Designing for Efficient Deconstruction

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Executive Summary
Green building is getting an ever growing portion of the spotlight in today's world. As people become more knowledgeable about the environmental issues, they are pushing for solutions that can aid in making society more sustainable. This has taken many forms, but there is a lot of potential in building construction that could be utilized from this movement.

Designing buildings for efficient deconstruction could be one of the keys to improve the sustainability of buildings. Deconstruction is often passed over for the speed and perceived low price of demolition. This leaves many building materials that could be salvageable to be wasted and dumped needlessly in landfills.

In order to fight this, knowledge of the deconstruction must be communicated. There are current building methods that could be should be fine tuned for this purpose, making them more mainstream and accepted. The materials that would be ideal for making these buildings have been in use for many years, but they need only be designed in such a way that they can be simply deconstructed. This concept of designing buildings for deconstruction may need to alter some perceptions about buildings before they can become mainstream. If done correctly, this could change the way many buildings are designed in the future.

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Introduction
With environmental and sustainable issues ranking high in priority in today’s society, resource use is one of the topics under the microscope. Terms such as recycling and reusing come to mind; maximizing efficiency is the key. By using materials to their utmost potential, consumption can be reduced, thus supporting sustainable practices. This concept can be applied in many fields, but one large opportunity is the construction industry. One method of reducing resource consumption for buildings is to increase effectiveness of material recovery, thus reducing the reliance upon new or “virgin” resources.

In order to achieve this, a change in the general perspective towards buildings may need to be changed. Traditionally, most designers and builders create structures that are expected to stand the test of time. Aside from a few exceptions, this is the norm, and once the building is completed, the building is left as is until demolition because the building no longer serves its purpose. In the past, when torn down, much of the building materials were simply hauled to the dump. Today, some of those materials are salvaged, but generally, only a portion can be reused. It takes time to sort through the debris to find parts that are undamaged enough to be reused once again. A change in mindset would be designing the buildings for efficient deconstruction. There are some existing construction methods that could be ideal for making such designs. They have not become mainstream for buildings construction, but they could be the key to changing the future of green buildings.

The first part of this paper discusses the definition of deconstruction and what currently takes place when buildings reach the end of their life cycles; how the buildings are taken apart and what materials are reclaimed. Then prefabricated construction types will be discussed and their eligibility and potential role as the forefront of new building designs. The materials that will most likely be used in designs for structural deconstruction are reviewed in the next section. The main contenders are steel, concrete, and wood, each with its properties and advantages. Then the paper will be closed up with a discussion of the changes that may need to take place before buildings made for deconstruction can be accepted.
What is Deconstruction?
Deconstruction is about harvesting building materials from existing structures that have reached the end of their life cycle to be utilized once more; reclaiming what is often considered waste products. Deconstruction has been defined as construction in reverse. This is runs counter to the methods of demolition, which often offer destruction of and clearing of existing structures on sites with an emphasis on speed and economical rates. A significant amount of waste is created; resources that could be made use of in new purposes. The material available from old buildings may still hold their value, or in some cases, be even more valuable than they were in their original application.

Structural and non-structural are the two categories that make up deconstruction. Contractors are usually granted the rights to the building material salvage by the building owner. Non-structural methods, known also as “soft-stripping” or “high-grading”, concentrate on salvaging high and low value non-structural components such as finished flooring, cabinetry, windows, doors, trim, appliances, fixtures and hardware (NAHB RESEARCH CENTER, INC., 2001). These components can be recovered relatively easily with minimal need for destructive access or structural bracing. This is already a mature industry that caters to used building material markets located primarily in or around disadvantaged communities throughout the United States.

Structural deconstruction on the other hand can be considered a growing market, especially now that it is linked with the green building trend. In the past, salvage has been limited to bricks, dimension stone, large timbers, and highly valued rare species of softwoods and hardwoods. Brick and dimension limestone were especially valued in the existing, specific high-end sectors of the market as they have a tradition of reuse due to their durability and time worn color changes. Engineered wood products such as glulam, laminated veneer lumber, and Parallam, can be expected to show up as material salvage as they become more common in the construction industry. Lower end markets for structural materials have emerged, but remain weak as they deal primarily in recovered common dimension lumber; the removal costs of dimensional lumber is not competitive with purchasing new materials on the open market (NAHB RESEARCH CENTER, INC., 2001).

The practicality of using deconstruction is heavily dependent upon the project. Time and labor costs are the primary driver; deconstruction can take weeks while demolition can be done be done within a very short timeframe. It should be noted that the economic value of salvaging materials from a building can cover some of its cost, if not all of it; tipping fees as well as the cost of new materials are reduced for the reused material (BRATKOVICH, Steve, 2009). If the reclaimed resources can be used the project that is replacing the current building site, or a site nearby, then transportation costs will be minimized or non-existent. Structural deconstruction is affected most by time constraints since non-structural deconstruction commonly takes place before demolition, and can be done before demolition permits are even issued. Another factor that works against structural deconstruction is encountered during projects. Sometimes there are financial incentives for contractors that finish on time or ahead of schedule; this is especially true for commercial projects. Large-scale commercial and public buildings often have more consistent supply of salvageable material than smaller residential projects.
There is an issue concerning the variable nature of the structural building materials harvested from building sites. This is caused by the very nature of deconstruction; structural deconstruction requires some kind of mechanical demolition activity for removal. An example would be brick materials, which are pulled away from the structure by mechanical means before being separated by manual methods. This invariably causes some damage to the salvaged material (NAHB RESEARCH CENTER, INC., 2001). The time issue also factors in, causing contractors to hastily complete the deconstruction to get started on the project. These factors reduce the quantity and quality of the recovered material supply and potentially impair the presence of the structural deconstruction material market as a source of building material.

Materials recovered need not be reused in the exact role they were originally utilized. Metals such as steel and aluminum can be reformed, while wood can be reprocessed. To keep with sustainability objectives, processing should be kept minimal in order to curb the energy usage; this makes salvaged wood material suitable to be transformed into alternate forms. This could be of particular use for the low-grade structural material market that deals in dimensional lumber.

**Designing for Deconstruction**

**Basic Deconstruction Design**

Simply put, for ease of deconstruction, construction methods and materials that are difficult or impossible to disassemble should not be used. Adhesives and nails should be avoided as they drastically increase the time needed for the deconstruction process; they also have issues concerning damage to the attached materials. This is most noticeable on wood products; particularly high grade or rare woods that are valuable. Nails can potentially split or damage pieces while adhesives have a tendency to tear the wood surfaces they are attached to when being removed. Materials will no doubt be machined into better form before being reused, but the damage done may result in having more wood trimmed off a piece, reducing the potential value of the wood.

Since time is such a pressing matter when it comes to the demolition stage of a building, it is important to make the process as streamlined as possible so that contractors do not find deconstruction to be such a burden on their schedule. Architecture plays a large role in easing the deconstruction process. A new trend in green design is separating a building’s infrastructure into layers, making them more visible and readily accessible when the time came for deconstruction. Using high-grade, durable materials would be ideal to increase their survivability and value reclamation. A consistent use of material grades may also speed up the deconstruction process. Using a number of different grades may make identification for difficult when sorting materials for reuse or resale. Simple construction methods should be utilized. To further improve efficiency, components should be easily separable, primarily through the use of mechanical fasteners. Bolts and fasteners are versatile and are well suited for the task. In addition, easy access to the fasteners should be included, increasing the speed of the deconstruction process.
Prefabricated buildings

Prefabricated buildings are a natural extension of buildings designed for deconstruction. The industry existed before the massive public push for green designs, but the core competencies that allow the industry to thrive fits in very well with the goals deconstruction. There are two main types of prefabricated buildings; manufactured buildings and modular buildings. Along with being potential methods of designs used for deconstruction, both are created in factories, giving them advantages over site-built buildings. Prefabricated buildings are usually created in factories, away from the damaging effects of weather. Furthermore, since the sections or modules are part of standardized product, companies can have greater control over productivity as well as quality. Having correctly sized material to work with improves workmanship and can also minimize waste produced during the assembly process. The manufacturer can achieve cost savings due to economies of scale, allowing them to pass it on to their customers.

Manufactured Buildings

Complete sections of a building are completed in a factory before being sent to a building site for construction. Companies that make manufactured buildings usual concentrate on homes; while making a single design would cut down on cost, they often offer a number of different designs that share common components. All the sections of the house are created before being packaged and shipped together to the build site. This could make it ideal for producing houses that can be designed for deconstruction since all the required mechanical fasteners could be packed to go along to the job site.

Since the buildings are created in sections, they could ideally be designed to be taken apart. Designated areas for fasteners could be marked where sections are joined. If there was a popular home design, or a line of similar designs, a manual could be created with a set procedure for deconstruction when the end of the buildings life cycle came about. In North America, the wall panels will be created using wood frame housing techniques and so the use of dimension lumber is unavoidable; however, for large spans, beams made of engineered wood products can be utilized, making them available for salvage in the future. In this way, manufactured buildings could be one of the potential methods of producing buildings made for efficient deconstructive.

Modular Buildings

Modular buildings are structures that are made up of many smaller sections. Like manufactured buildings, they are produced within a factory. The main difference is that each module produced is a complete unit, usually made to join with one or more other modules. In many cases, a single module can be considered a building even if it stands alone. By definition, if each module was considered a component of a large building, then it could be said that modular buildings are already the optimum concept for efficient deconstruction. When a building meets the end of its life cycle, each module can simply be taken apart from one another and be reused. Because modules are so versatile, they could be useful for renovations as well. Modules could be added on to increase the size of building, or if there are alternate designs with the same module connections, then they could replace existing modules to change the layout of the house (MODULAR BUILDING SYSTEMS ASSOCIATION, 2009).
The concept of modular buildings allows them to be flexible. They have been particularly useful in providing housing in remote regions, where they can provide cost savings over traditional site-built homes due to the minimal amount of labor to needed to install the module. Modular buildings have also found use as temporary shelters in disaster zones. They are ready for use once they are off the truck and they can be disassembled after the incident has passed.

**Potential Materials used for Designing for structural Deconstruction**

When creating a building designed for deconstruction, choice of material will make a big difference. The decision will determine the survivability as well the potential salvage when deconstructed. There are a number of contenders, each with their unique properties. Buildings designed for deconstruction will most likely incorporate more than one of these materials.

**Steel**

Steel is one of the ideal materials fitting for deconstructive purposes. It is a strong material that has strength properties that are homogeneous in all directions. Since steel beams are manufactured to standardized dimensions, very little waste is generated during construction; any waste that is produced may be recycled. In larger-scale buildings steel will most likely used in the form of beams that will be in contact with cement. Depending on the project, the beams may or may not be exposed to the elements, affecting its life span; if upkeep is maintained, steel structures can last for an extended period of time. When recovered, any concrete still attached can be easily removed by mechanical means. Steel beams are connected to one another, as well as other materials, through mechanical fasteners, making them relatively easy to separate. Steel is an ideal material for deconstruction. Aside from using recovered steel material directly into a new project, it can also be recycled. This is most likely what would happen to recovered steel rebar from demolished reinforced concrete. Steel does not lose any of its inherent physical properties during the recycling process, and requires less energy input when compared with refining iron ore. Recycling of steel has taken place for over 150 years and roughly three quarters of all steel annually produced has been recycled; this shows that people are aware of its properties and they would be open to using steel in designs for building deconstruction.

**Concrete**

As the most used man-made material in the world, concrete will no doubt be encountered during the deconstruction process. It is made of hardened mixture of water, aggregate and cement. Concrete works best when facing compression loads; if there are tensile forces expected, then steel rebar is inserted to create reinforced concrete. In the past, concrete from demolished sites were simply hauled away to landfills for disposal. Now, with the increase of environmental awareness, concrete is recycled. Due to the formed nature of the concrete, when removing it, demolition activity is necessary to dislodge it, dealing significant damage to the concrete (MUKERJI, Chandra, 2005). Since concrete needs to be newly formed in place in order for it to be used as a structural component, demolished concrete cannot be used directly in new buildings.

Concrete is processed by a crushing machine, breaking it down into small pieces. Any metallic objects such as rebar are removed via magnets and the pieces are sorted by size. Any pieces considered too
large are sent through the crusher again. This new form is primarily used as filler material. Depending on the size of the pieces, they can be used as a replacement for gravel or even as aggregate for mixing new concrete. Recycling this material keeps it out of landfills, freeing up precious space; it also reduces the need for gravel mining.

Concrete is not a perfect fit as an ideal material for deconstructive purposes, as it cannot be easily be dismantled from a structure; however, since it is capable of being recycled and its use is so widespread, it will still be an integral part of many buildings. It will still be used in many structures as foundation, fire retardant barriers and heavy structure.

**Wood**

Wood has been in use as a building material since humans began making shelters. Its use still continues today in many forms. Wood is used in timber frame construction, a common method of producing housing in many parts of the world, in the form of dimension lumber. When large expanses need to be spanned, timbers were used in the past; however, due to the increasing price of large timbers, beams made of engineered wood products can now be used that are just as strong, if not stronger. In some cases, engineered wood products can also be lighter, like the I-joist.

Wood is unique among these contenders as it is a renewable resource. Coming from trees, wood has properties which are not found in other materials since it is composed of cells and is anisotropic. Wood is a fitting material for the push towards greater sustainability since it is made of the carbon dioxide that is taken in by living trees and plays a major role in the carbon life cycle. By using wood for constructive purposes, the material is kept from being burnt or decomposed, which would release the carbon dioxide back into environment. Wood products are considered part of the carbon sink; the longer the wood stays in use by people, the longer the carbon is kept in place. Keeping wood in use also reduces the need for new wood to be harvested from trees, helping sustainability. Studies have also found that the energy input required to make wood products is less than steel and concrete, adding to its advantage as a green product.

Traditionally, only highly valued wood pieces were recovered from demolition sites, because there was a perception that regular dimension lumber was inexpensive, expendable, and had little use once it was broken. This is a misconception as lumber, even if it is damaged to the point where it can no longer serve its role again, can be recycled. Wood kept in its natural form is a good material, but it can be put to use in engineered wood products. By breaking down the wood into smaller pieces and reforming them, the effect of defects or damage from the original piece is distributed across the new product and minimized. Different engineered wood products may require different types or grades of wood, but much of the material can be taken from recycled wood. Panel products such as particle board and medium density fiberboard are made up of wood material that is broken down into such small pieces before resin is applied, that almost any existing deficiencies are of no concern to the performance of the end product. Oriented strand board requires larger chips to be pressed into the board, but the concept is the same.
Aside from breaking dimension lumber down to small chips and particles, if some sections of dimension lumber can be salvaged, but are too short to be of much use on their own, they can be finger jointed with other pieces to create longer lengths. With the surface area provided by finger joints, the applied resin is able to keep the pieces together. This same technique is used when creating glued laminated lumber (BRATKOVICH, Steve, 2009). Pieces of dimension lumber are finger jointed, and the new pieces are glued together to create larger beams. Due to the finger joints, glued laminated lumber can, in theory, be made to any desired length. When being pressed and heated to cure the resin, the beams can be bent, allowing for curved structures to be created.

Old timbers that are salvaged from deconstruction can be reused. When kept in good condition, timbers were found to be as strong as they were when they were installed. There have been many examples of this where timbers were taken out of older structures and reused, one of which is the C. K. Choi Building in UBC, also known as the Asian Center. 90 percent of its structure was created from salvaged timbers from the adjacent building, which was 75 years old (C.K. CHOI BUILDING, 2000). Only some on-site resizing and recertification was needed before the timbers were inserted for the new building. Many other parts of the Asian Center used recycled non-structural materials from the existing building; this along with a energy efficient design won the building a number of environmental design awards.

Another example where existing timbers were reused was the Main Library of UBC. When this building underwent renovation into the I. K. Barber Learning Center, which included clearing out most of the existing structure within the building, the trusses which held the roof up were kept in place. (PARKER, Philip and Hume, Stephen, 2008). Inside the new library, there is also a small non loading structure that is made of large Douglas Fir timbers that were made in 1900; from the same batch that was used to build the library. They were shipped to South Africa for use in the construction of an orphanage. When the building was renovated in 1980, the timbers were removed and put into storage. When the Main Library was upgraded to the I. K. Barber Learning Center, the timbers were sought out and bought so they could be showcased. Even through all the use and transportation, the timbers were in excellent shape.

Timbers and beams made of engineered wood beams could be ideal for use for deconstructive designs. Since they are large and robust, they can easily be joined together with mechanical fasteners. This will allow them to be taken apart easily with minimal damage to the pieces.

Log buildings are designs that are in the area of structures that could be ideal for deconstructive purposes. Since whole logs are used to create the building, the material is large and robust, and is often joined using simple techniques. If taken apart, the logs can easily be used in other applications; this can be in the form of transferring it into the construction of a new log home, or being machined into another form of wood product. The only downside to log buildings is the size limitation of the building, leaving to be used primarily for homes. Log construction would be inadequate in meeting the needs for large commercial and industrial projects that may require very large spaces, or several stories.
**Discussion**

The average service life for a building in North America ranges from 76 to 100 years, depending on the construction method and use (O’CONNOR, Jennifer, 2004). Commercial buildings were found to have the shortest service lives, ranging from 26 to 50 years. For buildings to be designed for efficient deconstruction, a recommend service life should be suggested. Buildings can last a long time if properly taken care of. Many home owners grow attached to their homes and like keep them as they are. If the advantages of deconstruction can be communicated and designs become widespread, this could alter perceptions. For example, if prefabricated homes using efficient deconstructive methods become mainstream, than owners of builders may decide to take advantage of the flexibility and opt for more renovations or even quicker replacement of buildings since the process is less time consuming.

This gives rise to the question of how taking deconstruction into consideration could affect the types of buildings created. With the increasing population density across the world, there may be a shift, especially in terms of housing. In North America, single family housing is the norm, but in the future, row housing, duplexes, or town houses could become much more common. This would fit in with prefabricated home manufacturers, as there would most likely be a lot of common designs that they could manufacture, allowing for greater increases in economies of scale.

**Conclusion**

As the shift continues toward green products and designs, wood should see greater usage in larger-scale projects instead of being solely used for house construction. Concrete and steel will remain in use since they are needed for construction of very large structures. Wood cannot completely overtake these two materials, but it can certainly be used to complement the structures.

Deconstruction already exists in the world today and has been in use for centuries, but using innovative designs, buildings can be created to make the process more efficient and favorable. The advantages of deconstruction must be further communicated so that it is considered as a viable option when the life cycle of a building comes to an end. Should the concepts of efficient deconstruction be adopted in the future, this could alter the way that people view buildings, as they not only provide areas to live and work, but are also places that are aiding in creating a greener and more sustainable culture.
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