
REPORT 10

DECONSTRUCTION AND MATERIALS REUSE IN THE UNITED STATES

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Abstract: The demolition of buildings produces enormous amounts of debris that in most countries results in a significant portion of the total municipal waste stream. Deconstruction – the systematic disassembly of buildings in order to maximize recovered materials reuse and recycling - is emerging as an alternative to demolition around the world. While the process of demolition often leads to the mixing of various materials and contamination of non-hazardous components, deconstruction is actually the source separation of materials. This paper will present an overview of the issues of deconstruction and materials reuse in the United States. The issues covered will include waste impact of the construction industry, deconstruction tools and techniques, economics of deconstruction and marketing of used building materials, materials reuse businesses, and barriers to deconstruction.

Keywords: Construction and Demolition Waste; Deconstruction; Landfilling; Materials Reuse; Repair; Sustainable Development

1.0 INTRODUCTION

The demolition of building structures produces enormous amounts of materials that in most countries results in a significant waste stream. In the U.S., construction and demolition (C&D) waste is about 143 million metric tonnes (MMT) annually that is for the most part landfilled. Deconstruction may be defined as the disassembly of structures for the purpose of reusing components and building materials. The primary intent is to divert the maximum amount of building materials from the waste stream. Top priority is placed on the direct reuse of materials in new or existing structures. Immediate reuse allows the materials to retain their current economic value

Deconstruction of buildings has several advantages over conventional demolition and is also faced with several challenges. The advantages are an increased diversion rate of demolition debris from landfills; “sustainable” economic development through reuse and recycling; potential reuse of building components; increased ease of materials recycling; and enhanced environmental protection, both locally and globally. Deconstruction preserves the invested embodied energy of materials, thus substituting recovered existing materials for the input of embodied energy in the harvesting and manufacturing of new materials.

The challenges faced by deconstruction are significant but readily overcome if changes in design and policy occur. These challenges include: existing buildings have not been designed for dismantling; building components have not been designed for disassembly; tools for deconstructing existing buildings often do not exist; disposal costs for

demolition waste are frequently low; dismantling of buildings requires additional time; building codes and materials standards often do not address the reuse of building components; unknown cost factors in the deconstruction process; lack of a broad industry identity with commensurate standardized practices; buildings built before the mid-1970's with lead-based paint and asbestos containing materials; and the economic and environmental benefits that are not well-established.

Generally the main problem facing deconstruction today is the fact that architects and builders of the past visualized their creations as being permanent and did not make provisions for their future disassembly. Consequently, techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at institutions around the world, and government policy is beginning to address the advantages of deconstruction by increasing disposal costs or in some cases, forbidding the disposal of otherwise useful materials. Designing buildings to build for ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. The objective of this paper is to provide information about building deconstruction and materials reuse programs in the United States.

1.1 Waste Impact Of The Construction Industry

The construction industry contributes an incredibly large amount of waste to the municipal solid waste stream (MSW) in the United States each year. Quantifying This annual waste production is an inexact science. To date, the most thorough attempt to estimate the total tonnage of Construction and Demolition (C&D) debris was made by Franklin Associates of Prairie Village, Kansas. Their work, titled *Characterization of Building-Related Construction and Demolition Debris in the United States*, was developed for the EPA in 1998 and produced a reasonable estimation of tonnage of waste generated through residential and non-residential demolition, renovation and construction for the year 1996. The following work is an estimation of the tons of debris produced during the year 2000. The techniques used to derive these numbers are the same as those used in the Franklin Associates report. The numbers utilize easily accessible U.S. Census information for the year 2000 combined with research statistics taken directly from the Franklin Associates Report (1998).

Estimated Generation of New Residential Construction Debris

The techniques used to estimate the amount of debris generated per year by the residential construction industry are as follows:

1. Estimate the total dollars of new residential construction put in place during the year 2000:

This value was found by adding the total value of Private New Housing Units to Public Housing and Redevelopment (Current Construction Reports C-30, 2002).

Private New Housing Units	\$265,047 million
Public Housing and Redevelopment	<u>\$ 4,308 million</u>

2. Estimate the average cost of residential construction per square foot for the year 2000:

This number was found by dividing the total value of residential construction put in place by the total sq. ft. of new construction put in place. The most current values obtained for these variables were for the year 1998. To adjust the 1998 numbers to 2000, the values were projected from 1988 to 1998 to 2000 proportionately (Construction and Housing, 2002).

	<u>1988</u>		<u>1998</u>		<u>2000</u>
Value (billion \$)	116.2	(48%)	173	(9.6%)	188.6
Total Mill. Sq. Ft.	2,181	(33%)	2,902	(6.6%)	3093

The percentages in the first column were given numbers and the numbers in the second column were in extrapolation based on a two year interval, rather than the ten year interval.

Value of Construction put in place (million \$) / Total Square Feet of Construction put in place (2000) = $188,600/3,093 = \$61/\text{ft}^2$ ($\$675/\text{m}^2$)

3. Estimate the Total Square Feet of New Construction for the year 2000

This number is found by dividing the Total Dollars of new residential construction from the first problem (\$269.355 billion) and dividing it by the estimated cost per square foot of residential construction (\$61/sq. ft.)
 $\$269.355 / \$61/\text{sq.ft.} = 4.416 \text{ billion ft}^2$ (410 million m^2)

4. Estimate the average residential construction waste generation per square foot

The Franklin Associates report uses $4.38 \text{ lb}/\text{ft}^2$ ($21.5 \text{ Kg}/\text{m}^2$) of waste generation in their calculations. This number coincides with recent reports that a 2000 square foot (187 m^2) house produces 8000 lbs (3630 Kg) of debris so this number was kept for calculations.

5. Calculate total generation of debris by the residential construction industry for 2000

This number is found by multiplying the total square feet of new construction by the debris generation per square foot and dividing that number by 2000 to get tons.

$(4,416 \times 4.38) / 2000 = 9.67 \text{ million tons}$ (8.8 MMT) of debris generation (2000)

Estimated Generation of New Non-Residential Construction Debris

The techniques used to estimate the debris generated per year by the non-residential construction industry are as follows:

1. Estimate the total dollars of new non-residential construction put in place during the year 2000

This value was found by adding the total values of private non-residential construction, public industrial, public educational, public hospital, and public other (Current Construction Reports C-30, 2002).

	<u>(2000)</u>
Private Non-Residential	\$208,241 million
Public Industrial	\$ 1,157 million
Public Educational	\$ 49,814 million
Public Hospital	\$ 4,135 million
Public Other	<u>\$ 29,151 million</u>
	<i>\$292,498 million</i>

2. Estimate the average cost of non-residential construction per square foot for the year 2000

This value was found by dividing the total value of non-residential construction put in place by the total square feet of new non-residential construction put in place. The most current value obtained for these variables were for the year 1998. To adjust the 1998 numbers to 2000, the values from 1988 to 1998 to 2000 were projected proportionately. (Construction and Housing, 2002)

	<u>1988</u>		<u>1998</u>		<u>2000</u>
Value (billion \$)	97.9	(37%)	134	(7.4%)	143.9
Total (Million sq. ft.)	1,413	(12%)	1,581	(2.4%)	1,619

Value of construction put in place / Total square feet of construction put in place (2000)
 $= 143.9 / 1.619 = \$88.88/\text{ft}^2$ (\$958/m²)

3. Estimate the total square feet of new non-residential construction for the year 2000

This number is found by dividing the Total Dollars of new non-residential construction from item no. 1 above (\$292,498 million) and dividing it by the estimated cost per square foot of non-residential construction (\$88.88/ft²)

$$\$292.498 / \$88.88/\text{ft}^2 = 3.29 \text{ billion ft}^2 (305 \text{ million m}^2)$$

4. Estimate the average non-residential construction waste generation

For the purpose of this paper, the Franklin Associates estimation of 4.02 lbs/ft^2 (19.6 Kg/m^2) was used.

5. Calculate total generation of debris by the non-residential construction industry for 2000

This number is found by multiplying the total square feet of new non-residential construction by the debris generation per square foot and dividing the number by 2000 to get tons.

$$(3,290 \times 4.02) / 2000 = 6.614 \text{ million tons (6 MMT) for the year 2000}$$

Estimated Generation of Residential Renovation Debris

The techniques used to estimate the amount of debris generated per year by the residential renovation industry are as follows:

1. Estimate the total dollars spent on improvements and repairs for the year 2000

This value was obtained by adding the amount spent on improvements for the year 2000 to the amount on repairs (Expenditures for Improvement and Repairs, 2002).

Improvements	\$110,739 million
Repairs	<u>\$ 42,236 million</u>
	<i>\$152,975 million</i>

2. The Franklin Associates report provides the following estimates in their report for the year 1996

Estimates for Remodeling	Million jobs	Tons/job	Million Tons
kitchens (minor)	1.25	0.75	0.937
kitchens (major)	1.25	4.50	5.625
baths (minor)	1.80	0.25	0.450
baths (major)	1.20	1.00	1.200
additions	1.25	0.75	0.938

Replacements

Concrete from driveway replacements	13.000 tons/year
Asphalt roofs	6.800
Wood roofs	1.400
Heating and A/C replacements	1.574
Kitchen remodeling	6.562

Bathroom remodeling	1.650
Additions	0.938

3. Estimate the percent increase in debris generation from 1996 to 2000

Because of the lack of available information regarding this subject, the information available was used and extrapolated using a price conversion factor from 1996 to 2000 to calculate a plausible inflation percentage to apply. This begins with a price index conversion factor from 2000 dollars to 1996 dollars: Conversion Factor = 0.886.

This conversion factor can be used to compute how much the expenditures in 2000 (\$152,975 million) would be equivalent to in 1996: 1996 expenditures = 0.886 x \$152,975 = \$135,537 million.

The actual expenditures in 1996 on renovations was \$114,300 million. Using the value that the 2000 expenditures would equate to in 1996 and the actual expenditures for 1996, we can obtain an approximate percentage increase in the amount on renovation. This percent increase could be applied to the number of jobs and thus the amount of waste generation.

$$(\$135,537 - \$114,300) / \$114,300 = 18.6\%$$

4. Apply the increase to the jobs and tonnage provided in the Franklin Associates report

	<u>1996</u>	<u>2000</u>
Concrete from Driveway Repl.	13.000 (18.6%)	15.418
Asphalt Roofs	6.800 (18.6%)	8.065
Wood Roofs	1.400 (18.6%)	1.660
Heating and A/C Repl.	1.574 (18.6%)	1.867
Kitchen Remodeling	6.562 (18.6%)	7.783
Bathroom Remodeling	1.650 (18.6%)	1.957
Additions	<u>0.938 (18.6%)</u>	<u>1.112</u>
<i>TOTAL</i>	<i>31,924 million tons</i>	<i>37.862 tons (34.5</i>

MMT)

Estimated Generation of Non-Residential Renovation Debris

The techniques used to estimate the amount of debris generated per year by the non-residential renovation industry are as follows:

1. Estimate the total dollars spent on non-residential improvements and repairs during the year 2000

This value was found by interpreting the proportion of dollars spent on non-residential renovation to dollars spent on residential renovation to be the same for the year 2000 that

it was in 1996. The Franklin Associates report assumed this proportion to remain constant enough to use it for 1996, so it will also be used in this calculation:

$$(\$100,400 / \$114,300) \times \$152,975 = \$134,372 \text{ million}$$

	<u>1996</u>	<u>2000</u>
Non-Residential renovation	\$100,400	\$134,372
<u>Residential renovation</u>	<u>\$114,300</u>	<u>\$152,975</u>
TOTAL	\$214,700 million	\$287,347 million

In following with the methodology of the Franklin Associates report, the amount of debris produced in non-residential renovation will be assumed to be directly proportional to the amount produced in residential renovation. Because the amount spent on non-residential renovation was approximately 87.8% (\$134,372/\$152,975) of that spent on residential renovation, it will be assumed that the amount of waste produced in non-residential renovation is also 87.8% of that produced in residential renovation.

$$(0.878 \times 37.862) = 33.243 \text{ million tons (30.218 MMT)}$$

Estimated Generation of Residential and Non-Residential Demolition Debris

In their work for the EPA, *Characterization of Building-Related Construction and Demolition Debris in the United States*, Franklin and Associates estimated that approximately 245,000 residential building and 45,000 non-residential buildings were demolished in 1996. The numbers were computed by averaging the available U.S. Census numbers from the years 1984 to 1995. Because U.S. Census demolition statistics were discontinued as of 1995, it is not currently possible to calculate a reasonable national approximation of demolition statistics.

For the purposes of estimating annual waste for the year 2000, the same numbers were used for residential and non-residential demolition debris as those used in the Franklin Associates report. The first reason for doing this was the aforementioned lack of current demolition statistics. Additionally, because the Franklin Associates used an average of the years 1984 to 1995 for their 1996 estimate, they assumed that there is not an upward trend associated with time in the number of demolitions taking place. If there is, it is quite possible that it would be offset by the rise in environmental awareness and tipping fees during that time. Thus, the following estimation of residential and non-residential demolition debris is taken directly from the Franklin Associates report.

Residential Demolition Debris

Number of demolitions (2000)	245,000
Average size of demolished residence	1396 ft ²
Estimated waste generation per foot	115 lb/ ft ²
Total	19.7 million tons (17.9 MMT)

Non-Residential Demolition Debris

Number of demolitions (2000)	45,000
Average size of demolished residence	13,299 ft ²
Estimated waste generation per foot	173 lb/ft ²
<i>Total</i>	<i>50.4 million tons (45.8 MMT)</i>

Table 1. Summary of Estimated Building-Related C&D Debris Generation, 2000
(Million Tons)

Residential	Non-residential	Totals	
<u>Construction</u>	9.670	6.615	16.285 (10%)
<u>Renovation</u>	37.862	33.243	71.104 (45%)
<u>Demolition</u>	19.700	50.400	70.100 (45%)
TOTALS	67.232 (43%)	90.257 (57%)	157,489 (100%)

Note: 1 Million Ton = 0.91 Million Metric Ton (MMT)

Thus, according to the calculations above, the total C&D waste generated for the year 2000 was approximately 157.5 million tons (143.3 MMT). This represents a 16% increase in waste production in the industry over the four-year period from 1996 to 2000. Because many of the numbers used in the above calculations are based on assumed progressions and extrapolation of previous years, the accuracy of this estimate is unknown.

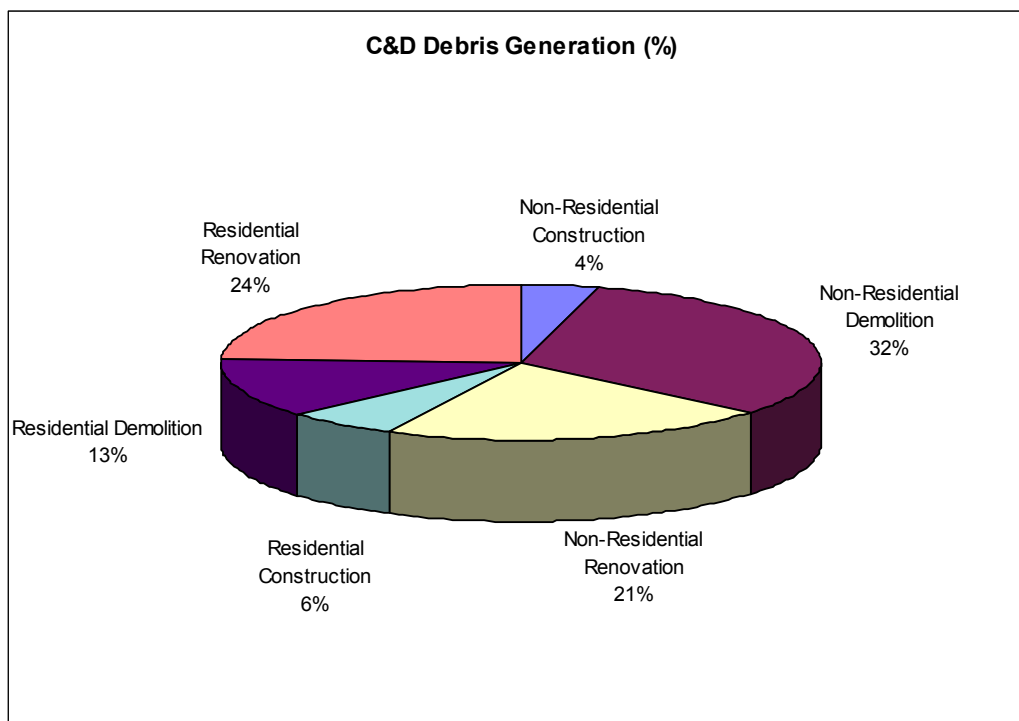


Figure 1. Construction and Demolition Waste Generation in 2000

1.2 Waste Statistics

According to the debris generation statistics from the previous section, the demolition industry (renovation and demolition) produced more than 140 million tons of waste in 2000. This equates to 90% of all C&D waste for the year. This statistic conveys the importance of deconstruction as a method for recovering reusable building components. The EPA estimates that 35 to 45 percent of this debris is sent to Municipal Solid Waste (MSW) landfills or unpermitted landfills, and 20 to 30 percent is reused or recycled (Franklin Associates). For the purposes of this discussion we will assume that 75% of C&D waste is currently landfilled and 25% is recovered for recycling and reuse.

Table 2 establishes estimated quantities of materials bound for C&D landfills, MSW and unpermitted landfills, or recovery. It can be seen from this table that more than 115 million tons of construction and demolition waste was landfilled in the year 2000. Of this, over 90 million tons resulted directly from demolition and renovation waste.

Table 2. Estimated Quantities of Materials bounds for C&D landfills, MSW and permitted unpermitted landfills, or recovery.

	<i>C&D Landfills (40%)</i>	<i>MSW Landfills, Onsite Management, Unpermitted Landfills (35%)</i>	<i>Recovered</i>	<i>Total</i>
<i>Residential</i>				
<i>demolition</i>	7.880	6.895	4.925	19.700
<i>renovation</i>	15.145	13.252	9.465	37.862
<i>construction</i>	3.868	3.385	2.418	9.670
<i>Non-Residential</i>				
<i>demolition</i>	20.160	17.640	12.600	50.400
<i>renovation</i>	13.297	11.339	8.311	33.243
<i>construction</i>	2.646	2.315	1.654	6.615
Total	62.996	55.121	39.372	157.490

The potential C&D waste diversion due to deconstruction is astounding. For example, let us quickly consider a conservative scenario in which the United States could reach a deconstruction rate of 75,000 out of the estimated 290,000 buildings that were demolished in the year 2000. These demolitions generate approximately 70.1 million tons of debris (see Table 1). Assuming that 75% of demolition debris is landfilled (the number is probably quite higher), then approximately 52.5 million tons of demolition debris was landfilled in 2000. Let us say, for the sake of argument, that we deconstruct 75,000 of those buildings that would be otherwise destined for demolition. And let us say that we achieve a 75% recovery rate on these buildings. This would result in an approximate recovery of 9 million tons of waste from these 75,000 buildings. 9 million tons of demolition debris diverted from the waste stream with the potential to be reused and recycled, thus reducing the necessity to extract virgin materials from the earth. This would be a 17% decrease in demolition debris to be landfilled. Keep in mind that this is a conservative scenario and does not account for possible reuse of renovation debris. The potential waste diversion through wide scale deconstruction is actually much higher.

2.0 DECONSTRUCTION STRATEGIES, MACHINERY, AND TOOLS

2.1 Planning Issues for Deconstruction

There are numerous logistical issues to take into account when considering deconstruction as a building removal method. Steps must be taken to assure the owner that the building is a good candidate for deconstruction, that adequate time is available for the deconstruction, that the proper environmental assessments and permits have been obtained, that all hazardous materials have been accounted for, and that the right contractor for the job has been hired. These issues are identified and explored in the following discussion.

Building Inventory

The first decision to be made in the deconstruction planning process is whether or not the target building is a good candidate to be deconstructed. Not every building consists of the right components and is in the right physical condition to be disassembled for material salvage. The decision whether or not to deconstruct can be facilitated by a detailed inventory of the building's components. The detailed inventory serves to identify the cost effectiveness of deconstruction. This inventory can be made by anyone with knowledge of building construction techniques. A builder, architect, structural engineer, or a materials inspector would good candidates. Advice from someone who has an understanding of the materials salvage market may also be helpful. "A detailed building inventory requires inspection of every component, focusing on its condition and the manner in which it is secured to the structure" (Deconstruction: EPA, 2003). The inventory serves to identify construction methods and fasteners, as well as hazardous materials, which have a direct affect on economic feasibility. Table 3 outlines building characteristics that are generally present in highly deconstructable buildings.

Table 3. Characteristics of highly deconstructable buildings

Favorable Characteristics for Cost-Effective Building Deconstruction

- 1) *Wood framed buildings using heavy timbers and unique woods such as Douglas fir, American chestnut, and old growth southern yellow pine. These components are often found in buildings that were constructed before World War II.*
 - 2) *Buildings that are constructed using high value specialty items such as hardwood flooring, architectural mouldings, and unique doors or electrical fixtures.*
 - 3) *Buildings constructed with high-quality brick and low quality mortar. These will be easy to break-up and clean.*
 - 4) *Buildings that are generally structurally sound and weather tight. These buildings will have less rotted and decayed materials*
- (A Guide to Deconstruction, 2000)*

Provide Adequate Time

Deconstruction is by nature a labor intensive process. It is estimated that the deconstruction of a building, depending on its extent, takes at-least two times and up to ten times as long as the demolition of the same building. Frequently, when a building needs to be removed it is because the owner of the property has another intended use for the property. In this scenario time is of the essence. Careful consideration should be taken to make sure that all parties are willing to sacrifice the time to properly deconstruct the building.

Permitting and Environmental Assessments

Most jurisdictions require demolition permits to remove a building. In many areas the permit is the same whether it be for deconstruction or for demolition. Only in areas where deconstruction has become established does it require a separate permit. The permits are generally not difficult to obtain. However, certain steps will often be required before the permit will be issued. "Approval of the demolition permit will often be linked to disconnection of electrical power, capping of all gas and sewer lines; and abatement of hazardous materials such as lead and asbestos" (Kibert et al, 2000). In areas where implementation of deconstruction is of high priority, lag time may be required before demolition will be allowed. The purpose of this is to eliminate the discrepancy between the speed of demolition and the time consumption of deconstruction, thus creating an incentive to deconstruct.

An environmental assessment should be made on the site in order to identify hazardous materials. "For commercial properties, it is the responsibility of the property owner(s) to make reasonable efforts to identify hazardous materials on the site prior to demolition or deconstruction. Reasonable efforts include a thorough visual, noninvasive inspection of all aspects of the site and structures by individual(s) trained in environmental assessment" (Deconstruction Training, 2001). Many commercial owners employ a consulting firm to conduct this environmental assessment. This provides tangible evidence that reasonable efforts were made to identify hazardous materials. There are no such requirements for residential property owners. Materials Hazards include lead-based paint and asbestos, underground fuel storage tanks, and electrical transformers or their components containing polychlorinated biphenyls (PCB) (Deconstruction Training, 2001).

Hazardous Materials Abatement

The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) both have federal regulations governing the management of asbestos containing materials (ACM) and lead-based paint (LBP) in buildings. OSHA worker protection requirements for both ACM and LBP are tougher on deconstruction than demolition because the exposure is much greater. EPA disposal regulations do not distinguish between deconstruction and demolition.

Contracting Process

The most important step for the owner in the deconstruction planning process is choosing a contractor. The owner should carefully draft a Request for Proposal/Invitation to Bid to solicit key information from Bidders. A deconstruction contractor must have an in depth understanding of demolition, construction, and the efficient flow of materials. Table 4 provides helpful suggestions concerning the selection of a deconstruction contractor.

Table 4. Tips for selecting deconstruction contractor

<i>Contractor Selection</i> <i>1) Match the capabilities and approach of the contractor to the characteristics of the building. Large buildings (more than three stories) and small masonry buildings will probably require heavy machinery for safe and cost-effective structural salvage. Light-framed, smaller building can often be most cost-effectively disassembled with manual labor.</i> <i>2) Require the submittal of a Resource Management Plan which outlines how the specified material recovery goals will be achieved.</i> <i>3) Specify separate goals for reuse and recycling, and consider giving reuse greater relative weight.</i> <i>4) Provide as much assistance as possible to reach the material recovery goals. For example, provide a list of reuse and recycling strategies/outlets located near the site.</i> <i>5) Divide the building removal into separate contracts, e.g., hazardous material abatement, building disassembly, processing of materials, and final site restoration. Some contractors may specialize in one of these areas.</i> <i>(A Guide to Deconstruction, 2000)</i>
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In order to tip the balance of feasibility in favor of deconstruction, partnerships are often a preferable option. Joint ventures between not-for-profit organizations, resident-owned businesses, developers, and private general contractors can make a deconstruction project cost effective. The following case study (see Table 5) examines the successful use of joint ventures in building deconstruction by the Hartford Housing Authority.

Table 5. Joint Ventures Case Study

***Case Study: Joint Ventures – Hartford Housing Authority
Hartford, Connecticut***

With partial funding through a HUD HOPE VI grant, the Hartford Housing Authority and a private developer joined forces with Manafort Brothers, Inc., a private demolition contractor, to deconstruct two buildings at Stowe Village. With years of experience in the deconstruction and salvage business, Manafort was key to the success of the project. Nine public housing residents were trained during the project and remained in the Laborer's International Union of North America. The project turned out to be so successful that the city of Hartford has identified other buildings for deconstruction and provided a warehouse for storage of materials (A Guide to Deconstruction, 2000)

2.3 Deconstruction Techniques, Methods, and Tools

Deconstruction can take a variety of forms. A building is a candidate for complete structural disassembly when a large portion of the materials have potential for reuse. Not all deconstruction projects involve complete disassembly of the building. A deconstruction project could fall within the category of a complete structural disassembly, a small soft-stripping project, or an individual assembly project.

Soft-stripping involves the removal of specific components of the building before demolition. For example, in a structurally weak building that does not have much salvageable material, only a few items may be desirable enough to salvage before demolishing the remainder of the building. Good candidates for soft-stripping include: plumbing or electrical fixtures, appliances, HVAC equipment, cabinets, doors, windows, hardwood, and tile flooring (A Guide to Deconstruction, 2000).

While the entirety of the building may not be worth deconstructing, certain assemblies within the building may be. Perhaps the rafters in an old building are of high quality heavy timbers and thus command a high salvage value. In scenarios like this, particular building assemblies may be targeted for removal before the building is demolished. Rafters, floor joists, wall framing members, and sheathing materials may be of size and condition to warrant salvage (A Guide to Deconstruction, 2000).

The chronology of the deconstruction process is of utmost importance. The proper sequence of disassembly increases jobsite safety and efficiency and protects salvageable materials from unnecessary damage. Whole building deconstruction can be broken down into the five basic steps listed in the Table 6.

Table 6. Deconstruction basic steps

5 Basic Steps to Building Deconstruction

- 1) Remove the trim work, including door casings and moldings.*
 - 2) Take out kitchen appliances, plumbing, cabinets, windows, and doors.*
 - 3) Remove the floor coverings, wall coverings, insulation, wiring, and plumbing pipes.*
 - 4) Disassemble the roof.*
 - 5) Dismantle the walls, frame, and flooring, one story at a time.*
- (Deconstruction Training, 2001)*

Having the proper tools and equipment on hand on a deconstruction project will decrease material damage and make the worker's jobs much easier. Project managers should carry an inventory checklist of tools on site. In addition to the traditional, tools and equipment are now being developed for the specific purpose of facilitating efficiency in building disassembly. These products, the pneumatic Nail Kicker and various shaping and surfacing machines, will be discussed later in this paper.

Deconstruction Sequence

The first step in removing a piece of material for salvage is to identify how that piece is fastened within the building. An understanding of how materials are installed is paramount in being able to uninstall them without damage. The following deconstruction sequencing is used for a basic residential structure. The piece by piece deconstruction of the buildings closely follows the five steps outlined earlier in this section. After each step in this process all nails should be removed and the materials should be sorted, stacked, and cleaned.

- Cabinet Removal
- Light Fixture Removal
- Window Removal
- Door Removal
- Floor Coverings
- Roof Deconstruction
- Wall Deconstruction
- Floor Deconstruction

2.4 Worker Training and Safety

Just as in the construction industry, efficiency and safety on the jobsite are of paramount importance in deconstruction. Training of workers in the areas of deconstruction techniques and field safety measures has a positive overall effect on the project.

Increased labor productivity reduces labor costs on the project. It also reduces project completion time, which is a barrier to the establishment of deconstruction. Similarly, minimizing workplace accidents has a reduction effect on long term costs for the deconstruction agent/contractor. In deconstruction, which by nature is a small profit margin industry, all possible cost reductions can be the difference between whether the project is cost-effective or not. Deconstruction workers should receive basic worker training, large equipment training, hazardous materials training, fall protection training, and, in some cases, rescue procedures training.

Basic Worker Training

The deconstruction process is generally more labor intensive and less technologically advanced. The skill level required to get the job done is not high. However, a well-planned, coordinated effort is required to complete a deconstruction project efficiently and cost-effectively. Workers should be trained in the use of the necessary hand and power tools, they should be made familiar of the various building materials and fasteners, and they should be taught construction techniques and the construction process. “Knowledge of construction techniques and the construction process will assist in the ‘reverse construction’ of the structures” (Kibert et al, 2000). Increased efficiency is not the only positive effect of this basic training. Combined with the experience of the actual deconstruction, this training provides workers with marketable skills that could lead to future careers in related industries. Table 7 provides a case study in worker training.

Table 7. Worker training case study

Case Study: Peoria Housing Authority

The JATC, a cooperative committee comprised of representatives from the PHA, local labor unions, and the Contractors’ Association, formed to provide construction training to public housing residents. The 2,000 hour program, which includes 160 hours devoted to deconstruction, provides workers with training in all aspects of building maintenance and repair.

The removal of building components offers trainees the opportunity to develop skills in a variety of areas:

- *Reseal toilet tanks and replace parts*
- *Replace faucet assemblies*
- *Repair refrigerator evaporator fans*
- *Replace range burners and igniters*
- *Replace burners in boilers*
- *Refinish cabinets and doors*

All of these are marketable skills that would merit consideration for employment with plumbing contractors, carpenters, or as a freelance handyman.

(A Guide to Deconstruction 11)

Large Equipment Training

Deconstruction does not generally require the operation of much large equipment. The exception to this is the forklift. The forklift is an important machine in deconstruction. It is used in the movement of building components around the jobsite, generally from the building to the storage area. In order to minimize job place accidents, care must be taken to be sure that all drivers of forklifts are properly trained. The Occupation Safety and Health Administration (OSHA) states, “Only drivers authorized by the employer and trained in the safe operations of industrial trucks or industrial tow tractors shall be permitted to operate such vehicles. Methods shall be devised to train operators in the safe operation of industrial trucks” (Deconstruction Training, 2001). There are multiply types of forklifts and workers must be certified to drive each forklift they operate.

Hazardous Materials Training

Workers should go through some formal training regarding hazardous materials such as lead-based paint (LBP) and Asbestos containing materials (ACM). This training is an essential job safety measure due to the potentially high levels of exposure that workers can experience on deconstruction projects. Raising worker awareness of proper handling techniques greatly diminishes the potential for exposure and related problems. For example, the University of Florida Center for Construction and Environment requires that all of its deconstruction workers attend an 8-hour ACM and LBP awareness training course (Guy Reuse and Recycling 9). This course is provided by the University of Florida’s Center for Training, Research and Education for Environmental Occupations (TREEO Center) and is in compliance with OSHA’s asbestos section 29 CFR 1926.1101 and lead section 29 CFR 1926.62.

Fall Protection and Rescue Procedures

Maintaining a reasonable level of jobsite safety is not only an economic and legal issue. Maximizing jobsite safety should be looked upon as a moral obligation. “A typical day in the construction industry in the United States will see one to three workers die from falls in the workplace. Falls are the leading cause of injury in the construction industry” (Deconstruction Training, 2001). OSHA requires employers to train workers who might be exposed to fall hazards on the use of fall protection equipment and rescue procedures.

It is required by OSHA that prompt rescue of fallen employees be provided for. It is important that emergency rescue procedures be established before work on the project has begun. Despite adequate precautionary procedures to avoid injurious falls, the nature of the industry dictates that accidents will occasionally occur. Steps must be taken and procedures established to protect the victim and rescuers in event of a fall.

3.0 WHOLE BUILDING REUSE

3.1 In Situ Building Reuse

Deconstruction should only be considered when adaptive reuse of the building is not an option. When a building reaches the end of its useful life, renovating the structure for reuse is always preferable to taking it down. In-situ building reuse is the modification of a building on site to be used again, generally for a similar purpose. Often times, such as when a business goes under, a building may simply be abandoned. Or a military base may close down, leaving hundreds of buildings with no purpose. In either of these situations the building may be in excellent overall condition and the location may be ideal. All too often such buildings simply go to waste. They rot away and are later demolished. Reuse of these buildings is an economical way to alleviate this problem. Not only that, but reuse minimizes the structure's impact on the waste stream, preserves its structural integrity, creates cheap infrastructure for the community, and often creates jobs, helping to stimulate the local economy. Any building whose useful life has come to an end and remains in relatively good condition is a potential candidate for reuse. Table 8 outlines factors that should be considered when analyzing the potential of a building for reuse.

Table 8. Factors influencing the potential of a building for reuse

<i>Factors Influencing a Building's Reuse Potential</i> <i>• The structure should be in good condition. The extant of work required to revive a rotted through building would cause it to not be cost-effective.</i> <i>• Should the building remain on site? If the land on which the building sits would better serve another purpose, deconstruction or moving the building to a new site for reuse (as discussed in the next section) may be a more feasible option.</i> <i>• Structures of historical value should be considered very carefully for reuse in order to preserve architectural styles that are no longer in use.</i> <i>• Generally the building should be converted for a similar use. It would obviously not be cost-effective to convert an old barn into an airport.</i>

Military base closings have provided numerous examples of successful in-situ reuse of buildings. Table 9 is a case study that explores the planned reuse of military barracks as part of the Fort Ord Pilot Deconstruction Project. These barracks are ideal for in-situ reuse as an affordable housing neighborhood. Their characteristics strikingly resemble the favorable factors listed in the above table. Their reuse will be for a similar purpose as their original use, as residences. This will serve to make the conversion simple and economical. Additionally, the layout of the site is already ideal for use as a small

neighborhood and the unique architecture of the barracks and site are considered to be worth preserving.

Table 9. In-situ reuse of military barracks

Case Study: Fort Ord Pilot Deconstruction Project

A group of forty-six barracks on the closed military base is to be converted for use as a colony of artist's studios with living quarters, public serving galleries, and educational buildings. The buildings will be converted to be used for a similar purpose as that for which they were originally built. This simplifies the project, making it more economical. Living quarters will be converted to artists' studios with living quarters and family housing, mess halls converted to public serving galleries, etc. The layout of the site is ideal for use as a small, quaint community.

The benefits of the reuse of these barracks are numerous. Compared to deconstruction, which was also implemented in other areas of Fort Ord, in-situ reuse is a more effective way to minimize waste generation from the barracks. Additionally, the minimal conversion necessary serves to minimize the cost and maintain the architectural integrity and "character" of the site and structures, and the project will provide the art community with affordable housing and a stimulating congregating area.

(Congleton, 2003)

3.2 Moving Buildings to New Sites for Reuse

The end of a building's useful life does not necessarily equate to the end of a building's structural integrity or physical usefulness. Occasionally, a building's useful life can end because it is no longer practical at the site on which it sits. For example, a barn on an old farm may be in excellent structural condition. However, if that farm is being developed into a shopping center, then the barn is no longer of good use on that site. In the case of a situation like this, removal of the entire building for reuse in another area, perhaps for another purpose, may be the best option. A building is generally a good candidate to be moved if the site is no longer accepting of that building and the building is in good shape or represents cultural, architectural, or historical significance.



Figure 2. Relocation of a barn for adaptive building reuse

The most important factor influencing the potential movement of a building to a new site is the old site's capacity to accept the building. A building should only be moved if there is a problem with it being where it is. Perhaps the building was originally built on a site which will not, due to its geology, sufficiently support the building. For example, a house built on a sink hole may be an excellent candidate for movement to a new site. Alternatively, the site may no longer be used for the purpose which is served by the building in question, thus necessitating a move. The barn example above exemplifies this situation.

Also contributing to the potential movement of a building are its physical characteristics. Of particular importance are buildings of high historical, architectural, or aesthetic significance. People, by nature, want to preserve those things that represent memories of times and places. Historically significant buildings serve a similar purpose as old photographs. They embody and preserve past cultures and ideologies. It is for this reason that there is a growing trend of people who prefer to renovate, restore and refurbish old houses into their homes in order to connect with more gracious elements of past living and secure a "slice of history".



Figure 3. Moving an entire building to preserve its historical/architectural value

Of course, the environmental benefits of moving a building, as opposed to deconstructing or demolishing it, should not be ignored. Moving the building to a new site serves to reduce, if not eliminate, the amount of waste generated by that building. The following case study (Table 10) examines Barn to be Home, a company that specializes in moving barns to new sites to be converted into homes.

Table 10. Moving barns to be converted into homes

Case Study: Barn to be Home

Barn to be Home's mission is to build partnerships and networks between individuals with antique structures to preserve and those who wish to utilize these structures for adaptive building reuse. Barn to be Home specializes in the relocation and adaptive reuse of "America's vanishing agricultural icon, the Barn." They are a licensed general contractor that can also provide design and structural engineering services for the barn to home conversions.

(Barn to be Home 1)

ISSUES OF COMPONENT REUSE

3.3 Benefits of Component Reuse

The world today is facing the reality of the impacts of over-consumption and environmental abuse. This realization will hopefully result in a shift from environmentally detrimental business practices to those that minimize environmental impact. Deconstruction and component reuse represents such a shift. The reuse of deconstructed building components, as opposed to the landfilling of demolished building components, presents obvious environmental advantages while maintaining comparable, if not favorable, economic characteristics. The benefits of component reuse can be described not only by their environmental and economic benefits, but also by their social and historical benefits.

Environmental Benefits

Without a doubt, the most important benefits provided by the reuse of deconstructed building materials are those they provide to our environment. Each timber that is reused is one less timber to be landfilled. Component Reuse diverts large volumes of Construction and Demolition Waste from landfilling. This preserves precious landfill space. Table 11 shows recovery rates for various deconstruction projects throughout the United States (Kibert et al, 2000). Recovery rates for lightwood framed construction are discussed in a paper by Chini and Nguyen (2003).

Table 11. Recovery rate for various deconstruction projects

Location	Case Study	Reuse/Recycling Rate
<i>San Francisco, CA</i>	<i>Presidio</i>	<i>87%</i>
<i>Fort McCoy, WI</i>	<i>USArmy Barracks</i>	<i>85%</i>
<i>San Diego, CA</i>	<i>US Navy Motor Pool Building</i>	<i>84%</i>
<i>Marina, Ca</i>	<i>Fort Ord</i>	<i>80-90%</i>
<i>Twin Cities, MN</i>	<i>Army Ammunition Plant</i>	<i>60-80%</i>
<i>Baltimore, MD</i>	<i>Four Unit Residential housing</i>	<i>76%</i>
<i>Port of Oakland, Ca</i>	<i>Warehouse</i>	<i>70%</i>
<i>Minneapolis, MN</i>	<i>Residential Building</i>	<i>50-75%</i>

The reuse of building components reduces the demand for newly manufactured materials. This reduction in manufacturing would in turn lead to less energy consumption in the manufacturing process and a reduction in the extraction of raw materials from the earth. Less material extraction and manufacturing means less associated pollution. For example, the reuse of a large old-growth timber means that that quantity of raw material

need not be extracted from the earth, transported to a manufacturing plant, cut, milled, treated, packaged, and transported to a storage facility. The associated energy consumption and pollution would thus be eliminated. Table 12 looks at the amount of lumber available for reuse in the United States.

Table 12. Lumber available for reuse

Case Study: Lumber Available for Reuse in the United States

The March 2002 article Wood-Framed Building Deconstruction, made an educated guess of the amount of lumber available for reuse. The purpose of this was not so much to come up with an exact number as to portray the astounding waste reduction possibilities of deconstruction. The following variables were assumed in the calculations:

- 1) An average of 13,000 Board Feet of lumber used in framing the average home.*
- 2) 245,000 homes demolished annually*
- 3) 25% loss during extraction*
- 4) The average size home demolished is half the size of today's homes*

Based on these assumptions, it was estimated that 1.2 billion board feet of lumber could be reused annually if deconstruction were implemented in place of demolition. This is large reduction in the waste stream. Note that these calculations assume that the average demolished house is half the size as today's average house. This is probably not accurate and thus their estimation could be quite small.

(Falk, 2000)

Finally, deconstruction necessitates an inspection for hazardous materials. The subsequent disposal of these hazardous waste materials reduces airborne asbestos, lead particles, and dust in the atmosphere that would be created through demolition (Macozoma, 2001).

Social and Economic Benefits

Setting the substantial environmental benefits aside, deconstruction is a cost-effective alternative to demolition. Numerous studies have shown that, although total costs are generally higher, the resale of materials on deconstruction products makes deconstruction a cheaper option than demolition. Table 13 shows an economic summary of a deconstruction project conducted by the Powell Center for Construction and Environment (PCCE) in Gainesville, Florida (Guy, 2003). This table gives a cost comparison of

deconstruction versus demolition on the project. Notice that overall costs for deconstruction, after material salvage, were less than 30% of demolition costs.

Table 13. Deconstruction versus demolition cost for a residential building

	Total Net Demolition			Total Net Deconstruction		
COSTS (\$)						
Permit	50.00			50.00		
Asbestos Survey	1200.00			1200.00		
Asbestos Abatement	740.00			740.00		
Disposal	5873.67	96.67 tons		1344.01	22.12 tons	
Toilet	63.00			63.00		
Supplies	10.00			637.93		
Labor and Equipment	3504.36			8469.38		
Total costs	11441	5.68 per SF		12504	6.21 per SF	
REVENUES (\$)						
Salvage	0.00			9415.00	4.67 per SF	
Total Net Costs	11441	5.68 per SF		3089.32	1.53 per SF	

Deconstruction creates more employment and training opportunities for low-skilled workers than does demolition. This brings jobs and career opportunities into the community, which stimulates the local economy. It has been estimated that for every landfill job created, resource recovery creates ten. The skills learned in deconstruction are marketable in the construction industry. In showing workers how to take a building apart, they learn how the building is put together.

Deconstruction and component reuse stimulate the economy through the creation of a salvaged materials market. This market provides the opportunity for the development of small businesses. Of course, the availability of cheap building materials is a cost savings to the community in its own right. Particularly in low income areas, deconstruction results in the availability of high quality used building materials that may not otherwise be affordable.

According to Macozoma (2001), other economic benefits of deconstruction include but are not limited to:

- Cost saving from avoided transportation and disposal costs of C&D waste.
- Delayed capital expenditure for the development of new landfills due to extended lives of existing landfill sites.
- Delayed closure costs for existing landfills.

-
- Cost savings from avoided procurement costs of virgin materials.
 - Improved financial performance of the construction industry due to reduced energy and pollution costs.

Historical Benefits

The reuse of old building components serves to preserve architecture and craftsmanship that is no longer available today. Deconstruction serves to preserve this architecture and craftsmanship through salvage and resale. Often times, items of historical significance command a high price on the salvage market because they are in high demand by collectors.

Many of the woods and heavy timbers used in building construction before 1950 are now in short supply. Many of the materials used in the construction of buildings during the days of old-growth harvest are unavailable from any other resource today. This creates a strong demand for such materials on the salvage market. These materials are generally considered to be of higher aesthetic quality (and thus of higher value) than the lumber produced today.

3.5 Component Recertification Requirements

Component recertification, particularly lumber re-grading for structural use, has become a hot topic in the deconstruction industry. Quality control is crucial in the trade of lumber products. The grade stamp on lumber verifies the quality of each piece of lumber. Currently, existing grading rules can be used to grade salvaged lumber. However, these rules do not specifically address salvaged lumber. Rules governing the evaluation of severe drying, nail holes, and other salvaged lumber specific defects are lacking (Falk, 2000). Current grading procedures are time consuming and expensive. Grading of salvaged lumber, other than in very large quantities, is not cost-effective. Another problem is that certificate requirements typically require that an entire batch of graded material be given one grading certificate. This limits the sale to one order (Falk, 2000). Because the extent to which salvaged lumber defects and their affect on its strength are somewhat uncertain, grading agencies are hesitant to give it their stamp of approval. When they do, they minimize risk by downgrading the lumber or restricting it from particular applications. The Southern Pine Inspection Bureau, which is the grading agency that governs the state of Florida, uses a disclaimer stating, “they do not re-grade wood to be sold and used for structural lumber” (Kibert et al, 2000). These issues create a barrier to the implementation of deconstruction by raising costs and reducing the possible applications of salvaged wood. In addition, structural salvaged lumber would draw a much higher price on the market than non-structural wood. Currently, steps are being taken to develop a nationally recognized salvaged lumber re-grading system.

The USDA/Fs – Forest Products Laboratory is in the process of developing a certification for used wood materials (Grothe, 2002). The implementation of this certification process would alleviate this barrier to deconstruction dramatically. They are using mechanical

testing to develop engineering data showing the strength qualities of salvaged lumber and how it is affected by warp, knots, bolt and nails holes, etc. These tests are ongoing.

4.0 ENHANCING MATERIALS RECYCLABILITY

4.1 General Issues of Materials Recycling

In a perfect world, the term recycling would describe a process in which raw materials achieve an endless useful life. Each conversion for reuse of the material would have future reuse possibilities designed in. Michael Braungart, of McDonough Braungart Design Chemistry, describes this process, “Korean rice husks used as packaging for stereo components are now being reused as building insulation. After use as insulation, the rice husks can be used again as bricks” (Cannell, 2000). It is true that nothing can be used forever. The passing of time eventually renders all materials useless. However, the concept of an endless useful life potential for raw materials is achievable. “Closed-loop” recycling should be the end goal of the recycling industry in order to maximize the usefulness of virgin materials and minimize the necessity to extract them.

Currently, the recycling of materials frequently does not allow for future use of the material after the initial conversion. When lumber extracted from deconstruction or demolition site is ground into mulch and poured into somebody’s back yard, the useful life of the material is extended and that quantity of virgin materials is preserved. However, the possibility for future use after that is virtually eliminated. Processes such as this, which we usually call recycling, are not actually recycling at all. The process of reducing a raw material’s quality, potential for future uses, and economic value, is called downcycling. The process of reusing a material for similar uses, thus maintaining the possibility for reuse again later, is recycling. The process of increasing the material’s quality, potential for future use, and economic value is called upcycling.

Downcycling

Downcycling currently holds an important position in our society. Most forms of recycling today are actually down-cycling. Currently, the technology is not available to recycle most products in such a manner that they are not degraded in some way. As long as this is the case, downcycling will be the best means of maximizing the useful life of raw materials and minimizing extraction of virgin materials. The recycling of paper, on the surface, appears to be a closed-loop cycle. In reality, however, it is not. Inks cannot be reused and are disposed of as waste sludge. The paper fibers are reduced in length and their strength is reduced. New fibers must be added to reinforce the paper’s strength. Thus it is not a closed-loop recycling system. Downcycling should be the last option in the recycling contingent. Whenever possible, techniques utilizing a higher level of sustainability should be incorporated.

Upcycling

Upcycling, as stated earlier, is a process in which the material's quality, potential for future reuse, and economic value is increased during the conversion process. Upcycling maximizes the lifecycle of raw materials. The above mentioned example of the Korean rice husks exemplifies the upcycling ideology. The husks are used as packaging material, a low value product. From there they are used in building insulation, a slightly higher value product. And from that point they become bricks, an even higher value product. Additionally, the bricks have the potential for further recycling down the road. The value of the raw material, the rice husks, is increased for us, the users of the material, at every stage. Upcycling is the ideal form of conversion of materials for reuse due to its high level of environmental and economic impact.

4.2 Recycling Issues for Specific Materials

Nearly all building materials have the potential for reuse following their initial useful life. Although reuse possibilities are available for building materials following demolition, deconstruction maximizes this potential because it allows these materials to be recovered with the least possible amount of damage. Additionally, the organizational nature of deconstruction involves sorting separate materials, which further facilitates reuse opportunities. Wood, steel, concrete, carpet, brick, plastics, and drywall all have high reuse potential.

Wood

Every year in the United States over 42 billion board feet of lumber gets dumped into landfills (Falk, 2003). Reuse of wood recovered from demolished and deconstructed buildings is an important means of reducing this landfill burden. It is estimated that for every 2,000 square feet of wood floor recovered, an estimated 1 acre of woodland is spared from being cleared (Falk, 2003). With the exception of scrap steel, wood products have the highest recoverability level of any building materials. This is due to the large amount of recoverable wood in the deconstruction and demolition market. Additionally, the ways in which wood can be reused are numerous.

“The spectrum of wood-based waste that might be converted to housing products includes full-sized used lumber salvaged from razed buildings, wood resulting from building demolition, old wooden pallets, scrap wood from new construction sites, preservative-treated wood waste from treating facilities and building construction, old wooden utility poles of railroad ties, wastepaper, yard trimmings, and wood fiber found in the sludge produced by paper mills” (Falk, 2003). This proliferation of available materials makes wood products an important piece of the waste diversion puzzle. Wood products can be recycled for direct reuse in similar applications, they can be downcycled into mulch, or they can be upcycled into more valuable items, such as custom cabinetry or furniture.

Many wood products can be recovered and reused directly, with little or no processing necessary. Currently, recovered structural timbers are in high demand in the United States because of their lack of availability from any other source. Virgin stocks were overexploited during the years of heavy logging and have yet to recover. People value the timbers for their aesthetic quality and historical significance. Additionally, dimension framing lumber can be recovered and reused as is. The market for recycled dimension lumber is still a fledgling industry. The reuse applications for recovered lumber are currently limited due to a lack of standardized grading requirements (Chini and Acquaye, 2001). This should change with the establishment of grading requirements. Once the structural uses of recovered dimension lumber are established, the demand will increase exponentially. Reusing recovered wood products in similar applications extends the lifecycle of the product because it maintains the potential for further recycling down the line.

Concrete

Currently, applications for used concrete involve downcycling the materials for use as a lower quality product. For example, concrete can be crushed up into a small aggregate and used in asphalt or new concrete. Currently, no commercial uses of recovered concrete involve upcycling of the material to a higher quality material with high future recyclability.

Steel

The North American steel industry is far ahead of any other building material industry in its use of recycling to conserve raw materials and create economic opportunity. "Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States for one year and every ton of steel recycled saves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone" (Fact Sheet, 2003). The steel industry's overall recycling rate is nearly 68% (Fact Sheet, 2003). This includes the recycling of cans, automobiles, appliances, construction materials, and many other steel products. All new steel products contain recycled steel.

There are two processes for making steel. The Basic Oxygen Furnace process, which is used to produce the steel needed for packaging, car bodies, appliances and steel framing, uses a minimum of 25% recycled steel. The Electric Arc Furnace process, which is used to produce steel shapes such as railroad ties and bridge spans, uses nearly 100% recycled steel (Fact Sheet, 2003). Every steel product you purchase contains recycled steel in it, so by buying it you help to close the recycling loop.

Brick

The preferred method of recycling used bricks is to remove them undamaged and reuse them directly. The only current method used commercially to enable used bricks to be made suitable for reuse in their original form involves cleaning the old mortar from the bricks by hand (Masonry Recycling, 2003). A small blunt hand axe can be used to knock

the mortar from the bricks. The problem with this is that it is extremely difficult to remove modern Portland cement based mortar from bricks using the technique described above. Thus only old bricks are generally cleaned and recycled by this method. There are however, studies in progress involving the use of pressure waves to break the bond between the mortar and the bricks. This may become a viable solution and create more brick recycling opportunities in the near future. There are currently studies ongoing concerning the use of crushed brick in road base. The results have been inconclusive to this point.

Asphalt Roof Shingles

Between 8 and 12 million tons of roofing shingles are manufactured annually in the U.S. (Schroeder, 2003). Around 65 percent of these shingles are used for re-roofing. Thus, between 5 and 8 million tons of old waste shingles are produced annually (Schroeder 6). Currently, the most practical use for used asphalt roof shingles involves grinding up cuttings to be used in asphalt road paving. Though this is a form of downcycling of the material, it manages to divert material that would otherwise be headed for the landfill. The following case study examines the use of recycled roof shingle clippings in roadwork in the state of Minnesota Table 14).

Table 14. use of recycled roof shingle clippings in hot-mix asphalt

Case Study: Use of Recycled Roof Shingles in Roadways in Minnesota
Benefitting from a public-private partnership between local asphalt producer Bituminous Roadways and the Minnesota Office of Environmental Assistance, Minnesotat road crews are using a 5% roofing shingle byproduct in hot-mix asphalt. This recycled aggregate reuses the cuttings from shingles composed of paper or fiberglass mat. The resulting high performance asphalt is suitable for a variety of residential paving and reconstruction applications. Used roofing (tear-off) shingles are not yet allowed in these applications. (Schroeder, 2003)

Carpet

The United States carpet industry produces about 1 billion square meters of carpet per year. Of this approximately 70 percent is used to replace existing carpet; this translates into 1.2 million tons of carpet waste produced annually (Schroeder 5). Most carpet is downcycled by being ground up and used as a component in other products (i.e. building insulation, asphalt pavements, and Portland cement concrete). The following case study examines BASF's use of upcycling to increase the recyclability and economic value of used carpet (Table 15).

Table 15. Upcycling used carpet

Case Study: BASF Savant – Upcycling Carpet Fiber

*In the 1990's BASF developed a carpet material called Savant, made from nylon 6 carpet fiber. Nylon 6 carpet fiber is a material that can be easily depolymerized into its precursor, caprolactam. The heat used in this process can be largely recovered, and caprolactam, in turn can be re-polymerized and made again into nylon 6, thus creating a closed-loop recycling process. Because it is made of this nylon 6, Savant can be recycled and used again and again. In response to this technology, BASF has created a carpet take back program in order to recover old nylon 6 carpet. Rather than being downcycled into a material with less value, the used nylon is upcycled into a product of greater quality.
(Braungart and McDonough, 2003)*

Plastics

Plastics recycling is now an established national industry. According to the 2000 State of Plastics Recycling, nearly 1700 companies handling and reclaiming post-consumer plastics were in business in 1999. This was nearly six times greater than the 300 companies in business in 1986. The primary market for recycled PET bottles continues to be fiber for carpet and textiles and the primary market for recycled HDPE is bottles. However, *Recycled Plastic Products Directory* (Recycled Plastic, 2003) lists over 1,300 plastic products from recycled content, including waterproof paper products and even plastic lumber for structural applications. New ASTM (American Society for Testing and Materials) standards are paving the way for plastic lumber that could be used in framing, railroad ties, and marine pilings (State of Plastics Recycling, 2000). The use of recycled plastics for such applications could mean longer life and less maintenance, which translated to lower cost over the life of the product.

The limiting factor in the plastic recycling industry is currently the supply of raw materials that feeds the industry. Because of the maturation of the industry and the fact that nearly every major community has already implemented plastic recycling programs, growth has slowed. There was only a 4% increase in the pounds of plastic collected in 1999 compared with that of 1998 (State of Plastics Recycling, 2000).

4.3 Deconstruction as a Method for Increasing Materials Recyclability

Demolition results in a non-homogenous heap of damaged materials. The recyclability of these materials is thus reduced by the demolition process itself. There is a positive correlation between the proliferation of building demolition in our country and the proliferation of downcycling of materials. Direct reuse and upcycling of building materials generally requires that they be recovered in good condition. Demolition frequently damages building materials to the point that their only usefulness lies in being

downcycled to less valuable materials. This reduction of the recyclability of the materials serves to reduce their economic value, increase their future negative effect on the waste stream, and increase the future necessity of raw materials extraction to take their place.

Deconstruction, on the other hand, serves to increase the recyclability of raw materials. Deconstruction results in numerous piles of homogenous building materials with minimal damage. This is because time and care are taken in recovering and sorting materials with as little negative effect on their quality as is humanly possible. The two factors unique to deconstruction that increase the recyclability of building materials are its organizational nature and the lack of damage incurred by the materials during the recovery process.

Sorting

The organizational nature of deconstruction increases the recyclability of the materials within the building. Should the same building be demolished by wrecking ball, the resulting trash heap would most easily be disposed of by hauling to a landfill. The individual components would have to be sorted after demolition in order to address their individual potential for recycling. This extra cost serves as a deterrent to recycling for demolition contractors. Deconstruction, by nature, requires the removal and sorting of individual building components. Piles of brick, wood, roof shingles, drywall, and other materials can then be recycled based on their own properties.

Recovering with Minimal Damage

Great pains are taken during the deconstruction process to recover building materials with minimal or no damage. Methods for efficient and safe extraction of materials are improving daily. Deconstruction improves materials recyclability by creating a supply of used building materials that are in good condition. This supply would not exist on any large scale without deconstruction. For example, structural timbers recovered from deconstruction can be reused in similar applications. This means that their potential for recycling will be available further on down the line. Conversely, structural timbers that have been destroyed by demolition only serve to be mulched up or sent to the landfill. Bricks recovered through deconstruction can be cleaned and sold for reuse, protecting their future recyclability. Bricks recovered from demolition would in far too poor of condition to be reused. Their only potential would be for being ground up and used in lesser applications. To sum it up, deconstruction increases material recyclability by creating the opportunity for material reuse and upcycling, whereas demolition promotes downcycling and landfilling.

6.0 ECONOMICS OF DECONSTRUCTION AND MARKETING OF USED BUILDING MATERIALS

6.1 Assessing the Economics of Deconstruction

There are two levels of economic assessment of the feasibility of deconstruction. Regional economic potential must be assessed in areas where the implementation of deconstruction on any substantial level is being considered. On a smaller scale, site economic assessments must be made when considering an individual building for deconstruction.

Assessing Regional Economic Potential for Deconstruction

For the potential deconstruction contractor/agent, many factors must be assessed when choosing a region to implement deconstruction on a large scale. Not all regions provide the right mix of scenarios that make deconstruction, from a business standpoint, economically viable. The region's building stock, reuse market, and level of public sector involvement all play a key roll in whether deconstruction can thrive, or even survive, in the area.

The most important factor to be considered when assessing the economic potential of a particular region is its building stock. "Building deconstruction, like demolition, depends on the availability of buildings that will form the feedstock for the industry" (Macozoma, 2001). In order for deconstruction to be a favorable operation, the region must contain a large number of buildings available for removal. Not only this, but the buildings must be suitable for deconstruction. For example, a city with a large number of vacant buildings containing a rare type of high quality wood would be an excellent candidate for implementation of deconstruction. The large number of deconstructable building would provide the necessary business opportunities while the value of the recovered wood would provide the necessary resale income to make the business profitable. Other factors affecting the deconstructibility of a building will be discussed in the next section.

The level of development and new construction activity in an area can affect the available building stock for deconstruction. High development requires land. This can often mean that a substantial number of older buildings could become available for removal. A thorough examination of the local reuse market is necessary when determining a region's economic potential for deconstruction. "The supply and demand of salvage building materials can determine the success or failure of building deconstruction" (Macozoma, 2001). In order for deconstruction to be implemented in a given area investment will have to be made into used building material businesses and material storage facilities. This will provide the distribution points necessary for resale of materials. The local demand for used products must be high enough to offset the cost of developing these distribution centers. Export markets and large metropolitan areas provide the most consistent demand for used building materials (Grothe and Neun, 2002).

Used Building Material Retail Operations (UBMRO's) are an essential element in the economic feasibility of deconstruction (Grothe and Neun, 2002). If UBMRO's are already established or can be established in an area where deconstruction is being considered on a full scale level, the chances of successful implementation are greatly increased. Non-profit UBMRO's provide deconstruction agents with outlets for their salvaged materials when the up front cost of a private retail operation or material storage

facility is prohibitive (Grothe and Neun, 2002). In areas with a high supply and demand for high price salvaged materials, the deconstruction agents themselves may succeed in developing UBMRO's.

On-site sales is an equally important means of selling salvaged building materials. Time constraints are usually the limiting factor when selling materials on-site. However, many sites lend themselves well to this means of distribution. An ideal deconstruction site for on-site sales would be one located in a high traffic area and selling low cost materials (see Table 16).

Table 16. On-site sales of salvaged materials

***Case Study: On-Site Sale of Building Materials from Deconstructed Building
901 State Road 301, Gainesville, Florida***

*This house was deconstructed by the Powell Center for Construction and Environment, led by Bradley Guy. The house was located at the corner of a shopping center site in a high traffic, high visibility area of town. There was room on all sides of the site for laying out materials and the locale was a low-income neighborhood, which facilitated the sale of cheap building materials. The site was entirely cleared of salvaged materials by the last day of the project and sales netted \$4,613.
(Guy, 2003)*

A key issue in an economic assessment of a particular region's deconstruction potential is the level of involvement of the public sector. Government programs supporting deconstruction can do wonders in getting the ball rolling, which is quite possibly the most difficult step in the deconstruction development process.

State and local funding supporting deconstruction can be the difference between success and failure for the industry. Funding of non-profit UBMRO's and community service worker programs greatly reduces costs incurred by deconstruction contractors. Incentives supporting deconstruction need not only take place in the form of financial aid. Kibert et al suggest that incentives for deconstruction be developed in the form of disincentives for disposal. "By creating an environment not conducive to wasteful practices an incentive is created to waste less" (Kibert et al, 2000). Examples of disincentives suggested by Kibert et al include mandates that all demolition companies attend deconstruction seminar and raising the cost for demolition permits while lowering the cost of deconstruction permits.

Community developed job training programs are being implemented in many cities around the country. These programs are a blessing in more ways than one. At one level they provide low cost labor to the deconstruction industry. Time saved on finding labor

and money saved per labor hour increase the chances of deconstruction succeeding in the area. On another level the increased job opportunities serves to stimulate the local economy. The U.S. Department of Health and Human Services summarizes the importance of deconstruction training programs by stating, "Building deconstruction offers new opportunities for career and new enterprises and provides an excellent training ground for employment in the wider construction field where there are serious and growing shortages of trained workers throughout the United States (Grothe and Neun, 2002).

Because deconstruction success rides heavily on the sale of used building materials, local perception of these materials can be a make or break factor. Poor public perception can negatively affect the materials resale market, which would negatively affect the profit potential of deconstruction. A thorough discussion of consumer tastes and perceptions will be given in later sections.

Site Economic Potential for Deconstruction

A potential deconstruction site must be evaluated for economic feasibility before any action takes place. At this point it is assumed that the decision has already been made to exploit the region's economic potential. Thus regional issues will not be considered in the following discussion. This discussion will focus on the site itself and its economic potential for deconstruction.

An individual building's economic feasibility for deconstruction, disregarding social factors such as environmental concerns, is decided by its cost comparison with demolition. A contractor's decision in many cases will be decided purely by comparing the net incomes of the two removal techniques.

In almost all cases, the cost of deconstruction is higher than that of demolition. This is due to the labor intensive nature of deconstruction. However, the salvage value regained in deconstruction often makes it more cost effective than demolition. Because the labor intensive factor of deconstruction is somewhat unavoidable, it is important to focus on minimizing other factors in the cost to make it more competitive. Minimizing costs and maximizing salvage value of building materials is essential to maximizing the potential of deconstruction. Having well trained workers, as discussed before, can have a major impact on overall cost. A high level of safety, also discussed before, reduces overall costs of deconstruction projects. These factors, however, are organizational factors that do not affect the potential of the site itself. Factors affecting economic potential of the site include its architecture and composition, project time constraints, and site accessibility. Table 17 shows that deconstruction, when conducted correctly, can be more profitable than demolition (Deconstruction:EPA, 2003).

Table 17. Comparison between demolition and deconstruction costs

Cost Savings with Deconstruction: Presidio Building #901		
9,180 Sq. Ft. Wood Construction		
<i>Labor</i>	<i>(\$33,000)</i>	
<i>Equipment/Disposal</i>	<i>(\$12,000)</i>	
<i>Administration</i>	<i>(\$8,000)</i>	
<i>Total Expenses</i>	<i>(\$53,000)</i>	<i>(\$16,800)</i>
<i>Material Salvage Value</i>	<i>\$43,660</i>	
<i>Net Cost</i>	<i>(\$9,340)</i>	<i>(\$16,800)</i>
Savings	\$7,460	

Deconstruction, as a rule, is a longer process than demolition. In the cut throat world of development and construction, time is money. “The long process of getting demolition permits often cuts into the time needed to deconstruct a buildings; once a permit is secured, developers are under pressure to demolish the building as soon as possible to make up for financial losses incurred while waiting for a permit” (Deconstruction Training Manual, 2001). When site development is on a tight schedule, deconstruction may be ruled out without any economic assessment being made.

As discussed previously, buildings that would be a good choice for deconstruction should exhibit the following characteristics:

- 1) Wood framed buildings using heavy timbers and unique woods such as Douglas Fir, American Chestnut, and Old Growth Southern Yellow Pine.
 - 2) Buildings that are constructed using high value specialty items such as hardwood flooring, architectural moulding, and unique doors or electrical fixtures.
 - 3) Buildings constructed with high quality brick and low quality mortar.
 - 4) Buildings that are generally structurally sound and water tight. These buildings will have less rotted and decayed materials.
- (A Guide to Deconstruction, 2000)

The above mentioned structural characteristics enhance the resale value of the project. High quality wood timbers are of particularly high value because over harvest has created a supply shortage in the United States. Also of high value are items with historical significance. High levels of lead based paint and asbestos containing materials increase costs on deconstruction projects due to laborious removal policies.

The accessibility of the site directly affects the labor time to deconstruct the building. How much labor involved in the deconstruction, as previously discussed, directly affects the profitability of the project. An open site that with easy entrance can drastically minimize labor costs, whereas a congested, wooded site can greatly increase labor costs. An open site allows for a more manageable work flow during the deconstruction. Workers can move more freely, materials can be removed and store more easily, and disposal vehicles can better access the site. A congested site has the opposite affect.

A thorough economic assessment of the site allows the deconstruction agent/contractor to make an educated decision on whether to bid on the project. The building's assessment can be used to give it a rating, which can be used in deciding whether to proceed. A thorough discussion of deconstruction assessment tools can be found in the following section.

6.2 Deconstruction Assessment Models / Tools

As discussed previously, a preliminary assessment of the economic feasibility of deconstruction is necessary before any other action is taken on the project. It is possible that the project may not possess the necessary characteristics for cost-effective deconstruction. Assessment models and tools for this purpose range from informal site visits to complex computer programs. An assessment of deconstruction potential can be made via an informal site visit, visually assessing the qualities of the building. On a slightly more thorough level, a detailed building inventory may be taken and analyzed to determine the economic potential of the project. Recently, computer models have been developed to determine the feasibility of deconstruction projects. This section provides a detailed discussion of these three assessment tools.

Site Visit

A cheap, informal means of assessing the economic potential of a deconstruction site is a site visit. The site visit should be conducted by the deconstruction agent or someone knowledgeable in construction processes and factors affecting deconstruction potential. During the site visit, the characteristics of the site that affect deconstructibility are visually observed. Based on these observations, a decision can be made as to whether the project should be pursued. The factors observed during the site visit are summarized in the chart below. Although quick and inexpensive, a site visit is not a thorough means of assessing economic potential. The lack of a thorough financial analysis of the materials in the building increases the risk of economic loss. It is recommended that a site visit be conducted in conjunction with a detailed building materials inventory, as discussed in the next section.

Building Materials Inventory

“The most important part of assessing the feasibility of deconstruction for a structure is a detailed inventory of how and of what the building is made” (Macozoma, 2001). A detailed building materials inventory is an invasive technique whereas each type of material in the building is identified, quantified, and assessed for its condition and method of installation. These factors can have a substantial impact on the cost-effectiveness of salvage. Invasive inspection of the structure not only serves to identify hidden layers of salvageable materials but also aids in the identification of hazardous materials, which may not have been visible during the initial site visit.

An initial site survey combined with a detailed building materials inventory is the recommended approach for accurate economic assessment of deconstructibility. However, the downside to a handwritten assessment in this manner is the time required. It has already been established that a major barrier to implementation of deconstruction is its time consuming nature. The extent to which the length of the deconstruction process can be minimized is key to its success. Developing a spreadsheet, hand calculating materials, salvage values, labor costs, and preparing a final analysis is a laborious process that increases the cost of deconstruction and delays the project.

Computer-Based Deconstruction Feasibility Tool

As previously stated, the downside to a thorough building material inventory assessment is that it can be very time consuming for those performing the assessment to develop and organize the spreadsheets, quantify the materials and their salvage values, and make an accurate final analysis of deconstruction potential. To solve this problem, Bradley Guy of the University of Florida's Powell Center for Construction and Environment has developed a computer software program that can quickly estimate both potential salvage value and deconstruction costs. This step-by-step program will assist in making a rapid assessment of economic potential and facilitate "pre-sales" of materials before the deconstruction process begins. Economic variables such as local labor and disposal costs can be easily manipulated using the program to determine the optimal use for the building (Guy, 2003).

6.5 Materials Reuse Businesses

Do-It-Yourself (DIY) Outlets

Construction and Demolition (C&D) waste is produced at many levels. Although the demolition of huge commercial structures puts a large strain on the waste stream, emphasis should also be placed on the reduction of waste created on a smaller, individual basis. Private homeowners, contractors, and handymen take part in home improvement projects and small-scale demolitions and deconstructions all across the country everyday. Each individual project may not produce a large amount of waste. However, taken as a whole, a large amount of waste is contributed to the waste stream by these types of projects.

Salvaged building materials centers provide an outlet for handymen, homeowners, and contractors to unload unwanted building components without throwing them away. These unloaded materials in turn create a supply of affordable building components that can be reused by other individuals. This opportunity for cyclical use of materials serves to reduce the landfilling of C&D waste and ease the demand for raw materials extraction. The weekend do-it-yourselfer benefits from the availability of cheap materials for repair work and small projects that do not require the use of new, more expensive materials.

Individuals donating used building materials will benefit from tax-deductions at many outlets.

The following two case studies examine two different types of do-it-yourself outlets. ReSource 2000 is a for-profit business based on the resale of donated building materials (Table 18). The Used Building Materials Center in the Monroe County Landfill is a non-profit exchange center based on creating a cyclical movement of materials that avoids landfilling (Table 19).

Table 18. Resource 2000 – a for-profit do-it-yourself outlet

***Case Study: ReSource 2000
Boulder, Colorado***

ReSource 2000 is a used building materials outlet that obtains used components and resells them in their sales yard. Homeowners and contractors are encouraged by ReSource 2000 to take it upon themselves to donate their unwanted building materials, rather than just throw them away. Besides the obvious environmental and social benefits associated with the donation of unwanted building materials, individuals benefit from the fact that materials donated to ReSource 2000 are tax deductible. ReSource 2000 has given deconstruction materials large-scale donors deductions ranging from \$2,900 to \$65,000 dollars. ReSource 2000 encourages the donation of lumber, plywood, sheetgoods, roofing, doors, windows, light fixtures, cabinets, fencing, hardware, plumbing, ducting, insulation, and brick. ReSource 2000 then sells these materials at affordable prices to builders and do-it-yourselfers. (ReSource2000, 2003)

Table 19. Used Building Materials Center – a non-profit exchange center

***Case Study: Used Building Materials Center
Monroe County Landfill, Indiana***

Located at the Monroe County Landfill in Bloomington, Indiana, the Used Building Materials Center provides a “swap-and-trade” opportunity for do-it-yourselfers and contractors to unload or obtain used building components. The motto at the Used Building Materials Center is, “Take what you can use ... drop off what you can’t.” Construction and demolition waste makes up 40 percent of the total waste disposal in the Monroe County Landfill. The Used Building Materials Center was developed at the landfill after officials recognized the need to minimize the environmental impact of construction waste. (Used Building Materials Center, 2003)

Industry Associations

Because it is often slow, inconvenient, and expensive to advertise and store used building materials, the tendency of the average owner or demolition contractor has always been and still is to landfill those materials, with no potential for resource conservation and reuse. At the same time, there is a growing consumer need for materials that are less expensive and/or environmentally friendly. Young, rapidly expanding industries such as the deconstruction industry and the used building materials industry frequently need the help of external forces in order to efficiently bridge the logistical gap between building materials recovery and building materials resale. A number of associations currently exist whose purpose is to bring companies together in order to promote networking, information exchange, lobby for government support, and improve the efficiency of the industry. The following non-profit organizations are working to establish a global network for the deconstruction and used building materials industries.

Used Building Materials Association (UBMA)

The Used Building Materials Association (UBMA) is a non-profit, membership based organization that represents companies and organizers involved in the acquisition and/or redistribution of used building materials. They represent for-profit and non-profit companies in Canada and the United States that acquire and sell used building materials. The UBMA also represents companies that process and recycle building materials such as concrete and asphalt. Their mission is to help companies gather and redistribute building materials in a financially sustainable way (Used Building Materials Association, 2003).

Construction Materials Recycling Association (CMRA)

The Construction Materials Recycling Association (CMRA) is an association devoted exclusively to the needs of the rapidly expanding North American construction waste and demolition debris processing and recycling industry. Those needs include (Construction Materials Recycling Association, 2003):

- Information exchange on issues and technology facing the industry including a listing of available literature on relevant topics.
- Campaign to promote the acceptance and use of recycled construction materials including concrete, asphalt, wood, and gypsum, among others.
- Provide information and support to the C&D recycling industry's side of important issues that affect recyclers.
- They represent the industry at trade shows and other industry functions related to C&D recycling in order to raise the visibility of C&D recycling.

Reuse Development Organization (ReDO)

The Reuse Development Organization (ReDO) is a national and international tax exempt, non-profit organization promoting reuse on every level. ReDo was created to fill an informational void in the reuse industry. ReDo is providing education, training, and technical assistance to start up and operate reuse programs, while working to create a national reuse network and infrastructure. ReDO's mission statement: To promote reuse as an environmentally sound, socially beneficial and economical means for managing surplus and discarded materials (Reuse Development Organization, 2003).

Reusable Building Materials Exchange

The Reusable Building Materials Exchange is a website that provides a convenient way for contractors, home remodelers, reuse businesses, and other interested persons to easily exchange small or large quantities of used or surplus building materials. This web-site increases the efficiency and cost-effectiveness of the industry by providing a vehicle by which to sell used building materials to the public.

Once registered, sellers can create and post their own listings. Each listing will contain a description of the materials along with the name and telephone number of the seller. Buyers can browse the listings of materials wanted or available in several material type categories (e.g. lumber, masonry, doors, windows), and they may browse on more than one category at a time. The actual transactions are carried out directly between the interested parties (Reusable Building Materials Exchange, 2003).

7.0 DESIGN OF BUILDINGS AND COMPONENTS FOR DECONSTRUCTION

With existing buildings containing so many useful materials it is important that these materials be accessible for reuse after the building has exceeded its service life. When considering buildings as a future source of raw materials designing for disassembly is a key element in material retrievability. Additional issues are material durability, desirability and longevity. Materials must be durable if they are to be used over several service lives.

By definition deconstruction is an age-old concept of reusing existing structure components to create new facilities. However, designing for deconstruction from a practical standpoint is a difficult concept to grasp. Designers conceptualize their buildings as being timeless and no designer intends on spending intensive labor creating a building only to be torn down. The designer's perception is that the building will stand forever. Similarly, no contractor believes that their structures will be torn down. Designing and building structures to be taken apart run counter to these professionals' principals. Marketability is always a concern in construction. Many products today are not produced with recycling in mind, just the selling cost.

Manufacturers today focus on generating the least expensive product for the short term. A return to traditional materials and methods means incorporating products and building techniques, which have stood the test of time and are still preferred by home buyers. For example, a vinyl window specified at the time of deconstruction may not be worth reusing or recycling.

Design for Disassembly has been used most frequently in Europe in response to Extended Producer Responsibility (EPR) laws that require companies to take back and recycle their products. The automotive industry pioneered techniques for disassembly that the construction industry can employ. There are currently no EPR laws in the U.S., but private industry may be forced to change its practices as landfills overflow and tipping fees rise.

7.1 Design techniques for allowing component extraction by disassembly

Case study – Dibros Corporation

For an example of potential design changes that could facilitate disassembly a Florida builder was interviewed regarding designing for deconstruction. Dibros principals Miguel Diaz and his son Luis A. Diaz are among many builders in the Gainesville, Florida location. Dibros, in order to make their development more attractive to potential homebuilders, has committed to developing a “neighborhood” using the concepts of New Urbanism. New Urbanism also stresses “traffic calming” through street design and takes the focus away from the automobile and puts the focus on the people. This concept also mixes retail and light commercial businesses with housing. Dibros began planning their community as most builders do, by surveying the land and then planning roads and lots accordingly. However, Luis Diaz decided that instead of having the design dictate the layout, he would let the land dictate the design. Dibros created a Computer Aided Drafting (CAD) plan of the land and marked trees, which ultimately determined the layout of roads, lots and common parks. From the start, this community was developed in a nontraditional manner. Additionally Dibros is interested in new, innovative, environmentally friendly construction materials as well innovative construction techniques.

Components of a Dibros Home

For the purposes of deconstruction, it is important to look at the typical components of a home built by Dibros. Listed in Table 10 are the highest cost items in a typical Dibros home.

Table 10 Highest cost items in a typical Dibros home.

Description	Total Cost (\$)	Description	Total Cost (\$)
Roof and Floor Truss System	7826	Building Panels	2064
Lumber	6939	Welded Steel Railing / handrail	1920
Wall Covering	5733	Appliances	1901
Stem Wall Concrete	2888	Roofing	1562
Siding	2846	Paint	1357
Drywall	2428	Interior Doors	1226
Framing Hardware	2262	Plaster Stucco	1196

After reviewing this list for items, which warranted further research we eliminated items such as paint and stucco which from a deconstruction standpoint have little value. Further investigation of these components shows the highest cost item, the Roof and Floor Truss System, to be the most expensive item. The trusses are constructed of engineered wood in Melbourne, Florida. The builder agrees that purchasing from a local producer would be less costly. However, Space Coast Truss provides them with excellent quality control. Lumber is the next highest cost category. These components will be further investigated to determine the feasibility of reuse or recommendations for an alternative material.

Foundation Systems and Flooring

The foundation system is a concrete slab and for the house that was examined the finished floor was Hartco wood flooring. Hartco Flooring is a 3/8" glue down laminated wood flooring with true wood layers. It should be noted that flooring and floor covering are subject to physical abuse from feet and heavy objects, and, as the lowest spot in a room, they tend to collect dirt, moisture, and other contaminants. A good flooring material should be highly durable to reduce the frequency with which it must be replaced, and it should be easy to clean. At the same time, softer surfaces may be preferred for reasons of comfort, noise absorption, and style, setting up a potential conflict for the designer. There are also raw material and manufacturing impacts to be considered with many types of carpeting and other floor coverings.

Concrete Slab

The acceptance of concrete slabs comes from a purely marketability standpoint. It takes less time and cost to install. After the service life of the home, the concrete slabs may be reprocessed. The broken concrete can be sent to a ready mix concrete plant that can incorporate crushed concrete (used as aggregate) back into the concrete manufacturing process. The crushed concrete is most often not immediately reused except when it is crushed on site and used as a temporary road base.

Alternative flooring methods are addressed below as to their deconstructibility.

- Carpet systems, including carpet pads and carpet adhesive, have been identified by the EPA as a potential source of indoor air pollution. Although carpet recycling is technologically difficult due to the contaminants and multiple components of used carpet, some companies now have extensive recycling programs. Carpet padding has long been made of recycled materials and is

-
- extremely recyclable. One problem with carpet is that it will hold dirt and pesticides, creating a unhealthy environment. The life expectancy of carpet on slab is reduced due to the harsh backing concrete offers.
- Thin wood flooring composites are glued down. Any attempt to remove it will lessen the quality of the material, making it less desirable for reuse. It is essential to ensure the adhesive is not toxic or in any way harmful to the environment for disposal purposes. These products do not take excessive abuse and will not permit numerous resurfacings.
 - Ceramic and porcelain tiles have high embodied energy but their durability makes them environmentally sound in the long run. Some high quality ceramic tile incorporates recycled glass from automobile windshields. As a floor covering, tile is durable and recyclable.
 - Linoleum cannot be reused and does not contain any recycled content.

Concrete is less forgiving to both the human body and the materials that cover the slab. Concrete slabs can have other problems: cracking from settling and major demolition is required to repair utilities under the slab.

Crawl Space

In comparison to the concrete slab on grade, a crawl space provides many deconstruction options. The construction time and cost are higher but it may provide less maintenance concerns compared to a concrete slab. The alternatives for coverings are the same as for a concrete slab except the following:

- Wood flooring over a crawl space is a return to traditional tongue and groove wood that has always stood the test of time. It does not require excessive resurfacing, provides a cleaner surface, and is more forgiving to the human body and other materials. The quality of floor temperature is also easier to control.
- Area rugs can be incorporated which protect the wood and provide a more favorable environment. Wall-to-wall carpeting can be used with an extended life expectancy. Crawl spaces provide easier and cleaner coordination of utilities, not to mention easier access for maintenance. The space can also be incorporated into a passive cooling system throughout the facility reducing consumed energy.

Framing

Dibros currently uses southern yellow pine framing. Using wood versus steel framing in structures depends on personal preference can benefit either side. From a deconstruction standpoint wood and steel both have advantages and disadvantages.

Wood

Wood is a renewable resource if it is purchased from a sustainably managed forest. This is more difficult than it may initially appear. The process of following the lumber from forest to mill to manufacturer is not easy and is costly. It should be noted that it takes approximately 40 to 50 trees to construct a 2000 square foot house [7]. From a deconstruction standpoint there is a potential to immediately reuse some of the wood salvaged from the site. The wood that cannot be immediately reused may be recycled.

Steel

Although steel is manufactured using a finite resource, it is the most recycled material in North America. Steel framing members contain at least 28% recycled content and generate as little as one cubic yard of recyclable scrap [20]. Steel framing requires approximately 30% more labor to construct than a typical wood framed home. To immediately reuse steel framing members, they must be deconstructed with great care to avoid warping, twisting, or bending during disassembly. Even though the steel may not be available for immediate reuse, all of the steel can be recycled.

Wall Finishes

Dibros currently uses gypsum drywall in 4'*12'*½" sheets with a texture finish veneer plaster.

A disadvantage of drywall is the large amount of waste generated during construction. Drywall generates about 15% of all construction waste and represents the highest percentage by weight of waste in residential construction. For a typical 2000 square foot home, 2000 pounds or five cubic yards of waste is generated. This equates to one pound of waste per square foot of building. Recycled gypsum drywall is available and is becoming more prevalent in the U.S. Specific types of drywall for fire rating and moisture resistance contain products, which can prevent recycling. In addition to the large quantities of waste created in the construction process, drywall has little to no value with respect to material recovery. The drywall acts more as a barrier to the materials that deconstructors are trying to retrieve.

Roofing

Dibros currently uses asphalt roofing shingles. Roofing provides one of the most fundamental functions of the building, shelter. Roofs must endure drastic temperature swings and experience long term exposure to ultraviolet light, high winds, and extreme precipitation. Durability is critical in roofing because a failure can mean serious damage not just to the roofing itself, but to the entire roofing system, building, and its contents. This type of damage multiplies the economic and environmental cost of less reliable roofing materials. Roofing can also have a significant impact on cooling loads. The use of lighter colored, low-solar absorbency roofing surfaces is one of the key measures in life cycle energy costing associated with a home. All roofing options do not allow for immediate reuse and comparisons of the various options are listed below.

Asphalt

Asphalt roofing is the most affordable initial cost option for roofing. Its service life can range from 10 to 30 years depending upon the grade of tile purchased. As far as deconstruction is concerned, the tile may not be immediately reused nor is it readily recycled. Manufacturers publicize the recycling of asphalt roofing in road mix designs, however, the Florida Department of Transportation does not use asphalt roofing in their paving operations. Research is being conducted to incorporate asphalt roofing into mix designs. However the roofing the FDOT is using is waste from the manufacturing process, not waste from the roofs of homes. FDOT reports there is simply too much

contamination and inconsistency in the “take-offs” to use this waste when trying to create a predictable mix design.

Metal

Options for metal roofing include galvanized steel, aluminum, and copper. Metal roofing is an alternative to the common problems experienced with traditional roofing shingles. Metal roofing does cost more initially than a typical shingle or tile roof, but it is actually cheaper because of its longer service life, approximately 3 times that of a shingle roof. In addition to the longer service life, metal roofs have fewer maintenance requirements, provide a better appearance, and a greater value for homes [21]. Because of their low maintenance and long life, steel roofing systems can ultimately be one of the lowest cost roofing materials [22]. The benefit related to deconstructibility of metal roofs is the well-established metal scrap market. Even in regions of the U.S. where there is no deconstruction infrastructure there will often be scrap metal dealers. Aluminum is also one of the most valuable materials to recycle.

Wood

Wood shingles may not be immediately reused, but may be readily recycled. The expected life of a wood shingle roof, however, is only 15 to 20 years. Building codes require that wood shingles carry a specific fire rating which affects their make up and recyclability.

Polymer Materials

There are a variety of new products on the market made from recycled polymers. One product is made from asphalt and recycled baby diapers, which has the appearance of slate and includes a 50 year warranty. With this composite type material, reuse or re-recycling will be very difficult.

Tile / Concrete

Clay and concrete tiles are also an option where hail is not a serious threat. Both of these roofing options offer excellent service lives. Local availability of these products is an issue due to their relatively high weight, which could result in higher transportation costs. Tile and concrete roof tiles can be deconstructed and the material can be crushed and used in new concrete as aggregate or as roadbase.

Slate

Slate is one of the most durable roofing options with an expected lifespan of over 100 years.

This roofing material is also very expensive yet desirable. Slate is reusable if it is not cracked.

Pre-manufactured nail holes reduce the amount of waste created.

Siding

Dibros currently uses a combination of Hardiplank and concrete stone, depending upon the customer's specifications.

Vinyl

Vinyl siding has a 20 year warranty because of its innate durability and flexibility. It is installed with nails or other fasteners that increase the labor associated with deconstruction. Vinyl offers low maintenance and it does not need to be painted or stained. However its recyclability is questionable since heating of vinyl produces hydrochloric acid (HCl). Recycling of vinyl results in downcycling, meaning that existing vinyl siding will not be recycled into vinyl siding again, but a product lower on the product cycle chain.

Wood

Wood is a traditional material, just like brick, but unlike brick, it will require more maintenance and has a shorter life. Life expectancy is shorter because of the possibility of termites and weathering. In addition, wood requires continuous upkeep, maintenance, and painting. If wood is properly maintained it may be removed and reused. Removal could be facilitated through the use of screws versus nails.

Hardiplank™

Hardiplank™ is an extremely durable composite made of portland cement, ground sand, and cellulose wood fiber. This product offers a 50-year warranty and is resistant to humidity, rain, and termites. Hardiplank™ is potentially 100% recyclable. However, there is no current recycling process in place.

Brick

Brick offers the best immediate re-use potential. Locally produced brick and stone are long lasting, low maintenance finishes that reduce transportation costs and environmental impacts. Molded cementitious stone replaces the environmental impact of quarrying and transport of natural stone with the impacts of producing cement.

Design for Deconstruction – Some Recommendations

There are four elements in designing for deconstruction:

1. Reuse existing buildings and materials – It is possible for new buildings to be designed facilitate the reuse of existing materials from existing structures
2. Design for durability and adaptability – Longevity is determined by the durability of materials, quality of construction, and by the buildings adaptability to changing needs. Durability needs to be properly balanced with adaptability. Different material life spans must be factored into the design.
3. Design for disassembly
4. Use less material to realize the design

8.0 POLICY, REGULATION, STANDARDS, LIABILITY

Environmental Policy and Incentives - National

There are very few policies in place on a national level that mandate environmentally friendly construction, buildings, designs, and materials. Without policy favoring sustainability, researchers look to the governments to offer incentives that will begin to sway the construction industry when designing and building for the future. Currently there are few incentives, and those that are offered are not nearly enough to persuade business to invest the extra money in designing for the environment. The U.S. EPA runs a program that started in 1992 called Design for the Environment. This program forms voluntary partnerships with industry, universities, research institutions, public interest groups, and other government agencies. The program attempts to change current business practices and to reach people and industries that have the power to make major design and engineering changes. Their ultimate goal is to incorporate environmental considerations into the traditional business decision-making process.

The U.S. Department of Energy, Office of Pollution Prevention, has begun a Pollution Prevention by Design project in an attempt to help engineers, designers, and planners incorporate pollution prevention strategies into the design of new products, processes, and facilities. The problem facing the industry is not the invention, or innovation, but the education and implementation of new techniques and concepts.

Existing Federal Laws and Executive Orders, which pertain to the construction industry, are primarily focused on energy conservation. The following is a listing of these regulations in place:

- Energy Policy and Conservation Act (EPCA of 1975)
- Resource Conservation and Recovery Act (RCRA of 1976)
- National Energy Conservation Policy Act (NECPA of 1978)
- Comprehensive Omnibus Budget Reconciliation Act (COBRA of 1985)
- Federal Energy Management Improvement Act (FEMIA of 1988)
- Energy Policy Act (EPACT of 1992)
- Executive Memorandum (“Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds”)
- 10CFR435
- 10CFR436
- Executive Orders: 12759, 12843, 12844, 12845, 12856, 12873, 12902

Over the past two decades, public concern and support for the environmental protection have risen significantly, spurring the development of an expansive array of new policies that substantially increased the government’s responsibilities for the environment and natural resources. The implementation of these policies, however, has been far more difficult and controversial. Government is an important player in the environmental arena, but it cannot pursue forceful initiatives unless the public supports such action. Ultimately, society’s values will fuel the government’s response to a rapidly changing world environment that will involve severe economic and social dislocations in the

future. Environmental policy is difficult to predict, the U.S. is moving from a nation that exploited resources without concern for the future to one that must shift to sustainability if it is to maintain the quality of life for present and future generation. If green plans were proposed in the U.S., they would survive the political process [27]. Several states have already implemented their own progressive environmental policies that are stricter than Federal regulations.

Incentives - Two major changes in federal policy are also creating major opportunities for deconstruction: the demolition of public housing under the HOPE VI programs and the conversion of closed military bases across the U.S. If deconstruction were employed in conjunction with demolition to remove public housing across the country, as well as other public and private sector structures, communities could reap substantial environmental, economic, and social benefits for their residents, at little or no additional cost compared to traditional demolition.

Forty-four states and the District of Columbia have set solid waste diversion and/or recycling goals. Several states are beginning to insist on environmental preservation. Blatant disregard for the environment is no longer tolerated. One example is the California Resource Recovery Association, which is actively pursuing manufacturer responsibility legislation.

The California Resource Recovery Association

- *If it can't be assimilated into the environment, then it can only be leased*
- *Anything not biodegradable/recyclable is tagged with its constituents and manufacturer*
- *Mandated deposit laws for certain materials*
- *Mandatory separation of wastes*
- *Mandatory procurement of recycling products for public projects*
- *Product disposal borne at manufacturer level, "advanced disposal fees" for manufacturer wastes*
- *Advanced fees mean that disposal is calculated upfront as part of the costs of producing the product and is internalized by company.*
- *This is like pollution permits, whereby quotas could be traded between those with product stewardship and those without, this would be called a "processing fee"*
- *Eco-labeling and materials labeling is consistent.*
- *Product made with minimum recycled content requirements.*

Federal Government Support

Several federal government agencies demonstrated support for deconstruction by providing financial and technical assistance to pilot projects across the country. The U.S. EPA supported the Riverdale Housing Project. The EPA provided grant funding to the National Association of Home Builders Research Center, the Green Institute, and the Materials for the Future Foundation. In addition to the financial support, the EPA has also provided technical assistance on deconstruction projects. The Department of Health and

Human Services' (HHS), Office of Community Services, The Department of Defense, Office of Economic Adjustment, and the U.S. Department of Agriculture's Forest Products Lab (FPL) have all contributed to the deconstruction research effort. The FPL has been evaluating the grades and strength characteristics of used lumber and timber. They are working cooperatively with lumber grading agencies to develop grading criteria and grade stamps for used lumber.

Case Study: Implementation

Location: Hartford, Connecticut

The City of Hartford, Connecticut, has set aside funding from a state demolition grant to deconstruct 350 abandoned buildings as part of a program to develop deconstruction service companies that train workers for skilled employment.

9.0 BARRIERS TO DECONSTRUCTION

9.1 Consumer Tastes

The successful implementation of deconstruction relies on successful resale of recovered building components. If materials cannot consistently be marketed and sold in a timely manner, it is virtually impossible for deconstruction to be profitable. For this reason, consumer tastes and perceptions concerning used and recycled building materials is often a barrier to the successful implementation of deconstruction. According to *Recycled Construction Product Market (2003)*, the most influential persons regarding the purchase of used and recycled building materials are the planners, the builders, and the consumers.

Planners

Architects and landscape architects have the potential for impacting the use of used building materials in new construction. Although architects tend to be more open to the use of used and recycled materials than builders, their perception overall appears to remain negative. Brand or manufacturer loyalty poses one barrier to expanding the use of used and recycled building materials. Currently, architects are more likely to specify a particular product from a product line or manufacturer they trust than to establish a non-brand specification which allows used materials to fill that specification (*Recycled Construction Product Market, 2003*).

Builders

Builders and their subcontractors play an important role in the selection of construction materials. In an industry whose motto is, "If it was good enough for my father, it is good enough for me," the movement towards new products is slow (*Recycled Construction Product Market, 2003*). This attitude reflects real worries in construction, where products

that are not up to high standards of quality and safety can cause disastrous accidents. For this reason, builders are the market segment that is slowest to accept used and recycled building materials. Table 20 lists contractors' view of the salvaged building materials.

Table 20. Contractors' view of the salvaged building materials

Contractors' Negative Perception of Recovery and Reuse of Building Materials
Contractors view the use of reused and recycled building materials negatively for the following because they perceive them to have the following characteristics:

- *Dimensional Problems: Contractor's view finding used materials that fit into a pre-dimensioned space as more difficult than purchasing a new product.*
- *Inconsistency in Supply: Contractor's perceive the inconsistent availability of the right quantity and size of used materials as inconvenient.*
- *High Risk: Due to the high personal risk involved when something goes awry in the construction process, builders are reluctant to trust used and recycled products.*
- *Poor Quality: It all boils down to the overall perception that used and recycled materials are of lesser quality than virgin materials.*
- *Expensive: Contractor's tend to view reused and recycled materials to be overall more expensive than virgin materials.*

(Grothe and Neun, 2002)

Consumers

Those people purchasing commercial and residential construction, as well as those renovating buildings, are extremely important in driving the environmentally sound construction movement, including the use of recycled and reused building materials. The prevailing attitude remains that reused and recycled building materials are "substandard but environmentally friendly." Many architects and builders have admitted that they would use more used and recycled products if their clients directed them to do so (Recycled Construction Product Markets, 2003).

Suggestions

Though definitely on the rise, perceptions of reused and recycled building materials must be improved in order for the long term profitability of deconstruction to increase. The following aspects of the industry and consumer perceptions must be addressed in order to rectify the many doubts consumers have concerning recycled and reused building materials.

- **Information Availability** – Aided by the numerous industry associations discussed and increased publicity, information accurately explaining the benefits

of recycled and reused building materials has become much more accessible over the last few years. However, as a whole, public knowledge concerning these products is too low. The natural increase in available information and networking that will occur naturally as the industry grows should help to rectify this problem.

- **Overcoming the Perception of Risk** – Because of the perception of risk, products must show they perform as well or better than virgin products. Component recertification processes must be refined and standardized before this can occur. Additionally, recycled products should be tested and certified in order to offset the high-risk aversion of the industry.

In the end, the increased use of reused and recycled building materials is in the hands of the architects, builders, and consumers that use them. Slowly but surely, perceptions have become increasingly positive over the last few years. The natural trend towards increased social and environmental responsibility, along with the maturation of the deconstruction industry, will aid in the effort to improve perception of reused and recycled building materials. This will increase the profitability of the building materials salvage market, making deconstruction a more desirable business alternative.

9.2 Lack of Design for Deconstruction Strategies

The aim of design for deconstruction is for the next generation of buildings to be more efficiently disassembled at the end of their useful lives. More efficient disassembly implies a process that is quicker, causes less damage to recovered building components, and is safer for the workers involved. The problem facing the industry today is that the benefits of design for deconstruction will not be realized until many years from now. Currently, the lack of design for deconstruction in the buildings that are coming to the end of their useful lives is a major barrier to efficient and profitable deconstruction (Chini and Balachandran, 2002).

Buildings that are approaching the end of their useful lives today were not built with deconstruction in mind. Deconstruction is a fledgling industry, much younger than the houses being deconstructed. There are several aspects of design for deconstruction that are currently hindering the materials recovery process. These are lack of kept construction records, abundance of hazardous materials, use of adhesives to hold fasten building components, and lack of labeling of building components.

Construction Records

Today, buildings to be deconstructed do not contain of the original construction information. This lack of information drastically decreases the speed and efficiency of the deconstruction process. The presence of blueprints, materials lists, location of wiring systems, and photographs of connections used in the construction of the building would aid in the planning and implementation of its dismantling (Guy, 2001).

Abundance of Hazardous Materials

Government policies concerning hazardous materials abatement are higher for deconstruction than they are for demolition. This is due to the higher exposure levels for deconstruction workers. These stringent policies increase the cost and time necessary to complete a deconstruction project. Additionally, hazardous materials drastically increase the salvageability of building components. Design for deconstruction will focus on limiting the presence of hazardous materials.

Use of Adhesives

The use of various glues and adhesives in the installation of building materials may increase the stability of those building systems but it serves to decrease the efficiency of the deconstruction process and increase the likelihood of damage during extraction. This is particularly true with glue use on wood products and the grouts used in masonry construction. The glues previously used in wood construction tend to cause splitting and cracking of the wood during extraction. Certain mortars used to bond bricks are not conducive to later separation and cleaning of the bricks. It is only possible to clean bricks that are bonded with soft lime mortar. Those bricks that are bonded with Portland cement based mortar cannot be effectively separated and cleaned.

Currently, it is not standard practice for building components to be labeled before installation. The recovery process is slowed by the necessity to identify the components makeup, how it was fastened, what kind of chemicals may or may not be present, etc... Design for deconstruction will identify issues involving labeling of building components to speed up the deconstruction process.

9.3 Lack of Tools and Training

Tools

The successful large scale implementation of deconstruction in the United States is contingent upon increasing the efficiency of the deconstruction process. Currently, time constraints pose a legitimate threat to the growth of the deconstruction industry. In the construction industry, where time is of the essence, the extra time involved to remove a building via deconstruction, as opposed to removal through demolition, may be a deterrent. Additionally, time is money in the construction industry. The level of efficiency on any project is directly proportional to its profitability, deconstruction must become a more profitable industry if it is to be implemented on any substantial level.

Several factors are limiting the efficiency of the deconstruction process. As discussed earlier in this chapter, the lack of design for deconstruction has a negative effect on its efficiency. However, the benefits of designing buildings for disassembly will not be felt until the useful lives of the next generation of buildings have expired. There are other factors affecting the efficiency of deconstruction that can be and are being improved right

now. One of the major factors affecting the efficiency of the deconstruction process is the current lack of tools available that stimulate the speed of deconstruction while minimizing the damage incurred by recovered materials.

To date, the tools used during the deconstruction process have generally been the same hand tools used in the construction process. These tools were not designed with the efficient, safe disassembly of buildings in mind. For example, crow bars are frequently used tools on deconstruction sites for prying apart building components such as wooden planks. However, a crow bar was designed to pry apart wooden planks without damaging them. Consequently, the planks are often split during extraction. This damages the wood, reducing its reusability and thus its resale value. Tools must be developed that facilitate the speed and safety of materials recovery during deconstruction while at the same time minimizing the damage incurred by those materials.

The following case study examines a tool that has already been developed to speed up the deconstruction process. The Nail Kicker, developed by Reconnx, is used to remove nails from wood (table 21). According to Reconnx, at a labor rate of \$7.50/per hour, a \$439 Nail Kicker powered by a \$350 air compressor pays itself off.

Table 21. Reconnx Nail Kicker – a new tool for deconstruction

Case Study: Nail Kicker by Reconnx

*The Nail kicker is a handheld pneumatic denailer, similar to a nail gun, that kicks nails out of lumber without destroying the wood. The Nail Kicker serves to increase the speed and automation of the usually labor-intensive task of deconstructing wood-framed buildings. By minimizing the damage caused to the wood, the Nail Kicker also increases cost-effectiveness of lumber salvage and reuse. The Nail Kicker is up to 4 times faster than pulling nails with the back side of a hammer. It can kick nails byg and small out of plywood, flooring, and even 2x materials.
(Reconnx, 2003)*

Another company that is designing tools to increase the efficiency of deconstruction is Auburn Machinery, Inc. of Auburn, Alabama. Auburn Machinery is developing planning machines that resize waste lumber into standard sizes, while at the same time removing unwanted paint and chemicals from the surface of the wood (Table 22).

Table 22. Auburn Machinery Wood Recovery machine

***Case Study: Auburn Machinery, Inc.
Auburn, Alabama***

Auburn Machinery is developing machinery for planing and ripping serves to resize and resurface non-uniform recovered wood products. These machines also serve to remove lead-based paint or other unwanted chemicals from the surface of recovered wood. Additionally, Auburn is developing material handling devices that aid in the sorting, stacking, and labeling of recovered products. The goal of these products it to promote the efficient transformation of recovered wood into usable products. (Auburn Machinery, Inc., 2003)

Training

The implementation of deconstruction as a widespread building removal technique remains slow while the knowledge of its potential benefits is rising rapidly. One reason for this may be that builders and demolition contractors are reluctant to pursue that which they are not familiar with. The lack of deconstruction training available is thus a barrier to its growth as an industry. Development of programs that promote deconstruction of buildings as an alternative to traditional demolition by training contractors how to effectively dismantle structures with the purpose of reclaiming materials will facilitate the full-scale implementation of the deconstruction industry. One such program is already being developed. ReSource 2000, a program developed by the Boulder Energy Conservation Center, has begun a program aimed at training contractors about the deconstruction process.

9.4 Lack of Markets for Used Components

The economic structure of the deconstruction industry requires that the recovered materials be sold in order to achieve any level of profitability. Thus, access to salvaged materials markets is a critical element to the successful implementation of deconstruction. At this juncture, a lack of markets for used building materials is a barrier to deconstruction. The strength of the used building materials market in a given area is directly related to the area's local attitude toward used building materials and the population and location of the area.

As discussed earlier in this chapter, perception of low value of salvaged building materials remains a problem in the construction industry today. This perception of low value has a direct influence on the demand for salvage materials. Thus, the presence of negative perception has an adverse affect on the market for used components. As time passes, the continued effort of the deconstruction industry to educate the public on the benefits of using salvaged building components will serve to alleviate this issue.

Large metropolitan areas tend to support the strongest used building materials markets. There is obviously a positive correlation between the size of a city and its demand for consumer goods. Additionally, the available building stock for deconstruction will tend to be greater in highly developed areas such as large cities. The following case study examines the used building materials market in Milwaukee, Wisconsin, where implementation of deconstruction has been very successful (Table 23).

Table 23. Used building materials market in Milwaukee, Wisconsin

Case Study: Used Building Materials Market – Milwaukee, Wisconsin

Milwaukee has been very successful thus far in its local efforts to implement deconstruction. One of the major factors in Milwaukee's success has been the well developed used materials market in the area. Milwaukee itself is a decent sized city. Additionally, Milwaukee is closely located to the large Metropolitan areas of Chicago, Illinois and Madison, Wisconsin. This has facilitated the smooth distribution of used building materials. Milwaukee's public perception of used building materials is high due to the high level of public education concerning the benefits of deconstruction and materials salvage. Milwaukee public officials have been very supportive of deconstruction activity and have developed guidelines for recovered wood in residential and commercial buildings.
(Grothe and Neun, 2002)

Export Markets in border and port cities create an additional market for used building materials (feasibility). These markets have the capability to increase the consumer base for deconstructed materials exponentially. The following case study examines the export market for used building materials in Miami, Florida (Table 24).

Table 24. Export market for used building materials in Miami, Florida

Case Study: Export Market for Used Building Materials – Miami, Florida

Export of used building materials is a strong market in the Miami area, and exporters were identified as a major customer group for recovered materials. Several used building materials markets in the Miami area sell approximately half of their material to exporters from Central American and Caribbean countries. One exporter to Belize sends a truck to purchase materials from a used building material retail operation on a monthly basis. Top selling items include windows, doors, iron bars, awnings, shutters, cabinets, toilets, and sinks.
(Grothe and Neun, 2002)

So far in this discussion it has been established that large, port cities with high public perception of used building materials have the most healthy markets for used materials. Then problem facing the deconstruction industry at this point is that the majority of towns in the United States do not enjoy this combination of characteristics. A major focus of the construction industry must be to network together those areas that may not be able to establish strong reuse markets with those that can. The use of the internet creates an additional medium to obtain and sell used building materials. "Internet sales have the potential to change existing market relationships by allowing end users to purchase materials at reduced prices from sources other than their traditional supplier" (Grothe and Neun, 2002). Currently, Internet sales are more conducive to the sell of high-end salvaged building materials because of the intensely high demand for these goods, particularly high-quality structural timbers. Low-end materials do not benefit as well from the internet because added shipping and processing fees tend to negate the money saving benefits of these materials. The following case study examines the Used Building Materials Exchange, an internet site aimed at providing an international network of salvaged materials distributors (Table 25).

Table 25. Used Building Materials Exchange website.

Case Study: Used Building Materials Exchange

The Used Building Materials Exchange is an internet site created to facilitate the movement of used building components. Members of the website can post listings, similar to classified ads, advertising the components that they are selling or those that they are looking to obtain. Generally, a listing for would identify the component for sale, the price, the name of the seller, and the seller's contact information. The advantage of the Used Building Materials Exchange is that facilitates the globalization of the building materials reuse market.
(Used Building Materials Exchange, 2003)

CONCLUSIONS

Deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling buildings in a manner that will allow the reuse or efficient recycling of the materials. Deconstruction is emerging as an alternative to demolition in the US and around the world. Techniques and tools for dismantling existing structures are under development, research to support deconstruction is ongoing at several institutions, and some government agencies are realizing the advantages of deconstruction over demolition by funding research in area of deconstruction and materials reuse. In addition, young, rapidly expanding industries on deconstruction and used building materials are forming to efficiently bridge the logistical gap between building materials recovery and building materials resale. A number of associations are formed to bring companies together in order to promote networking, information exchange, lobby for government support, and improve the efficiency of the industry.

Designing buildings to be built in ease of future deconstruction is beginning to receive attention and architects and other designers are starting to consider this factor for new buildings. The first international conference on deconstruction and materials reuse was organized by the Powell Center for Construction and Environment at the University of Florida on May 7-10, 2003 in Gainesville, Florida. This conference was an excellent forum for exchange of information among research organizations, practitioners, manufacturers, and used building materials businesses around the world. The conference Proceedings (CIB Publication 287, 2003) includes thirty six papers that address the key technical, economic, environmental and policy issues needed to make deconstruction and reuse of building materials an alternative to demolition and landfilling.

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