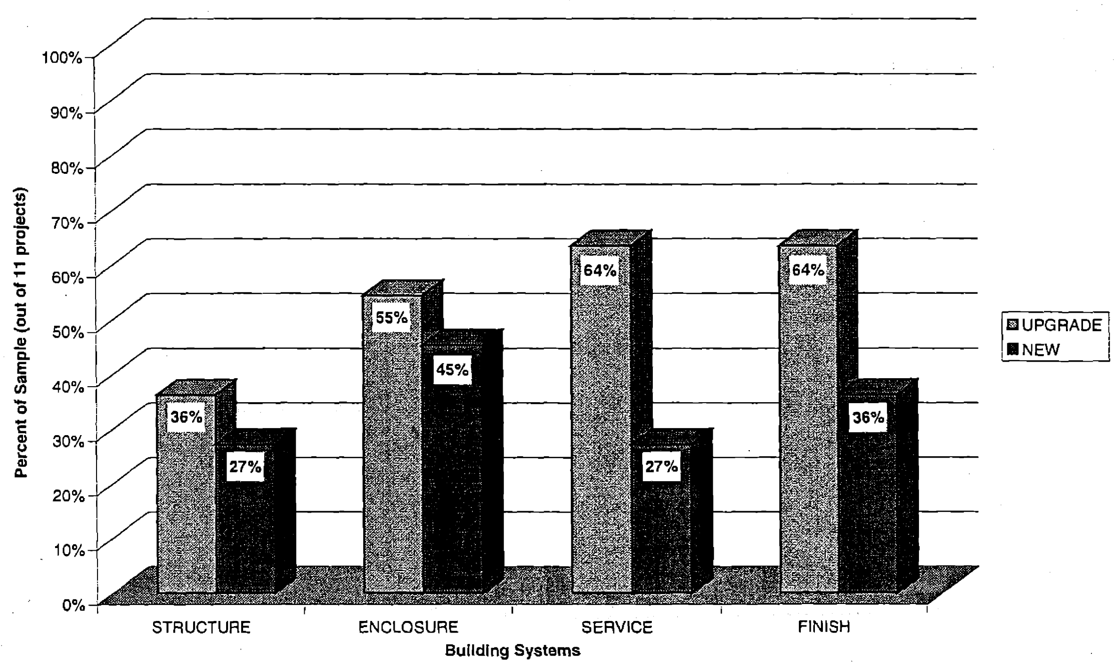


Figure 5.5 – Changes in Capacity: Loads/Conditions and Volume for Same Usage

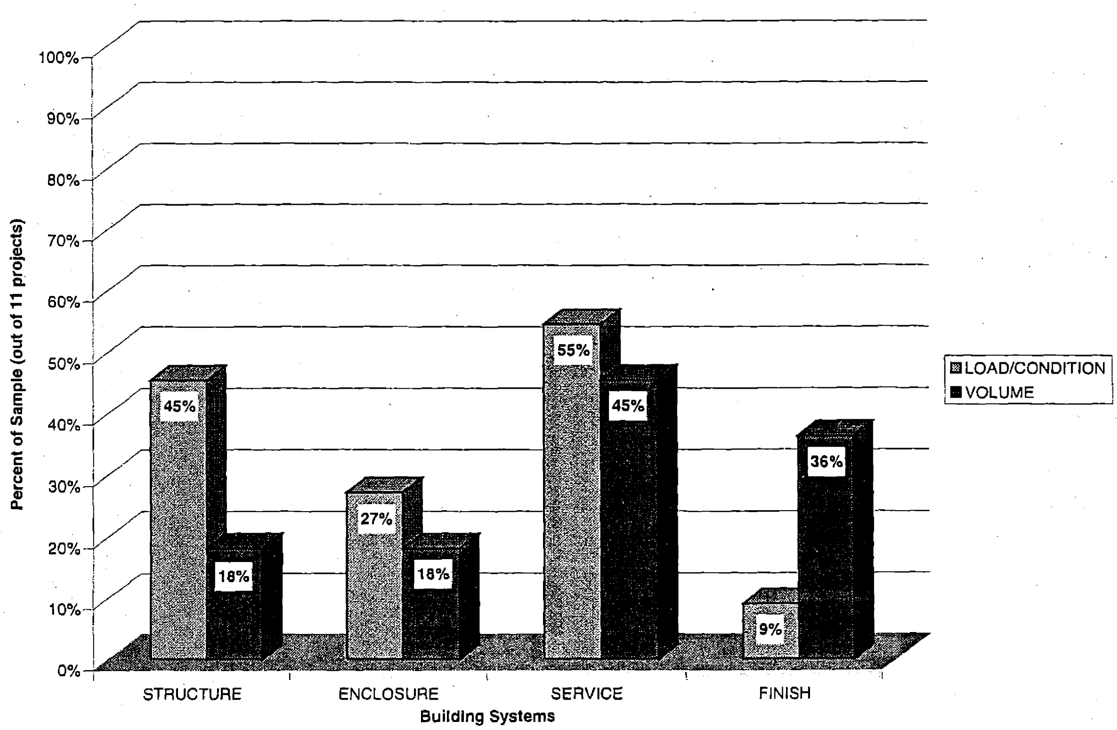
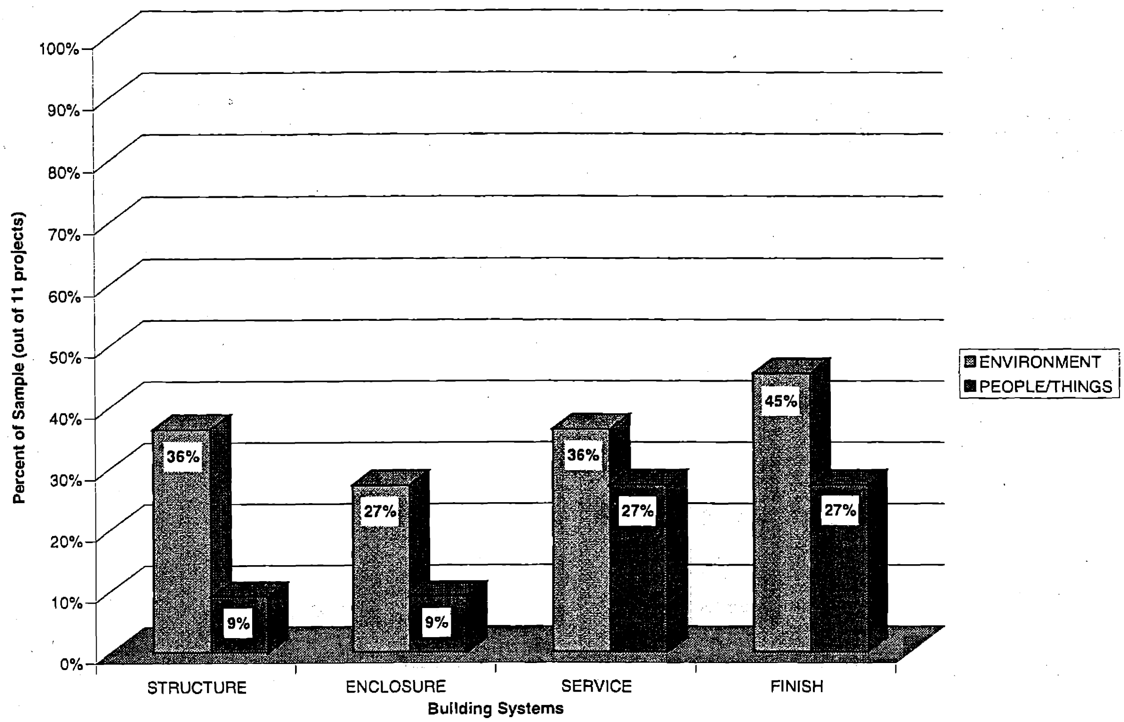


Figure 5.6 – Changes in Flow: Environment and People/Things



The results presented in the Tables 5.4, and 5.5, and represented by Figures 5.4, 5.5, and 5.6 display several general trends for those projects that were renovated to meet requirements for the same usage class. By definition, Tables 5.4 and 5.5, and Figure 5.4 show that none of the 11 projects exhibited any modification of their systems during renovation, since they were staying within the same usage class. They do show that a majority of the projects experienced functional upgrades within their exterior enclosure, services and interior finish systems. Figure 5.5 shows that a majority of the projects experienced changes in capacity for loads/conditions within the services systems. This is expected, since most renovation projects within the same usage class involve the enhancing of existing services to meet the power and technological needs of the current and future times. It is interesting to note that these 11 projects also presented fewer changes in volume capacity, environmental flow, and the flow of people/things for all of the building systems studied than the full sample.

5.1.3 Sample Displaying Renovation for a Different Usage Class

While 11 of the 26 projects presented renovation for the same usage, the remaining 15 projects were renovated to meet a new and different usage. Like the same usage sample, the building systems within these projects and their relevant changes were determined and counts were made. The number of changes and types of changes experienced within this sample is shown in Table 5.6. Again frequencies were calculated for this sample using these number counts as presented in Table 5.7. These frequencies represent the percentage of the 15 different usage case studies examined that experienced each of the respective change subcategories. These frequencies are graphically represented within Figures 5.7, 5.8, and 5.9. Figure 5.7 provides the percentages of the 15 different usage projects that experienced changes in function (Upgrade of existing functions, the incorporation of new functions, and modification for different usage). Figure 5.8 represents the percentage that experienced changes in capacity (Loads/conditions and volume). The percentage that experienced changes in flow (Environment and people/things) is represented within Figure 5.9.

Table 5.6 – The Numbers of Buildings in the Sample Displaying Renovation for a Different Usage (15) which Experienced the Respective Changes

Changes in Function				
	Structural	**Enclosure**	**Services**	**Finish**
Upgrade	1	12	3	2
New Functions	4	4	7	1
Modification (out of 15)	13	11	13	13
Changes in Capacity				
	Structural	**Enclosure**	**Services**	**Finish**
Loads/Conditions	7	7	12	1
Volume	8	5	12	9
Changes in Flow				
	Structural	**Enclosure**	**Services**	**Finish**
Environment	8	11	9	9
People/Things	9	2	2	10

Table 5.7 – The Percentage of the Sample Displaying Renovation for a Different Usage (15) which Experienced the Respective Changes

Changes in Function				
	Structural	Enclosure	Services	Finish
Upgrade	7%	80%	20%	13%
New Functions	27%	27%	47%	7%
Modification (out of 15)	87%	73%	87%	87%
Changes in Capacity				
	Structural	Enclosure	Services	Finish
Loads/Conditions	47%	47%	80%	7%
Volume	53%	33%	80%	60%
Changes in Flow				
	Structural	Enclosure	Services	Finish
Environment	53%	73%	60%	60%
People/Things	60%	13%	13%	67%

Figure 5.7 – Changes in Function: Upgrade, New Functions and Modification for Different Usage

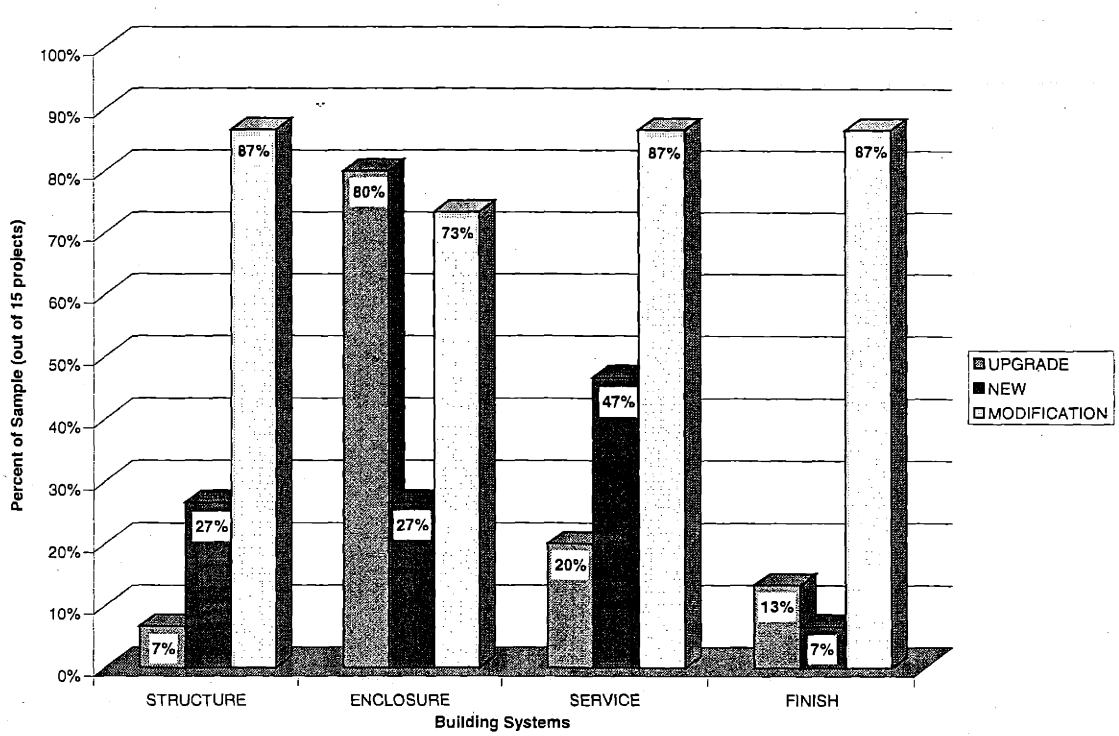


Figure 5.8 – Changes in Capacity: Loads/Conditions and Volume for Different Usage

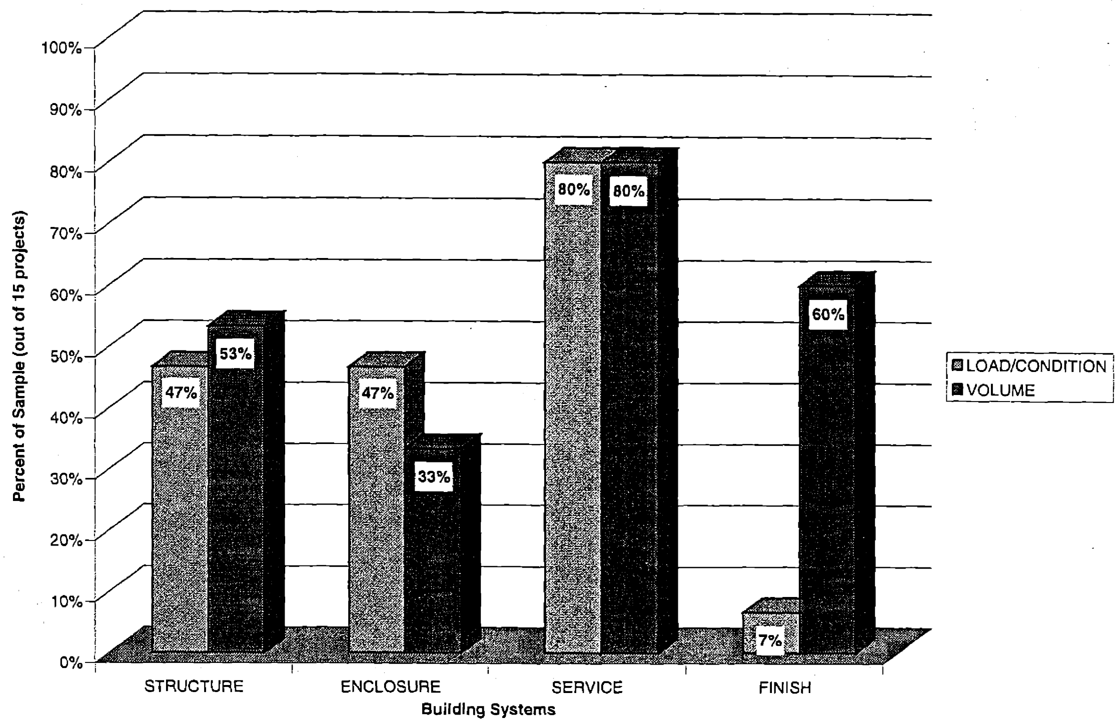
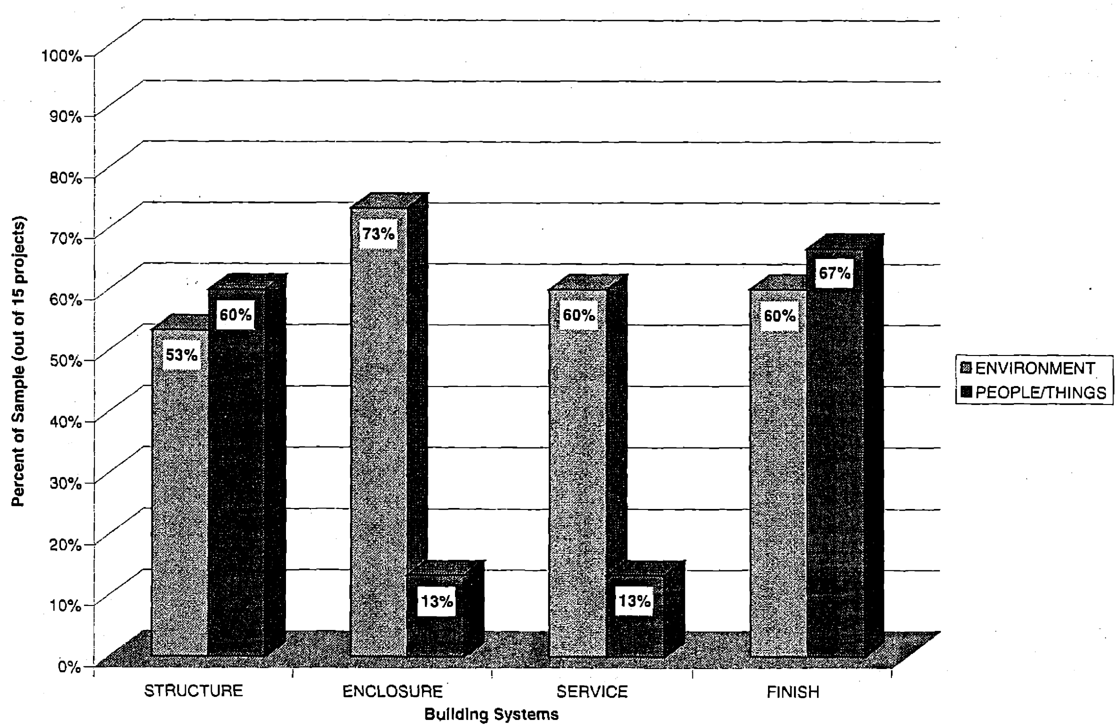


Figure 5.9 – Changes in Flow: Environment and People/Things for Different Usage



The results presented in these tables and figures provide interesting trends within renovation for a different and new usage class. By definition, Figure 5.7 shows that a large majority of the buildings studied presented some form of modification within all four of the building systems (structural, exterior enclosure, services and interior finish systems). It also shows that a majority of the projects incorporated some form of functional upgrade of the exterior enclosure system. The data, as shown in Figure 5.8, reveals that a majority of the projects experienced changes in the capacity of loads/conditions for the services systems. It also shows that a majority experienced changes in volume capacity for the structural, service and interior finish systems. Figure 5.9 shows that a majority of the projects presented changes in environmental flow for all four building systems, while the majority of projects experiencing changes in the flow of people/things was limited to the structural and interior finish systems.

5.1.4 Comparison of Renovation for Same and Different Usage Class

The results of the counts and frequencies displayed within the previous sections of this chapter show interesting differences within the change categories experienced by the building systems for renovation for same usage and renovation for different usage. It is important to note that this comparison excludes any results involving the modification for different usage change subcategory, based on its definition.

Comparing the buildings renovated for the same usage to those renovated for a different usage, several interesting trends arise. These same usage buildings displayed a higher percentage of changes in function for the structural system, a lower percentage for the exterior enclosure and higher percentages for both the services and interior finish systems. The higher percentage of change encountered within the structural system is unusual. However, this can be largely attributed to the categorization and definition of the modification change subcategory. The lower percentage of change in the exterior enclosure system and the higher percentages for the services and interior finish systems are expected. Traditionally, renovation projects embody the upgrade or revamping of the services within a building as well as a reorganization of the building's interior finish system. This is particularly relevant to buildings that are renovated to meet the same usage class.

Changes in capacity for the same usage buildings resulted in a lower percentage of change in volume for the structural system, and a lower percentage in both loads/conditions and volume for the exterior enclosure, services, and interior finish systems than the new usage buildings. The lower percentage of volume changes within all of the building systems is expected. Renovation for the same usage commonly does not require large changes in the buildings or its systems volume. The lower percentage of changes in loads/conditions for the exterior enclosure system is also expected. However, the lower percentage of changes in loads/conditions for the services system was not expected. In most renovation projects, in which a building is being restored to meet its same usage class, the work is concentrated within the building's services and bringing them up to current and future standards. This task commonly involves increasing the power capacity and depth of the existing services, but it appears from this sample that renovation for same usage does not necessarily entail increases in service capacity.

Changes in flow for the same usage buildings resulted in a lower percentage of change in both environmental flow and the flow of people/things for the structural system, a lower percentage in environmental flow for both the exterior enclosure and the services systems, and a lower percentage in both environmental flow and the flow of people/things for the interior finish system than the new usage buildings. The lower percentages in change for both environmental flow and the flow of people and things for the structural and interior finish systems are expected. Renovation for the same usage generally doesn't involve much work in these systems which might effect or result in great changes to the overall flow within a building. The lower percentage of environmental flow change in both the exterior enclosure and services systems, on the other hand, is unusual. It is often perceived that one of the primary reasons behind the renovation of a building for same usage is to improve and make the environment within and around the building more comfortable to its occupants. This goal has commonly been achieved through work on the exterior enclosure and services systems; however, analysis of this sample of same usage buildings indicates that renovation for same usage may not include significant changes to the exterior enclosure or services systems to accomplish environmental or process flows.

5.2 Patterns across the Case Studies

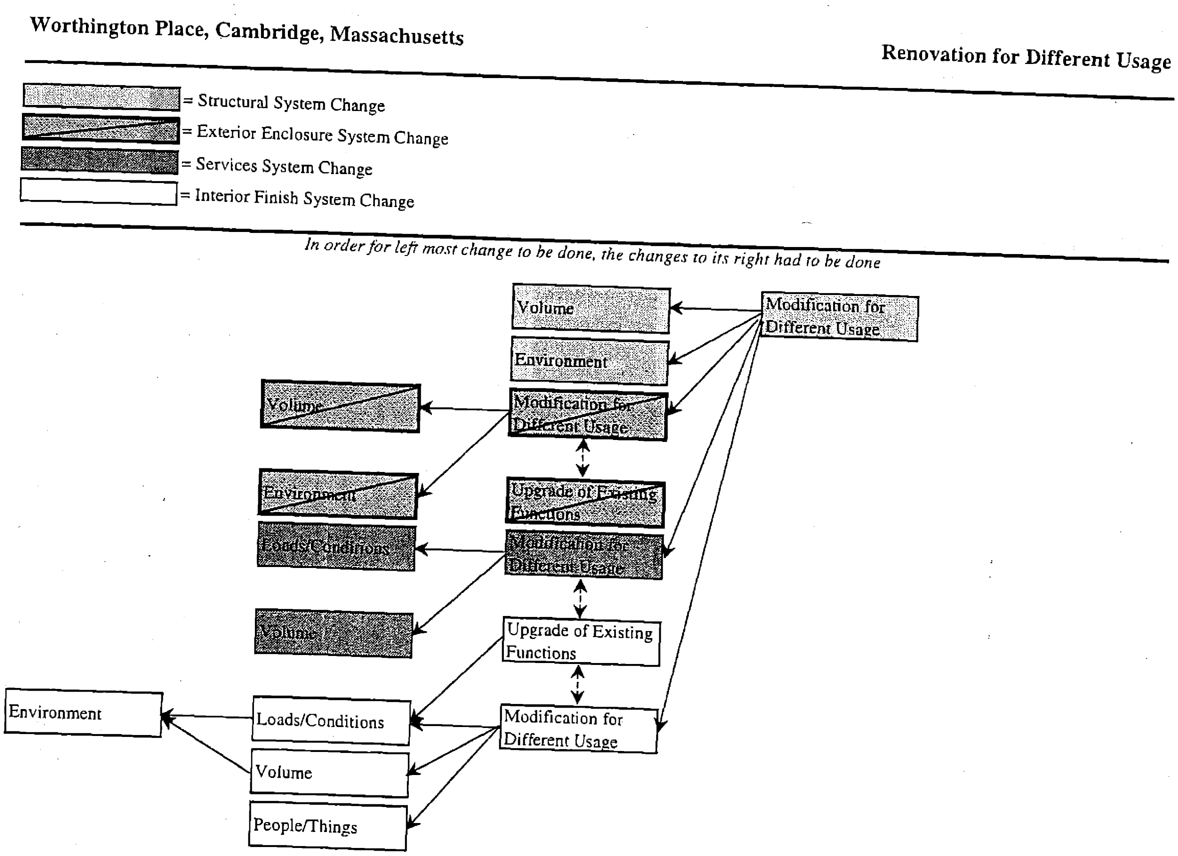
Through the analyses that were performed on the 26 case studies, several links among the change categories and the building systems became evident. While particular building systems might have experienced changes in one change category, that change might have been in response to a change experienced in another building system, or even a different type of change experienced by the building system. For example, the incorporation of a new HVAC condensing unit might increase the loads applied to the building's structural system, thus requiring upgrade or reinforcement of the structural system to meet the new load requirements. In other words, the service system experienced a functional change that resulted in a change in the capacity for loads/conditions of the structural system, thus requiring a structural upgrade to meet the new loads (e.g., Building N42, MIT). Several different links for each of the systems and for each of the different change categories were discovered within the 26 case studies analyzed.

The changes that occurred within each of the 26 detailed case studies were organized according to the progression in which they were completed. These organizational change charts are presented within Appendix B, with each of the respective 26 building cases. An example of one of these charts is shown in Figure 5.10. This figure represents the progression of changes experienced by the Worthington Place project in Cambridge, Massachusetts (Appendix B). For example, before the modification of the exterior enclosure system could be made, the modification to the structural system had to be made. Meanwhile, the upgrade of the exterior enclosure system occurs simultaneously with the modification of the enclosure system as shown by the dashed line with the double arrows.

By developing and examining charts, like this one, for each of the 26 case studies, some interesting trends became apparent. By separating the cases into two categories according to renovation for the same and different usage class, some differences emerged. The progression of changes for buildings renovated for the same usage did not have as many levels of change. Furthermore, the changes within one building system was not as reliant on changes in other building systems for the same usage buildings; in other words, the changes within the building systems were for the most part uncoupled from changes within the other building systems. A few of these projects also displayed changes within only one of their building systems (Citicorp Building, Federal Office Building, and Iowa State University Office, see Appendix B). This lower amount of coupling among the building systems and the changes which they experience, as well as the few projects displaying changes in only one building system, could be attributed to the case studies which were used, and possibly to the strategy of building selection for same usage renovation.

With regards to the buildings that were renovated for a new usage, all of the projects displayed cluttered and entangled progressions of change. A larger majority of projects showed that the building systems and the changes within them were coupled together and interacted with each other. This was predominantly true for the structural and services systems within these projects.

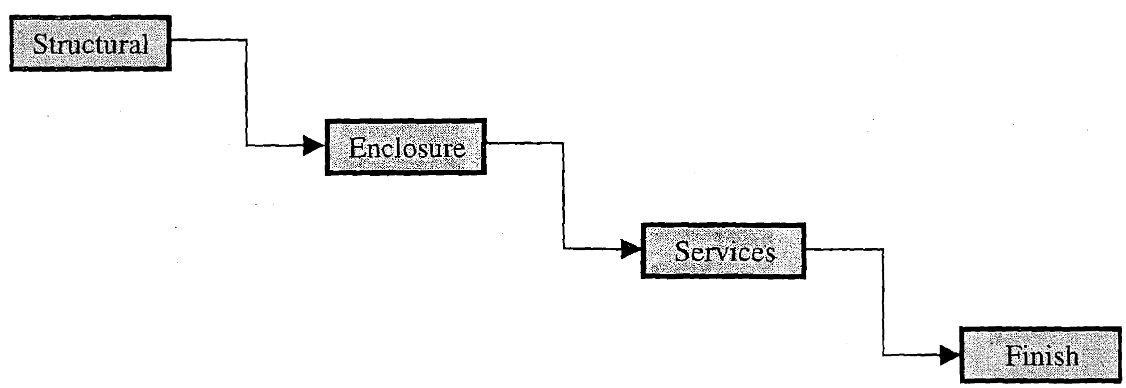
Figure 5.10 – Example of Change Progression Chart: Worthington Place, Cambridge, Massachusetts



5.3 Cascade of Building System Changes

In the past, common thought within the building construction industry presented a general cascade with which changes in building systems generally occur. Traditionally, it has been believed that changes to the structural system precede changes to the exterior enclosure system that in turn preceded changes to the services systems followed by changes to the interior finish system. This general cascade of changes within the building systems is represented by Figure 5.11. In a sense, these building systems and hence any changes within them have remained coupled in the past. For example, when changes are required in the service system, changes are usually also made within the interior finish system. In the past, it was thought that most building renovations follow the same general pattern. Depending on the scale of the renovation to be performed, work would generally follow this pattern, beginning with the upgrade or modification of the structural system, then proceeding to changes to the exterior enclosure system, followed by work on the service systems and finishing with changes to the interior finish systems.

Figure 5.11 – General Cascade of Changes within Building Systems



While this pattern or cascade in building system changes is common, it does not always have to occur for building renovations to succeed. During the analyses performed on the case studies used in this research, each case was compared to this system cascade. The cases were examined according to the end product with which they were to be renovated for: renovation to meet the same usage, or renovation to meet a new and different usage.

Although some of the cases renovated for the same usages appear to follow the traditional cascade, a large proportion of them does not. The eleven case studies that presented renovation for the same usage and the links between the changes in the building systems are represented by Figure 5.12 and summarized within Table 5.8 as shown below.

Figure 5.12 – Links between Changes in Building Systems for Same Usage

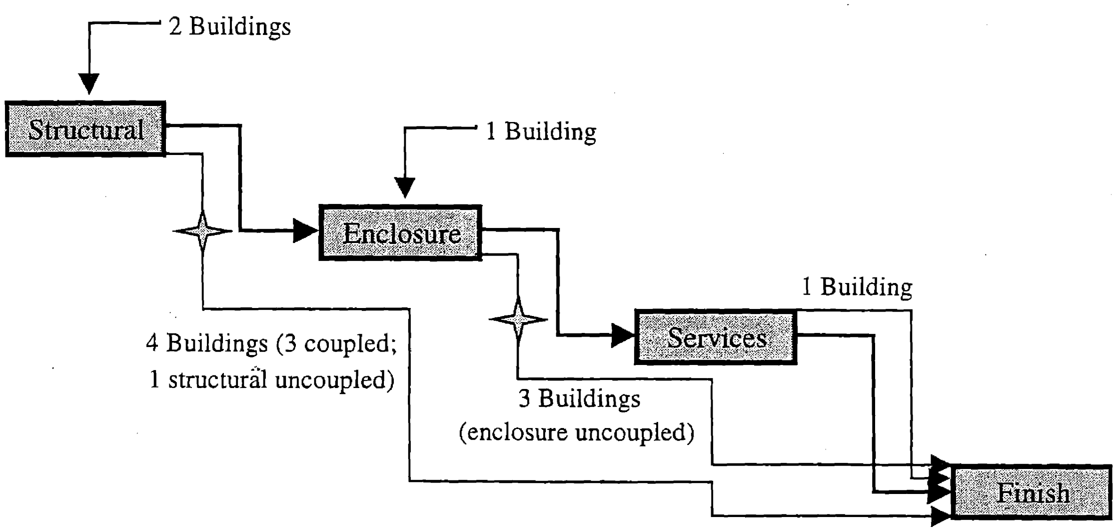


Table 5.8 – Cascade of System Changes within the Detailed Case Studies of Buildings Renovated for the Same Usage

	SAME USAGE			
PROJECT	**STRUCTURAL**	**EXTERIOR ENCLOSURE**	**SERVICE**	**INTERIOR FINISH**
Building 16, MIT				
Citicorp Tower				
Federal Office Building				
Grand Central Station				
Iowa State University Office				
Mount Auburn Hospital				
New York Life Building				
Rush - St. Luke's Medical				
Standard Life Tower				
28 State Street				
Union Station				

= UNCOUPLED = COUPLED

Out of the eleven projects, four buildings required work within all four of the building systems. Out of these four buildings, three of them (Mt. Auburn Hospital, Rush Presbyterian/St. Luke's Medical Center, and Union Station) followed the general cascade, while the fourth (28 State Street) had uncoupled the work on the structural system from the work performed on the remaining three systems (which continued to follow the cascade). Three of the buildings (Building 16, New York Life Building, and Standard Life Tower) displayed work on the last three systems (enclosure, service and interior finish), yet with the work on the exterior enclosure system was uncoupled from the work on the final two systems. Meanwhile, 2 buildings (Citicorp Building and Iowa State University Office Building) had work performed solely on their structural systems and 1 building (Federal Office Building) had work performed solely on its exterior enclosure system with minimal disruption of the other systems. The work performed on the service and interior finish systems for all eleven of the buildings remained entirely coupled together. This includes the work performed on Grand Central Station, which consisted largely of work performed on these two systems.

The building cases that displayed renovation for a new and different usage show similar results. These results are represented within Figure 5.13 shown below and summarized within Table 5.9, at the top of the following page.

Figure 5.13 – Links between Changes in Building Systems for Different Usage

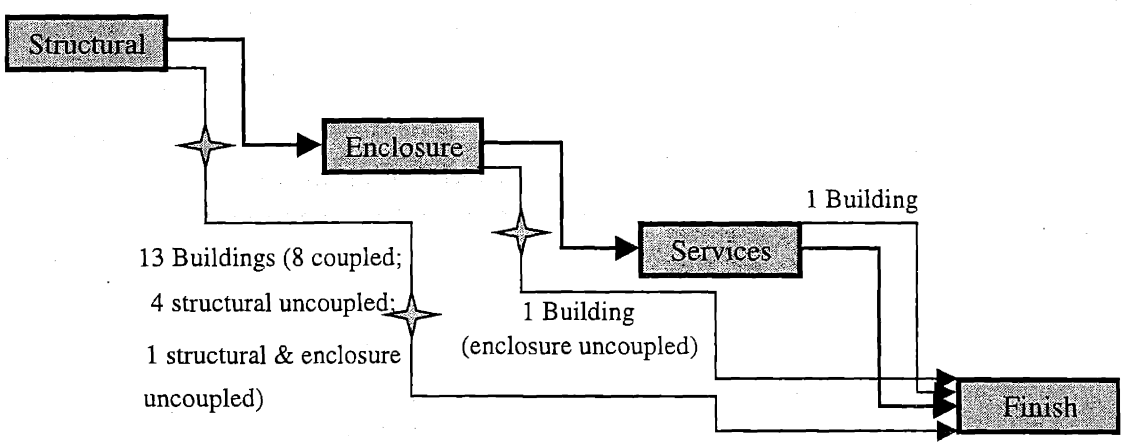


Table 5.9 – Cascade of System Changes within the Detailed Case Studies of Buildings Renovated for a Different Usage

DIFFERENT USAGE				
PROJECT	STRUCTURAL	EXTERIOR ENCLOSURE	SERVICE	INTERIOR FINISH
270 Albany Street				
Building N42, MIT				
Building 314				
DEC Headquarters				
Globe Department Store				
K. Wayne Smith Building				
Lafayette Corporate Center				
Liberty Tree Building				
705 Mount Auburn Street				
Philadelphia Naval Base				
Polaroid Building				
Sage Hall				
266 Second Avenue				
255 State Street				
Worthington Place				

= UNCOUPLED = COUPLED

Out of the 15 projects, 13 buildings required work within all four of the building systems. Out of these 13 buildings, eight of them (Building N42, Globe Department Store, K. Wayne Smith Building, Lafayette Corporate Center, 705 Mt. Auburn Street, Philadelphia Naval Base, Sage Hall, and Worthington Place) followed the general cascade. Four of these projects (270 Albany Street, Building 314, 266 Second Avenue, and 255 State Street) had uncoupled the work on the structural system from the work performed on the remaining three systems (which continued to follow the cascade). The last of the projects (Polaroid Building) had the work on both the structural and the exterior enclosure systems uncoupled from the work on the remaining systems. This project was also very interesting as the work on the exterior was preceded by the work on the service and interior finish systems, thus going totally against the general cascade. Out of the remaining two projects, one (Liberty Tree Building) displayed work on the last three systems (enclosure, service and interior finish) with the work on the exterior enclosure system remaining uncoupled from the work on the final two systems. Meanwhile, the last building project (DEC

Headquarters) had work performed on the service and interior finish systems. For all 15 of the buildings, the work on these two systems remained entirely coupled together.

Upon analyzing these trends it becomes evident that the nature of the system change differs depending on whether it is within the same usage versus the different usage category. For instance, renovation for different usage often requires changes within the structural system (13 out of 15 projects), while renovation for the same usage often leaves the structural system unchanged (6 out of 11 projects). In all of the projects, regardless of their end usage class, the service and interior finish system changes are coupled.

Are these trends required with regards to coupling system changes or are they simply predisposed theory and actions? While there is evidence that changes within the structural and enclosure systems can be uncoupled from changes within the other systems, it appears that changes within the service and interior finish systems are locked together. Determining how to uncouple the changes within any and all of the systems, including those in the service and interior finish systems, might introduce a new level of flexibility within buildings. This certainly is an issue that could and should be explored further.

5.4 Cascade of Building Usage

Along with a cascade in changes within the building systems, a cascade in building usage also exists within the sample of building cases studied. Past belief has been that a building is built to meet one use and is intended to only meet that one use for an extended period of time. When the building can no longer functionally meet that use, then it was either abandoned or demolished so a new building could replace it. Although this train of thought is rapidly becoming extinct within the building construction industry within the United States and a few other countries, a large proportion of the countries in the world continue to follow it. The cascades of building use discovered through this research provide overriding evidence that any building can be reused, not only to meet its originally intended usage but also, if need be, an entirely new usage (as long as the building in question possesses the initial requirements for a renovated facility, namely a structural system).

Although all 45 of the projects used for this research presented renovation to the same or a new usage, the changes in usage for the 26 detailed case studies were examined in more detail. The end uses for each of these 26 building cases are shown below in Table 5.10. Out of this sample of building cases, 11 were renovated to meet their initial usage class or upgrade that usage class, while the remaining 15 projects were renovated to meet an entirely new usage class.

Table 5.10 – Building Samples Studied: Usage after Renovation

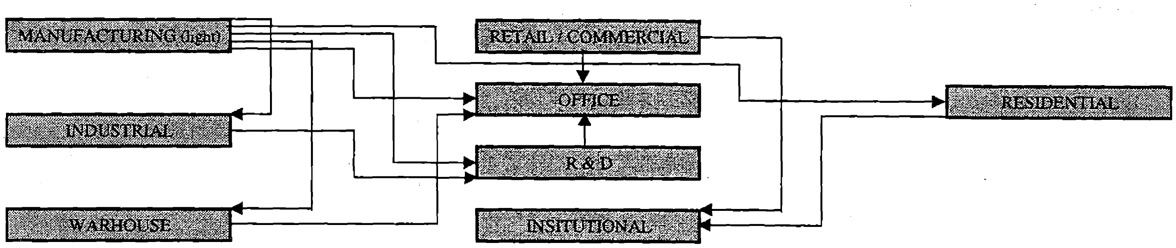
Building Usage	Same Use	Different Use
Manufacturing	-	-
Industrial	-	1 Building
Warehouse	-	-
Retail	2 Buildings	-
Office	6 Buildings	9 Buildings
R & D	-	2 Buildings
Institutional	3 Buildings	2 Buildings
Residential	-	1 Building
Total Sample	*11 Buildings*	*15 Buildings*

The projects that were renovated to meet the same usage class involved the upgrade of the building's current conditions to increase their comfort and marketability while also enhancing their safety. The majority of these projects were office buildings (6 out of the 11 projects), while the remaining projects were institutional buildings (2 hospitals and 1 academic) and retail/commercial buildings (2 railroad stations).

The end usage classes for the projects that were renovated to meet a new usage are somewhat similar to those presented by the projects renovated to meet the same usage. As shown in Table 5.10, the majority of these projects resulted in an office building usage class (9 out of the 15 projects). Two of the building renovations resulted in research and development facilities, while another two resulted in institutional facilities. The remaining two building projects were renovated to meet industrial usage and residential usage respectively.

While the end usage class for these building is important, it is the cascade of building usage change that they each present which is most interesting. The most interesting aspect of this analysis was seeing what usage each of these buildings were initially constructed for, and witnessing the changes which allowed them to meet their new usage. This cascade in usage class is represented by Figure 5.14 below. Following this cascade, several different usage paths become apparent. Buildings that were once used for light manufacturing purposes have been renovated to meet the industrial, warehouse, office, research and development, and even residential usage requirements. Meanwhile, retail/commercial and residential buildings are being converted into institutional buildings, namely academic facilities.

Figure 5.14 – Changes in Usage Class for the Detailed Samples for Different Usage



While this cascade presents the initial and end usage classes that were represented by the 15 case studies, it fails to represent the entire picture for a few of them. Several of these projects are not experiencing their first experience with conversion, but in fact are experiencing their second, since these projects are being renovated to meet their third usage class. All fifteen of the buildings renovated to meet new usage and the history of their usage classes are displayed within Table 5.11 on the following page. As shown in this table, five of the fifteen projects have been renovated to meet their third usage class.

Through the analysis performed on these buildings, it was interesting to discover the influences that certain building usage classes and/or the cascades of building usage classes placed on the types of changes which a building encountered to meet a new usage. Larger, more open plan buildings, such as warehouses, light manufacturing buildings, and industrial buildings, present the easiest structures to work with. These buildings provide the best capabilities to meet several different usage types due to their large bay spans, high load capacities, and high floor to ceiling heights. Other building types, such as retail, office, R & D, institutional, and residential, present more difficult obstacles for renovation to overcome. These buildings often incorporate lower load capacities which meet the minimum requirements for the building's usage, low floor to ceiling heights to maximize the number of floors and rooms, and an entangled maze of services and interior finish space which can make renovation a much more arduous and expensive task. However, by incorporating flexibility within all of these buildings, it is believed that they too can be renovated and reused in a much more efficient and easier manner.

Table 5.11 – Building Samples Studied: List of Past Usage Classes for Buildings that were renovated to meet a new/different Usage

PROJECT	FIRST USAGE	SECOND USAGE	THIRD USAGE
270 Albany Street	Plate Glass Manufacturing Building	Heart-shaped Candy Box Manufacturing Building	Research / Development & Office
Building N42, MIT	Laundry Building	Office Space	High Tech Office Space
Building 314	Automobile Assembly Plant	Research / Development, Lab & Office Space	
DEC Headquarters	Light Manufacturing and Office Space	Class 'A' Office Space	
Globe Department Store	Department Store and Warehouse	Academic Building: Classrooms and Offices	
K. Wayne Smith Building	Automobile Distribution Warehouse	Office Space	
Lafayette Corporate Center	Retail Building	Office Building with some retail space	
Liberty Tree Building	Retail Building with some Office space	Office Building with some retail space	
705 Mount Auburn Street	Telephone Manufacturing and storage building	Warehouse	Office Space
Philadelphia Naval Base	Naval Foundry	Commercial Building: Light Manufacturing.	
Polaroid Building	Chemical Research and Development building	Office, Lab and some Light Manufacturing	Office Space
Sage Hall	Women's Dormitory	Academic Building: Classrooms and Offices	
266 Second Avenue	Manufacturing building	Research / Development, Lab & Office Space	
255 State Street	Warehouse	Office Building (for one tenant)	Office Building (for multiple tenants)
Worthington Place	Metal stamping industrial plant	Apartment building	

6 Conclusions and Recommendations for Further Research

6.1 Summary

The purpose of this research was to develop a theory and framework to assess the capabilities of a building to accommodate change over time, specifically focusing on the renovation and reuse of existing low to mid-rise buildings. Unlike past studies on building renovation and reuse, this research moves away from the exogenous factors (e.g., building location, social and community issues, building age, or building deterioration as explained in Chapter 2). It instead concentrates on the physical engineering systems within a building that influence the feasibility of renovation and reuse.

6.2 Conclusions

An assessment framework, which presents the critical characteristics that influence the accommodation of change within a building, was successfully developed. While this framework does not present a concrete answer to the problems associated with changes within buildings and the renovation required to meet them, it does offer a check list which can help ease the design and construction planning processes. Furthermore, the framework and the data which were used to create it present several interesting trends, interactions, and links for building renovation and reuse as a whole, as well as the building systems and change categories that were studied.

Although in the past it has been perceived that the building construction industry has been reluctant to accept and incorporate new methods, techniques and design alternatives, this research shows that this is no longer true. This research examined several building renovation projects as well as three new construction projects that actually incorporated change within their designs. Most of these projects incorporated new design ideas that placed an overall emphasis on designing to accommodate not only the changes for the new renovated use but also possible future potential uses. These examples display the growing trend towards planning ahead and incorporating possible future changes within the design and construction of both new and existing buildings and the activities which they house. This trend is particularly evident in the projects that were headed by developers which supply and own R & D facilities, such as Lyme

Properties of New Hampshire and Boston Properties of Massachusetts, and by institutions and universities such as Massachusetts Institute of Technology and the Mount Auburn Hospital in Cambridge, Massachusetts.

This growing trend towards incorporating a capacity to accommodate future change stems primarily from a change in the overall outlook on the costs associated with building construction. While initial costs of design and construction have traditionally been held as the main factor in whether to pursue a project, several of the case studies analyzed within this research suggest that more projects are using lifecycle costs as the main decision factor. One such project was 270 Albany Street, in which the developer/owner, Lyme Properties, despite having a single long-term tenant for the entire building, had the building designed and renovated to meet the needs for up to five tenants. When asked why they did so during an interview, the developer stressed that it is easier and much more cost efficient to spend a little extra money upfront, and save more money down the road, than to focus on reducing initial costs (Whinney interview, 1998).

While these general trends appeared with regards to the building construction industry as a whole, and the renovation and reuse of buildings within it, the individual case studies showed several interesting trends, interactions and links that existed within and among the four building systems and the change subcategories. Each of these individual trends and interactions emphasized the preconception that the subject of building flexibility and building design for incorporating capabilities to accommodate change over time is a very complex issue.

The complexity associated with building flexibility and design to accommodate change is particularly apparent within and among the building systems and the changes that they experience, specifically in the interactions and dependencies between and among these building systems. Strong links exist between the structural and services systems for both changes in function and changes in capacity. In addition, strong links exist between the services and interior finish systems for all three change categories (Function, Capacity, and Flow). However, the exterior enclosure system appears to be more uncoupled from the other systems with regards to changes performed on the studied facilities. While some of these links are considered common within the design and construction industry (primarily the link between the services and interior finish systems and the changes that they experience), others were often not explicitly recognized.

The cascade within the building systems further displays the links that appear to exist between the different building systems. These cascades show that the service and interior finish systems are strongly coupled. That is, all of the buildings studied which displayed changes and renovation within the services system also displayed associated changes within the interior finish system. A majority of the projects that experience changes within the other two systems (structural and exterior enclosure) also show that they too are generally coupled along with the services and interior finish systems. However, a few cases did show that work on the structural system and the exterior enclosure systems can be uncoupled from work in other systems and therefore performed without disrupting the other systems (Figures 5.14 and 5.15, and Tables 5.8 and 5.9 in Chapter 5).

Each of the individual case studies examined for this research presented a different type of trend or varied from the traditional cascade of building system change. Although the projects which involved work in the services and interior finish uniformly showed that all of the work performed on the service and interior finish systems was coupled and therefore done together, the projects show a variety of other trends with regards to work on the other building systems. Furthermore, some projects had work performed on only one system while leaving the other systems essentially untouched and undisrupted. These various trends in building changes and various links between them and the systems in which they are being performed emphasize the complexity of the task that this research addresses. There is no clear-cut answer that miraculously unfolded as the research on the case studies progressed. There is, however, evidence that the task of developing a design methodology for incorporating the capability to accommodate change within buildings is possible through further research on this subject and the issues which it has identified.

6.3 Recommendations for Further Research

When this research began, the ultimate question was whether or not a reasonable accurate design tool for incorporating the accommodation of change within building design could be developed. Could a general framework be created and applied to all types of building projects, whether they are new buildings or existing buildings being renovated? Could the complicated issues that have plagued the reuse of existing buildings be determined and identified so that future projects can plan for them ahead of time? The evidence brought forth by this research (i.e., the successful development of a design framework which provides the critical characteristics which should be considered prior to building construction and renovation design) suggests that the answers to these questions could be yes.

While this research and the framework it created do not present any concrete answers to providing building flexibility, they do provide a foundation from which further research can and should be performed on a building's ability to accommodate future change. The organization of the empirical data obtained from the case studies into the proposed framework provides a tool not only for construction professionals, but also for future researchers to perform further analysis on determining how and why building systems might change. Through such further study, a potential method of predicting and calculating the probability of the different types of changes which effect the individual building systems could be developed. Given the knowledge of the types of change that do occur, further research could be performed on determining how to most effectively accommodate these changes. Such research might incorporate the development of several different design and/or construction strategies that could be implemented not only within the design for buildings undergoing renovation but also within the design of new buildings. These strategies could also incorporate various methods of evaluating buildings and their various systems and components. For example, an evaluation method which takes into account the engineering economics of pursuing various different design methodologies which incorporate capabilities to accommodate and compares them to the economics of traditional design methodologies.

One area from the results of this research in which further research should be performed is on the links and interactions that exist between the different building systems and the changes which they experience. These links and interactions make the issue of building flexibility and the design for incorporating this flexibility a very complex issue. This complexity effects the overall design and construction of a building. Within most of the projects studied, it was these interactions and links that made the renovation which ensued difficult and more expensive than initially predicted. Perhaps by developing a method of design that accounts for these interactions and eliminates them by uncoupling the different building systems entirely from one another, the overall building construction and renovation process could be simplified.

Appendix A: General Case Study Data

Table A.1 – List of General Case Studies Used for Research

PROJECT NAME	LOCATION
Abbott Laboratories	Las Colinas, TX
Charles River Business Center	Watertown, MA
75 Federal Street	Boston, MA
Fitzpatrick Family Group Hotel	Manhattan, NY
Fort Point Channel Warehouses	Boston, MA
GE Vapor Lamp Company	Hoboken, NJ
Hingham Shipyard	Hingham, MA
Hood Business Park	Charlestown, MA
Mass. Museum of Contemporary Art	North Adams, MA
Navy Pier	Chicago, IL
New Bedford Aquarium	New Bedford, MA
Nukeland	Kalkar, Germany
Stop and Shop Building	Boston, MA
Toyota Motor Corp. Parts Center	Ontario, CA
Trump International Hotel and Tower	New York, NY
Two Tequesta Point Condominiums	Miami, FL
Union Station - 2	Kansas City, MO
U.S. Courthouse/Federal building	Phoenix, AZ
Washington Junior High School	Duluth, MN

PROJECT DATA SHEET

DATE: 1/19/98

PROJECT TITLE: Abbott Laboratories

LOCATION: Las Colinas, Texas

PROJECT OWNER: Abott Laboratories' Diagnostic Division

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
John Wells, PE, Reed, Wells, Benson and Co.
Dallas, TX
( )

ARCHITECT:
Marcel Quimby, AIA, PM, Henningson, Durham and Richardson, Inc.
Dallas, TX
( )

CIVIL ENGINEER:
Randy Hagens, SE, Doyle Engineering Group
Dallas, TX
( )

SUBCONTRACTORS:

( )

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: None - new building

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: To respond to customer demands for products, they must turn office space into manufacturing space - and back again- in a heartbeat; design and build a mix use facility which would allow Abbott the flexibility to change over the next couple of years or for the life of the building.

FUTURE USAGE: 4 story mix use facility - manufacturing, warehouse, office and laboratory space.

NEW SYSTEMS:

STRUCTURAL: Steel structure - large open footprint; 1st Floor: 27 ft. high ceilings, 87,300 sf of warehouse space; 2nd Floor: Mezzanine connection to the existing building, and private conference space; 3rd/4th Floors: 160,000 sf of manufacturing, office and laboratory space; large bays, 28 x 40 ft.

ENCLOSURE: Energy efficient low emission glass windows

SERVICE: Utility columns, variable volume air handling units; Access flooring and structural columns flanked by utility risers; Special early suppression fast response sprinkler system used to allow construction over warehouse space; Two centrifugal chillers provide chilled water to 4 variable volume air handling systems on each floor; each system has steam humidifiers to provide humidity control.

FINISH: Elevators, electrical closets, mechanical rooms, rest rooms, and private conference space put at the ends of the building leaving the center of the building open; Demountable partitions used;

EXPECTED FUTURE CHANGES: Use of the office space for new manufacturing lines and vice versa.

NOTES:

The facility's flexibility is expected to save $500,000 in rearrangement costs per year.

PROJECT DATA SHEET

DATE: 4/2/98

PROJECT TITLE: The Charles River Business Center

LOCATION: Arsenal Street, Watertown

PROJECT OWNER: Watertown Arsenal Development Corp.

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Developer - O'Neill Properties Group
Philadelphia, PA

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: May-98
FINISH DATE: Nov-99

PAST USAGE: U.S. Army Arsenal - 10 building historic site

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: 645,000 sf of office and research and development space on a speculative basis

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 4/2/98

PROJECT TITLE: 75 Federal Street

LOCATION: Boston, MA

PROJECT OWNER: Equity Office Properties - Mike Quinn, General Manager

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Class B+ office building

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: Class A- Office space (6 year long renovation project entailing a floor by floor upgrade)

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 11/21/97

PROJECT TITLE: Fitzpatrick Family Group Hotel

LOCATION: 141 E. 44th Street, Manhattan, NY

PROJECT OWNER: Joint Venture: Fitzpatrick Family Group of Hotels and Blackacre Capital Group

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
HRH Construction Corporation
909 Third Avenue, New York City, NY 10022

ARCHITECT:
Martin J. Brockstedt, Interior designer

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Oct-97
FINISH DATE: May-98

PAST USAGE: Office building

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: First Class - European style boutique hotel - 75,000 sf, 156 rooms and suites, including a penthouse

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 12/10/97

PROJECT TITLE: Boston Globe Article: "Converting warehouses into premium offices"

LOCATION: Fort Point Channel area, Boston, MA (North Station, South Station including the leather district)

PROJECT OWNER: Various

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:

FINISH DATE:

PAST USAGE: Warehouses

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: lack of available office space within Boston; the construction of the Central Artery and proposed convention center; saving these buildings adds to the character of Boston; Warehouses are "cheap space".

FUTURE USAGE: Class B office space, shops and residences

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

"We had a rash of new buildings in the 60's that were not hospitable, so that in part spawned the preservation movement."

PROJECT DATA SHEET

DATE: 1/9/98

PROJECT TITLE: GE Vapor Lamp Company

LOCATION: Hoboken, NJ

PROJECT OWNER: Grand Street Artists Alliance

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Production center for mercury vapor lamps and switches (1910-1960s)

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Widespread unknown mercury contamination forced the EPA to condemn the building. GE who sold the building to the Artist Association claimed that "the building was never intended for residential use."

FUTURE USAGE: Modern, code compliant living spaces and studios

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 2/9/98

PROJECT TITLE: Hingham Shipyard

LOCATION: Hingham, MA

PROJECT OWNER: Developer - Paul Trendowicz, SeaChain LLC and the state of Massachusetts

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Navy destroyer escort manufacturing building plant

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Shipyard is considered an eyesore by many within the surrounding community; it has been very underutilized over the last 50 years; prime waterfront property in a prime location;

FUTURE USAGE: 550 town houses ($300,000-600,000), an 80 room inn, 246,000 sf retail and restaurant space, 36,000 sf of offices, and a new 1,600 space parking lot.

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 1/13/98

PROJECT TITLE: Hood Business Park

LOCATION: Charlestown, MA

PROJECT OWNER: Hood Business Park LLC

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Developer - Nordic Properties
31 Third Avenue, Burlington, MA
(617) 272-4000

ARCHITECT:
Symmes, Maini, and McKee Associates
Boston, MA
(617) 547-5400

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Headquarters and main dairy facility for H.P. Hoods and Sons until 1996
~23 acre property

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: 400,000 sf Office Park in four separate buildings

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 7/20/98

PROJECT TITLE: Mass Moca - Massachusetts Museum of Contemporary Art

LOCATION: North Adams, Massachusetts

PROJECT OWNER:

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

Bruner/ Cott and Associates
Cambridge, MA

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Mill - Sprague Electric Company

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: Art center - multi-disciplinary center for visual, performing and media arts - 200,000 sf of galleries, indoor and outdoor performance spaces, cafes, retail shops and commercial offices

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 1/16/98

PROJECT TITLE: Navy Pier

LOCATION: shore of Lake Michigan, Chicago, IL

PROJECT OWNER: Hood Business Park LLC

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Kevin Dyball, CM/GC, Schal Bovis Inc.
Chicago, IL

ARCHITECT:
Rick Fawell, VP, VOA Associates Inc.
Chicago, IL

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Navy Pier

PAST SYSTEMS:

STRUCTURAL: 12 inch thick concrete pier built on weak landfill soil

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Massive $190 million rehabilitation; had to make sure that the entire structure could withstand the intense Lake Michigan conditions; wanted to maximize flexibility with a column free space.

FUTURE USAGE: Hub of activity: an exhibit hall constructed on the pier where "visitors can dine, attend the theater, learn at a convention, shop or take a thrill ride."

NEW SYSTEMS:

STRUCTURAL: New concrete caissons, 60 ft on center, were drilled into the load bearing clay material at ~70 ft; holes were punched through the existing pier slab for the caissons; a new precast concrete superstructure was built on top of the old pier; a prefabricated and prefinished steel space frame roof systems topped the new structure; structural system has a very high load capacity

ENCLOSURE: Architectural wall cladding panels used on the exterior; integrated, metal panels used for the roof;

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 11/20/97

PROJECT TITLE: New Bedford Aquarium

LOCATION: New Bedford, MA

PROJECT OWNER:

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

Peter Chermayeff, Robert Bowen, Maureen Armstrong & Frederick Satkin
Cambridge Seven Associates, Inc., Cambridge, MA
(617) 492-7000

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE: May-99

PAST USAGE: Commonwealth Electric Power Plant - Closed 1993

PAST SYSTEMS:

STRUCTURAL: Structurally sound - Won't require much surgery

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Looking for a design/build contract; site has not been used in over 4 years - "brownfields" evaluations must be made to determine the amount of hazardous materials on site; asbestos is known and abatement is required

FUTURE USAGE: New Bedford Ocean Science Center - 270,000 sf complex: Aquarium, center for marine research businesses and a large screen theater

NEW SYSTEMS:

STRUCTURAL: The nine story tall turbine room will be converted into the aquarium, explorium and center and thus would require some slight structural modifications to suit these functions.

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 1/19/98

PROJECT TITLE: Nukeland

LOCATION: Kalkar, Germany

PROJECT OWNER: Henny Van Der Most

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Cooling tower from a mothballed nuclear power plant

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: The $4.5 billion plant was never fitted with nuclear fuel.

FUTURE USAGE: "Free climbing and air stream-flying" Theme Park

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 1/9/98

PROJECT TITLE: Former Stop and Shop Building

LOCATION: Causeway Street, North End, Boston, MA

PROJECT OWNER: Boston Realty Corp.

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

Finegold, Alexander and Associates

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Mid 1998

FINISH DATE:

PAST USAGE: Stop and Shop Grocery store

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Addition of 6 floors to the existing structure with parking in the basement and first floor levels.

FUTURE USAGE: Mixed use residential development - 240 residential units including lofts, 1, 2, and 3 bedroom units ranging from 950 sf to 1400 sf.

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 1/19/98

PROJECT TITLE: Toyota Motor Corp. Parts Center

LOCATION: Interstate 15, Ontario, CA

PROJECT OWNER: Toyota

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
John E. Clement, Snyder Langston
Irvine, CA

ARCHITECT:
MNB Architects (Moffatt, Nichol & Bonney Engineers, Inc.)

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Jun-95
FINISH DATE: Aug-96

PAST USAGE: None - New structure

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Designed to include amenities that will save the company money in the long run by lowering costs for maintenance, operations and insurance.

FUTURE USAGE: Warehouse

NEW SYSTEMS:

STRUCTURAL: Steel structural system

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

Minimized the number of control joints in the floors; installed extra-fast acting fire safety sprinklers- thus allowing plastic parts to be stored anywhere within the warehouse; includes two 52 ft. high towers that house air handling equipment out of the way of the warehouse operations.

PROJECT DATA SHEET

DATE: 7/8/98

PROJECT TITLE: Trump International Hotel and Tower

LOCATION: One Central Park West, New York, NY

PROJECT OWNER: Trump Organization, the Galbreath Co. and G.E. Pension Trust

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:
Philip Johnson

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Office building

PAST SYSTEMS:

STRUCTURAL: Steel framed

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: Hotel / Apartment building

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Bronze tinted glass curtainwall exterior

SERVICE:

FINISH: Gracious foyers, 10 ft ceiling heights, serving kitchens, marble master baths with whirlpool tubs, walls of glass and great views.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 7/8/98

PROJECT TITLE: Two Tequesta Point Condominiums

LOCATION: Miami-Dade County, Florida

PROJECT OWNER: Developer - Stephen L. Owens, President, Swire Properties

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Pavarini Construction Co. Inc.
Miami, Florida

ARCHITECT:
J. Scott Architecture
Miami, Florida

CIVIL ENGINEER:
Richard B. Klien, Rive, Klien & Timmons
Miami, Florida

SUBCONTRACTORS: PEER REVIEWERs
CHM Consulting Engineers Inc.
Coral Gables, Florida
Leslie E. Robertson Associates, New York, NY - analyzed wind loads

BUILDING INFORMATION:

START DATE: ____
FINISH DATE: ____

PAST USAGE: 40 story condominium building

PAST SYSTEMS:

STRUCTURAL: D building plan; 66 reinforced concrete column lines with 6 inch thick flat slabs and shear walls;

ENCLOSURE: ____

SERVICE: ____

FINISH:

SPECIAL CONCERNS: Building was 10 - 30% underdesigned in certain places; However there was never any danger of collapse and no "life-safety concern on the building"; problem consists of a series of columns that were underdesigned for gravity loads, and some slenderness problems; Building code withstand a 30 year storm but the codes asks for a 50 year storm.

FUTURE USAGE: Same

NEW SYSTEMS:

STRUCTURAL: Five, 2 x 1 ft reinforced concrete columns were strengthened by increasing them to 2 ft square by casting a 1 x 2 ft reinforced concrete column with embedded steel along them; column lines upsized from the foundation to the roof; to fix the slenderness problem either 1 or 1.5 ft deep reinforced concrete drop panels were installed at about 1/3 of the column slab locations under the 5th & 6th floor slabs thus reducing the unbraced length of the columns to 12 ft; In order to address slab underdesign and some punching shear problems, interior concrete block walls were transformed into load bearing walls at 7 locations, and adding a 4 ft deep beam at an eighth location every 8 floors.

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 4/27/98

PROJECT TITLE: Union Station

LOCATION: Kansas City, MO

PROJECT OWNER: Union Station Assistance Corp. and the Kansas City Museum Association

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
JE Dunn Construction Company and Malco Steel Inc.
Kansas City, MO

ARCHITECT:
Union Station Architects (5 firm Joint Venture - HNTB, and others)

CIVIL ENGINEER: PROGRAM MANAGEMENT
Hines (Houston, TX) and M.A. Mortenson (Minneapolis, MN)

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE: Nov-99

PAST USAGE: 6 story, 10 level, 800,000 sf rail complex originally constructed on a 13 acre site in 1914

PAST SYSTEMS:

STRUCTURAL: structural steel superstructure with concrete slab floors

ENCLOSURE: Masonry enclosure

SERVICE:

FINISH:

SPECIAL CONCERNS: Listed on the national registry of historic places; has lain dormant for over a decade;

FUTURE USAGE: Intermodal transportation center and the home of a contemporary museum called Science City, a planetarium and a large screen theater; office and retail space also integrated into the scheme

NEW SYSTEMS:

STRUCTURAL: Construction of a new 1200 sf glass enclosed skywalk to connect the complex to the nearby Crown Center (65,000 sf of new construction); required structural repair ranging from the moderate rusting of structural steel members to the severe, requiring total replacement of 12 x 16 inch columns; To create unobstructed views in the theater two 12 x 14 inch columns spaced 23 ft apart in each of three bays were removed, resulting in spans of 69 ft; concrete slabs damaged by exhaust of trains passing underneath the station were reinforced

ENCLOSURE: Leaking roof was repaired with a system of glass-reinforced concrete tiles that were placed on top of the existing precast planks ($7 million)

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 1/19/98

PROJECT TITLE: U.S. Courthouse and Federal Building

LOCATION: Phoenix, Arizona (middle of the Sonoran Desert)

PROJECT OWNER:

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:
Richard Meier and Partners
New York, NY

CIVIL ENGINEER:
Ove Arup and Partners
New York, NY

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Late 1996
FINISH DATE: By 2000

PAST USAGE: None - New structure

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Using a glass atrium design with passive cooling system in a desert environment and making it work.

FUTURE USAGE: Federal Courthouse and Office Building

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Shading systems used (comprising of metal fins) to achieve 80-100% shading of direct solar radiation during peak hours; building organized around a 6 story 58,000 sf rectangular glass atrium.

SERVICE: Passive climate control system.

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT DATA SHEET

DATE: 11/23/97

PROJECT TITLE: Washington Junior High School

LOCATION: Duluth,
Minn.

PROJECT OWNER: Artspace, Inc., Minneapolis and the City of Duluth

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
David Bjerkness, LHB Engineers and Architects
Duluth, Minnesota

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Fall 1995
FINISH DATE: Fall 1996

PAST USAGE: Junior High School

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE: Masonry, brick exterior

SERVICE:

FINISH:

SPECIAL CONCERNS: Change in enrollment in 1992 rendered the 86 year old building redundant - renovation has won a preservation alliance of Minnesota honor award for adaptive reuse of a historic building - parking issue - confined site

FUTURE USAGE: Residences, artist's studios and a community center

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Existing high ceilings and windows reused in the 39 new apartments; Old exterior preserved

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

Appendix B: Detailed Case Study Data

Table B.1 – List of General Case Studies Used for Research

PROJECT NAME	LOCATION
270 Albany Street	Cambridge, MA
Building 16, MIT	Cambridge, MA
Building N42, MIT	Cambridge, MA
Building 314	Indianapolis, IN
Citicorp Tower	Manhattan, NY
DEC Headquarters	Maynard, MA
Federal Office Building	Norfolk, VA
Globe Department Store	Waukegan, IL
Grand Central Station	New York, NY
Iowa State University Office	Ames, Iowa
K. Wayne Smith Building	Dublin, OH
Lafayette Corporate Center	Boston, MA
Liberty Tree Building	Boston, MA
Mount Auburn Hospital	Cambridge, MA
705 Mount Auburn Street	Cambridge, MA
New York Life Building	Kansas City, MO
Philadelphia Naval Base	Philadelphia, PA
Polaroid Building	Cambridge, MA
Rush - St. Luke's Medical	Chicago, IL
Sage Hall	Ithaca, NY
266 Second Avenue	Waltham, MA
Standard Life Tower	Calgary, Alberta
28 State Street	Boston, MA
255 State Street	Boston, MA
Union Station	Seattle, WA
Worthington Place	Cambridge, MA

270 Albany Street, Cambridge, Massachusetts

270 Albany Street was built in 1920 to serve as a light manufacturing building for the production of plate glass. In 1935, its usage changed as it became a manufacturing plant for heart shaped candy boxes. The building continued to be used for this purpose until it closed down in 1990. After it had remained vacant and unused for several years, the building was purchased by Lyme Properties of New Hampshire and was renovated in 1998 for office and research and development usage (Rose, interview, 1998).

The building is a two story tall cast in place concrete structure with a full basement level. The design of the building, with 10 inch thick concrete slab floors, span lengths of 20 x 20 feet, and floor to ceiling heights of 9, 15 and 10 feet respectively (lower to second floor) allows it to be applicable for several different building usage types. Due to the type of building system used, the overall load capacity of the structure is very high, especially for the intended use as office and research and development space. Due to this added load capacity, the building's structural system was able to accommodate several modifications that aided its new usage and ultimately provide the building with added flexibility over time.

The most interesting part about this project is the fact that this opportunity for future flexibility was acknowledged by the developer, and therefore became an integral part in the design and implementation of this renovation project. Although the developer has acquired one tenant who will rent the entire building over a 10 year period, they have not limited the design of the building to that one tenant. Instead they have designed the building to suit up to five different tenants. The developer further used this methodology of planning ahead by working closely with the tenant on the interior fit-out of the building. This allowed the developer to take into account the tenant's needs and the possibility of any future changes that the tenant expects to encounter within the first few years of occupancy.

The additional load capacity, which the somewhat overbuilt cast-in-place concrete structure possesses, also allowed the building to accommodate a couple of building additions. The renovation therefore incorporated the construction of an oversized penthouse on the roof of the main building section (for service equipment) and a small one-story addition to the top of the building's one story tall right wing as a meeting and lunchroom. By constructing the penthouse on top of the roof for the service equipment, the developer was able to free up valuable office/ R & D space within the lower "basement" floor of the building. Through the construction of the one story addition, it was also able to increase the overall useable office space as well as provide an enclosed area to house a service elevator. The high load capacity building structure also allowed the incision of six oversized utility shafts through the cast-in-place concrete slab floors. These shafts were designed with the intent that work on utilities could be performed during the lifecycle of the interior space without disrupting that space. In order to achieve this objective, these shafts were oversized to allow utility workers room to gain access and perform work as well as room for new service components (such as utility equipment, piping and communication cables) to be installed. These two examples of the flexibility that the structural system provides also display the link that commonly exists between the structural and services systems.

Ultimately this building project is a perfect example of how some professionals within the building construction industry are planning ahead, incorporating lifecycle costs of a building and designing that building in ways that reduce those costs while increasing the attractiveness of the building. This building project also shows some of the benefits through the flexibility which slightly overbuilding a structural system can provide.

PROJECT DATA SHEET

DATE: 1/25/98

PROJECT TITLE: 270 Albany Street

LOCATION: Cambridge, MA

PROJECT OWNER: Lyme Properties, Lyme, NH - Dan Whinney

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Chip Crane, PM; Jose Rose, Assistant PM, Sienna Construction
Cambridge, MA
(617) 547 - 4546

ARCHITECT:
Jeff Hoseth, BTS Shaw and Associates
Boston, MA
(617) 478 - 0300

CIVIL ENGINEER:

SUBCONTRACTORS: OTHERS
Historic Assistant - Margot Webber, (617) 332 - 7678
Cambridge Historic Commission - Charlie Sullivan, (617) 349 - 4683

BUILDING INFORMATION:

START DATE: 6-Nov-97
FINISH DATE: Aug-98

PAST USAGE: 1920 - 1935: Plate Glass Manufacturing Building with drive-up windshield replacement line.
1935 - 1990s: Box Manufacturing Building - Heart shaped candy boxes

PAST SYSTEMS:

STRUCTURAL: Cast in place concrete; 10 inch thick concrete slab floors; span lengths 20 x 20 ft.; lower level: 9 ft. floor to ceiling height; 1st Floor: 15 ft. floor to ceiling height; 2nd Floor: 10 ft. floor to ceiling height.

ENCLOSURE: Brick masonry enclosure with cinder block fill where original large steel framed windows once existed between the columns. Original windows were operable to provide some means of ventilation.

SERVICE: Toilet rooms built above the slabs on raised flooring; Heating consisted of a coal fired hot water boiler and cast iron steam radiators; No air conditioning;

FINISH: Open area plan; No finish; Bare concrete left exposed

SPECIAL CONCERNS: Application for a historic designation for the building's exterior enclosure so that it can be restored to its original appearance with the large windows.

FUTURE USAGE: Biotechnology Office and Laboratory Space (15 year lease)

NEW SYSTEMS:

STRUCTURAL: Essentially same; Addition of a 7000 sf x 16 ft. tall penthouse on the roof to house the new mechanical systems; Addition of a floor to the building's side which was only one story tall; New elevator shaft constructed in this area. Six large utility shafts cut through the slabs to run mechanical systems, etc.

ENCLOSURE: Brick and Concrete exterior repaired and cleaned; cinder block fill demoed and replaced with large steel framed operable windows to restore exterior to its historic appearance.

SERVICE: All services new; Elevator, HVAC, plumbing, electrical, sprinkler, all were either non-existent or in poor condition and therefore were installed. HVAC is a single central unit which can be controlled and monitored in separate zones, thus allowing the building to suit various amounts of tenants.

FINISH: Some partitions with the rest of the space left open for flexible laboratory configurations.

EXPECTED FUTURE CHANGES: Worked with the tenant to fit out the interior space, while taking into account possible changes that will definitely be encountered in the next couple of years.

NOTES:

Incorporation of Future Changes: renovation included the installation and use of several oversized shaft space and an oversized penthouse space to provide flexibility for new equipment and services to be installed.

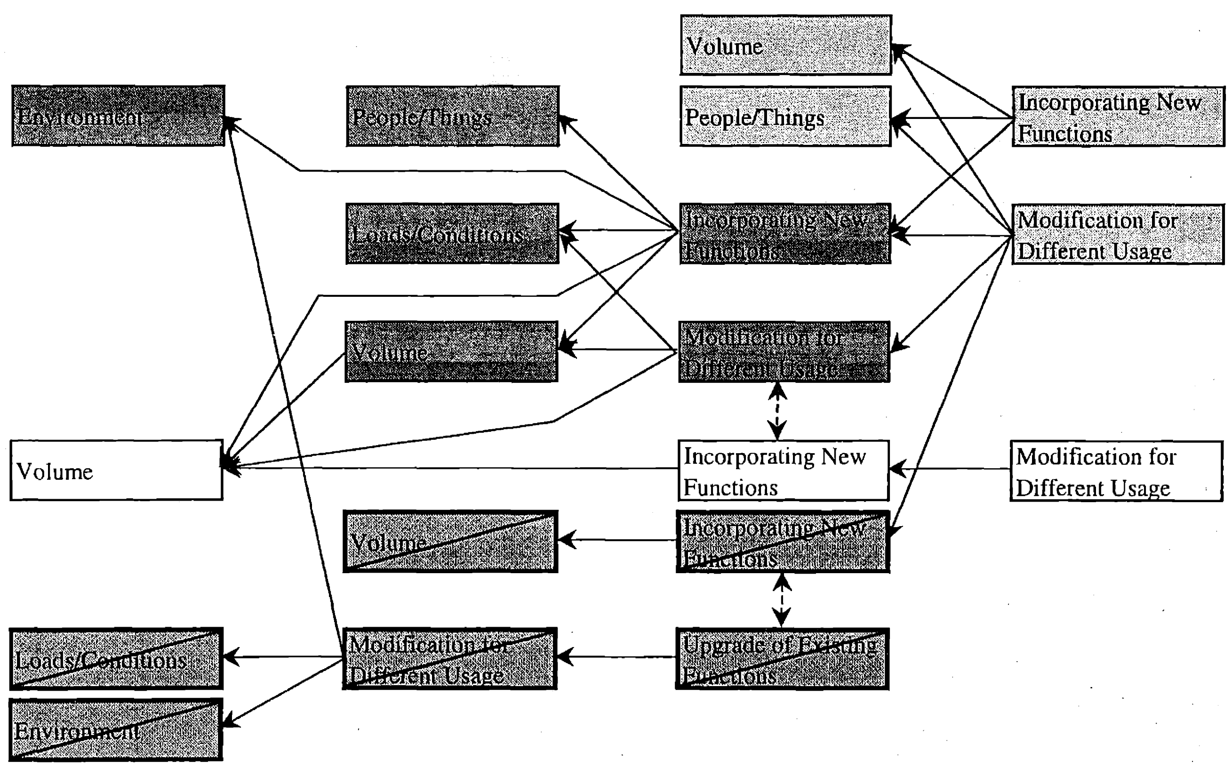
PROJECT: 270 Albany Street

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade Concrete / brick exterior repaired and repointed		
FUNCTION	**Incorporating New Functions**	1 New Function New elevator shaft constructed	1 New Function New precast concrete panel exterior installed on the penthouse addition	2 New Functions New HVAC system installed; New elevator installed	1 New Function New steel stud and drywall partitions used to create office space and restroom, mechanical spaces
FUNCTION	**Modification for New Usage**	Minor Holes cut in floor slabs for utility shafts; additional penthouse floor built for mechanical equipment; additional second floor constructed over the part of the building which was only 1 story	Major Cinder block infill within original window openings was demolished and new full length steel framed operable windows with insulated glass were installed in its place (match original early 1900s facade)	Major Plumbing, electrical, sprinkler systems all upgraded to meet the requirements for office and research and development use; The heating system was also upgraded to meet these requirements	Major Entire interior gutted and redesigned to meet the tenants needs
CAPACITY	**Loads / Conditions**	None Existing structure had more than enough load capacity	Yes Shear taken by the cinder block infill now transferred to the new window casings	Yes Electric, HVAC systems revamped in power capacity to meet office and R & D usage requirements for multiple tenants	
CAPACITY	**Volume**	Large Penthouse addition adds space for mechanical equipment and thus frees up more interior space for office use	Medium Additional exterior installed for the penthouse addition	Large HVAC, electric, plumbing, sprinkler systems, etc., all increased in depth and overall volume to meet the requirements for up to 5 tenants	Small Enclosed shaft areas provide space for services to be run: extra space is provided within these shafts to allow repairs and replacement to/of existing services
FLOW	**Environment**		Yes Replacement of cinder block infill with windows provides more natural light plus a source of ventilation for the building thus enhancing the working environment within the building	Yes New windows provide natural light source for building, as well as a ventilation source; New HVAC system also enhances the overall working environment within the building	
FLOW	**People / Things**	Yes Penthouse addition allows rest of the building to be used for office space			

= Structural System Change
= Exterior Enclosure System Change
= Services System Change
= Interior Finish System Change

<------> = Changes Performed Simultaneously

In order for left most change to be done, the changes to its right had to be done



Building 16, MIT, Cambridge, Massachusetts

Building 16 is an academic building on the Massachusetts Institute of Technology campus that houses classrooms, offices and laboratories for organic and inorganic chemistry. As the laboratory areas within the building became old and outdated the school decided to completely renovate the building to meet the current needs of the academic courses that use its facilities. An important design goal for this renovation project was the incorporation of flexibility in space and services so that the building can function properly for many years into the future. With this goal in mind, the design for the renovation of this facility incorporated the accommodation of the building's needs for the next 25-30 years, with no renovations expected in the short term of 8-10 years (Design and Construction Services, 1994).

This design incorporated several different methods of providing building flexibility through its service and interior finish systems. Within the service systems, for example, the renovation included the installation of new high technological fiber optic cabling to meet current academic needs as well as additional lines for possible future needs. Meanwhile, the interior finish system incorporated exposed ceilings in most of the laboratory spaces for easy access to the utilities. Furthermore, all of the labs and office spaces were designed with room for possible expansion. These spaces incorporated a larger amount of modular furniture and a lower amount of fixed, built-in furniture, thus allowing a greater number of possible organizations of the interior space. By planning ahead and incorporating future needs with the design for this renovation, MIT intended to extend the useful life of this building's facilities as well as decrease the overall lifecycle costs required to maintain and operate them.

PROJECT DATA SHEET

DATE: 12/12/97

PROJECT TITLE: Building 16

LOCATION: Cambridge, MA

PROJECT OWNER: MIT

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

Beacon Skanska Construction Company
270 Congress Street, Boston, MA 02210
(617)574-1400

ARCHITECT:

Ellenzweig Associates, Inc.
1280 Massachusetts Avenue, Cambridge, MA 02138
(617) 491-5575

CIVIL ENGINEER: STRUCTURAL
Souza True and Partners
653 Mt. Auburn Street, Watertown, MA 02172
(617) 926-6100

SUBCONTRACTORS:

Plumbing/Fire: BR & A/ Sullivan Partnership, Suite 302, Union Wharf, Boston, MA 02109. (617) 523-8227.

Mechanical/Electric: Sullivan Consulting Engineers, 1320 Soldier Field Road, Boston, MA 02135. (617) 254-0016

BUILDING INFORMATION:

START DATE: ____________

FINISH DATE: ____________

PAST USAGE: Academic building with classrooms, offices and wet laboratories.

PAST SYSTEMS:

STRUCTURAL: ____________

ENCLOSURE: ____________

SERVICE: Safety stations and gas cylinder storage inadequate. Storage cabinets under the fume hoods not vented. HVAC - campus steam and campus chilled water.

FINISH: Lab benches which are too small; Aisles between these benches are too narrow; Casework consists of wood with metal tops- all in very poor condition; Layouts fail to accommodate in lab equipment efficiently.

SPECIAL CONCERNS: Renovation occurred while facilities beside it were in use; renovation should accommodate the buildings needs for the next 25-30 year use cycle without any additional renovations in the short term (8-10 years).

FUTURE USAGE: Same – Upgrade and slight modification of the existing facilities.

NEW SYSTEMS:

STRUCTURAL: None

ENCLOSURE: Some new windows were installed at the ends of corridors in order to introduce natural light into the building. Some of the exterior was repair due to aging deterioration.

SERVICE: High tech cable/communication lines installed; replaced/rebuilt much of the HVAC system; Most of the plumbing system was replaced and reconfigured; Electrical system was tested, repaired where necessary and additions were made to it; existing steam heating system reused; new air condensers installed into the tightly packed basement.

FINISH: Built-in desks placed along walls with heaters so they remain free of blockage, and to help maximize the useable space.

EXPECTED FUTURE CHANGES: Removal of old and installation of new laboratory equipment; possible future renovation of lab space.

NOTES: Incorporation of Future Changes: exposed ceilings used except in some labs which used a hung ceiling, for easy access to utilities; labs, office space designed with room for possible expansion; use of a lower amount of built in furniture, etc. (less $)

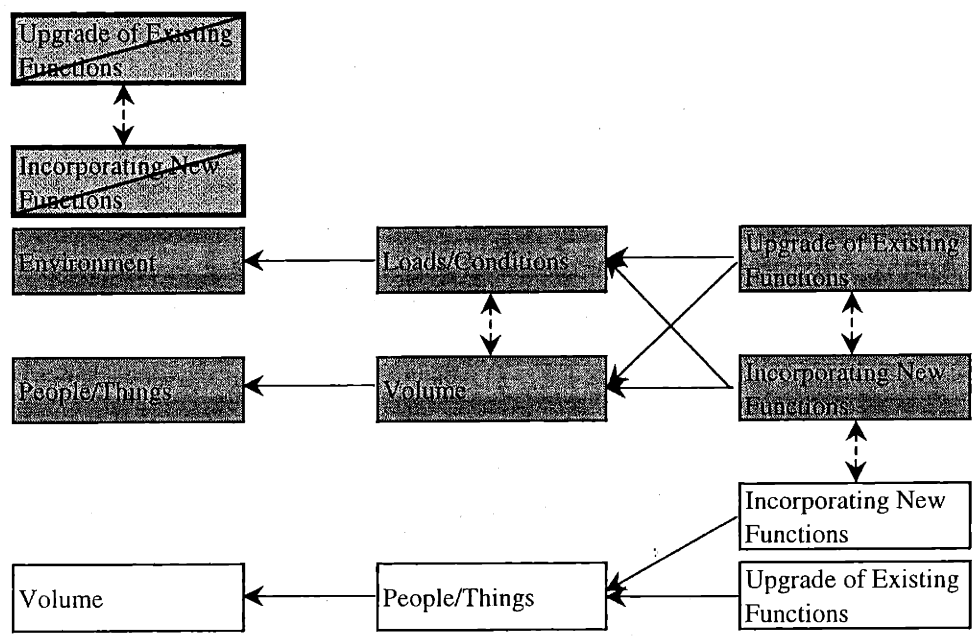
PROJECT: Building 16

		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions		Repair and Upgrade	Repair and Upgrade	Upgrade
			Exterior facade refinished; Some windows upgraded	HVAC rebuilt and replaced ; plumbing system upgraded; Some parts of the electric system reused, rest of it was replaced with current technology	Floors carpeted in the hallways and the offices; Tiled vinyl installed in the laboratories and restrooms
	Incorporating New Functions		1 New Function	1 New Functions	3 New Function
			Some new windows were installed in holes which were punched through the existing concrete block filled walls	New high tech telecommunications system installed and added to the existing electrical system	Interior entirely gutted, new metal stud and drywall walls installed to create interior space; moveable furniture installed within the laboratories; Some built in furniture also installed
	Modification for New Usage				
CAPACITY	Loads / Conditions			Yes	
				Electric system revamped in power and types of capacities to meet building's current and future needs	
	Volume			Large	Small
				Greater number of outlets, more cabling / piping provided for future needs	Rearrangement of interior changes the overall volume of the building's interior space
FLOW	Environment			Yes	Some
				New HVAC, etc., allows better, broader use of laboratory facilities and office space	Public flow changed somewhat through the new corridors and public areas
	People / Things			Yes	Yes
				Larger volumes allow the use of several different organizational arrangements within the laboratories and offices	Laboratory designs used moveable furniture, etc. to increase the flow of people within the space and provide safer aisles and movement paths

= Structural System Change
= Exterior Enclosure System Change
= Services System Change
= Interior Finish System Change

←------→ = Changes Performed Simultaneously

In order for left most change to be done, the changes to its right had to be done



Building N42, MIT, Cambridge, Massachusetts

Building N42 is another building on MIT's campus that recently underwent renovation. This building was originally built over 100 years ago and has since been used as a laundry building and an office building. The recent renovation changed the building for use as MIT's Information Systems office building.

This building required work in all of the systems to meet the requirements of its new usage. The work that was performed on the building's structural system shows how the type of structural system can affect the ease with which a facility can change to incorporate a new usage type. The masonry bearing wall and timber framed interior structural system required reinforcement in several different areas. These reinforcements were in response to the installation of new rooftop HVAC equipment, the installation of a new passenger elevator, the increase in floor loads within the building from increase density of activities, and the location of new openings within the existing bearing walls.

This project also shows the link that exists between the service and structural systems. The new use of the building required the installation of all new HVAC equipment. This equipment was installed on the roof of the existing building. However, the masonry bearing wall and timber framed structural system was unable to support the distributed loads associated with the new equipment. Therefore, a new steel superstructure had to be constructed above the roof in order to carry the loads of the equipment and transfer them down to the bearing walls of the building. If a different structural system had existed, this steel superstructure might not have been necessary.

The type of structural system also influenced the decision to renovate the building rather than simply demolish it and build a new structure, since it could adequately meet the load requirements for the new use and thus provided the opportunity to renovate. "If they were planning longer than a 10-15 year life for this building, it would have been more reasonable to demolish and build a new structure; however, considering a 10-15 year life, it was more cost efficient to renovate for its purpose now"(McKennan, interview, 1997).

PROJECT DATA SHEET

DATE: 10/30/97

PROJECT TITLE: Building N42

LOCATION: MIT, Massachusetts Avenue, Cambridge, MA 02139

PROJECT OWNER: MIT

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
John McKennan - Turner Construction Special Projects Group

ARCHITECT:
Perry and Radford Architects

(617) 547-4723

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Laundry building; Office space

PAST SYSTEMS:

STRUCTURAL: Masonry bearing walls (brick) with wood timber flooring and roof system.

ENCLOSURE: Brick masonry bearing walls with double hung windows

SERVICE:

FINISH:

SPECIAL CONCERNS: Geotechnical issues: water table 5' below the basement floor; the installation of the new elevator and elevator shaft required the installation of pressure injected piles - danger for a 100+ year old building.

FUTURE USAGE: MIT information systems building (Office space)
(10-15 year usage period expected)

NEW SYSTEMS:

STRUCTURAL: Some areas of reinforcing needed; steel beams, columns, lintels around and over new openings; roof/floors reinforced by sistering fir beams at long span areas; raised roof structure (steel) was constructed to support the new rooftop HVAC system equipment.

ENCLOSURE: Windows replaced; exterior façade repointed and washed on 2 side of the building (Massachusetts Ave and Windsor Ave sides remained untouched and in good condition)

SERVICE: New HVAC, electric, mechanical, communications, etc.; Central temperature control with automated temperature sensors with manual computer system; new elevator installed.

FINISH: Metal stud and sheetrock walls constructed to arrange the interior space between the three masonry bearing walls.

EXPECTED FUTURE CHANGES: Demolish in 10-15 years and build a new structure.

NOTES:
"25 years from now we'll tear this down." - Sarcastic remark by PM
If planning longer than a 10-15 year life it would have been more reasonable to demolish and build a new structure; however, considering a 10-15 year life, it was more cost efficient to renovate for its purpose now.

PROJECT: Building N42, MIT

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Service**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade Windows upgraded in efficiency; Exterior brickwork repointed and cleaned; Roof was repaired and renovated		
	Incorporating New Functions				
	Modification for New Usage	Major New elevator shaft and foundation constructed; Raised steel frame constructed on the roof in order to carry the weight of the new air handling systems and transfer it into the load bearing masonry walls; Some holes were cut into the interior masonry load bearing wall for new access points that required reinforcement		Major HVAC, telecommunications, sprinkler, electrical and plumbing systems all installed to meet the requirements for high tech. Office building use; New passenger elevator installed to couple the previously existing freight elevator	Major Interior entirely gutted and new non-load bearing metal stud and drywall partition walls were constructed to make distinct private rooms and common areas; New metal framed staircase also installed within the center of the building to provide more fire egress
CAPACITY	**Loads / Conditions**	Yes The roof and floor joists lack sufficient strength to relieve bending when weight was applied on them (e.g. a person walked across them they sagged) and therefore they were reinforced by sistered joists		Yes Systems all revamped in capacity to meet the power requirements and other requirements for the building's usage class	
	Volume			Medium Systems increased in volume to meet the current as well as potential future needs of the building's occupants	
FLOW	**Environment**			Yes New HVAC system as well as other systems help to create a pleasant working environment for the occupants of the building; use of indirect lighting etc.	Yes Open area transformed into smaller areas with a larger proportion of private rooms and office space
	People / Things	Yes Openings which were cut into the center bearing wall increased the amount of available passage between the two sides of the building		Yes Ductwork required for most of the services decreased the available headroom thus restricting some of the flow around the building; The new elevator provides a convenient conveyance for accessing all floors	Yes Flow of people within the building changed dramatically as people must now walk through a maze of cubicles and private offices as they move throughout the building.

Building N42, MIT, Cambridge, Massachusetts **Renovation for Different Usage**

= Structural System Change

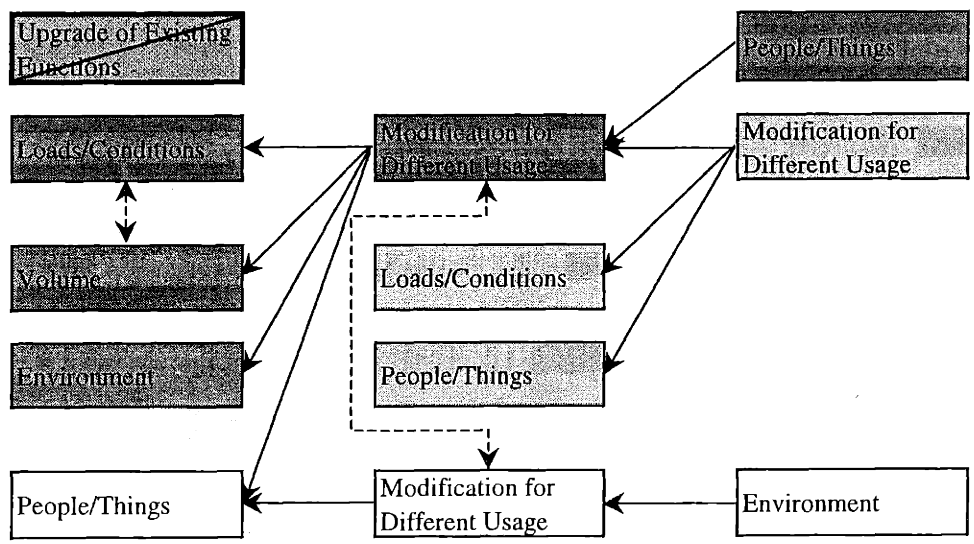
= Exterior Enclosure System Change

= Services System Change

= Interior Finish System Change

<------> = Changes Performed Simultaneously

In order for left most change to be done, the changes to its right had to be done



Building 314, Indianapolis, Indiana

This 75-year-old building was originally constructed as a 5 story, 307,540-sf automobile assembly plant for Nordyke and Marmon, and therefore presents a structural system that is ideal for manufacturing. This system is a reinforced cast-in-place concrete column and flat floor slab system. The new owner of the building has since renovated the building for use as laboratory and office space (Watkins-Miller, 1998).

Due to its design as a manufacturing plant, the building's structural system was more than strong enough to support the required loads of the new usage. Therefore, the building required no work structurally, aside from the construction of a 5-story tall glass atrium on the south side of the building for a new central staircase. While the structural system required little change, the other three systems required extensive change. A new precast concrete exterior with all new windows masked the existing exterior enclosure (but, notably, did not replace it). Meanwhile, the most interesting part of the renovation involved the work performed on the service and interior finish systems.

Again we see a strong link between the service and interior finish systems. The changes within the service systems included running all utilities overhead in the lab spaces in order to allow for unlimited laboratory configurations. The changes within the finish system included the design of laboratory spaces in a "dance floor" arrangement, that is, with all fixed casework and equipment on the perimeter and moveable tables, racks, etc. in the center. The interior was also designed so that both the office and laboratory spaces were of the same standard size with smaller common areas used for fumehoods, alcoves, and sinks. All of these design aspects were incorporated to further promote the flexibility of the building over its lifecycle.

PROJECT DATA SHEET

DATE: 5/4/98

PROJECT TITLE: Building 314

LOCATION: Lilly Technology Center, Indianapolis, Indiana

PROJECT OWNER: Eli Lilly and Co.

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Jerry Polly, PE, PM, Flad and Associates
644 Science Drive, Madison, WI 53705
(608) 238-2661

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: 5 story, 307,540 sf Nordyke and Marmon automobile assembly plant - 600 x 80 ft floor plan; 75 year old building

PAST SYSTEMS:

STRUCTURAL: "ideal for manufacturing"; reinforced concrete columns with concrete flat slab floors.

ENCLOSURE: Masonry and glass infill exterior skin - narrow 80 ft. width allowed the provision of natural light to the workers.

SERVICE:

FINISH: 14 ft. clear floor to ceiling heights

SPECIAL CONCERNS:

FUTURE USAGE: Laboratory and office space

NEW SYSTEMS:

STRUCTURAL: existing building was structurally sound and strong and therefore no work was necessary; however, a 5 story tall central atrium and staircase was constructed on the south side of the existing building

ENCLOSURE: A new precast concrete exterior was placed over the outside of the existing masonry system; new energy efficient, ultraviolet filtering windows were also installed – also placed outside the existing walls; 5 story central atrium and staircase on south side enclosed by a glass curtainwall

SERVICE: Utilities ran overhead in the lab spaces to allow unlimited lab configurations; Indirect lighting and task lighting installed; huge air handling systems installed at both ends of the building (due to the high amount of air circulation within the building, the energy efficiency is limited).

FINISH: Floor to ceiling partitions with 7 feet of glass separate labs from the central corridors (used to help stimulate idea sharing and social interaction between lab areas); labs designed with a dance floor layout (provides flexibility for future changes) with fixed casework on the perimeter and moveable tables, racks, etc. in the center; labs separated by common areas with fume hood alcoves, sinks, etc… Offices and labs are all a standard size to further promote Flexibility

EXPECTED FUTURE CHANGES:

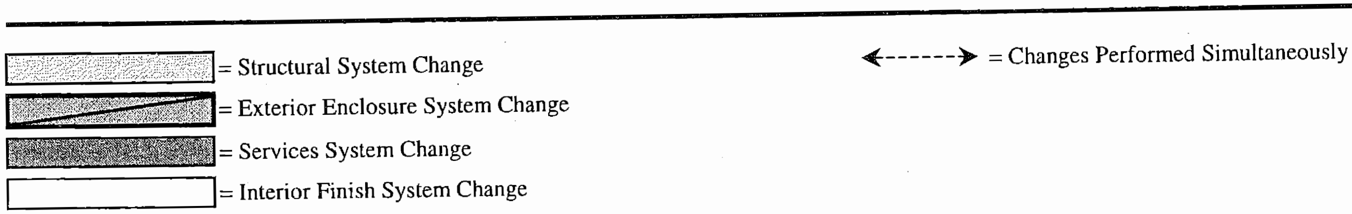
NOTES:

PROJECT: Building 314

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Service**	**Finish**
FUNCTION	**Upgrade of Existing Functions**				
FUNCTION	**Incorporating New Functions**				
FUNCTION	**Modification for New Usage**	Major 5 story atrium and central staircase was built and incorporated into the south side of the building	Major New precast panel exterior placed outside of the existing masonry system; New energy efficient windows replaced the original windows; New atrium and central stairway enclosed with a curtainwall exterior to increase the amount of natural light flowing into the building	Major Electrical, mechanical, HVAC, communications, and sprinkler systems all were either upgraded or installed to meet the requirements for laboratory and research usage	Major The design of the interior included the use of new floor to ceiling partitions with 7 ft. of glass to separate the laboratory rooms from the corridors; The labs incorporated a dance floor layout with fixed equipment and furniture on the perimeter and moveable in the center; Further flexibility was provided as all labs and office rooms were designed with the same dimensions with smaller common areas used for fumehoods etc.
CAPACITY	**Loads / Conditions**		Yes The new façade was used to save on maintenance costs and provide a much better energy efficient enclosure; Better materials for facing the common freeze/thaw cycles	Yes All of the existing systems were revamped to meet the requirements for laboratory space (HVAC especially - as air circulation was a very important issue)	
CAPACITY	**Volume**	Large Addition of the atrium and enclosed central staircase increased the overall structural system for the building	Large New enclosure simply fastened to the outside of the existing enclosure – similar to a giant mask; Addition of atrium also increased the volume of exterior enclosure that required work	Large The systems were all increased in depth to meet the current laboratory usage requirements but more importantly to allow greater flexibility in laboratory arrangements over time	Medium 14 ft. tall floor to ceiling heights were used to fit the utilities overhead
FLOW	**Environment**	Yes The atrium allows southern sunlight to pour into the building through the glass curtainwall exterior and thus creates a bright focal or common point for employees to congregate	Yes The new façade presents a much more attractive and welcoming building; The installation of the new windows and the glass curtainwall atrium provide the workspaces within the building with more natural light thus creating a better working environment	Yes The upgrade and installation of the new HVAC and air circulation system increases the building's overall safety and comfort within it laboratory spaces	Yes The glass partitions that were used to define the laboratory space stimulates idea sharing between employees; Overall the building experienced a drastic change from open industrial space into more enclosed yet social laboratories and private offices.
FLOW	**People / Things**	Yes New staircase within the atrium shortens the necessary distance to travel by half by bringing people to the middle of the building rather than the ends			Yes New interior revolutionized the laboratory space and makes it a much more interactive work space - promotes productivity and creativity through idea sharing; Interior also permits great flexibility in the arrangement of office and laboratory space

Building 314, Indianapolis, Indiana

Renovation for Different Usage



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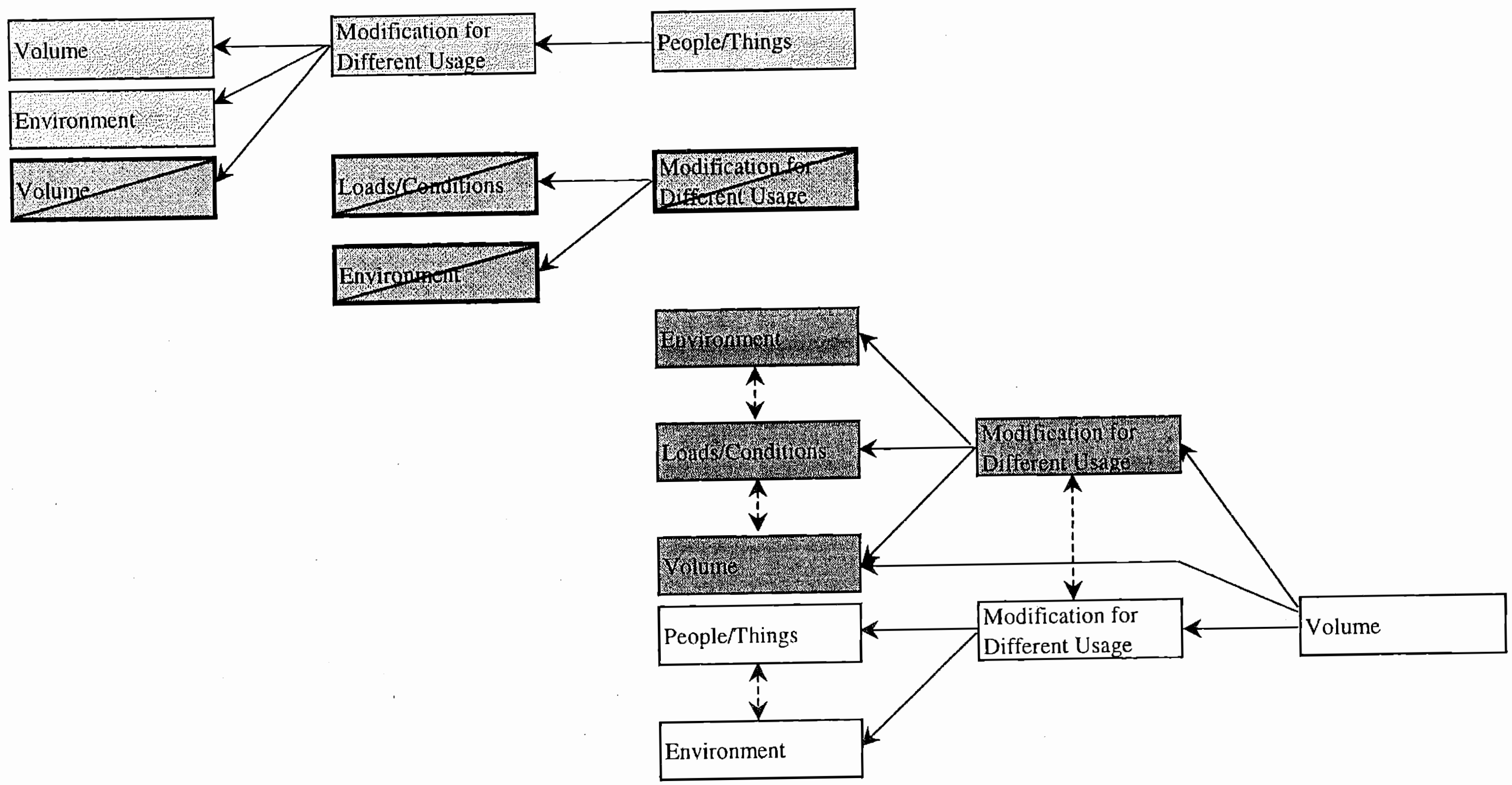

Citicorp Building, Manhattan, New York

The Citicorp building is an office building in Manhattan, New York. The interesting aspect of this building project is how it displays that work on the structural building system is capable of being uncoupled from the other systems when required. This building was originally designed with welded connections to meet the requirements for withstanding a 16-year windstorm. However, during construction planning, these welded connections were substituted with bolted connections that presented the same strength characteristics and that were less expensive to fabricate. However, miscalculations were made, and the bolted connections lacked the sufficient strength to withstand a 16-year windstorm (Morgenstern, 1995). Therefore, emergency work to strengthen the connections had to be performed.

The design of the building allowed the work to be performed on the weak connections without disturbing the workers within the building and without disturbing the other building systems to any great extent (some modification of the interior finish system was necessary in order to reach the respective connections). The reinforcing of the connections involve the welding of heavy 2" thick steel plates over more than 200 bolted connections within the structure to insure that the building was structurally sound as initially designed. In the end the design of the building allowed the necessary modifications to the structural system to be performed quickly and easily.

PROJECT DATA SHEET

DATE: 5/20/98

PROJECT TITLE: Citicorp Tower

LOCATION: Manhattan, NY

PROJECT OWNER: Citicorp

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER: STRUCTURAL
LeMessurier Inc.
Cambridge, MA

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Office Building

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

PROJECT: Citicorp

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Service**	**Finish**
FUNCTION	**Upgrade of Existing Functions**	Repair and Upgrade			Repair
		Heavy 2" thick steel plates welded over ~200 bolted joints to reinforce braces			Some interior drywall cut out so reinforcing of joints could be performed - It was replaced and repaired afterwards
	Incorporating New Functions				
	Modification for New Usage				
CAPACITY	**Loads / Conditions**	Yes			
		Bolted connections substitution failed to account for diagonal wind forces – catastrophic failure possible - had to reinforce the joints			
	Volume				
FLOW	**Environment**				
	People / Things				

Citicorp Building, Manhattan, New York

Renovation for Same Usage

= Structural System Change

= Exterior Enclosure System Change

= Services System Change

= Interior Finish System Change

<------> = Changes Performed Simultaneously

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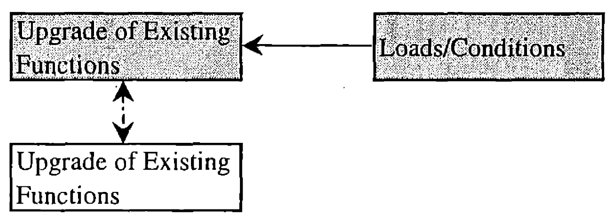

DEC Headquarters, Maynard, Massachusetts

DEC Headquarters is a set of 18 buildings in Maynard, Massachusetts that have been renovated from office and light manufacturing use into Class 'A' office buildings. The building complex is now named Clock Tower Place. Because they were originally built to suit the needs for a high technological company, these buildings already included the appropriate mechanical, HVAC, electrical and telecommunications systems required for today's high-class office space. However, some work including the replacement of the windows, the conversion of freight elevators into passenger elevators and the renovation of the interior finish space to comply with current codes was required to meet the new usage requirements. In the long run, these buildings are a prime example of how buildings can be designed for one usage and can easily adapt for a new usage by incorporating particular aspects within the main building systems (Miara, 1998).

PROJECT DATA SHEET

DATE: 5/4/98

PROJECT TITLE: DEC Headquarters - Clock Tower Place

LOCATION: Maynard, MA

PROJECT OWNER: Wellesley Rosewood Capital Corp. LLC

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Office, light manufacturing buildings - 18 building complex; each approximately 7,000 - 365,000 sf in size on a 38 acre lot

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS:

FUTURE USAGE: Class A office space

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Windows were replaced

SERVICE: Freight elevators needed to be converted to or replaced by passenger elevators.

FINISH: Renovated to comply with the American with Disabilities Act; otherwise it consists of open space.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: DEC Headquarters

		BUILDING SYSTEMS			
		Structural	Enclosure	Service	Finish
FUNCTION	Upgrade of Existing Functions				
	Incorporating New Functions				
	Modification for New Usage		Minor	Minor	Major
			Windows required replacement to meet the needs of an office building	Buildings have state of the art services yet the freight elevators had to be converted into passenger elevators to meet the requirements for office use	Buildings required complete interior renovation to comply with office use requirements as well as federal requirements such as the American with Disabilities Act; Space left open for tenant fit out
CAPACITY	Loads / Conditions				
	Volume				
FLOW	Environment		Yes		
			Buildings present a nice campus like setting in the route 128 area		
	People / Things				

DEC Headquarters, Maynard, Massachusetts

Renovation for Different Usage

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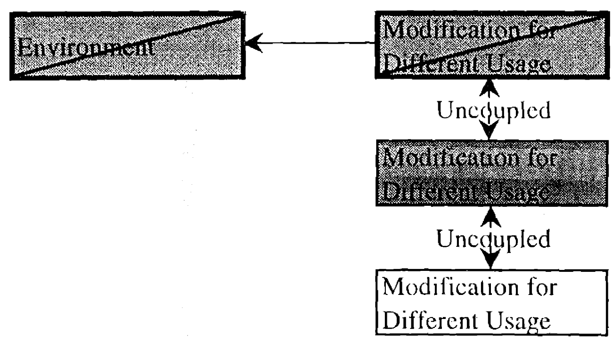

Federal Office Building, Norfolk, Virginia

This building project involved a federal office building in Norfolk, Virginia whose exterior enclosure system consisting of brick masonry was in danger of catastrophic failure. The work that was performed to solve this problem shows that work on the exterior enclosure system of a building can be uncoupled entirely from the other building systems; the exterior enclosure system was repaired with no work necessary on any other system within the building. The solution involved the emergency replacement of the exterior while the building's occupants continued to work inside. A new precast concrete panel system and new higher light transmission windows with thermally efficient glass replaced the original façade. The renovation also included the installation of a new roof and the replacement of the damaged brick façade of the two-level parking garage structure at the base of the building. The design of the building with a brick masonry non-load bearing façade allowed such a project to be performed so easily and without disturbing the building's occupants or any of the other building systems (Sawyer, 1997).

PROJECT DATA SHEET

DATE: 1/16/98

PROJECT TITLE: Federal Office Building

LOCATION: Norfolk, VA

PROJECT OWNER:

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Project Consultant Engineer - MMM Design
Norfolk, VA

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Federal office building

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE: Brick with windows

SERVICE:

FINISH:

SPECIAL CONCERNS: Recladding the building from the outside to minimize the disruption to the 10 federal tenants within it; replacement was an emergency - original brick cladding was in danger of failure

FUTURE USAGE: Same

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Precast concrete panels and new higher light transmission windows with thermally efficient glass replaced the existing exterior; new roof installed; the damaged brick face of the two level parking structure at the buildings base was replaced

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Federal Office Building

		BUILDING SYSTEMS			
		Structural	Enclosure	Service	Finish
FUNCTION	Upgrade of Existing Functions		Repair and Upgrade Failing brick enclosure replaced by precast panel enclosure; window frames left intact, glass replaced		
	Incorporating New Functions				
	Modification for New Usage				
CAPACITY	Loads / Conditions		Yes Material failure possible due to load conditions placed on the exterior		
	Volume				
FLOW	Environment				
	People / Things				

Federal Office Building, Norfolk, Virginia **Renovation for Same Usage**

= Structural System Change

= Exterior Enclosure System Change

= Services System Change

= Interior Finish System Change

<------> = Changes Performed Simultaneously

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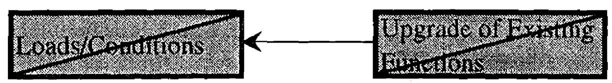


Globe Department Store, Waukegan, Illinois

The Globe Department Store is an old department store in Waukegan, Illinois that was transformed into an academic building by the College of Lake County. The structural system consists of masonry bearing walls with timber framed floors possessing sufficient load capacity and enough flexibility to allow an atrium to be cut through the center of the building. The existing roof and exterior enclosure were in very poor condition with severe water damage caused by the tough winters in the area. Therefore, the roof was renovated and upgraded, including a large 10-ft x 40-ft skylight over the atrium, and the building facades were reconstructed to resemble the building's original 1890's appearance. New thermally energy efficient windows were also incorporated within the renovation of the exterior façade. The existing services were inoperable and therefore entirely new service systems had to be installed within the building to meet the requirements of its new usage. The new service systems that were installed also took into account future needs of the building to provide future flexibility within the building's interior design (Vangen, 1998).

PROJECT DATA SHEET

DATE: 5/20/98

PROJECT TITLE: Globe Department Store

LOCATION: Waukegan, IL

PROJECT OWNER: College of Lake County

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Boller Construction

ARCHITECT:
Arthur Del Muro, Legats Architects Inc.
651 West Washington Blvd., Suite 400, Chicago, IL 60661
(847) 263-3535

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Department Store

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE: Porcelain enameled metal panels for cladding; severe water damage; roof was a total loss

SERVICE: Existing heating, ventilation and air conditioning units all were a total loss

FINISH: Water damage to building walls and floors

SPECIAL CONCERNS:

FUTURE USAGE: Academic Building - College

NEW SYSTEMS:

STRUCTURAL: 3 story atrium constructed within the center of the building to allow better ventilation and flow of natural light

ENCLOSURE: 10 x 40 ft. skylight placed over the atrium; porcelain panels removed and replaced by the application of an exterior insulation and finish system that restored the building to its 1890s style and fixed all of its leakage problems; New thermal insulated windows were also installed.

SERVICE: The original elevator and shaft were replaced with a larger more efficient unit; new light fixtures installed; sprinkler system was added; electrical/ communic. systems upgraded to a fiber optic system.

FINISH: Damaged wood floors repaired and/or replaced and support columns and portions of the original brick walls were cleaned and left exposed to retain pieces of the building's original look and feel; catwalk style stairs and walkways constructed inside.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Globe Department Store

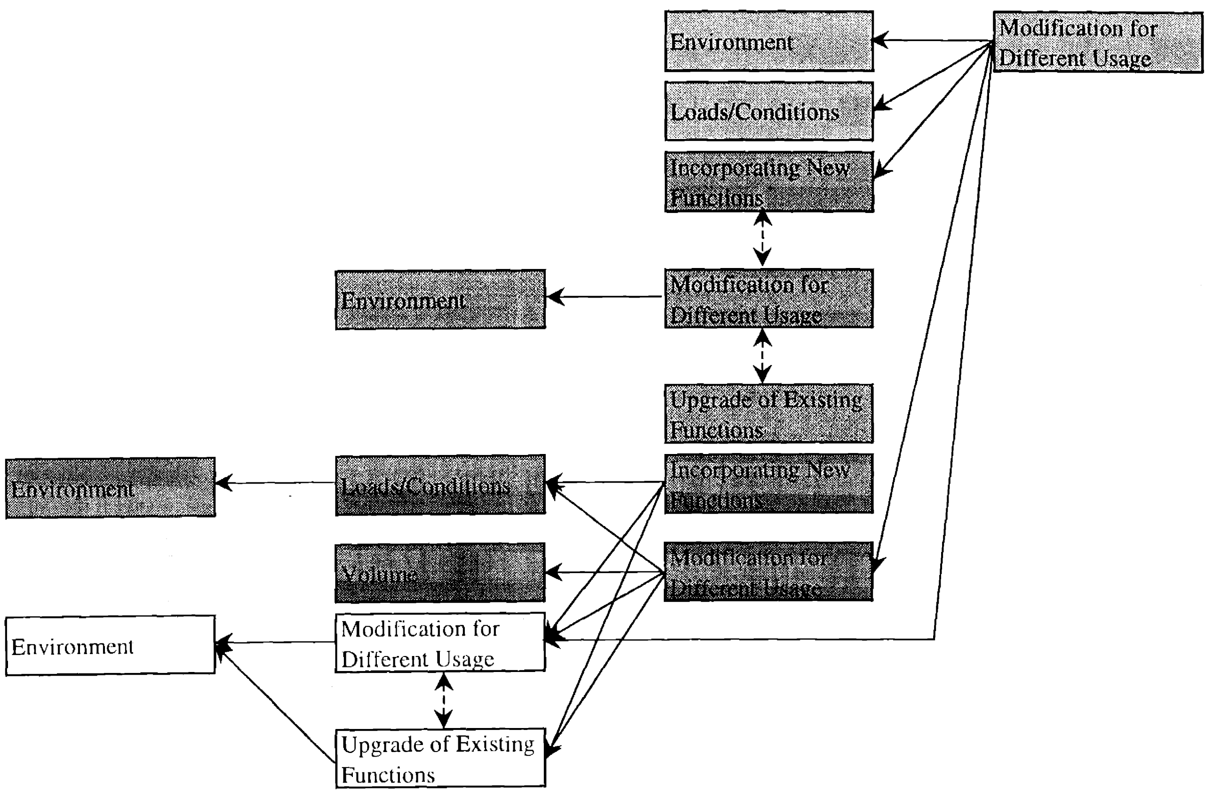
		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions		Repair and Upgrade		Repair
			Roof which was a total loss was entirely replaced and upgraded		Damaged wood floors repaired or replaced entirely; Portions of the brick walls and the support columns cleaned and left exposed for historic reasons
	Incorporating New Functions		1 New Function	1 New Function	
			A 10 x 40 ft. skylight was installed over the new atrium	Entirely new sprinkler system installed	
	Modification for New Usage	Major	Major	Major	Minor
		3 story atrium cut into the center of the building; reconstruction of the elevator shaft	Porcelain panels removed and an exterior insulation and finish system was applied to restore the building's original 1890s style; Thermal insulated windows installed throughout the building; Atrium skylight installed	Existing elevator and shaft replaced with a larger unit; New light fixtures installed; electrical and communications systems upgraded to a fiber optic system to meet usage needs	Interior transformed from an open department store and warehouse design into a more private enclosed academic design (individual classrooms, offices, etc.)
CAPACITY	Loads / Conditions	Yes		Yes	
		Structure able to allow atrium to be cut into it (masonry bearing walls with timber framed flooring)		Electrical and communication systems upgraded to meet capacity needed for academic use; Elevator also upgraded to meet this use	
	Volume			Medium	
				Electrical, communication, sprinkler and HVAC systems all increased in depth to meet the current and future potential academic needs	
FLOW	Environment	Yes	Yes	Yes	Yes
		Atrium allows natural light to flow through the building's cat-walk style stairs and walkways - makes space a much more pleasing and comfortable working environment	Restorátion of the exterior to meet the appearance of the original appearance improved the overall aesthetics of the building; Windows etc., helped promote energy savings etc.	New systems and system upgrades create a much more comfortable environment for students and employees	New interior enhances comfort and helps to provide a bright and welcome setting for students and faculty to work within
	People / Things				

Globe Department Store, Waukegan, Illinois — Renovation for Different Usage

= Structural System Change
= Exterior Enclosure System Change
= Services System Change
= Interior Finish System Change

<-----> = Changes Performed Simultaneously

In order for left most change to be done, the changes to its right had to be done



Grand Central Station, New York, New York

This historic building has long served as the main hub for rail traffic heading north from the New York City. In 1967, the building was declared a landmark; however, for decades since it has suffered from lack of maintenance and has greatly needed repair. The renovation of the building incorporated the repair of some deteriorated portions of the structural steel, but the majority of the work consisted of work on the services and interior finish systems within the building (Rasmussen, 1997).

Through the work performed on the services and interior finish systems, the common link between the two systems again became evident. The changes to the services included the installation of 7 new elevators, 6 new escalators, the redesign and replacement of all of the utilities (electrical, plumbing, heating and generators), and the installation of new fire safety and sprinkler systems. Lead and asbestos abatements were performed, and a large proportion of the interior finish was restored, including the vaulted cerulean blue-sky ceiling. The work on the interior finish also included the construction of a new Bottocino marble staircase on the east side of the building to match the historic one that existed on the west side of the building.

The most interesting thing about this entire renovation project was the fact that the work was performed during the station's regular hours of operation with only a 4-hour closure in the middle of each night. Furthermore, most of the structural changes which were required had to be performed without the aid of accurate original drawings. Overall, this building renovation project displays how important incorporating building maintenance within the initial design of a building is and how important effectively performing that maintenance over the building's lifetime is for avoiding problems with deterioration.

PROJECT DATA SHEET

DATE: 1/15/98

PROJECT TITLE: Grand Central Station

LOCATION: New York City, NY

PROJECT OWNER: New York City

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
PM - GCT Venture Inc. (LaSalle Partners and Williams Jackson Ewing)
GC - Lehrer McGovern Bovis, Inc., New York

ARCHITECT:
Beyer, Blinder, Belle

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Hub for rail traffic heading north from the city

PAST SYSTEMS:

STRUCTURAL: Structural steel building with lightweight latticed columns surrounded by reinforced concrete terra cotta tiles and ornate decorative stone.

ENCLOSURE: Indiana limestone, Stoney Creek granite and painted metal windows

SERVICE:

FINISH:

SPECIAL CONCERNS: Crews had to work on the structure during regular station operation, with only a 4 hour window in the middle each night; they had to make structural changes without the help of accurate original drawings; 1967 the building was declared a landmark - however over the years it had suffered from lack of maintenance.

FUTURE USAGE: Same

NEW SYSTEMS:

STRUCTURAL: Same - Framing overall sound - some areas of deterioration did however exist and therefore required repair or replacement

ENCLOSURE: Same

SERVICE: Two new banks of escalators installed; all of the utilities were redesigned and replaced (lights, plumbing, heating and generators); new chilled water equip. and rooftop cooling towers installed; power supply increased to 13,200 V; new sprinkler and fire safety systems installed; total of 7 new elevators and 6 new escalators were installed

FINISH: The vaulted, cerulean blue sky ceiling was restored; asbestos and lead abatement was performed; a new Bottocino marble staircase was constructed on the east side of the building to match the historic one on the building's west side.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Grand Central Station

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**	Repair		Repair and Upgrade	Repair and Upgrade
		Some areas of steel were deteriorated and therefore required repair and replacement		All utilities redesigned and replaced; Lighting upgraded	Asbestos and lead abatement performed; Vaulted historical ceiling restored
	Incorporating New Functions			4 New Functions	1 New Function
				Installation of 6 additional escalators; Installation of new HVAC equipment; installation of 7 new elevators; Installation of new fire safety and sprinkler systems	New marble staircase built to create twin identical staircases within the main lobby of the station (new one matches the historical existing staircase)
	Modification for New Usage				
CAPACITY	**Loads / Conditions**	Yes		Yes	
		Deterioration of some areas of structural steel required attention		Electric power supply increased to meet building's usage needs	
	Volume				
FLOW	**Environment**				
	People / Things			Yes	Yes
				Addition of new conveyances helped to ease the flow of people through the station	New staircase provides greater access to the second floor of the station - thus relieving some of the traffic from the original staircase

Grand Central Station, New York, New York

Renovation for Same Usage

= Structural System Change

= Exterior Enclosure System Change

= Services System Change

= Interior Finish System Change

←------→ = Changes Performed Simultaneously

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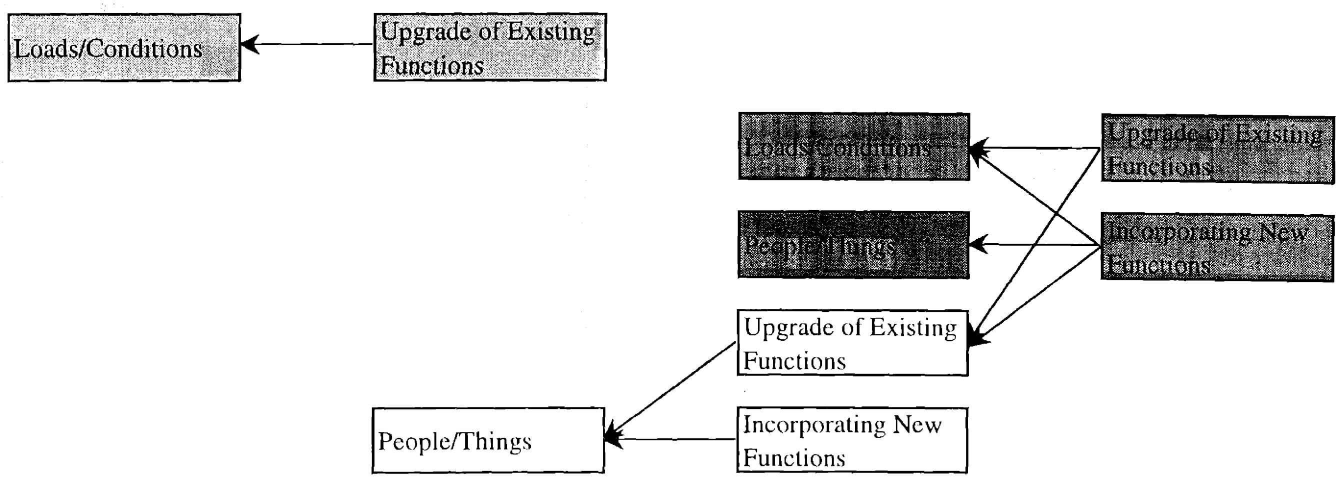


Iowa State University Office, Ames, Iowa

This building is a 2-story office building at Iowa State University in Ames, Iowa. The building's design consists of a steel frame with a 6-inch thick composite concrete slab on deck for the second floor. The interior finish of the building represents the traditional open office plan design. The initial design and construction of the building was made to meet the minimum passable requirements for load capacities within the floors in order to minimize the initial costs for constructing the building. Subsequently, although these structural floors did pass load capacity requirements, they still lacked the sufficient strength to prevent the high vibrations which occurred within them because of the building's usage. These vibrations were causing worker discomfort and were thus making the building a very undesirable place to work. To fix the problem, a set of trusses was attached underneath the floor beams to reduce the vibrations ("Floors: Truss...", 1998).

This case displays one of the more frequent problems encountered when a building has been designed to meet the minimum requirements to minimize the initial costs. Rather than considering the specific requirements for maintaining occupant comfort within the building and designing the building with slightly over-designed floor slabs, the owner chose to instead minimize its initial investment. In truth, the initial savings that the owner made were erased by the costs that accompanied the necessary repairs to the building to provide the building's occupants with the required comfort.

PROJECT DATA SHEET

DATE: 7/7/98

PROJECT TITLE: Iowa State University Office

LOCATION: Ames, Iowa

PROJECT OWNER: Iowa State University

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:
Dean Morton

CIVIL ENGINEER:
STRUCTURAL
Robert Britson - Shuck-Britson Inc.
Des Moines, Iowa
Thomas M. Murray

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE: Jul-98

PAST USAGE: 2 story office building

PAST SYSTEMS:

STRUCTURAL: Steel framed with 6 inch thick composite concrete on deck floors

ENCLOSURE:

SERVICE:

FINISH: Open office plan environment

SPECIAL CONCERNS: High vibrations within the building were causing worker discomfort; caused by insufficient (yet passable) load capacity of the structural floors.

FUTURE USAGE: Same

NEW SYSTEMS:

STRUCTURAL: Trusses attached underneath the floor beams to prevent high vibrations

ENCLOSURE:

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

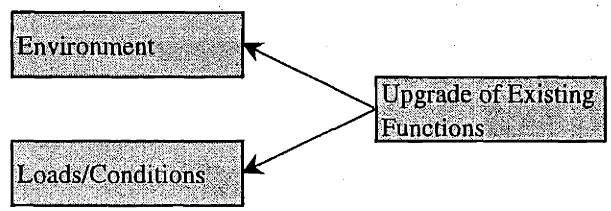
NOTES:

PROJECT: Iowa State University Office

		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions	Upgrade			
		Steel Trusses attached under the existing floors to prevent/reduce excessive vibrations			
	Incorporating New Functions				
	Modification for New Usage				
CAPACITY	Loads / Conditions	Yes			
		Original 6" thick composite concrete on deck floor allowed vibrations of ~0.8% g			
	Volume				
FLOW	Environment	Yes			
		The upgrade of the structure helps reduce the uncomfort which the users experience - reduces amount of motion sickness cases			
	People / Things				

Iowa State University Office Building, Ames, Iowa **Renovation for Same Usage**

In order for left most change to be done, the changes to its right had to be done



K. Wayne Smith Building, Dublin, Ohio

The K. Wayne Smith building was originally designed as a regional Volkswagen Co. distribution warehouse and therefore possessed a strong structural system, a bland exterior precast panel system and minimal heating, cooling and electrical systems with an open warehouse interior plan. The building's new owner decided to renovate the building into an office building which accommodates conference and training areas, offices, an employee fitness center, and some warehouse space (Watkins-Miller, 1997).

To meet this new usage class, a second floor was constructed within the structure. Although the structural system within the existing building was strong and stable, some re-engineering of the foundation and reinforcement of the interior columns was necessary. Aside from the structural changes, the most interesting aspect of this renovation project was its inclusion of building flexibility as one of the major design goals. Much of this flexibility became evident within the service and interior finish systems. Changes within these systems included the installation of additional rooftop mechanical systems, the installation of underfloor cabling, and the use of a modular wiring distribution system underneath a raised paneled floor. This allowed the areas within the building to accommodate several different possible organizational arrangements of cubicle and office space, as well as the necessary flexibility to meet possible future needs.

PROJECT DATA SHEET

DATE: 1/16/98

PROJECT TITLE: K. Wayne Smith Building

LOCATION: Dublin, OH

PROJECT OWNER: OCLC Online Computer Library Center, LLC

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Gilbane Building Co.

ARCHITECT:
URS Greiner

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Regional Volkswagen Co. distribution warehouse

PAST SYSTEMS:

STRUCTURAL: Steel framing and heavy duty concrete slab

ENCLOSURE: Precast concrete panel exterior

SERVICE: Minimal heating and cooling requirements met for warehouse use

FINISH: Open warehouse plan

SPECIAL CONCERNS: Provision of flexibility a major goal

FUTURE USAGE: Office building accommodating conference and training areas, offices, an Employee fitness center and some warehouse space.

NEW SYSTEMS:

STRUCTURAL: New 8 inch thick flat plate concrete slab second floor installed within building; Second floor set back from the perimeter of the building; new single ply roof Also installed

ENCLOSURE: New light finish painted on the exterior panels; 60 new windows were punched Through the exterior precast concrete panels in a staggered pattern.

SERVICE: Additional mechanical rooftop equipment installed; underfloor cabling Installed; modular wiring distribution system used under a raised paneled floor

FINISH: Private conference areas, offices, etc. concentrated in the center of the building Leaving the perimeter as open space with enormous amounts of natural light; Helps with ventilation within the building.

EXPECTED FUTURE CHANGES:.

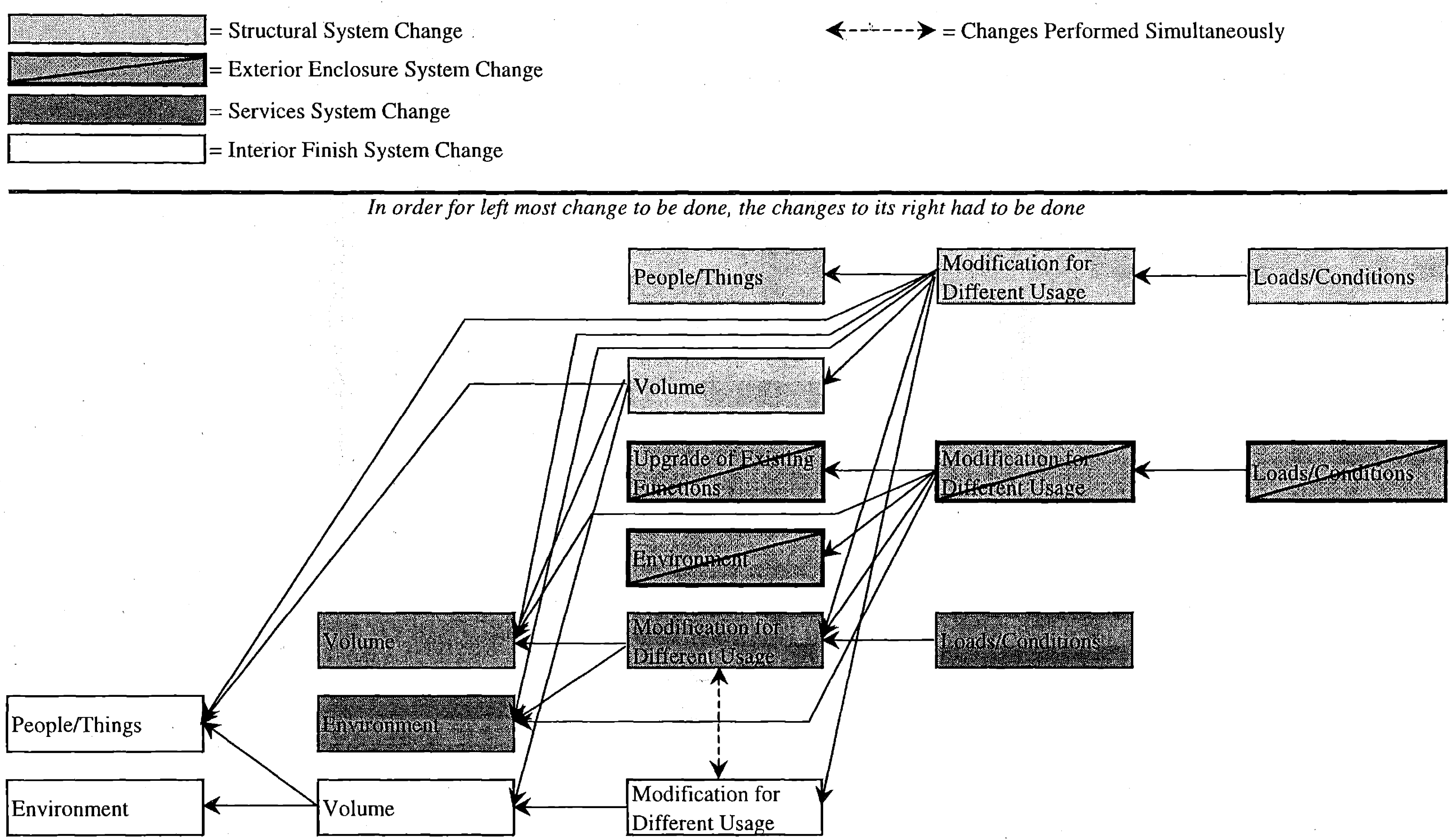
NOTES:

PROJECT: K. Wayne Smith Building

		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions		Upgrade New light finish paint applied to the exterior		
	Incorporating New Functions				
	Modification for New Usage	Major New 8 inch thick flat plat concrete slab second floor installed within the building	Major 60 new windows were punched through the existing precast panel exterior; roof was replaced with a single ply roof with an atrium	Major HVAC, plumbing, electrical, communications and sprinkler systems all upgraded or installed to meet the new usage needs	Major Second floor of the building set back from the perimeter; Building interior modified to accommodate conference areas, training areas, offices, a fitness area and warehouse space
CAPACITY	Loads / Conditions	Yes Re-engineering of the foundation was required due to the additional loads applied by the construction of the new second floor; interior columns required reinforcement to carried the loads	Yes New windows had to be staggered from floor to floor in order to safely accommodate the change in loads and capacity of the precast panels	Yes Building was set up to two different primary utility services; Electrical and communications services upgraded in power to meet the future needs of the company	
	Volume	Large Large 20 ft. tall open space transformed into a two story building		Large Transformation of a one story tall warehouse into a two story tall office building required a much greater volume and depth of various services	Large The construction of a second floor
FLOW	Environment		Yes Windows help provide more natural light into the building; Paint helps to unify the building with the rest of the company's campus	Yes The installation of a new HVAC system increases the comfort within the building and thus creates a much better working environment	Yes The second floor was set back from the perimeter in order to maximize the amount of natural light flowing into the building as well as to enhance the passive flow of air; open office plan which is used in the office areas helps to expose the occupants working within the building to this light
	People / Things	Yes Flow within the building changes from a one story building to a two story building			Yes Open space transformed into two stories of office interrupted by rooms, etc. thus causing a change in the overall flow of people within the building

K. Wayne Smith Building, Dublin, Ohio

Renovation for Different Usage



Lafayette Corporate Center, Boston, Massachusetts

The Lafayette Corporate Center is a building located on Washington Street in Boston, Massachusetts and its renovation is evidence of the movement to revitalize the Downtown area of the city. The building was originally built as a 3 story tall mall and retail center. The renovation of the building upon completion will provide a 600,000-sf retail and office complex with 75,000-sf in retail space on the first floor and the remainder of the building for office fitout. To provide this space, a large 3-story addition had to be constructed above the existing building. The addition to the structure required structural reinforcement of the lower three floors and minor remediation of the footings (Lawlor, 1998).

The owner decided that it was better to "grandfather" (i.e., accepted under previous rules) the building's floorplate and to add to the structure and suffer the costs associated with the modifications necessary for the renovation due to the tight site constraints of the site which the building exists than to tear it down and seek approval for a new building. However, if the building was originally built with the structural capacity to accept additional loads, or other usage classes, these costs would have been decreased dramatically.

PROJECT DATA SHEET

DATE: 1/15/98

PROJECT TITLE: Lafayette Corporate Center

LOCATION: Washington Street, Boston, MA

PROJECT OWNER:

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Scott Manard, Suffolk Construction Co.
Boston, MA
(617) 210-4778

ARCHITECT:
James Gray, PM, ADD Inc.
80 Prospect Street, Cambridge, MA
(617) 661-0165

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE: Nov-98

PAST USAGE: Mall / Retail center

PAST SYSTEMS:

STRUCTURAL: 3 story structural steel frame with concrete slab floors

ENCLOSURE: Masonry exterior

SERVICE: Mechanical - heat pump condenser water loop; Electrical - 120 208 loop system Sprinkler and fire protection systems.

FINISH: Metal stud and drywall interior walls making up interior space

SPECIAL CONCERNS: Addition of three additional floors to the top of the existing structure; Entire building gutted and demolished down to its structural framing.

FUTURE USAGE: 600,000 sf retail and office space complex; 75,000 sf retail space; upper 5 floors plus small part of the first floor for office use, while the majority of the first floor, namely side facing Washington Street will be used for retail

NEW SYSTEMS:

STRUCTURAL: Addition of the three floors to the top of the existing structure; steel reinforcement of the lower three floors and the foundation necessary; minor footing remediation required.

ENCLOSURE: New Precast concrete exterior to replace the older masonry exterior which was demolished(?
)

SERVICE: All new systems installed; new mechanical - chilled water; new electrical - 480 227 transformer board; new sprinkler and plumbing systems installed

FINISH: Finish - metal stud and drywall used to construct all lobbies and corridors within the building; remainder of the building left unfinished for individual fit out by tenants.

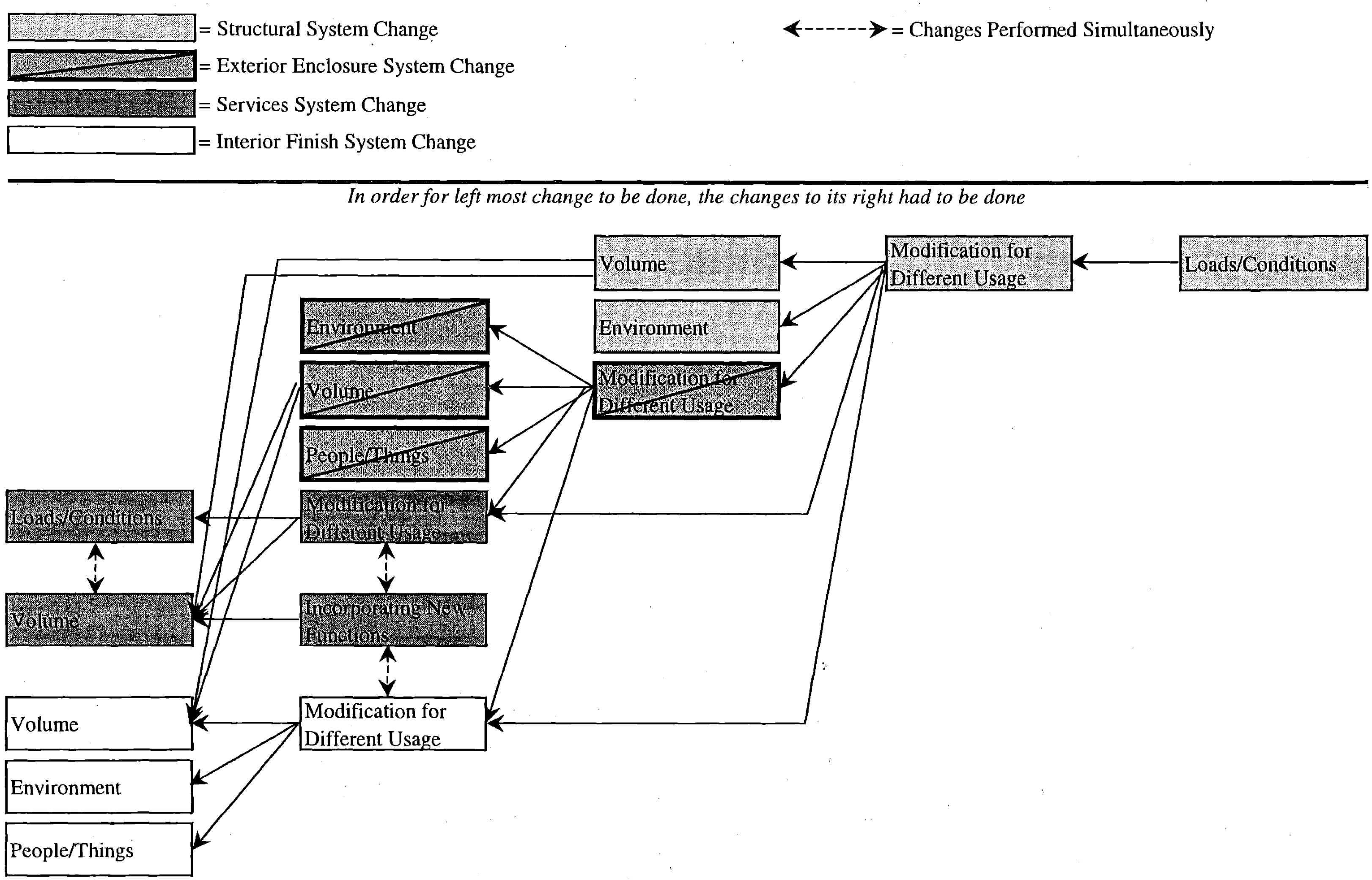
EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Lafayette Corporate Center

		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions				
	Incorporating New Functions			1 New Function Communications system added to the original list of common systems	
	Modification for New Usage	Major Construction of 3 additional floors atop the existing building; Reinforcement of the lower floors required; Minor footing remediation required as well	Major Existing enclosure entirely demolished so that the structural system could be exposed and reinforced; entirely new exterior to be installed	Major HVAC, plumbing, electrical, communications and sprinkler systems all upgraded or replaced to meet the new usage needs	Major Interior entirely gutted; new interior to be constructed consists of the finishing of 3 main lobbies and all interior corridors with the remainder of the building left for tenant fit out
CAPACITY	Loads / Conditions	Yes The addition increased the overall loads placed lower floors and foundation of the existing building and therefore reinforcement was required; The new loads used for the entire building were configured for office use		Yes Electrical system power capacity increased	
	Volume	Large 3 floors equaling approximately 340,000 sf were added to the existing structure	Large Overall building exterior volume increased by the addition coupled with the demolition of the existing exterior	Large The new addition of 3 floors and the new usage class will require a greater volume and depth of services to adequately meet the needs of the building's tenants	Large The addition to the structure increases the amount of useable interior space considerably
FLOW	Environment	Maybe Larger building in a tight constricted neighborhood might have some effects both good and bad on the surrounding neighborhood	Maybe The new exterior of this building within the particular neighborhood that it is in might raise some eyebrows		Yes Open retail space transformed into more private office space to be fitout by individual tenants; Public restricted to the common lobbies and hallways
	People / Things		Yes The incorporation of strip windows and a much nicer precast panel exterior might help promote the working environment within and around the building thus effecting the flow of people around and through it		Yes New lobbies and corridors change the overall flow of people through the entire building; People will now have to move through a maze of corridors and office space to move from one point in the building to the other

Lafayette Corporate Center, Boston, Massachusetts **Renovation for Different Usage**



Liberty Tree Building, Boston, Massachusetts

The Liberty Tree Building is a historic building that has been located on State Street in Boston, Massachusetts within Boston's legendary "combat zone" area for over 100 years. This building was originally constructed as a mercantile building with some office space. The structural and enclosure systems consisted of a historic masonry building façade with a heavy timber framed structure inside. While these systems did not require much rehabilitative work other than the replacement of windows and the cleaning and repointing of the exterior masonry, the services and interior finish systems required a vast amount of work. All new service systems and an entirely new interior finish system were installed in order to meet the required needs of the building's new usage as office space designed for individual tenant fit out (Martinelli, interview, 1997).

While this building is not an example of a building that has incorporated possible future changes within its design, it does serve as an example of how the renovation of a single building can provide opportunities for shifts within the atmosphere of the neighborhood it exists. There are two interesting things about this renovation project. The first is the particular location that the building exists. The "combat zone" has remained notorious as a bad section of the city of Boston. However the city has put forth a major effort to attempt to revitalize this area. The renovation of the Liberty Tree Building, which now houses the Massachusetts Department of Motor Vehicles, is one of the first major steps towards reaching this goal. The second thing is the fact that the project was a historic renovation. Despite the accretion of materials and systems over time, which was entirely removed, this building was still adaptable for new use without disrupting its historic heritage.

PROJECT DATA SHEET

DATE: 11/20/97

PROJECT TITLE: Liberty Tree Building

LOCATION: 114 State Street, Boston, MA

PROJECT OWNER: Massachusetts Department of Motor Vehicles (Tenant) - Private Developer

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Scott Martinelli, Shawmut Design and Construction
560 Harrison Ave, Boston, MA 02118
(617) 210-9157

ARCHITECT:
Bergheimer Associates
Boston, MA

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Aug-97
FINISH DATE: Mar-98

PAST USAGE: Mercantile and office building (75-100 years)

PAST SYSTEMS:

STRUCTURAL: Heavy timber and masonry structural system

ENCLOSURE: Brick masonry exterior walls

SERVICE: Steam heating; very old and outdated mechanical, electrical, conveyances, etc.

FINISH: Timber stud walls with plaster

SPECIAL CONCERNS: Asbestos removal, repair and restoration of the historic façade.

FUTURE USAGE: Office - tenant MDMV ; rest of space left for fitout; also 1800 sf of retail space

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Masonry enclosure cut and repointed; new windows were installed within the Original sashes

SERVICE: All new systems installed; new mechanical - rooftop chilled water units; new Electrical; new sprinkler and plumbing systems installed, etc.

FINISH: Metal stud and drywall partitions used for the new interior spaces

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Liberty Tree Building

		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions		Repair and Upgrade Brick Masonry exterior walls cut and repointed; glass in windows replaced, while the frames were reused		
	Incorporating New Functions				
	Modification for New Usage			Major All services upgraded and revamped to meet the needs of several different tenants	Major Open commercial retail areas converted into more defined smaller tenant space, etc.
CAPACITY	Loads / Conditions			Yes Services revamped to provide a variety of tenant types with adequate service	
	Volume			Medium Depth of services increased to meet the needs of multiple tenants	
FLOW	Environment		Yes Historic façade restored thus helping to enhance and restore the surrounding neighborhood		
	People / Things				

Liberty Tree Building, Boston, Massachusetts

Renovation for Different Usage

= Structural System Change

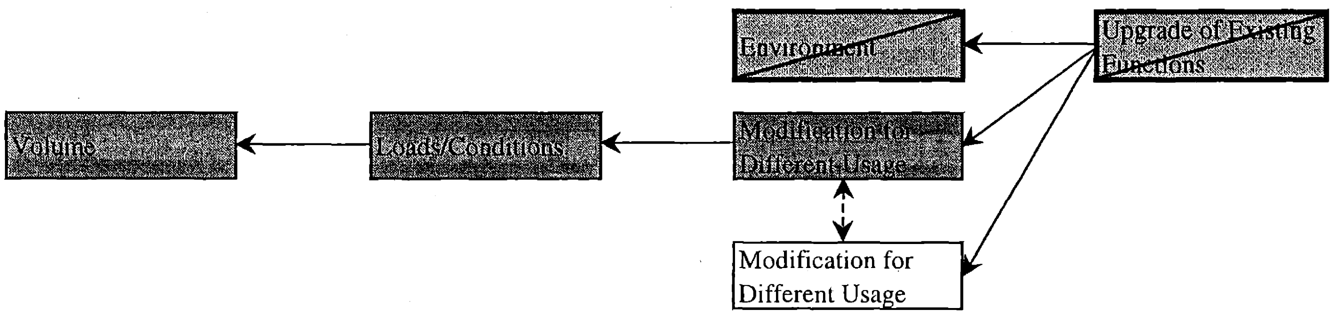
= Exterior Enclosure System Change

= Services System Change

= Interior Finish System Change

<------> = Changes Performed Simultaneously

In order for left most change to be done, the changes to its right had to be done



Mount Auburn Hospital, Cambridge, Massachusetts

The Mount Auburn Hospital is a facility that is located on Mount Auburn Street in Cambridge, Massachusetts. The site of the hospital is very constrained, with major roads on three sides and a large park on the fourth side. Due to these site constraints, the original design for the building complex provided the necessary structural capacity to accommodate possible future vertical expansion of the facility (Brenneman, 1998).

The recent renovation of the hospital included the construction of a 2-story addition of approximately 12,000-sf above the surgical areas of the hospital, the renovation of the basement level to house new mechanical rooms and the renovation and upgrade of some interior spaces. Construction was performed on the addition as well as the room renovations while the hospital remained open.

Overall, this is an important case for showing how incorporating possible future changes (expansion, etc.) within the original design can allow a building to evolve with changing times and thus adapt to future regulations and needs.

PROJECT DATA SHEET

DATE: 11/6/97

PROJECT TITLE: Mt. Auburn Hospital

LOCATION: Mt. Auburn Street, Cambridge, MA

PROJECT OWNER: Mt. Auburn Hospital

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Jack Fritz - Shepley Bullfinch
Bob Douglass - Walsh Brothers Construction
(617) 499-5004

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE: February-March 1998

PAST USAGE: Hospital

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: Construction being performed above, and around areas in which specialized surgery is taking place; work also being done in other areas while regular operation of the hospital continues

FUTURE USAGE: Same - simple renovation, upgrade and addition to the existing building

NEW SYSTEMS:

STRUCTURAL: Two story steel framed addition constructed above the operating rooms; New mechanical rooms constructed in the basement - construction required some forms of structural reinforcement of the existing structure

ENCLOSURE: New brick enclosure with windows (inoperable) placed on the exterior of the addition to the building; new roof also constructed

SERVICE: Electrical systems upgraded; new mechanical rooms constructed within the basement to house mechanical units for addition to the building

FINISH: Several areas were completely gutted adjacent to the addition; new operating rooms/areas were constructed in these areas; private patient rooms throughout the rest of the hospital were each individually renovated to enhance noise reduction and privacy

EXPECTED FUTURE CHANGES:

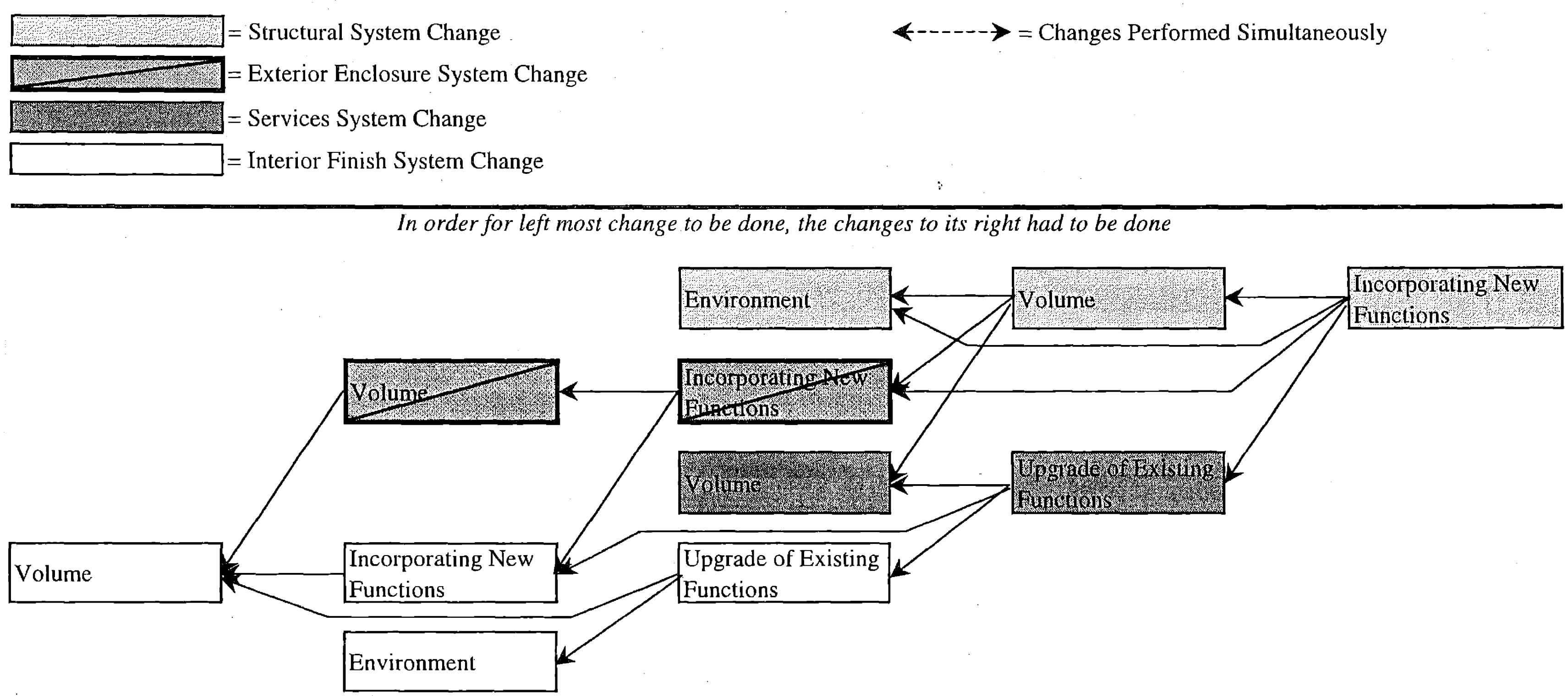
NOTES:

PROJECT: Mount Auburn Hospital

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**			Upgrade Mechanical, electrical, communications systems all upgraded and enhanced to meet current and future hospital needs	Upgrade Areas adjacent to the addition were completely gutted and remodeled; renovation incorporated the upgrade of existing medical/surgical units and private patient rooms
	Incorporating New Functions	1 New Function 2 story addition constructed on the top of the rear lab building	1 New Function New brick façade with windows installed on the addition to match the existing exterior of the hospital		1 New Function Finishing of the interior of the new addition
	Modification of New Usage				
CAPACITY	**Loads / Conditions**	None Building capable of accepting additional loads of the addition			
	Volume	Large Addition of 2 stories consisting of ~12,000 sf of building space	Large Addition	Large Services required expansion to supply the new addition with adequate service	Large Addition
FLOW	**Environment**	Yes Addition and renovation of the structure affects ~1/2 of the hospitals departments			Yes Finish upgrade will help reduce noise in private patient rooms, etc. and thus increase patient comfort
	People / Things				

Mt. Auburn Hospital, Cambridge, Massachusetts

Renovation for Same Usage



705 Mt. Auburn Street, Watertown, Massachusetts

This building which is located at 705 Mount Auburn Street in Watertown, Massachusetts was originally designed for the manufacturing and warehousing of telephones by AT & T. It was later bought by Mt. Auburn Hospital and used as a storage building. The new usage for the building is for office or research and development fit-out (Hubbard, interview, 1997).

This shift in usage required several changes within the building. The structural system, which was originally designed for manufacturing telephones, possessed the structural capacity necessary to allow several modifications to be performed on the building. Such modifications included the installation of an additional floor between the existing 1st and 2nd floors of the low-rise portion of the building and the construction of a large atrium through the center of the low-rise portion of the building. Other changes were required in the services and interior finish systems. Due to the excessive structural capacity of the existing building, all of these changes could be made with little difficulty and at very little expense.

PROJECT DATA SHEET

DATE: 1/13/98

PROJECT TITLE: 705 Mt. Auburn Street - GE Building Renovation

LOCATION: 705 Mt. Auburn Street, Watertown, MA

PROJECT OWNER: Prospectus (Developer); Tufts Health (Tenant)

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Kim Hubbard, PE, Kennedy and Rossi Inc.
181 Bedford Street, Suite 3, Lexington, MA 02173
(781) 648-3095

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Aug-97
FINISH DATE: 20-Mar-98

PAST USAGE: Manufacturing Utility Company - Westing Electric; Records and storage Building - Mt. Auburn Hospital; 400,000 sf total floor space

PAST SYSTEMS:

STRUCTURAL: Cast in place concrete: 3 low rise floors, 7 high rise floors

ENCLOSURE: Brick façade with dirty industrial metal framed windows

SERVICE: electrical and fire protection (sprinklers)

FINISH: None - all open area with some small enclosed mechanical and restroom facilities

SPECIAL CONCERNS: Asbestos abatement required.

FUTURE USAGE: Office building / tenant fitout space

NEW SYSTEMS:

STRUCTURAL: Same structural system; however, entire new second floor was constructed between the existing first and second floors (20 ft floor to ceiling height); atrium cut into center of the low rise section of building to provide natural light to all workers; existing structure had high enough load capacity and type of design to allow such structural modifications to be made.

ENCLOSURE: Same yet the exterior brick was repointed and washed; some reinforcement of the façade was necessary (brick had to be tied into the exterior wall to prevent brick from falling off building); all new windows were installed; new glass skylight was installed over the atrium that was constructed.

SERVICE: All new electrical, HVAC, plumbing systems installed; existing sprinkler system was salvaged and reused (upgraded); 2 types of HVAC were installed: 1)ductwork was used in the low rise section 2)Heat pumps were used in the high rise section of the building (due to variances in the floor to ceiling heights)

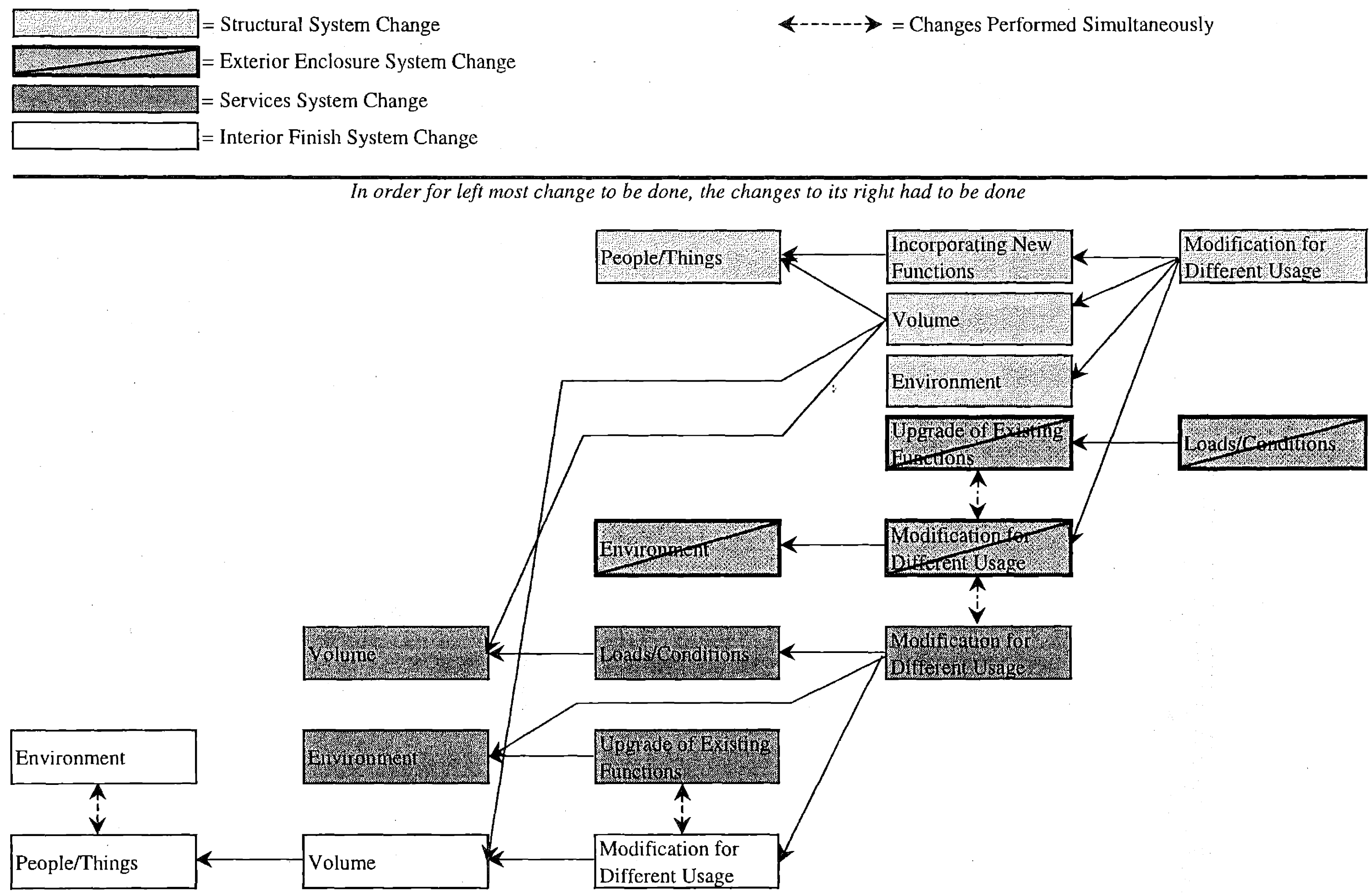
FINISH: Floors 1-3 were totally finished to meet the tenant's (Tufts') requirements; open areas left on the perimeter with private offices, restrooms, mechanical rooms, kitchenettes, conference rooms left near the building's center; floors carpeted; metal stud walls and drywall used to construct private areas; cafeteria/eating area constructed on the first floor for use by all three floors (by atrium); large three story tall staircase installed within the atrium connecting all 3 floors.

EXPECTED FUTURE CHANGES: Finishing of the interior on the other floors is expected as more tenants are acquired

NOTES: "Cheap Project"

PROJECT: 705 Mount Auburn Street

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade The brick façade was repointed and reinforced; All windows were replaced with upgraded energy efficient windows; the roof was upgraded and replaced	Repair and Upgrade The existing sprinkler system was repaired and upgraded to meet the needs of the building's new usage requirements	
	Incorporating New Functions	2 New Functions Construction of an interstitial floor between the existing first and second floors to create a new second floor within the building; 3 story tall steel framed precast concrete T slab garage constructed and attached to building's rear	1 New Function The new atrium was enclosed with a large triangular shaped skylight in the middle of the low rise portion of the building		
	Modification for New Usage	Major Atrium extending through the center of the low rise portion of the existing building was cut into the existing superstructure; Portion of the existing building in the rear was demolished to provide space for the construction of the new garage that was required to transform the building to office usage	Minor Installation of the glass skylight over the new atrium	Major Installation of new HVAC and computer/ communications systems; the electrical and plumbing systems were both upgraded to meet the necessary office use requirements, as well as those specific tenant requirements	Major Floors 1-3 were entirely finished according to the tenants needs and requirements; all other interior space was left wide open for future fit out according to future tenants needs
CAPACITY	**Loads / Conditions**		Yes Wall ties were installed in order to support a large proportion of the brickwork which required repair work	Yes Some increases in the capacity of the services to meet the requirements for office usage and provide services to meet the needs of multiple tenants	
	Volume	Medium Installation of a new intermediate floor to create a new second floor and provide added leasable office space within the building		Large All of the systems required some form of upgrade or installation which entailed an increase in their volume and depth to meet the requirements for office use and multiple tenants	Medium Fit out of floors changes the overall volume of the interior space as it moves from open areas to more private areas in the center with open areas on the perimeter of the building
FLOW	**Environment**	Yes Atrium creates a much nicer working environment by increasing the amount of natural lighting which the workers experience and allowing more office space	Yes The skylight above the atrium allows a greater amount of light to flow into the building thus creating more useable interior space for office use	Yes Installation/upgrade of the services help to promote a much more comfortable working environment within the building	Yes Arrangement of fixed offices in the building's center with open space for cubicles on the perimeter by the windows aids the working environment
	People / Things	Yes Construction of parking garage provides the workers easy access to the building & some weather protection; The construction of the new second floor adds more work space and changes the overall building flow			Yes The arrangement of fixed offices in the center of the building with open space for cubicles on the perimeter by the windows changes the overall flow of people through the finished portions of the building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Modification for Different Usage
Loads/Conditions
Incorporating New Functions
Volume
Environment
Upgrade of Existing Functions
Modification for Different Usage
Modification for Different Usage
People/Things
Environment
Loads/Conditions
Upgrade of Existing Functions
Modification for Different Usage
Volume
Environment
Volume
Environment
People/Things

New York Life Building, Kansas City, Missouri

"This is a shining example of how a project team can take a dilapidated structure and make it a prominent asset to its city"(Patterson, 1997). The owner took this abandoned, blighted Italian renaissance structure which was built in 1888 as an office building, and revitalized it into a class A office building with 200,000 SF of leasable space (Patterson, 1997).

The ten story steel-framed structure was very sound structurally, but many changes were required to revitalize it and bring it up to Class A code. The majority of the exterior enclosure was in good condition, but the roof and the historic glass atrium required repair and upgrade. The majority of the work consisted of the service and interior finish systems; new HVAC, electrical and plumbing systems of state-of-the-art technology were installed, and new finishes, consisting of natural environmentally responsible building materials, were used.

PROJECT DATA SHEET

DATE: 1/19/98

PROJECT TITLE: New York Life Building

LOCATION: 20 W. Ninth Street, Kansas City, MO

PROJECT OWNER: Owner: Utilicorp United; Developer: Hugh Zimmer - The Zimmer Companies, Inc., Kansas City, MO

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
J. E. Dunn Construction Company
929 Holmes, Kansas City, MO 64106-2682
(816) 474-8600

ARCHITECT:
Kevin Harden, Principal, Gastinger Walker Harden Architects
Kansas City, MO
(816) 421-8200

CIVIL ENGINEER:
Structural - Charles Page and Associates, Inc.
Mechanical/ Electrical - Smith and Boucher, Inc.

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: New York Life Building - abandoned, blighted Italian renaissance structure; built in 1888 - Office building

PAST SYSTEMS:

STRUCTURAL: 10 story steel framed structure (first built in the area)

ENCLOSURE:

SERVICE:

FINISH: Cast-iron, barrel-vaulted lobby skylight, mosaic Italian marble floors, red Vermont and pink Tennessee marble walls, a cast iron staircase with cherry hand rail and copper plated cast iron fireplaces.

SPECIAL CONCERNS: To produce a fully code compliant building with state of the art technology and environmentally responsible building materials.

FUTURE USAGE: 200,000 sf of Class 'A' Office space
(Seven year payback period)

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Existing atrium leaking severely: unable for repair; New atrium built over the existing atrium (historic reasons); roof repaired.

SERVICE: Air handling system which complies with the latest American Society of Heating, Refrigerating and Air Conditioning Engineers standards; lighting system which adjusts levels to amount of daylight coming into the building.

FINISH: Paints with low volatile organic compounds (VOCs); wall finishes made from natural materials.

EXPECTED FUTURE CHANGES:

NOTES:

"[This is a] shining example of how a project team can take a dilapidated structure and make it a prominent asset to its city."

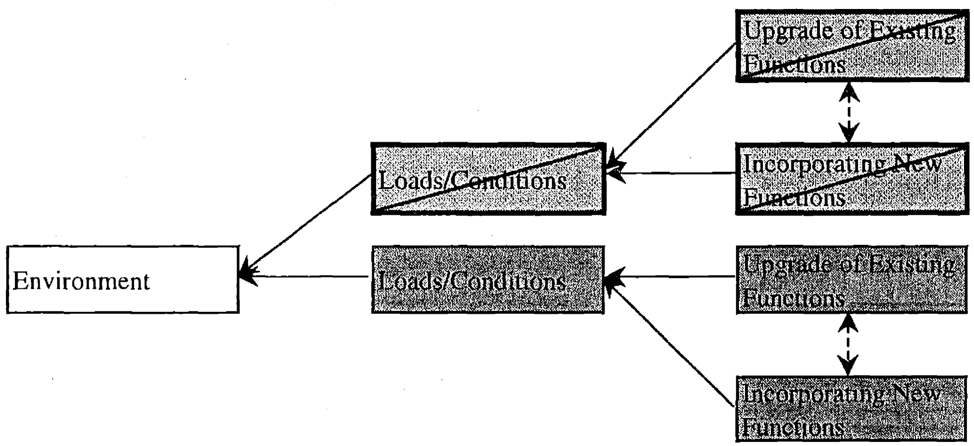
PROJECT: New York Life Building

		Structural	Enclosure	Services	Finish
		BUILDING SYSTEMS			
FUNCTION	Upgrade of Existing Functions		Repair	Upgrade	
			Roof repaired and retarred	Electrical systems upgraded to include new high tech sunlight responsive lighting, etc.	
	Incorporating New Functions		1 New Function	1 New Function	
			New atrium built over the existing historical atrium to provide a weather tight seal	New code compliant HVAC systems installed	
	Modification for New Usage				
CAPACITY	Loads / Conditions		Yes	Yes	
			Existing atrium leaked severely and was unable to be repaired, thus requiring the construction of a new atrium over it	HVAC upgraded / replaced to meet the necessary code requirements in power, etc.	
	Volume				
FLOW	Environment				Yes
					New low VOC paints and wall finishes used from natural materials to create a safer and nicer interior working environment
	People / Things				

New York Life Building, Kansas City, Missouri

Renovation for Same Usage

In order for left most change to be done, the changes to its right had to be done



Philadelphia Naval Base Foundry, Philadelphia, Pennsylvania

The Philadelphia Naval Base Foundry was originally constructed in 1918 as a foundry for the U. S. Navy. Since then, due to the lack of maintenance and to the weather conditions in the building's location, the building had become functionally obsolete and a severe hazard to human occupancy and use. An extensive rehabilitation job had to be performed to prepare the building for a new use. This project included the remediation of hazardous materials like asbestos, lead paint, chlorinated biphenyls and various metals. A large portion of the structural system had to be modified and repaired due to severe deterioration and warping over time, as well as current load and conditional requirements. The entire exterior enclosure system had to be replaced due to the same deterioration cause from exposure to the environment. The mechanical and electrical systems, as well as equipment, were upgraded, and some new equipment (cranes) was installed. In the end, the building was again safe for human use, and has now became a commercial building for the production of propellers, propeller shaft sleeves and miscellaneous castings for emergency ship repairs (Loomis, 1996).

Overall, this building case is a prime example of how effective maintenance as well as effective design which incorporates maintenance can effect the overall longevity of a building and also decrease the building overall lifecycle costs. If this building had been maintained adequately or if this building had been designed to include materials that did not require frequent maintenance, then the major problem with the building's safety and obsolescence might have been avoided entirely or reduced. This renovation project also presents the link between the structural and services systems. The installation of new equipment required the modification of a large portion of the structural system to meet the load capacity requirements.

PROJECT DATA SHEET

DATE: 1/20/98

PROJECT TITLE: Philadelphia Naval Base Foundry

LOCATION: Philadelphia, PA Naval Shipyard

PROJECT OWNER: U. S. Navy

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Summer 1996
FINISH DATE: Spring 1997

PAST USAGE: Naval Foundry

PAST SYSTEMS:

STRUCTURAL: Riveted Steel structure supported by a deep pile foundation, 3 bays wide by 27 bays long with a bay spacing of 24 ft.

ENCLOSURE: Gypsum concrete roof deck; Masonry siding

SERVICE: 8 Large structural cranes plus applicable mechanical and electrical systems

FINISH:

SPECIAL CONCERNS: Hazardous materials; Asbestos used in roofing systems and insulation; lead paint applied in coating the structural steel and chlorinated biphenyls have contaminated the floor of the electrical room; various metals also present.

FUTURE USAGE: New commercial building - will produce propellers, propeller shaft sleeves, and miscellaneous castings for emergency ship repairs.

NEW SYSTEMS:

STRUCTURAL: Structural steel modified to meet the current load condition requirements; several areas of degradation of the steel were found and required repair or replacement;

ENCLOSURE: Structural integrity of the gypsum concrete roof deck and masonry exterior was questionable due to exposure to the environment; renovation of the building included a complete replacement of the exterior enclosure.

SERVICE: Mechanical and electrical systems as well as equipment upgraded; 5 new cranes added and installed and one old crane replaced.

FINISH:

EXPECTED FUTURE CHANGES:

NOTES:

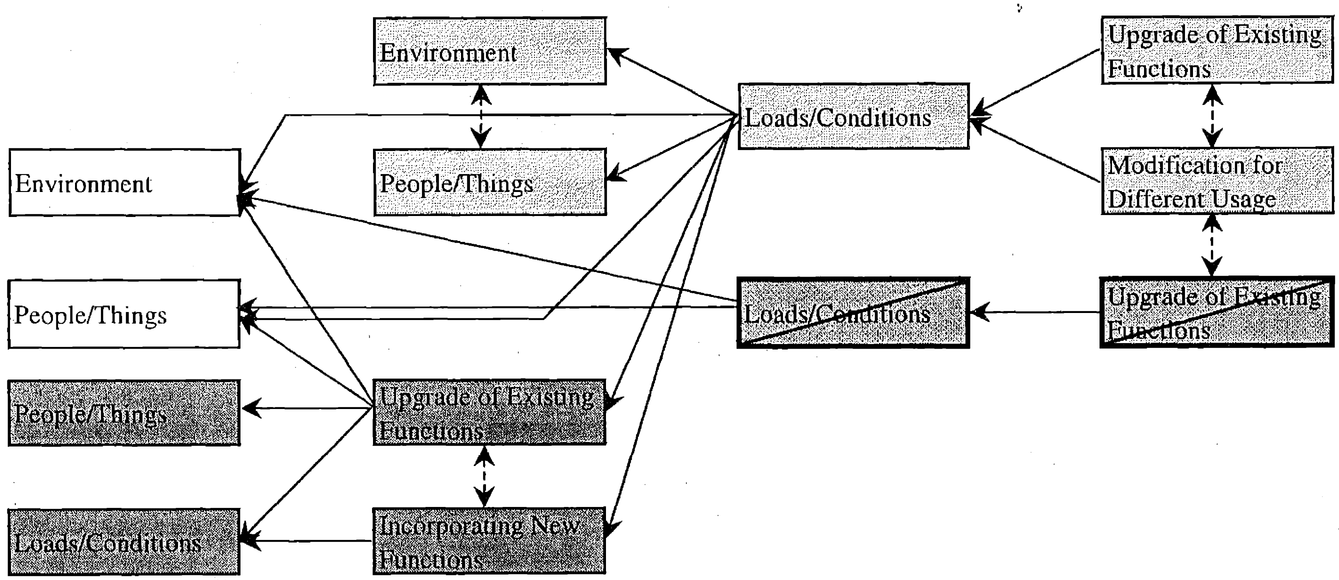
Building was first constructed in 1918.

PROJECT: Philadelphia Naval Base Foundry

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**	Repair and Upgrade	Upgrade	Repair and Upgrade	
		Steel connections etc. repaired or replaced entirely	Entire building façade was renovated and upgraded	The mechanical and electrical systems as well as all existing equipment within the building were all upgraded and repaired; One of the existing cranes within the building was replaced by an upgraded version of the failing crane	
	Incorporating New Functions			1 New Function	
				5 new cranes were installed within the building	
	Modification for New Usage	Major			
		Structural steel was modified to insure safe working conditions were achieved within the facility			
CAPACITY	**Loads / Conditions**	Yes	Yes	Yes	
		Loads on the building were increased by the installation of additional cranes; Several areas of the structural system had insufficient capacity to carry these new loads as well as the existing loads and therefore required upgrade	The exterior enclosure (roof and walls) lacked the sufficient strength and thus required replacement or repair	Electrical and mechanical systems upgraded in power to meet the current and future requirements of the foundry	
	Volume				
FLOW	**Environment**	Yes			Yes
		Deterioration of the existing steel structural system made the building unsuitable for human occupancy- the renovation of the building created a safe environment			Asbestos and lead paint abatement was performed; PCBs and metal remediation was performed; Both helped insure the health safety within the building and allowed it to be safe for human use
	People / Things	Yes		Yes	Yes
		Before renovation the building was unsafe for human use and therefore flow within it was prohibited; upon the completion of the renovation flow within the building was again permitted		Upgrading the existing services has enhanced the safety of the foundry thus allow it to once again permit human use	Through the remediation and abatement procedures the building is now safe for human use

Philadelphia Naval Base Foundry, Philadelphia, Pennsylvania **Renovation for Different Usage**

In order for left most change to be done, the changes to its right had to be done



Polaroid Building, Cambridge, Massachusetts

The Polaroid Building is a very old cast-in-place concrete building with waffle slab floors that is located on Memorial Drive in Cambridge, Massachusetts. This building was used as a chemical research and development building until 1938, and was then used for offices, labs, and some light manufacturing until the mid 1990s. The renovation of this building, as well as any work on the building's site, was restricted by several factors, including historic preservation of the building's exterior, the location of MWRA easements on site, and Chapter 91 of the Massachusetts building codes (which restricts any work performed within a certain distance of such easements) (Thomas, interview, 1998).

The interesting thing about this building is the fact that the renovation process went entirely against tradition. In most renovation projects, the work begins on the exterior of the building and then moves to the building's interior. However, problems with the historic preservation commission forced the renovation of this building to do the reverse: begin with the renovation of the building's interior and end with the renovation of the exterior façade. This change in sequence displays that work on the different building systems can be done in an uncoupled fashion. Traditionally, most work on buildings follows the same general pattern: the structural system is worked on first, then the exterior enclosure system, followed by the service systems and finally the interior finish system (the last two are often worked on in tandem). This project shows that this trend, although common, does not have to be followed in order to complete a renovation project efficiently and successfully.

PROJECT DATA SHEET

DATE: 2/24/98

PROJECT TITLE: Polaroid Building

LOCATION: Memorial Drive, Cambridge, MA

PROJECT OWNER: Polaroid / Spaulding and Slye

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
CM - John Thomas; PM - Hillary Thomas; APM- Mike ?, Spaulding & Slye
Boston, MA

ARCHITECT:
Spaulding and Slye

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE: Jul-98

PAST USAGE: Until 1938 - B & B Chemical Research and Development building; After 1938 - used for offices, labs and some light manufacturing.

PAST SYSTEMS:

STRUCTURAL: Cast in place concrete with waffle slabs

ENCLOSURE: Glazed brick on 3 sides of the building (left, right and front); masonry block on the rear façade; metal framed windows

SERVICE: Steam heating system, electrical, plumbing and mechanical (including sprinkler system) all present yet for most part in poor condition.

FINISH: 1960s interior appearance: pink painted concrete walls, etc.

SPECIAL CONCERNS: "3 projects in 1": trying to obtain historic permission to renovate the exterior; must get approval to build addition to the rear of the main building as well as to demolish the rear two buildings and construct new ones; must determine where sewer onsite goes- unable to dig it up due to constrainment by MWRA easements and Chapter 91; Floor to ceiling heights differ from floor to floor; renovation starting on the interior and then proceeding to the exterior; lead paint problem with removing the windows

FUTURE USAGE: Office headquarters for Polaroid - Front Building; two rear buildings to be built for future tenant fitout (15 year timeline)

NEW SYSTEMS:

STRUCTURAL: Addition to be constructed to the rear of the front building; old staircases removed and holes filled in to continue the floors.

ENCLOSURE: Brick exterior replaced entirely in some areas, other areas it was washed and repointed; all windows were replaced (lead paint considerations)

SERVICE: All new mechanical, HVAC, electrical, communication systems installed; 2 new air handling units and condensers installed (building split down the middle and set up into two zones); electric VAV tapped into the original switch gear in the rear of the building; all mechanicals etc. tapped into the original offstreet lines.

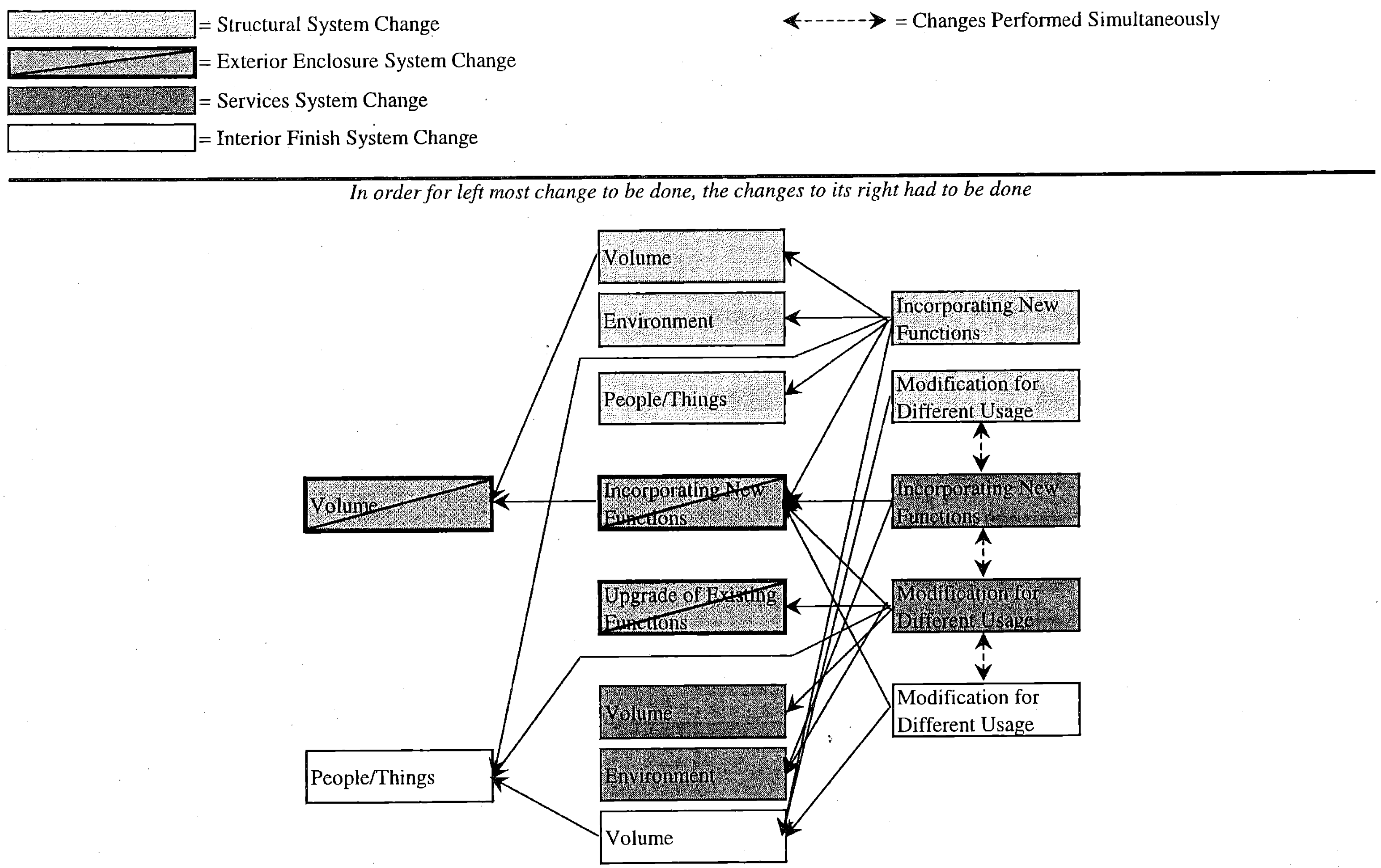
FINISH: Metal stud non-load bearing walls with drywall used to create interior office partitions and conference rooms; porcelain tile bathrooms and front hall; carpet used everywhere else in the building.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Polaroid Building

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Service**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade Historic brick façade on the front and sides of the building repaired; the windows also repaired and upgraded to meet historical requirements		
	Incorporating New Functions	1 New Function The construction of a new entrance in the rear - a 3 story triangular shaped addition to the building	1 New Function The addition to the rear of the building required a new façade	2 New Functions New communications system installed; New air conditioning system installed	
	Modification for New Usage	Minor The existing staircase within the building was removed and the holes in the floors for it were filled so the floor space could be used for office space; New staircase will be installed within the addition to the rear of the structure; * Major work done on the rest of the lot as two buildings behind the main building were demolished for the construction of 2 new buildings and garage		Major The original steam heating system was replaced by 2 new air handling units; the original electrical, plumbing and mechanical systems were all replaced to meet the needs for office use	Major The interior was almost entirely gutted and redesigned to provide individual office spaces
CAPACITY	**Loads / Conditions**				
	Volume	Small The addition to the rear of the building increase the overall volume of the building slightly and will house the new stairway thus allowing the old one to be filled in and thus allow more space within the existing building to be used for office space	Small The addition to the rear of the building increases the total amount of brick and glass required for the exterior enclosure of the building	Large The systems were enhanced to meet the use for office space - both the volume and the size of the systems were increased	Small The renovation of the interior increase the encountered volume changes due to the addition constructed on the rear of the building and the rearrangement of the interior wall partitions to create more individual private office spaces
FLOW	**Environment**	Yes The construction of the two new buildings in the rear as well as the construction of a garage and a courtyard will all change the overall layout and appearance of the site into a campus-like setting		Yes The incorporation of air conditioning as well as the upgrade of the rest of the services helps to increase the comfort level within the building's working environment	
	People / Things	Yes The new campus-like setting for the building's site will allow people to easily move from building to building as well as to the garage and courtyard areas			Yes The flow of people changes through the construction of the new staircase within the addition on the building's rear and due to the 90 degree rotation of the existing elevator so that it faced the main hallway



In order for left most change to be done, the changes to its right had to be done

Rush Presbyterian / St. Luke's Medical Center, Chicago, Illinois

The Rush Presbyterian / St. Luke's Medical Center in Chicago, Illinois, is a 9 story academic building which stands besides a small nursing building. Due to the tight site constraints in the area, this building was initially design over 20 years ago to accommodate the addition of up to 5 stories to the top of the original 9 stories (McManamy, 1997; "News: Engineers...", 1997).

The renovation of the building incorporated a two-story addition to the top of the existing 9-story building. This addition will be used to house the nursing center so that the existing nursing center beside the building can be razed to make room for a new 7 story research center. The work involved in constructing the addition proceeded during regular hours of building operation with the noisy work being performed at night. By incorporating the required structural capacity for vertical expansion within the initial design and construction of the facility, the building was able to overcome its site constraint problems and adapt to its changing requirements overtime. Such thought processes could be incorporated into the design of all structures so that they too are capable of accepting and accommodating changes which might occur over their individual lifecycles.

PROJECT DATA SHEET

DATE: 12/27/97

PROJECT TITLE: Rush Presbyterian/ St. Luke's Medical Center

LOCATION: Chicago, IL

PROJECT OWNER: Rush Presbyterian/ St. Luke's Medical Center

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Muhammad Azim, VP, CM – Morse Deisal International
New York, NY

ARCHITECT:
Keith Johnk, Hanson Lind Meyer
Chicago, IL

CIVIL ENGINEER: STRUCTURAL
John Kusswurm, Hanson Lind Meyer
Chicago, IL

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: 9 Story academic center adjacent to nursing building

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

SPECIAL CONCERNS: In the initial design over 20 years ago the academic center was designed to accommodate the addition of up to 5 extra floors; addition of two stories had to be performed while the rest of the facility continued to operate; removal of the existing roof to get to the columns caused some problems; Noisy work was performed at night.

FUTURE USAGE: The Addition of 2 stories to the academic center to house the nursing center so that the nursing center adjacent to the building can be razed for the construction of a new 7 story research center

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE:

SERVICE:

FINISH:

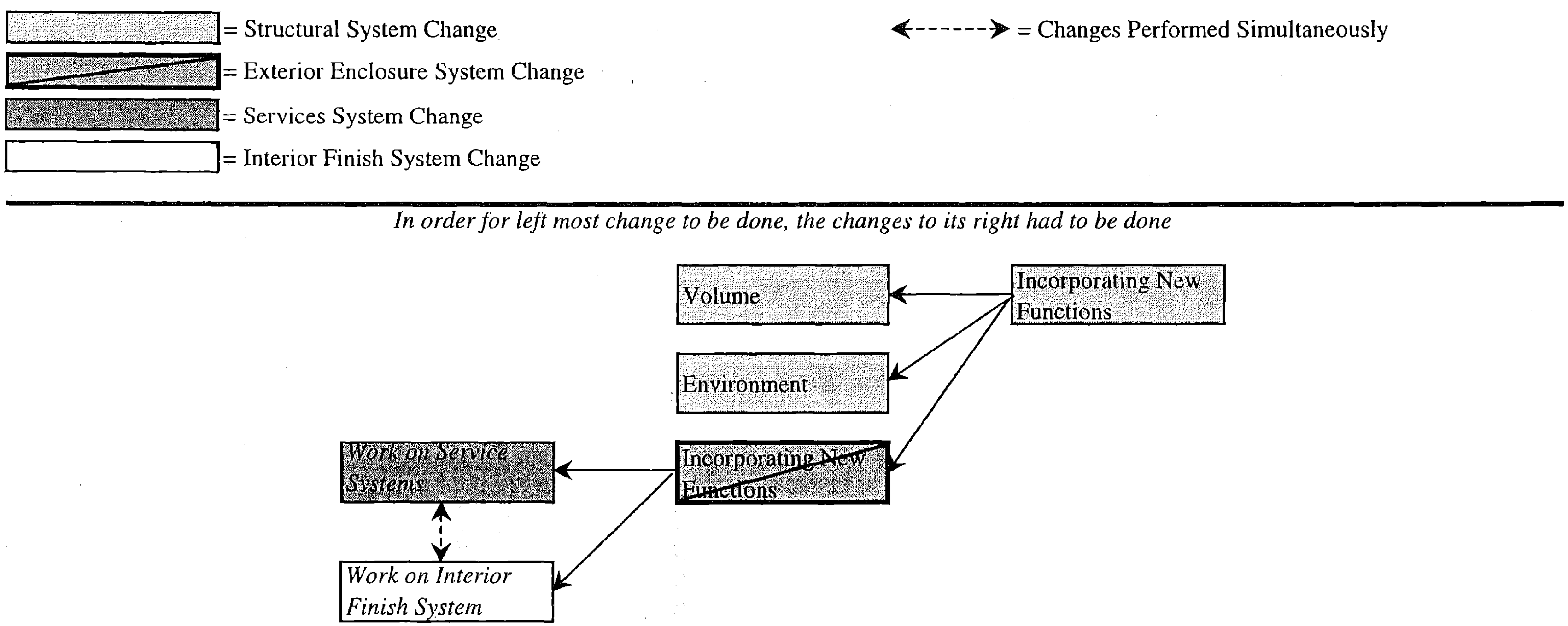
EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: St. Luke's Medical Center

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**				
	Incorporating New Functions	1 New Function Addition of 2 steel framed stories to the top of the existing building	1 New Function New exterior installed to house the additional floors on the top of the existing building		
	Modification for New Usage				
CAPACITY	**Loads / Conditions**	None The building was originally over-designed to accommodate such an addition			
	Volume	Large The addition of two floors to the top of a 9 story building			
FLOW	**Environment**	Yes The addition will allow the nursing center adjacent to the building to be razed for the construction of a new 7 story research center			
	People / Things				

Rush Presbyterian/St. Luke's Medical Center, Chicago, Illinois — Renovation for Same Usage



Sage Hall, Cornell University, Ithaca, New York

Sage Hall is a historic 123-year-old, 80,000-sf building that served as a woman's dormitory at Cornell University in Ithaca, New York. The structural system consists of brickbearing masonry walls with wood timber framed floors. The university needed a new building to house its School of Management, and Sage Hall was the prime candidate. Because the structural system was in considerable danger of failure, the university initially wanted to demolish Sage Hall and build a new building on the site. However, the building's façade was historically protected, and they were therefore forced to renovate the structure. Because the exterior façade of the building was historically protected, the designers had to devise a method of reconstructing the building from the inside out; they had to leave the exterior brick bearing walls intact while constructing a new structural system within them (Angelo, 1997).

In order to perform this exterior wall stabilization, the design used a specially designed structural steel framed truss system to support the exterior walls while a new 16 ft. deep drilled caisson basement level and 145,000-sf steel framed structure was constructed within it. One of the interesting aspects of this project is that it goes entirely against the traditional definition of a renovation project. The building's foundation and a large portion of the building's superstructure were demolished and a new foundation and superstructure were constructed in their place. The part of the original structural system that remained (the exterior masonry façade/bearing wall) was transformed into a self-load bearing exterior façade, and was tied into the new steel superstructure that was constructed behind it. This shows that a link exists between the structural and exterior enclosure systems of buildings.

PROJECT DATA SHEET

DATE: 11/23/97

PROJECT TITLE: Sage Hall

LOCATION: Cornell University, Ithaca, NY

PROJECT OWNER: Cornell University

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Beacon Skanska Construction Co.
Boston, MA

ARCHITECT:
Alan Chimacoff, The Hillier Group
500 Alexander Park #Cn23, Princeton, NJ 08540
(609) 452-8888

CIVIL ENGINEER: STRUCTURAL
Roger McCoy, Senior Associate, LeMessurier Consultants Inc.
Cambridge, MA

SUBCONTRACTORS:
Brownell Management Corp., Scotia, NY

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Women's dormitory

PAST SYSTEMS:

STRUCTURAL: Brickbearing wall building - 80,000 sf wood framed interior; failing foundations and wood trusses; failed current fire-resistance standards

ENCLOSURE: Brick Gothic revival exterior enclosure

SERVICE:

FINISH:

SPECIAL CONCERNS: building over 123 years old; had been declared a local landmark in 1990; got permission to gut the interior of the building but façade had to be maintained; saving the exterior walls and the mansard roofline required the use of special braced steel towers to temporarily hold the walls up while the new building skeleton was constructed within the shell

FUTURE USAGE: Samuel Curtis Johnson Graduate school of Management ($38 Million)

NEW SYSTEMS:

STRUCTURAL: 145,000 sf steel framed structure constructed within the existing façade to replace the original timber framed failing structure; new 16 ft deep basement constructed using drilled caissons.

ENCLOSURE: Old historically protected exterior was maintained

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

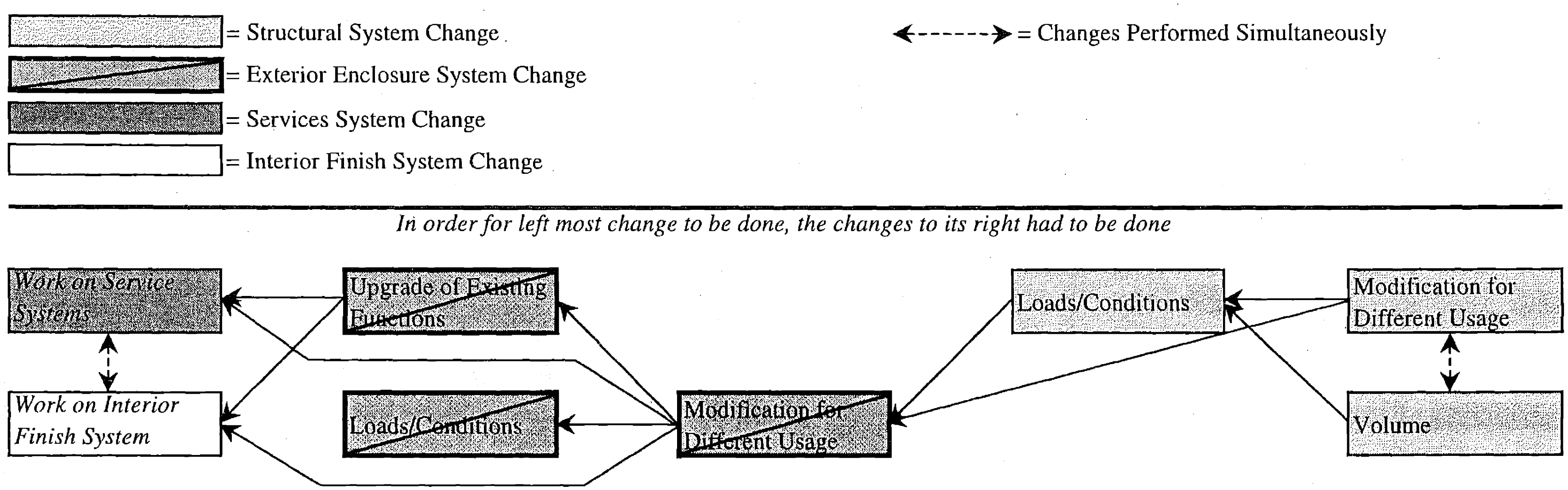
NOTES:

"We elected to seek themes in the old building that could be used in the new, such as grouping of windows...We felt that it was crucial to build inside the original footprint."

PROJECT: Sage Hall

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade		
			Masonry enclosure repointed; Windows all upgraded and replaced		
	Incorporating New Functions			Yes?	
	Modification for New Usage	Major	Major	Major?	Major?
		Entire foundation and structural frame removed and replaced due to the deterioration of the existing and its high possibility of failure	New roof was built as old one was failing and demolished so that the new services could be installed within the building; Existing load bearing façade transformed into a non - load bearing wall and tied into the new steel superstructure		
CAPACITY	**Loads / Conditions**	Yes	Yes	Yes?	
		Timber frame replaced by steel frame for structural reasons; Existing foundation was replaced by drilled caissons thus creating a full 16 ft. deep basement	Existing load bearing wall was transformed into a non-load bearing wall thus relieving much of the stress on the historic façade and transferring into the new steel superstructure of the building		
	Volume	Large		Large?	Large?
		The construction of the new structural system increased the useable interior space within the building from 80,000 sf to 145,000 sf; This included the 16 ft. deep basement			
FLOW	**Environment**			Yes?	Yes?
	People / Things			Yes?	Yes?

Sage Hall, Cornell University, Ithaca, New York — Renovation for Different Usage



266 Second Avenue, Waltham, Massachusetts

This building which is located in Waltham, Massachusetts is a prime example of the traditional definition of a renovation project. The renovation of a building has two minimum requirements. These requirements are that the building foundation and the structural frame of the existing building must still be standing (Lion, 1982). 266 Second Avenue was entirely stripped down to its structural components due to the poor characteristics of its exterior and interior systems, and its lack of capacity to fully meet the requirements for the new usage. Because it was originally designed and built as a manufacturing building, its exterior façade consisted of a precast concrete 'T' paneled system with small narrow windows. This exterior enclosure system gave the building a very institutional appearance and it also was a source of water leakage problems for the building. The services within the existing building were minimal, since they were simply required to meet the needs for light manufacturing use (Muller, interview, 1997).

These factors, combined the fact that the building was being renovated for high tech office and research and development use, made the decision to strip the building down to its structural skeleton the most logical choice. While the existing building was not completely able to suit the new usage needs without substantial rehabilitative work, the new design for the building has incorporated some forms of future planning. The majority of this "thinking ahead" involved the service systems. The new building was constructed with extra power upon the tenants' request to meet future needs of the equipment within the building.

PROJECT DATA SHEET

DATE: 12/4/97

PROJECT TITLE: 266 Second Avenue

LOCATION: Waltham, MA

PROJECT OWNER: CC & F Second Avenue Trust

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
John Moriarity & Associates
Winchester, MA

ARCHITECT:
Lafreniere Architects

CIVIL ENGINEER:

SUBCONTRACTORS:
HVAC, electrical, plumbing: Abbood/Holloran, Associates

BUILDING INFORMATION:

START DATE: Jul-97
FINISH DATE: Jan-98

PAST USAGE: Manufacturing building

PAST SYSTEMS:

STRUCTURAL: Steel framed building with precast concrete slab floors

ENCLOSURE: Precast concrete T paneled exterior; unpleasant, institutional appearance; small windows

SERVICE: Minimal electric, plumbing and other systems to meet use for light manufacturing.

FINISH: Metal studs and drywall partitions

SPECIAL CONCERNS: Exterior had severe water problems due to age; also had problems due to appearance

FUTURE USAGE: Tenant space: base building = 2 tenants plus a common cafeteria.

NEW SYSTEMS:

STRUCTURAL: Same; Rear stairway removed, hole filled in; new stairway constructed in new hole on the opposite rear corner of the building.

ENCLOSURE: Precast panels replaced existing exterior which was completely removed; new strip windows installed around building; new curtain walls installed at the two entrances for the building.

SERVICE: Entire new plumbing, fire protection; HVAC and electrical systems upgraded to meet use by several possible tenants; 4 new 75 ton train units installed (HVAC); Freight elevator upgraded and renovated for passenger usage requirements.

FINISH: Metal stud and drywall used to construct private offices in the first floor office space; second floor space it was used to construct the common areas and the central areas leaving the perimeter of the building open for office use.

EXPECTED FUTURE CHANGES:

NOTES:

Extra power was added to the second floor offices equipment room to meet their individual power needs; indirect lighting used in all office areas.

PROJECT: 266 Second Avenue

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair		
			The existing roof was simply patched in areas		
	Incorporating New Functions			4 New Functions	
				Installation of new fire alarm, plumbing, sprinkler & HVAC systems	
	Modification for New Usage	Minor	Major	Major	Major
		Steel frame with concrete slab used to fill the hole in the second floor that was used for the staircase which was removed; New hole cut in the second floor in the adjacent corner to the rear of the building so that a new staircase could be installed	The original precast concrete T exterior was replaced with a new precast panel and strip window exterior; the new entranceways to the building (one in the center of the building's front and one in the rear right corner of the building) were accented by the installation of a glass curtainwall exterior	The existing elevator was upgraded for use as passenger elevator; the electrical system was upgraded according to the tenants particular needs and desires	The interior was entirely gutted; The main lobbies and cafeteria areas were constructed and finished while the rest of the interior was redesigned and constructed according to the tenants particular requirements and needs - first floor = individual private office rooms, 2nd floor = open office space on the perimeter with enclosed offices, etc. in the middle
CAPACITY	**Loads / Conditions**			Yes	
				The electrical system was upgraded in power in order to accommodate laboratory and research and development use and high tech telecommunication capabilities	
	Volume			Large	Small
				All of the systems were revamped in volume to meet the future needs of the building's tenants	Open space transformed into more private and smaller rooms and hallways
FLOW	**Environment**		Yes	Yes	Yes
			New exterior promotes the building's use and occupancy - more aesthetically pleasing; The larger strip windows and curtainwall facades provide the building's interior with more natural light	The new HVAC provides a much better working environment; Indirect hanging ceiling lights also aids this environment	Construction of the cafeteria; Public is restricted to the lobbies and small corridors within the building
	People / Things	Yes	Yes		Yes
		People must now use the stairs on the right rear corner of the building or those located at the front of the building to move from the first to the second floors (elevator also located in the front)	The curtainwall exterior walls help to accent the common areas and entrances to the building		The interior walls separate and define definitive rooms and hallways; people are forced to walk through a maze of hallways and rooms to move around much of the building

= Structural System Change

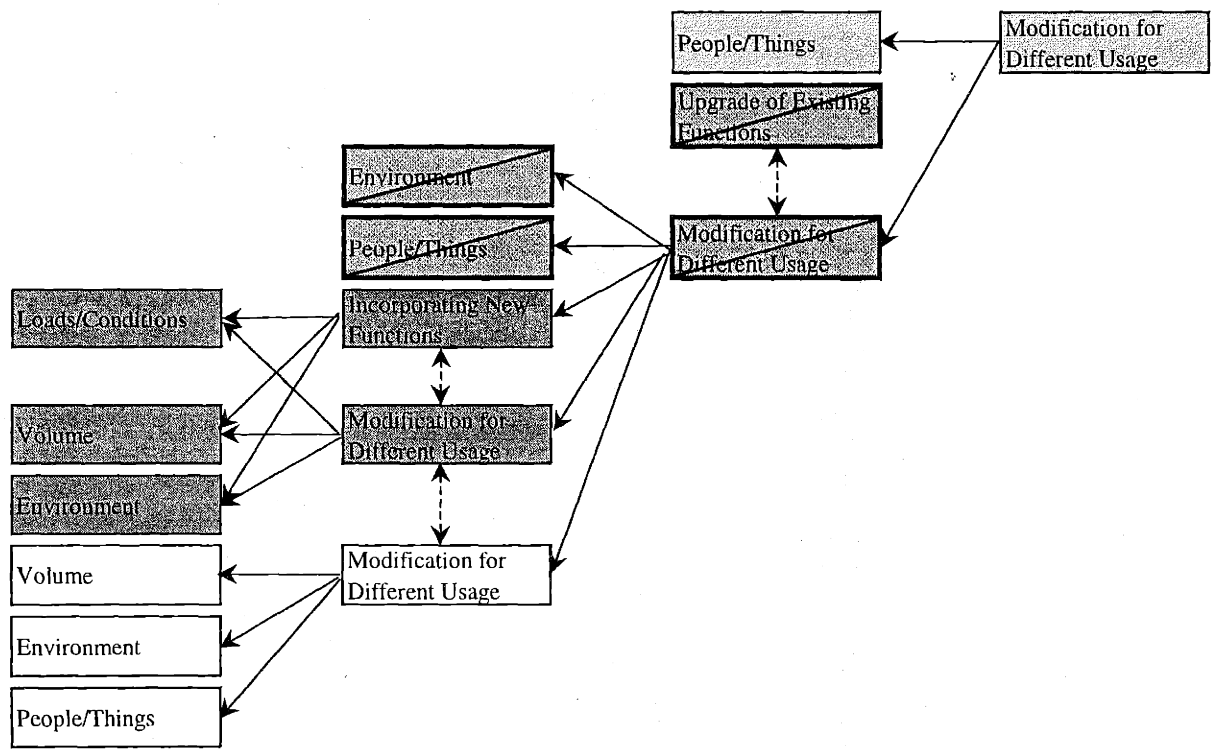
= Exterior Enclosure System Change

= Services System Change

= Interior Finish System Change

<------> = Changes Performed Simultaneously

In order for left most change to be done, the changes to its right had to be done



Standard Life Tower, Calgary, Alberta

The renovation of the Standard Life Tower in Calgary, Alberta is another example of the revitalization of a office building that was old and nearing complete obsolescence into a class A office building. The structural and enclosure systems were for the most part left untouched, aside from the cleaning and waterproofing of the porous concrete exterior panels, and the construction of a new entranceway (Monroe, 1998).

The majority of the work revolved around the services and interior finish systems, again showing the strong link between the two building systems. The work on the services included the installation of a new electrical system with a computerized (programmable) building directory, the installation of microprocessor controls within the elevators, the installation of a new HVAC system, the installation of new sprinklers, fire alarm and smoke removal systems. The work on the services also included the installation of a new security system consisting of proximity card access controls, security cameras and panic buttons. The work on the interior finish system included the enlargement of the main lobby and the installation of good natural finish material within it, as well as the elevators and elevator lobbies on each floor. The rest of the office space was left for tenant fit out. By performing the renovation of this blighted building, the owners were able to raise rental rates from $2-3 /SF to $24 /SF, and increase the occupancy rates from 43% to 100%.

By redesigning the building's services and interior finish, the owner was able to transform this building into a prosperous Class 'A' office building. Much of this success is attributed to the amount of services and hence the amount of flexibility which the building has to offer its prospective tenants.

PROJECT DATA SHEET

DATE: 5/20/98

PROJECT TITLE: Standard Life Tower

LOCATION: Calgary, Alberta

PROJECT OWNER: Standard Life Insurance Company

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT: BLK Architects and Domus Interior Architecture Inc.

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Class 'B' office space

PAST SYSTEMS:

STRUCTURAL:

ENCLOSURE: Weather worn, post tensioned cast in place concrete exterior; existing entrance consisted of glazing which had mullions at 2 ft 6 inch centers.

SERVICE: Moderate systems - Air conditioning using CFC refrigerants.

FINISH: Standard interior space for office fitout

SPECIAL CONCERNS:

FUTURE USAGE: Class 'A' office space

NEW SYSTEMS:

STRUCTURAL:

ENCLOSURE: Porous concrete panels were power washed and coated with a waterproofing sealant; Stainless steel and glass arch with structural glass with no mullions replaced the existing entranceway

SERVICE: Computerized (programmable) building directory installed; elevators upgraded with microprocessor controls; ice storage system and 3 new chillers supplemented by an automated induction and ceiling air distribution HVAC control system; adjustable air-volume controls floor to floor A/C; sprinklers, auto fire detection alarm system, smoke removal system, proximity card access control, security cameras and panic buttons all installed.

FINISH: Lobby enlarged - finished with good materials; elevator lobbies finished with the same materials; rest of building left for individual tenant fitout.

EXPECTED FUTURE CHANGES:

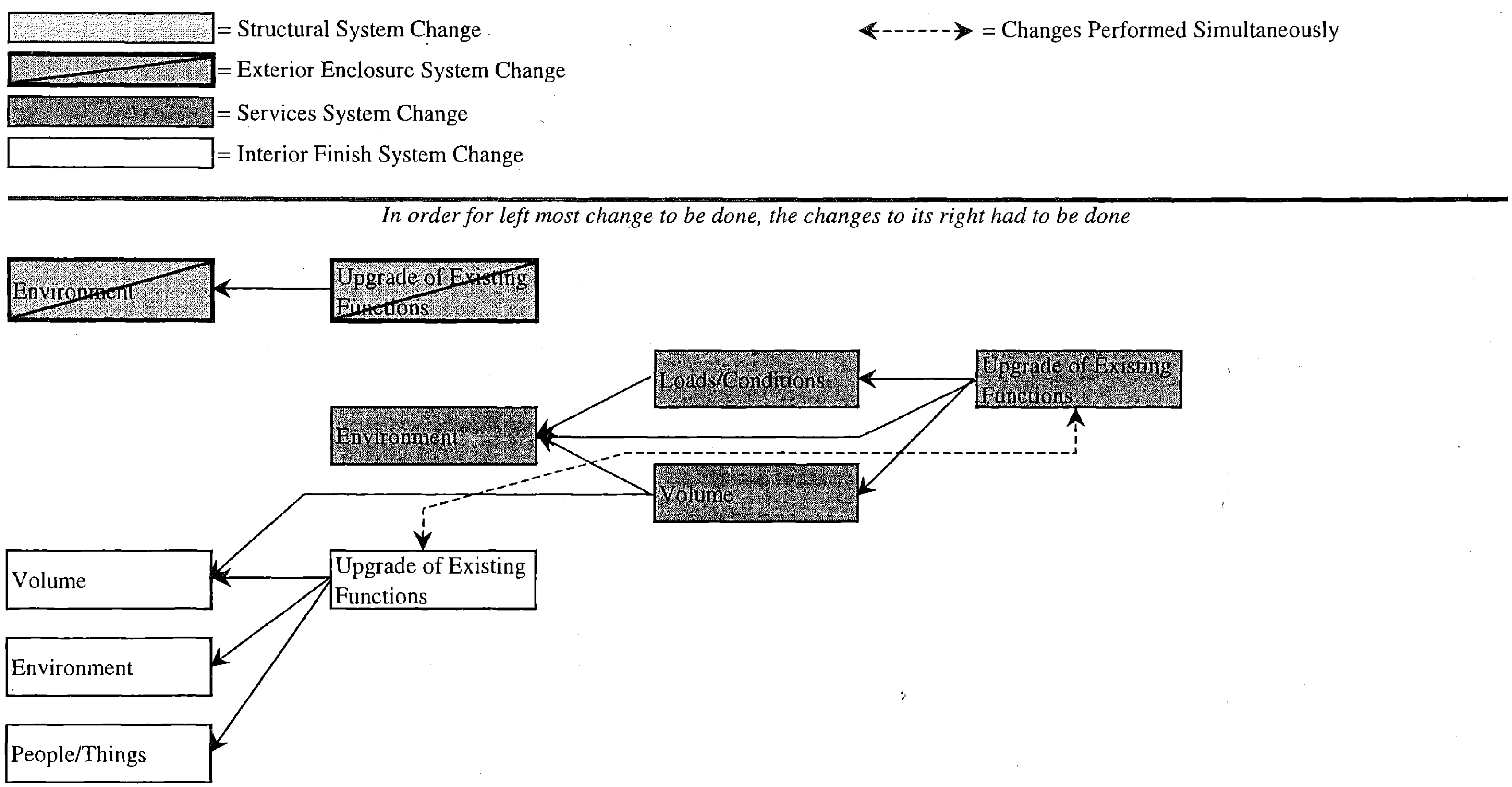
NOTES:

Moved from a $2-3 / sf building to a $24 / sf building

PROJECT: Standard Life Tower

		BUILDING SYSTEMS			
		Structural	Enclosure	Services	Finish
FUNCTION	Upgrade of Existing Functions		Repair and Upgrade	Upgrade	Upgrade
			Porous concrete panels powerwashed and coated with a waterproofer; existing entrance spiced up with a stainless steel arch and glass curtainwall	Existing services upgraded to meet tenants needs - energy savings, life safety and security	Main lobby and individual elevator lobbies refinished with extravagant materials
	Incorporating New Functions				
	Modification for New Usage				
CAPACITY	Loads / Conditions			Yes	
				Electrical, communication, and safety/security systems all revamped to provide much more efficient service	
	Volume			Large	Medium
				All services increased in depth for use by multiple high class tenants	Main lobby enlarged considerably
FLOW	Environment		Yes	Yes	Yes
			Renovation of the exterior has improved the aesthetic appearance; New glass lobby allows more natural lighting, thus increasing building comfort	Services improved comfort and air quality and saved energy overall	New finish work promotes rental, increased rental rates from $2-3 /sf to $24 /sf; occupancy rates increased from 43% to 100%
	People / Things				Yes
					Connected to the intercity walkway tunnel

Standard Life Tower, Calgary, Alberta — Renovation for Same Usage



28 State Street, Boston, Massachusetts

28 State Street is an office building in Boston that became outdated and nearly unleaseable due to its lack of available parking, problems with building sway, and large amount of asbestos contamination. The renovation of this building entailed the refurbishment of all four of its building systems with a majority of the work consisting within the exterior enclosure, services, and interior finish building systems. The changes within the structural system included the demolition and redesign of three underground building levels that were once used for the mechanical space so that a parking garage could be constructed. Seismic dampers were also installed within the building to decrease the amount of sway within the building (Patterson, 1998).

Extensive work was performed on the exterior of the building to enhance its appearance within the surrounding neighborhood. New windows were installed, a huge elegant new entranceway and lobby were constructed as well as a new additional entranceway. The most extensive work that was performed incorporated changes within the services and finish systems. The mechanical systems, which were originally housed within the 3 basement levels of the building, were removed and replaced by smaller and more efficient units on the 4th, 5th and 36th floors of the building. Meanwhile, the new interior finish consisted of materials that were aesthetically pleasing, durable, and capable of easily being maintained and repaired if required.

This building is another example of how initially designing a structure to meet the necessary requirements to insure the comfort of the building's occupants is important. The insufficient structural strength to prevent building sway, the lack of parking, and the aesthetic problems all could have been avoided if they were incorporated into the initial designs for the building. However, by instituting these changes within the building's renovation, the owner was able to change this blighted structure that was on the road to complete obsolescence into a Class 'A' office building in one of the best locations in Boston. Furthermore, the owner took the step towards incorporating maintenance and building flexibility into the design through its choice of services and types of materials.

PROJECT DATA SHEET

DATE: 5/21/98

PROJECT TITLE: 28 State Street

LOCATION: Boston, MA

PROJECT OWNER: Equity Office Properties Trust, Chicago, IL

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Suffulk Construction Company
Boston, MA

ARCHITECT:
Elkus/ Manfredi Architects, Ltd.
Boston, MA

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Office space

PAST SYSTEMS:

STRUCTURAL: Building had problems with swaying in the wind

ENCLOSURE: Windows were operable and inefficient; granite paneled exterior, with holes that were filled in by a dark sealant which made the building appear like it had acne

SERVICE: Mechanical and electrical systems outdated; failed to meet current codes;

subground levels housed the mechanical plant for the entire building.

FINISH:

SPECIAL CONCERNS: $ 10 million asbestos abatement; No parking

FUTURE USAGE: Class 'A' office space

NEW SYSTEMS:

STRUCTURAL: 3 levels of underground space underwent massive demolition to make room for a parking garage; seismic dampers were installed within the building in effort to help decrease the amount of building sway

ENCLOSURE: 28 ft. elliptical glass wall installed in the new lobby; new entrance on Congress Street with 2 revolving and 2 leaf doors; acne holes reopened and filled with a compound of stone that blended with the granite face; windows were upgraded to double paned insulated glass with better shading coefficients and thermal resistance.

SERVICE: Floor by floor packaged condenser water units that feed a low temp variable air volume system; air handling equipment placed on the 4th, 5th and 36th floors; oval ductwork used to maximize the floor to ceiling heights (thin, rigid and cut down the noise); recessed lighting; new restrooms on every floor; new energy management system; new microprocessor based elevators

FINISH: Used materials that were aesthetically pleasing, as timeless as possible, and that could be maintained/repaired if need be; lobby enlarged by 12 ft. and had 2 grand staircases with retail space outlined on both levels (1st & 2nd); Finishes included: curved hand crafted mahogany, granite floors, and ellipses painted blue to accent the ceiling

EXPECTED FUTURE CHANGES:

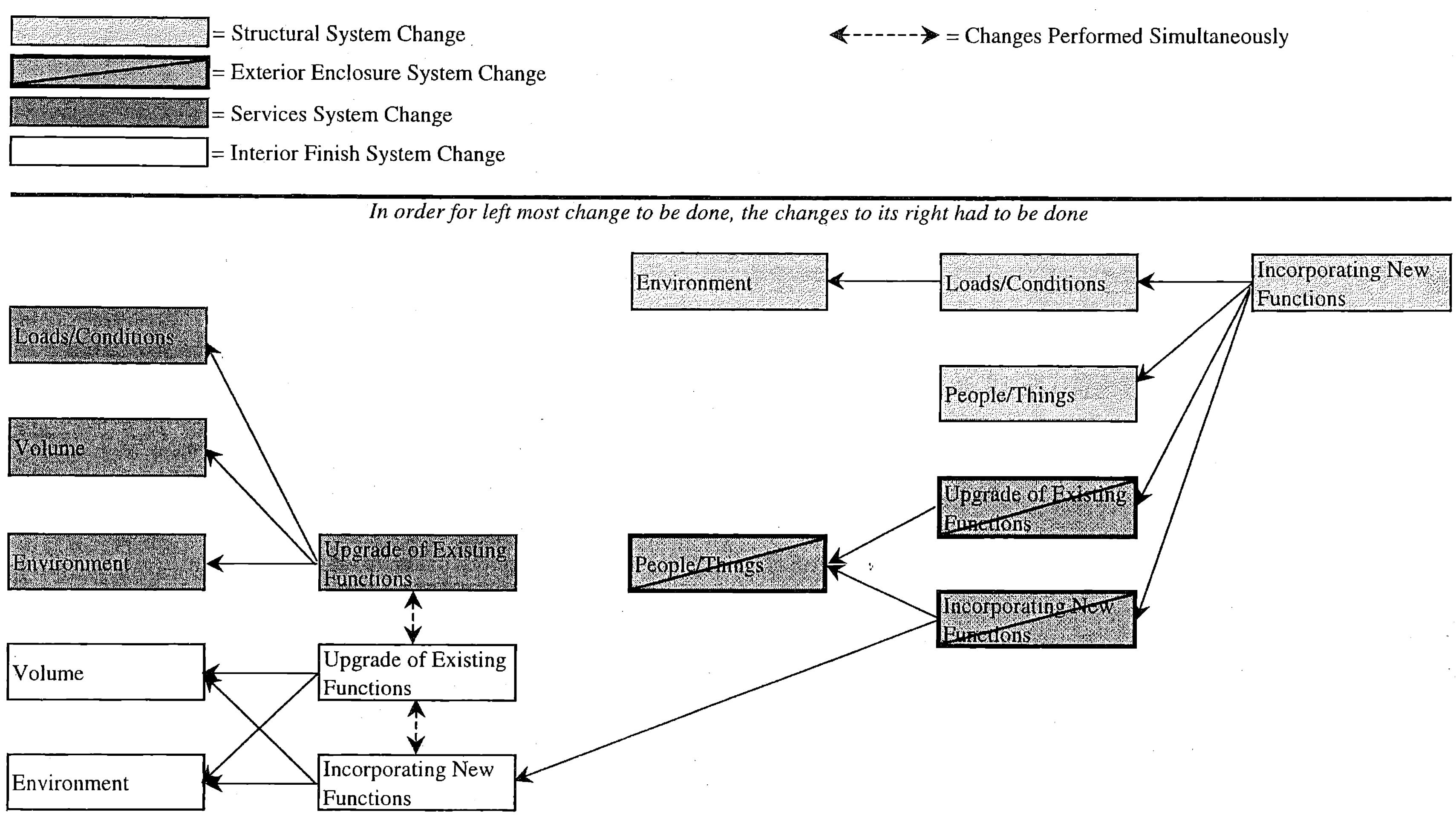
NOTES:

PROJECT: 28 State Street

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade Lobby enhanced by 28 ft. elliptical glass wall; "Acne" holes reopened and filled with stone compound that matched the granite exterior; New double paned insulated glass windows installed	Repair and Upgrade Floor to floor HVAC units with air handling equipment placed on floors 4,5 and 36 replace the existing HVAC systems; Better recessed lighting installed; Elevators upgraded to microprocessor based ones	Upgrade Use of better quality materials within the interior; relocation of restrooms to better locations on all of the building's floors
	Incorporating New Functions	2 New Functions 3 underground levels demolished and transformed from mechanical space into parking; Seismic dampers installed to reduce building sway	1 New Function New entrance with 2 revolving and 2 leaf doors installed on the side of the building facing Congress Street		1 New Function 2 grand staircases extending from the first to the second floor constructed within the main lobby; new retail space highlighted in this area by an interior glass wall
	Modification for New Usage				
CAPACITY	**Loads / Conditions**	Yes Seismic dampers installed to help reduce swaying that was experienced with wind gusts		Yes Oval ductwork used for the HVAC system so that the floor to ceiling heights could be maximized	
	Volume			Large HVAC system upgrade required massive increases in the overall depth of service - changed from a single central unit to floor to floor units	Medium The existing lobby was increased in height by 12 ft.
FLOW	**Environment**	Yes Seismic dampers reduced the amount of sway in the building thus making it a much more comfortable working place	Yes Refill of the acne holes improves the building's appearance; New glass lobby enhances the building and provides a much more welcome entrance	Yes New services / upgrades increase the comfort within the building's working environment	Yes New materials, etc., make the interior a much more welcoming space and presents a much higher class of building
	People / Things	Yes Parking lot under the building provides easy access to the building and protection from the weather	Yes New lobby and second entrance provide more and easier access points to the building		

28 State Street, Boston, Massachusetts

Renovation for Same Usage



255 State Street, Boston, Massachusetts

This building located at the end of State Street in Boston, Massachusetts is a prime example of why planning ahead and fully inspecting an existing building's design is important, as well as planning ahead and making the original design flexible enough for future modifications and usage classes. This building, which was originally designed and constructed in 1926, was used as a warehouse building until 1980. In 1980, it was renovated for office use with one single tenant in mind. The current renovation on the structure involves modifying the building to meet the needs of multiple Class 'A' office tenants rather than just one single tenant. While this building appeared like a prime candidate for renovation upon the beginning of the work, it was soon realized that in fact the renovation entailed a lot more work than expected ("On Spec", 1998; Kliener, interview, 1998).

This extra work is largely attributed to the original structure system type that was used for the building. The building consists of a cast-in-place (CIP) concrete structure with large mushroom capped columns and flat slab floors. However, unlike the traditionally reinforced CIP structures, the reinforcing steel within the slabs does not run longitudinally but instead runs in large concentric loops around particular stress areas (e.g. column caps). These loops were designed to act in tension and hence balance the stresses within the structure. However, in order for this method of design to work efficiently, the reinforcing steel had to be installed to near perfection, which unfortunately did not happen. With current codes, this type of design would not comply; however, it does possess sufficient strength for use as office space.

Because of this design type and the poor quality of its construction, several problems arose in the modifications of the existing slab floors. Any structural modifications had to be restricted to the central core of the building, and involved precise incisions of utility shafts and the construction of a new elevator shaft. Although the renovation was able to proceed despite this problem, the entire project might have gone better if two factors were considered prior to performing the work. The project might have gone better if first, the existing building system type was analyzed fully prior to renovation and second, if the initial design for the building incorporated a more traditional longitudinal reinforcing design for the concrete slab floors which are capable of accepting modifications.

PROJECT DATA SHEET

DATE: 2/9/98

PROJECT TITLE: 255 State Street

LOCATION: Boston, MA

PROJECT OWNER: Fidelity Capital Real Estate Investors

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
Gilbane Building Company
Boston, MA
(617) 441-3236

ARCHITECT:
Peter Kliener, Schwartz, Silver Architects
530 Atlantic Avenue, Boston, MA 02210
(617) 542-6650

CIVIL ENGINEER: MECHANICAL
R. G. Vanderweil

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: 220,000 sf office building - 1980; warehouse building - 1926 to 1980

PAST SYSTEMS:

STRUCTURAL: Cast in place concrete; large mushroom capped columns; flat slab with reinforcing loops (rebar arranged in circular patterns around stress areas) which act in tension to balance the stresses within the structure; would not comply with current codes

ENCLOSURE: Masonry façade: limestone and brick with windows; exterior concrete in poor condition

SERVICE: Coal boiler system with hot water pumps; central cooler; all mechanical systems located within the basement; toilet rooms added in 1979; all systems set up to meet the needs of a single tenant, and therefore are incapable of accommodating type 'A' class office tenants

FINISH: Demising walls - steel studs with drywall used for partitions within the building

SPECIAL CONCERNS: Problems with building during renovation: Poor standards of the concrete; due to the method of reinforcing used the reinforcing steel had to installed near perfect - it wasn't; this causes large problems with modification; all structural modifications were restricted to the building's central core.

FUTURE USAGE: Multi-tenant class 'A' upscale office building

NEW SYSTEMS:

STRUCTURAL: Several structural modifications made: holes/shafts cut into the center of the building's floors; old staircase shafts filled in; staircases moved into the center core of the building using existing elevator shaft hole; new elevator installed and shaft constructed

ENCLOSURE: Brick exterior redone due to poor craftsmanship which was used in initially installing it; most of it was failing and falling apart; precast panels with glass windows were installed for the remainder of the exterior

SERVICE: All toilet rooms were reconfigured slightly and renovated; new rooftop condensed water cooling tower installed; Air conditioning installed using the original shaft space; Package units including a chiller were installed on each floor thus occupying a large amount of space on those floors; electric heating units also installed on each floor; VAV units were installed on the exterior.

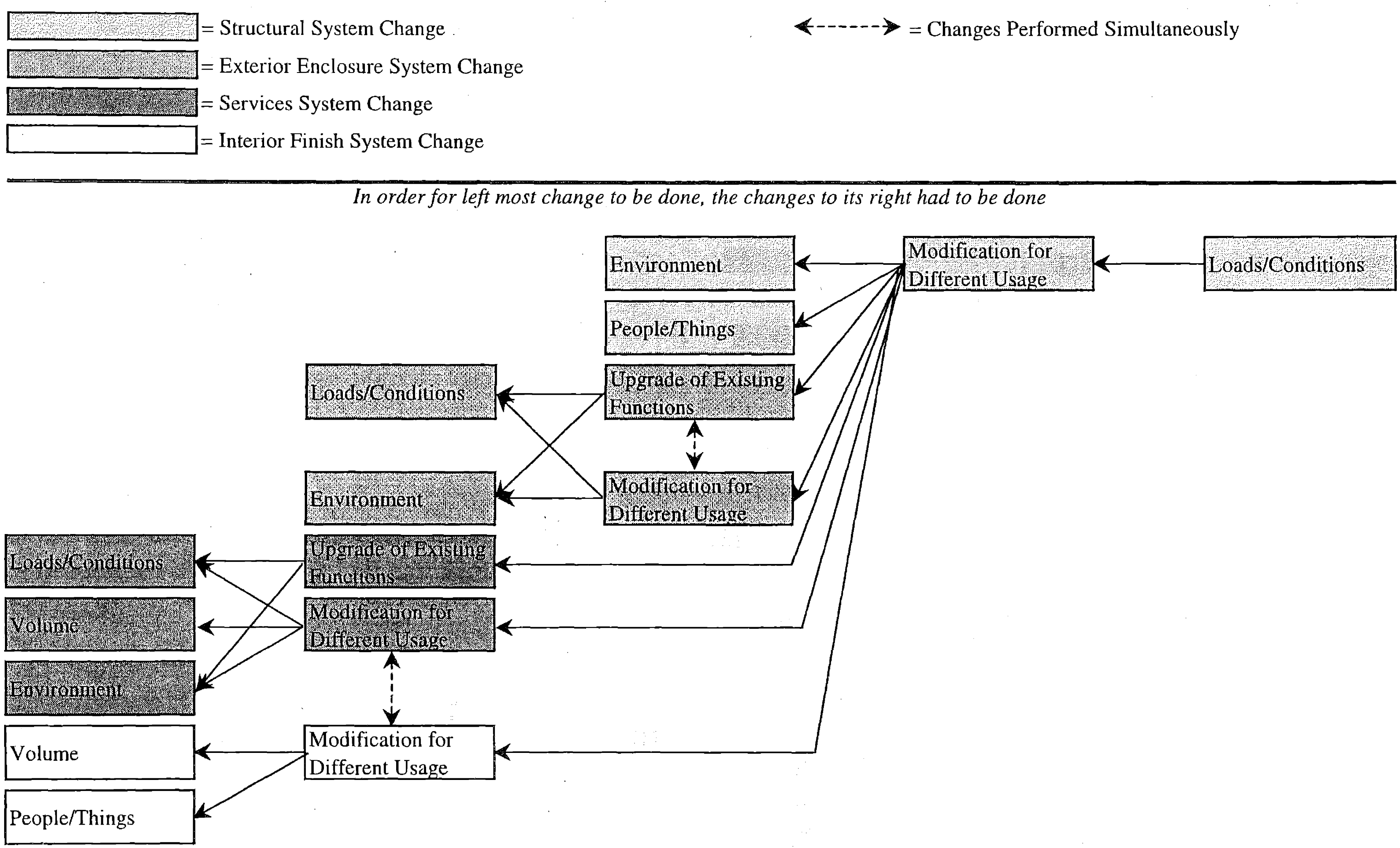
FINISH: Open office plan: central core housing elevators, stairs, restrooms, kitchen areas, and mechanical rooms, surrounded by a perimeter of open office space left for tenant fitout.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: 255 State Street

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair	Repair and Upgrade	
			Brick portions of exterior enclosure required repair due to poor craftsmanship	All toilet rooms were reconfigured slightly and renovated	
	Incorporating New Functions				
	Modification for New Usage	Major	Major	Major	Major
		Holes and shafts were cut into the center of the building's floors for utilities; old stairwells removed and holes filled in; New stairwells moved to the center of the building using existing elevator shaft holes; new elevator shaft constructed	The remainder of the exterior was replaced entirely with new precast panels and glass windows	Systems initially designed and constructed to meet needs of a single tenant for entire building, so all required modifications to meet needs for multiple tenants; New rooftop condensed water cooling tower installed; Air conditioning installed using existing shaft space; Package units including a chiller & electric heating units installed on each floor; VAV units installed on exterior	The interior was gutted and remodeled with an open office plan: central core which houses elevators, stairwells, restrooms, kitchen areas, and mechanical rooms surrounded by a perimeter of open office space left for tenant fit out
CAPACITY	**Loads / Conditions**	Yes	Yes	Yes	
		Poor standard of concrete superstructure; method of reinforcement used for cast in place concrete slab floors required perfect installation which was never achieved; thus causing problems which restricted modifications to the building's central core	Due to poor craftsmanship in the laying of a large proportion of the exterior brick façade, it was in danger of failing and thus required repair and replacement	The electrical, mechanical, HVAC etc. units were all upgraded and increased in power and load capacity to meet the needs of several tenants	
	Volume			Large	Small
				Systems were all revamped in volume to meet the future needs of multiple tenants; to provide this a large amount of each floor space was sacrificed for mechanical/utility space	Some of the usable interior office space was sacrificed for use as mechanical and conveyance space and shafts
FLOW	**Environment**	Yes	Yes	Yes	
		By concentrating all of the service shafts, stairwells and elevators to the central core of the building the perimeter floor area was now left free for office use	By repairing and replacing the failing areas of the exterior façade the building was again safe and much more aesthetically pleasing	The new HVAC provides a much better working environment; The new systems also allow the building to be occupied by several different tenants	
	People / Things	Yes			Yes
		Modification concentrated all of the egress to the central core thus changing the flow of people from the original stairwells on the sides of the building to the new ones in the center			Building floor design leaves the interior spaces for common use by people while the exterior space remains for use as office areas, etc.


= Structural System Change
= Exterior Enclosure System Change
= Services System Change
= Interior Finish System Change
= Changes Performed Simultaneously
In order for left most change to be done, the changes to its right had to be done
Loads/Conditions
Modification for Different Usage
Environment
People/Things
Upgrade of Existing Functions
Modification for Different Usage
Loads/Conditions
Environment
Upgrade of Existing Functions
Modification for Different Usage
Modification for Different Usage
Loads/Conditions
Volume
Environment
Volume
People/Things

Union Station, Seattle, Washington

Union Station in Seattle, Washington is an old historic structure that was once a coal gasification plant. Although the building is structurally sound, the remaining systems required substantial reconstruction in order to bring the building back to an occupiable state. Approximately $3.3 million was spent to dispose of residual coal tar brought to the surface by the driving of new foundation piles in the areas surrounding the building. Upon renovation of the facility, it will house office space as well as the Seattle Area Regional Transit Authority's commuter light-rail and bus system. Overall, this project simply was a traditional rehabilitation of one of the most prominent brownfield sites in the state of Washington ("Seattle's Union Station", 1997).

PROJECT DATA SHEET

DATE: 1/16/98

PROJECT TITLE: Union Station

LOCATION: Seattle, Washington

PROJECT OWNER: Nitzestagen

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE:
FINISH DATE:

PAST USAGE: Coal gasification plant

PAST SYSTEMS:

STRUCTURAL: Sound structurally

ENCLOSURE: Badly deteriorated concrete; tile roof with a glass atrium

SERVICE:

FINISH: Office had to be removed

SPECIAL CONCERNS: " One of the prominent brownfield sites in the state of Washington."; $3.3 million spent to dispose of residual coal tar brought to surface by driving piles; whole renovation project to cost $20 million.

FUTURE USAGE: Office space and Seattle Area Regional Transit Authority's Commuter light-rail and bus system hub.

NEW SYSTEMS:

STRUCTURAL: Same

ENCLOSURE: Torn apart and then restored - restored the concrete cornices, the tile roof and the glass atrium.

SERVICE:

FINISH:

EXPECTED FUTURE CHANGES:

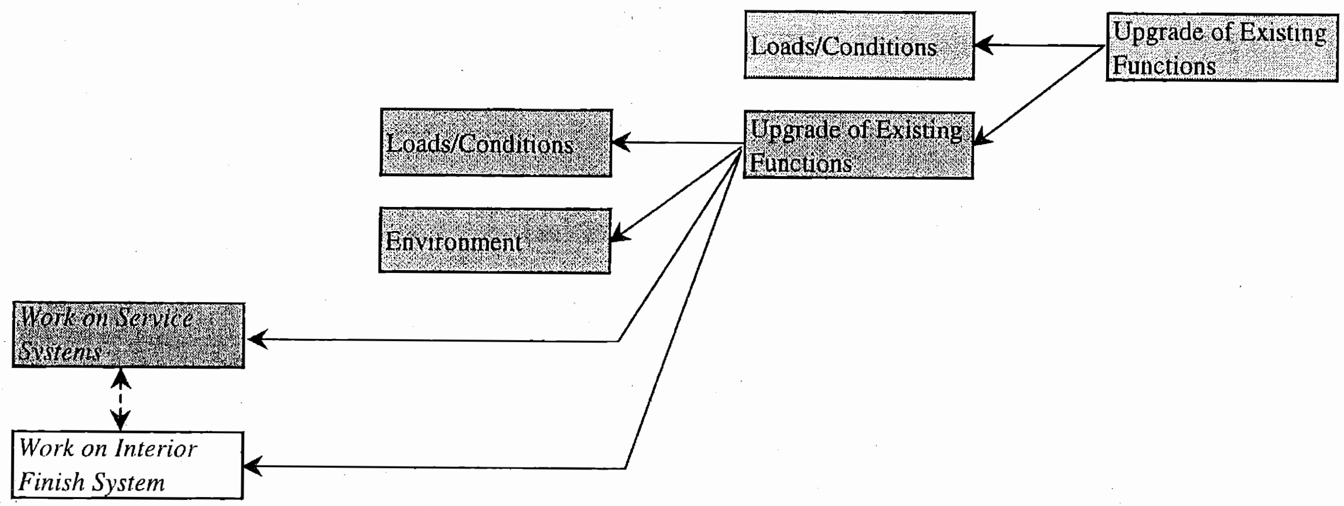
NOTES:

PROJECT: Union Station, Seattle, Washington

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**	Upgrade Structure sound yet some seismic upgrade was required to bring building up to code	Upgrade Concrete exterior glass atrium and tile roof both badly deteriorated and were torn apart and then restored	Upgrade?	Upgrade Interior badly deteriorated and thus was gutted completely and then rebuilt
	Incorporating New Functions				
	Modification for New Usage				
CAPACITY	**Loads / Conditions**	Yes Seismic upgrades of structural system	Yes Exterior's condition very near to failing and thus required upgrade and repair; also required seismic upgrades		
	Volume				
FLOW	**Environment**		Yes Upgrade of the building's exterior restores it to its historic stature; thus helping to improve morale within the surrounding community		
	People / Things				

Union Station, Seattle, Washington **Renovation for Different Usage**

In order for left most change to be done, the changes to its right had to be done



Worthington Place, Cambridge, Massachusetts

Worthington Place is a building complex in Cambridge, Massachusetts which consists of three main buildings that are all tied together: a 5 story cast-in-place concrete structure with mushroom capped columns and flat slab floors, a 4 story steel framed structure with brick façade and timber floored decks, and a 2 story steel and timber framed structure. This complex was originally designed as a metal stamping industrial plant, and therefore possessed sufficient load capacities but meager service and finish systems (Russell, interview, 1997).

This case study provides another example of the flexibility which excess structural load capacity can offer in the reuse of a building's interior space. The types of structural systems within the complex and their load capacities allowed the construction of a large atrium within the 4 story steel framed structure, as well as the addition of two floors to the top of half of the cast-in-place structure and the installation of another floor in the 5 story part between the 5^{th} floor and the roof. However, although the building allowed the changes to be easily made, the new design for the building fails to incorporate any future possible changes that might occur or that might be required. The new design of the complex was simply made to meet the needs for apartment residential use without any consideration of possible future changes for the future (e.g., the inclusion of laundry service within the individual apartments versus one public laundry room).

PROJECT DATA SHEET

DATE: 12/16/97

PROJECT TITLE: Worthington Place

LOCATION: Kendall Square, Cambridge, MA

PROJECT OWNER: Worthington - Dick Russell, contact

GENERAL CONTRACTOR / CM / PM (NAME ADDRESS & PHONE):
CWC Builders Inc.
7 Wells Ave., Ste. 4, Newton, MA 02159
(617) 965-2800 (2880-fax)

ARCHITECT:

CIVIL ENGINEER:

SUBCONTRACTORS:

BUILDING INFORMATION:

START DATE: Jul-97
FINISH DATE: Aug-98

PAST USAGE: Metal stamping industrial plant

PAST SYSTEMS:

STRUCTURAL: Steel structure for the left building and rear building; cast in place concrete structure in the front building

ENCLOSURE: Brick veneer with glass windows in the left and rear buildings; front building has a concrete exterior with large full length steel and glass windows.

SERVICE: Steam boiler serviced all of the buildings; sprinkler system (risers plus piping) supplied; no air conditioning; mediocre electrical system; small service elevator

FINISH: None: open floor areas - industrial use for metal stamping

SPECIAL CONCERNS: Historical façade - must be preserved; heating and cooling efficiency problems due to the windows and ceiling heights; high windows in the rear building are not very useful.

FUTURE USAGE: 1 to 2 bedroom apartments; ~180 total; ~$1800/month rent plus utilities

NEW SYSTEMS:

STRUCTURAL: Same as the previous; addition of a fifth floor to the top of the building on the left; additional floor (6th) installed above the 5th floor of the concrete building in the front due to the high ceiling heights.

ENCLOSURE: Same due to the historic requirements; brick façades washed and repointed; new energy efficient windows resembling the original windows installed

SERVICE: Vertical 2 pipe whalen heat pump units installed within each apartment; electrical system upgraded; laundry room installed into the building; sprinkler risers reused, new piping installed; new elevator installed; old elevator replaced with new passenger elevator

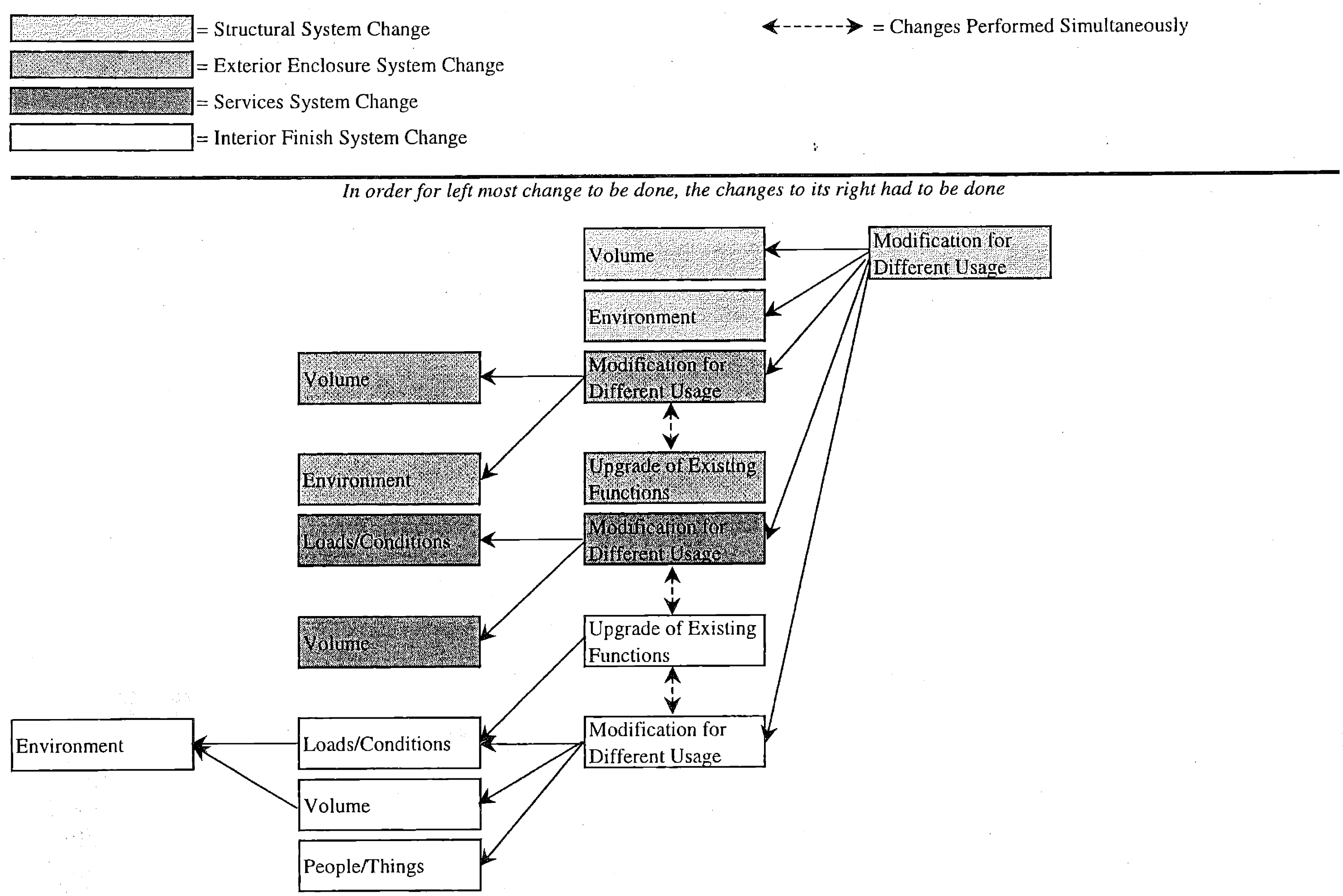
FINISH: Metal stud walls with gypsum board painted used to construct the interior space into individual apartments; gypcrete placed on the floors to level them; all floors carpeted, vinyl placed in the kitchen and bathroom areas.

EXPECTED FUTURE CHANGES:

NOTES:

PROJECT: Worthington Place

		BUILDING SYSTEMS			
		Structural	**Enclosure**	**Services**	**Finish**
FUNCTION	**Upgrade of Existing Functions**		Repair and Upgrade Concrete & brick exterior of the building complex were cleaned and repaired; historic windows replaced with upgraded identical steel framed windows; roofs repaired & upgraded		Repair and Upgrade Gypcrete poured on existing floors to level them out before carpet was laid; concrete ceilings cleaned and then painted and left exposed within the individual apartments
FUNCTION	**Incorporating New Functions**	2 New Functions Construction of new 5th & 6th floors over 4 story portion of complex; construction of new 6th floor between 5th floor & roof of 5 story CIP concrete portion of building; construction of elevator shaft in 4 story building		2 New Functions A new elevator was installed within the main lobby of the building extending up the 4 story steel structure; An entirely new laundry room was constructed within the complex with the required washer and dryers	
FUNCTION	**Modification for New Usage**	Major The construction of the new floors within the two portions of the building created more leasable building space which equaled more apartments; central atrium constructed within the main 4 story tall steel building by cutting out flooring (wooden deck on steel structure)	Major The construction of the new floors above the 4 story portion of the building complex required the installation of a new exterior which was set back form the perimeter of the building to meet historic requirements; atrium was capped by a large glass skylight shape in a triangular fashion	Major Existing steam boiler was replaced by individual 2 pipe whalen heating units - one unit was installed within each apartment and all were installed in a vertical arrangement with each other; electrical, sprinkler, elevator & plumbing systems all upgraded to meet residential requirements	Major Open area floor plan changed into a private enclosed arrangement of interior space; Apartments constructed using metal stud and drywall wall partitions; Floors carpeted rooms & corridors, vinyl tile used in bathroom & kitchen areas; ceilings in apartments exposed, in halls enclosed by drywall
CAPACITY	**Loads / Conditions**			Yes The plumbing, sprinkler, electrical and HVAC systems were all revamped to meet the requirements for residential usage	Yes The additional floors that were constructed use load bearing metal and wood stud walls and floor joists
CAPACITY	**Volume**	Large While construction of the atrium took away a lot of potential useful floor space the construction of the additional floors were used to balance the loss out	Small Addition of the floors above the existing 4 story concrete portion of the complex required the installation of a new exterior and roofing system	Large Change in building use to residential required a drastic change in the volume and depth of the services: electrical, HVAC, sprinkler, plumbing, etc.	Large Move away from a large open area design for the floors into a much more confined and private maze of apartments and corridor spaces
FLOW	**Environment**	Yes Atrium changed unusable space for apartments into a nice channel for natural lighting above the main lobby, thus providing a much warmer entrance	Yes Skylight above atrium allows natural light to flow into the building's main lobby thus making a much nicer and more welcoming entranceway		Yes Transformation of interior space from open areas into a maze of private apartment units changes the overall flow within the building
FLOW	**People / Things**				Yes flow of people through the building complex is now restricted to the public hallways and lobbies; People are forced to move through a maze of corridors and rooms to get from one point to the other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Modification for Different Usage
Volume
Environment
Modification for Different Usage
Upgrade of Existing Functions
Modification for Different Usage
Upgrade of Existing Functions
Modification for Different Usage
Volume
Environment
Loads/Conditions
Volume
Loads/Conditions
Volume
People/Things
Environment

Appendix C: Framework Definitions and Links

CHANGES IN FUNCTION

UPGRADE OF EXISTING FUNCTIONS

Structural System

Load Capacity:	Compare the designed capacity and conditions of the structural components and the types of loading they support with the current load requirements and regulations
Building Codes:	Compare the past and current codes to insure that the building's structure meets the occupancy requirements
System Type:	Must consider the existing materials and framing type and insure that it can support the new load conditions for the building's occupancy class
Links to:	Structural (Loads / Conditions, Environment) Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage) Enclosure (Upgrade of Existing Functions)

Exterior Enclosure System

Load Capacity:	Must determine the load bearing characteristics of the exterior (which portions are load bearing vs. which are not) and compare their designed capacity and conditions with the capacity and conditions required for the building's occupancy and other requirements.
System Type:	Must analyze the existing materials and siding type used for the exterior to insure that it meets code requirements and is in sufficient condition to meet the building's usage requirements
Performance Requirements:	Must determine if the exterior enclosure meets the current requirements for: Energy Efficiency, Weather Tightness, and Accessibility (Entrances)
Special Requirements:	Must determine if the exterior is protected by Historic Preservation
Links to:	Structural (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage) Services (Modification for New Usage) Enclosure (Modification for New Usage, Loads/Conditions, Environment, People/Things)

Services System

Load (Power) Capacity:	Compare the existing service systems and their power capacities to the necessary loads required by current usage needs to determine if systems require upgrade, repair and/or replacement.
System Type:	Identify the existing types of systems, their size, and their efficiency and determine if they best fit the building's future usage needs.
Performance Requirements:	Determine if the systems efficiently provide the necessary performance requirements for the building's future usage class: Efficiency, Light, Air, Warmth, and Cooling
Links to:	Structural (Modification for New Usage, Loads/Conditions) Services (Loads/Conditions, Volume, Environment, People/Things) Finish (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Environment, People/Things)

Interior Finish System

System Type:	Determine and compare the materials, framing type, and their conditions (level of deterioration) to the building's future usage requirements for the interior space
Special Requirements:	Must determine if any part of the interior is protected by Historic Preservation
Spatial Dimensions:	Determine and compare the existing volume (Room Size, Environment, Distance from Natural Light, Noise Reduction) of the interior to that required to meet the building's future usage class.
Building Codes:	Compare the past and current codes to insure that the building's layout of interior space meets the occupancy requirements (ADA requirements, etc.)
Performance Requirements:	Determine if the current interior finish layout fulfills the necessary performance requirements for the building's future usage: Accessibility, Light
Links to:	Finish (Loads/Conditions, Volume, Environment, People/Things) Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage)

CHANGES IN FUNCTION

INCORPORATING NEW FUNCTIONS

Structural System	
Load Capacity:	Analyze the existing structural system and determine if it can carry the new load conditions imposed by the addition of the new functions.
Building Codes:	Compare the past and current codes to insure that the building's structure meets the occupancy requirements.
Site/Building Issue:	Before incorporating new functions it must be determined how the existing space will be effected (Site/Working Constraints) and how the new functions will be incorporated into the existing building (Construction Planning)
Performance Requirements:	Must compare the existing performance requirements to those for the building's future usage to determine what new functions are necessary for the structural system: Accessibility, Parking and Conveyances
Spatial Dimensions:	Compare the existing spatial dimensions of the building's structural system and its ability to support those dimensions with those required for the building's future usage to insure that increases in volume, and/or the addition of floors/atriums can be made
Links to:	Structural (Modification for New Usage, Loads/Conditions, Volume, Environment, People/Things) Enclosure (Incorporating New Functions) Services (Upgrade of Existing Functions, Incorporating New Functions) Finish (Volume)
Exterior Enclosure System	
Load Capacity:	Must determine the load carrying characteristics of the exterior enclosure (load vs. non-load bearing) to insure that it can support any new functions adequately
Spatial Dimensions:	Compare the existing spatial dimensions of the building's enclosure system and its ability to support those dimensions with those required for the building's future usage to insure that increases in volume, and/or the addition of floors/atriums can be made
Performance Requirements:	Must compare the existing condition of the exterior and its ability to meet the required performance requirements to its potential capability to meet the building's future usage requirements: Weather Tightness, Accessibility (Entrances)
Links to:	Structural (Incorporating New Functions, Modification for New Usage, Volume) Enclosure (Loads/Conditions, Volume, Environment, People/Things) Services (Incorporating New Functions, Modification for New Usage) Finish (Incorporating New Functions, Modification for New Usage)
Services System	
Load (Power) Capacity:	Before incorporating new service systems it is necessary to determine that the building has the power necessary to run those systems effectively and efficiently, and if not to insure that the needed power is obtained.
System Type:	Must examine the existing services and the materials they consist of to insure that they are applicable to any new equipment and can potentially be reused with that equipment
Performance Requirements:	Must compare the existing condition of the services and their ability to meet the required performance requirements to their potential capability to meet the building's future usage requirements in Accessibility (Conveyances), Energy Efficiency, Light, Air, Warmth, and Cooling
Building Codes:	Compare the past and current codes to the existing service systems to insure that they meet the occupancy requirements.
Links to:	Structural (Incorporating New Functions, Modification for New Usage, Loads/Conditions) Enclosure (Incorporating New Functions, Modification for New Usage) Services (Loads/Conditions, Volume, Environment, People/Things) Finish (Upgrade of Existing Functions, Modification for New Usage, Volume, People/Things)
Interior Finish System	
Spatial Dimensions:	Compare the existing volume (Layout of Interior Space, Room Size) of the interior finish system to the required volume to insure that new functions can be adequately incorporated
Building Codes:	Compare the past and current codes to the existing interior finish system to insure that it meets the occupancy requirements (ADA regulations, etc.).
Performance Requirements:	Must compare the existing condition of the interior finish system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility
Links to:	Enclosure (Incorporating New Functions) Services (Upgrade of Existing Functions) Finish (Modification for New Usage, Volume, Environment, People/Things)

CHANGES IN FUNCTION

MODIFICATION FOR DIFFERENT USAGE

Structural System

Load Capacity:	Identify the existing load capacity of the building's structural system and determine its ability to withstand the loads and conditions associated with the new usage and any modifications required to meet this usage.
System Types:	Identify the type of materials and the framing type of the existing structural system to determine its ability to support the building's future usage (Certain building materials/framing types permit modification easier than others)
Site/Building Issue:	Must determine the capabilities of the site to accommodate a new building usage, and the ability of the structural systems to accommodate any restrictions (Site/Working Constraints, Location)
Performance Requirements:	Must compare the existing condition of the structural system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility, Natural Light, Ventilation, Etc.
Links to:	Structural (Incorporating New Functions, Loads/Conditions, Volume, Environment, People/Things) Enclosure (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Volume) Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Volume, Environment) Finish (Modification for New Usage, Volume, People/Things)

Exterior Enclosure System

Load Capacity:	Identify the existing load capacity of the building's enclosure system (load vs. non-load bearing) and determine its ability to withstand the loads and conditions associated with the new usage and any modifications required to meet this usage.
Special Requirements:	Must determine if the exterior is protected by Historic Preservation
Performance Requirements:	Must compare the existing condition of the enclosure system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Energy efficiency, Weather tightness, Accessibility (Entrances), Natural light, Ventilation, Etc.
Links to:	Structural (Modification for New Usage, Loads/Conditions) Enclosure (Upgrade of Existing Functions, Loads/Conditions, Volume, Environment, People/Things) Services (Incorporating New Functions, Modification for New Usage, Volume, Environment) Finish (Modification for New Usage)

Services System

Load (Power) Capacity:	Before modifying the building for new usage, it is necessary to determine that the building has the power necessary to run the services required effectively and efficiently, and if not to insure that the needed power is obtained.
System Type:	Must examine the existing services and the materials they consist of to insure that they are capable of servicing the new building usage requirements and can potentially be reused for that purpose.
Performance Requirements:	Must compare the existing condition of the services and their ability to meet the required performance requirements with their potential capability to meet the building's future usage requirements in Energy Efficiency
Links to:	Structural (Modification for New Usage) Enclosure (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage) Services (Loads/Conditions, Volume, Environment, People/Things) Finish (Upgrade of Existing Functions, Modification for New Usage, Volume, People/Things)

Interior Finish System

Spatial Dimensions:	Compare the existing volume (Layout of Interior Space, Room Size) of the interior finish system to the required volume to insure that new usage can be incorporated
Building Codes:	Compare the past and current codes to the existing interior finish system to insure that it meets the occupancy requirements (ADA regulations, etc.).
Performance Requirements:	Must compare the existing condition of the interior finish system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility, natural lighting, noise reduction, and social/productivity issues
Links to:	Structural (Modification for New Usage) Enclosure (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage) Services (Incorporating New Functions, Modification for New Usage) Finish (Incorporating New Functions, Loads/Conditions, Volume, Environment, People/Things)

CHANGES IN CAPACITY		
LOADS/CONDITIONS		
Structural System		
Load Capacity:	Compare the designed capacity and conditions of the structural components and the types of loading they support with the current load requirements and regulations	
Building Codes:	Compare the past and current codes to the existing structural system to insure that it meets the occupancy requirements (ADA regulations, etc.).	
System Types:	Must consider the existing materials and framing type and insure that it can support the new load conditions for the building's occupancy class	
Links to:	Structural (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Volume, Environment, People/Things) Enclosure (Modification for New Usage) Services (Upgrade of Existing Functions, Incorporating New Functions) Finish (Environment, People/Things)	
Exterior Enclosure System		
Load Capacity:	Identify the existing load capacity of the building's enclosure system (load vs. non-load bearing) and determine its ability to withstand the loads and conditions associated with the building's future usage.	
Building Codes:	Compare the past and current codes to the existing enclosure system to insure that it meets the occupancy requirements (ADA regulations, etc.).	
Performance Requirements:	Must compare the existing condition of the enclosure system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Energy Efficiency, Weather Tightness	
System Types:	Must analyze the existing materials and siding type used for the exterior to insure that it meets code requirements and is in sufficient condition to meet the building's usage requirements	
Links to:	Enclosure (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage) Finish (Environment, People/Things)	
Services System		
Load (Power) Capacity:	Compare the existing service systems and their power capacities to the necessary loads required by current usage needs to determine if systems require upgrade, repair and/or replacement.	
System Type:	Identify the existing types of systems, their size, and their efficiency and determine if they best fit the building's future usage needs.	
Performance Requirements:	Must compare the existing condition of the services and their ability to meet the required performance requirements with their potential capability to meet the building's future usage requirements in Energy Efficiency, Air, Ventilation, Warmth, and Cooling	
Building Codes:	Compare the past and current codes to the existing services to insure that they meet the occupancy requirements (ADA regulations, etc.).	
Links to:	Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Volume, Environment) Finish (Environment)	
Interior Finish System		
Load Capacity:	Must determine where any load-bearing member of the interior finish system exists (interior walls, columns, etc.) and if so how to work around it without disturbing the other building systems and the building's stability as a whole	
Links to:	Finish (Upgrade of Existing Functions, Modification for New Usage, Environment)	

CHANGES IN CAPACITY	
VOLUME	
Structural System	
Load Capacity:	Before incorporating a change in building volume, the load capacity of the structural system and its ability to support the necessary volume changes must be determined
Building Codes:	Compare the past and current codes to the existing structural system to insure that it meets the occupancy requirements (ADA regulations, etc.).
Site/Building Issue:	Certain building usages require a greater amount of useable building space, however the building is limited by Site Constraints, Zoning Restrictions, and Location issues. These constraints must be considered when changes in volume are necessary.
Spatial Dimensions:	Compare the existing spatial dimensions of the building's structural system and its ability to support those dimensions with those required for the building's future usage to insure that increases in Volume, Room Size, Bay Span, Floor to Ceiling Heights, and Additions of Atriums/Floors can be made
Performance Requirements:	Must compare the existing condition of the structural system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility, Natural Lighting
Links to:	Structural (Incorporating New Functions, Modification for New Usage, Loads/Conditions, Environment, People/Things) Enclosure (Incorporating New Functions, Volume) Services (Volume) Finish (Volume, People/Things)
Exterior Enclosure System	
Load Capacity:	Identify the load capacity of the existing exterior enclosure system and determine that it can support the additional loads associated with any increases in the exterior volume.
Spatial Dimensions:	Compare the existing spatial dimensions of the building's enclosure system and its ability to support those dimensions with those required for the building's future usage to insure that increases in Volume, Additions of Atriums/Floors can be made
Links to:	Structural (Modification for New Usage, Volume) Enclosure (Incorporating New Functions, Modification for New Usage) Services (Volume) Finish (Volume)
Services System	
Load (Power) Capacity:	Compare the existing service systems and their power capacities to the necessary loads required by current usage needs to determine if systems require upgrade, repair and/or replacement which may incorporate an increase in volume or depth.
Spatial Dimensions:	Compare the existing spatial dimensions of the building's services and their ability to support those dimensions with those required for the building's future usage to insure that increases in Volume, Additions of Atriums/Floors, Floor to Ceiling Heights, Utility Shaft Size, Etc. can be made and can be sufficiently serviced
Performance Requirements:	Must compare the existing condition of the services and their ability to meet the required performance requirements with their potential capability to meet the building's future usage requirements in Energy Efficiency, Air, Ventilation, Warmth, Cooling, and Power
Building Codes:	Compare the past and current codes to the existing services to insure that they meet the occupancy requirements (ADA regulations, etc.).
Links to:	Structural (Modification for New Usage, Volume) Enclosure (Modification for New Usage, Volume) Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Loads/Conditions, Environment, People/Things) Finish (Volume)
Interior Finish System	
Performance Requirements:	Must compare the existing condition of the interior finish system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility, Distance from Natural Light
Spatial Dimensions:	Compare the existing spatial dimensions of the building's finish and its ability to support those dimensions with those required for the building's future usage to insure that increases in Volume, Room Size, Additions of Atriums/Floors, Etc. can be made
Links to:	Structural (Incorporating New Functions, Modification for New Usage, Volume) Enclosure (Volume) Services (Incorporating New Functions, Modification for New Usage, Volume) Finish (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Environment, People/Things)

CHANGES IN FLOW		
ENVIRONMENT		
Structural System		
Load Capacity:	Compare the designed capacity and conditions of the structural components and the types of loading they support with the current load requirements and regulations to insure that the building environment is safe	
Site/Building Issue:	Site constraints and location can often lead to changes in the environment within and surrounding a building being renovated as the work often has to proceed while ordinary functions continue to operate. This thus requires careful Construction Planning.	
Performance Requirements:	Must compare the existing condition of the structural system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in User Comfort, Natural Light Sources	
Links to:	Structural (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Loads/Conditions, Volume)	
Exterior Enclosure System		
Special Requirements:	Must determine if the exterior is protected by Historic Preservation, as a building being historically restored can often change the environment within the surrounding neighborhood	
Performance Requirements:	Must compare the existing condition of the enclosure system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in User Comfort, Natural Light Sources, Ventilation, Aesthetics, Accessibility (Entrances)	
Links to:	Enclosure (Upgrade of Existing Functions, Modification for New Usage)	
Services System		
Performance Requirements:	Must compare the existing condition of the services and their ability to meet the required performance requirements with their potential capability to meet the building's future usage requirements in User Comfort, Air, Ventilation, Warmth, and Cooling	
Building Codes:	Compare the past and current codes to the existing services to insure that they meet the occupancy requirements (ADA regulations, etc.).	
Links to:	Structural (Modification for New Usage) Enclosure (Modification for New Usage) Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Loads/Conditions, Volume)	
Interior Finish System		
Performance Requirements:	Must compare the existing condition of the interior finish system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in User Comfort, Natural Light, Privacy, Noise Reduction, and Social/Productivity Issues	
Spatial Dimensions:	Compare the existing spatial dimensions of the building's finish and its ability to support those dimensions with those required for the building's future usage to insure that increases in Volume, Layout of Interior Space, Room Size can be made	
Site/Building Issues:	Must identify and determine if any Environmental Hazards or other Constraints exist within the building which may harm its future occupants. Such hazards as asbestos, lead paint, PCBs, etc. must be considered and removed prior to renovation.	
Links to:	Structural (Loads/Conditions) Enclosure (Loads/Conditions) Services (Upgrade of Existing Functions, Loads/Conditions) Finish (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Loads/Conditions, Volume)	

CHANGES IN FLOW

PEOPLE / THINGS

Structural System

Load Capacity:	Compare the designed capacity and conditions of the structural components and the types of loading they support with the current load requirements and regulations to insure that the building is safe human occupancy and flow
System Type:	Identify the type of materials and the framing type of the existing structural system to determine its ability to support the building's future usage. Certain building materials/framing types permit modification easier than others and thus allow the flow within the building to change easier.
Spatial Dimensions:	Compare the existing spatial dimensions of the building's structural system and its ability to support those dimensions with those required for the building's future usage to insure that increases in Volume, Room Size, Bay Span, and Additions of Atriums/Floors can be safely made
Performance Requirements:	Must compare the existing condition of the structural system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility
Links to:	Structural (Incorporating New Functions, Modification for New Usage, Loads/Conditions, Volume)

Exterior Enclosure System

Performance Requirements:	Must compare the existing condition of the enclosure system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility, Natural Light Sources, and Ventilation
Links to:	Enclosure (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage)

Services System

Performance Requirements:	Must compare the existing condition of the services and their ability to meet the required performance requirements with their potential capability to meet the building's future usage requirements in Accessibility (Conveyances)
Spatial Dimension:	Compare the existing spatial dimensions of the building's services and their ability to support those dimensions with those required for the building's future usage to insure that increases in Floor to Ceiling Heights, Utility Shaft Size and Space can be made to allow the building to be sufficiently serviced.
System Types:	Identify the existing types of systems, their size, and their efficiency and determine if they best fit the building's future usage needs for moving throughout a building (conveyances).
Links to:	Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Volume)

Interior Finish System

Performance Requirements:	Must compare the existing condition of the interior finish system and its ability to meet the required performance requirements with its potential capability to meet the building's future usage requirements in Accessibility, Social/Productivity Issues
Site/Building Issues:	Must identify and determine if any Environmental Hazards or other Constraints exist within the building which may harm its future occupants. Such hazards as asbestos, lead paint, PCBs, etc. must be considered and removed prior to renovation.
Spatial Dimensions:	Compare the existing spatial dimensions of the building's finish and its ability to support those dimensions with those required for the building's future usage to insure that increases in Bay Span, Room Size, Private vs. Open Areas can be made which all effect the flow of people and things within a building.
Links to:	Structural (Incorporating New Functions, Modification for New Usage, Loads/Conditions, Volume) Enclosure (Loads/Conditions) Services (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage) Finish (Upgrade of Existing Functions, Incorporating New Functions, Modification for New Usage, Volume)

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