

Approaches and Associated Costs of Building Demolition and Deconstruction

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ABSTRACT

Approaches and associated costs of building demolition and deconstruction

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Building demolition, deconstruction and preparing the environment for new construction is an important aspect of urban development. As the built environment ages and plans for new developments occur, the opportunities for deconstruction, demolition and renovation emerge. This aspect has taken on great importance with the widespread residential, industrial and commercial property abandonment in certain urban areas such as Detroit, Michigan. This research provides technical, economic, and environmental inputs for the selection of building removal methods.

Demolition, using heavy equipment is the traditional process for building removal. Modern demolition equipment removes structures quickly, destroying the materials within and creating solid waste destined for landfills. On the other hand, deconstruction can work to offset the environmental impacts of the building related waste. Deconstruction not only diverts wastes from landfills, it also reduces greenhouse gas emissions by reducing the need to extract and ship new materials and also gives rise to a new industry of skilled jobs. In order to transform the industry, demolition should incorporate successful aspects of deconstruction, and future construction should incorporate design for deconstruction. Deconstruction can be more cost effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvaged material. On average, gross deconstruction costs are higher than demolition costs, but the net cost of deconstruction with salvage is lower than demolition. For deconstruction to be more practicable and profitable, it is important that attractive policies, incentives, and market/supply chain for deconstructed material are available.

Dedicated to my country, Afghanistan.

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CHAPTER 1

1.0 INTRODUCTION

1.1. INTRODUCTION

Building demolition, deconstruction and preparing the environment for new construction is an important aspect of urban development. As the built environment ages and plans for new developments occur, the opportunities for deconstruction, demolition and renovation expand. Throughout history, people have demolished structures to make room for new structures and to rehabilitate existing ones.

When buildings need to be removed from a site, the typical and mostly economical option is to demolish the building and haul the waste to landfills. Many quick and relatively inexpensive methods can be used to demolish the building and clear the site. On the other hand, these methods create substantial amounts of waste. The growing trend is to reuse materials in new or existing structures. The material that are not suitable for reuse should be recycled and sending material to a landfill should be the last resort. Hence, when the building contains large amounts of reusable and recyclable materials it is important to incorporate deconstruction into demolition. Whoever not all buildings are good candidates for deconstruction because they were not designed and built to be deconstructed. Though in the experimental phase, the new trend in construction industry is to design and build the buildings for deconstruction (Diven & Shaurette, 2010; EPA, 2008).

Deconstruction and demolition can be implemented using a number of approaches. These approaches vary according to the type of structure, size, equipment required, availability of resources, schedule requirements, regulatory requirements, disposal requirements, recycling

requirements, etc. All the above noted factors will have significant impact on the cost of the operation (Diven & Shaurette, 2010; Guy et al., 2003).

Projects can vary from low-rise residential and commercial buildings to high-rise residential and commercial, industrial buildings and structures, underwater structures, bridges, roads, pavements, railway lines, etc. Approaches to every project can be different considering the different requirements of planning and resource allocation. While the demolition and deconstruction of low-rise buildings are less complex and can be performed by most contractors, demolition and deconstruction of high-rise buildings are more complex and are mostly performed by experienced contractors equipped with necessary resources (Diven & Shaurette, 2010).

This document will discuss demolition, deconstruction and design for deconstruction based on the available literature and the existing industry practices. Costs associated with demolition and deconstruction projects will also be explored and compared. Finally, removal of abandoned properties in urban areas of Michigan will be discussed.

1.1.1. Demolition

Demolition is an engineering project where a building or structure that needs to be removed from a site, after reaching the end of its useful life, is knocked down with the help of heavy equipment or manual tools and rendered into rubble and debris. In some cases, some of the material is recycled such as concrete and steel and the rest of the material is hauled to landfills.

Many factors are considered in the planning of demolition projects. Major factors are the construction type, safety issues, cost, site access, protection of adjacent structures, unforeseen conditions, scheduling, sequence of work, and the disposal, recycling, reuse of material. A variety

of regulations and standards apply to the demolition industry such as safety, environmental requirements for site, environmental requirements for hazardous material, and community specific regulations amongst other (Diven & Shaurette, 2010).

Modern demolition equipment remove the buildings and structures quickly, creating waste destined for landfills. The environmental impacts of demolition are substantial, wasting large amounts of energy and resources.

1.1.2. Deconstruction

Deconstruction is the disassembly of building in order to recover maximum amount of material for reuse and recycle. Deconstruction is also known as green demolition, un-building or reverse construction. It is often a part of the conventional demolition process as an initial salvage phase. Most of the same regulations that apply to demolition such as safety, environmental and community specific regulations apply to deconstruction as well (Guy, et al., 2003)

Deconstruction has many economic, environmental and social benefits. The benefits of reuse and recycling of waste streams from building construction and demolition include diversion of waste materials from landfill sites and reduced depletion of natural resources. Both of these benefits contribute to the sustainable development practices within the building industry.

Not all buildings are good candidates for deconstruction. In general, buildings constructed before 1950 are better candidates for deconstruction because they may contain higher value of wood and other structural and ornamental elements for recovery, and they have less complicated fasteners and glues used for assembly (EPA, 2008)

The new trend in construction industry is to design and build for deconstruction. The incorporation of design for deconstruction or DfD is in its development stages and it will take time for it to be adopted for all or most of the new construction (EPA, 2008).

1.1.3. Design for Deconstruction

Design for Deconstruction or Design for Disassembly is a technique that considers the entire lifecycle of a building including design, manufacturing, construction, renovation, operation and eventually deconstruction. It creates a closed loop building management option where the building systems, components and materials are designed to be easily rearranged, dismantled, renovated, recovered and reused (EPA, 2008).

Incorporating design for deconstruction in new construction offers great potential for reuse of material and closing the loop of mining and use of new resources to a good extent. Though not every building is a good candidate for design for deconstruction, a growing number of examples are occurring in the field (EPA, 2008; EPA 2006).

1.2. NEED STATEMENT

Throughout history, demolition work has been imperative due to need for new construction and rehabilitation of spaces. With growing economies, aging environment and increasing urbanization; construction, renovation, demolition and deconstruction industries have substantial growth projections.

Demolition, deconstruction and design for deconstruction are major parts of the construction industry and will continue to grow. While there is a large amount of varied popular literature and industry practices available, there is a lack of common understanding of approaches, standard cost databases or standardized cost quantification practices. This points to a need to understand these activities based on the available literature and industry practices; leading to systematic understanding of approaches that are used in practice and their associated costs.

1.2.1. Growth of demolition and deconstruction industry

With economic growth, increasing urbanization and ageing environment the construction and demolition industry is set to grow.

Many cities with major urban growth in the United States and elsewhere are constantly renewed. Old industrial sites are remodeled to accommodate new machinery and equipment, or they are demolished and new offices and residencies are built. Dilapidated housing is demolished, to make way for new and more efficient residences. In such cities, demolition is a sign of economic activity, growth, expansion and renewal (Diven & Taylor, 2006).

“The scale of construction, renovation and demolition activities are expected to grow substantially. According to one estimate, the built space in the United States will grow from 300 billion square feet in year 2000 to 430 billion square feet by year 2030. In addition to the new construction of 130 billion square feet, one quarter of the construction that existed in 2000 will be replaced by 2030.” (EPA, 2008).

While this growth can be viewed as challenging, it is an opportunity for the application of sustainable practices in demolition through deconstruction and more efficient use of resources through implementation of design for deconstruction.

1.2.2. Sustainability

Constructing buildings, renovation and taking them down all together have substantial environmental impacts because of all the natural resources used for building construction and the large amounts of construction and demolition waste that are directed to landfills. In order to promote sustainability in the demolition industry, it is important to incorporate deconstruction into the demolition, and possibly adaptation of design and build for deconstruction to recover all systems and materials for reuse in future construction.

The facts below about construction, demolition and renovation waste in the United States compiled by the Environmental Protection Agency (Guy. et al., 2003), highlights the need for incorporating sustainable practices in the demolition industry:

- U.S. companies generate 136 million tons of building- related construction and demolition (C&D) waste per year.
- 92% of building-related C&D waste is from renovation and demolition.
- C&D waste is approximately 30% of all solid waste produced in this country excluding road and bridge debris.
- It estimated that only 20-30% of C&D waste is presently recycled.
- Excluding food and fuel, construction activities consume 60% of the total materials used in the U.S. economy.

- About 245,000 residential structures and 44,000 commercial structures are demolished each year in the US.
- Many older buildings contain asbestos and lead-based paint both hazardous to human health in renovation and demolition processes.
- Heavily leaded paint was used in about 1/3 of homes constructed before 1940, about 1/2 of homes constructed between 1940 and 1960, and then to a lesser extent until it was limited to 0.06% in any product in 1978.
- Landfills and incinerators are increasingly more expensive and problematic to open, operate and close.
- In order to sustain human society into the next century, resource efficiency will have to increase by a factor of 10.

Therefore, practicing reuse and recycling can strengthen our natural resources and decrease the environmental impacts.

1.2.3. Abandoned private properties

Many cities in the United States which used to be the hubs of industrial activities are presently facing economic and social decline with those industries declining. This issue is well prevalent in Michigan, where it has resulted in private property abandonment and blight in the cities of Detroit, Flint, etc. LaMore & LeBlanc (2014) assert that many communities in Michigan have suffered population and economic decline for decades, resulting in widespread residential, industrial and commercial property abandonment. These property abandonment cause blight and leads to social decline which threatens the public health and welfare of communities.

These abandoned properties need to be removed and the sites need to be restored for future use. Otherwise they turn into blight, triggering a spiral of social decline. Based on the understanding of the policies that will lead to dismantling, removal, and restoration of these properties, there is a need to identify most appropriate approaches for the removal of such structures with an understanding of the associated costs of removal.

Based on the above discussions, it can be summarized that there is a need for the following:

1. Removal of abandoned properties.
2. Use of deconstruction over demolition for the removal of abandoned properties due to the environmental, economic and social benefits of deconstruction.
3. Consideration of incorporation of design for deconstruction for all new construction due to the potential benefits of deconstruction.

1.3. RESEARCH GOALS AND OBJECTIVES

As discussed earlier, various approaches used for demolition and deconstruction are selected based on many factors. The goal of this research is to provide a systematic understanding of various approaches for removal of buildings.

Following are the objectives of this research:

1. Understand various approaches for demolition, deconstruction and design for deconstruction through literature review, case studies and interviews of contractors.
2. Analyze costs associated with approaches and possible quantification process.
3. Develop a comparison matrix for demolition and deconstruction.

4. Identify and recommend approaches which are suitable for removal of abandoned properties in Michigan.

1.4. SCOPE

The scope of this paper is limited to demolition and deconstruction of low-rise residential and mid-rise residential and commercial buildings. In addition, even though the understanding of approaches and associated costs are based on literature review, the identification of best practices in Michigan are based on interviews, observations, site visits and surveys.

1.5. METHODOLOGY

The approach adopted for this research is a descriptive approach. Extensive amounts of popular and some scholarly literature is available in these fields. The main aim is to identify and compile literature and summarize them for the purpose of understanding various approaches in demolition, deconstruction, and design for deconstruction and associated costs of these approaches.

Following is the methodology used for achieving each of the objectives:

1. Understand various approaches for demolition, deconstruction and design for deconstruction.
 - Literature review:

Various academic papers, thesis reports, case studies, industry reports and manuals are available in these fields. This research aims to compile and analyze the best practices and key lessons that can aid in the planning and implementation of demolition, deconstruction and design for deconstruction projects.

- Site visits, survey and contractor interviews

A limited number of site visits and interviews will be carried out in order to understand the practices prevalent in the demolition and deconstruction industry in Michigan. These site visits and interviews will help compile and analyze the factors affecting the whole project planning and implementation.

2. Understand cost associated with various approaches and possible quantification process for demolition and deconstruction.

- Analyze cost databases:

A limited amount of data is available for quantification of costs related to demolition and specially deconstruction projects. The aim is to study available cost databases to be able to understand major cost factors associated with various approaches.

- Literature review:

A limited amount of literature is available regarding the cost of implementation of demolition and deconstruction projects. Few case studies are also available discussing the major cost factors in demolition and deconstruction projects. The aim is to compile and analyze the available literature and case studies to understand the quantification of such projects.

- Site visits, survey and contractor interviews:

Based on the site visits, surveys and contractor interviews carried out in the first objective, major cost factors in these projects will be identified.

3. Develop a comparison matrix for demolition and deconstruction.

- Self-analysis and observation:

Based on objective one and two, a comparison matrix will be developed for demolition and deconstruction. This will be a self-analysis work that will be based on the achieved objectives mentioned above.

4. Identify approaches suitable for removal of abandoned properties in Michigan.

- Site visits, survey and contractor interviews:

Based on the site visits, surveys and contractor interviews carried out in the first objective, most suitable approaches will be identified for Michigan.

- Self-analysis and observation:

Achieving the first, second and third objectives mentioned above will help in an understanding of demolition and deconstruction projects in Michigan. Based on self-analysis best practices will be identified.

1.6. PROJECTED OUTPUTS

This research will provide information regarding technical, management and cost issues related to demolition and deconstruction projects. It will include modern practices, various approaches, factors affecting decisions, equipment and resources needed, recycling and reuse of materials, regulatory requirements, costs, etc.

The research will provide a reference for contractors and owners who hire demolition and deconstruction contractors for projects. The comparative study approach will provide information on associated costs for various approaches to select for different projects.

The following outputs are expected to be achieved from this paper:

- Various approaches in building demolition and deconstruction
- Major cost factors associated with various approaches
- Suitable approaches for removal of abandoned properties in Michigan.

1.7. SUMMARY

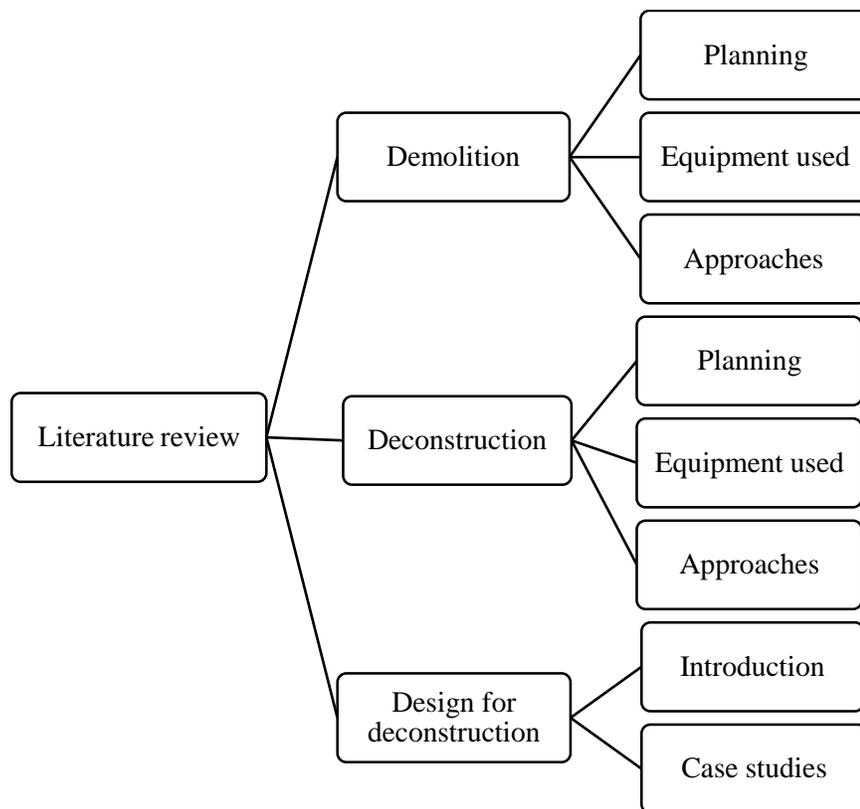
This chapter provides an overview of the need for studying building demolition and deconstruction and associated costs, the goals and objectives, the scope, methodology and projected outputs of this study. It is established that demolition and deconstruction are important parts of the construction industry and are projected to grow. Finally, though not all buildings are suitable, incorporating design for deconstruction in new construction is a very sustainable since it offers great potential for material reuse and to a good extent, closing the loop of mining and use of new resources. The following chapter will provide a literature review of demolition, deconstruction and design for deconstruction.

CHAPTER 2

2.0. LITERATURE REVIEW

2.1. CHAPTER OVERVIEW

This chapter provides an overview of the literature reviewed for the research. The literature review is based on three broad topics of demolition, deconstruction and design for deconstruction. Demolition and deconstruction are reviewed for planning, equipment and approaches used for each. An introduction of design for deconstruction with case studies are provided. The following chart provides an overall understanding of the structure of this chapter.



2.2. DEMOLITION

Typically, when a building or structure needs to be removed from a site after reaching the end of its useful life, it is knocked down with the help of heavy equipment or manual tools and rendered into rubble and debris. In some cases some of the material is recycled like concrete and steel buildings and the rest of the material is hauled to landfills.

"Demolition is an engineered project to reduce a building, structure, paved surface, or utility infrastructure through manual and/or mechanized means, with or without the assistance of explosive materials to piles of mixed rubble and debris. Demolition usually provides the quickest method of removing a facility and segregates the debris or rubble into various components for recycling where practicable" (Diven & Shaurette, 2010).

2.2.1 Planning demolition projects

Many factors are considered in planning demolition projects. Major factors are the construction type, safety issues, cost, site access, protection of adjacent structures, unforeseen conditions, scheduling, sequence of work, and the disposal, recycling, reuse of material. A variety of regulations and standards apply to the demolition industry such as safety, environmental requirements for site, environmental requirements for hazardous material, and community specific regulations amongst other.

It is very important to pay attention to initial preparation and planning of a demolition project. Some of the common planning practices for demolition projects are discussed in the following sections.

2.2.2. Analyzing the project

Before a demolition project is planned and executed, many factors are considered in determining the methods used. Some the factors, which are discussed subsequently in details, are as follows (Diven & Taylor, 2006; Diven & Shaurette, 2010; BDHK, 2004):

- Site survey
- Regulations and standards
- Safety requirements
- Job site security
- Environmental regulations
- Hazardous material
- Local authorities regulations
- Utilities and permits
- Debris and waste handling

2.2.2.1 Site survey

The first step in a potential demolition project is a site visit to examine the building. This consists of surveying the building to evaluate the basic material types and the overall condition of the structure. Based on the findings of these surveys, a demolition plan shall then be prepared.

It is important that during survey, the existing record plan, including layout plan showing adjoining properties, pedestrian walkway, roads and street, etc. also be recorded and considered.

The Building Survey shall cover the following (Diven & Shaurette, 2010; BDHK, 2004):

- The materials and methods of construction
- Original structural system
- The existing use and, if possible, the past uses of the building prior to demolition;
- The presence of hazardous materials.
- Adjoining properties and site conditions
- Utilities
- Shared facilities with adjoining building
- Adjoining pedestrian and vehicular traffic conditions;
- The sensitivity of neighborhood with respect to noise, dust, vibration and traffic impact

2.2.2.2. Regulations and standards

A variety of regulations and standards apply to demolition projects. These regulations are generally provided to prevent contamination of the environment and to provide a safe and healthy working environment. These regulations and standards contain federal, state and local standards that are important in deciding the means and methods to execute a demolition project. Regulations commonly associated with demolition projects can be classified in the following categories (Diven & Taylor, 2006):

- Safety
- Environmental-site requirements

- Environmental- hazardous materials requirements
- Community specific regulation

2.2.2.3. Safety requirements

Site safety features shall emphasize protection of the public, particularly, the pedestrian and vehicular traffic and the adjacent properties. Proper safety features shall be designed to make sure that the demolition can be carried out safely and the site personnel is protected. The Contractor shall carry out the demolition works including precautionary measures in accordance with the approved plans and other related documents, and provide continuous supervision to the works.

All mandated federal and local regulations should be identified. The OSHA regulations apply to both construction and demolition projects. Demolition specific standards are set forth in CFR 1926, Sub-part T of OSHA regulations. Some states have additional safety regulations such as the MIOSHA regulations in Michigan, which should be strictly followed by the demolition contractors (Diven & Taylor, 2006).

Some of the regulations particularly important for demolition projects are as follows (HUD-NAHB, 2000; Diven & Shaurette, 2010):

- Integrating safety into the job
- Worker training
- Engineering survey for structures to be demolished
- Hazard communication standard compliance
- Medical services

- Fire protection and prevention
- Site conditions and accessibility
- Public protection
- Personal protective equipment
- Fall prevention and protection
- Equipment safety
- Safe handling of Asbestos, PCBs and lead
- Safe use of cutting torches and arc welding
- Safe use of hand tools
- Safe blasting and explosive handling procedures
- Confined space safety practices
- Safe practice when demolishing stacks

2.2.2.4. Jobsite security

Security measures should be put in place to create a safe and secure demolition jobsite. These measures are important not only to keep the workers safe but also the public from potential dangers. There are a number of issues to be considered such as illegal entry to the site, vandalism and theft. The measures may include fencing, signage, pedestrian walkways, scaffolding, screen covers, enclosures, temporary lighting, etc. (Diven & Taylor, 2006; BDHK, 2004).

2.2.2.5. Environmental regulations

The general requirements to minimize environmental impacts from construction sites can also be applied to demolition processes. Some of the regulations are as follows:

2.2.2.5.1. Water

“The National Pollution Discharge Elimination System (NPDES) administered by EPA requires that the owner of a demolition site over one acre obtain a permit and devise and implement a plan to prevent pollutants conveyed by rainwater or snow melt from leaving the site” (Diven & Shaurette, 2010).

2.2.2.5.2. Air pollution

Concrete breaking, handling of debris and hauling process are main sources of dust from building demolition. Dust mitigation measures complying with the National Emission Standards for Hazardous Air Pollutants (NESHAP) Regulations shall be adopted to minimize dust emissions. Burning of waste shall not be allowed. Diesel fumes generated by mechanical plant or equipment shall be subject to the control of the Air Pollution Control Regulations.

2.2.2.5.3. Noise

Noise pollution arise from the demolition works including, but not limited to, the use of specified powered mechanical equipment such as pneumatic breakers, excavators and generators, etc., scaffolding, erection of temporary works, loading and transportation of debris, etc. The noise can affect the workers, and the receivers in the vicinity of the demolition site. Silent type machines and tools shall be used to reduce noise impact as much as practicable. Demolition activity shall not be performed within the restricted hours as established by EPA or municipalities. OSHA establishes some regulations regarding noise in the workplace (EPA, 2006).

2.2.2.6. Hazardous material

If hazardous materials, such as asbestos containing materials, petroleum contamination and radioactive contamination, exist in the building, further investigation and removal of such hazardous material or contamination by specialists shall be provided. Many large contractors are qualified to perform hazardous materials removal work with their own forces, whereas others may use companies that specialize in handling hazardous material (BDHK, 2004).

Other materials such as LPG cylinders in domestic flats, toxic and corrosive chemicals for industrial undertakings, and any other hazardous materials have to be identified and properly handled and removed prior to the commencement of the demolition of the building.

OSHA has established extensive standards and regulations that must be followed during the handling of hazardous materials. Some other regulations by states and other federal agencies are also enacted to add to the requirements for handling hazardous material.

The removal process for hazardous materials requires careful planning process before commencing the demolition work. These processes may include survey, notifications and permits, trainings, personal protection equipment.

The following list includes some of the hazardous materials that may be found on a demolition project taken from (EPA, 2004; Diven & Shaurette, 2010):

- Asbestos Containing Materials (ACM): friable ACM and Non-friable ACM
- Polychlorinated Biphenyls (PCBs): require special removal, transportation, and disposal
- Lead-Based Paints (LBPs) not all LBP is identified as hazardous, but testing is usually required before using a landfill for disposal

- Mercury: mostly from instrumentation, it is one of the most dangerous elements of humans
- Biological Hazards: bird and animal droppings, etc.
- Chemicals: from industrial to household, not all chemicals are identified hazardous
- Petroleum Oils Lubricants (POLs): most POLs are not hazardous however removal and disposal is regulated
- Radiological Hazards: in some instrumentation and emergency lighting
- Dust: fugitive dust is usually non-hazardous, but may cause respiratory problems and contain fine particles of silica
- Fluorocarbons: refrigerants, these require special removal techniques, and some types may be recycled
- Mold: only some types of mold are hazardous
- Creosote: railroad ties and pilings

According to the regulations of (NESHAPS), the removal of hazardous material such as ACM requires notification to EPA or its designated state agency of intent to remove ACM. Various states have notice and permit requirements prior to beginning demolition activities (EPA, 2004; Diven & Shaurette, 2010). The contractor must be aware of all the regulations and fees because it can affect overall cost of the project tremendously.

2.2.2.7. Local authorities regulations

Many states may implement regulations and standards that are more stringent than the federal regulations in construction and demolition projects. All these requirements must be considered while planning the demolition project. Some of the local regulations may apply to the following points (Diven & Taylor, 2006; Diven & Shaurette, 2010):

- Permit requirements for specific building type
- Restrictions on use of certain methods like use of explosives
- Restrictions on work hours
- Permits to use municipal utilities like water lines and hydrants
- Haul restrictions
- Traffic regulations

2.2.2.8. Utilities and permits

The demolition plan shall ensure that during the course of demolition, no existing utilities in the vicinity of the demolition sites are affected by the demolition operation. All utility companies and relevant agencies shall be consulted prior to demolition of the structure.

Some of the common utilities that need to be disconnected from the structure include the following:

Electricity, Water, Gas, Telecommunication, Drainage, Overhead and Underground Cables, Railway Tunnel and its accessories, such as vent shafts, Sewage Tunnel and its accessories and Disused Tunnel. Some temporary utilities are required to provide a safe and healthy work

environment (BDHK, 2004). Thus, it is necessary to acquire all the permits for demolition and utility disconnection before any work can start on site.

2.2.2.9. Debris and waste handling

One of the major tasks and costs involved in demolition projects are sorting, recycling, hauling and disposing of the demolition waste. Better site management and practice could facilitate and allow on site sorting, and separation at source of demolition waste. It is better if the sequence of demolition is planned to allow the separation and sorting of building materials.

Before the 1990s, most of the demolition debris was not sorted out and hauled and disposed to landfills. As the public became aware of the environmental problems of disposing off waste to landfills with diminishing capacity, recycling became more important (EPA, 2004).

The method of 'selective demolition' is highly encouraged for recycling purposes. It involves demolition and removal of wastes of the same category one at a time. The goal is to facilitate recycling of wastes for beneficial reuse, thus minimizing the burden on municipal landfills and public filling areas. In general, domestic wastes such as furniture, household appliances, etc., metal components such as window frames, pipes, etc., timber components such as doors, wooden floors, etc., other wastes such as tiles, asphaltic materials, ceramic products should be removed first. Most of these materials may be recycled. The building demolition shall begin after all the above non-structural materials have been stripped and removed (Diven & Shaurette, 2010).

The debris disposal and management system should clearly lay down the following details (BDHK, 2004):

- method of handling demolished building debris

- the routing and movement of debris from each floor to on grade holding area prior to leaving the site
- means of transportation of debris off site
- time and frequency of debris disposal off site
- record scheme on the tonnage of each truck load, truck license plate, driver's name, trip tickets and location of dump site

Most demolition projects specify that the contractor will be responsible for the legal disposal of all materials removed from the building. Particular client requirements, however, may be included in the bid documents (e.g., required crushing of concrete rubble for use on the site). Since recycling demolition materials has become an important part of nearly all demolition work, the demolition planning process should identify both local recycling requirements and the wishes of the client. Recycling can either increase or reduce demolition cost, depending on the circumstances of the job and the market value of the products to be recycled.

2.2.2.9.1. Chutes

Debris waste and other materials shall not be thrown, tipped or shot down from a height where they are liable to cause injury to any person on or near the site. Existing lift shaft, light well and openings on floor may be used to convey debris down the building floors. Areas adjacent to the openings of these features used as a chute shall be barricaded when they are not in use. Warning signs shall be posted to prevent workers from entering the area. As an option, plastic chutes may be used inside the floor openings and lift wells to minimize noise and confine the falling debris (BDHK, 2004).

2.2.2.9.2 Dust

To prevent dust generation during the debris hauling, water spraying is applied during the hauling process. However, the Contractor shall ensure proper control of water supply and floor drainage system in order to avoid flooding which is a nuisance and may cause overloading of floors (BDHK, 2004).

2.2.3. Demolition equipment and tools

Many different equipment and attachments have been developed by manufacturers for demolition work. Some heavy equipment used in demolition projects are as follows: excavators, impact hammers, cranes with wrecking balls, loaders with grapple bucket, concrete crackers, crawler crusher, vacuum track, floor scraper, etc. There are also small hand tools and robotic demolition tools and equipment that are mostly used for selective demolition work. Some of these equipment are describe in the following sections.

2.2.3.1. Excavators

Excavators with different sizes, reach distances and various specialty attachments have been developed for demolition work. The most common type used are crawler excavators equipped with grapple or bucket and thumb and are shown in the figures below (Brook, 2000; Diven & Shaurette, 2010).



Figure 2.1. Crawler Excavator with hydraulic hammer attachment

(Source:http://www.centralpoolsandspas.com/cms/images/stories/concrete_removal.jpg>)



Figure 2.2. Excavator with grapple attachment

(Source: <http://excavatorgrapples.com/exgr/wp-content/uploads/2012/10/HDG-Grapple-8-300x199.jpg>)



Figure 2.3. Excavator with concrete pulverizer attachment.

(Source: http://img.directindustry.com/images_di/photo-g/excavator-concrete-pulverizers-61578-4745351.jpg)



Figure 2.4. Excavator with pulverizer attachment.

(Source: http://img.directindustry.com/images_di/photo-g/excavator-concrete-pulverizers-56763-3880565.jpg)

2.2.3.2. Specialized robotic demolition equipment

Many small machines which resemble mini-excavators, can be operated by remote controls have been developed for specialized work. They can be fitted with grapples, shears, concrete crackers, hydraulic hammers, impact hammers, etc. (Brook, 2000; Diven & Shaurette, 2010).

These machines can be used in places where large equipment can't reach, demolition of floors where load restrictions can't allow heavy equipment or places which are not safe for laborers to work in. Figures 2.5 and 2.6 below show robotic demolition equipment.



Figure 2.5. Robotic concrete splitter being controlled by a joystick. A lot of different attachments can be used with these machines

(Source: http://i.ytimg.com/vi/jlaOUMqoe_8/0.jpg)



Figure 2.6. Robotic concrete cracker being controlled by a joystick.

(Source: http://www.brokk.com/img/informu1/3Akershus_in_Oslo.jpg)



Figure 7. Wheel loader loading debris.

(Source: http://www.recyclingproductnews.com/files/slides/lo_cale_image/listing/0012/2860_00000_rmt_intermercato_grapple_scale_mj2013p_junew_.jpg)



(Figure 8. Crawler excavator loading debris into trucks used for hauling away the material to landfill
Source: <http://utilitycontractoronline.com/pix/blog/11-25-13/Bobcat.JPG>)

2.2.3.3. Hand tools and specialized equipment

There are various types of tools and specialized equipment used for selective demolition work and places where the demolition work has to be done by hands and not heavy equipment. Figure 2.9 below shows a Jack hammer used for cracking concrete and figure 2.10 shows a cutting torch that is used for cutting steel.



Figure 2.9. Jack hammer used for cracking concrete and paved surfaces.

(Source:<http://us.123rf.com/450wm/americanspirit/americanspirit1307/americanspirit130704261/20801667-hispanic-male-breaking-concrete-with-yellow-jackhammer.jpg>)



Figure 2.10. Steel cutting torches are used for selective demolition of steel structures

(Source:<http://graphics8.nytimes.com/images/2011/01/11/blogs/11CRDeutsche2/11CRDeutsche2-blog480.jpg>)

2.2.4. Approaches to demolition projects

Building demolition is achieved by a variety of means and methods, using many kinds of equipment and tools. Demolition experts can recommend which methods are appropriate for particular projects. For simplicity, demolition methods can be grouped under the categories of mechanical demolition, Explosive demolition, and Selective demolition (Diven & Shaurette, 2010; BDHK, 2004).

2.2.4.1. Mechanical demolition

A large variety of specialized demolition equipment has been developed and most demolition projects rely on heavy equipment to get the projects done. Though wrecking ball and cranes have been used for large, high-rise demolition projects for a long time, a lot of high pressure hydraulics tools with attachments such as shears, breakers, concrete pulverizers, and others tools have been developed and are being used widely in demolition projects.

Some machines can operate in confined work areas and can separate the building materials as they “chew” the building apart. This method is described as progressive wrecking. The work can be done from a safe distance by machines such as excavators and front-loaders also.

Progressive wrecking of structures and buildings can be accomplished using one or a combination of the three methods described below (Diven & Shaurette, 2010):

1. Machines with high reach booms: this is a safe method that can be implemented in areas of restricted access. Buildings and structures up to a height of 120 feet can be demolished using this method. Large excavators are fitted with third member booms to allow safe work at heights. Some attachments such as shears, grapples and concrete crackers are used.

Figure 2.11 shows a high reach excavator used for demolition.



Figure 2.11. High Reach Excavator with a boom reach of 21-32 meters.

(Source:http://r3.forconstructionpros.com/files/cygnus/image/FCP/2012/OCT/640x360/volvo-ec380dhr-excavator_10819128.jpg)

2. Cranes and wrecking balls: for buildings and structures of up to twelve story or less can be demolished using cranes and wrecking balls. The work is performed from a safe distance with swinging the wrecking ball by cranes. The wrecking balls are made of cast steel and weigh around 1500 to 10000 pounds.
3. Floor by floor: for buildings that are more than twelve stories and buildings and structures that don't have sufficient operation room, small excavators and skid steer loaders and can be used to demolish the building one floor at a time. The loaders and mini excavators demolish the concrete and masonry, and torches are used for cutting the steel (Brook, 2000; Diven & Shaurette, 2010).

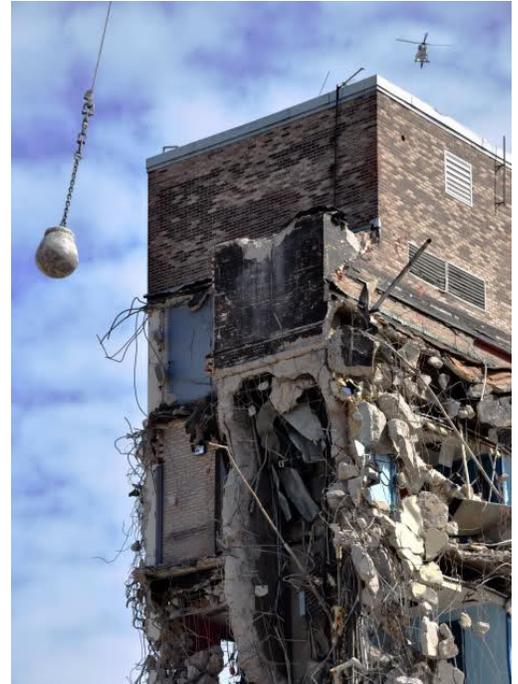
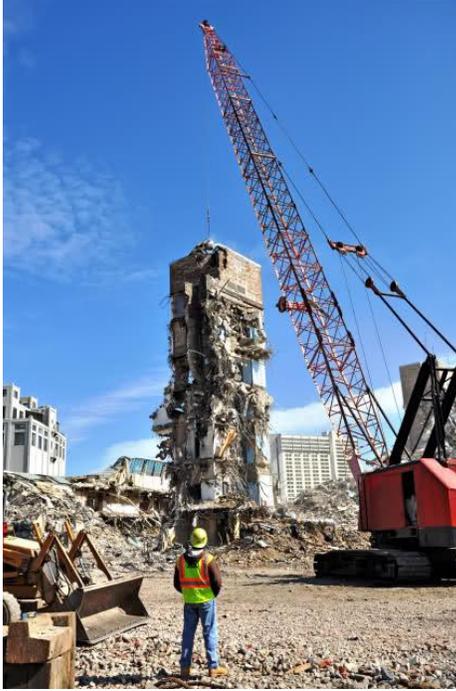


Figure 2.12-2.13. Crawler crane with wrecking ball, knocking down a structure from a safe distance.
(Source: <http://upload.wikimedia.org/wikipedia/commons/5/59/Abrissbirne.jpg>)

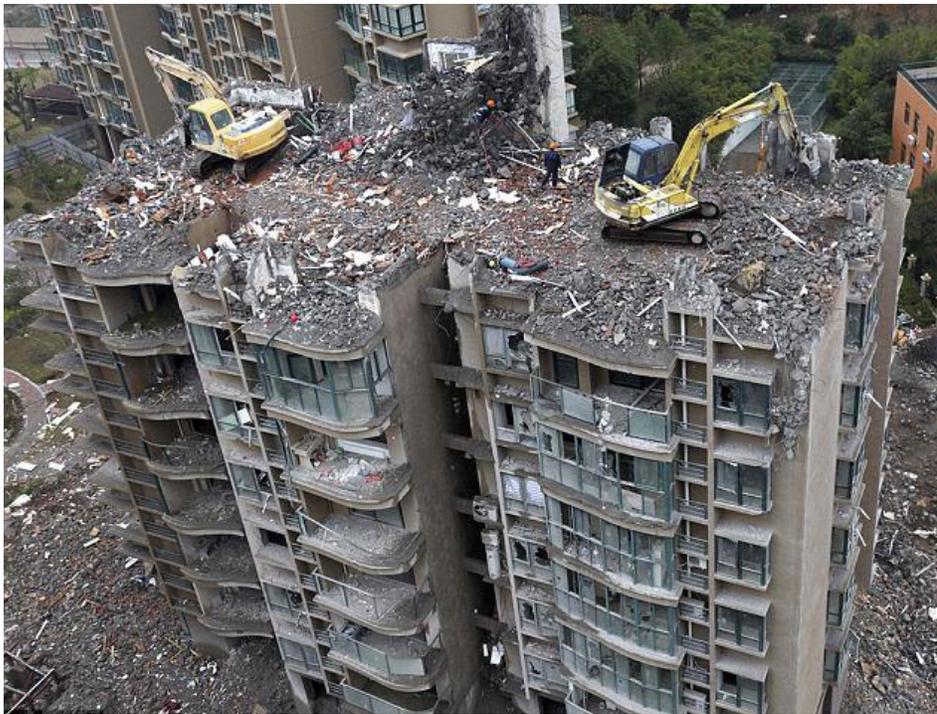


Figure 2.14. Excavators demolishing building floor by floor

(Source: http://cdn.theatlantic.com/static/infocus/china112012/s_c46_RTR2UY5Y.jpg)

2.2.4.2 Tripping and pulling the structures

Large buildings and structures can be demolished by tripping or pulling. It is important to insure that there is sufficient space for the structure to fall on without impacting any neighboring buildings or underground structures.

Tripping buildings and structures is done by weakening the structure columns and shear walls strategically. Next a crane is used with a wrecking ball to bring down the weakened building (Diven & Shaurette, 2010).

Unlike tipping, pulling a building or structure is done by attaching heavy-duty cables to columns at high points in the structure and; the lower floor columns and shear walls are weakened strategically. Heavy machinery is then used to pull the cables and bring down the structure in the desired direction (Diven & Shaurette, 2010). Figure 2.15 below shows an excavator pulling down walls.



Figure 2.15. Crawler excavator pulling down walls.

(Source: http://www.3rdemolition.com/casestudy_images/warehouse3.jpg)

Foundations and below grade structures: can be demolished using excavators and breaking concrete with hydraulic hammers. Excavators are used with buckets, thumbs and grapples to wreck the foundations and then remove the debris out (Brook, 2000). Figure 2.16 shows removal of foundation concrete by excavators. Figure 2.17 shows a robotic excavator that can be used for removal of floor concrete.



Figure 2.16. Excavators digging out foundation concrete. The wheel excavator is using the bucket to remove the material where the crawler excavator is using the concrete cracker attachment to break the concrete

(Source:http://www.heavyequipmentguide.ca/files/slides/locale_image/listing/0046/11481_00000_e05_doosan_dxb170h_hydraulic_breaker.jpg)



Figure 2.17. Robotic excavator breaking concrete in the basement floor.

(<http://www.aggregatetechnologies.com/wp-content/uploads/2012/12/Photo-Dec-17-5-35-04-PM.jpg>)

2.2.4.3. Selective demolition

Selective demolition uses combination of hand labor and small, specialized equipment and tools. It is defined as careful demolition procedure where parts of a structure or building is removed (Diven & Shaurette, 2010). Interior demolition and selective demolition are most often accomplished with small, skid-steer loaders and small excavators equipped with a variety of hydraulic attachments that include breakers for concrete, shears for cutting small steel, and material-handling buckets and forks. In the last twenty years, effective remote-controlled machines have been developed that can be used in hazardous environments, confined spaces, areas that have been damaged or are structurally weakened, and areas that are sensitive to noise or vibration. These machines are also being used in radioactive environments (Brook, 2000).



Figure 2.18. Robotic machine used for selective demolition of concrete flooring with a concrete cutter.

(Source: [http://www.nmldiamonddrilling.co.uk/uploads/Image/Robotic%20Demolition\(1\).jpg](http://www.nmldiamonddrilling.co.uk/uploads/Image/Robotic%20Demolition(1).jpg))



Figure 2.19. Removing flooring sheets by simple hand tools is an example of selective demolition

(Source: http://www.mccullough-construction.com/phpages/wp-content/uploads/2009/07/03_6003ExecBlvd.jpg)

2.2.4.4. Explosive demolition

Explosion or Implosion methods are very effective for bringing down high structures that would be difficult to reach with equipment or too expensive to demolish one floor at a time. These methods use highly specialized explosives to undermine the supports of a structure so it collapses either within its own footprint or in a predetermined path. The implosion process is especially suited for high-rise buildings (usually more than twelve stories) and a variety of special structures (e.g., cooling towers, nuclear reactor containments, space launch towers, smokestacks, boilers, steel mill furnaces, and so on) (Diven & Taylor, 2006).

In this method the explosives are used to weaken the structural support system of a structure that is columns and shear walls so the structure can no longer support the load of the structure and comes down. Common explosives—usually various forms of dynamite and ammonium nitrate—are frequently used to blast heavy concrete such as that in bridge piers and machinery foundations. Figure 2.20 shows a demolition project where explosives are used.

Implosion demolition is usually done by very specialized contractors and most of them work as subcontractors to conventional contractors performing demolition work.



Figure. 2.20. Controlled implosion of a high-rise building.

The building is collapsing within its foot print, thus ensuring the neighboring buildings are not affected.

(Source: <http://www.gulfdemolition.com/images/ex1.jpg>)

2.3. DECONSTRUCTION

Deconstruction is basically the opposite of construction where the building is disassembled into basic materials such as lumber, steel, windows, mechanical equipment, etc. while maintaining the integrity of the material as much as possible for reuse. Reuse is the more desired outcome compared to recycle as it provides low cost building material for the community and avoids debris going to landfills.

"Deconstruction is a process of building disassembly in order to recover the maximum amount of materials for their highest and best reuse. Re-use is the preferred outcome because it requires less energy, raw materials, and pollution than recycling does in order to continue the life of the material. As a consequence of deconstruction, there are also many opportunities for recycling other materials along the way." (Guy, et al., 2003)

Deconstruction is also known as Green demolition, un-building, building disassembly or reverse construction. Sometimes it is partly involved in the conventional demolition process, as an initial salvage phase by recycling and reuse of material. It can be as simple as stripping out utilities, appliances or cabinetry for reuse in another project, or it can involve taking apart the whole building frame.

2.3.1 Benefits of deconstruction

Deconstruction has economic, environmental and social benefits. The benefits of reuse and recycling of waste streams from building construction and demolition include diversion of waste materials from landfill sites and reduced depletion of natural resources. Both of these benefits contribute to sustainable development within building industry.

The social benefits include creating more jobs for unskilled labor who can be easily trained to perform deconstruction jobs. Additional benefits of deconstruction include the following (EPA, 2008):

- Reducing pollution, greenhouse gases emissions, and the need for landfilling
- Conserving energy and natural resources
- Creating job training and employment opportunities
- Providing materials for building construction and value adding manufacturing enterprise
- Lower building removing costs: because of the added value of material salvage and avoided disposal costs

2.3.2. Planning deconstruction projects

Deconstruction in almost all cases requires more time than demolition — during the planning phase as well as the building removal phase. The planning requires more time because the whole sequence of dismantling different material has to be planned carefully as to make sure smooth flow of work, safe environment, and structural integrity of building while laborers are working on removing nonstructural elements, insuring integrity of salvaged material for reuse, etc.

Some of the common planning practices used for deconstruction projects are discussed in the following sections.

2.3.3. Analyzing the project

Before a deconstruction project is executed, many factors are considered in determining the methods and sequence of work to be performed. The most important step is to survey the type of material and identify them for reuse, recycle and disposal. Some of the factors are as follows (Guy, et al. 2003; HUD-NAHB, 2000):

- Site survey
- Safety requirements
- Environmental regulations
- Historic preservation
- Permits and Utilities
- Organizational plan
- Site plan
- Site security
- Material management

2.3.3.1. Site survey

The first step in a deconstruction project is a site visit to examine the building. This consists of surveying the type and condition of material in the building or structure. All the material has to be identified for reuse, recycle and disposal to landfills. This called inventory of material. The condition of material in the structure and the manner they are secured to the structure can have

impact on the effectiveness of the salvage of material, especially for reuse as those material have to be in good condition after salvage for reuse in new construction. The structural design of the building or structure has to be completely understood and possible hazards need to be identified. Some structural elements of the building may need temporary bracing while the deconstruction work is being done till it reaches to the stage where the structural elements of the building can also be removed safely. Basically this survey can be used to identify the tools, techniques, approaches and schedule to be employed for this job (Guy, et al., 2003).

2.3.3.2. Safety requirements

The Safety Plan is an accident prevention plan. Safety is a daily activity, and should be incorporated through daily safety talks at the beginning of the workday. (OSHA)

Maintaining a safe workplace for the employees and the general public that may be impacted by the deconstruction project is an important aspect of a successful project. In general both public and private clients are more likely to seek contractors with good safety records for their project.

Elements of the Safety includes worker orientation and training, hazard identification and training, guidelines for the use of tools, personal protection equipment use, site conditions, accessibility, first aide, fire protection , procedures for correcting unsafe behavior etc. (Guy, et al., 2003; IWMB, 2001).

2.3.3.3. Environmental regulations

Proper management and removal of hazardous material is a highly regulated operation and it can have heavy impact on the successful execution of a deconstruction or project.

Environmental surveys for lead and asbestos must be completed for any building built before 1978. The US EPA, OSHA and HUD all have regulations for dealing with asbestos containing materials (ACM) and lead-based paint materials (LBP). Although the EPA NESHAPS regulations exempt demolitions from the removal of non-friable ACM, deconstruction and salvage necessitate the removal of ALL asbestos before work begins. The deconstruction costs and processes will be heavily influenced by the presence of ACM and LBP materials (Guy, et al., 2003; IWMB, 2001).

2.3.3.4. Historic preservation

Historic preservation or salvage is the careful removal of building components for their historic value. Some features as special brick and terra-cotta, carved stone, carved stonework, cast iron features, timber pieces, stained glass windows, etc. can be considered for salvage and reused later in other buildings or may end up in museums (Diven & Taylor, 2006).

Government regulatory departments like municipalities or historic preservation organization should be contacted to research any historic building or district designations and the local deconstruction permits processes associated with historic buildings.

2.3.3.5. Permits and utilities

Most local regulations require deconstruction permits or formal notification of intent to be obtained in order to remove a building. In general the procedure required for obtaining the permit for demolition are the same required for deconstruction permit (IWMB, 2001).

Disconnection of all utilities must take place before any work can begin on site like electricity, natural gas, water, wastewater, telephone and cable. Some temporary services may still be needed for safe and clean work environment like temporary electricity. The disconnection of the utilities is sometimes included in the demolition permit approval process.

2.3.3.6. Organizational plan

A key element of a successful deconstruction project is development of a detailed and comprehensive management plan. Planning comprehensively before execution of work can result in successful completion of the project. Issues such as site supervision, schedules, labor organization, tools and equipment, site safety and training are issues that has to be clearly defined in the planning stage. Competent people should be responsible for specific operations (HUD-NAHB, 2000; Guy, et al., 2003).

2.3.3.7. Site plan

The location of the site and the constraints of the building or structure in accordance to its foot print and neighboring buildings is a very sensitive issue to be determined while planning a deconstruction project. The location of all the operations happening on the site has to be identified

in a site plan after the site survey has been done. More importantly the management of material on site, there inventory, storage, hauling and removing them from site has to be issues paid attention to while considering a site plan for the operation. This site plan also have a huge impact on the issue of safety for workers and also general public and properties (Guy, et al., 2003).

2.3.3.8. Site security

Site security includes preventing the theft of equipment and tools, as well as the safety of anyone trespassing onto the site. A partially dismantled house can be a temptation to vandals. Before any work begins, the decision about whether salvaged materials will remain overnight will determine the needs for fencing, and lockable containers for storage or the time that it will take each day to remove materials from the site. Signage and warning tape should be used as due diligence to protect the public from the hazards of a deconstruction site (IWMB, 2001).

2.3.3.9. Material management plan

Efficient management of material is an important part of the project. Recovered materials have three places to go: Reuse, Recycle or Disposal. Efficiently managing the materials, allocation of responsibilities for managing the materials, and the methods for planning and communicating efficient materials “flow” on the site are very important for successful execution of project. The major parts are removing material from structure, cleaning, sorting, stacking, recycling, hauling and disposing material that can’t be reused or recycled. Deconstruction is creating materials for reuse in the most cost-effective manner so, removing materials without damaging them and keeping them in good condition when handling them will have to be insured. Increasing the amount

of salvage on site and reducing the amount of disposed material are important to increase income for contractors in deconstruction projects (Endicott, et al.; Guy, et al., 2003). Figures 2.21 and 2.22 below show different ways of creating stacks of material on site.



Figure 2.21. Sorting material by type results in efficient flow of operations on site. The pictures show different ways of creating stacks for material.

(Source: https://www.archsd.gov.hk/archsd/html/teachingkits/TK1/images/construction_waste_management_clip_image004.jpg)



Figure 2.22. Using containers for sorting material on site

(Source: <http://www.vivianmandaladesignstudio.com/wp-content/uploads/2014/02/Sorting-Construction-Waste2.jpg>)

2.3.4. Deconstruction equipment and tools

A wide variety of specialized demolition and deconstruction equipment have been developed. Mostly demolition projects rely on heavy equipment and machinery while deconstruction rely on smaller automatic and hand tools.

2.3.4.1. Deconstruction tools

Because in deconstruction most of the material has to be carefully salvaged for reuse and recycle, smaller hand tools and equipment are used for the projects. Some of the tools and equipment used for deconstruction are as follow, according to T. Reiff president of “The Reuse People” (as cited in Endicott, et al., 2005):

- Axe (small and large)
- Pick axe
- Cats paw
- Chain saw
- Crow bars
- Short and long (prefer “Gorilla Bar” type crow bar)
- De-nailing gun and air compressor
- Drill
- Cordless with batteries and battery charger Hammers
- Ladders: 6 and 8 foot, 20’ extension ladders (fiberglass preferred)

- Measuring tape
- Nails and screws
- Pliers Saws: bow saw, hand saw, hack saw rotary saw, Skil saw with grinder and wood cutting blades Sawz-alls with bi-metal blades
- Screw drivers regular and phillips head
- Shovels: regular and specialty Snow shovels Roofing shovels
- Sledgehammers (small and large)
- Post-hole digger
- Pry bars
- Rakes Tamping bar or “Grizzly Bar”
- Tin snips
- Vise grips
- Wheelbarrows
- Wire and bolt cutters
- Wrenches adjustable
- 20 C.Y. to 40 C.Y. roll-off
- Covered truck to remove salvage
- Debris chutes
- Man-lift, Hi-lift, Fork Lift

- Pneumatic or electric hammer with chisels
- Rolling scaffold
- Fall protection
- Safety equipment
- Respiratory protection safety suits and equipment

2.3.5. Reusable and recyclable material

Products of the deconstruction process fall into one of three broad categories: reused, recycled and disposed. In current practice, reused and recycled materials can typically make up about 85% of a building's total weight, according to T. Reiff president of "The Reuse People" (as cited in Endicott, et al., 2005).

2.3.5.1. Reuse

Instead of demolishing the whole building, this process tends to impact the least amount of change to the existing building components by carefully dismantling each constituent. Ideally the best situation in the end of the life cycle is the reuse of the whole building or the components in a new combination. This practice does not change the material form and thus uses the least energy and extra material when closing the loop of the component or building life cycle, according to Reiff (as cited in Endicott, et al., 2005). After the deconstruction of a building, some parts of the salvaged components and materials can be sold on-site, taken to the warehouse, or consigned to other

resellers and sold to the public. Other materials may either be shipped to low-income markets or donated to other nonprofit agencies.

According to “The Reuse People”, reused materials generally include, according to TRP presentation (as cited in Endicott, et al., 2005):

- Appliances
- Architectural Pieces
- Bricks
- Cabinets & Vanities
- Doors
- Electrical
- Flooring
- Granite & Marble
- HVAC
- Lumber
- Plumbing
- Plywood & Oriented Strand Board
- Roofing Tiles
- Structural Steel
- Windows



Figure 2.23. Doors removed carefully from structures for reuse.

(Source: The Reuse People (trp.org))



Figure 2.24. Windows removed carefully from structures for reuse.

(Source: The Reuse People (trp.org))

2.3.5.2. Recycle

This scenario is composed of three major processes. The first process group is deconstruction of end-of-life buildings followed by the second, separation of used materials. Finally, in the third process group, the used materials are reproduced and transformed to new products then reintroduced into the life cycle of buildings (EPA, 2004).

Presently structures and components are not designed to be reused or recycled since the components cannot be easily dismantled and separated once the building is demolished. Contingent on the contamination, a considerable part of the recycled materials is limited to low quality use or even landfilling (Endicott, et al., 2005). Figure 2.25 below shows the recycling of concrete.

Typical recycled materials include, according to (TRP, 2005):

- Aluminum
- Asphalt
- Asphalt Shingles
- Carpet Padding
- Cast Iron
- Concrete
- Concrete Block
- Copper



Figure 2.25. Concrete being recycled by crushing

(Source: <http://www.on-siterecycling.com/products/images/rm100-recycling-concrete.jpg>)

- Glass
- Scrap Steel
- Stucco (when untreated)
- Wood (when untreated)

2.3.5.3. Disposed

The material that has very little or no recycle value like material mentioned below.

Typical disposed materials include (TRP, 2005):

- Ceramic Tile (because of glue)
- Drywall (because of paint)
- Plaster
- Stucco (when treated)
- Wood (when treated)

2.3.6. Various material handling

Corresponding to the various materials and components used in construction are the different means, methods, tools, and techniques required to deconstruct the structures. The tools and techniques used, as well as some difficulties associated with deconstruction, for steel, masonry, concrete, and timber are described in this section.

2.3.6.1. Steel

There are a number of different processes for removing steel from existing structures for reuse or recycling. Crushers and pulverizers have been developed to remove reinforcing steel bars (rebar) from reinforced concrete structures. Heavy-duty magnets can be used to remove reinforcing steel during the process of crushing reinforced concrete.

Several opportunities for further development of tools and techniques exist in this area. For example, a tool with an automated ability to remove bolts from connections could increase the number of sections available for reuse instead of recycling. Currently, the ends of beams are usually distorted in the removal process requiring that these damaged ends be cut off. The National Federation of Demolition Contractors and the Institution of Demolition Engineers are two organizations that can assist the industry in further development of such tools and techniques (Endicott, et al., 2005).

2.3.6.2. Masonry

As is the case with all materials and structures, hand deconstruction results in the highest quality of reclaimed materials. By using this meticulous method, contractor profits are maximized from the sale of components to reclamation yards and recycling facilities (or the maximum tax benefits are realized for the homeowner who donates the components to a not-for-profit organization). This reality has been very evident in the case of masonry and brick.

In some cases, the contractor hand-cleans the bricks and in other cases the reclamation yards remove the mortar themselves. However, the increased use of ordinary Portland cement (OPC) in place of lime-based mortars has presented a problem for brick reuse. The lime-based mortars are much easier to separate from the brick. Therefore, there exists a “need to investigate practical and

cost-effective removal techniques for OPC mortars”. According to Hobbs (as cited in Endicott, et al., 2005). Figure 2.26 below shows bricks that have been salvaged and cleaned for reuse.



Figure 2.26. Bricks cleaned up after being removed from building and ready for reuse.

(Source: The Reuse People (trp.org))

2.3.6.3. Concrete

In most cases, concrete frames in concrete buildings are cast-in-place and cannot be deconstructed for reuse in their original form. Pre-cast concrete components such as beams, columns, stairs, and hollow-core floor slabs can be deconstructed provided the joints are simply supported. Unfortunately, most joints are cast-in-place and that concrete is stronger than the precast components it joins. New uniform jointing methods are being developed which hopefully will be designed for deconstruction (EPA, 2006).

According to Hobbs (as cited in Endicott, et al., 2005) pre-cast concrete flooring systems are commonly used in construction and are one of the simplest concrete components to deconstruct. However, in some cases they are covered with a 50 mm cast-in-place concrete layer in order to provide a monolithic slab, which prohibits deconstruction.

One tool that is commonly used in repair applications holds promise in deconstruction. High pressure water-jetting can cut concrete while leaving both the reinforcing steel and concrete clean and reusable. Heating methods such as thermal lances may be used increasingly in the future because they can cut through reinforced concrete while leaving the majority of the concrete element intact.

2.3.6.4. Timber

Most existing timber components contain nails and screws. These must be removed for safe handling before reuse or recycling. This is most often done by hand and generally is only economically warranted for high value items like large section beams and old growth timber.

Lower value components such as studs and small section joists must be free of nails and screws before they are chipped in recycling operations. Research and development is required in the area of timber reuse and recycling. Although large amounts of timber are demanded and required in a majority of residential construction projects, reclaimed lumber is not permitted for use in structural applications because of the nailed and screwed connections. Furthermore, re-coding the wood is expensive and not economically feasible at this point. The Scandinavians have developed one method to remedy this problem. They reclaim defect free timber for reuse or recycling by identifying ‘connector free zones’ within the timber cross section that can be easily removed using a rip saw, according to Hobbs (as cited in Endicott, et al., 2005).

2.3.7. Approaches to deconstruction projects

Three deconstruction models are currently being used across United States (DBRTF, 2014):

- Full deconstruction
- Hybrid deconstruction
- Partial deconstruction (“skim” model)

2.3.7.1. Full deconstruction

Is removing a structure entirely through manual deconstruction intervention. This practice usually takes anywhere from five to seven days or longer, depending on the size of the structure and costs approximately 50 percent more than mechanical demolition (DBRTF, 2014).

2.3.7.2. Hybrid

The hybrid method combines the presence of human beings on the site, along with an excavator. This variation of traditional deconstruction speeds up the work by using the excavator to carefully assist the manpower on the ground by gently pulling down walls, porches, roofs, staircases, and major elements. A crew of individuals can then get at these more easily, whether on site or for transport to a warehouse to be taken apart manually. This practice usually takes anywhere from one to three days, creates a lot of dust, and costs approximately 25 percent more than mechanical demolition (DBRTF, 2014).

2.3.7.3. Partial demolition

Sometimes referred to as the “skim” model, is a nuanced version of the full deconstruction model. A “skim” model of deconstruction delicately balances the input (labor cost) with the throughput (salvaged materials of value) over a much shorter period of time, one to three days versus five to seven days or longer for full deconstruction. Typical materials manually removed from the structure under a “skim” method of deconstruction are the higher-market resale items such as hardwood floors, trim molding, stained glass windows, doors, and door jams. In addition the estimated cost increase is only 10 to 12.5 percent more than mechanical demolition (DBRTF, 2014).

2.4. DESIGN FOR DECONSTRUCTION (DFD)

Deconstruction has emerged as an important practice for reducing the amount of demolition waste that goes to landfills by reusing and recycling construction material. Reuse being a more favorable outcome as it requires less resources for being used into a new construction thus causing less waste, but in most cases it is not easy to deconstruct buildings and structures because they were not build to be deconstructed. A new concept is being pioneered by construction professionals called Design for Deconstruction.

Design for Deconstruction or Design for Disassembly is a technique that considers the entire lifecycle of a building; design, manufacturing, construction, renovation, operation and eventually deconstruction. It creates a closed loop building management option where the building systems, components and materials are designed to be easily rearranged, dismantled, renovated, recovered and reused (EPA, 2006).

The traditional flow of resources in construction is a linear flow. The raw resources are mined from earth and are processed into construction material, using a lot of energy and resources needed for the process from mining to transportation to manufacturing and are simply disposed of as waste to landfills.

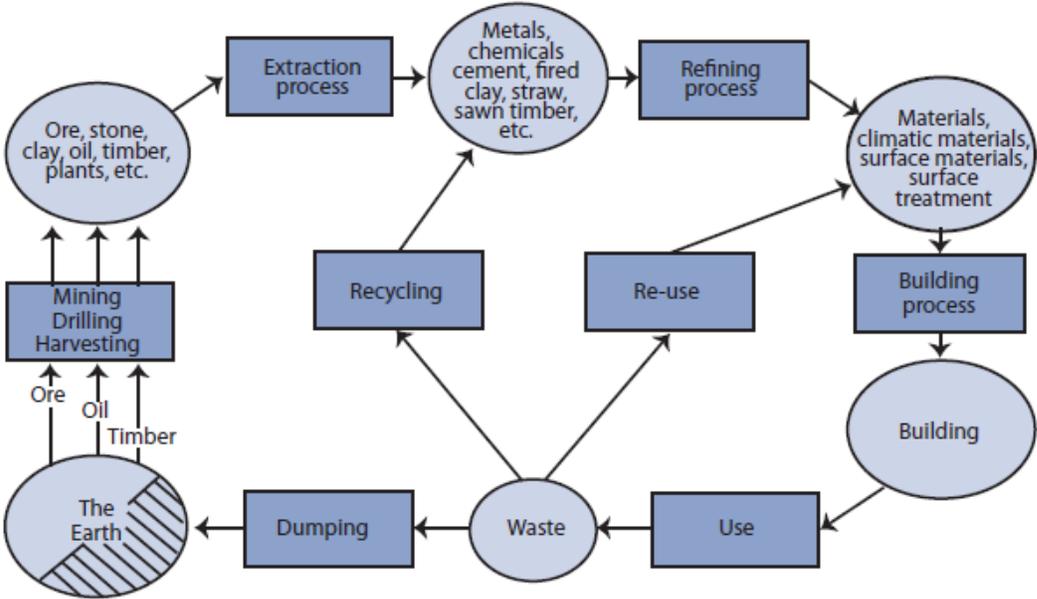


Figure. 2.28. Closing the loop in material life cycle (EPA, 2008).

The main benefit of Design for Deconstruction is to close the loop of resource use. This is done by reducing the environmental impact of waste generated by renovation and deconstruction of buildings because the material can economically recovered and reused, saving the material from going to landfills and at the same time avoiding logging or mining of new virgin resources from our ecosystem (Webster, et al., 2005; EPA, 2006).

Material salvaged from a deconstruction project is valued based on the function it can provide in being used for new construction when assembled and therefore material are more valuable to be reused than to be recycled. For example concrete can be recycled, but it can only be used as low value aggregate, wood debris can be ground up but only used for wood fiber or mulch and therefore loses its valuable properties to be used as construction material for new buildings. The challenge is that these materials were not put together to be recovered and reused and the goal of Design for Deconstruction is to figure out how to put buildings together so that they can be economically taken apart and reused in new construction (Webster, et al., 2005).

Efforts have always been made to create new construction systems that can encourage assembly of buildings with standardized parts and connections, mass production and modular design but they have not yet been able to come into the construction fields successfully. The Design for Deconstruction is aiming to work with the current construction systems rather than working on completely new construction systems (EPA, 2006).

Design for Deconstruction is not just concerned with the salvage of material at the end of the life-cycle of a building but by making building components easier and faster to remove and reassemble it meets the evolving functions of a building use over its lifetime. An important aspect of Design for Deconstruction is to provide structural system with flexibility to reconfigure spaces. The utilities and infrastructure of the buildings to be easily accessible for maintenance and upgrade.

According to (EPA, 2006) the principles of Design for Deconstruction are applied at three levels of buildings and structures: materials, assemblies and building systems. In addition, building information is an important aspect of Design for Deconstruction.

2.4.1. Materials

Caution should be applied while selecting construction material. The material being used should have the value to be recovered and reused in future. Hazardous material such as asbestos and lead based paints should be avoided as much as possible. If for reasons of performance they still have to be used, they should be tagged and identified properly so that they can be handled with caution at the end of their useful life (EPA, 2006).

Using fewer material types simplifies deconstruction. Composites should be avoided where possible. If the architectural aspects and performance allow, fewer material types with careful interface should be considered (Webster, et al., 2005; EPA, 2008).

Using less material to realize a design makes a building design less complicated, require less labor and reduce the waste of resource usage while construction and also requires less labor to deconstruct (EPA, 2006).

It is encouraged to reuse salvaged material from existing buildings as this will minimize waste, incorporate reused material and support the market for reuse of material.

2.4.2. Assemblies

Assemblies dictate how material come together to create fitted architectural blocks to complete structures. Less adhesive and sealants should be used where possible and be replaced by simple and stronger fittings and fasteners. Glues and chemicals damage materials and being removed, instead the use of bolts, screws and mechanical connections are favored (EPA, 2006).

Assemblies should be readily accessible and where possible exposed to allow maintenance and disassembly. It should be easy to repair assemblies when needed and other material should not be

degraded for maintenance. For example to replace a window, there shouldn't be a need to cut and patch drywall and stucco (DfD, 2006).

Modularity and prefabrication of assemblies and components can promote reconfiguration, reuse and recycle to a large extent. Fewer but larger components are favored. The assemblies should be modularized only when it makes it easier to construct and deconstruct (EPA, 2006).

2.4.3. Building systems

Building systems are mostly modified to accommodate each other such as infill, substructure, enclosure, mechanical, electrical, HVAC, etc. Disentangling all these systems from each other makes it easier to maintain individual systems and facilitate adaptation and deconstruction of each system (EPA, 2006).

Separating building systems and layers helps with flexibility and adaptability. Different utilities such as HVAC, plumbing, electricity, etc need to be separated from structural components and each other and should be readily accessible. Often in buildings, it is the utilities that require regular maintenance and replacing. This will not only help during the life time of the building but during the end of the lifecycle also, as it is much easy to recover and reuse if in good condition.

Separating or disentangling the utilities from the structure also is one of the main goals in Design for Deconstruction. For example if the utilities are disentangled from the interior walls of the building, the walls assemblies can be reconfigured as needed during the lifetime of the building to create a flow of usefulness.

2.4.4. Building Information

All the concepts of Design for Deconstruction implemented in building construction needs to be clearly recorded with drawings and photographs of the utilities before they are concealed behind walls and ceilings. This information should be maintained throughout the life time of the building. These documents can be used to reconfigure assemblies, components and spaces as needed during use and can also help with deconstruction at the end of the lifecycle of the building (EPA, 2006).

The concepts of Design for Deconstruction are in its conceptual stages in the United States. The architect and engineers don't build buildings with the consideration of the building to be taken down when its useful lifetime ends. The issues and concepts of Design for Deconstruction are addressed through education and research (DfD, 2006).

2.4.5. Case studies

In the following section, two case studies are provided that have implemented the concepts of Design for Deconstruction in an effort to make these practices more widely accepted in construction industry.

The first case study is a residential structure and the second case study is a school building. In both the projects the United States Environmental Protection Agency (USEPA) had partnered with others to implement these projects as pioneering projects of Design for Deconstruction.

2.4.5.1. Boulevard House

This is a residential Design for Deconstruction project that has been referenced from Lifecycle Construction Resource Guide (EPA, 2008). The project is a joint venture between the U.S Environmental Protection Agency (EPA), Community Housing Resource Center (CHRC) and Pennsylvania State University's Hamer Center (EPA, Lifecycle construction resource guide, 2008).

This project is an effort to introduce best practices of DfD in residential design. Reducing the Environmental impact of the project during construction phase, the flexibility of the design for remodeling spaces in future and the ability to deconstruction the building are highlights of this project presented in the following section. Figure 2.9 provides a description of the project.

	Project Type	Design for Deconstruction
	Location	71 Boulevard Atlanta, Georgia
	Building Type	Single Family Residential Home
	Size	2,166 ft ²
	Owner	The Community Housing Resource Center
	Completion Date	June 2006

Figure.29 Description of the project

Source: (EPA, 2008)

2.4.5.1.1. Repositioning Interior Walls

The interior walls of this home can be moved and relocated without creating any waste or compromising structural integrity of the structure. This is achieved by spanning the floors and ceiling from exterior wall to exterior wall and making the interior walls non-structural. The utilities have been disentangled from the interior walls so they are not a problem when moving the walls.

The flexibility of the plan is demonstrated in the figures 2.30 and 2.31 below.

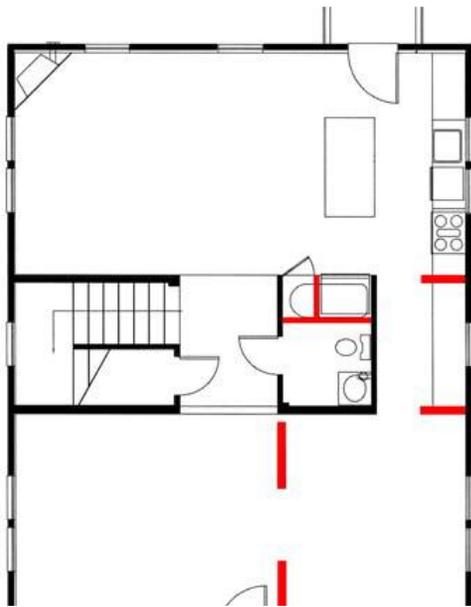


Figure 2.30. Current plan

Source: (Korber, et. all, 2006)

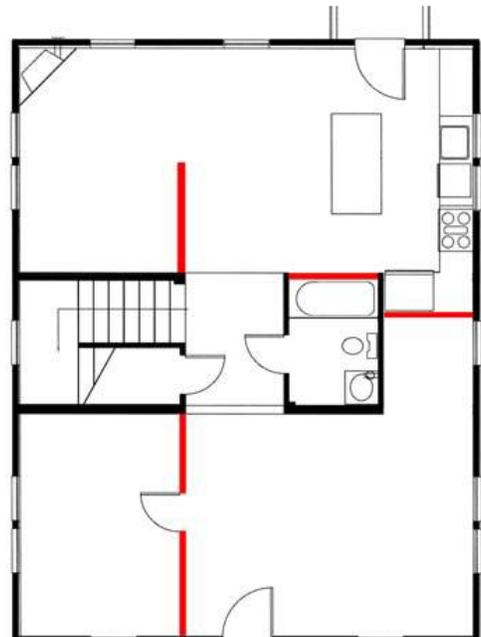


Figure 2.31. Potential future plan

Source: (Korber, et. all, 2006)

2.4.5.1.2. Disentangled heating and cooling systems

Instead of using one HVAC system for the whole house it was split into two parts, one for each floor. Two smaller air-conditioning pumps were used instead of one large pump. The unit for the first floor is located in the basement crawl space and the second floor unit is placed in the attic. This reduces the amount of duct work and the need for a core to run from basement to the top floor to provide the duct work. This also allows the interior walls to be moved and relocated without having to deal with reconfiguring the system (EPA, 2008).

2.4.5.1.3. Plumbing and electrical systems

The electrical and plumbing systems are bundled in a central location to avoid running them through all the interior walls. These duct works were also placed in the attic and crawl spaces to keep them untangled from the interior walls to be able to disassemble the interior walls without having to deal with the utilities (EPA, 2008).

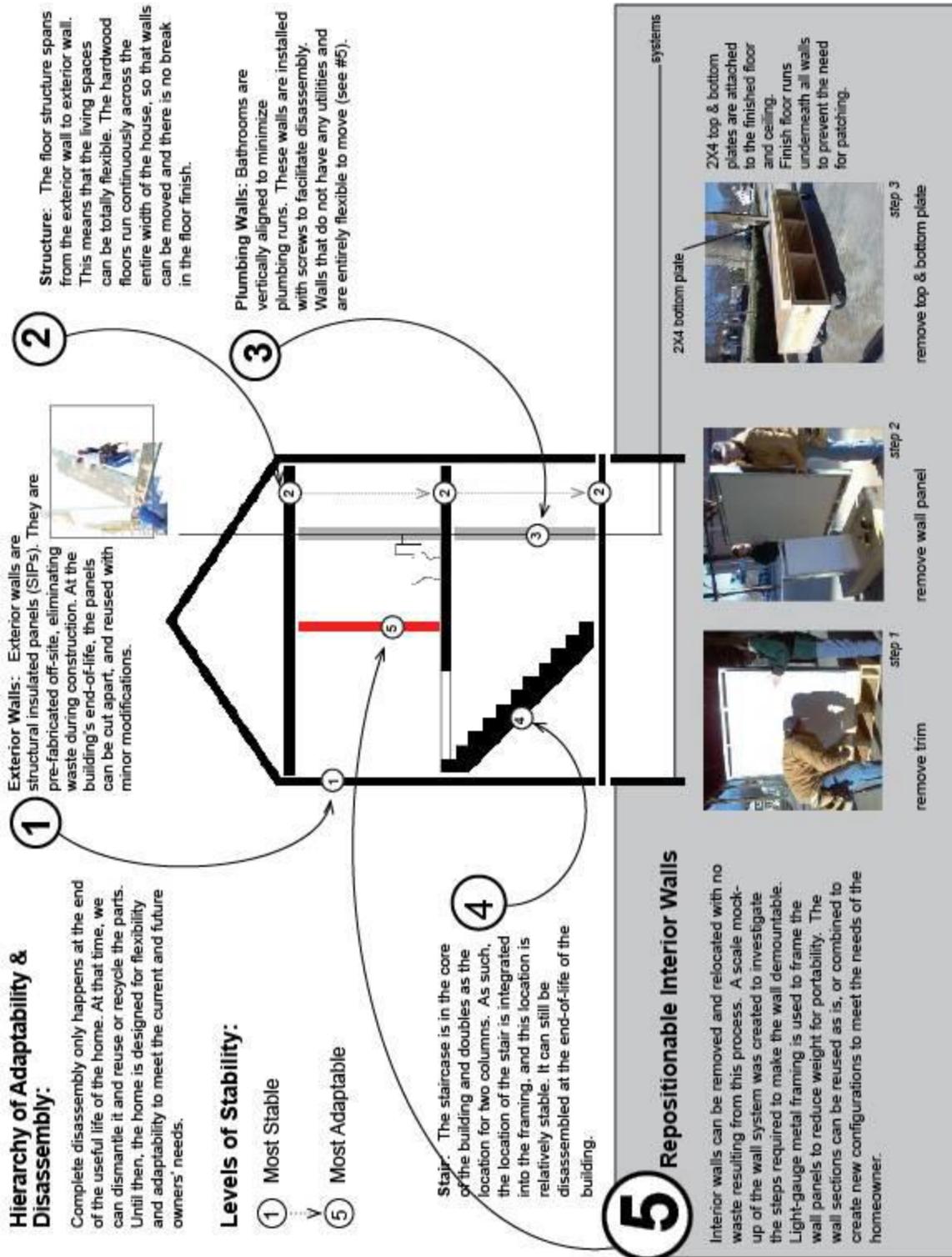
Figure 2.33. Photos showing Construction details of the movable walls. Screws are used instead of glue or nails to attach the parts. For ease of disassembly and deconstruction the screws are left revealed.

Source: (Korber, et. all, 2006)



Figure 2.34. Description of the Design for Deconstruction concepts implemented in the project.

Source: (Korber, et. all, 2006)



2.4.5.2. Chartwell School

Project Type	Design for Deconstruction
Location	25-acre site on the decommissioned Fort Ord military base in Seaside, California
Building Type	School
Size	12,955 ft ² classroom building 8,272 ft ² multipurpose building
Owner	Chartwell School
Completion Date	September 2006

Figure 2.35. Description of the project

Source: (EPA, 2008)

This project was partially funded by the United States Environmental Protection Agency's Office of Solid Waste and Emergency Response (OSWER) Resource Conservation Fund. The Chartwell School was designed to help promote practices to readily disassemble building components and material for reuse and replacement (EPA, 2008).

This school aims to be a development model in the region by implementing sustainable practices to minimize the environmental impacts of the project throughout its lifecycle and at the same provide a healthy environment for the occupants of the building. Certain unique approaches were explored in this project by professionals. Some of the highlights of the project are as following (EPA, 2008):

The school is designed for adaptability to accommodate changes in space organization, this is done by making all the interior walls non-structural partitions that can be removed without compromising the structural integrity of the building. The interior shear walls which are structural are over designed to accommodate any opening cuts for windows and doors if needed in the future. Figure 2.36 demonstrates the utility plan of the school.

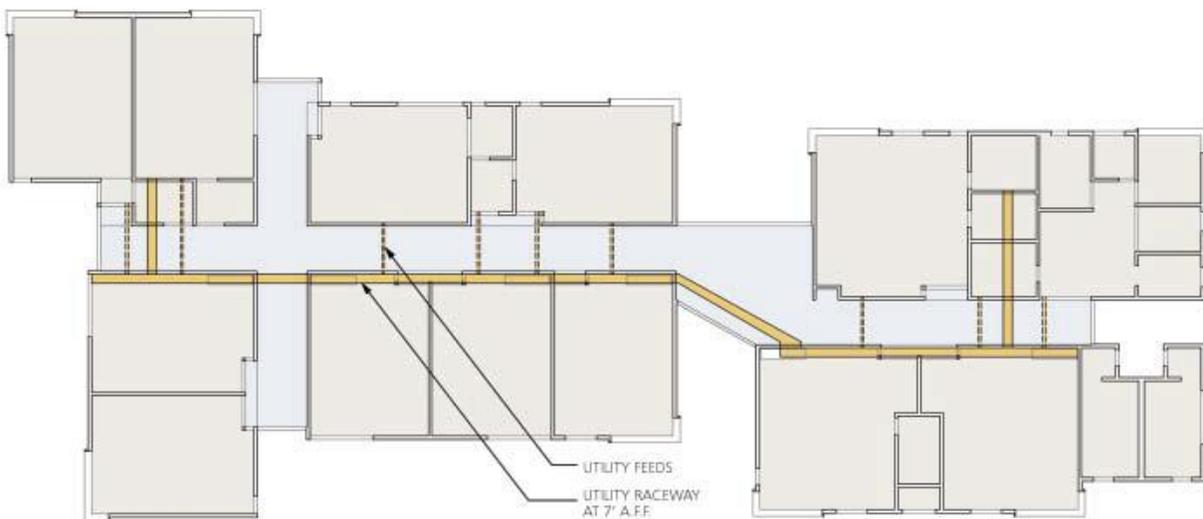


Figure 2.36. Plan of the School showing utility raceway

Source: (EPA, 2006)

2.4.5.2.1. Utilities

All the utilities in this building are exposed and placed in a raceway through the recessed shelf along the corridor. This approach disentangles the utilities from the structure so the interior walls can be disassembled and moved if needed without having to reconfigure the utilities. Maintenance and recovery of utilities when needed is made easier. The wooden frame of the structure does not

accommodate the utilities, which results in fewer holes in the wood framing which increases its value to be salvaged in the end of the lifecycle of the building.

2.4.5.2.2. *Modular framing*

The design of this school is a modular design, which allows for all the room sizes, doors, windows, interior partitions land on a module layout. This allows for ease in disassembly and remodeling. This building incorporates fewer high capacity fasteners for the structure which can be removed easily in the future. The structure is based on 24” on-center module instead of a 16” on-center wood frame, this approach saved up to 30 percent in lumber needs which decreased the labor also (EPA, 2008). Figures below show the conventional framing method and the modular framing.



Figure 2.37. Conventional 16” o-c framing requires 2618 bf lumber

Source: (EPA, 2006)



Figure 2.38. 24” o-c framing requires 1908 bf lumber

Source: (EPA, 2006)

2.4.5.2.3. Creativity with material and detailing

Some of the key principles followed in this project for Design for Deconstruction include: use of fewer but larger components that require less labor and ease the process of deconstruction, simplified connections by using fewer high capacity fasteners instead of nailing and use of chemicals, keeping details and utilities exposed for ease of understanding the structure and ease of deconstruction in the future (EPA, 2006).

For roof framing Structural Insulated Panels were selected in order to simplify connection and reduce labor and waste. A single SIP unit combines the roof sheathing, insulation and ceiling finish in one single component. They come in large unit sizes and are connected to the structure with large screws. These units can be easily removed in the future and used for another building (EPA, 2006). Figures below provide structural, roofing and window details used in the project.



Figure. 2.39. Roof trusses spanning from exterior wall to exterior walls. Source: (EPA, 2006)

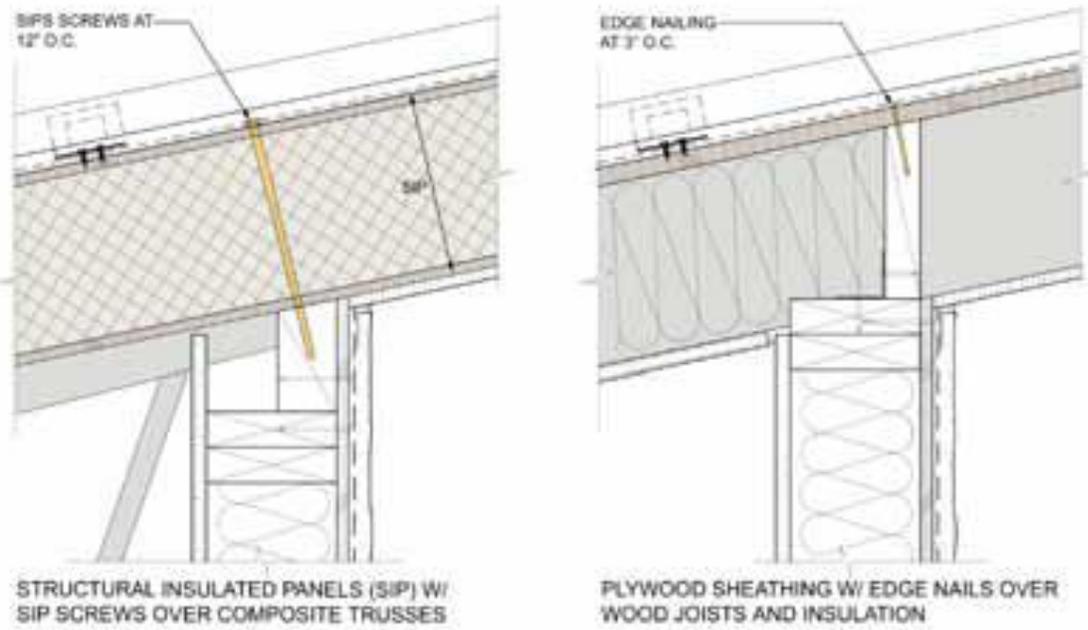


Figure 2.40. Structural Insulated Panels and Conventional roofing details. Source: (EPA, 2006)

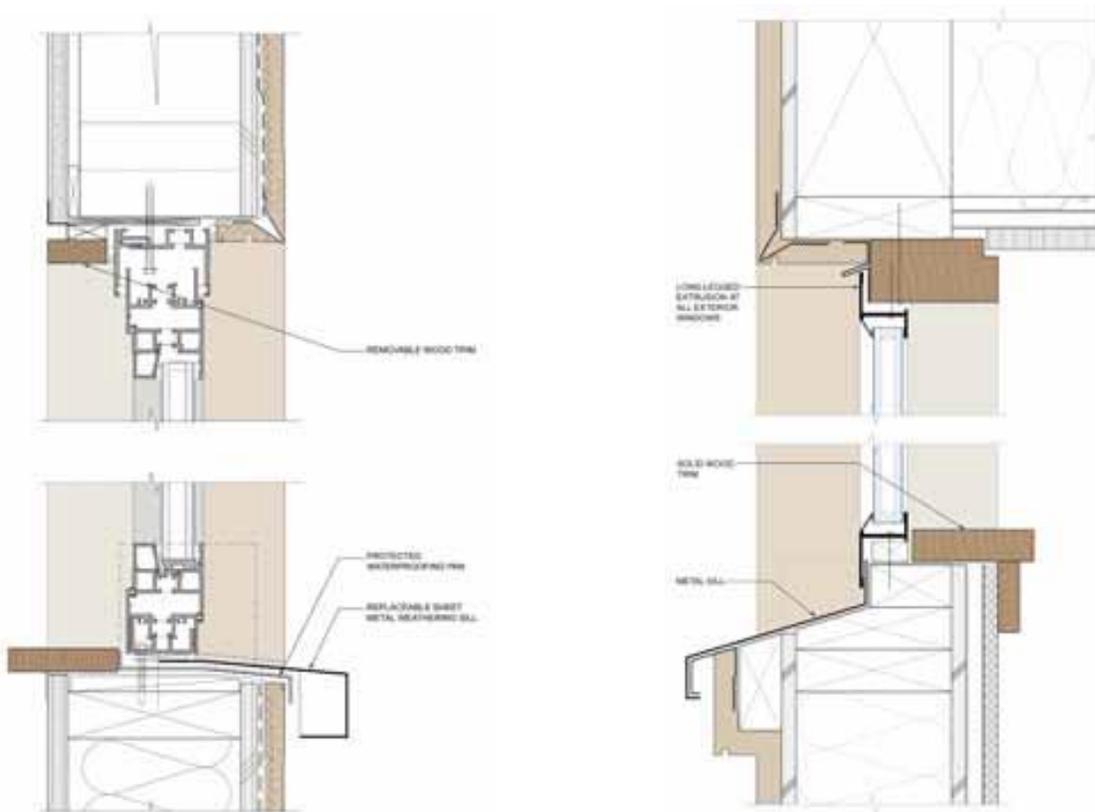


Figure 2.41. Removable window details. Source: (EPA, 2006)

2.4.5.2.4. Windows

Two alternate window details were developed to address the issues of providing the ability to remove the windows without touching the cladding and components around the window frame. This facilitates the removal of windows without damaging them for future use, or without damaging the cladding around the windows.

2.4.5.2.5. Exterior siding

Some of the wood used for exterior siding in this project is salvaged wood from other projects. The challenge was provide detailing for exterior paneling to be able to remove and salvage the wood at the end of lifecycle of this building and reuse it. Normally the siding would be nailed to the frame, but that creates holes in the wood and makes it difficult to remove the wood without damaging it. Screws could have been used but if they are painted over during the building lifetime and concealed, they become difficult to remove. And even the screws create holes in the wood and make it defective.

Many alternate details were provided for this project that included: use of tongue and groove method with the used of metal clips to hold the panels, use of channels for sliding the panels into the frame, use of very strong double stick tape. Some of these detailing are shown in figures 2.42 through 2.45 below.



Figure. 2.42. Siding attached with double stick tape.
Source: (EPA, 2006)



Figure. 2.43. Siding attached with C-channels.
Source: (EPA, 2006)

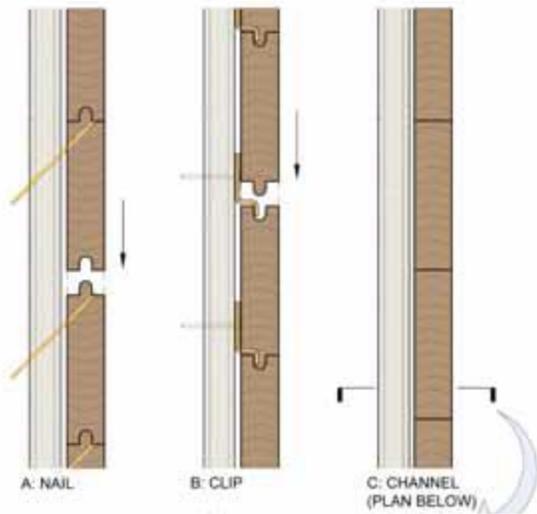


Figure. 2.44. Siding construction detail.
Source: (EPA, 2006)



Figure 2.45. Siding done with Tongue and Groove method with clips.
Source: (EPA, 2006)

2.4.5.2.6. Building information

One of the main objectives of Design for Deconstruction approach is to provide construction drawings, specifications and instructions for deconstruction of the building in the future. Many approaches were implemented in Chartwell School to provide and maintain this information (EPA, 2008):

- A final record of drawings with a hard cover were provided and included information for reproduction rather than removal of drawings from the bound.
- Some building components and materials were directly labeled in the building, for example the roof trusses are labelled for engineers to determine future use of the trusses.
- Most of the utilities and construction details were left exposed to make the need for drawings less critical.
- Permanent signage were provided with the contact information about architect and engineering design team for future reference when needed.

2.5. Summary

Demolition and deconstruction are rapidly growing parts of the construction industry. These are complex businesses and require technical and managerial skills combined with experience. Demolition using heavy equipment is the traditional process for building removal. Modern demolition equipment removes structures quickly, destroying the materials within and creating solid waste destined for landfills. Some recycling does occur during the demolition process, most typically concrete, brick, metal, asphalt pavement, and wood. However, landfill costs in many states are still low, enabling wasteful disposal practices.

Environmental impacts from demolition activities are sizeable, both upstream and downstream. Deconstruction can work to offset the environmental impacts of the building related waste. Deconstruction not only diverts wastes from landfills, it also reduces greenhouse gas emissions by reducing the need to extract and ship new materials and also gives rise to a new industry of skilled jobs. In order to transform the industry, demolition should incorporate successful aspects of deconstruction, and future construction should incorporate design for deconstruction for maximum use of material.

This chapter reviewed the planning and management aspects of demolition and deconstruction. Further, the various approaches used for demolition and deconstruction and equipment needed to carry out the projects are reviewed. It is important to mention that both demolition and deconstruction are complex businesses and various aspects of each can be studied separately in more detailed manner. The scope of this study briefly covered aspects such as modern practices, equipment, safety issues, regulations, material handling, etc.

The next chapter reviews the cost aspects of both demolition and deconstruction.

CHAPTER 3

3.0. COMPARISON OF DEMOLITION AND DECONSTRUCTION; COST AND PROCESS

3.1. INTRODUCTION

This chapter presents the approaches used in cost estimation of demolition and deconstruction projects. All the pre-estimation tasks that are necessary for gathering information and planning for the project are introduced with their impact on the cost. A breakdown of the major cost components of a demolition and deconstruction project are presented through case studies. Interviews with contractors are analyzed and a summary is presented. Finally, a comparison matrix of demolition and deconstruction is presented followed by a cost comparison of both approaches.

3.2. COST ESTIMATION OF DEMOLITION PROJECTS

It is important to figure out the net cost of demolition. According to (Guy, 2001) the net cost for demolition project is: $(\text{Demolition} + \text{Disposal}) - (\text{Salvage value})$. This section discusses various factors that impact cost estimation and items covered in a demolition estimate; and provides a sense of the cost of demolition through a case study and available literature and database sources.

3.2.1 Cost estimation factors

Many factors are determined while planning and executing a demolition project. These factors determine the approach to be used and have impact on the cost of the project. Some of the factors can be as following (Lui, et al., 2012; Diven & Shaurette, 2010):

- Preparatory estimating tasks
- Project location
- Available information
- Schedule
- Weather
- Regulatory requirements

- Project size
- Available resources
- Salvage
- Quantity takeoff

3.2.1.1 Preparatory estimating tasks

This includes thorough understanding of the specifications of the project to be demolished. Normally the specifications of the project might be provided by the clients' architectural or engineering firm. But the estimator needs to understand and list all the sections that will affect the cost and also the information needed for cost estimation such as insurances, bonds, subcontractors list, work plans, etc. This may also include a Rough Order of Magnitude (ROM) cost for a project which can help the contractor determine if the project is suitable to match the available resources of the company (Lui, et al., 2012; Diven & Shaurette, 2010).

3.2.1.2 Regulatory requirements

As discussed earlier, there are regulatory requirements at the federal, state, county, city and owner level that can affect the cost of the work and the estimator needs to be completely familiar with them and include them in the cost estimation. Compliance with some of these regulations might be very costly but they help in creating safe and environmentally responsible projects if properly applied. For example, the environmental regulations may require the contractor to comply with Storm Water Pollution Prevention Plan (SWPPP) which can cost up to thousands of dollars to install and maintain (Diven & Taylor, 2006).

Demolition permits and some other permits required for projects such as, the Asbestos Containing Material removal, utility works, street use, etc. usually issued by local municipalities can also well

exceed thousands of dollars. The estimator needs to be aware of them and include them in the cost estimation.

3.2.1.3 Project location

The location factor must be taken into account by the estimator. Demolition of projects in congested urban settings or in operating industrial plants is much higher because of the cost needed for the protection of adjacent structures and utilities. The location of the project may restrict accessibility or use of large equipment and instead may require small equipment and hand labor which significantly affects the cost.

Remote sites on the other hand requires considerable planning and management to accomplish mobilization and demobilization of equipment and personnel. Some location factors that can affect the cost are as follows (Lui, et al., 2012; Diven & Shaurette, 2010).

- Temporary living quarters
- Personnel transportation
- Security
- Mobilization of equipment and tools

3.2.1.4 Project size

The size of the demolition project has a significant impact on the unit cost of the project. A larger project may cost less per unit than a relatively smaller project, this is due to the spread of the cost over a larger area. For example, if the cost of mobilization and demobilization is about \$5,000

each for two projects of 3,000sf and 20,000sf building demolition. The cost of mobilization and demobilization per square footage is about \$1.67/sf for the 3,000sf building, where it will cost \$0.25/sf for the 20,000 sf building (Diven & Shaurette, 2010).

Height of the building also impacts unit cost of the project. Higher buildings cost more per unit than low rise buildings. This is due to the increased cost of safety measurements and material handling amongst many other factors.

3.2.1.5 Available information

The estimator should attain information regarding the demolition projects from several sources including (Diven & Taylor, 2006):

Company records: available data about previously implemented demolition projects by the company are good resources for the estimator to cross check quantity take-offs and costs.

As-built drawings of the structure: access to as-built drawings of the structure will assist the estimator in accurately quantifying building components. This can save time and increase accuracy of takeoffs in comparison to the process of measuring on site and calculating quantities.

Utility locations: the owner will try to provide drawings for locating utilities in and around the structure accurately but in some cases it is not possible. Therefore, the estimator should allow costs in the estimation for locating utilities of should mentions that the utility survey is not included in the cost if that is the case.

Site inspection: enough time should be allowed for thorough inspection of the site. The site visit is important for the estimator to determine the effects of added costs if any and verify the accuracy of the drawings.

Disposal and recycling sites: the estimator should be fully aware of the location of businesses that provide landfill and recycling yards in the work area.

Former use of property: it is necessary to understand previous use of the building for cost estimation. The possibility of chemicals and contaminants presence on the site can impact the cost significantly. Similarly if any previously demolished building material is buried under the site, it will impact the cost of removal of the material significantly.

Hazardous material survey: the presence of Asbestos and other hazardous material on demolition projects are a major cost factors. In some cases the removal of such material may cost more than the project itself.

3.2.1.6 Available resources

The estimator should be fully aware of the availability of qualified personnel and equipment necessary for a project. The estimator usually assumes that the company will have the necessary equipment for a demolition project, the company may own some of these equipment. But if the equipment is not available for a project the estimator should consider the rental cost of the equipment for estimation.

3.2.1.7 Schedule

Some projects may require unrealistic or very difficult schedule performance. The estimator should take into account overtime costs, late completion penalties, additional personnel and equipment costs that are required for completion of the project (Diven & Taylor, 2006).

3.2.1.8 Salvage

Net values of material and equipment that can be removed from a demolition project for salvage purposes should be taken into account by the estimator. The ownership of such material should also be well resolved before a project can start. Sometimes the owner may want to keep such material or equipment and this issue can create a lot of financial and legal issues (Diven & Shaurette, 2010).

3.2.1.9 Weather

Unusual weather conditions and time of the year can impact the cost of demolition. The estimator should consider the weather and in most cases allow for some contingency in the estimation, this allowance can cover the weather-related costs (Lui, et al., 2012).

3.2.1.10 Quantity takeoff

A site visit to the demolition project is one of the most important opportunities for the estimator to determine the accuracy of information provided to her/him and verify drawings, measure building

material, utilities, proximity of structure, ground conditions and any other information that will affect the cost and schedule of the project. It is important for the estimator to calculate and categorize the following items (Diven & Shaurette, 2010):

Hazardous Material: a thorough survey of presence of hazardous material on site will provide the information regarding the quantities of such material on site. These surveys might be provided by the owner along with specifications of the project. If not provided, then the contractor should inform the owner of all the additional compensation needed for survey and removal of such material.

Building material: material such as concrete, brick, CMU blocks, wood, steel, etc. should be calculated by the estimator from the available drawings or by measurement on site.

Site restoration: the quantity and type of material needed for restoration of site such as backfill, compaction, landscaping, fence, etc needed for the project after the completion of demolition work should be estimated for cost considerations.

Salvage value: the estimator also needs to carefully quantify the negative cost item that is the salvage material that can be retrieved from the project and will have impact on the overall cost of the project.

3.2.2 Cost components of a demolition project

Accurate and reliable demolition budgets must account for the cost of a variety of items. These include the demolition contractor's requirements for personnel and equipment, as well as any costs required by the client for a typical project (e.g., safety officer, fire watchman, pedestrian controller,

traffic controller, and so on) (Lui, et al., 2012; Diven & Shaurette, 2010). Table 3.1 shows the major cost components of a demolition project.

Table 3.1 Major cost components generally covered in an estimate of demolition projects.

Cost Components of a Demolition project
Permits
Mobilization and demobilization of equipment and personnel
Survey
Site protection and safety
Engineering services
Environmental surveys
Utility work
Supplies (e.g., scaffolding, lumber for protection, cutting gases, etc.)
Demolition labor and equipment
Security personnel
Material handling
Disposal fees
Earthwork
Cleanup
New construction
General and administrative expenses
Credit for salvage
Subcontractors

3.2.3. Demolition case study

Over several decades, many techniques have been developed to analyze and estimate the construction costs of buildings. On the other hand, the cost parameters of demolition, which can be viewed as the reversed process of construction, have not been formulated (Lui, et al., 2012). This section aims at understanding the major cost components used for estimating demolition project cost. It uses residential building as a case study.

The state of Michigan recently awarded the contract for the demolition of about 1,700 blighted publicly owned houses at a cost of \$20.1 million for the Genesee County Land Bank Authority. The aim of the project was to sell some of the vacant lots to interested adjacent owners and maintain the remaining lots for up to 5 years after demolition (Genesee County Land bank, 2014). The major cost components of the demolition work are presented below in Table 3.2. On an average each residential structure costed \$10,600 to demolish.

Table 3.2 Full cost of demolition of a house in Michigan (Genesee County Land Bank, 2014)

No.	Cost Item	Cost (\$)
1	Property inspections and surveys	300 – 600
2	Abatement and disposal of hazardous material	0 – 15,000
3	Utility cuts	250 – 600
4	Demolition permit	75 – 350
5	Structure and basement removal	2,300 – 25,000
6	Backfill with clean soil and initial site grading	1,200 – 2,000
7	Final grade including seeding and mulching	500 – 750
8	Full Cost of Demolition Per House Average	10,600

Since 2003, the Land Bank has managed the demolition of more than 3,000 structures in cooperation with the City of Flint. Based on demolition activity under the recent federally funded Neighborhood Stabilization Programs (NSP), the average cost of demolition was \$10,600. According to the Michigan State Housing Development Authority (MSHDA), the state-wide average for single family demolition under NSP 2 was \$12,000. The Land Bank's average demolition cost is in line with other similar efforts, e.g. that of Cuyahoga County Land Bank in Ohio (Genesee County Land Bank, 2014).

The cost of demolition-related activities varies greatly based on the size and condition of the structure. Costs can range anywhere from \$3,000 to \$25,000 (Genesee County Land Bank, 2014). Abatement and demolition contractors develop their cost estimates based on the size and the complexity of the job. The building material of the house also impacts the costs, e.g., brick structures often cost more to demolish than wood structures. The amount of recyclable material in the structure can also help to reduce the overall cost, e.g., as contractors may be able to salvage any remaining metals in the structure.

The abatement of asbestos and hazardous materials greatly impacts the cost of a demolition. Some structures are loaded with asbestos-containing materials and can cost as much as \$15,000 to abate while others have few or no abatement costs. Houses that are severely burned often do not have inspection or abatement costs. However, all debris material must be treated as hazardous and asbestos-containing and disposed of in special landfills with higher tipping fees. The complexity of the project and the expertise required on the site also impacts the cost (Genesee County Land Bank, 2014).

Assuming that an average house is about 2,000 SF, including the garage, shed, etc. The cost of demolition work is about \$5/sq.ft. Many structures have fallen into a particular level of decay due to neglect, the elements, or a previous fire, and there is little or no salvage value remaining. The structures are on the city's emergency demolition list and have to come down immediately.

It should be noted that two cost components are major cost items in this case; Abatement and disposal of hazardous material and Structure & basement removal. The cost of these components can highly impact the overall cost of demolition based on the type of construction and material present in the structures.

3.2.4. Sources for Cost estimation of demolition projects

The estimator must have the knowledge of expected production rates each task to be performed in a demolition project. This might be known from previous experiences or job records of the company or the use of databases such as R.S. Means facilities construction cost data reference book (RSMMeans, 2014).

3.2.4.1 RSMMeans building construction cost data (RSMMeans, 2014)

Since 1942, RSMMeans has been actively engaged in construction cost publishing and consulting throughout North America. The primary objective is to provide construction industry professionals with the current construction cost data. All the cost data has been divided into 50 divisions according to the master format system of classification and numbering.

Division 2- Existing Conditions; provide cost data relating to various cost components of demolition and deconstruction projects. Particularly the sub-divisions i.e. 02 40 00 Demolition and

structure Moving, provide cost data for selective demolition. This subdivision does not include rubbish handling and disposal, Hazardous material handling, etc. Each of these items should be estimated using other sub-divisions in the data base.

In addition to subdivision 02 40 00, one can find selective demolition items in each division. Example. Roofing demolition is in Division 7. Many unit costs from various subdivisions might be used when estimating demolition projects such as:

- Concrete superstructure
- Concrete slab on grade
- Concrete foundations
- Concrete crushing
- Wood frame building
- Assemblies
- Steel frame buildings and structures
- Cost of handling, trucking, and disposal of building components

Subdivision 02 41 16 provides cost data for structure demolition based on the type and size of structures. These costs do not include hauling and dumping of debris, removal of hazardous material. Other subdivisions i.e. 02 50 00 Containment of hazardous waste, 02 80 00 Hazardous material disposal should be used in conjunction with this subdivision to estimate the overall cost of demolition projects. Some of the costs are provided below. Table 3.3 shows demolition cost of residential structures based on area, type of construction and number of story of the building.

Table 3.3 Demolition cost of various residential structures based on type, height and area of structures (RSMMeans, 2014).

Type of structure	Area	Total cost
Single family, wood construction	1,600 s.f	\$5,725
Single family, wood construction	3,200 s.f	\$11,500
Two family, wood construction	2,400 s.f	\$8,575
Two family, wood construction	4,200 s.f	\$15,300
Three family, 3 story, wood construction	3,200 s.f	\$11,500
Three family, 3 story, wood construction	5,400 s.f	\$19,100

3.2.4.2 Buildingjournal.com. (<http://buildingjournal.com/estimating-demolition.html>, 2014)

Another reference for achieving unit cost for demolition projects is “Buildingjournal.com”. It is an online database which provides unit cost of demolition works based on project size, type, and location. Examples from this online cost database have been presented below. It should be noted that various cost items, that is, the presence of hazardous material removal and disposal, have not been clearly defined in this cost database. Where these items can highly effect the overall cost of the project. Figure 3.1-3.3 below show cost estimation of various projects based on their height.

Figure. 3.1 Cost estimation of demolition for apartments which are 1 to 3 story high, using the online source (<http://buildingjournal.com/commercial-construction-estimating-demolition.html>, 2014).

Type of Building	Apartment 1-3 Story ▼	
Project Location	National Average ▼	
Type of Work	Demolition ▼	
Cost Index	Median ▼	
<hr/>		
Square Feet	20,000.00	
<hr/>		
Subtotal	12,334.61	
Overhead	10.00%	1,233.46
Profit	5.00%	616.73
Bonding	1.00%	123.35
<hr/>		
Total Budget	14,308.15	
Per Square Foot	0.72	

Figure. 3.2 Cost estimation of demolition for apartments which are 4 to 7 story high, using the online source (<http://buildingjournal.com/commercial-construction-estimating-demolition.html>, 2014).

Type of Building	Apartment 4-7 Story ▼	
Project Location	National Average ▼	
Type of Work	Demolition ▼	
Cost Index	Median ▼	
<hr/>		
Square Feet	40,000.00	
<hr/>		
Subtotal	31,705.27	
Overhead	10.00%	3,170.53
Profit	5.00%	1,585.26
Bonding	1.00%	317.05
<hr/>		
Total Budget	36,778.12	
Per Square Foot	0.92	

Figure. 3.3 Cost estimation of demolition for apartments which are 8 to 24 story high, using the online source (<http://buildingjournal.com/commercial-construction-estimating-demolition.html>, 2014).

Type of Building	Apartment 8-24 Story ▼	
Project Location	National Average ▼	
Type of Work	Demolition ▼	
Cost Index	Median ▼	
<hr/>		
Square Feet	100,000.00	
<hr/>		
Subtotal	97,693.44	
Overhead	10.00%	9,769.34
Profit	5.00%	4,884.67
Bonding	1.00%	976.93
<hr/>		
Total Budget	113,324.39	
Per Square Foot	1.13	

It can be inferred from the above database that the cost of demolition for apartment buildings increase as the number of story or height of the building increases. This is due to various factors, that is, the increased cost of safety, increased cost of material handling and removal, etc.

The online cost database (buildingjournal.com) provides a quick estimation of a demolition project without considering the details of the type of structure and material used among many other important factors that highly affect the cost of demolition project. The RSMeans cost database provides a more comprehensive estimation of demolition projects.

Estimating demolition projects are challenging because projects are different and contractors may use various approaches based on their own experience.

3.3. COST ESTIMATION OF DECONSTRUCTION PROJECTS

The estimate for deconstruction basically contains two major parts: the cost to deconstruct and the value of the salvaged materials, a combination of which will provide the net cost of deconstruction.

Guy (2001) developed economic equation for deconstruction to estimate the net income for the work. The net cost equation for deconstruction is:

(Price Paid by Owner + Salvage Value) - (Pre-Deconstruction + Deconstruction + Processing + Transportation + Disposal).

According to (CCE, 2001) the major cost components are:

- Labor
- Tools and Equipment
- Handling and transportation of material
- Overhead
- Profit

The major salvage value is gained through:

- Reuse Material Value
- Recycle Material Value
- Tax Credits for Materials

3.3.1 Cost estimation steps for a deconstruction project

In order to properly identify the costs associated with any deconstruction project, the major process involved must be established. The following indicates the major steps in the process for which the cost component must be determined:

- Survey
- Material management
- Hazardous material
- Historic preservation
- Demolition permits and utilities
- Compliance with regulations

3.3.1.1 Survey

There must be a site visit by the estimator to examine the building through a visual survey in order to estimate the basic material type and overall condition of the building. This includes taking an inventory of the materials (types and quantities) and measuring the building. Categories of material are: reuse, recycle, hazardous disposal, C&D disposal, solid waste disposal (IWMB, 2001).

3.3.1.2. Material management

Material management on site and removal of material from site is a major cost component of the deconstruction process. After a complete survey and inventory of material, the estimator must also know where the reusable, recyclable, hazardous disposal, C&D disposal, and solid waste disposal will go and the means to get it there. Understand and prepare specific outlets (contacts), general markets (advertisement) and methods (equipment, labor, sub-contracts) for removal of all materials from site (CCE, 2001).

3.3.1.3. Hazardous material

The estimator should be thorough with the cost of survey and removal of hazardous material which can significantly impact the cost of the project. In some cases the client themselves provide complete surveys and pay for removal of the hazardous material. If that is not the case the

contractor must inform the client of all cost associated with it. Environmental surveys for lead and asbestos has to be completed for any building completed before 1978. The process of deconstruction is heavily influenced by the presence of asbestos containing materials (ACM) and lead-based paint materials (LBP). Asbestos abatement involves the removal of all ACMs before work begins. Proper notifications and permits must be obtained from the appropriate statutory authorities (Guy et al., 2003).

3.3.1.4. Historic preservation

Buildings in older parts of a city or those appearing old may have a historic preservation oversight by local municipality, thus, it is important to obtain the necessary permits. The estimator must consider the cost of obtaining these permits, and the cost associated with the preservation process (Divine & Taylor, 2006).

3.3.1.5. Demolition permits and utilities

The estimator must consider the cost of obtaining permits from local municipalities for the project. And before the start of any work, all utilities must be disconnected. This includes electricity, natural gas, water, wastewater, telephone, and cable. It is important to find out if the disconnection of utilities is included in the demolition permit approval process or has to be obtained separately (IWMB, 2001).

3.3.1.6. Compliance with regulations

OSHA specifies the completion of a building engineering survey and dismantling plan before a demolition work starts. This plan highlights known hazards at the time of inspection, the structural fabric of the building, and the general schedule, tasks, techniques, and tasks to be employed in the deconstruction work (Guy et al., 2003).. The estimator should include the costs of compliance with these specifications, especially in the case of deconstruction projects, safety can be of high cost.

3.3.2 Cost components of a deconstruction project

Deconstruction projects require more time and labor hours as compared to demolition project. Therefor it requires extensive planning and management. Table 3.4 below provides a summary of the major costs components of a deconstruction project identified above.

Table 3.4 Major Cost Components for Deconstruction

Major Cost Components of a Deconstruction Project
Survey
Environmental Health and Compliance
Historic Preservation
Permits and utility work
Engineering Survey
Safety
Material management
Estimate: Costs (Labor, Tools/Equipment, Landfill, Oh & Profit)
Estimate: Salvage Value (Reuse, Recycle)

3.3.3. Deconstruction case study

The Center for Construction and Environment (CCE, 2001) deconstructed six (6) houses during 1999-2000 to examine the cost effectiveness of deconstruction and salvage when compared to traditional demolition. This research was funded through the Florida Department of Environmental Protection (FDEP) Innovative Recycling Projects grant program. One of the six residential structures has been presented here as a case study of the deconstruction cost estimation. The selected building is identified as (2930 NW 6th Street), located in Gainesville, Florida, built in 1915.

This was a one-story house with a detached garage, the garage was approximately 500 SF of the total 2014 SF. The house was wood raised on brick piers, the garage was a CMU wall construction on concrete slab. This building had several additions and several layers of interior finishes, i.e. two wood floors and two roof finishes, a metal roof laid over an asphalt roof. The interior walls were predominantly plaster and lathe. The plaster was separated from the lathe to see if the lathe could be recycled or used for fuel in pottery kilns. This project was affected by a summer heat wave and several rain days. The site had ample room for the layout of de-nailing areas and roll-offs, and did not require extensive site work to make space around the building.

Deconstruction costs were collected for labor, other costs, disposal costs, environmental assessment and salvage costs. This case study represents a situation where there are no materials storage, inventory, and sales personnel costs. Materials are given a retail value and deducted from the deconstruction costs for a net deconstruction costs without the additional costs for overhead on the materials themselves. Table 3.5 below shows a summary of the cost for the deconstruction of the building.

Table. 3.5 Economic summary for the building deconstruction (CCE, 2001).

No.	Cost Item	Cost (\$)
1	Permit	50.00
2	Asbestos survey	1,200.00
3	Asbestos abatement	740.00
4	Disposal	1,334.00
5	Supplies	637.93
6	Labor and equipment cost	8,469.38
7	Toilet	63.00
	Total Cost	12,504.32
8	Salvage value	9,415.00
9	Net Cost of Deconstruction	3,089.32

The cost of deconstruction before deducting the salvage value is 6.21 per SF. And after the deduction of salvage value it is 1.53 per SF.

Labor productivity data was collected in the following task categories:

Supervision: directing and planning the flow of work on the job site.

Deconstruction: Labor involved in the initial removal of materials from the structure. Any manual or mechanical procedure required to remove materials for salvage either the direct handling of a material or removing other materials to gain access to the salvage material.

Demolition: The hand or mechanical removal of building materials for direct disposal.

Processing: Preparing materials for redistribution in reusable form. De-nailing is the most typical processing activity.

Non-production: non-production occurs when no work is being performed. This includes breaks and lunch, and the unloading and clean-up of daily tools. Any work stoppage greater than five minutes and not coordinated by the supervisor is considered non-production.

Clean-up / Disposal: sweeping and/or removing debris or demolition materials from a work area and/or disposal into a roll-off container. Clean-up does not involve de-nailing, loading, stacking or transporting processed materials.

Loading/unloading: loading or unloading materials from the site onto a truck for transport and at the final storage area. Any efforts to move, stack or place the lumber is a loading activity.

Table 3.6 below shows the percentage and number of labor hours spent on each of the categories of work explained above.

Table. 3.6 Labor time by work categories (CCE, 2001).

Category Hours									
House #		Super	Decon	Process	Demo	Dis/Clean	Non-Pro	Load	Total
2930	hr	60.50	179.50	204.80	0.00	100.00	52.75	80.00	677.55
Percentage	%	8.93	26.49	30.23	0.00	14.76	7.79	11.81	100
Hours / SF		0.030	0.089	0.102	0.000	0.050	0.026	0.040	0.336

The “gross” deconstruction cost was \$6.47/SF, which is approximately 26% higher than demolition. Disposal costs for deconstruction were 15% of the total costs. Gross deconstruction cost is the first cost of the deconstruction which includes all labor and disposal but does not include any salvage revenues. Asbestos and lead surveys and remediation was an average of \$0.97/SF or 15% of the costs for deconstruction.

The average salvage value was \$3.28/SF. The “price” of salvaged lumber was estimated at between 25-50% of new lumber retail value in local stores. The price of other items were estimated as very

low costs for used goods, based on the experience of an used building materials store owner/operator in Gainesville, Florida.

3.4. INTERVIEWS AND ANALYSIS

Various academic papers, thesis reports, case studies, industry reports and manuals available in the fields of demolition and deconstruction were reviewed for the purpose of literature review and discussed in the previous chapters and sections. Based on the literature review the best practices and key lessons were compiled and presented. In order to understand the practices prevalent in the demolition and deconstruction industry in Michigan, a limited number of interviews were carried out and their summary is discussed below.

The purpose of the interviews was to compile and analyze the factors affecting the entire project planning and implementation, understand the major cost factors in demolition and deconstruction projects, difference between demolition and deconstruction, from the contractor's point of view. The interviews were intended to gather project specific information from the contractors on the following aspects:

- Planning for a project
- Difference between demolition and deconstruction
- Cost estimation or quantification process for demolition and deconstruction projects
- Major cost factors
- Selecting an approach
- Implementation

The first part of the interview included questions regarding the background of the contractors and their experience and area of practice. The second part were about project planning, implementation, cost estimation, approaches and difference between building demolition and deconstruction.

3.4.1. Analysis and summary of the interviews

A small number of contractors working in Detroit area and Lansing were interviewed. In addition to interview summary, some information about the views of the National Demolition Association (NDA) are also presented, because they represent more than 1,000 US and Canadian demolition contractors.

3.4.1.1. Background of the contractors

The interviewees were both large and small sized contracting companies mainly involved in demolition, and the contractors have membership of the National Demolition Association (NDA). The interview questionnaire is provided in Appendix A. The large sized contracting companies are involved in large scale residential demolition projects and also commercial and industrial demolition in the Detroit area. The small sized contracting companies are mainly involved in small number of residential demolitions in Michigan. All contractors claim to be involved in salvage and recycling of materials in demolition projects at different scales when it is economically feasible. It should be noted that due to time limitations, none of the interviewees were a specialized deconstruction company, and this limits the scope of the summary of industry's definition of demolition and deconstruction, as it based on the views of the demolition contractors only.

3.4.1.2. Demolition vs. deconstruction

Definition of both demolition and deconstruction varied according to various contractors and projects. Demolition was defined by contractors mainly in two different ways; the first definition was knocking down a building, changing it into rubble and clearing the site for future use. This definition mainly related to demolition of large number of residential structures by large contractors. The second definition was to dismantle the structure, salvage and recycle material and send to landfills what is left of the rubble. This definition related to projects which were economically feasible to salvage and recycle like commercial and industrial structures. Deconstruction was defined as being able to disassemble building components and materials and reassemble and use it somewhere else.

Deconstruction was defined as much more time consuming and labor intensive compared to demolition. The safety costs are higher since more labor are working inside the buildings. So in most cases economically not feasible. If the cost of recycle is much more than disposal of the material to landfills, the contractors mostly decide to dispose the material. The tipping fees to landfills in Michigan are lower than many states, but the main cost components are the hauling and moving fees.

It was also pointed out that deconstruction is more favorable in the West coast because the labor cost is cheaper compared to East coast and mid-west and also the landfill tipping fees are higher in the west coast, therefore the contractors there favor deconstruction over demolition.

The decisions of whether to demolish or deconstruct a building are completely based on the economics of the project. If the building consists of high value salvageable material it is deconstructed and stripped off of all the material and then demolished as necessary. This approach

is highly favorable in the case of commercial and industrial structures where structural wood, steel frames, copper wires, insulation material and other high value material are salvaged. Most of the components are favored for reuse if appropriate, if not, then are sold as scrap as in the case of steel which is sold for \$400/Ton. In the case of basement and foundation concrete, recycling the concrete is a more economical option than transporting to landfills. Therefore, it is mostly recycled on site and sold to others to be used as backfill material and aggregate.

In the case of residential demolition in the Detroit area, the large contractors mostly perform complete demolition and send the rubble to landfills. As there are less valuable material to salvage and it takes just few hours to completely demolish a residence and move on to the next. The small sized contractors favored skim deconstruction where they would strip off salvageable material in the residential projects and then demolish.

3.4.1.3. Approaches to project cost estimation, planning and implementation

The contractors based their approaches on experience of the company. The first step and mostly costly component of the project was defined as the initial survey where building material and components are inspected thoroughly to obtain a good understanding of the project, especially in the case of commercial and industrial structures. The estimation department estimates the project magnitude and cost. Other major components were defined as large equipment and machinery use, hazardous material abatement and removal, structural demolition work like basements and slabs, etc. The larger sized contracting companies own most of the heavy equipment and machines while the smaller contractors preferred renting them. The machines are worn out much faster than when used on construction sites.

While deciding the method of demolition to be used, contractors mostly depend on their experience and gut feeling. In the case of high-rise buildings high reach boom excavators are mostly used. But the more experienced contractor proposed a different approach of weakening the supports at the ground floors and using the pull down method to bring the down the building quickly. Explosive demolition though the quickest method mostly is rarely used because they are expensive. In the case of residential structures, excavators with hauling trucks are used with a very limited number of labor on site.

The average cost of demolition of a residential structure was defined to be around \$12,000 or less by the large contractors. The small sized contractors stated the average about \$15,000. The large contractors mostly demolish many residences in a close proximity which automatically costs less than a small sized contractor demolishing a single or couple residences.

3.4.2. National Demolition Association (NDA)

The National Demolition Association represents more than 1,000 U.S. and Canadian companies that offer demolition services as well as a range of demolition-related services and products. It provides education, advocacy, and industry updates to member companies and public as well as increasing awareness of the economic and societal benefits of the demolition. The following information is obtained from the official website of the National Demolition Association and a summary is presented of their view towards the demolition and deconstruction industry (NDA, 2015).

Demolition is defined as “a complex set of tasks involving structural dismantlement, site clearance, environmental remediation, salvage, recycling, and industrial recovery. Demolition is a highly

sophisticated craft which involves the use of hydraulic equipment with specialized attachments, cranes, loaders, wrecking balls and in some cases explosives”.

Deconstruction is defined as “the labor-intensive demolition of a structure in order to maximize the amount of potentially recyclable materials from the building. It often involves a considerable amount of hand demolition and sort separation in preparation for marketing the structure’s components”.

The difference between demolition and deconstruction is defined as “considering that conventional demolition contractors routinely recycle up to 90% of the material generated on a typical demolition site, there is little difference between the two methods. Demolition saves the labor-intensive nature of deconstruction”.

In author’s opinion, these statements are misleading and do not justify the environmental, social and possibly economic benefits of deconstruction. It was found that very few of the demolition projects recycle up to 90% of the material because not even a full deconstruction project can achieve such a level of material recycle. Because demolition is a more established industry with larger profits for contractors, it is pushed and recommended mostly and therefore it is implemented at 90% of the projects for instance at the Detroit blight removal projects. It is absolutely necessary to increase the public awareness of the benefits of deconstruction over demolition.

3.5. COMPARISON OF DEMOLITION VS. DECONSTRUCTION

This section presents a comparison of demolition and deconstruction after the understanding reached through the literature review as well as the industry interviews. Table 3.7 outlines a comparison matrix of demolition and deconstruction.

Table 3.7 Comparison between building demolition and deconstruction (EPA, 2008; EPA 2006; Diven & Shaurette, 2010; Guy, 2003; IWMB, 2001; CCE, 2000).

Attribute	Demolition	Deconstruction
Definition	Change a building or structure to a pile of debris and mixed rubble, recycle where practicable by segregating the debris and haul the rubble to landfills	Disassemble components and material from a building or structure for maximum reuse and recycle
Impacts	Heavy impact on the environment due to disposal of material to landfills and wastage of resources	Environmentally beneficial due to reuse of material and preserving maximum construction material. Avoids depletion of energy and new material. Conservation of natural resources.
	Socially does not benefit communities as it is more dependent on use of heavy machinery	Creates new employment opportunities for unskilled work force as it is dependent largely on labor
	Quickly executed, often more economic for contractors and owners who want the site clear for investment	Operationally costs more but adds the benefits of value from salvaged material which may result in reduced cost
Planning	Intensive machine operation planning	Intensive labor training and working plans
Site survey	Structure, Material, Method of construction, Adjoining properties, Utilities, Hazardous material, Location, Neighborhood, Access...	Requires more intensive survey of Structure, Material Classification for Reuse, Recycle and Disposal, Components and connections, Hazardous Material, Location, Access
Safety	Workers on site, Pedestrian and vehicular safety, adjoining properties... Many cases performed from a safe distance by heavy machines	Workers safety, training, equipment safety, site... Personnel Safety more sensitive issue as workers engaged inside the building mostly
Tools and Equipment	Heavy and large machines and tools used for quick operations	Smaller hand tools and equipment used to carefully remove material in an integrated condition

Schedule	Requires less time	Requires more time
Labor	Less labor intensive, depend on heavy machine operations	More labor intensive operation
Material Handling	Heavy operations by machines: Sorting for recycle, hauling and disposal	All material separated as deconstructed into different categories, De-nailed, Cleaned for reuse and sorted for recycle
Material Disposal	Huge amount of waste produced which is aimed at landfills. Hauling and tipping costs are higher	Reduces the amount of waste by up to 75% as most material aimed for reuse and recycle
Approaches	Many approaches are based on heavy and specialized equipment and tools and some cases use of explosives for quick operations.	Based on the components to be disassembled, approaches are labor intensive and time consuming. Attention is paid to the components to preserve their structural integrity while deconstructed.
Structures	All structures can be demolished and changed into rubble	Not all buildings are good candidates for deconstruction
Site Security	Focus on workers safety and the general public and adjoining structures safety	Besides workers' safety, material security on site is important because salvaged material is vulnerable to theft
Asbestos Containing Material	If asbestos containing material present in the building, wet demolition can be used without having to remove the material with great cost	Asbestos containing material, if present in the buildings, require huge cost and time investment to remove
Pollution	Creates more waste during site clearance. More noise and dust with the use of heavy machinery and operations	Greater protection of the local site including soil and vegetation. Creates less dust and noise
Future	As the environmental impacts of demolition is widely discussed, future construction goals will be to avoid demolition where possible	Building practices to encourage deconstruction and Design for Deconstruction to be incorporated into construction industry

Deconstruction is an idealized method from the perspective of perfecting material reuse and recycling, by which the building is dismantled in terms of its valuable construction elements. As compared to Demolition which is mostly about changing a building into rubble as fast as possible and making the site ready for its future use. While demolition is mostly quick but is not an environmentally responsible approach. And though deconstruction may be a socially, environmentally and sometimes economically beneficial approach for removal of buildings, not all the buildings are good candidates to be deconstructed.

Typically, when a building reaches the end of its useful life, heavy equipment is used to demolish the structure. All parts of the structure are rendered into rubble which is a mix of wood, masonry, metals, and other materials. In some cases, especially with large concrete and steel buildings, raw material may be recycled, but for most light framed residential structures, the demolition waste ends up in landfills. Deconstruction on the other hand, is the selective dismantling or removal of materials from a building for reuse and recycle where possible and sending the least of the material to landfills. Wood flooring, raised panel doors and windows, ornate exterior and interior trim, electrical and plumbing fixtures, framing and bricks can have high salvage value. The goal of deconstruction is to encourage maximum reuse and recycle of construction material. Deconstruction is an environmentally responsible approach to removal of structures compared to demolition as it prevents waste from going to landfills and resource depletion (IWMB, 2001; EPA, 2006).

Though the cost of operations in deconstruction is typically more than demolition, the real cost savings in deconstruction depend on the market value of the salvaged material (CCE, 2000). Many deconstruction operations are run by non-profit organizations. One reason for this is that a non-

profit deconstruction firm can factor the tax-deductible donation benefit to the client into the bid. This is an added benefit to the non-profit approach to deconstruction.

Deconstruction uses less machinery and more labor. It requires training for crew members to be able to safely extract salvageable material without damaging them. This provides new employment opportunities for minimally skilled work force (IWMB, 2001). Deconstruction in almost all cases requires significantly more time than demolition. Developers are always under financial pressure to clear the site as quickly as possible and this is a disincentive to deconstruction compared to demolition.

Hazardous material regulation, safety and management can be more difficult or intensive for deconstruction than demolition. In the case of deconstruction the workers should be well aware of the existing and temporary supports inside the buildings and should follow strict safety rules to avoid dangerous situations because they work inside the buildings in the case of deconstruction. But in the case of demolition workers can operate machines from a safer distance from the structure. If deconstruction is cost-competitive with demolition, it is a clear winner: It is better for the environment (greater reuse and recycling, cleaner cleared lots, and less disposal) and for the local economy (more jobs and availability of lower cost building materials).

3.6. COST COMPARISON OF DEMOLITION AND DECONSTRUCTION

Deconstruction can be more cost effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvage (CCE, 2001). For deconstruction to be economically feasible, salvage value and revenue from resale of recovered materials is very important and comprises large part of the income. Furthermore, a greater opportunity is savings in

transportation and disposal costs. The net income from deconstruction can be increased by carefully salvaging more material with the least damage, so amount of waste material is reduced while increasing reuse and recycling potential of salvaged materials.

According to Macozoma (2002), in many cases, there are problems with the storage space for salvaged materials, and with the location of end markets to avoid additional costs for transportation. Therefore, there is a need for investment promoting the establishment of secondary material businesses such as used building material stores, recycling companies that divert salvaged waste into secondary materials, and product manufacturers that use secondary feedstock.

According to the CCE (2001), based on the study of deconstruction of 6 houses in Florida, which was mainly done to compare the costs of deconstruction to traditional demolition work, the average estimated demolition cost using all six (6) houses, was \$5.36/SF and disposal was an average of 40% of the total costs. The average “gross” deconstruction cost was \$6.47/SF, which is approximately 26% higher average cost than demolition. Disposal costs for deconstruction were on average 15% of the total costs. Gross deconstruction is the first cost of the deconstruction which includes all labor and disposal but does not include any salvage revenues. Asbestos and lead surveys and remediation was an average of \$0.97/SF for both demolition and deconstruction. This is 18% of the costs for demolition and 15% of the costs for deconstruction. Avoiding this cost on a consistent basis for small scale demolitions makes deconstruction un-competitive with demolition. Table 3.8 below provides a cost comparison of demolition vs. deconstruction for the same project.

Table. 3.8 Economic summary of demolition vs. deconstruction of a one story residential building (CCE, 2001). *(This building is presented in the case study for deconstruction estimation in the previous section).*

Cost items	Total net demolition cost	Total net deconstruction
Permit	\$50	\$50
Asbestos survey	\$1,200	\$1,200
Asbestos abatement	\$740	\$740
Disposal	\$5,873	\$1,344
Toilets	\$63	\$63
Supplies	\$10	\$637
Labor and equipment	\$3,504	\$8,469
Total cost	\$11,441	\$12,504
Salvage value	\$0.00	\$9,415
Total net cost	\$11,441	\$3,089
Total net cost per square foot	\$5.68 per SF	\$1.53 per SF

This was a one-story house with a detached garage, the garage was approximately 500 SF of the total 2014 SF. The house was wood raised on brick piers, the garage was a CMU wall construction on concrete slab. This building had several additions and several layers of interior finishes, i.e. two wood floors and two roof finishes, a metal roof laid over an asphalt roof. The interior walls were predominantly plaster and lathe. The plaster was separated from the lathe to see if the lathe could be recycled or used for fuel in pottery kilns.

Table 3.9 below presents another comparison of cost between demolition and deconstruction for a typical residential structure.

Table. 3.9 Cost comparison of demolition and deconstruction of residential structures. (Guy, et al., 2003).

Cost Element	Average Demolition Costs	Average Deconstruction Costs
Size (SF)	1,476	1,476
Labor/Equipment (\$/SF)	1.74	3.64
Testing for Asbestos & Lead (\$/SF)	0.97	0.97
Disposal (\$/SF)	2.17	0.97
Other Costs: permit, etc. (\$/SF)	0.48	0.89
Gross Cost (\$/SF)	5.36	6.47
Salvage (\$/SF)	0.00	3.28
Net Cost (\$/SF)	5.36	3.19
Net Cost (\$/SF) 50% Salvage	5.36	4.83

The gross cost of deconstruction per square foot of area is higher than the gross cost of demolition as seen in the table above. The real cost saving in deconstruction is dependent on the type and quality of salvage material that is valued based on reuse and recycle.

Some private companies have also presented a cost comparison of demolition vs. deconstruction projects as shown below. But according to the author these costs might have been inflated for commercial purposes. Table 3.10 below is a cost comparison of a residential structure for demolition and deconstruction presented on the official website of the Piece by Piece, who are one company amongst many promoting deconstruction.

Table. 3.10 Cost comparison of a 2500 sq.ft residential structure by piece by piece deconstruction company (<http://www.piecebypiececon.com/costs.html>, 2014).

Cost items	Deconstruction	Demolition
Labor cost	\$16,875	\$10,000
Disposal cost	\$1,667	\$6,250
Total cost	\$18,542	\$16,250
Salvage value	\$7,500	\$0
Tax savings	\$2,625	\$0
Final cost	\$15,917	\$16,250
Salvage value is based on used building materials selling for 1/3 of their new price – the industry average. Factors such as age, condition and design obviously affects the value of salvaged materials. Tax savings are based on an owner tax bracket of 35%.		

As presented in the table above, the gross cost of deconstruction is higher than gross cost of demolition, but the net cost of deconstruction is less than demolition. Though a salvage value of \$7500 is stated but the details of the quality and type of material being salvaged is not presented. The marketability of salvaged material has also not been detailed out. At the current situation the market demand for salvaged material does not support deconstruction projects viability. That is if a complete deconstruction of the project takes place where the maximum amount of material is being reused and recycled.

Table. 3.11. Cost comparison of demolition vs. deconstruction of a residential structure by The Reuse People. (<http://www.thereusepeople.org/deconstruction>, 2014).

Cost items	TRP deconstruction	Demolition
Physical lowering of house	\$17,238	\$6,000
Disposal	\$4,100	\$4,100
Appraisal of salvaged material	\$3,000	\$0
Cost	\$24,338	\$10,100
Donation value	\$88,000	\$0
Tax savings	\$24,640	\$0
Total costs	\$24,338	\$1,100
After tax benefits	\$302	\$10,100
The after tax benefits between the two methods is \$10,402; not only does the tax savings completely cover the cost of deconstruction, but the homeowner also saves \$10,100 in demolition fees.		
Total salvaged material would generally appraise for \$77,000 to \$112,000 in good reusable condition. Assuming a tax bracket of 28% the after tax cash value, based on a typical value of \$88,000 is \$24,640.		

The Reuse People is another company that promotes deconstruction in the west coast. A cost comparison of demolition vs. deconstruction is presented on their web page. This cost comparison shows a big difference while calculating the gross cost of deconstruction as compared to demolition. Estimating a value of \$88,000 for salvaged material is also not detailed out. No other paper has provided such a high value of savings in salvaged material. According to the author of this report, it is highly impossible for a typical residential structure that is to be demolished to have a salvaged value of material for reuse to be \$112,000 as stated above.

Deconstruction can be more cost effective than demolition when considering the cost reduction in landfill disposal costs and the revenues gained from salvaged material. On average, the operational deconstruction costs or gross deconstruction costs are higher than demolition costs, but the net cost of deconstruction, after considering the income that is achieved from the resale and recycle of the salvaged material, is lower than demolition. It should be noted that the salvage value is highly based on the type, condition and value of the salvaged material. Material should be carefully salvaged with least damage in order to be reused.

Waste transportation and disposal costs are one of the main cost components in a demolition project. The distance and tipping fees of the landfills considerably affect this cost component. In a deconstruction project, maximum amount of the material is targeted for resale and recycle which reduces the waste disposal costs in the project. On the other hand, there are problems with salvaged material such as storage, transportation and end markets availability. These cost factors should be considered while estimating the salvage value of material. The current situation of the market demand for salvaged material often does not support deconstruction projects feasibility.

Asbestos and lead survey and remediation is another important cost component. In smaller demolition projects, based on the type of hazardous material, often the hazardous material remediation cost is avoided and the material are disposed in a manner that would not require abatement such as, use of wet demolition approach. In this approach the debris is kept wet from start of the demolition project till they are safely disposed to landfills. The non-friable asbestos and lead containing material are safely disposed. But this cost cannot be avoided in the case of deconstruction projects, therefore making it un-competitive with demolition in many cases.

Every project is different and therefore should be studied separately in order to figure out the economic feasibility of the project to be deconstructed or demolished. Factors such as location, material type and condition, marketability of the material, transportation and tipping fees of landfills and labor wages in the area should all be studied in order to economically compare a project for demolition and deconstruction. Hence, it can be said that deconstruction can be cost effective compared to demolition in many projects, but it cannot be true in all projects and should be studied separately on a case by case basis.

In the author's opinion, demolition of a typical residential structure in Michigan should cost between \$10,000 to \$11,000. If the same residence is to be deconstructed, it should cost between \$13,000 to \$15,000. In the author's opinion, a typical house that is due to be demolished or deconstructed typically would not have a very large salvageable stock of material, but it will still contain some amount of salvage value. The typical residence deconstruction should result in a salvage value of about \$4,000 to \$5,000, depending on the quality and type of material and availability of market. If the salvaged material has a marketable quality, it could be sold at a higher retail price, but normally it might be sold at a lower price as a whole sale. It should be noted that a lot of the cost factors that have been discussed in the earlier sections would be specific to projects and would affect the cost of the project.

3.7. SUMMARY

This chapter provided an overview of cost estimation of demolition and deconstruction projects, industry view of both methods and a comparison of demolition vs. deconstruction projects. The comparison is done for planning, cost and execution of both approaches. Extensive planning is required for both demolition and deconstruction cost estimation. Overall deconstruction can be

more cost effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvage (CCE, 2001).

On average, according to the study done by (CCE, 2001), deconstruction costs for residential buildings in Florida were 26% higher than demolition costs. On average, the net cost of deconstruction with salvage was 37% lower costs than demolition using retail salvage values and 10% lower using “wholesale” prices.

CHAPTER 4

4.0. REMOVAL OF ABANDONED PROPERTIES IN MICHIGAN

4.1. INTRODUCTION

America's industrial decline in many urban communities has caused population and economic loss for years. This has resulted in large amount of properties being abandoned and left to decay. Empty neighborhoods are becoming an increasingly daunting problem across the country and these buildings and structures need to be removed. The practices of demolition and deconstruction are definitely related to decisions regarding removal of these structures. This chapter provides an overview of the private property abandonment in the United States and specifically in Michigan. It discusses the abandonment and removal topics in light of the approaches and costs of demolition and deconstruction discussed in earlier chapters. The current practices in place for the removal of the abandoned properties in Michigan are also discussed.

4.2. PRIVATE PROPERTY ABANDONMENT IN THE UNITED STATES

Industrial decline in America has left behind large amount of abandoned and decaying neighborhoods. "Many cities in the United States which used to be the hubs of industrial activities are presently facing economic and social decline and have suffered population loss. For the last 40 years these communities have experienced residential, industrial and commercial property abandonment. The abandonment results in blight, resulting in large number of vacant properties in communities which set in motion social and economic decline" (LaMore & LeBlanc, 2014). This issue is well prevalent in Michigan, where it has resulted in private property abandonment and blight in cities such as Detroit, Flint and many others.

Detroit once the hub of American industry has been largely abandoned and left to rust. Las Vegas edged Detroit for the title of America's most abandoned city. Atlanta came in third, followed by Greensboro, N.C., and Dayton, Ohio. Cities such as Detroit and Dayton are casualties of America's lengthy industrial decline, whereas others, including Las Vegas and Orlando, are mostly victims of the recent housing bust (Greenburg, 2009).

The private property abandonment and blight creates social and economic problems for communities and individuals and adds strain on public resources. It increases unemployment, poverty and crime in communities. This is because the neighborhood becomes dominated by joblessness, racial segregation and isolation from private economy (LaMore & LeBlanc, 2014). Blighted and contaminated properties also create negative economic implications for the surrounding properties. According to Paul (2008), property values for industrial and commercial sites within 1.5 mile radius of a brownfield site are typically 10% lower than similar properties not located within the 1.5 mile radius. Abandoned properties are not only a public safety hazard for the community, but they are a clear economic threat to non-abandoned properties.

According to (LaMore & LeBlanc, 2014), the current pattern of abandonment of private properties in many communities is largely due to the current land ownership policies that allow landowners to abandon their privately held parcels and burden the public sector with the cost of blight removal. It is necessary to put in place policies that will put an end to this practice of property abandonment by owners. It is certain that all the abandoned properties need to be removed and the sites need to be restored for future use. Otherwise they turn into blight, triggering a spiral of social decline. Based on the understanding of the policies that will lead to dismantling, removal, and restoration of these properties, there is a need to identify most appropriate approaches for the removal of such structures.

The current practice of removal of abandoned buildings typically includes complete demolition of the building, changing it into rubble and hauling the waste into landfills. Salvage of material is also incorporated into the demolition work when economically feasible. But these methods are creating substantial amount of waste. Hence, when the building contains large amounts of reusable and recyclable materials it is important to incorporate deconstruction into demolition. But because not all the buildings are good candidates for deconstruction, the economic feasibility of deconstruction of abandoned buildings need to be justified.

4.3. REMOVAL OF ABANDONED PRIVATE PROPERTIES IN MICHIGAN

Decline of the auto industry and the economic recession has caused widespread private commercial and residential property abandonment in Michigan for many years. According to the Center for Automotive Research, over half of the originally constructed automotive plants within the State of Michigan have closed, leaving only 65 still in operation (Brugeman, et al., 2011). Many of the abandoned commercial properties have become sights for crime and vandalism.

The State of Michigan has increased the efforts to slow down the increase of blight and alleviate the effects of abandonment. The State Senate introduced a bill that causes property owners to face a lawsuit if they fail to act on issued blight citations (State Senate, Michigan, 2013). Local and statewide programs have also been enacted with goals of eliminating blight. The Department of Human Services of the State of Michigan (DHS), the Michigan State Housing Authority (MSHDA), and the Michigan Land Bank Fast Track Authority (MLB) enacted the Blight Elimination program in 2012 which gives communities the opportunity to apply for funding that fund the demolition of blighted properties. The Neighborhood Stabilization Program (NSP), administered by the Department of Housing and Urban Development (HUD), focuses on

residential abandoned properties and helps fund communities to stabilize. A variety of taxpayer supported programs are also created to combat commercial and industrial abandonment ranging from brownfield redevelopment tax credits to direct investments in failing industries (LaMore & LeBlanc, 2014).

Private property abandonment places a substantial burden on limited public resources for the removal of blighted properties. It is estimated that the removal of an abandoned single family home costs approximately \$10,600 (Genesee County Land bank, 2014). In some cities there are hundreds of such abandoned properties which can amount to millions in blight removal cost.

The US Treasury Department allocated \$498 million to Michigan in 2010 as part of the Hardest Hit Fund program (Gallagher, L., 2009). In July of 2012 \$25 million was allocated for blight demolition with \$15 million for the city of Detroit and remaining \$10 million spread across Michigan (Eggert, 2012). In 2013 \$100 million was allocated for blight elimination in Detroit, Flint, Saginaw, Grand Rapids and Pontiac (Behnan & Hinkle, 2009). In October of 2014 a total of \$75 million is allocated to eliminate blight in Michigan and it comes from the Hardest Hit Fund program. \$50 million is allocated for Detroit, \$5.5 million for Jackson, \$6 million for Lansing, \$5 million for Highland Park, and remaining eight communities – Inkster, Encore, Muskegon Heights, River Rouge, Port Huron, Hamtrack, Ironwood and Adrian - will receive between \$375,000 to \$2.2 million. In the summer of 2015 it is expected that as many as 240 blighted houses in Lansing could be demolished using the \$6 million federal money (Behnan & Hinkle, 2009).

4.4. REMOVAL OF ABANDONED PROPERTIES IN DETROIT

In particular, Detroit's problems run much deeper. An industrial boomtown during the first half of the 20th century, Detroit's population increased from 285,000 in 1900 to 990,000 in 1920, reaching a peak of 1.8 million in 1950. But starting in the 1960s, Detroit began a swift decline. Detroit's population is now 900,000 half of what it was in the middle of the century and many of its neighborhoods languish in varying states of decay. Most scholars blame rapid suburbanization, outsourcing of manufacturing jobs, and federal programs they say exacerbated the situation by creating a culture of joblessness and dependency (Greenburg, 2009).

Detroit has internationally gained the reputation of urban ruin and is fighting to get rid of the blighted properties for many years. At last it has started to show results, as of December 2014 the city of Detroit is demolishing about 200 vacant houses a week and the city wants to reach a goal of demolishing about 10,000 houses in one year. Much of the demolition work is concentrated in about 20 neighborhoods where the blight removal can have immediate positive effects (Behnan & Hinkle, 2009).

The Land Bank Authority in Detroit has filed close to 1,200 lawsuits in 2014 against owners of nuisance properties and so far has won consent agreements in more than 500 cases. The Land Bank then sells these properties to neighbors living adjacent or close by the property and have to keep the property free of nuisance (Behnan & Hinkle, 2009).

Despite the progress in removing blighted properties in Michigan. There are a lot of challenges that daunt the projects. Shortage of trained workers, trucks, bulldozers, and even clean dirt to fill the basements of the demolished houses are some of the challenges. The demolition contractors in most cases have had to buy sand and other fill from quarries at increased cost and inconvenience (Gallagher, L., 2009).

Several important efforts have helped the city of Detroit to keep pace with the need to remove thousands of blighted properties quickly. The Detroit Blight Removal Task Force is an important part of the administration, which has mapped out the city's roughly 380,000 parcels, creating the best digital database of the conditions of properties in the city. The Detroit Land Bank Authority is another important administrative body through which municipalities can hold, improve and sell tax foreclosed properties. For blight removal the Land Bank Authority readies the properties for demolition by clearing up any legal issues and hands out lists of properties to Detroit Building Authority, which works with private contractors to remove structures (Gallagher, L., 2009).

The Detroit Blight Removal Task Force has identified 78,506 blighted structures in Detroit in the following (DBRTF, 2014):

- Residential Structures Four Units or Less (legally defined as single-family): 72,328 units
- Residential Structures over Four Units (legally defined as multi-family): 707 units
- Commercial Structures with lot sizes smaller than 25,000 square feet: 3,904 units
- Commercial Structures with lot sizes greater than 25,000 square feet: 220 units
- Industrial Structures: 339 units

4.4.1. Deconstruction in Detroit

The absence of market demand for harvested materials, the increased costs and the impact of deconstruction on schedules are presented as challenges in the Detroit city blight removal projects (DBRTF, 2014). The Task Force has selected residential structures of four units or less as the best deconstruction candidates in Detroit. The current resale and wholesale distribution market can support deconstruction of only about 10 percent of Detroit's present inventory of blighted

structures in this category. That means that, under today's conditions, about 7,000 buildings can be cost-effectively deconstructed and recycled. The Task Force recommends starting with the "skim" model of deconstruction, where the property is appropriate and a market exists. This would result in an estimated 30- 35 new jobs in deconstruction and salvaging (DBRTF, 2014).

4.4.2. Demolition in Detroit

Mechanical demolition will likely address 90 percent of all removals necessary in Detroit. Mechanical demolition typically includes a three-person crew and can occur in as little as three hours once it has begun. The recommended approach for demolition of structures in Detroit is wet/wet demolition. A "wet/wet" demolition is wetting down as much of the demolition site as possible at all times, including the bucket and the debris pile and wetting down the load on the truck as it's being hauled to the landfill (load stays wet the entire time). A typical candidate for mechanical demolition is a structure with one or more of the following characteristics (DBRTF, 2014):

- The structure is on the city's emergency demolition list and has to come down immediately;
- Structures that require significant asbestos abatement solutions which are typically too cost-prohibitive to be good rehabilitation or deconstruction candidates;
- The structure is in a defined geographic area with high levels of vacancy and blight, where there is an opportunity to demolish at some level of scale;
- The structure has fallen into a particular level of decay due to neglect, the elements, or a previous fire, and there is little or no salvage value remaining.

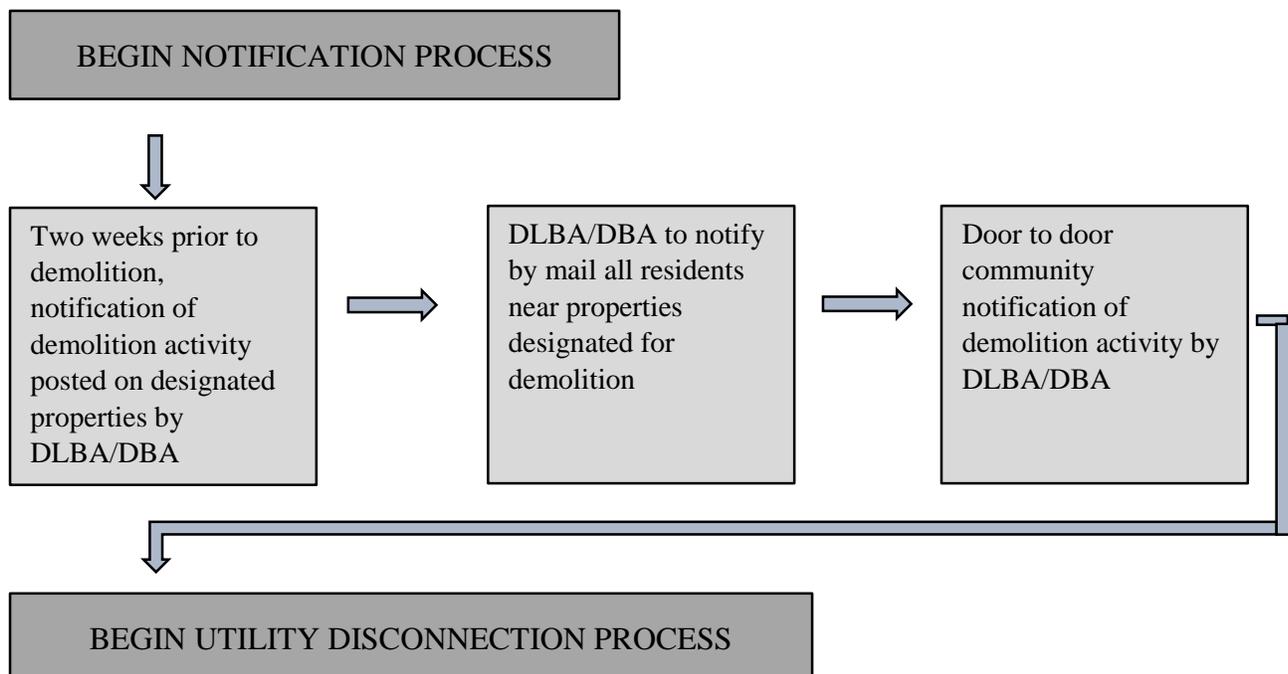
4.4.3 Recycling Detroit's demolition waste

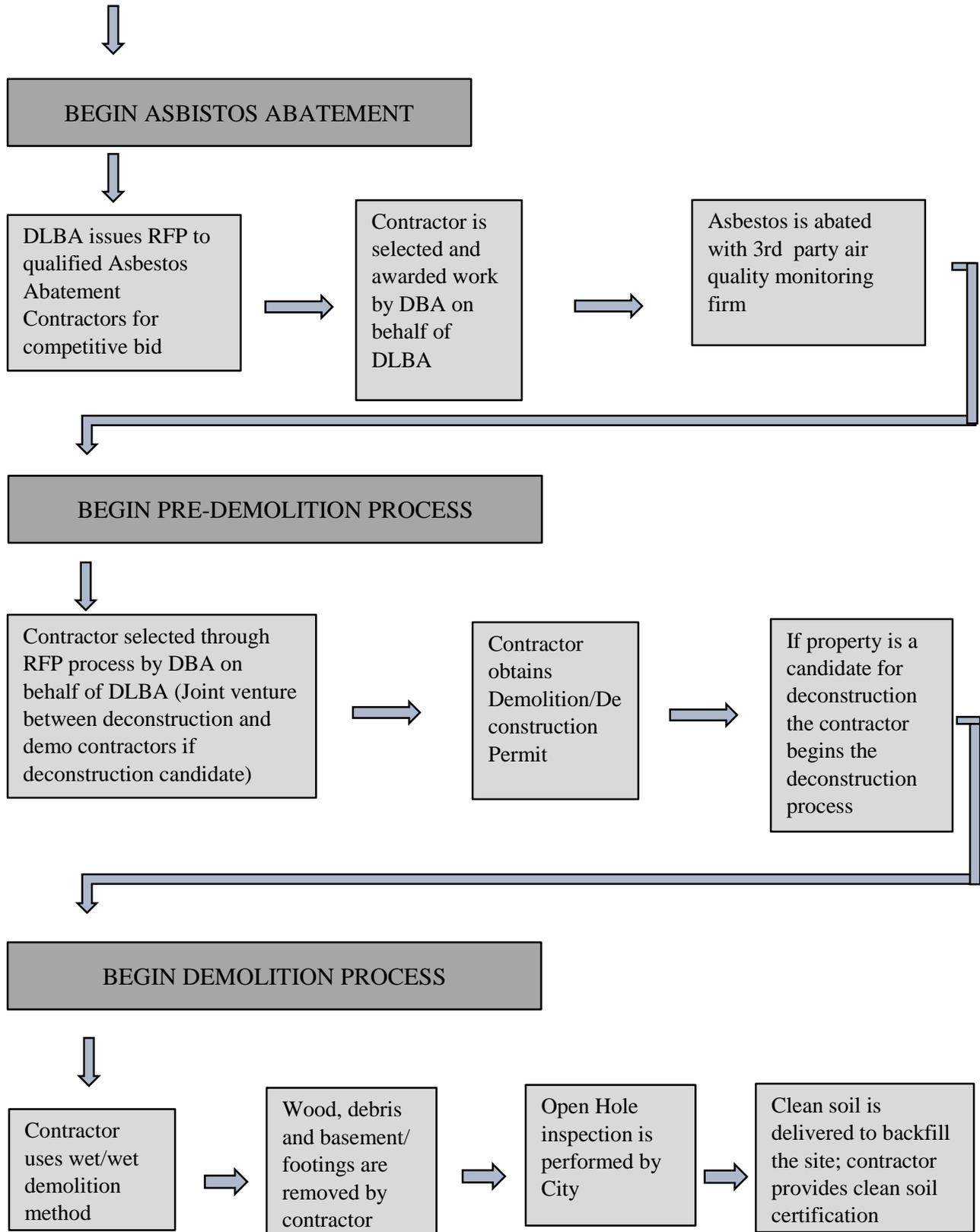
The landfills in Michigan are located at the southeast, which are generally about 30 miles from Detroit city. Though the landfills have more capacity than required for the blight removal waste from the city of Detroit, it also has low prices which even invites landfill from Canada. The goal of city is to divert waste from landfills where possible (DBA, 2014).

The largest single cost factor for demolition in Detroit is the cost of trucking debris from the city to these landfill locations. If recycling centers are provided within city limits, it would reduce the average demolition cost dramatically, considering the offset from recycling versus the hauling, fuel, tipping fees and limited hours of operation at the landfill. Recycling centers within the city of Detroit would also keep revenue from this project in the city, creating jobs for Detroiters. A recycling materials market must exist for recycling centers to make the investment in Detroit. Funding sources for deconstruction and demolition must be defined to support the need for recycling centers as well as contractor growth. The potential cost savings of two recycling centers within city limits is approximately 10 percent of total demolition cost per structure. If the average cost of demolition, including any deconstruction, is \$10,000, this could save at least \$1,000 per demolition project. Assuming approximately 72,000 structural demolition candidates, this could result in a cost savings of up to \$72 million. Locating two recycling centers within the city would cut the average trucking distance by one-half for demolition contractors. Contractors could also pay lower tipping fees through large-scale, pre-negotiated contracts with the Detroit Land Bank Authority. In addition, an anticipated 120 new jobs are possible through the creation of two recycling centers (DBRTF, 2014).

4.4.4. Recommended demolition process by Detroit Blight Removal Task Force

The Detroit Blight Removal Task Force has provided recommendations along with concerned authorities in order to insure efficiency in the blight removal process from start to end. The Task Force recommends that Detroit Land Bank Authority should ask demolition and deconstruction companies to submit combined Request For Proposal (RFP) where deconstruction is viable. This is to ensure increased coordination and decrease the hand-off time from deconstruction to demolition. It is also recommended that the RFPs are based on the size of the job and size of contractors. This method allows large contractors to secure large jobs, because the smaller contractors do not have sufficient finances to handle larger demolition projects. The city always gives priorities to Detroit based contractors. If firms outside of Detroit are needed to achieve targeted volumes they should be required to hire qualified Detroit residents to perform the work (DBRTF, 2014). The following illustrates the recommended demolition clearance process by Detroit Blight Removal Task Force.





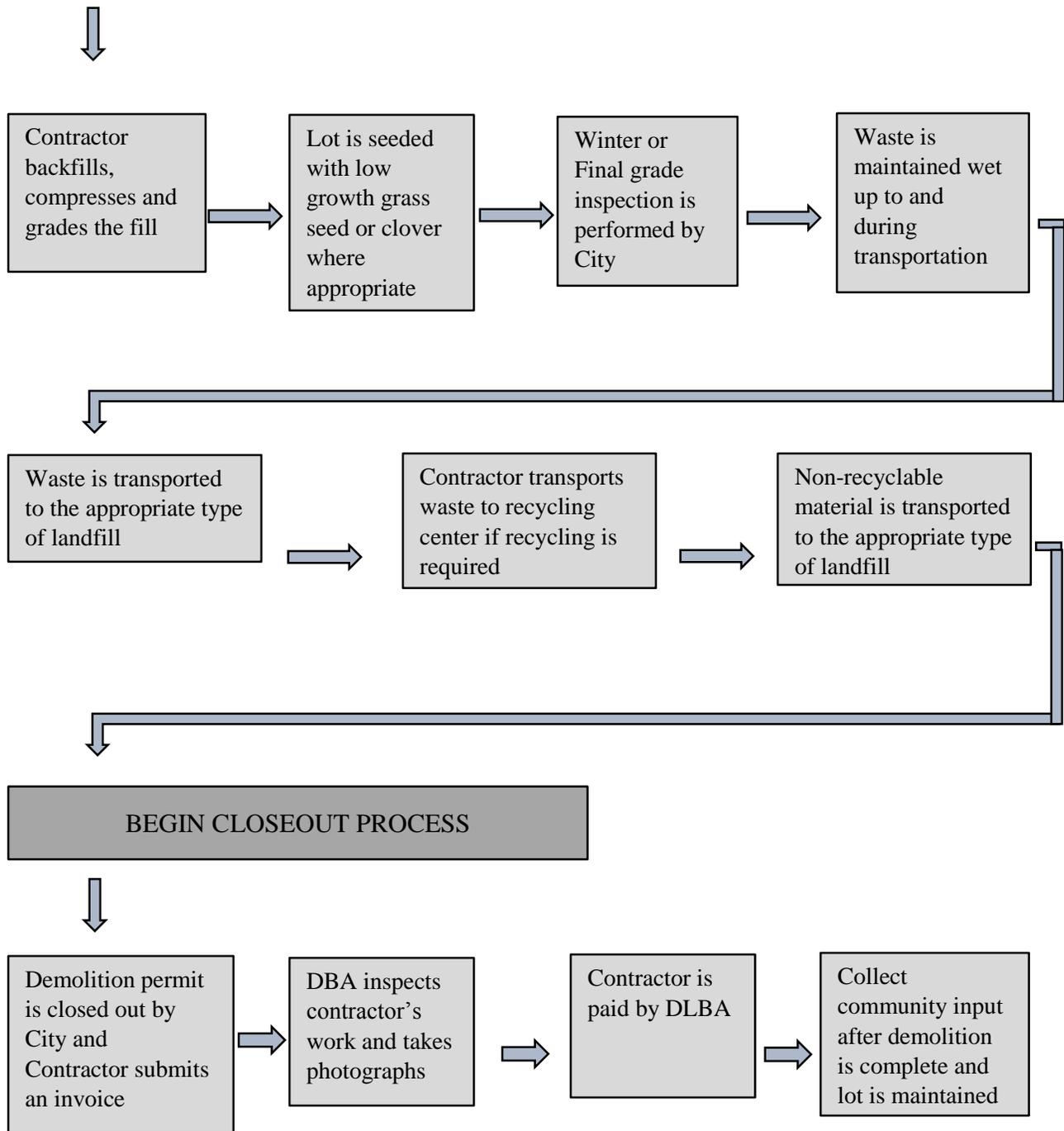


Figure 4.1 Recommended building demolition process in Detroit (DBRTF, 2014)

4.5. SUMMARY

This chapter reviewed the property abandonment issues related to various communities in the United States and in particular Michigan. Due to the industrial decline in many communities in the United States, there are a large number of abandoned buildings that are left to decay and the state governments are responsible for removal of such blighted properties.

In the case of Michigan, even though large amounts of funds are dedicated currently for blight removal and contractors are demolishing hundreds of buildings per week, deconstruction has been implemented on a very small scale. This is creating large amounts of waste that are going to landfills and are depriving the people of Michigan of potential job opportunities, environmental benefits and efficient use of construction material.

CHAPTER 5

5.0. SUMMARY, CONCLUSIONS AND AREAS OF FUTURE RESEARCH

5.1. INTRODUCTION

This research discussed demolition, deconstruction and design for deconstruction based on the available literature and the existing industry practices. Costs associated with demolition and deconstruction projects were discussed and compared. A comparison of demolition and deconstruction was presented. Finally, removal of abandoned properties in urban areas of Michigan were discussed. This chapter presents a summary, observation and conclusion of the research based on the objectives that were initially identified. Finally, potential future areas of research are presented.

5.2. RESEARCH LIMITATIONS

The research had some limitations and in the author's opinion the following two were the main limitations in this research:

1. *Few interviews conducted*: the research was primarily limited by the very few number of interviews that were conducted with professionals in the industry. Especially in the case of deconstruction, no specialized firm or contractor was interviewed. An increased number of interviews with both demolition and deconstruction professionals would have provided a more detailed understanding of the practices in the industry.
2. *Cost recommendations are driven from case studies only*: all the data and recommendations provided for the cost of demolition and deconstruction are driven from case studies only.

Site visits, contractor's cost database details and in-depth study of the cost on the field would have provided a more detailed and up to date cost recommendations for the study.

5.3. SUMMARY, OBSERVATIONS AND RECOMMENDATIONS

The goal of this research was to investigate and compile analysis regarding the various approaches in demolition and deconstruction of buildings and the associated costs. Following is a discussion of the work done under the objectives of the research:

5.3.1. Understand various approaches for demolition, deconstruction and design for deconstruction

Various academic papers, thesis reports, case studies, industry reports and manuals available in these fields were studied and the best practices and key lessons are compiled and analyzed. Steps required for planning and implementation of demolition, deconstruction and design for deconstruction projects were discussed. Further, the various approaches used for demolition and deconstruction and equipment needed to carry out the projects were reviewed.

It is established that demolition using heavy equipment is the traditional process for building removal. Modern demolition equipment removes structures quickly, destroying the materials within and creating solid waste destined for landfills. Environmental impacts from demolition activities are sizeable, both upstream and downstream. On the other hand, deconstruction can work to offset the environmental impacts of the building related waste. Deconstruction not only diverts wastes from landfills, it also reduces greenhouse gas emissions by reducing the need to extract and ship new materials and also gives rise to a new industry of skilled jobs. In order to transform the industry, demolition should incorporate successful aspects of deconstruction, and future

construction should incorporate design for deconstruction for maximum use of low cost construction material.

5.3.2. Understand costs associated with various approaches and possible quantification process for demolition and deconstruction

Various academic papers, thesis reports, case studies, industry reports and manuals available in the fields were studied and the best practices and key lessons were identified for approaches used in cost estimation of demolition and deconstruction projects. All the pre-estimation tasks that are necessary for gathering information and planning for the project were introduced with their impact on the cost. A breakdown of the major cost components of a demolition and deconstruction projects were presented through case studies. A limited number of interviews with contractors were also conducted and a summary and analysis was presented. The interviews provided information regarding the planning, estimation and implementation of the demolition and deconstruction projects from the contractors' point of view.

It is established that, overall deconstruction can be more cost effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvaged material. On average, deconstruction costs are higher than demolition costs, but the net cost of deconstruction with salvage is lower than demolition using retail salvage values or wholesale prices for the salvaged material.

5.3.3. Develop a comparison matrix for demolition and deconstruction

Based on the lessons learned and information gained from the literature review, industry review and interviews, a comparison matrix for demolition and deconstruction was presented. The

comparison matrix mostly compared the requirements for planning and implementation of both approaches. A cost comparison of demolition and deconstruction was also presented through literature review and case studies.

Demolition is heavily mechanized operation with quick and sometimes economic solutions to removal of buildings, but deconstruction is dependent on labor and small hand tools to operate. Therefore, deconstruction is more time consuming, requires more stringent workers safety measures and requires extensive site planning.

5.3.4. Identify approaches suitable for removal of abandoned properties in Michigan

Decline of the auto industry and the economic recession has caused widespread private commercial and residential property abandonment in Michigan for many years. Available literature in the field was reviewed, information of the current status of blight removal in Michigan was studied based on the information available in state journals and government websites. In particular, the case of Detroit was studied. Detroit has internationally gained the reputation of urban ruin and is fighting to get rid of the blighted properties for many years. As of December 2014, the city of Detroit is demolishing about 200 vacant houses a week and the city wants to reach a goal of demolishing about 10,000 houses in one year. The absence of market demand for harvested materials, the increased costs and the impact of deconstruction on schedules are presented as challenges in the Detroit city blight removal projects. As a result, only 10% of the blighted structures in Detroit are deconstructed presently and the rest are all demolished. Especially, in the case of residential structures, the whole buildings are changed into rubble and sent to landfills. The basis of selection of only 10% of the buildings for deconstruction are not very clear and justified in the case of Detroit. It is absolutely necessary that the economic feasibility, environmental and social benefits

of deconstruction in the case of Michigan are studied and analyzed. It is also recommended to study the marketability of the salvaged material in Detroit at different levels, so that deconstruction is more profitable to contractors.

For deconstruction to be more practicable and profitable for contractors, it is important that incentives are provided for deconstruction process. Policies need to be put in place that give deconstruction an edge over demolition. Increasing landfill tipping fees, and using volume-based fees may be more important to encourage deconstruction. Enforcement of hazardous materials regulations for asbestos surveying and handling will insure that small scale demolition projects do not receive an economic advantage based upon avoiding hazardous materials management costs. Permitting should be created for “deconstruction permits” that allows time for deconstruction with a reduced time delay overall than would be allowed for a demolition permit. Permit fees for deconstruction should be waived and demolition fees should be based not on the value of the work or other arbitrary factors such as number of stories, but on the projected volume of wastes.

5.4. AREAS OF FUTURE RESEARCH

Demolition, deconstruction and design for deconstruction are major parts of the construction industry and will continue to grow. These are complex business and require extensive planning, and technical and managerial skills to be successfully implemented. There is a scope for further research in these fields. Some of the important topics on which research can be done in future are enlisted below.

1. *Marketability of salvaged material:* one of the main challenges facing deconstruction is the absence of market demand for harvested material. The extra costs of handling, storing and

transporting the harvested material reduces the cost competitiveness of reuse and recycle. Hence, research can be based on supply chain management of harvested material from deconstruction process.

2. *Policies and incentives*: State policies can highly be effective in promoting deconstruction over demolition. Research can be based on studying policy changes at a State or Federal level to encourage deconstruction and make it more profitable for contractors and owners. This can be specifically studied in the case of Michigan, because demolition of blighted structures is being implemented at a very high level and incentives that can promote deconstruction need to be studied specifically in blight removal projects.
3. *Incorporation of maximum deconstruction in demolition*: Techniques, approaches and policies that can insure maximum reuse and recycle of construction material from demolition projects can be studied. Research can be conducted to study maximum incorporation of deconstruction into demolition, which may have the potential benefits of reduced schedules of demolition and environmental benefits of deconstruction.

This research provides information regarding technical, management and cost issues related to demolition and deconstruction projects. It includes modern practices, various approaches, factors affecting decisions, equipment and resources needed, recycling and reuse of materials, regulatory requirements, and cost estimation process for demolition and deconstruction. The comparative study of demolition and deconstruction provides a guide to choose the most suitable approach for removal of an existing structure.

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APPENDIX A

SURVEY OF CONTRACTORS

What to produce

The objective of this survey is to understand the practices and associated costs prevalent in the demolition and deconstruction industry in Michigan. Following is the information I need to produce from this survey:

- Major factors that affect the planning and implementation of demolition and deconstruction projects from contractors' point of view.
- A range of costs for demolition and deconstruction projects.
- Cost comparison matrix for demolition and deconstruction projects.

What information is needed

Based on the above mentioned objectives or information that needs to be produced, the survey intends to gather information on the practical aspects of demolition and deconstruction from contractor's point of view. In order to achieve the above mentioned objectives the survey should be able to gather project specific information from the contractors on the following aspects:

- Information regarding the contractor
- Planning for a project
- Cost estimation or quantification process for demolition and deconstruction projects.
- Major cost factors in demolition and deconstruction projects.
- Selecting an approach
- Implementation

In order to gather the information needed, I have considered two typical buildings for demolition and deconstruction. One is a two story single family residence of about 2500 square foot area. Another is a multifamily residential building of five story. Each case will be considered separately for demolition and deconstruction. Cost estimations will be provided based on the cost items with a cost range for different scenarios.

1. Single family residence:

According to the National Home Builders Association an average home size in the United States is about 2700 sq.ft. or less. I have chosen 2500 square feet area of the house with two floors and a basement. The construction is considered typical wood frame structure with gabled roof.

2. Multifamily apartment building:

A 5 story multi-family residential structure. The foot print of the building is 100x50 ft. The building has a complete basement also. Total build-up area of the structure is about 30,000 sq.ft. The construction includes steel construction for the first 3 floors and two floors above maybe of wood frame structure. The site is located at a down-town area surrounded by other buildings.

What questions to ask:

The first part of the survey will include questions regarding the background of the contractor, years of experience and area of specialty, etc. The contractor will be provided with questions

based on two cases and will be asked to provide information regarding the planning and implementation of demolition or deconstruction of the buildings. The questions will include the following aspects:

- Planning for the project
- Equipment and personnel needed
- Approach
- Cost components
- Cost estimation

I. BACKGROUND OF THE COMPANY/CONTRACTOR

1. Which of the following building disassembly businesses does your firm engage in?

- a. Demolition
- b. Deconstruction
- c. Demolition and deconstruction
- d. Salvage
- e. Other.....

2. What role do you play in the firm?

- a. Owner
- b. Construction/Project Manager
- c. Estimator
- d. Other.....

3. What state or geographic region do you mainly operate in?

4. How many demolition/deconstruction projects have you worked on and over how many years?

- a. Demolition projects.....
- b. Deconstruction projects.....

II. BUILDING DEMOLITION/DECONSTRUCTION COST SPECIFIC QUESTIONS

1. What are the initial steps you take before deciding on a particular approach and estimation for a project?

2. Based on which main factors do you decide whether to demolish a structure or deconstruct it, if you were given option?

3. What in your opinion are the significant differences between deconstruction and demolition of buildings?

4. What is the cost estimation process you go through once you have settled on an approach?

5. What would you consider the main components of a building demolition/deconstruction project for estimating the cost of the project?

- a. Survey
- b. Hazardous Material Abatement
- c. Permit
- d. Engineering Survey
- e. Labor
- f. Equipment
- g. Overhead and Profit
- h. Disposal Cost
- i. Transport Cost
- j. Others.....

6. What are the overall cost range for different type of structures?

- . Single family house
- . Mid-rise office building
- . High-rise building
- . Multi-family
- . Industrial building

