

Building Deconstruction: Reuse and Recycling of Building Materials

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ABSTRACT

The CCE deconstructed six (6) houses during 1999-2000 to examine the cost-effectiveness of deconstruction and salvage when compared to traditional demolition. This research was funded by the Florida Department of Environmental Protection (FDEP) Innovative Recycling Projects grant program through Alachua County, Florida. The one and two-story houses represented typical Southeastern US wood-framed residential construction from 1900 to 1950. Regulatory issues included the costs and implementation of demolition, and historic permitting practices in the Gainesville / Alachua County, Florida region, and handling of lead-based paint (LBP) materials and asbestos containing materials (ACM). Worker safety issues and technical issues included protection from environmental and site hazards and a case-by-case materials management process for each building. Reuse and materials redistribution included on-site and off-site redistribution and associated costs and benefits. Over 500 pieces of salvaged lumber were visually graded by the Southern Pine Inspection Bureau, to understand the damage of use and the deconstruction process on salvaged lumber for potential reuse in structural applications. Conclusions are presented on the means to encourage use of deconstruction and the need for further research to develop the deconstruction and reuse industries.

KEYWORDS: deconstruction, selective dismantling, C&D wastes management, building salvage, building materials reuse.

Project Background

From August, 1999 to May, 2000 the Center for Construction and Environment, University of Florida, deconstructed six (6) wood-framed residential structures in Gainesville, Florida. University students provided labor on the first three buildings and Americorps National Civilian Community Corps teams (*NCCC) worked on the second three. Houses were acquired mainly through word of mouth. The process included issues of historic preservation, demolition delay requirements, licensed contractor requirements and environmental, safety and health certifications for hazardous materials management. Each house was tested for lead-based paint (LBP) and asbestos containing material (ACM). All structures were completely removed from the site, comparable to a total demolition. Time and activity data was collected for each worker and all associated costs and estimated revenues from salvaged materials were calculated. Each building was also estimated for demolition in order to make a comparison with deconstruction and salvage. There was considerable variety in the buildings' conditions, the location of the buildings, and the efficiency of each deconstruction.

Buildings Summary

The structures ranged from approximately 1000 to 2000 SF and were both one and two-story. The oldest structure was built in 1900 and the youngest built in 1950. The typical construction was a raised wood floor structure on brick and/or concrete piers, light wood wall-framing, roof rafters, and interior and exterior wood cladding and sheathing. Two structures had plaster and

lathe interior wall finishes. In one case gypsum wallboard was applied directly over the wood beadboard interior wall finish. One structure also had two roof finishes, metal over asphalt shingles, and two floor finishes, an oak floor laid directly on top of a pine floor. All of the structures had rot from water damage principally in kitchen or bath floor areas, but including wall areas from roof leaks.

Table 1. Summary of Buildings

| Building address # | 2930 | 711 | 14 | 2812 | 901 | 3650 |
|------------------------------|-------------|------------|-----------|-------------|------------|-------------|
| Built | 1915 | 1945 | 1900 | 1900 | 1920's | 1950 |
| Stories | 1 | 2 | 2 | 1 | 1 | 1 |
| Light framed wood construct. | Y / CMU | Y | Y | Y | Y | Y |
| Size (SF) | 2,014 | 1,436 | 2,059 | 1,238 | 992 | 1,118 |
| Urban or rural-sized parcel | Rural | Urban | Urban | Rural | Rural | Rural |
| Additions | Y | Y | Y | Y | Y | Y |
| # of additions | 3 | 1 | 1 | 2 | 3 | 1 |
| Internal renovations | Y | N | Y | N | Y | N |
| Inhabitable | Y | N | Y | N | Y | Y |
| Require major repair | N | Y | N | Y | N | N |
| Asbestos | | | | | | |
| Exterior wall finish | Y | N | N | N | N | N |
| Roofing | N | N | Y | N | N | N |
| Insulation | N | N | Y | N | N | N |
| Floor tile | Y | N | Y | N | N | Y |
| Drywall | N | N | Y | N | N | N |
| Abatement | Y | N | Y | N | N | Y |
| Lead-based paint | | | | | | |
| Interior trim | N | N | Y | Y | N | N |
| Exterior trim | Y | Y | N | Y | N | Y |
| Interior surfaces | N | Y | N | N | Y | N |
| Exterior surfaces | N | Y | Y | N | Y | Y |
| Reason for removal | | | | | | |
| Redevelopment site | Y | | Y | Y | Y | |
| Taxes / expense | | | | | | Y |
| Safety / disuse | | Y | | | | |
| Homeless / fire hazard | | | | Y | | |

All of the structures had additions, and these were typically for; 1) adding living space, 2) adding kitchen and bathroom facilities on older structures, 3) enclosing an existing open porch area. Four (4) out of six (6) could be made habitable, and three (3) of six (6) had been recently occupied prior to the building's removal. One (1) house had been occupied by homeless persons without heating, kitchen, or bathroom facilities. Three (3) of the six (6) structures were found to have asbestos containing materials (ACM) requiring abatement. Two (2) of the structures contained only non-friable asbestos which could have been "wet demolished" by mechanical means but would have required the entire demolition wastes load to be disposed of in a hazardous materials landfill. Only one building had LBP only on the inside, typically LBP was found on exterior window and door trim, where it was used in gloss and semi-gloss paint for durability.

Two (2) of the six (6) buildings were on property slated for immediate commercial or multi-family redevelopment, two (2) were on property slated for long-term redevelopment, and two (2)

buildings were on land not slated for redevelopment. The latter two (2) structures may have been left vacant for an indeterminate length of time if they had not been used for this project. The average size of the six structures was 1,476 SF.

Based upon literature review and anecdotal information, this sample of structures would appear to be representative of residential demolitions in the United States. Approximately 94% of all residential buildings built each year in the US are light wood-framed construction (NAHB, 1994). The predominance of site redevelopment as the rationale for building removals was consistent with anecdotal information from other sources.

Data Collection

On-site labor was documented by recording each worker's activities on a 15-minute time increment. There have been several well-documented deconstruction pilot projects in the US with this detail of data collection, most notably the Fort Ord Pilot Deconstruction project conducted by the Fort Ord Reuse Authority (Cook, 1997) and the Riverdale Pilot Deconstruction Project conducted by the National Association of Home Builders Research Center (NAHBRC, 1997). These projects provided models for creating the data collection process. Data was divided into two categories; the deconstruction of the structure and the processing of the salvaged materials. The cost of a traditional demolition was calculated for each structure, including asbestos and lead surveys and abatement comparable to deconstruction, and disposal costs. Salvage revenues were estimated using a percentage (25-50%) of retail prices from local building materials suppliers and the experience of a former used building materials store owner/operator in Gainesville, Florida. Disposal costs were estimated by weight and costs data provided by the wastes haulers for the project.

Worker labor activities were sub-divided into categories by the location in, or component of, the building in order to calculate the costs of deconstructing a particular component of the building, and the costs to salvage a unit of a particular material. The latter information was used to assign a unit cost of extraction and processing that could be compared to the pricing units for materials, i.e. number, linear feet, or board foot of material. Labor productivity data was collected in the following task categories:

- (S) upervision
- (Decon) struction
- (Demo) lition
- (P) rocessing
- (N) on-production
- (C) lean-up / (Dis) posal
- (L) oading/unloading

The largest percentage of time on any deconstruction was the deconstruction activity, an average of 26% of total time. The next greatest percentage of time was spent in processing materials at an average of 24%. Disposal and cleaning required an average of 17% of total time. Demolition required an average of ~10% of total time. The house with the largest percentage of time spent for deconstruction was the house at 901 SR 301 (47.8%). This house was being removed for redevelopment and had a very short time-frame for the deconstruction. It was also located on a

major highway in the corner of a shopping center site, and materials were redistributed by placing them neatly in separate piles at the site and posting signs to encourage passersby to remove the materials themselves. All of the materials were removed within one day after the completion of the deconstruction.

The house with the lowest percentage of time in deconstruction was the house at 711 NW 7th Avenue (12%). This structure was in the poorest condition of any of the structures and therefore had the least amount of salvage. Commensurately, this building had the highest percentage of time spent in demolition, disposal, and cleaning (39.6%). Excluding the house at 711 NW 7th Avenue which had a very low salvage rate and very little processing (4.3%), processing was a relatively consistent percentage of time between 18 – 30% of total time. These two houses were examples of the extremes that could occur in deconstruction projects.

Table 2. Labor Time by Work Categories

| Category | Hours | S | Dec | P | Dem | Dis/C | N | L | Total |
|-----------------------|-------|-------|---------------|---------------|-------|---------------|-------|-------|--------------|
| 2930 | hr | 60.50 | 179.50 | 204.80 | 0.00 | 100.00 | 52.75 | 80.00 | 677.55 |
| 2014 SF | % | 8.93 | 26.49 | 30.23 | 0.00 | 14.76 | 7.79 | 11.81 | |
| per SF | hr | 0.030 | 0.089 | 0.102 | 0.000 | 0.050 | 0.026 | 0.040 | 0.336 |
| 711 | hr | 20.50 | 24.33 | 8.67 | 42.95 | 80.50 | 14.33 | 12.25 | 203.53 |
| 1436 SF | % | 10.07 | 11.95 | 4.26 | 21.10 | 39.55 | 7.04 | 6.02 | |
| per SF | hr | 0.014 | 0.017 | 0.006 | 0.030 | 0.056 | 0.010 | 0.009 | 0.142 |
| 14 | hr | 62.13 | 113.56 | 124.56 | 26.67 | 81.00 | 27.00 | 42.87 | 477.79 |
| 2059 SF | % | 13.00 | 23.77 | 26.07 | 5.58 | 16.95 | 5.65 | 8.97 | |
| per SF | hr | 0.030 | 0.055 | 0.060 | 0.013 | 0.039 | 0.013 | 0.021 | 0.232 |
| 2812 | hr | 29 | 133.13 | 217.63 | 39.13 | 63.25 | 53.75 | 21.5 | 557.39 |
| 1238 SF | % | 5.20 | 23.88 | 39.04 | 7.02 | 11.35 | 9.64 | 3.86 | |
| per SF | hr | 0.023 | 0.108 | 0.176 | 0.032 | 0.051 | 0.043 | 0.017 | 0.450 |
| 901 | hr | 11.75 | 124.75 | 47 | 27 | 25.75 | 23 | 1.75 | 261.00 |
| 992 SF | % | 4.50 | 47.80 | 18.01 | 10.34 | 9.87 | 8.81 | 0.67 | |
| per SF | hr | 0.012 | 0.126 | 0.047 | 0.027 | 0.026 | 0.023 | 0.002 | 0.263 |
| 3650 | hr | 16 | 84 | 91.85 | 64.5 | 35 | 50.5 | 17.25 | 359.10 |
| 1118 SF | % | 4.46 | 23.39 | 25.58 | 17.96 | 9.75 | 14.06 | 4.80 | |
| per SF | hr | 0.014 | 0.075 | 0.082 | 0.058 | 0.031 | 0.045 | 0.015 | 0.321 |
| | | | | | | | | | |
| Average % | | 7.69 | 26.21 | 23.86 | 10.34 | 17.04 | 8.83 | 6.02 | 100.00 |
| Average per SF | | 0.021 | 0.078 | 0.079 | 0.027 | 0.042 | 0.027 | 0.017 | 0.291 |

The deconstruction process roughly follows the reverse of the construction process. The materials that have been put on last will come off first. Variations occur for the whole building when, for example, an addition will be removed in its entirety separately from the rest of the building. The practice of focusing on each material type in a reverse order of the construction process is more efficient for separating materials for reuse, recycling, and disposal at the time of removal. Additions are an impediment to removing one type of material or whole sections of the original structure, but can provide a working surface for other parts of the building, and be structurally dependent on other parts of the building. For these reasons, additions were typically

removed in their entirety, regardless of breaking up the material-by-material consistency of the deconstruction process.

Economics

The net cost of the deconstruction is modeled by the expression: $(Deconstruction + Disposal + Processing) - (Contract Price + Salvage Value) = Net Deconstruction Costs$. The net cost for demolition is: $(Demolition + Disposal) - (Contract Price) = Net Demolition Costs$. If materials are not resold or redistributed on-site, or reused by the deconstruction contractor in new construction, transportation and storage costs may be additional costs for deconstruction. In order for deconstruction to be cost-effective and competitive with traditional demolition and disposal, the sum of the savings from disposal, and revenues from resale of materials, must be greater than the incremental increase in labor costs. Insuring that a building's materials are worth salvaging, having efficient resale mechanisms and markets, and decreasing processing effort, will increase the percentage of time able to be spent in deconstruction activity, and decrease time costs overall. Additionally, removing and reselling materials as quickly as possible will assist in overcoming the disincentive for deconstruction created by the time costs of development and building loans.

There are multiple options for contracts and costs/revenues between a building owner and the deconstruction contractor, such as:

- Deconstruction as a service to the building Owner and the Owner retains ownership of the salvaged materials. This can also be a guaranteed “buy back” of the materials and treated according, with some consideration for the Contractor's costs for processing and handling. The Owner will pay more than demolition but could be “buying” very high value materials.
- Deconstruction with shared ownership of the materials, with a reduction in the deconstruction contract based upon the Contractor receiving materials as in-kind payment.
- Deconstruction with the Contractor retaining all materials, and charging an internally calculated price based upon revenues to be received from resale of salvaged materials.
- A non-profit deconstructor performs a deconstruction for a fee and the Owner donates the materials as a tax write-off.

An economic factor for deconstruction on a redevelopment site is the time costs of money in financing and construction loan interests. A large site may allow an unwanted structure to be isolated from the other construction activity and be deconstructed without delaying the site development. In the case of a site where the new construction will take place on the footprint of the existing structure, the time for removal of the existing structure by deconstruction is a significant economic impediment.

Permitting

The City of Gainesville has a unique demolition permitting process which allows the City to place a 90-day demolition delay on any residence that may have historic value (older than 45 years). During this 90-day delay, the structure is posted as free to anyone willing to pay the costs

of moving. This delay can be waived by demonstrating a financial hardship. There are no historic districts or delays in Alachua County.

There is no differentiation in Alachua County and the City of Gainesville between a deconstruction and a demolition for permitting purposes. The total costs of permits range from \$60 to \$100 for single or two-story residential structures. The City of Gainesville charges by the total number of stories of a structure, and Alachua County charges by the estimated value of the demolition work. These permitting factors and low costs are not conducive to encouraging deconstruction.

A possible incentive for deconstruction under the 90-day delay ordinance is to shorten the delay to 30 days, for example, for a “deconstruction permit”. By shortening the delay for deconstruction, it would be less viable to claim economic hardship posed by the delay, some time is allowed to arrange a building removal, and sufficient time is allowed for deconstruction and still result in a net reduction over the 90-day delay.

The City of San Jose has been developing a Construction Demolition Debris Deposit (CDDD) as a means to encourage reuse and recycling of building materials. This deposit, similar to the bottle deposit, requires an upfront deposit based upon estimated waste generation. Upon completion of the project and documentation of reuse for distribution or transfer to an appropriate recycling option of 50% of the waste generated by the project, the refund is returned. This procedure combines the demolition permit with an economic incentive to reuse and recycle the demolition debris. It also encourages the development of the local reuse and recycling business sector to provide infrastructure and markets for contractors, without having to directly subsidize them.

Environmental Issues

For the purposes of maintaining worker health and safety, deconstruction is a distinct activity in EPA and OSHA regulations. Relevant environmental and worker health and safety regulations governing the deconstruction of buildings include: US EPA National Emission Standards for Hazardous Air Pollutants (NESHAPS) Asbestos Regulations (40 CFR 61, Subpart M), Occupational Health and Safety (OSHA) Asbestos Regulations (29 CFR 1910.1001), OSHA Lead Regulations (29 FCR 1926.26) and Classifications of Landfills Florida Statue Rule 62-701.200 (19).

Hazardous Materials in Deconstruction

The NESHAPS regulation requires any commercial properties or residential properties greater than 4 units to have a reasonable effort to identify hazardous materials prior to demolition or deconstruction. The NESHAPS regulation also controls the techniques for removal, containment, and transport of asbestos containing materials (ACM). The NESHAPS regulations exempt residential structures of 4 dwelling units or less. Residential units demolished as part of larger public or commercial projects such as highway construction and shopping centers are not exempt from NESHAPS even if less than 4 dwellings units. A group of individual residential buildings under the same ownership on a site is considered an installation and is also not exempt from the NESHAPS regulations. Hazardous materials are required to be disposed of in a lined landfill or other disposal facility that is permitted for those materials.

Worker environmental safety is regulated under OSHA and EPA guidelines regardless of the construction activity. The CCE utilized a certified LBP and ACM surveyor to perform a lead-based paint (LBP) survey and an asbestos survey when asbestos containing materials (ACM) are visually identified during the assessment of each case study building. The building assessment survey also included noting the presence of fluorescent lights, thermostats, or high-density discharge lamps that may contain mercury or PCBs, and containers of suspect chemicals, paint, oil, etc.

LBP is assumed in any structure built prior to and during the period between 1970 - 1980 and OSHA began ACM regulation in 1970. Between 83% and 86% of all homes built before 1978 in the United States have lead-based paint in them. The older the house, the more likely it is to contain lead-based paint and to have a higher concentration of lead in the paint. Houses built before 1950 pose the greatest hazard to children because they are much more likely to contain lead-based paint than newer houses. (Centers For Disease Control And Prevention Website (CDC))

Samples were taken from all suspect, homogeneous ACM and LBP surfaces on all of the structures in this study. Polarized Light Microscopy with dispersion staining was used to analyze the ACM samples using US EPA Interim Method for the Determination of Asbestos Minerals in Bulk Materials. LBP samples are tested using the NIOSH Method #7082. Samples were analyzed by EMSL Analytical, Inc., Program, Greensboro, NC. The HUD minimum threshold for the presence of lead is 0.5% Pb. A summary of LBP findings for the case study structures is provided in Table Five.

According to the US EPA, regulated ACM (RACM) is: a) friable asbestos material; b) Category I non-friable that has become friable; c) Category I non-friable that will be subject to sanding, grinding, cutting, abrading; d) Category II non-friable that has a high probability of becoming friable in the course of renovation or demolition activity.

Removal and disposal of all friable asbestos must be completed prior to demolition by a licensed professional asbestos abatement firm. Category I non-friable ACM (asphalt roofing shingles, floor tiles) and Category II non-friable ACM (asbestos siding shingles, transite board) need to be removed prior to demolition only if they are RACM. Category I non-friable ACM flooring and shingle materials and Category II non-friable ACM are not RACM and do not have to be abated prior to demolition if they are in good condition and not likely to become friable during demolition. Removal of Category I non-friable ACM is permitted according to the Resilient Floor Covering Institute (RFCI) and the National Roofing Contractors Association (NRCA) acceptable work practices. The NRCA association's recommendations are to remove asbestos shingles by hand and lower them to the ground. Theoretically, demolition should render all ACM to be regulated since it is comprised of crushing, cutting, and grinding activities. However, Category II non-friable ACM is allowed to be demolished in place using proper wetting and containment techniques during the removal and transport.

Because deconstruction poses a greater worker exposure than mechanical demolition it is prudent to remove all ACM, both RACM, and ACM that is in good condition. Any materials with asbestos are also not viable for reuse. In effect, all ACM must be abated prior to deconstruction

whether it is considered regulated or not, which could add significant costs to a deconstruction project over traditional demolition. Any components that are either intended for reuse with LBP remaining on the material or materials that have been repainted to encapsulate the LBP require notification that the material contains LBP. Salvaged materials are not allowed to sit on exposed soils where there is potential for the LBP to leach into the soil. In this case study, salvage materials were either loaded onto a truck each day and moved off-site to an appropriate storage facility, or stored on 6 mil polyethylene sheeting and a waterproof covering. Waste materials were placed directly into standard 20, 10 and 8 cubic yard roll-offs.

Table 3. Lead and Asbestos Sample Results by Location (6 houses)

| | Total | Floor | Int. fin. | Roof | Int. trim | Ext. trim | Ext. fin. | Insul. | Duct tape |
|-------------------|--------------|--------------|------------------|-------------|------------------|------------------|------------------|---------------|------------------|
| Suspect ACM | 50 | 27 | 17 | 3 | 0 | 0 | 1 | 1 | 1 |
| Percentage | | 54.0% | 34.0% | 6.0% | | | 2.0% | 2.0% | 2.0% |
| ACM | 12 | 9 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| Percentage | 24.0% | 75.0% | 8.3% | 8.3% | | | | | 8.3% |
| Suspect LBP | 35 | 1 | 14 | 0 | 4 | 9 | 7 | 0 | 0 |
| Percentage | | 2.9% | 40.0% | | 11.4% | 25.7% | 20.0% | | |
| LBP | 18 | 0 | 4 | 0 | 1 | 6 | 7 | 0 | 0 |
| Percentage | 51.4% | | 22.2% | | 5.6% | 33.3% | 38.9% | | |

A total of fifty (50) samples were taken from possible asbestos containing materials (ACM) in the six houses that were deconstructed. Of these 50 samples, twelve (24%) were found to be ACM. Seventy-five percent (75%) of the ACM was in flooring materials, and then a much lower percentage (8.3%) of the ACM was found equally in roofing materials, interior finishes, and insulating duct tape on mechanical equipment. Thirty-five samples were taken from painted surfaces. Of these 35 samples, eighteen (18) or 51%, were found to be LBP. The highest percentage of LBP was found on the exterior (72%), divided between finishes (39%) and trim (33%). Approximately twenty-two (22%) percent of LBP was found on interior wall surfaces, and five (5%) percent on interior trim. Based upon this limited sample, lead-based paint is approximately two (2) times more likely to be found on average than asbestos containing materials. ACM is considerably more likely to be found in flooring materials (3 out of 4 occurrences) and LBP is much more likely on exterior surfaces (3 out of 4 occurrences) than on interior surfaces. All six houses had lead-based paint on at least one surface.

Asbestos Abatement and Lead-Based Paint Protocol

A certified asbestos abatement contractor, Merit Abatement, Macclenny, Florida, was used for any asbestos abatement required during the project. At no time was any sanding, grinding, abrading, cutting, burning or heating of the LBP wood materials permitted. Since all ACM was abated prior to deconstruction, the primary worker health concern was for lead-based paint (LBP) materials. The primary threat of worker exposure to LBP is through ingestion - inhaling, eating, drinking and smoking while in proximity to the LBP. A hand washing station was established on the job-site and personal protective equipment (gloves) and filter masks were required of all workers.

In the event of known LBP in an interior environment, according to OSHA Lead Regulations (29 FCR 1926.26), workers are assumed to be exposed to LBP above acceptable levels until proven otherwise through personal air sampling. Methods to insure the removal of LBP and worker protection in this project were primarily building engineering and mitigation techniques. OSHA and EPA both recognize that deconstruction is a less destructive process than mechanical demolition, but conversely has the potential for greater worker exposure. There were two houses in this project that had LBP on interior trim and two different houses that had LBP on interior surfaces. Four houses had LBP on exterior trim or surfaces. Because of the high turnover of workers, and the fact that the presence of LBP was minimal in interior environments or on the exterior of the structures, the following protocol was established:

1. All workers received an approved 8-hour ACM and LBP awareness training course through the University of Florida TREEO Center.
2. All exterior windows and doors were the first elements removed from the buildings to immediately allow ventilation and prevent accumulation and concentrations of LBP dust.
3. All workers in the LBP environment were provided personal fit-tested and approved respirators if requested, and protective clothing.
4. A HEPA vacuum was utilized throughout the building interior to remove all dust and particulate matter to the maximum extent feasible.
5. Workers were rotated out of LBP environments on a short-cycle and regular basis.
6. Job-site hand washing station was provided.
7. Smoking was prohibited inside the structure and near any salvaged materials.
8. Workers were required to wash hands before breaks and lunch breaks.
9. Sanding, cutting, grinding, abraded, burning and heat-gun stripping of LBP surfaces were not permitted.
10. Workers were provided with uniform T-shirts and required to change them at the completion of the work shift and before leaving the job-site.
11. The job-site supervisor, who was the only person consistently on site for every structure, was tested for blood lead levels at the beginning and end of the project.

The asbestos and lead awareness training was provided by the University of Florida's Center for Training, Research and Education for Environmental Occupations (TREEO Center) and was in compliance with OSHA's asbestos section 29 CFR 1926.1101 and lead section 29 CFR 1926.62. The purpose of the training was to expand worker awareness of lead and asbestos issues.

Job Safety

A short classroom orientation was developed to introduce beginner workers to basic tips such as the appropriate angle of repose for ladders, communication with other workers, and use of tools and techniques for removing and processing materials. The supervisor was also responsible for daily job-safety supervision. Issues related to worker safety training included:

- Stabilizing weakened sections of buildings, and working in such a way as to keep the structures as stable as possible via the order of the deconstruction.
- Routes for materials after they have been removed including placing out a window or dropping from the roof for others to remove to the processing area.
- Handling windows (glass), long items, heavy items, and objects with the nails still in them.

- Understanding how components are connected and the best method and tool to use in removing it to minimize force which in turn can result in sudden movements, creating projectiles, slipping, etc.
- Importance of cleaning debris and removing materials from areas where they can be hazards either off or on the ground.
- Understanding load bearing components and stresses produced by gravity, including awareness of damaged components and weak points caused by termite, water damage, etc.
- Use of safety harnesses and 2x4s nailed horizontally for footholds when working on roofs.
- Using a two-person system for the majority of materials removal so that long wood members, for example, were able to be handled at both ends to protect both workers and materials from any sudden movements.

All workers were required to have their own steel-toed boots, long pants and shirts. Safety glasses, hardhats, eye plugs, and gloves were provided. Cleanup of debris on all work surfaces occurred after each phase of deconstruction. Piles of debris were not allowed to accumulate in work areas where they could generate a hazard or impediment to the workers.

Technical Issues

Deconstruction is the dismantling of a structure in the reverse order in which it was constructed. Entire additions to a building are removed at one time, and within each addition, materials were removed in the reverse order of their construction. Numerous issues were found to be relevant to the deconstruction process.

- The working platform or area and how well that assisted or impeded the deconstruction of an adjoining, overhead, or element below.
- Clearing a work site around the building, particularly so that roll-offs and the movement and stacking of materials was not impeded, was found to be critical.
- Timely removal and drop-off of the roll-offs in order to not impede the removal of components directly into the roll-off, while having them as close as possible to where the major deconstruction effort might be occurring. For example, having a roll-off next to the structure to capture asphalt roofing shingles, but removing it and placing the next roll-off to not impede the removal of exterior siding.
- Removing both reuseable / recyclable and disposable materials in a timely manner is critical to the safety of the job-site and the efficiency of both the deconstruction and the processing activities.
- Many nails are placed in such a way as to not be readily accessible to a prying device. Wood is sometimes damaged in the extraction process. In all cases, a material will be removable by use of levering, unscrewing or unbolting, and should not require a sledgehammer or other smashing tool.

- Arranging on-site removal of materials as they are processed in order to minimize the effort invested in loading, transporting and storing materials in another location, while at the same time insuring that materials left at the site are not stolen.
- Good deconstruction sites require sufficient room to work around the building, including de-nailing and stacking areas away from the structure, space for roll-off delivery and pick-ups, but that are also highly visible to attract potential customers for the salvaged materials.
- Coordinating workers and increasing their awareness of how materials must be removed and the importance of balancing efficiency with minimal damage to the materials is critical. Maintaining awareness of the difference between salvage and disposal requires a high degree of supervision.
- Placing denailing stations either inside or under trees for shade and catching nails on the interior floor surface, wheelbarrows, or tarps/carpet scraps.
- Nails were often more easily removed when the material was still in place in the building such as a along the length of a vertical stud wall member. Damage or multiple nails in the ends of lumber were more readily removed by using a battery-powered saw to simultaneously trim the end and cut off the nails.

2930 NW 6th Street

This was a one-story house, and the detached garage was an approximately 500 SF slab-on-grade structure with wood rafters and an asphalt shingle roof. The garage walls were bare concrete masonry unit (CMU) construction. The house was wood-framed construction raised on brick piers. This building had several additions and several layers of interior finishes, i.e. two wood floors and two roof finishes, and a metal roof laid over an asphalt roof. The interior walls were predominantly plaster and lathe. As an experiment, the plaster was separated from the lathe to see if the lathe could be recycled or used for fuel in pottery kilns. This project was affected by a summer heat wave and several rain days. The site had ample room for the layout of de-nailing areas and roll-offs, and did not require extensive sitework to make space around the building. ACM was found in vinyl floor covering and lead-based paint was present mainly in exterior trim, but also on the exterior finish.

Table 4. Economic Summary for 2930 NW 6th Street

| COSTS | Total Net Demolition | | | Total Net Deconstruct | | |
|--|-----------------------------|-------------|---------------|------------------------------|-------------|---------------|
| Permit | 50.00 | | | 50.00 | | |
| Asbestos survey | 1,200.00 | | | 1,200.00 | | |
| Asbestos abatement | 740.00 | | | 740.00 | | |
| Disposal | 5,873.67 | 96.67 | tons | 1,344.01 | 22.12 | tons |
| Toilet | 63.00 | | | 63.00 | | |
| Supplies | 10.00 | | | 637.93 | | |
| Labor and Equipment | 3,504.36 | | | 8,469.38 | | |
| Total Costs | 11,441.03 | 5.68 | per SF | 12,504.32 | 6.21 | per SF |
| REVENUES | | | | | | |
| Salvage | 0.00 | | | 9,415.00 | 4.67 | per SF |
| Total Net Costs | 11,441.03 | 5.68 | per SF | 3,089.32 | 1.53 | per SF |
| Average disposal costs are \$60.76 / ton, including drop fee, hauling and tipping fee. | | | | | | |
| Demolition weight estimated as 96#/sf, 1/4 of house is CMU on slab | | | | | | |

As noted in Table Four, this structure had a close to average deconstruction cost. It had minimal abatement costs, but high labor costs. A summer heat wave and multiple layers of materials applied over time contributed to a higher level of difficulty and the longest time for any of the deconstructions. However, this project had a high level of materials quality resulting in a very low “net” deconstruction cost. This revenue would have not been realized if there had not been time to overcome the project’s labor difficulties. The greatest salvage value by a considerable margin was to be found in the 1x3 tongue and groove pine flooring, in this case some of it at least 85 years old.

2812 NW 8th Street

This building was one story and had two main sections. The first was believed to have been built in 1900. The structure was in reasonably good condition, but had not been used for some time. At the time of the deconstruction it was inhabited by homeless persons. Several windows were missing, and there was minimal to no mechanical equipment. Plumbing consisted of one bathroom. The building had minimal electrical equipment and no insulation. A major portion of time was spent on clearing the site of trash and several dilapidated out-buildings. The site was large and wooded, allowing for room to maneuver but also requiring removal of underbrush for working areas. This site was secluded which benefited site security and allowing materials to remain on-site for periods of time, but precluded any on-site redistribution of materials.

This house had no asbestos at the time of the deconstruction. It was in such poor repair and with all mechanical systems and insulation removed, it can be speculated that it may have had asbestos at one time, but this was haphazardly removed over time. Lead-based paint was found in the interior wall surfaces, but with no windows for many years, it was a well ventilated interior.

Table 5. Economic Summary for 2812 NW 8th Street

| COSTS | Total Net Demolition | | | Total Net Deconstruct | | |
|--|-----------------------------|-------------|---------------|------------------------------|-------------|---------------|
| Permit | 50.00 | | | 50.00 | | |
| Asbestos survey | 853.00 | | | 853.00 | | |
| Disposal | 2,103.61 | 24.76 | tons | 671.18 | 7.90 | tons |
| Metal recycling | 0.00 | | | 100.00 | | |
| Truck | 62.00 | | | 517.00 | | |
| Toilet | 74.00 | | | 74.00 | | |
| Gas | 10.00 | | | 55.00 | | |
| Supplies | 10.00 | | | 155.00 | | |
| Labor and Equipment | 2,154.12 | 1.74 | per SF | 6,967.38 | 5.63 | per SF |
| Total Costs | 5,316.73 | 4.29 | per SF | 9,442.56 | 7.63 | per SF |
| REVENUES | | | | | | |
| Salvage | 0.00 | | | 4,613.25 | 3.73 | per SF |
| | | | | | | |
| Total Net Costs | 5,316.73 | 4.29 | per SF | 4,829.31 | 3.90 | per SF |
| | | | | | | |
| Average disposal costs are \$84.96 / ton, including drop fee, hauling and tipping fee. | | | | | | |
| Demolition weight estimated as average of typical houses at 40#/sf | | | | | | |

As noted in Table Five, this house had high deconstruction costs, more than 75% higher than the estimated demolition costs. Even though salvage value was relatively good, the “net” deconstruction costs were less than 10% less than demolition, within a contingency margin of error. One possible reason for the high costs was that this house was deconstructed using two separate Americorps*NCCC teams over several months. Therefore, the worker skill level remained low throughout the entire project rather than increasing as the project progressed. This house had its highest salvage value from the 1x3 T&G flooring material.

711 NW 7th Avenue

This structure was two stories and in extremely poor condition. It would not have necessarily been included in the study except as a community service. It was uninhabited at the time of the deconstruction and was owned by an elderly single woman who could not afford to have it demolished. There was some debris and potential contamination inside the structure. The site was extremely constrained. The project building was behind another building and access for roll-offs was gained by an adjoining lot. Large trees provided shading over the building and for denailing stations. Due to the poor condition of the building, the salvage was minimal. There was no asbestos in this house. Similar to the house at 2812 NW 8th Street, this house had remained dilapidated for many years. It had no insulation, and minimal mechanical systems. Lead-based paint was found extensively. This structure had its windows and doors intact and considerable dust and potential biological hazards from animal feces. In this instance, half-mask respirators were used extensively.

Table 6. Economic Summary for 711 NW 7th Avenue

| COSTS | Total Net Demolition | | Total Net Deconstruct | | |
|--|-----------------------------|--------------------|------------------------------|----------------|--------------------|
| Permit | 100.00 | | | 100.00 | |
| Asbestos survey | 1180.00 | | | 1180.00 | |
| Disposal | 3229.85 | 28.72 tons | | 2700.20 | 20.83 tons |
| Toilet | 63.00 | | | 63.00 | |
| Supplies | 10.00 | | | 601.59 | |
| Labor and Equipment | 2498.64 | | | 2544.13 | |
| Total Costs | 7081.49 | 4.93 per SF | | 7188.92 | 5.01 per SF |
| REVENUES | | | | | |
| Salvage | 0.00 | | | 555.73 | 0.39 per SF |
| | | | | | |
| Total Net Costs | 7081.49 | 4.93 per SF | | 6633.19 | 4.62 per SF |
| | | | | | |
| Average disposal costs are \$67.13 / ton, including drop fee, hauling and tipping fee. | | | | | |
| Demolition weight estimated as average of previous houses at 40#/sf | | | | | |

As noted in Table Six, this house had low total costs that were very favorable to demolition. The simplicity of this structure and low time spent on salvage meant it was in fact more of a hand demolition than a deconstruction. This house was also located behind another house, within only several feet, on a very constrained urban site. Access for roll-offs was gained by an adjoining lot. It was noted anecdotally that this house was prohibitive for mechanical demolition due to the inability to place heavy equipment on the site in proximity to the other structure on the site and the risk to the other house. In this case, regardless of the salvage value, the house lent itself to “hand demolition.”

14 NE 4th Street

This was a two-story structure in relatively good condition. It has been inhabited at the time of the deconstruction. The site was small and did not allow room for parking. There was sufficient space for only one roll-off at one time. This building had the most extensive presence of asbestos containing materials, including ACM gypsum drywall. It also had a high degree of salvageable materials particularly heart pine and older growth pine. Therefore, asbestos abatement costs were very high, and would have been prohibitive if not for the innate value of the salvage materials.

This house was heavily contaminated with ACM, in floor coverings, drywall, roofing, and insulation tape. The abatement costs were a considerable disincentive to deconstruction. However, this house was on a commercial redevelopment site and was therefore not exempt from NESHAPS regulations. Drywall would likely be considered non-friable RACM if a mechanical demolition were attempted on this structure, and therefore the presence of the ACM drywall material may not have not have allowed a demolition without abatement in any case.

Table 7. Economic Summary for 14 NE 4th Street

| COSTS | Total Net Demolition | | | Total Net Deconstruct | | |
|--|-----------------------------|-------------|---------------|------------------------------|-------------|---------------|
| Permit | 100.00 | | | 100.00 | | |
| Asbestos survey | 1,200.00 | | | 1,200.00 | | |
| Asbestos abatement | 2,637.00 | | | 2,637.00 | | |
| Disposal | 2,233.86 | 36.03 | tons | 1,174.28 | 18.94 | tons |
| Toilet | 63.00 | | | 63.00 | | |
| Supplies | 20.00 | | | 347.24 | | |
| Labor and Equipment | 3,582.66 | | | 5,972.38 | | |
| Total Costs | 9,836.52 | 4.78 | per SF | 11,493.90 | 5.58 | per SF |
| REVENUES | | | | | | |
| Salvage | 0.00 | | | 5,795.30 | 2.81 | per SF |
| | | | | | | |
| Total Net Costs | 9,836.52 | 4.78 | per SF | 5,698.60 | 2.77 | per SF |
| Average disposal costs are \$62.00 / ton, including drop fee, hauling and tipping fee. | | | | | | |
| Demolition weight estimated as average of similar houses at 35#/sf | | | | | | |

Although the asbestos abatement was a high percentage of costs, the building was an excellent candidate for cost-effective deconstruction because it was relatively large (2,000 SF) and was two-stories, concentrating a large mass of materials in one building footprint/site. This structure was also on a highly visible site adjacent to an historic district and proximate to lower income older neighborhoods, whereby the salvaged materials were desirable for nearby preservation and renovation efforts on similar building types. Materials were re-distributed directly from the site.

As in every other house with a pine floor, the 1x3 T&G flooring was far and away the most lucrative salvage material. As in comparable structures, other high value for salvage was gleaned from larger dimensional lumber (2x8) and wood-lap, or “novelty,” siding.

901 SR 301

This was the smallest structure that was deconstructed. It was located at the corner of a shopping center site with ample room for locating roll-offs as well as laying out materials for sorting, denailing and counting. Due to a time constraint, much of the materials were not denailed and much of the material was redistributed by laying out for passersby to remove themselves. Due to a combination of newer materials in good condition, no site clearing and a large site, and minimal time on processing and transporting off site, this building was a good example of a more optimal deconstruction scenario.

There was no ACM in this structure, and minimal LBP on interior and exterior finish. As noted previously, the first step in the deconstruction process was to remove all windows and doors for ventilation.

Table 8. Economic Summary for 901 SR 301

| COSTS | Total Net Demolition | | | Total Net Deconstruct | | |
|--|-----------------------------|-------------|---------------|------------------------------|-------------|---------------|
| Permit | 50.00 | | | 50.00 | | |
| Asbestos survey | 700.00 | | | 700.00 | | |
| Disposal | 1,874.88 | 22.32 | tons | 445.20 | 5.30 | tons |
| Truck | 62.00 | | | 293.13 | | |
| Toilet | 74.00 | | | 74.00 | | |
| Gas | 10.00 | | | 80.00 | | |
| Supplies | 10.00 | | | 100.00 | | |
| Labor and Equipment | 1,726.08 | | | 3,262.50 | | |
| Total Costs | 4,506.96 | 4.54 | per SF | 5,004.83 | 5.05 | per SF |
| REVENUES | | | | | | |
| Salvage | 0.00 | | | 4,613.95 | 4.65 | per SF |
| | | | | | | |
| Total Net Costs | 4,506.96 | 4.54 | per SF | 390.88 | 0.39 | per SF |
| | | | | | | |
| Average disposal costs are \$84.00 / ton, including drop fee, hauling and tipping fee. | | | | | | |
| Demolition weight estimated as average of previous houses at 45#/sf | | | | | | |

As noted in Table Eight, this house had a lower-than-average deconstruction cost, within 10% of the estimated demolition cost. The major constraint was time, due to the pending redevelopment of this shopping center out-parcel. Also as noted this house was optimal for salvage revenue due to the local and site conditions: a relatively low-income rural community; an extremely high-visibility site, at the only shipping center in the town, and on a 4-lane State Road; a bare site with ample room on all sides for laying out materials, and minimal time spent on processing which had little effect on value do to the local economic conditions. By the last day of the project, the site was entirely cleared of salvaged materials, eliminating any additional loading, transportation, and warehousing costs.

This house had an full array of salvageable materials. Consistent with other houses, the highest value items were wood flooring, dimensional lumber, and wood siding. It should be noted that the aluminum single pane windows are not a “sustainable” form of salvage, due to the recyclability of aluminum, and the energy in-efficiency of these windows. This is less of a concern in Florida than in a more heating climate, but nonetheless a total “life-cycle” energy costs concern.

3650 SW 24th Avenue

This was a one-story building on a large rural property. Several large bushes and smaller trees had to be removed to access the building. The house had not been inhabited for some time. The building envelope was in good condition. The flooring material had termite and water-damage which diminished the overall effectiveness of the deconstruction. This project was the last house deconstructed and the deconstruction crew had a greater level of understanding and skill. This house had asbestos floor tile, which was abated prior to the start of deconstruction. LBP was confined to the exterior of the house.

Table 9. Economic Summary for 3650 SW 24th Avenue

| COSTS | Total Net Demolition | | | Total Net Deconstruct | | |
|---|-----------------------------|-------------|---------------|------------------------------|-------------|---------------|
| Permit | 60.00 | | | 60.00 | | |
| Asbestos survey | 835.00 | | | 835.00 | | |
| Asbestos abatement | 1,841.00 | | | 1,841.00 | | |
| Disposal | 3,532.65 | 32.42 | tons | 1,937.44 | 12.00 | tons |
| Truck | 62.00 | | | 713.00 | | |
| Toilet | 74.00 | | | 74.00 | | |
| Labor and Equipment | 1,945.32 | | | 4,488.75 | | |
| Septic cap | 490.00 | | | 490.00 | | |
| Total Costs | 8,839.97 | 7.91 | per SF | 10,439.19 | 9.34 | per SF |
| REVENUES | | | | | | |
| Salvage | 0.00 | | | 3,819.65 | 3.42 | per SF |
| Total Net Costs | 8,839.97 | 7.91 | per SF | 6,619.54 | 5.92 | per SF |
| Average disposal costs are \$78.12 / ton, including drop fee, hauling and tipping fees. | | | | | | |
| Demolition weight estimated as average of similar houses at 58#/sf | | | | | | |

As noted in Table Nine, this house had the highest deconstruction cost of any of the 6 houses. This is relative to asbestos abatement costs which also made the estimated demolition cost higher.

The high-value items in this house remain consistent with other houses in the study, i.e. wood flooring, and dimensional lumber. The roof sheathing was comprised of 1x6 which as in good condition and therefore comprised a high salvage value for the structure.

Economic Summary

As described by the 6 case study houses, each has unique conditions, both opportunities and obstacles. Asbestos abatement costs can be a high percentage of cost and add time delays to the project. In the State of Florida, an asbestos abatement notification is required by the Department of Environmental Protection, ten working days in advance of the abatement. If additional asbestos is visually suspected, during deconstruction, work must be stopped and additional sampling and analysis performed before either proceeding with deconstruction or additional abatement.

Deconstruction is a complex equation of time restrictions (compared to mechanical demolition), environmental costs, labor costs, disposal costs, salvage rates and materials types. Uncertainty can be reduced by targeting only high value candidates, but this reduces the consistency of business for the deconstructor, and ability to maintain trained employees. A vertically integrated demolition/deconstructor company, and/or combining deconstructing with a used materials center, is one model that has been developed in many cases. The ability to perform deconstruction on an expanded scale often requires connections to job-training and other non-profit development programs such as the Habitat for Humanity ReStore program, which sells used building materials to raise capital to support affordable housing programs. The tax credit available for donations to non-profits such as Habitat is a valuable economic incentive. Other models include the reuse of salvage materials by renovation contractors who do partial

demolitions in the course of renovations and at the same time are a market for used building materials, especially for historic preservation purposes. Integrating a deconstruction and materials supply component to the renovator's building activities may provide value-adding activities. Lastly, the value adding to salvage materials, either through additional processing, such as milling, or remanufacture and manufacture of new products is a niche market with some potential.

Table 10. Costs and Salvage Summary

| Demolition Costs | | | | | | | |
|---|-------------|-------------|-------------|-------------|-------------|-------------|----------------|
| Address | 2930 | 711 | 14 | 2812 | 901 | 3650 | Average |
| Size SF | 2014 | 1436 | 2059 | 1238 | 992 | 1118 | 1476.17 |
| Stories | 1 | 2 | 2 | 1 | 1 | 1 | |
| Demolition labor \$/SF | 1.74 | 1.74 | 1.74 | 1.74 | 1.74 | 1.74 | 1.74 |
| Demolition labor/equip % of costs | 30.63 | 35.29 | 36.40 | 40.56 | 38.33 | 22.00 | 32.49 |
| Asbestos and lead \$/SF | 0.96 | 0.82 | 1.86 | 0.69 | 0.71 | 0.75 | 0.97 |
| Disposal \$/SF | 2.91 | 2.25 | 1.09 | 1.70 | 1.89 | 3.16 | 2.17 |
| Disposal #/SF | 96.00 | 40.00 | 35.00 | 40.00 | 45.00 | 58.00 | 52.33 |
| Disposal % of costs | 51.23 | 45.64 | 22.80 | 39.63 | 41.63 | 39.95 | 40.46 |
| Demolition \$/SF | 5.68 | 4.93 | 4.78 | 4.29 | 4.54 | 7.91 | 5.36 |
| Deconstruction Costs | | | | | | | |
| Deconstruction labor \$/SF | 4.21 | 1.77 | 2.90 | 5.63 | 3.29 | 4.02 | 3.64 |
| Deconstruction labor hr/SF | 0.34 | 0.14 | 0.23 | 0.45 | 0.26 | 0.32 | 0.29 |
| Deconstruction labor % of costs | 67.79 | 35.33 | 51.97 | 73.79 | 65.15 | 43.04 | 56.21 |
| Asbestos and lead \$/SF | 0.96 | 0.82 | 1.86 | 0.69 | 0.71 | 0.75 | 0.97 |
| Disposal \$/SF | 0.67 | 1.88 | 0.57 | 0.54 | 0.45 | 1.73 | 0.97 |
| Disposal #/SF | 21.97 | 29.01 | 18.40 | 12.76 | 10.69 | 21.47 | 19.05 |
| Disposal % of costs | 10.79 | 37.52 | 10.22 | 7.08 | 8.91 | 18.52 | 15.04 |
| Diversion from landfill % by weight | 77.12 | 27.47 | 47.43 | 68.10 | 76.25 | 62.99 | 59.89 |
| Gross Deconstruction \$/SF | 6.21 | 5.01 | 5.58 | 7.63 | 5.05 | 9.34 | 6.47 |
| Salvage \$/SF | 4.67 | 0.39 | 2.81 | 3.73 | 4.65 | 3.42 | 3.28 |
| Salvage \$/SF at 50% | 2.34 | 0.20 | 1.41 | 1.87 | 2.33 | 1.71 | 1.64 |
| Net Deconstruction \$/SF | 1.54 | 4.62 | 2.77 | 3.90 | 0.40 | 5.92 | 3.19 |
| Net Deconstruction \$/SF w/ 50% | 3.88 | 4.82 | 4.18 | 5.77 | 2.73 | 7.63 | 4.83 |
| Demolition - Gross Deconstruction \$/SF | -0.53 | -0.08 | -0.80 | -3.34 | -0.51 | -1.43 | -1.12 |
| Demolition - Net Deconstruction \$/SF | 4.14 | 0.31 | 2.01 | 0.39 | 4.14 | 1.99 | 2.16 |
| Demolition - Net Decon. W/ 50% | 1.81 | 0.12 | 0.61 | -1.48 | 1.82 | 0.28 | 0.52 |

Approximately 21% higher first costs for deconstruction over demolition

Approximately 37% savings for deconstruction over demolition with conservative salvage value

This model represents a situation where there are no materials storage, inventory, and sales personnel costs. Materials are given a retail value and deducted from the deconstruction costs for a net deconstruction costs without the additional costs for overhead on the materials themselves.

Disposal Costs

Several of the structures were in Alachua County where the hauler used a volume-based disposal fee. In order to make comparisons, all disposal cost data was normalized to a weight-based disposal cost. Weight-based disposal was \$34.00/ton in the City of Gainesville. Volume-based disposal was \$7.70/CY x 20CY roll-off = \$154.00 and is therefore a flat fee for each 20 CYs of construction and demolition waste. Each haul is based upon a flat fee of \$120.00/haul. It was apparent when comparing the difference in disposal costs based on weight versus volume, and the relatively light weight of the wood-framed houses and the lower density of wood wastes, that disposal fees in this project would have been a larger percentage of the cost if based on volume.

There is a considerable difference in disposal cost when using volume or weight of a heavier material such as concrete, or a lighter material such as wood. At about the point of the cost of 12 –16 tons of disposal of wood and drywall wastes in 4 – 20 CY roll-offs, Table ?, the total cost based on weight becomes equal to the total cost based on volume. At lower density, i.e. more wood, the volume-based fee is more costly, at higher density, i.e. more concrete and masonry, weight-based fee is more costly.

As noted in the Table Eleven, 20 CY roll-off disposals of lower weight are more expensive per ton when charged by weight, but the discrepancy is even greater when charging by volume. As the weight increases per 20 CY roll-off, from 2 to 8 tons, the total weight-based fee is \$100/ton for 2 tons / 20 CY and \$50/ton for 8 tons / 20 CY. The hauling fee is also reduced approximately 50% per ton over this range. An obvious incentive for C&D waste separation for recycling purposes is a prohibitively high disposal fee for mixed C&D waste, a weight-based fee for clean wood waste at a materials recovery facility, and a volume-based fee for clean concrete and masonry at a materials recovery facility.

Table 11. Disposal Variations Summary

| Weight (4 roll-offs) | Volume (4 roll-offs) | Weight-based Total Cost (\$) | Volume-based Total Cost (\$) |
|---------------------------|-------------------------|---------------------------------|---------------------------------|
| 8 tons | 80 cubic yards | 802.00 | 1,146.00 |
| 12 tons (wood) | 80 cubic yards | 938.04 | 1,146.00 |
| 16 tons (drywall) | 80 cubic yards | 1,074.08 | 1,146.00 |
| 20 tons | 80 cubic yards | 1,240.00 | 1,146.00 |
| 24 tons | 80 cubic yards | 1,345.92 | 1,146.00 |
| 28 tons (asphalt) | 80 cubic yards | 1,482.00 | 1,146.00 |
| 32 tons | 80 cubic yards | 1,617.92 | 1,146.00 |
| 64 tons (concrete/rubble) | 80 cubic yards | 2,434.00 | 1,146.00 |

For the purposes of this analysis, C& D wastes has been estimated at:

Wood wastes 3 tons / 20 CY
 Drywall 3.5 - 4 tons / 20 CY
 Asphalt shingles 7 tons / 20 CY
 Mixed rubble 14 tons / 20 CY
 (NAHB, 1995)

This analysis indicates that wood C&D recycling would be encouraged generally through volume-based disposal fees for mixed C&D waste. If a municipality wished to encourage

concrete and masonry, drywall, asphalt shingle recycling, then a weight-based disposal fee for mixed C&D waste will provide an incentive for recycling of these materials, but less incentive for site separation of the lighter wood materials from heavier materials, and less incentive overall.

Economic Summary Recommendations

The average estimated demolition cost using all six (6) houses, was \$5.36/SF and disposal was an average of 40% of the total costs. One house, 711 NW 7th Avenue was an anomaly, with minimal salvage value. The average “gross” deconstruction cost was \$6.47/SF, which is approximately 21% higher cost than the average estimated demolition. Gross deconstruction is the first cost of the deconstruction which includes all labor and disposal but does not include any salvage revenues. Disposal costs for deconstruction were on average 15% of the total costs. Asbestos and lead surveys and remediation were an average of \$0.97/SF for both demolition and deconstruction. This is 18% of the costs for demolition and 15% of the costs for deconstruction.

The average salvage value from the deconstructions was \$3.28/SF. The “price” of salvaged lumber was estimated at between 25-50% of new lumber retail value in local stores. The price of other items were estimated as very low costs used goods, based on the experience of an used building materials store owner/operator in Gainesville, Florida. Subtracting average salvage from gross deconstruction, the average net deconstruction costs were \$3.19/SF which is approximately 37% lower cost per square foot than traditional demolition. It is important to note that the costs calculations for demolition to an Owner or Contractor end with the disposal of materials in a landfill. There are future costs which accrue to the municipality or to the owner of the landfill that are not included in the costs of disposal. The costs and savings for deconstruction include the deconstruction (including disposal) and any additional costs to handle the materials until they are redistributed. Upon redistribution, (sale) the net deconstruction costs can be fully calculated. This study did not include a calculation of the operating costs of a redistribution center or business. Unless sales are conducted on-site, this is a necessary cost for receiving the revenues from salvaged materials resale. Deconstruction and reuse will benefit from labor and facilities infrastructure support from local government. When considering the economic multiplier effect of the activities and wages that would accrue from the reuse through processing or use in new construction, this investment would begin to pay back immediately whereas the investments in landfills would have less payback in job creation. Disposal is a one time economic multiplier.

A reused materials price estimate can be made using a consignment scenario. This scenario supposes that the deconstruction contractor places materials in consignment at a separate reused materials facility at 50% of the used material price, in effect using a price of 12.5-25% of the price of new lumber and halving the used goods prices. In this scenario the average salvage values estimated in this project were \$1.64/SF or half of \$3.28/SF. Using this calculation, the net deconstruction costs were approximately 10% lower than traditional demolition.

Table 12. Comparison Between Demolition and Deconstruction Costs

| Costs | Demolition | Deconstruction | Deconstruction Savings | Additional Costs for Deconstruction as % of Total Demolition Costs |
|------------------|---------------|----------------------|------------------------|--|
| Labor | \$1.74 (33%) | \$3.64 (56%) | - \$1.90 | +35% |
| Disposal | \$2.17 (40%) | \$0.97 (15%) | +\$1.20 | - 22% |
| Hazardous | \$0.97 (18%) | \$0.97 (15%) | \$0.00 | 0% |
| Other | \$0.48 (9%) | \$0.89 (14%) | - \$0.41 | + 8% |
| Total | \$5.36 | \$6.47 | - \$1.11 | +21% |
| Salvage | \$0.00 | \$3.28/\$1.64 | +\$3.28/\$1.64 | -61-31% |
| Net Costs | \$5.36 | \$3.19/\$4.83 | +\$2.17/\$0.53 | |

The added investment for deconstruction over demolition was \$2.31/SF for a total net savings of from \$2.17 to \$0.53/SF. From this added \$2.31/SF investment, the benefit-cost ratio for disposal savings were $\$1.20 / \$2.31 = 0.52$ while the benefit-cost ratio for savings from salvage was $\$3.28$ or $\$1.64 / \$2.31 = 1.42$ or 0.71 . The revenues from salvaged materials is a greater proportion of the “return on investment” of deconstruction than the reduction in disposal costs when compared to demolition by a ratio of from 2.73 to 1.36, depending on the method of pricing the salvage. In practical terms, the economic viability of deconstruction and reuse of salvaged materials in Gainesville, Florida is a function of targeting the highest value materials in lieu of returning to the building Owner avoided disposal costs. This can mean midnight raids with chain saws to remove the flooring from a structure, which does less to promote whole house deconstruction. It also means that lower value materials will available to the community. Conversely, if disposal costs are higher, such that the Owner receives an economic benefit from lower disposal costs of the building removal, the deconstruction itself becomes a viable economic activity independently of high returns from the salvage materials.

Since a social benefit to deconstruction is creating low-costs building materials, increasing tipping fees, and using volume-based fees, may be more important to encourage deconstruction for a combination of social, community economic and environmental benefits, than value-adding for high-value salvaged materials.

On-site sales considerably reduce off-site materials handling costs (increasing salvage revenues) and will also aid in reducing on-site time for the deconstruction, when time spent processing can be used in the actual deconstruction activity.

Where off-site sales are needed, or value-adding desirable, a deconstruction entity that also operates a reused materials facility will enable the combined entity to be more profitable and maintain a consistent work force. The off-site facility/staff allows for flexibility in responding quickly to deconstruction projects when they present themselves, and processing the materials, and deconstruction provides a diversity of materials for the reuse facility.

Enforcement of hazardous materials regulations for asbestos surveying and handling will insure that small scale demolition projects do not receive an economic advantage based upon avoiding hazardous materials management costs.

The costs of time delays for deconstruction at a large redevelopment site may exceed savings from deconstruction based upon the deconstruction contractor’s lower net costs. Bidding lower than demolition will reduce the deconstructor’s profit, which is mostly based on resale of the materials, a less certain added cost than the deconstruction work itself.

Permitting should be created for “deconstruction permits” that allows time for deconstruction with a reduced time delay overall than would be allowed for a demolition permit. Permit fees for deconstruction should be waived and demolition fees should be based not on the value of the work or other arbitrary factors such as number of stories, but on the projected volume of wastes. Fees can then be rebated based upon proof of diversion of the materials to an accepted recycling or reuse end use.

Materials Processing and Redistribution

In several instances, at the 901 house, and the 14 house, materials were mostly redistributed directly off the site. The viability of this strategy was borne out by the high profile locations of these sites and, perceptually, by the demographics of the immediate areas. In one case, 14, was at edge of the Downtown area, a historic district, and lower income neighborhoods. The 901 house was in a predominantly lower income rural community, at the site of the one shopping center in the community, and on the main highway. Other sites were either within a residential area or in more rural areas within the community and had little pass-by traffic. This was an advantage when materials or roll-offs were left on site, such that pilfering was minimized.

Wood Grading

Salvaged lumber from this project was visually graded by an inspector from the Southern Pine Inspection Bureau, Pensacola, Florida. Each piece of lumber was graded twice. The first time, the piece was graded “as is,” taking note of the particular defect that dictated the grade. Human-made defects, such as a bolt hole, were equated with the natural defects found in unused timber, in this case, a knot. Damage to an end could either limit the grade of the entire piece or be ignored for grading a shorter section of the piece which had a more serious defect. In this case, any this more pronounced grade-limiting defect was noted. A common example of this type of defect was termite damage, which was considered the most limiting defect of any kind.

Table 13. Sizes of Graded Salvaged Lumber

| Lumber | | | | | |
|---------------|--|---------------|----------|------------------|----------|
| Size | | Pieces | % | Volume BF | % |
| 2x4 | | 210 | 40.31 | 1620.81 | 31.21 |
| 2x6 | | 186 | 35.70 | 2172.00 | 41.82 |
| 2x8 | | 117 | 22.46 | 1285.01 | 24.74 |
| 4x6 | | 8 | 1.54 | 116.00 | 2.23 |
| Total | | 521 | | 5193.82 | |

After the initial grading, a second grade was given where a defect could be corrected by additional processing. This processing was mainly limited to trimming damaged ends, or removing a human-made notch, such as a bird’s mouth on a roof rafter.

As noted in Table Fourteen, the grade limiting defects were predominantly “damage.” Of the 296 pieces graded for damage, 96 (32%) were for termite damage, the remainder were typically end damage or human-made notches. Assuming no human-made construction or deconstruction damage, the single greatest natural defect was from termite damage. Human-made damage was the single greatest reason overall for a down-grade. This information points out the need for construction techniques which preserve the integrity of the materials, and for the need for connecting systems and wood construction designs, and hence “design for deconstruction,” which do not damage the lumber and protect it from termites.

Table 14. Reason for Grade Reduction for Lumber

| Reason for Lower Grade | 2x4 | 2x6 | 2x8 | 4x6 | Total | % | |
|------------------------|-----|-----|-----|-----|------------|-------|--|
| Shake | 17 | 2 | 1 | | 20 | 4.65 | |
| Split | 2 | | 3 | | 5 | 1.16 | |
| Knots | 11 | 10 | 4 | | 25 | 5.81 | |
| Damage | 92 | 115 | 82 | 7 | 296 | 68.84 | |
| Wane | 12 | 14 | 4 | | 30 | 6.98 | |
| Slope of grain | 1 | 1 | 1 | | 3 | 0.70 | |
| Warp | 3 | 1 | 2 | | 6 | 1.40 | |
| Twist/other | 17 | 8 | 4 | | 29 | 6.74 | |
| Unknown | | | | | 16 | 3.72 | |
| Total | | | | | 430 | | |

As noted in Table Fifteen, the most common “as is” grades were # 4 and # 2. Almost half (47%) of all graded lumber received a # 4 grade.

Table 15. Grading of Salvaged Lumber Before Accounting for Damage

| Untrimmed Grade | 2x4 | 2x6 | 2x8 | 4x6 | Total | % |
|---------------------|------------|------------|------------|----------|------------|--------------|
| dss | 33 | 10 | | 1 | 44 | 8.45 |
| ss | 20 | 23 | 4 | | 47 | 9.02 |
| #1 | 6 | 2 | 9 | | 17 | 3.26 |
| #2 | 64 | 25 | 14 | | 103 | 19.77 |
| #3 | 33 | 6 | 6 | | 45 | 8.64 |
| #4 | 51 | 110 | 82 | | 243 | 46.64 |
| No grade | 3 | 10 | 2 | 7 | 22 | 4.22 |
| Total pieces | 210 | 186 | 117 | 8 | 521 | |

Of the total of 521 pieces graded, 430 were #1 or lower. Of this total, only 172 were found to be up-gradeable. The principal reason for not being able to upgrade a piece was termite damage. As illustrated in Tables Fifteen and Sixteen, trimming the ends of the lumber greatly increased the proportion of higher grades. The number of dss and ss graded lumber pieces went from 17% of the total to 36% of the total. The percentage of #2 lumber went from about 20% to 31% of the total. This trimming often has the initial added benefit of rapidly removing end nails. The typical

presumed trim was either 12” or 18” from one or both ends. Based on this limited sample, non-termite damaged salvaged lumber has a great potential for achieving high grades for reuse.

Table 16. “Re-graded” Lumber After Accounting for Damage

| Trimmed Grade | 2x4 | 2x6 | 2x8 | 4x6 | Total | % |
|-------------------------|-----------|-----------|-----------|----------|--------------|--------------|
| dss | 11 | | | 1 | 12 | 6.98 |
| ss | 14 | 44 | 24 | | 82 | 47.67 |
| #1 | 7 | | | | 7 | 4.07 |
| #2 | 17 | 28 | 16 | | 61 | 35.47 |
| #3 | | 3 | | | 3 | 1.74 |
| #4 | | | | | 0 | 0.00 |
| No grade | | | | 7 | 7 | 4.07 |
| Total | 49 | 75 | 40 | 8 | 172 | |
| Percent of Total | | | | | 33.01 | |

Conclusions

Deconstruction can be more cost-effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvage. In this study, there were estimates made for storage and personnel costs of a separate resale facility as a means for recouping the value of the materials over time. It was found that sale to a secondary broker will typically be 20% (remanufacturing) to 50% (resale) of the retail price. Salvage value estimated at 50% of retail is equivalent to the deconstructor operating a resale facility and is a “wholesale” price. On average, deconstruction first costs were 21% higher than demolition costs. On average, the net cost of deconstruction with salvage was 37% lower than demolition using retail salvage values and 10% lower using “wholesale” prices. The CCE had success with on-site redistribution of the materials when the job-site was either on a busy road, or in the urban core area, near both lower-income neighborhoods and/or a historic district.

Each additional increment of salvage value will have an additional unit of labor cost. The savings in disposal costs between gross deconstruction and demolition were on average 41% per house. Because disposal savings for deconstruction versus demolition are a lower percentage than salvage savings (41% to 53%), there is less of an increment to gain in increasing salvage (100-53 = 47%) than in increasing disposal costs (100-41 = 59%). This would seem to indicate that there is more potential for encouraging deconstruction by raising disposal fees than by attempting to gain more salvage value and that the value of salvaged materials will be well-supported by subsidies targeted towards storage space and retail outlets which in turn create more jobs. Increasing salvage per building will have an additional cost, producing a diminishing return as the more valuable items are stripped more efficiently than harder-to-access materials, and as less damaged materials give way to options for salvaging the more damaged and shorter pieces of lumber, for instance. A longer board may take the same amount of time to remove but has more board feet than a shorter piece. Every building will have this balance point of diminishing returns but that point will be pushed further towards salvage more effectively by increasing disposal costs than in effect working harder to gain more salvage which is more likely a static value per unit of material.

If reused materials, especially wood, increase in value over time, this will provide an additional incentive. Value-adding to salvage materials is being explored in several venues in the US, most notably by the Materials for the Future Foundation. Many specialty wood mills use salvaged materials to manufacture flooring. It is less likely to be effective, however, as older buildings (50 to 150 years old) with more pure and higher value materials are gradually demolished and there is a greater percentage of buildings available for deconstruction that were built in the last 50 years. These more recent buildings already show the effects of resource depletion by containing more composite materials, newer growth wood, little heart pine or weather and insect resistant species, and less materials with architectural salvage value. Materials such as beadboard and 1x sheathing materials were replaced by gypsum wallboard and plywood in this time and the use of asbestos was more prevalent. If salvaged materials do not increase in value the reverse incentive of making it more expensive to throw them away will maintain a market for them and more stability for resale entities. This “subsidy” allows for the maintenance of a lower prices for used materials and provides social and economic benefits for those who cannot readily afford new materials.

One method of increasing value of deconstruction is the re-grading of salvaged lumber for structural use. The CCE had over 500 pieces (over 5,000 board feet) of 2x4, 2x6, and 2x8 southern pine lumber re-graded by the Southern Pine Inspection Bureau. This sample is not adequate to make any broad conclusions. Approximately 47% of the pieces received a number 4 or lower grade. 40% of the pieces received a number 2 or higher. Approximately 17% of the pieces received a dense select structural (DSS) or select structural (SS) grade. The determining factor for 68% of the non-DSS or SS pieces’ grade was damage, typically for end damage from the deconstructing process, notches or damage from the construction process, for example bird’s mouths in roof members, and lastly termite damage. Of the pieces graded for damage, termites were the determining factor for 32% of them. 172 pieces or approximately 33% of the total pieces were found to be “up-gradeable” with either trimming or ripping to make a shorter or narrower piece.

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