Deconstruction - Building Disassembly and Material Salvage: The Riverdale Case Study

Prepared for:
US Environmental Protection Agency
The Urban and Economic Development Division

By:
NAHB Research Center, Inc.
Upper Marlboro, Maryland

Assistance Agreement Number:
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EXECUTIVE SUMMARY

Demolition firms, contractors specializing in building salvage, and private/public property owners each have questions about how and under what conditions building disassembly and salvage can be cost-competitive with standard demolition. In an effort to address a number of these questions, the manual disassembly and salvage of common building materials--brick, framing lumber, hardwood flooring, windows, doors, assorted fixtures--were fully documented for a 2,000 square foot, 4-unit, residential building in an urban area of Baltimore County, Maryland. Although this single project cannot address all of the issues involved in the comparison of deconstruction and straight demolition, key results are presented below.

- **Labor requirements**: The research team documented the time required to manually disassemble and salvage/recycle/dispose of 25 different building materials. Examples include: .038 hours per square foot of oak strip flooring, .54 hours per window, .009 hours per square foot of plaster, .02 hours per lineal foot of rafter (see Table 4, page 15).

- **Labor activities**: For total manual deconstruction, approximately half of the labor was spent on disassembly and half was spent on "processing" (denailing, sorting, stacking) (See Table 8, page 18).

- **Job Training Potential**: Manual disassembly of light-frame (low-rise residential) buildings represents an excellent opportunity to identify and develop low-skilled workers with an aptitude and interest in the building trades.

- **Diversion rate**: 70% by volume of all materials from the building were salvaged or recycled (See Table 9, page 19).

- **Salvage value**: Commodities such as framing lumber have wide application and are relatively easily sold for approximately 50% of full, new retail value. More finished and use-specific materials such as windows have a much lower proportion of retail value and require more intensive and targeted marketing.

- **Total cost comparison**: Standard demolition (including no salvage and limited recycling of metals, wood, and clean rubble) was estimated at $3.50 to $5.00 a square foot. Total cost for deconstruction (including maximum salvage and recycling) was estimated at $4.50 to $5.40 per square foot (See Table 12, page 25).

- **Environmental benefits**: Not reflected in the standard cost comparison are potential environmental benefits of deconstruction. These include decreased disturbance to the site, conserved landfill space, the energy saved by reused materials replacing new building materials, and decreased air-borne lead, asbestos, and nuisance dust at and around the job site.

- **Lead and asbestos**: US Environmental Protection Agency (EPA) regulations for the disposal of lead and asbestos-containing materials make no distinction between demolition and deconstruction. The Occupational Safety and Health Administration (OSHA) regulations *implicitly* place a greater burden for the manual handling of some asbestos materials and *explicitly* place a greater burden on the manual handling of lead-containing materials (See *Industry Issues*, pages 4 & 5 and Appendix A).

- **Davis-Bacon wage requirements**: Prevailing wage requirements under the Davis-Bacon Act are not specified for federal projects for which no subsequent construction is planned (See *Industry Issues*, page 8 and Appendix A).

- **Workers compensation insurance**: Insurance agents may inappropriately categorize manual disassembly employees. Employers should create detailed descriptions of worker tasks and search for an agent/insurance firm willing to pursue correct worker classification (See *Industry Issues*, page 7 and Appendix A).

Recommendations for the deconstruction industry include:

- **Engage EPA and OSHA on regulatory issues**: The industry needs clarification on how relevant regulations from each agency relate to one another and how OSHA regulations are to be applied to manual deconstruction.

- **Engage the Departments of Housing and Urban Development (HUD) and Health and Human Services (HHS)** on job creation: With over 100,000 units of public housing projects slated for removal in urban areas across the country, manual disassembly and salvage may represent welfare-to-work and small business development opportunities.

- **Establish an educational policy on half-mask respirators**: OSHA requirements and anecdotal industry evidence on worker performance/sick time suggest that an educational campaign on respirator use for the building removal industry may be needed.

- **Develop a methodology for grading salvaged lumber**: The industry needs guidance on acceptable structural reuse of salvaged framing lumber.

- **Share information**: Members of this developing industry need a forum for sharing information on a wide range of issues. The newly formed Used Building Material Association (UBMA) includes this in their mandate.

INTRODUCTION

Objectives and Structure of the Report

"Deconstruction" is a new term to describe an old process--the selective dismantlement or removal of materials from buildings instead of demolition. Many progressive demolition firms--given the right disposal costs, labor rates, ready markets, and sufficient job time--are stripping out highly accessible recyclables or reusables before demolition. However, entrepreneurs attempting more comprehensive dismantlement and salvage have many questions about the feasibility of deconstruction, particularly for light-frame[1] buildings.

The objectives of the Riverdale case study documented in this report were as follows:

- To identify major issues hindering deconstruction as an alternative to conventional demolition.
- To determine unit labor requirements (hours per square foot or linear foot of material) for specific deconstruction activities.
- To evaluate jobsite practices such as sequencing, layout of operations, tools and workers required, and flow of materials.
- To determine market opportunities and values of salvaged building materials.
- To disseminate information on building disassembly and salvage.

It is not possible for a single case study to comprehensively address each of the issues the building removal industry faces. The concerns and considerations of a small contract firm working on buildings such as single-family homes and barns may be quite different than those of a demolition firm accustomed to working on large commercial structures. This case study was designed to address, to the fullest extent possible, the issues for all members of the industry.

This report is structured around the major sections described below. Throughout the report, information on the Riverdale Village case study is italicized and indented and used as an example.

- **Industry Issues** - A wide range of environmental, regulatory, worker, and logistical issues must either be addressed prior to the start of work or are issues that affect the overall process of building removal.
- **Project Description** - The Riverdale Village case study was the vehicle the Research Center used to investigate the many issues surrounding a comparison of the two approaches to building removal--deconstruction and demolition.
- **Project Results** - Information on the detailed labor studies; quantities of materials salvaged, recycled, and landfilled; and a cost analysis from the body of this report.

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[1] The term "light-frame" refers to structures of three stories or less, usually stick-framed in wood.

- **Recommendations** - Recommendations for future work on deconstruction in general and on the Riverdale project in particular complete the report.

- **Appendices** - Detailed information on certain topics has been placed in appendices to maintain the flow of the report.

Case Study Site Description

Riverdale: The Riverdale Village deconstruction case study involved the manual disassembly and salvage of a 2,000 square foot building made up of four residential units. The building is part of a 27-acre, 600-unit housing development (See page 10 for a detailed description of the site and structures). The Riverdale Village housing development was selected for the case study for the following reasons:

Photo 1: Disassembly of Roof Deck

- The owner - The Riverdale Village owner, the Maryland Office of HUD, was very interested in the potential for using a new approach to building removal at Riverdale and was willing to provide access to any buildings needed for the investigation. This included securing the site with a perimeter fence, giving Research Center staff and contractors unlimited access to the site, and providing the Research Center with all available background information on the site.

- The size of the development - If the deconstruction pilot project proved successful, the deconstruction of the 300,000 square feet of buildings would give information on the economies of scale in dismantlement activities and marketing salvaged materials.

- The status of the development - Riverdale Village provided an isolated site with restricted access and with a nine to twelve month window of opportunity for deconstruction research.

- The buildings - The Riverdale buildings fit criteria established for a deconstruction pilot:

  1. Built prior to 1950 - Post World War II construction technology brought engineered wood products (plywood and OSB) and composite materials that are difficult to disassemble or have low salvage value.

  2. Exterior structural brick and interior stick-framed with wood - Other deconstruction projects have provided information on salvaging heavy timber-framed structures. An important project objective was to provide information on salvage value and labor requirements for brick and light-framed structures.

  3. Simple, affordable housing units - Riverdale units did not contain any unique or high-value materials which could "guarantee" cost-effectiveness. The salvage value of common materials and components drove the cost comparison.

  4. Buildings structurally sound - Riverdale units were generally weather tight so that rot and decay of building materials were essentially non-existent.

INDUSTRY ISSUES

A new or different approach to removing a building from a site can trigger changes in many aspects of a company's operation. This section addresses many of the issues that a demolition firm or salvage contractor must consider when comparing an approach which focuses on demolition to an approach that emphasizes salvage. After each issue is presented, an indented section describes how these issues came into play at Riverdale.

Several of the topics in this section are quite complex and may be further complicated by rules and regulations at the state and/or local level. ***It is essential that practitioners use the additional information in Appendix A, check local and state regulations, and consider using legal counsel if issues remain unresolved.***

Environmental Assessment

For commercial properties (commercial meaning non-residential or residential property greater than four units), 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, non-invasive inspection of all aspects of the site and structures by individual(s) trained in environmental assessment. The most common problems encountered are building materials containing lead paint or asbestos, underground fuel storage tanks, and electrical transformers or other components containing PCBs. Although not a requirement, many commercial property owners employ a consulting firm to conduct a Phase I Environmental Site Assessment (ESA) and, if indicated, a subsequent Phase II investigation. While no consulting firm will be willing or able to guarantee the environmental condition of a commercial site, use of a trained inspector following industry standards for environmental assessment such as those set out in American Society for Testing and Materials (ASTM) standard 1527-94 or 1528-94 is evidence that reasonable efforts were made to identify hazardous materials.

For residential properties of four units or less, there are no formal environmental assessment standards. The materials most likely to be problematic are lead- and asbestos-containing materials. Lead and asbestos are covered in subsequent sections.

> ***Riverdale***: *A Phase I ESA and subsequent Phase II investigation were completed on the site in September and October of 1995. In summary, the Phase I Survey identified "no major environmental problems". The Phase I Survey included some spot testing of paint from exterior doors, exterior door trim and exterior door frames which tested positive for lead content.*
>
> *The Phase II investigation indicated that 35 of the 64 samples taken were greater than 1 percent by weight in asbestos, meeting the requirement for an "Asbestos-Containing Material" (ACM). The positive samples included non-friable floor tiles in kitchens and bathrooms and friable pipe insulation. Virtually all of the asbestos insulation was located in basements. Twenty-nine negative samples included selected floor tiles, ceiling plasters, wall plasters, roofing material, insulation panels, and shower wall tiles.*

Building Material Inventory

The most important part of assessing the feasibility of deconstruction for a particular structure is a detailed inventory of how and of what the building is made. Every component, its condition, and the manner in which it is secured to the structure can have an impact on the cost-effectiveness of salvage. The condition of wood rafters or the type of mortar used or the type of nail used to fasten hardwood flooring may have no significance if a building is to be demolished. Each of the above, however, can have a profound effect on the value of the material to be salvaged and/or the labor required to recover the material.

NOTE: A detailed building material inventory includes invasive inspection of the structure. This provides the opportunity to identify hazardous materials not available for inspection during the non-invasive, standard ESA as described above. It is important to be on the lookout for these otherwise unidentified hazardous materials because of the impact they can have on the feasibility of deconstruction. The individual(s) conducting the inventory should have construction experience and experience in identifying lead and asbestos hazards.

> ***Riverdale***: *The building material inventory at Riverdale involved characterizing and quantifying almost all components of the building, from roof to foundation. Two individuals with residential construction backgrounds equipped with flashlights, clipboards, a camera, basic hand tools, and a ladder took approximately 4 hours to complete the inventory. See Appendix B for a copy of the form used to compile the inventory and see the Project Results section of this report for more information on the specific materials.*

Asbestos Abatement

There are two sets of federal regulations[2] involved in the management of asbestos-containing materials (ACM)[3]: Environmental Protection Agency (EPA) rules for the handling and disposal of ACM; and Occupational Safety and Health Administration (OSHA) regulations specifying practices for worker protection.

The EPA rules for asbestos (National Emission Standard for Hazardous Air Pollutants--NESHAP) contain no language that would require different hauling and disposal procedures for deconstruction and demolition. Most importantly, the abatement of ACM floor tiles and ACM roofing shingles prior to demolition or deconstruction activity is not required by EPA.

There is an asbestos NESHAP residential building exemption which applies to the demolition or renovation of any residential structure of four units or less. EPA has determined that the total amount of asbestos in such residential structures is small enough that NESHAP does not apply.

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[2] State and local handling and disposal regulations must meet, but can exceed, the requirements of federal regulations--check both state and local regulations in your work area.

[3] Determination of asbestos content can only be made through laboratory analysis using polarized light microscopy and standardized, fiber-counting procedures.

By contrast, OSHA rules for worker exposure to asbestos could place a greater burden on deconstruction than demolition. There are clear worker protection practices for the *manual* removal of ACM floor tiles (see Appendix A). No such worker protection practices exist for heavy equipment operators performing *mechanical* demolition.

> ***Riverdale****: Because of the OSHA regulations discussed above, all ACM floor tiles in the units slated for deconstruction were removed by a licensed asbestos abatement contractor. The abatement plan for the Riverdale units involved in the case study was developed by the abatement contractor and approved by an air quality inspector from the Baltimore County Department of Environmental Protection. During the removal of the floor tiles, the abatement contractor uncovered a paper underlayment which he suspected to be ACM, a material not accessible for inspection/identification during the environmental assessments. Subsequent lab testing of several underlayment samples indicated that a substantial portion of the floor underlayment in the units was 40% asbestos and the material was classified as friable.*
>
> *Abatement of the paper underlayment required removal of all hardwood flooring to gain access to the paper. The abatement contractor agreed to salvage and decontaminate the hardwood flooring.*

NOTE: The discovery of the previously unidentified ACM underlayment meant that the material was managed with foresight and planning. Managing the large and unexpected increase in the cost of asbestos abatement was another matter. Had the ACM underlayment not been identified at this stage of site disposition, the material could have been missed entirely during demolition or dealt with under time and contract constraints during building removal.

Lead Abatement

Both EPA and OSHA also have rules governing the management of lead-based paint[4] (LBP) in buildings. EPA regulations describe the conditions under which LBP building materials must be disposed of as hazardous waste. The language of EPA disposal regulations makes no distinction between a deconstruction and demolition approach.

OSHA rules identify manual demolition of any material containing lead as an activity that is *presumed to require* lead exposure worker protection measures, regardless of absolute levels of lead in painted surfaces (See Appendix A for a more detailed discussion of OSHA lead requirements). While the OSHA rules do not exempt mechanical demolition from proof of worker exposure, there is *no presumption* of exposure levels that require worker protection measures for mechanical demolition. OSHA has targeted activities that generate large amounts of dust with workers in close proximity.

OSHA worker protection requirements for both lead and asbestos create a clear distinction between the activities of manual deconstruction and conventional mechanical demolition.

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[4] Neither EPA nor OSHA have quantitative definitions for lead-based paint. The one most commonly used is the US Department of Housing and Urban Developments definition: surface coatings containing lead equal to or greater than 1.0 mg/cm^2 or 0.5% by weight.

***Riverdale**: The lead-based paint testing from Riverdale indicated that only the exterior doors and their frames exhibited the HUD threshold 0.5% lead content. The doors were carefully removed for salvage and the door frames discarded. The discarded frames were such a small percentage of the disposal total that a Toxicity Characteristic Leaching Procedure (TCLP) test[5] on the load was not indicated. No special worker protection measures were taken during the removal of the plaster because the tested lead levels of wall and ceiling surfaces were five to 250 times below the 0.5% content that defines LBP. The OSHA rules as described above set no minimum threshold for lead content, creating uncertainty for practical and prudent worker protection during manual deconstruction.*

NOTE: OSHA also has a standard for worker exposure to air-borne "Particulates Not Otherwise Regulated" (PNOR), or "nuisance dust". Exceeding the PNOR action level of 15 mg/m^3 requires the use of half-mask respirators. Activities such as plaster removal are likely to result in plaster dust in the air in concentrations exceeding the PNOR action level.

Permitting

Many (but not all) local building jurisdictions require demolition permits or formal notification of intent to remove a building. 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 with action levels of lead and asbestos. In general, there will be no difference between the procedures required to obtain a permit for demolition or deconstruction.

***Riverdale**: The demolition/deconstruction permit for Riverdale was granted by the building department of Baltimore County, MD. No contractor's license or bonding was required to pull the permit. The permit was not granted until a licensed plumber capped all sewer and gas lines and asbestos abatement had been performed by a licensed abatement contractor.*

Lumber Grading

Framing lumber salvaged from older buildings may have either a lumber grade stamp that is no longer accepted by local building inspectors or lack any lumber grade stamp at all. Grade stamps on salvaged lumber may be invalidated by alterations to the lumber (drilled holes, notches, checking, through-nail penetrations, etc.) or simply by age. It is unclear when, if at all, lumber grade stamps can expire. Many lumber graders have been reluctant to regrade salvaged lumber because they feel they lack background information and a methodology to follow on the structural performance of lumber that has been under load for an extended period of time. The USDA Forest Products Laboratory is currently performing structural tests of salvaged lumber in an effort to provide guidance on this issue.

***Riverdale**: Grading stamps were not evident on any of the structural lumber (2X4s, 2X8s, 2X10s) in the Riverdale pilot building. No efforts were made to have the lumber graded (When the framing lumber was sold, the buyer was informed of the lack of grade stamp).*

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[5] The TCLP test is a measure of the potential for lead to leach out of mixed waste material. The test is discussed in Appendix A.

Site Security

The focus of site security for a demolition project is the safety of workers and the general public. While safety is no less important for a deconstruction project, there is the added importance of protecting the salvaged materials. In most cases, the value of the salvaged material has been realized through disassembly, cleaning, and organized storage--all features that make the materials more vulnerable to theft. Consider a perimeter fence with a locked gate for deconstruction projects.

> ***Riverdale**: The perimeter fence at Riverdale surrounded the entire 27 acre site. Built to HUD specification, the fence was approximately 6 feet high, topped with a triple strand of barbed wire, with posts set in concrete footings. Salvaged finished materials--doors, windows, hardwood flooring--were stored in nearby empty units.*

Job Site Safety

Fall protection, maintenance of structural integrity, and fire prevention are three issues that must be considered during deconstruction that are often less important during conventional demolition. OSHA requires the use of certified harness and belay systems for all but flat roof work. Although no formal procedures or standards exist for structural disassembly, the sequence must be such that collapse of the structure is prevented and all workers must be aware of critical supports, both existing and temporary. Fire is a concern on any job site but is even more important when building materials critical to the bottom-line of the project are stored on site.

> ***Riverdale**: Fall protection harnesses were available to all workers and employed when required or requested by workers. All sequencing decisions were made by experienced supervisors. Selected sheathing boards, rafters, joists, and other ties were often left in place to maintain structural integrity until the last of the component assembly was removed. Crew checks were conducted before brick sections were pulled down. Fire extinguishers were on the job site and readily available at all times.*

Workers' Compensation Insurance

Unlike some industries that have a single classification code for all or many of their workers, premiums for construction and demolition workers compensation insurance are based on the actual individual tasks performed during the work day. It is critical that deconstruction firms explain the nature of their work to insurance agents so that coverage and resulting premiums reflect the level of risk for their workers' activities.

> ***Riverdale**: The demolition contractor for the deconstruction pilot stated that the company's worker compensation rates were "at the top of the scale" because the company does engage in demolition involving explosives. As a result of the pilot project, the contractor is working with the company's insurance agent to reassess rates for workers engaged for a significant portion of their time in manual demolition or deconstruction. The contractor felt that the only change possible for these workers was a decrease, given the company's current rates for conventional demolition.*

Wage Requirements

Federal and many federally-assisted projects involving contracts for construction, alteration and/or repair, including painting and decorating, are typically covered by the prevailing wage requirements of the Davis-Bacon and Related Acts (DBRA). [40 USC276a - 276a-7]. This means that various classes of workers employed on such construction must be paid wages predetermined by the U.S. Department of Labor as prevailing for the type of construction and trades involved. These wage rates include any fringe benefits which may have been found to be prevailing.

Demolition work is subject to the prevailing wage requirements of DBRA if any construction work that follows the demolition is DBRA-covered activity. However, demolition work that "stands alone" (i.e., where no construction will follow), or that precedes construction work that is *not* subject to prevailing wage rates, is not itself DBRA-covered. For example, where an existing building is torn down and a DBRA-covered construction activity will follow the demolition, the demolition work is also covered. By contrast, where an existing building is torn down but no construction work is contemplated *or* the construction work is not DBRA-covered, the demolition work is not covered. There are exceptions to this guidance, as follows:

For demolition performed under the U.S. Housing Act of 1937, as amended, HUD-determined prevailing wage rates (provided by HUD Labor Relations field staff) are applicable. HUD rates would typically reflect construction wage rates prevailing in the area for the type of construction or demolition being undertaken (e.g., commercial; high-rise; residential use four stories or less).

> ***Riverdale****: The Riverdale housing development is slated for clearance and the land is to be converted into a park. With no plans for subsequent federal construction at the site, the Davis-Bacon Act prevailing wage requirements did not apply. All workers on the pilot project were paid at least minimum wage.*

Project Time Constraints

Deconstruction in almost all cases requires significantly more time than demolition. Building removal is in many cases done under very tight time constraints. For a property owner with plans to redevelop after building removal, time is money.

> ***Riverdale****: The Riverdale property is owned by a federal agency and is not slated for redevelopment. Although pressures to clear the site existed, there was ample time for the pilot deconstruction of the 2,000 square foot building.*

PROJECT DESCRIPTION

Participants

The project participants were as follows:

- **Project sponsor** - The project was sponsored by the U.S. Environmental Protection Agency's Urban and Economic Development Division, Washington D.C..
- **Property owner** - The Riverdale Village housing development is owned by the Maryland State Office of the U.S. Department of Housing and Urban Development, Baltimore, Maryland.
- **Project management** - All duties related to the facilitation of the project, including the identification of the site, selection of the Prime Contractor and all subcontractors, as well as site monitoring and site management were the responsibility of the NAHB Research Center, Inc., Upper Marlboro, Maryland.
- **Prime contractor** - Stop Corporation, an established demolition contractor based in White Hall, Maryland, provided labor, labor supervision, and necessary equipment. Stop Corporation was able to provide timely changes in labor needs and container service, as well as insights about local material recycling markets.
- **Deconstruction specialist** - Pete Hendricks, Wake Forest, North Carolina was hired as an advisor on deconstruction techniques and job sequencing. He brought 25 years of deconstruction experience to the job site.

On-site labor force

The labor crew consisted of a site manager, a deconstruction specialist, a job foreman, and four or five laborers. The approximate experience of the labor crew is presented below in Table 1. Though the idea of saving the material for re-use was new to Stop Corp., the crew on this project was a seasoned demolition crew, accustomed to their foreman and this type of work.

Table 1. Labor Force

Position	Construction Experience	Demolition Experience	Deconstruction Experience
Job Foreman	7-8 years	7-8 years	0 years
Laborers	2-3 years	2-3 years	0 years
Site Manager[1]	4 years	0 years	0 years
Deconstruction Spec.[1]	10 years	0 years	25 years

1. The site manager and deconstruction specialist were on site to provide guidance given the research nature of the project. While their labor contributions were included in the data acquisition, their positions would not be required under normal business circumstances.

Data Acquisition

To conduct a detailed labor study, a Research Center engineer employed a group-timing technique. The time study provided a detailed compilation of the tasks performed by the entire work crew and allowed detailed evaluation of the efficiency of the process. Each worker's labor was recorded in 15-minute intervals, which provided 32 observations per worker per day. Each observation included the task performed (disassembly, denailing, etc.) and the target building component (interior partition walls, asphalt shingles, roof rafters, etc.). See the *Project Results/Analysis* section of this report for more information.

In addition to the detailed time study, the Research Center measured the volume and (to the extent possible) the weight of all materials on site, whether salvaged, recycled, or landfilled.

Building Description

The Riverdale Village housing development consists of 1100 housing units built in 1948. Roughly 600 of these units have been slated for removal in preparation for future use as a public park. The 600 units are situated on roughly 27 acres of gently sloping land which contains established landscaping including many mature oak, maple and black gum trees. The remaining 500 units are currently occupied, managed by a party other than the Maryland State Office of Housing and Urban Development.

The 600 unit development consists of 25 two-story buildings, most of which contain 20 or 24 units. Buildings are either "L-" or "U-" shaped, configured in a repeating "4-plex" module (see Appendix D - Site Plan). All the 4-plexes are approximately 2000 square feet, two stories [two units upstairs (see Figure 1), two down], and are typically separated into efficiency and one- and two- bedroom units. The construction of each 4-plex is nearly identical (see Table 2), with the following notable exceptions:

- one 4-plex in each building contains the heating and hot water systems in a full basement, requiring a large chimney. All other 4-plexes in the building are built on a crawlspace;
- approximately 450 of the 600 units have pitched roofs, the others have flat roofs; and
- approximately 50 units were retrofit with a forced air system.

Photo 2: Riverdale Fourplex Ready for Deconstruction

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Figure 1. Upper level floor plan of the deconstructed 4-plex (lower level similar).

Table 2. Building Description

Size/Shape	2000 square foot, two-story 4-plex (rectangular footprint - 40' x 25'); gable roof	
Structural Components	Foundation wall	7' high basement walls consisting of 4 courses of 8" wide concrete masonry units (CMU) on 7 courses of 12" wide CMU
	Floors	wood framed (2x8s @ 16" o.c., with 1x6 sheathing boards)
	Interior walls	wood framed (2x4s)
	Exterior walls	8" double wythe masonry (4" brick, 4" CMU)
	Second level ceiling joists	wood framed (2x4s)
	Roof	wood framed (2x8s @ 16" o.c., with 1x6 sheathing boards)
Finishes	Floors	oak strip flooring, vinyl tiles, and ceramic tiles
	Walls	plaster over gypsum lath boards
Roofing	Asphalt shingles	
Windows	Double glazed, aluminum replacements	
Heating system	Gas-fired boiler with forced hot water/radiators - all routed in black pipe; water heater and copper domestic water piping	
Misc.	Aluminum cladding on fascia, soffit, and rake details, as well as exterior window trim; aluminum gutters and downspouts; other items include gas stoves and kitchen cabinets	

Sequence of Tasks

The building was essentially deconstructed in the reverse order of construction, i.e., those components installed last were removed first. In addition to disassembly, the salvaged materials were also processed in the following manner:

- Framing lumber - after denailing, the wood was stacked and banded outdoors (on spacers, under plastic) in piles according to size and length.
- Oak strip flooring - the strip flooring was banded in bundles of approximately 30-35 square feet (80 pounds) and stored indoors. The bundles were four layers high with finished surfaces facing each other for banding.
- Brick - after cleaning (removal of mortar), the brick was stacked outdoors on pallets in piles of 500 and covered.
- Other - windows, doors, stair treads, tubs, toilets, and sinks were all stored indoors.

The sequence of the disassembly, as well as a brief description of some of the tasks involved, are listed in Table 3. An agreement was made with the property owner to deconstruct the building down to the top of the foundation wall.

Table 3. Sequence of Disassembly Tasks

Day #	Component	Notes
1	Interior doors, interior trim, shelving, cabinets, fixtures, appliances, and radiators	Little recovery of these components due to low value; metal appliances and radiators removed for recycling.
2	Oak strip flooring	Tapered cutnails made for easy prying with a claw hammer and/or pry bar. Removal always starts at the tongue side (last piece down, first piece up).
3 & 4	Chimney top	Several courses of loose brick at the top of the chimney were removed early in the sequence for safety. This section was disassembled with a masonry hammer, chisel and sledge.
	Plaster and gypsum lath boards	See *Analysis* section for explanation.
5	Piping and wiring	Removed as a matter of course during wall and floor disassembly.
	Interior partition walls	Some studs were removed during plaster removal to open up the work space and increase the flow of materials.
	Windows	Cutting the caulking was much more time-consuming than the removal of fastening screws or nails.
	Gutters, fascias, and rakes	Aluminum components recycled.
6	Roofing material	Asphalt shingles separately removed for recycling. Fall protection--harnesses and safety lines--were employed.
	Roof sheathing boards	Three runs (eave, ridge, and mid-point) of the 1x6 sheathing boards were left nailed to the rafters to provide some structural integrity to the roof system.
7	Gable ends	The gable end was pulled off the building from the ground after releasing the sheathing boards (ends attached to end rafters) and cutting the ridge beam free.
	Roof framing	After prying the rafter free from the top plate (at the exterior wall), a worker stationed at the rafter mid-point walked the member free of the ridge beam.
	Ceiling joists	2X4 ceiling joists were not always removed individually--sections were allowed to "fall" as the supporting interior partition wall was removed.
8, 9 & 10	Upper section masonry walls & upper chimney	The large sections were pulled to the ground with a pick-up truck, and the smaller sections were pushed/pulled by hand.
11	Second level interior load bearing walls	Removed in sections as ceiling joists were removed.
	Second level floor joists and sheathing boards	The joists were pried free of the center-bearing wall and pulled from the joist pocket in the masonry wall.
12, 13 & 14	Stairs	The stairs were removed as one unit, including treads, risers and stringers.
	Lower section masonry	The large sections were pulled to the ground with a pick-up truck, and the

Day #	Component	Notes
	walls and lower chimney	smaller sections were pushed/pulled by hand.
	First level interior load bearing walls	Removed in conjunction with removal of floor joists.
15	First level floor joists and sheathing boards	Sheathing boards installed diagonally to floor joists made for easier prying and faster disassembly.

PROJECT RESULTS

This section of the report presents and analyzes the results of the detailed labor study, the value and marketability of used building materials, and the cost comparison of the two approaches to building removal. With the exception of the detailed labor study as presented in Table 4, the Riverdale results are dependent on the following site-specific conditions:

- building type and composition,
- labor cost and availability,
- prevailing disposal costs,
- availability of salvage markets, and,
- strength of market demand for used building materials.

While the specific numeric outcomes are important to examine, one of the key results of this project is the assessment and discussion of the key factors and underlying assumptions that drive the feasibility and cost-effectiveness of building disassembly and salvage.

Labor Summary and Analysis of Tasks

To determine labor requirements for specific deconstruction activities, the Research Center recorded each worker's labor in 15-minute intervals, which provided over 4,000 data points for the entire deconstruction project. Each observation was categorized into one of the four tasks outlined below:

- Disassembly - physical detachment from building (prying, lifting, pulling, etc.);
- Processing - moving disassembled materials to storage location (cleaning, separating, denailing, stocking, and bundling);
- Production support - required steps for disassembly or processing (talking business, supervision, erecting scaffold, etc.); and
- Non-production - down-time associated with job site activities and research (idle, breaks, research monitoring, etc.).

In addition, all of the tasks performed were categorized into either a "building" component or a "business" component. While the building components are self-explanatory, the business tasks included typical overhead (talking shop, supervision, etc.), as well as time related to the unique research nature of this project (meetings, paperwork and monitoring). Table 4 presents the following information:

- Total labor-hours for each task category;
- Total labor-hours for each building component;
- Total labor-hours for each business component; and
- Labor requirements for each building component expressed in a quantity of work per square foot, linear foot, or per unit.

Table 4 was organized to make the reader aware of time-consuming elements of deconstruction and to give reliable estimates of the time required for certain deconstruction tasks. It is assumed that the user will apply variables unique to their specific project (labor rates, building measurements, etc.) to estimate their total deconstruction costs.

Labor hours from Table 4 can be used in combination with more comprehensive references for estimating deconstruction/demolition square foot costs. The units in Table 4, e.g., hours per linear foot, were selected to match units used in a commonly used reference (*Repair & Remodeling Cost Data - Commercial/Residential*, 18th Annual Edition, 1997. R.S. Means Publishers, Kingston, MA). While the R.S. Means approach does not address deconstruction specifically, it does provide labor costs for selective demolition tasks.

Care should be taken in the use of labor rates for *individual* components from Table 4--some materials are dependent on the removal of additional materials. See the *Cost Analysis* section on pages 24 - 27 for a more detailed discussion of use of labor rates.

Table 4. Labor Summary of Tasks Performed

Component	**Tasks (hours)**				**Component Total**	**Labor-hours /unit**
	Disassembly	Processing	Prod. Support	Non-prod.		
Interior						
1. Interior doors, frames, trim Baseboards	5.75 4.75	5.25 5.0	---	---	11.0 9.75	0.55/each 0.19/lf
2. Kitchen cabinets Plumbing fixtures Radiators Appliances	2.75 7.75 1.5 0.25	0.5 1.75 0.5 2.75	---	---	3.25 9.5 2.0 3.0	0.27/each 0.59/each 0.13/each 0.60/each
3. Bathroom floor tile	2.50	0.50	---	---	3.0	0.038/sf
4. Oak strip flooring	19.25	27.0	0.25	---	46.50	0.038/sf
5. Plaster - upper level	34.25	10.0	5.50	---	49.75	0.012/sf (plaster area)
6. Plaster - lower level	23.75	10.75	2.0	---	36.50	0.009/sf (plaster area)
7. Piping and wiring	6.75	3.25	0.50	---	10.50	0.0072/lbs
8. Interior partition walls	6.25	24.75	3.0	---	34.0	0.18/lf
9. Windows and window trim	10.0	2.50	0.50	---	13.0	0.54 each
10. Ceiling joists	1.0	4.75	0.5	---	6.25	0.0075/lf
11. Interior load-bearing walls	2.75	15.5	1.75	---	20.0	0.027/lf
12. Second level sub-floor	16.0	6.0	1.25	---	23.25	0.023/sf
13. Second level joists	7.25	16.25	1.5	---	25.0	0.027/lf
14. First level sub-floor	7.75	8.0	---	---	15.75	0.016/sf

Component	Tasks (hours)				Component Total	Labor-hours /unit
	Disassembly	Processing	Prod. Support	Non-prod.		
15. First level joists	7.0	10.0		---	17.0	0.020/lf
16. Stairs	2.5	0.75	0.75	---	4.0	0.3/riser
Exterior						
17. Gutters, fascias, rakes	2.25	1.0	---	---	3.25	0.014/lf
18. Chimney	33.25	40.5	4.75	---	78.5	0.16/cu.ft.
19. Gable ends	8.0	3.0	0.75	---	11.75	0.053/sf
20. Masonry walls - upper section	14.75	104.5	20.5	---	139.75	0.25/sf (brick area)
21. Masonry walls - lower section	15.75	84	5.25	---	105.0	0.078/sf (brick area)
Roof						
22. Roofing material	17.75	18.25	1.75	---	37.75	2.68/100 sf
23. Roof Sheathing boards	21.25	14.5	1.5	---	37.25	0.028/sf
24. Roof framing	7.25	9.75	7	---	24.0	0.021/lf
25. Shed roof framing at entry	1.25	2.25	---	---	3.5	0.036/lf
Building Subtotal	**291.25**	**433.5**	**59**	**---**	**783.75**	
26. Talk shop	---	---	29	29.5	58.5	NA
27. Supervision	---	---	9.5	---	9.5	
28. Meetings, paper work, daily roll-out and roll-in of tools, etc.	---	---	38	43.5	81.5	
29. Research monitoring	---	---	---	89.5	89.5	
30. Lunch, breaks, idle	---	---	---	118.75	118.75	
Business Subtotal	**---**	**---**	**76.5**	**280.25**	**357.75**	
Grand Total	**291.25**	**433.5**	**135.5**	**280.25**	**1141.5**	

Several key points can be drawn from Table 4, including:

- **Masonry wall sections dropped from height increased brick recovery rate**. Because the building was constructed with high quality brick and low quality mortar, the impact created by masonry falling from the *upper* portion of the building broke most of the mortar free of the brick. Without the advantage of height, however, the brick falling from the lower section of the building did not break free of the mortar. Table 6 shows that while the total processing (cleaning) time for the upper portion brick was higher than the lower portion brick (104.5 versus 84), the processing time *per recovered brick* was lower.

Table 5. Time Required Per Building Component (as percentage of total)

	Building Component	Percent of Total Labor Hours
Structural	Masonry (incl. chimney) Wood framing, sheathing	41 28
Weather-proofing	Asphalt shingles Windows	4.8 1.6
Finish	Plaster Oak strip flooring Doors, door frames, baseboards, trim Plumbing fixtures, appliances, cabinets Bathroom tiles	10.9 5.9 2.6 2.3 0.4
Other	Piping, wiring Gutters, fascias, rakes	1.3 0.4

- **Manual disassembly of masonry walls requires more labor and yields a lower recovery rate than wood-framed walls**. Table 5 shows that the approach taken for masonry consumed 41 percent of the total labor hours with a relatively low percent recovery. By contrast, wood framing was easily taken apart with bars and hammers and with a high recovery rate of materials. Most of the masonry walls and chimney were pulled to the ground with a pick-up truck, although the smaller portions were pushed/pulled by hand.

Table 6. Brick Recovery Rate by Building Section (sections include the chimney)

	Total number of bricks	Number of bricks recovered	Brick recovery rate	Labor hours ("processing")	Labor hours per recovered brick
Upper section	5,592	3,245	58%	104.5	0.032
Lower section	12,208	2,255	18%	84	0.037

- **Taking the time to pull plaster directly into wheelbarrows was more efficient than pulling all the plaster to the floor and subsequently loading wheelbarrows**. Pulling the plaster directly into wheelbarrows (as was done on the lower level) required approximately 27 percent less labor hours. Because the plaster was applied over gypsum lath boards (instead of wood or metal lath) the plaster and lath could be pulled down in sections.

- **Disassembly of framing on a flat deck was faster (and safer) than on a pitched roof section**. Although the roof and the first and second subfloors were all sheathed with the same material (1x6 pine), Table 7 shows the relatively high disassembly labor for the roof.

Table 7. Sheathing Board Deconstruction by Component

	Labor (hours)	Area (square feet)	Production (hours/sf)
Roof	37.25	1,350	0.028
Second level sub-floor	23.25	1,000	0.023
First level sub-floor	15.75	1,000	0.016

- **Sheathing boards laid diagonally to joists are easier to remove than those laid perpendicular to joists**. The 45-degree angle between the diagonal sheathing and joists allowed a pry bar to *hook* under the sheathing board instead of being *hammered* under the sheathing board (as is the case for sheathing laid perpendicular). Table 7 shows that removing the first level sheathing boards (laid diagonally) required 32 percent less labor than the second level sheathing boards (laid perpendicular).

- **The high percentage of time spent "processing" materials requires close attention to the flow of materials**. Table 8 shows that 55 percent of the total labor hours were spent processing materials. The key elements of materials flow are discussed below.

Table 8. Time Required per Task Category

Task Category	**Percentage of Total Labor Hours**
Disassembly	37%
Processing	55%
Production Support	8%

1) For materials being hauled away during the deconstruction process (trash, inert rubble, etc.) a hauler providing timely service is critical. Considerable labor can be wasted reassigning workers or moving materials twice while waiting for a dumpster. For example, 13 additional labor-hours were spent shoveling plaster off the floor into wheelbarrows (as opposed to pulling plaster directly off walls into wheelbarrows) because the required dumpster had not yet arrived on site.

2) Containers, wood denailing/brick cleaning stations, and material storage should all be located carefully. These areas should be located to create a safe jobsite, minimize walking time, and maintain accessibility to stored materials by hauling equipment.

3) Flexibility is the key to job site efficiency. The supervisor should always be ready to move a denailing station, reassign workers, or change the size of a crew to accommodate the flow of materials.

Diversion Rate

In order to divert as much of the disassembled building materials from the landfill as possible, all materials were separated into one of the four categories listed below. The diversion rate is presented in Table 9.

1. salvage for reuse & resale;
2. salvage for reuse & donation (those materials with little or no resale value);
3. salvage for recycling (those materials requiring processing); and
4. landfill.

Table 9. Diversion Rate[1]

		Volume (cubic yards)	Weight (tons)
Materials Diverted			
Reuse & resale	Framing lumber/sheathing	49	8
	Brick	12	17.9
	Hardwood flooring	7	1.1
	Stair units/treads	4	0.4
	Windows	2	0.3
Reuse & Donation	Tubs/toilets/sinks	3	0.7
	Doors	3	0.4
	Shelves	0.5	0.1
	Kitchen cabinets	1	0.2
Recycle	Rubble	88	61.6
	Metals	13	2.3
	Asphalt shingles	10	3.5
Diversion Subtotal		192.5	96.5
Materials Landfilled			
	Plaster	48	21.6
	Painted wood (moldings, baseboard, etc.)	26	4.2
	Rubble	7	4.9
Landfill Subtotal		81	30.7
Diversion Rate		**70 %**	**76 %**

1. The diversion rates used here are based on common building material densities. See Appendix E for a list of the densities.

Salvage Values & Outlets for Materials

Salvage value

Salvaged building materials can be divided into three categories:

1) Materials whose value are a small fraction (10% - 25%) of their new counterpart. The low value of these materials is a function of their condition or original value.

> ***Riverdale:*** *The doors were of a relatively low original value--they demonstrated no particular craftsmanship or unique design features. The low-grade pine sheathing boards had numerous surface nail holes giving them limited general utility. Approximately 10 to 20 per cent of the framing lumber exhibited warping, splitting, or severe crowning which reduced its value to this range.*

2) Materials whose value is a significant portion (50% - 85%) of their new counterpart. These materials can substitute one-for-one for readily-available new counterparts. The previous use of these materials does not affect the way in which they can be reused.

> ***Riverdale:*** *Both the hardwood flooring and dimensional framing stock are still common, readily available building materials.*

3) Materials whose value may equal or exceed (100+%) their new counterparts. The value of these materials has increased over time because:

- one or more of their qualities can no longer be obtained in readily-available counterparts (for example, cut glass or antique brass door knobs) or,
- the qualities currently can only be obtained at a substantial premium (for example, 16" wide plank floor boards) or,
- the material can be processed or remilled to add significant value (for example, remilling large, douglas-fir beams into specialty flooring or furniture stock).

> ***Riverdale:*** *The units did not contain any items of this type.*

Factors affecting salvage value or marketability

Several key factors were identified affecting the value or the marketability of the materials.

- Types of materials - commodity materials such as framing lumber have wide application, are used in large quantities, and so are relatively easy to sell. Finished materials such as windows and hardwood flooring have specific dimensions, specific uses, and require more targeted marketing.
- Time of year - depending on geographic location, construction firms and do-it-yourselfers may be more interested in building materials in the spring or summer than in the winter.
- Condition of local economy - demand for *all* building materials can be expected to be stronger when construction and remodeling activity is strong.
- Retail building material prices - the value of used building materials can be considered strictly a function of new building material prices. When lumber prices go up, any

alternative to conventional retail becomes more attractive.

- Condition - the presentation of well stacked, sorted, and labeled materials may attract more attention than those loosely-piled.

Table 10 gives the estimated range of each material's value based on the experience of several building materials salvage firms and actual values for Riverdale materials from the site sale described in the following section. The range in the estimated values of materials represents either a variation in the quality of individual items within the stock or uncertainty in the price that materials command in the market place.

Table 10. Quantities of Salvaged Materials & Estimated Value

Item	**Description**	**Quantity**	**Retail unit value**	**Estimated unit value**[1]	**Estimated value**
Oak strip Hardwood flooring	2 1/4" wide 3 1/4" wide	700 sf 250 sf	$2 - $2.50 (/sf)	$.65-$1.00 (/sf)	$455 - $700 $162 - $250
Framing lumber - "higher" quality (estimated #2 grade, no stamp)	2x4 (jack/stud) 2x4 (8' - 10') 2x4 (12' - 14') 2x8 (x 12') 2x8 (x 14' - 15')	203 30 68 33 63	$≈2.00 $≈3.00 $≈4.50 $≈8.75 $≈10.00	$.90-$1.10 $.90-$1.10 $2.00-$2.40 $3.90-$4.80 $4.50-$5.50	$183 - $223 $27 - $33 $136 - $163 $128 - $158 $284 - $346
Framing lumber - "lower" quality (estimated construction grade, no stamp)	2x4 (jack/stud) 2x4 (8' - 10') 2x4 (12' - 14') 2x8 (x 12') 2x8 (x 14' - 15') 2x12 (x 10')	68 10 22 32 62 12	$≈2.00 $≈3.00 $≈4.50 $≈8.75 $≈10.00 $≈10.00	$.25-$.50 $.30-$.75 $.45-$1.10 $.90-$2.20 $1.00-$2.50 $1.00-$2.50	$17 - $34 $3 - $8 $10 - $24 $29 - $70 $62 - $155 $12 - $30
Sheathing boards (roof and floor)	1x6 (8' avg. length)	475	NA	$.10 - $.25	$50 - $120
Brick	flush	5500	$.30 - $.35	$.10 - $.20	$500 - $1000
Windows (double-glazed, aluminum replacements)	31" x 54" 34" x 45" 20" x 36"	16 4 4	$90 - $150	$15 - $30 $15 - $30 $10 - $15	$240 - $480 $60 - $120 $40 - $60
Doors (exterior and interior)	36" - ext. panel (poor condition) 18" - paneled 24" - paneled 30" - paneled	4 4 12 4	NA NA NA NA	$0 - $15 $5 - $10 $5 - $10 $5 - $10	$0 - $60 $20 - $40 $60 - $120 $20 - $40
Metals (recycled)[2]	Ferrous (pipe, radiators, ranges) Aluminum (trim) Copper (wire, pipe) Brass (plumbing fittings)	2.05 tons 200 lbs. 188 lbs. 36 lbs.			$84 $42 $111 $11
Tubs/toilets/sinks	Cast iron tubs/ stainless steel sinks	4 (each)		$5 - $10	$20 - $40
Stair units, stair treads	Oak treads/units include stringers	20 treads			$25 - $50
Total					**$2791-$4572**

[1] NA= Not Available

[2] The metal recycling prices are based on data from *Recycling Times*, mid-Atlantic region, February, 1997.

Marketing approaches

The Research Center identified four different approaches to marketing and a number of factors that can affect the value of materials.

1) Direct Marketing to Retailers/End users - This is a "yellow pages" approach which involves direct contact with potential buyers (primarily phone work) or indirect contact (word-of-mouth). Suggested headings in the phone book include "salvage", "building materials - used", "brick - used", "lumber - used", "materials - used", "building restoration and preservation", and "historical societies". Although few if any traditional retail lumber yards will be interested in used lumber, you might find a brick yard interested in quality, used brick. End users of salvaged framing lumber and sheathing boards include large construction firms, bridge and road contractors (or any other firm erecting concrete forms), and non-profit developers or builders of affordable housing (Use of lumber in non-structural applications such as form work avoids the issue of the absence or the expiration of grading stamps on used lumber). End users of salvaged brick include masons and landscapers. Other opportunities include local universities and community colleges, the Internet, and the *Old House Journal Restoration Directory*.

One of the disadvantages to direct marketing is the amount of time required to identify interested parties. It's quite possible, however, that time invested initially can pay back over the long run as a reputation for the supply of certain materials is established.

> ***Riverdale**: The Research Center identified one retailer of used brick in the greater Baltimore, Washington metropolitan area and several construction companies interested enough in the lumber to make a trip to the jobsite to see the materials but not interested enough to make an offer. A retailer of vintage, used lumber was not interested in the hardwood flooring because of size (not large enough for remilling), species (oak is readily available at new retail outlets), and age (too new for vintage lumber).*

2) Broker - A broker is an individual or firm with accumulated information about end users and markets. There are brokers who will handle used building materials. Although a broker may make a single offer for all of the materials, the offer will be a fraction of the material(s)' value because of his or her costs of subsequent marketing, transportation, and possible storage.

> ***Riverdale**: Completely by word of mouth, a broker came to Riverdale and inspected the salvaged materials, stating that he was willing to make an offer to take all of the materials. He did indicate, however, that the offer would be significantly less than the 25% to 75% that the Research Center was seeking (reflecting the costs described above).*

3) Auction - Regional, periodic, auctions for used building materials do exist. The materials are sold in lots to the highest bidder, with the auction company taking a percentage of proceeds. Transportation of the materials to the auction site is the responsibility of the seller, not the auction company.

> ***Riverdale**: By word of mouth, the Research Center identified a regional auction of used building materials with an estimated attendance of 6,000 to 8,000 individuals. The auction has been held twice annually at a local county fairgrounds for over 30 years. The transportation fee (truck and forklift rental) for hauling the 60,000 pounds of Riverdale*

materials 60 miles to the auction was approximately $500.00. Given the expected value of the Riverdale materials, the Research Center decided to attend but not participate in the auction. Research Center staff observed framing lumber selling for approximately 50 percent of new retail prices and windows selling for as little as 10% of retail.

4) Site Sale - This approach is basically a glorified yard sale with notice of the sale advertised in local newspapers, newsletters of affordable housing organizations, and mailed, "postal residents" sale magazines. Vending permits may be required in some areas. A site sale almost certainly has the lowest overhead because retail or temporary storage space and transportation of the materials are avoided.

Photo 3: Riverdale Salvaged Framing Lumber Stockpiled and Ready for Site Sale

Riverdale*: The Riverdale site sale was advertised in one issue of: the Baltimore Sun, the Baltimore Housing Roundtable newsletter, the area "Pennysaver" mailed magazine. "Used Building Material Sale" signs were placed on the well-traveled major city avenue adjacent to the site. Interested parties contacted during the "direct marketing" phase were also notified of the site sale.*

As described in Table 11, some quantity of almost every material was sold at the site sale. Of the approximately 85 people attending the site sale, about 50% were responding as drive-bys to the site signs set up on the day of the sale. Some materials were sold as the result of follow-up calls to the Research Center after the site sale. The remaining stock was donated to the Loading Dock in Baltimore where the materials will be quickly and easily sold at the lower range of estimated salvage prices.

As expected, the commodity materials--lumber and brick--required little marketing or established location/reputation for used building materials. Many customers or browsers commented that they needed time to check on dimensions, retail prices, their spouse's reaction before purchasing windows, doors, flooring. They also commented on the need for an established retail set-up to tap the true customer base for many of the salvaged building materials.

Table 11. Results of Riverdale Site Sale

Salvaged Material	% of total amount of item sold	Sale price as a % of estimated retail	Income
Framing - 2 x 4s ("higher" quality)	75%	45% - 50%	$300
Framing - 2 x 4s ("lower" quality)	15%	≈25%	$30
Framing - 2 x 8s ("higher" quality)	50%	45% - 50%	$380
Framing - 2 x 8s ("lower" quality)	40%	≈25%	$175
Sheathing - 1 x 6	5%	NA	$6
Brick	100%	45% - 50%	$825
Windows, doors, shutters	25%	≈10%	$154
Tubs, toilets, sinks, radiators	50%	less than 5%	$70
Hardwood flooring	50%	45% - 50%	$500
Total			**$2,440.00**

Cost Analysis

In order for deconstruction to be cost-competitive with conventional demolition, the added costs of deconstruction (primarily, the extra labor of disassembly) must be offset by the value of the salvaged building materials and their avoided disposal costs. Cost analyses can be accomplished for:

1. the overall project, and,
2. for some individual components.

Overall project

Table 12 (based on information from Tables 4, 9, and 10) compares the overall cost of deconstruction to conventional demolition. Because the work at Riverdale did not provide any information on demolition costs, a range for total demolition costs is provided. Contractors can use their own costs to complete the comparison.

Table 12. Comparison of Deconstruction and Demolition Costs: Overall Project[6]

COSTS/PREMIUMS	DECONSTRUCTION	DEMOLITION
Labor[1] (hours X rate)	-$11,443	Proprietary information: NA
Marketing[2]	-$≈500	
Equipment[3]	≈$0	
Disposal[4] (# pulls X rate)	-$900	
Recycling[5] (# pulls X rate)	-$1,000	
Recycling Value[6] (metals)	+$250	
Estimated Value of Salvaged Materials[6]	+ $2,791 to +$4,572	
TOTAL	-$9,021 to -$10,802	$-7,000 to -$10,000[7]

Assumptions: The assumptions below are used in place of actual costs to protect the proprietary nature of the Riverdale contractor's costs.
1. Labor details -740.25 hrs. @ $12.00/hr. (total cost to employer of semi-skilled laborer) + 128 hrs. @ $20.00/hr. (total cost to employer of foreman--this includes the 3 weeks at the job site and 8 hrs. for building material inventory).
2. Marketing - Approximately three labor days @ $350 total + $150 in newspaper advertising.
3. Equipment - The cost of equipment for deconstruction, e.g., rental fees for tools, was negligible.
4. Disposal - A pull fee of $300 for a 30-yard dumpster was used (3 pulls @ $300/pull).
5. Recycling - Wood, masonry, and shingles can all be recycled in the Baltimore area at a cost less than disposal. The fee for each was assumed to be $100 less (per 30-yard dumpster) than disposal (1 pull - roofing, 4 pulls masonry, 5 pulls total @ $200 ea.).
6. Recycling and Salvage value - See Table 10
7. TOTAL (demolition) - The range used was $3.50 - $5.00 per square foot and included building demolition and debris hauling and disposal. The range is based on R.S. Means and discussions with demolition contractors.

In this comparison, the total cost of Riverdale deconstruction was competitive with demolition over a significant portion of the range of the projected cost of demolition. There are several key points to be drawn from this comparison:

- "Labor only" approach - A commitment to using only manual labor was made before the pilot project started. This focus yielded the required labor units for each component of the building disassembly as presented in Table 4. The inefficiency of salvaging the brick and the 1x6 sheathing boards was suspected before and confirmed as these tasks were

[6] The cost of asbestos removal and disposal was treated as a sunk cost for both deconstruction and demolition and so was not included in the cost comparison.

performed. A combined manual/mechanical and more flexible salvage strategy may have improved the total cost comparison between demolition and deconstruction.

- Impact of project scale - The actual unit cost of demolition is more dependent on the scale of a project than deconstruction. Bringing in heavy moving and processing equipment for a 2,000 square foot project is less cost-effective than for a 100,000 square foot project. The economic comparison of demolition-only and deconstruction-only will be greatly affected by the scale of the project under consideration.

- Impact of leaving basement - The exclusion of the basement from this cost comparison could have an impact on the results. Because specifications have not been set for the final condition of the site, it is unclear how filling in of the basement space would be handled and what materials, if any, from demolition or deconstruction could be used as clean fill for the basement space.

- Impact of site disturbance - Manual disassembly and salvage left little to any "footprint" on the site. Soil and vegetation disturbance was practically zero. Since the site will eventually become a park, this may represent a substantial subsequent cost advantage to deconstruction, even for a combined manual/mechanical approach.

- Labor component of total cost - The labor rate, given the total time required to disassemble a building, is the single most important determinant of deconstruction's cost-effectiveness. Even relatively small changes in the labor rate have significant impact on the cost-effectiveness of deconstruction. While the impact of total salvage value and landfill costs are not insignificant, their impact is much smaller than the impact of labor costs.

- Avoided disposal cost - Although a total of 192 cubic yards of material was diverted from disposal at Riverdale, only 81.5 cubic yards of this total was salvaged material (*no* tipping fee) with the remainder consisting of recycled material (only a *reduced* tipping fee). Entirely wood-framed buildings would increase the avoided disposal costs because a larger portion of the diversion total would be salvaged rather than recycled.

- Total net salvage value - An expectation of 50% of retail and relatively easy sale of framing lumber and brick is not unrealistic. More finished or use-specific materials such as flooring, doors, and windows can be expected to require a larger investment of marketing time and resources.

- Using tables 4, 9, 10, and 11 for other analyses - Information from these tables can be used to work up overall analysis of other projects. Care should be taken in the use of individual values from Table 4, as discussed in detail in the following section.

Individual building components

It is straightforward to calculate the cost-effectiveness of salvaging individual building components whose disassembly and salvage are *independent* of other building materials. Building materials such as windows, doors, hardwood flooring, and cabinets have only the cost of their *own* disassembly and processing to weigh against their value in retail and avoided disposal.

Table 13 compares deconstruction and demolition for flooring and windows. In both cases, the disassembly and salvage of the material results in a net premium and the demolition in a net cost.

Table 13. Comparison of Deconstruction and Demolition Costs: Flooring and Windows

COSTS/PREMIUMS	DECONSTRUCTION		DEMOLITION[1]	
Building Material	Flooring	Windows	Flooring	Windows
Labor (hours X $15/hr)	-$697.50 (46.5 hrs)	-$195 (13 hrs)	≈ $0	≈ $0
Equipment	≈ $0	≈ $0	≈ $0	≈ $0
Disposal (# pulls X $10/cubic yard)	$0	$0	-≈$70 (7 cy)	-≈$20 (2 cy)
Salvage Value of Materials	+$750 (1000 sq. ft. @ $.75/sq. ft.)	+$360 (24 units @ $15 ea.)	≈ $0	≈ 0
TOTAL (Flooring)	+$52.50	+$165	-≈$70	-≈$20

1. The marginal costs of demolition labor and machinery are assumed to be near zero--the progress of the bulldozer and operator would probably be unaffected by the presence or absence of the windows or flooring.

The same type of comparison is difficult and impractical for building materials *dependent* on the disassembly of other materials for their salvage. For example, how would a comparison of the individual demolition and deconstruction cost be made for floor joists from the first floor? It would be difficult but possible to estimate from the total demolition cost of labor and machinery for demolition of just the floor joists. However, what portion of the labor for plaster from the walls and ceiling above the floor joists would need to be added to the labor of salvaging the floor joists? Should labor required to disassemble the roof system somehow be apportioned to the floor joists since removal of the roof system would be required to have access to the floor joists? Clearly, the "deeper" a salvageable material is within a building, the more likely it is that the cost-effective recovery of an individual material must be evaluated as a part of the project as a whole.

Extended Cost Analysis

There are two important but difficult to quantify benefits to deconstruction that warrant consideration in the cost comparison:

1. Environmental benefits - A direct and local environmental benefit to deconstruction is the reduced impact to the site, it's soils, ground cover, and vegetation. On a larger scale, the salvaged materials save the energy and emissions associated with the production of the new materials they displace (including the extraction and harvesting of raw materials) and conserve landfill space.

2. Job creation - While equipment and labor costs may be just two different lines on a firm's budget sheet, there is societal benefit to any operation that increases the employment of people over equipment. Job creation can be an important policy consideration for federal agencies or communities engaged in building removal.

RECOMMENDATIONS/FUTURE WORK

The Riverdale case study has raised as many issues as it has addressed. Recommendations for addressing some of these issues have been divided into two sections. The first section focuses on recommendations for the building removal industry at large and the second section provides recommendations for the individual practitioner.

Recommendations

For the Industry

- *Engage OSHA and EPA in a discussion of lead and asbestos requirements for deconstruction activities*. There is clearly room for discussions with both EPA and OSHA on how the regulations from each agency on hazardous materials relate to one another and how OSHA regulations are to be applied to manual deconstruction. The primary issues involve the disposition of Class I (non-friable) asbestos materials and the handling of lead-based paint materials during manual disassembly.

- *Consider an industry educational policy for the use of half-mask respirators*. OSHA requirements for "particulates not otherwise regulated" (PNOR) and anecdotal industry evidence on worker performance/sick time suggest the use of half-mask respirators during specific deconstruction activities such as plaster removal. An industry effort to educate practitioners on this matter might be helpful in discussions with OSHA regarding lead-based paint requirements.

- *Consider an industry policy of invasive inspection for hazardous materials*. The discovery of materials such as hidden asbestos after contracts are signed or even after work has begun can wreak havoc on schedules and the bottom line. Coring walls and floors as part of the building materials inventory could be considered as a standard procedure.

- *Target building owners for information on deconstruction*. Building owners are perhaps in the best position to "create" the additional time required for some level of disassembly and salvage. It is often the property owner's lack of understanding of and planning for building removal that makes straight demolition a foregone conclusion. Additionally, building owners cannot request a bid that specifies recycling and salvage if they are unaware of the process and under what conditions it is appropriate.

- *Develop a methodology for grading salvaged structural lumber*. The building salvage industry needs guidance on how to advise buyers on structural reuse of framing lumber.

- *Share information and experiences with workers compensation insurance*. The deconstruction industry can benefit from developing a pool of information on obtaining worker compensation insurance rates for workers to apply where policy writers are unsure of proper classification.

- *Investigate job training program opportunities*. Deconstruction provides an excellent training ground for the building trades because:

1. It identifies workers with an aptitude for hand tools and a sense of job site safety with limited to no use of power tools and without involving "irreplaceable" new building materials.

2. Taking a building apart is an excellent way of learning the way in which a building is put together.

3. Deconstruction provides job satisfaction as stockpiles of building materials accumulate instead of piles of debris.

- *Support the newly formed Used Building Materials Association (UBMA) and support efforts to address deconstruction issues in existing organizations such as the National Association of Demolition Contractors (NADC).* One of the most important ways (and sometimes the only way) that industry issues as presented above are addressed is through the efforts of trade associations such as UBMA and NADC. The UBMA has written a manual for establishing a used building material retail store and is discussing the development of a deconstruction field guide. Both organizations would benefit by establishing an ongoing dialogue with EPA and OSHA on lead and asbestos issues.

For the Practitioner - In the Office

- *Use the information in this case study to evaluate deconstruction opportunities at job sites*. This report contains information on the time required per task or material, on the value of salvage materials, and for evaluating deconstruction's cost-effectiveness. All can be used to help determine whether or not your business and/or particular buildings are appropriate for a disassembly-and-salvage approach.

- *Investigate Resilient Floor Covering Institute (RFCI) flooring removal training*. To be competitive with demolition, deconstruction workers, not professional asbestos abatement firms, must be eligible to remove Class I ACM such as floor tiles and vinyl flooring (See Appendix A).

- *Establish a marketing plan for all salvaged materials <u>before</u> you start a project.* Salvaged materials may be used on site for a subsequent construction project, stored on site for a site sale, or transferred to an intermediate location or retail center. The types of materials, time of year, the strength of the local economy, and the current retail price of building materials will all affect the net total value of the salvaged materials. Costs for marketing and warehousing or transporting the material, as well as the potential for value-added milling or re-working of materials, must all be considered.

- *Build deconstruction work crews with a recognition of deconstruction's blend of construction and demolition skills.* A good deconstruction crew knows when and where to use hand tools, heavy equipment, and understands efficient flow of materials. Deconstruction requires an understanding of both demolition and construction to maximize salvage values of materials and minimize the labor involved in disassembly and processing materials.

- *Conduct a thorough building material inventory to determine the feasibility of deconstruction.* Every component, its condition, and the manner in which it is secured to the structure can have an impact on the cost-effective salvage of the material. Appendix B contains a guideline for a building inventory.

- *Plan ahead for storage and flow of materials*. Be sure to consider the storage requirements of different materials (hardwood flooring versus framing lumber) as you consider the overall cost-effectiveness of deconstruction. To achieve efficient flow of materials at the site, deconstruction businesses must also be able to provide or obtain timely container service.

- *Transfer work done at height (for example, the roof) to the ground wherever possible.* Because disassembly labor is more efficient on the ground than at heights, lowering roof sections to the ground with a crane for disassembly may reduce labor costs, exposure to injury, worker compensation costs, etc.

- *Consider using a combined manual/mechanical approach for deconstruction.* While buildings framed entirely with wood may be cost-effectively deconstructed to the foundation with hand and/or power tools, the Riverdale case study indicates that buildings constructed with masonry will likely require a combined manual/heavy mechanical approach.

    Riverdale: *A natural extension of this project, which focused on manual disassembly and only one building, would be an expanded project involving a combined manual/heavy mechanical approach. A pilot with a larger scope could provide economies of scale for labor (multiple labor crews could be set up to perform individual tasks as opposed to individual crews performing multiple tasks), heavy machinery and marketing/brokering of salvaged building materials. A pilot involving heavy equipment would also be more representative of clearance of the entire site.*

APPENDICES

APPENDIX A: Expanded Discussion of Industry Issues

Environmental Site Assessment

ASTM Standards E 1527--Phase I Environmental Site Assessment Process--and E 1528--Practice for Transaction Screen Process--were developed to satisfy a requirement for innocent landowner defense for commercial real estate under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the federal legislation for "Superfund" sites. The two practices have become industry standards to evaluate environmental hazards on commercial property and to help protect property owners from liability under the Superfund legislation. Although both lead-based paint and asbestos are listed by the standard as "non-scope considerations", these materials are, in practice, an important part of environmental assessments for properties slated for site clearance. ASTM offers the publications for sale as well as training seminars on a regular basis across the country. Contact ASTM publications at (610) 832-9585.

Asbestos

Identification

There is no definitive way to determine the presence or absence of asbestos in the field. While experienced abatement contractors often have a good sense of which building components are suspect, identification and asbestos content can only be accomplished using polarized light microscopy and quantification of asbestos content must be done by certified laboratories following exacting standard procedures.

EPA

According to EPA rules [40 CFR §61.140 through §61.157, entitled subpart M: National Emission Standard for Asbestos], the removal and disposal of all *friable*[7] ACM must be accomplished prior to any building removal work. The techniques and equipment required for abating friable asbestos (full-mask respirators, negative air pressure systems) mean that only licensed, professional abatement firms handle these materials. EPA rules identify two other types of ACM: category I non-friable (materials like asphalt roofing shingles and floor tiles) and category II non-friable (materials such as asbestos siding shingles and transite board). Category I ACM need only be removed prior to building removal if the material's condition is such that the material has *become* friable. Category II ACM need only be removed if the material is *likely to become* friable during the building removal process.

For more information on handling and disposing of ACM, you can order your own free copy of *Guidance for Controlling Asbestos-Containing Materials in Buildings* (Publication No. EPA 560/5-85-024) by calling (800) 424-9065, or (202) 554-1404 in the greater Washington, DC area.

[7] Friable is defined in the regulations as the capability, when dry, to be crumbled, pulverized, or reduced to a powder by hand pressure.

OSHA
According to OSHA rules [29 CFR §1926.1101, "Occupational Exposure to Asbestos; Final Rule"], handling *any* ACM without asbestos abatement techniques and equipment is based on a permissible exposure limit (PEL) of no more than a 8-hour, time-weighted average (TWA) of 0.1 fiber per cubic centimeter or an excursion limit of 1.0 fiber per cubic centimeter in a sampling period of thirty minutes. Exposure to workers above this limit requires asbestos abatement measures (including full respirators, negative pressure systems, etc.). Typically the measurement of these exposures is handled by an industrial hygienist obtaining filter samples from workers wearing powered air supplies and respirators. Call OSHA's publication office at (202) 219-4667 for their free publication entitled, *Asbestos in Construction* (OSHA 3096).

Other Information
In response to the OSHA ruling on handling asbestos, two industry groups--the Resilient Floor Covering Institute (RFCI) and the National Roofing Contractors Association (NRCA)--worked with OSHA to develop acceptable work practices for handling non-friable ACM flooring and roofing shingles without asbestos abatement measures.

The RFCI work practices involve 12 hours of training for a supervisor, 8 hours of training for workers, record-keeping, wetting techniques, etc. (The rationale for the work practices is substantial independent testing of floor tile removal that demonstrated worker exposures always below the PEL). Any "intact" (flooring with any potential asbestos fibers still bound to the flooring matrix) floor tiles or sheet flooring can be removed by the trained workers without asbestos abatement procedures (respirators, negative pressure enclosures, etc.).

The NRCA recommendations involve removal of shingles with hand tools, lowering of roofing materials off the roof, consideration of wetting, etc. For more information or to obtain copies of industry recommendations for handling these category I ACM, contact the following:

Resilient Floor Covering Institute
966 Hungerford Dr., Suite 12B
Rockville, MD 20850
Ph: 301 340 7283
Fx: 301 340 7283

National Roofing Contractors Association
O'Hare Int. Ctr, 10255 Higgins Rd., Suite 600
Rosemont, IL 60018-5607
Ph: 800 323 9545
Fx: 847 299 1183

Disposal of friable asbestos is the responsibility of the licensed abatement contractor. The disposal of non-friable ACMs such as roofing shingles and resilient floor coverings is not regulated at the federal level. In most cases, these materials can be disposed of in a construction and demolition (C&D) or municipal solid waste (MSW) landfill, but check local landfill policies beforehand.

Lead

Identification
There are several different tests for lead-based paint--understanding the nature and reason for each test is important in understanding how to handle LBP.

1. LBP Test Sticks - The general *presence or absence* of lead can easily be determined in the field using paint sticks (the stick or "crayon" or swab is part of a rhodizonate spot test kit). The stick

must come in direct contact with each layer of paint being tested. These test kits are relatively inexpensive (less than $20), are readily available, and can be used by anyone. This test should only be used as an initial determination of the magnitude of the LBP problem on a project--positive results suggest more detailed analysis and negative results from test sticks are not accepted by regulatory agencies as conclusive evidence of the absence of lead.

2. <u>X-ray Fluorescence (XRF) and Atomic Absorption Spectroscopy (AAS)</u> - Determination of the *concentration of lead in paint or coatings* can be accomplished in the field by XRF equipment--milligrams per square centimeter--or in a laboratory by AAS--% by weight. These tests must be performed with highly trained technicians with equipment ranging in cost from $4,000 to $40,000. These tests have limited utility for the building removal industry (see discussion following number 4) and are most useful for large HUD or other rehabilitation projects.

3. <u>Toxicity Characteristic Leaching Procedure (TCLP)</u> - Determination of the *lead leaching potential in mixed debris* is accomplished by a TCLP. A TCLP must be conducted according to standard procedures with the sample sent to a certified laboratory for analysis. TCLP tests cost approximately $50 or less. A TCLP test determines whether or not a load of demolition debris must be handled as hazardous waste (5 parts per million or greater).

4. <u>Air Monitoring of Workers</u> - The determination of *lead concentration in the air* is done by collecting respiratory filter samples over a specific time period that are subsequently analyzed by a lab--micrograms per cubic meter. Usually, an industrial hygienist collects the samples and sends the samples out for laboratory analysis. Air sampling and testing can cost several hundred dollars. This test is required by OSHA to forego extensive worker protection practices for specific demolition activities such as plaster removal.

There is considerable discussion regarding the relationships between XRF (field test) and AAS (lab test) determinations of lead concentration, between XRF/AAS (concentrations of lead on surfaces) and TCLP determinations (concentrations of lead in mixed debris), and between XRF/AAS (surface concentration tests) and air sampling determinations (concentration of lead in air in work settings).

1. Uncertainties in XRF field determinations can require verification by AAS analysis.
2. No study has ever established a statistically satisfactory relationship between XRF/AAS and TCLP results.
3. The number of variables affecting the relationship between XRF/AAS and air sampling results lead to little if any relationship between concentrations of lead in materials and lead in the air during demolition or deconstruction activities.

The final result of all these uncertainties is that the best information most likely to be available on lead-based paint in a building--XRF or AAS test results--will provide little help and certainly no conclusive evidence that can be used in complying with EPA disposal regulations and OSHA worker protection requirements.

<u>EPA</u>

EPA rules on the disposal of LBP building materials [40 CFR §2612.24] require that the material be handled as hazardous if a Toxicity Characteristic Leaching Procedure (TCLP) reads more than 5 parts per million in lead. The TCLP is a test performed by certified laboratories. Building demolition debris--mixed plaster, masonry, roofing shingles, and LBP wood--generally passes the TCLP and so little demolition debris is, from a disposal perspective, handled as hazardous. Any time building components with significant lead levels (1.0 mg/cm^2 or greater) are segregated for disposal, a TCLP test should be considered.

Although unlikely to result in a failed TCLP, it is possible that salvage of building materials could change the overall concentration of lead in the fraction of the building destined for the landfill. The important points here are that you may not intentionally dilute your disposal mix to pass a TCLP but you are also not required to intentionally segregate LBP building materials. Recent research suggests that the long term leaching characteristics of LBP materials are such that disposal of these materials in either a C&D or a MSW landfill is appropriate. EPA is developing a proposal for disposal and management of LBP debris--it is expected to be published by late 1997.

<u>OSHA</u>
All of OSHA rules pertaining to LBP materials are based on exposure levels--the concentration of lead in the air. There is an action level (AL)--30μg/m^3 for an 8-hour time-weighted average--and a permissible exposure limit (PEL)--50 μg/m^3. The action level triggers compliance measures--respirators, protective work clothing, change areas, hand washing facilities, biological monitoring (blood level checks), and training. The PEL sets an absolute level of exposure for an 8-hour work day. It is the responsibility of the employer to observe the compliance measures if workers are conducting activities at or beyond the AL. Research data or data from other work projects can be used to demonstrate that specific activities and or materials do not lead to conditions at or beyond the action level--EXCEPT for specific activities identified by OSHA as an activity that is assumed to involve exposure levels at or above the AL. One of the activities so cited is manual demolition.

For more information on the OSHA lead rules, contact the OSHA Publications Office at (202) 219-4667 for a free copy of *Lead in Construction* (OSHA 3142). Another good reference is *What Remodelers Need to Know and Do About Lead: A Guide for Residential and Commercial Remodelers and Painters*, NAHB, 1993--call (202) 822-0299 to purchase a copy.

<u>Other Information</u>
XRF and AAS test results will be of little help in determining how you should handle LBP materials to meet EPA disposal requirements or OSHA worker protection requirements. Work with your local inspectors ahead of time so that you know before you start a project what they will and will not permit on the job site.

If LBP building materials are to be reused, steps must be taken to minimize lead hazards. The painted surface may be stripped using stripping solutions, recoated with non-LBP, or coated with some other protective coating. It the LBP building material is to be used for energy recovery, it may only be burned in combustors operated in compliance with Clean Air Act requirements. The use of LBP building material as mulch or ground cover is not appropriate since it may result in exposure to lead through inhalation or ingestion.

Workers Compensation Insurance

Workers compensation insurance is legislated at the state level. Thirty-two states subscribe to the National Council on Compensation Insurance (NCCI) which can be designated by the state to administer the insurance program. There is ample evidence in the construction and demolition industries of how widely workers compensation premiums can range based on the experience and diligence of the agent and insurance company you choose. It pays to understand how the worker compensation program works in your state and shop around for coverage.

For more information on how worker compensation premiums, actuarial rates, and classification codes work to determine your worker insurance costs, contact NCCI at 1 (800) 622-4123.

APPENDIX B: Building (Material) Inventory

The most important part of assessing the feasibility of deconstruction for a particular structure is a detailed inventory of how and what the building is made. Every component, its condition, and the manner in which it its secured to the structure can have an impact on the cost-effective salvage of the material.

A detailed building material inventory requires invasive inspection of the structure. This will identify hazardous materials not available for inspection during the non-invasive Environmental surveys described in Appendix A, as well as identify construction methods and fasteners which may impact the feasibility of deconstruction.

The Building Material Inventory Form (Table B1) lists the information necessary for a baseline evaluation. In addition to the form, sketching a floor plan may be helpful during follow-up calculations. Depending on the size of the building a thorough building inventory can be conducted in approximately four to 8 hours. Compiling the field notes into a written report, and preparing a final analysis of the feasibility of deconstructing the building will require additional time. With the inventory form completed the quantity of material in the building can be calculated (by square foot, linear foot, board foot, weight or volume), which will help determine the salvage value of recoverable material.

A completed inventory of a Riverdale 4-plex is also included in Table B2.

Table B1. Building Assessment Form (blank)

Building (Material) Inventory Form			
Building Identification:			
Roof System			
wood framing	roof type (gable, hip, mansard, etc.):		pitch:
	roofing material:		# of layers:
	rafter:	size:	length:
	ridge beam:	size:	length:
	spacing of framing members:		
	sheathing type (T&G, butt joint):	size:	
	ceiling joists:	size:	length:
Exterior Wall System			
masonry	width (single or double wythe, cavity, etc.):		
	location of rebar:		
	steel lintels:		
wood framing	stud:	size:	height:
	plate - top: bottom:		length:
	spacing of framing members:		
	sheathing type:	size:	length:
Floor System			
wood framing	joist:	size:	length:
	spacing of framing members:		
	center carrying beam for joists:	size:	length:
	sheathing/subfloor type:		

Interior Walls - Wood Framing			
load-bearing	stud:	size:	height:
	plate - top: bottom:		length:
	spacing of framing members:		
	total linear feet of wall:		
partition walls	stud:	size:	height:
	plate - top: bottom:		length:
	spacing of framing members:		
	total linear feet of wall:		
Foundation - Masonry			
	type (block, poured):	width:	height:
	location of rebar:		
	slab:	thickness:	rebar:
	chimney type (solid, lined):		size:
	sump pump:		
Fascia/Eave			
	fascia:		
	rake:		
	gutters:		

Connections Between Building Elements (anchor bolts, strapping, holdowns, etc.)			
	floor/wall:		
	wall/roof:		
	window/wall:		
Finish Materials			
	plaster/lath:		ceiling height:
	finish flooring (type):	fastening:	
	unpainted wood (type):	linear feet:	
	cabinets (type):		
	stair treads (type):	number:	width:
	shelving (type):		
	plumbing fixtures (type):		
	appliances (type):		
Heating System			
	system (type):		
	boiler/furnace:		
	hot water heater:		
	radiators:		
Other			
	doors (type):		size:
	windows (type):		size:
	metals - piping for plumbing, domestic hot water, etc.:		

Miscellaneous			
	extent of rot:		
	lumber grading stamp:		
	overall building dimensions:		
	date of construction (approx.):		
	complicating site conditions - steep grade, trees near the building:		

Table B2. Riverdale Village (4-plex) Building Assessment

Building (Material) Assessment Form			
Building Identification: *Riverdale Village 4-plex*			
Roof System			
wood framing	roof type (gable, hip, mansard, etc.):	*gable*	pitch: *7/12*
	roofing material: *asphalt shingles*		# of layers: *2*
	rafter:	size: *2x8*	length: *15′-4″*
	ridge beam: *stacked 2x4 and 2x6*	size:	length: *12′*
	spacing of framing members: *16″*		
	sheathing type (T&G, butt joint): *butt*	size: *1x6*	*8′ lengths (avg.)*
	ceiling joists:	size: *2x4*	length:*12′, 14′*
	collar ties and vertical bracing	*1x6*	*9′, 10′ lengths*
Exterior Wall System			
masonry	width (single or double wythe, cavity, etc.): *8″, double wythe - no cavity*	*4″ brick and 4″ CMU*	
	location of rebar: *none*		
	steel lintels: *none*		
wood framing	stud:	size:	height:
	plate - top: *(sill for rafters)* bottom:	size: *2x8*	length: *8′, 12′*
	spacing of framing members:		
	sheathing type:	size:	

Floor System	*Riverdale Village 4-plex*/con't		
wood framing	joist	size: *2x8*	length: *12', 14'*
	spacing of framing members: *16" o.c.*		
	center carrying beam for joists:	size: *2x12*	length: *10'*
	sheathing/subfloor type: *butt joint*	*1x6*	*8' avg. lengths*
Interior Walls - Wood Framing			
load-bearing	stud:	size: *2x4*	height: *7'-5"*
	plate - top: *double* bottom: *single*		length: *8',12'* length: *8',12'*
	spacing of framing members: *16" o.c.*		
	total linear feet of wall: *42'*		
partition walls	stud:	size: *2x4*	height: *7'-5"*
	plate - top: *double* bottom: *single*		length: *8', 12'*
	spacing of framing members: *16" o.c.*		
	total linear feet of wall: *66'*		
Foundation - Masonry			
	type (block, poured): *block*	width: *8" and 12"*	height: *7'-0"*
	location of rebar: *none*		
	slab: *not applicable*	thickness:	rebar:
	chimney type (solid,lined): *brick, block, & liner*		size: *51" x 51"*
	sump pump: *not operational*		

Fascia/Eave	*Riverdale Village 4-plex*/con't		
	fascia: *1x10, clad with aluminum*		
	rake: *1x6 horiz. lap siding, clad w/ alum.*		
	gutters: *alum. gutters and downspouts*		
Connections Between Building Elements (anchor bolts, strapping, holdowns, etc.)			
	floor/wall: *metal strapping @ 4'-0" o.c. - nailed to joist, set in mortar of masonry wall*		
	wall/roof: *16" long A.B. (@ top plate) @ 4'-0" o.c.*		
	window/wall: *brick arches - no metal connection*		
Finish Materials			
	plaster/lath: *3/8" and 3/4" plaster on 3/8" gypsum lath boards*		ceiling height: *8'*
	finish flooring (type): *oak strip*	fastening: *cutnails*	*2¼", 3¼" widths*
	unpainted wood (type): *none*	linear feet:	
	cabinets (type): *68" of base cabinets, 60" wall cabinets*		
	stair treads (type): *oak*	number: *20*	width: *36"*
	shelving (type): *1x12 painted*	*2', 4', 5', and 6' lengths*	
	plumbing fixtures (type): *cast iron tubs, toilets and sinks - 4 each*		
	appliances (type): *oven/range (4)*		
Heating System			
	system (type): *forced hot water with radiators*		
	boiler/furnace: *boiler*		
	hot water heater: *60 gallon*		
	radiators: 16 total - 17" (4), 20" (4), 24" (4), and 26" (4)		

Other *Riverdale Village 4-plex*/con't	
	doors (type): *4 exterior - solid core, paneled with sash - 36" width* *20 interior - solid core, paneled - 18", 24", and 30" widths*
	windows: *double glazed, alum. replacements - 31"x 54" (16), 34"x 45" (4), and 20"x 36" (4)*
	metals: *ferrous: radiators, iron scrap, range* *non-ferrous: alum. trim* *copper: wiring, piping* *brass: plumbing fittings*
Miscellaneous	
	extent of rot: *approx. 5% of all wood is rotted*
	lumber grading stamp: *none observed*
	overall building dimensions: *26'-4" x 42'-11"*
	date of construction (approx): *1948*
	complicating site conditions: *flat site; 6" dia. tree within 1' of building, 24" dia. tree 10' away; pavement near building*

APPENDIX C - Tools Required

The tools listed below are considered essential -- individual projects may require special tools.

Individual tools (each worker)

- claw hammer and masonry hammer
- long and short pry bars
- hard hat and dust masks

Jobsite tools

- reciprocating saw (2), circular saw, reversible drill and extension cords
- sledge hammer, axe, wrecking bar
- log chain with snap hooks and rope
- wheelbarrow (3), coal shovel (2) and flat nose shovel (2)
- straw broom (2), push broom, garden rake, leaf rake, pitch fork and weeding hoe
- saw horses (3 pairs)
- ladders - 6', 8', and extension
- brick carrier, masonry chisel
- channel locks, bull nose snips
- 25' tape measure
- tarps and poly
- banding tools
- fire extinguisher and first aid kit

Supporting equipment

- dumpsters
- chutes
- fork lift and flat bed
- pallets
- hand truck

APPENDIX D - Site Plan

(Two-story, attached residential units)

Riverdale Village **(not to scale)** **= denotes 4-plex**

Figure D1 - Riverdale Village Site Plan

Figure D2 - Job Site Layout

APPENDIX E - Material Densities

The densities listed below are approximate--considerable variations can occur given how materials are handled, compacted, mixed, etc.

Table E1: Building Material Densities

MATERIAL	DENSITY OF MATERIAL	BROKEN OR WASTE DENSITY
Wood	2.75 pounds/board foot	300 pounds/cubic yard
Drywall (½-inch)	1.8 pounds/square foot	350 pounds/cubic yard
Plaster	60 pounds (loose) - 160 pounds (hard mineral)/cubic foot	1000 pounds/cubic yard
Masonry (brick)	120 pounds/cubic foot	1800 pounds/cubic yard
Asphalt Roofing Shingles	225 pounds/100 square feet of coverage	700 pounds/cubic yard
Metals (aluminum, copper, brass, steel)	165-490 pounds/cubic foot	500 - 1500 pounds/cubic yard
Mixed Demolition Rubble	N/A	1400 pounds/cubic yard