WOOD WASTE MINIMIZATION PRACTICES IN RESIDENTIAL CONSTRUCTION

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The construction industry in the United States continues to generate a large amount of waste that is disposed in landfills. A large component of the waste stream emanating from construction projects is composed of wood and wood products. Addressing the problem of minimizing wood waste from construction has large economic and environmental implications. This research investigates industry best practices utilized to minimize wood waste generated by the construction of single family and multi-family housing to determine if these practices can be applied to the industry as a whole. Qualitative research was conducted using semi-structured interviews of construction professionals experienced in wood frame construction. In addition, quantitative research was conducted based on data from the United States Environmental Protection Agency and the United States Census Bureau to quantify the amount of waste wood generated by the construction of single family and multi-family housing. The research indicates that design, schedule constraints and inexperienced labour all contribute to the generation of waste wood. The most effective wood waste minimization practices include segregation and reuse, accurate quantity estimation, and deliveries matching construction sequence. Matching the most effective waste minimizing practices to the causes of waste generation in an economically sustainable manner is the key to wood waste reduction.

Keywords: construction waste, family housing, waste reduction, wood waste

INTRODUCTION

Historically, construction waste from commercial, institutional, or residential projects account for a large fraction of waste generated in the United States, with wood waste being the second largest component of construction waste behind concrete products (US EPA, 2019). Because of the scale of the construction industry, designing and constructing projects that generate less waste can make a significant difference both economically and environmentally. To minimize the amount of waste generated on residential construction sites, environmentalists, contractors, and designers continue to look for more ways to manage the amount of construction waste generated and to minimize the unnecessary amount of material needed for light-frame wood construction. However, construction and demolition waste continue to be an ongoing issue. According to the latest report published in 2019 by the United States Environmental Protection Agency (US EPA), "569 million tons of construction debris were generated in the United States in 2017, which is more than twice the amount of generated municipal solid waste" (US EPA, 2019). Of this amount, 40.2 million tons consisted of wood products.

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Formulating ways to minimize wood waste on construction projects requires an examination of the root causes that result in the generation of wood waste as well as the reason waste generators fail to take the necessary steps to eliminate waste. The research will investigate methods currently practiced in residential construction that minimize waste generation and maximize recycling wood waste.

LITERATURE REVIEW

Studies conducted by EPA concluded an increase of Construction and Demolition (C&D) waste generated over the years. An estimated 569 million tons of waste were generated in 2017, the latest data publicly published by EPA, which include buildings, roads, bridges, and other structures in the United States. Of that, about 7% or 40 million tons included wood construction and demolition material waste. Narrowing it down to building related only, in year 1996, the United States produced an estimated 136 million tons of C&D waste, and in year 2017, 184.2 million tons of C&D building related waste were generated (EPA.gov, 2019). Comparing years 1996 and 2017, amounts to an approximate 35.4 percent increase in C&D building related waste in the United States. There are several potential factors and challenges that may be contributing to this continued increase. Waste minimizing opportunities that exist for wood in residential and multi-family structures are investigated in this research. Many states, government agencies and organizations define C&D waste very similarly and sometimes may refer to it as Construction Demolition Waste (CDW). In this study, C&D wood waste is defined as wood framing debris material generated during construction, renovation, or demolition of a structure. This is material that is discarded and disposed and may have been originally intended to be used as part of the construction of a building but was damaged, defected or cut down to scrap material or is a result of material removed during the demolition of a structure. C&D wood can include dimensional lumber, plywood, treated wood, manufactured wood, and engineered wood products. In addition to wood, material considered in this research, other materials that fall under C&D may include concrete, asphalt, metals, gypsum board, roofing materials and specific land clearing debris.

Construction Wood Waste Impact

There are numerous reasons to reduce wood waste in construction but perhaps the most important is the environmental impact which includes the impact of the natural forest structure, carbon balance and the limited space that remains in the 3000 active landfills in the United States. By reducing and recycling construction materials, landfill space can be conserved and, therefore, reduce the number of new landfills needed in future. In addition, using recovered wood and fibres in place of removing fresh forest biomass reuses biomass which has already been removed from the natural cycle of forest growth structure (Gustavsson *et al.,* 2006). The continued use of new wood material or fresh biomass increases wood material production, reduces natural forests and contributes to global warming. According to a study conducted by Marzouk and Azab (2014), in addition to the conventional construction project objectives of cost, schedule, quality and safety, priority should be given to the problems impacting the environment which include contamination from landfills that lead to serious negative health effects, and the increase in greenhouse gases resulting from the transportation of waste and the processing of new materials.

In addition to the environmental impact, wood waste also effects the profit margins of construction companies. Simply put, wood waste is a commodity wasted. It is the material of choice for residential and multi-family construction in the United States

due the relatively low cost of material and installation. A light-frame wood building can be constructed much faster and cheaper as compared to buildings made of other construction materials. However, while it tends to be less costly than other structural materials, the amount of waste or scrap materials not used as part of the construction can build up and become costly (Multi-Story Wood Construction, 2014). The cost includes not only the material cost of the 3.3 million tons of wood construction waste but also includes the cost of landfill disposal.

Causes of Construction Wood Waste

According to Polat, *et al. (*2017), there are 34 contributors or causes of construction waste ranging from design issues, procurement, material handling, storage, construction site staff activities, project management decisions and external influences. Of these 34 contributors, the three causes that result in the most material waste are inexperienced workers, design and construction errors, and the use of conventional design methods.

A large amount of wood waste in construction can be attributed to the activities of workers and staff with insufficient training and limited experience. These activities can include quantity take-offs for wood material procurement or field crew handling the cutting and framing of the lumber material. According to Jing Zhang *et al. (*2005) in "Waste-Based Management in Residential Construction", "…poor quality requires time for fixing or redoing the "product" as well as wasted time and in materials". This can include waste from cutting material incorrectly or errors resulting from an inaccurate quantity take-off.

Design errors and last-minute changes by the architect or changes due to installation errors by the contractor can result in rework of material already installed or material that has already been special ordered, pre-cut or prefabricated. These errors can result in both time, material, and money wasted. These errors can be caused by poor design details that are difficult to construct in the field, last minute changes by the architect or client, design details that call for materials to be cut in non-standard sizes or shapes that result in scrap materials, mistakes during the construction process, lack of work experience by either designer or field staff and, lack of coordination between trades. (Luangcharoenrat *et al.,* 2019).

The traditional or platform design method used in most of today's residential and multi-family construction is also considered a contributing factor to wood waste. The traditional framing method is considered to be a resource intensive form of framing with a high life cycle energy consumption (McGinnis and Fumo, 2018). While moving away from the conventional methods may not eliminate the amount of scrap wood material generated in the field, it will reduce the amount of wood needed to build when compared to newer methods of framing.

Construction Wood Waste Minimisation Methods

The "three R's" (Reuse, Reduce and Recycle) are the primary ways to minimize wood waste on construction projects. One of the first activities that takes place before construction of a new residential housing development or multi-family building is the site clearing which can include the removal of existing structures located on the project site. Wood waste generated during the demolition phase or from material left after construction can produce either valuable waste or valueless waste. Valuable waste can be reused directly as construction material for another project or regenerated to be used in another form such as particle board, wood mulch, and wood

compost. The volume of valueless waste is disposed of in landfills (Zhang *et al.,* 2005). In place of choosing to demolish a building, some buildings may qualify to be deconstructed (US EPA, 2019). Deconstruction is the removal of a structure by dismantling it piece by piece in place of quickly knocking it down. To reduce the cost of deconstruction, which tends to be much greater than the cost of a whole-house demolishment, the structure can instead be "soft stripped" or go through a process of selective deconstruction which includes removal of high-value materials or fixtures prior to demolishment. This method minimizes the need for processing new wood material and minimizes the amount of wood that ends up in a landfill. However, depending on the project structural specifications or local requirements, using reclaimed materials may not be an option.

Source reduction focuses on preventing the material from becoming waste at the source. Source reduction can be accomplished in the design phase or in the field during construction. Some examples presented in several studies conducted include lean framing methods such as Advance Wood Framing, pre-cutting mathematical algorithms and material optimization methods that can be practiced in the field. Advance Framing or Optimum Valued Engineered Framing was developed in the early 70's and has slowly begun to appear in building designs. This method reduces the amount of lumber by 5 to 10 percent without compromising the building's structural integrity (McGinnis and Fumo, 2018). As presented by Manrique *et al. (*2011), who created an optimization model for residential wood framing using mathematical algorithms and optimization techniques, using the most appropriate method of planned cutting can reduce wood waste by 96%.

Recycling construction wood waste may be an option provided the waste material has not been contaminated. Waste wood material can be processed and regenerated in the form of wood mulch, particle board, or other engineered products such as recycled wood decking. These products are made entirely from recycled wood and plastic materials. The most common method of managing generated wood waste tends to include the use of dumpsters delivered to the project site. Recycling of wood products can be facilitated in the field by using a separate dumpster for wood products.

Many of the studies presented in the literature review described causes of wood waste and proven methods in reducing the level of waste. Some of these studies also conducted similar surveys ranking the causes of construction waste based on importance according to subjective views of various experienced construction professionals. Some include site observations, but few clarified what is and what is not actually being practiced, and the reasoning behind these decisions. This research is focused on determining the methods practiced to reduce wood waste in construction, the reason various reduction practices are not being used, and the challenges associated with the reduction of wood waste.

METHODOLOGY

Research Philosophy and Approach

The literature review revealed multiple ways to minimize wood waste. However, not every builder, framer, or contractor will or is able to adopt every single method. For those that are adopted, they are unlikely to be managed exactly the same by all companies. The wood minimization outcome or lack thereof will likely vary due to individual interests, challenges, feasibility, efforts, core values, etc. For that reason, this research relied on humanistic qualitative data. Qualitative methods such as those

provided through semi-structured interviews or observations provide a ‘deeper' understanding of social phenomena than what would be gained from purely quantitative methods (Silverman, 2011).

The research data was collected through a mixed method approach with (1) qualitative data through semi-structured interviews conducted on personnel experienced in wood frame construction and (2) quantitative data consisting of secondary sources provided by government agencies. The quantitative data was limited to government independent agency studies published for public use. This mixed method approach was selected to help evaluate the researchers’ interview findings with existing data related to residential construction.

Research Data Collection and Analysis

The collection of qualitative data was gathered though semi-structured interviews conducted either in person or over the phone. A total of eight construction professionals were interviewed including project managers, framing quality controls staff, site superintendents and company presidents from both general and framing contractors, based in different areas in the United States.

Each interview included the same set of questions concentrating on the challenges and methods of wood waste minimization. The questions were formulated to provide the interviewees multiple opportunities to share how they practice wood waste minimization out in the field or in the office. Because some of the wood waste reduction methods or strategies are relatively new methods, questions were also formulated to determine if the respondents were familiar with practices that may include advanced framing or wood cutting optimization software. Other questions were formulated to gather perceptions of the amount of waste generated and how they prioritize the issue of wood waste.

The interviews were voice recorded and later transcribed using ‘Otter Voice Meeting’ software. The transcribed content collected by each interview was read by the researcher to better capture the essence of the context and to correct voice transcription errors. It was further analysed using computer assisted qualitative data analysis software (QDA Software), ATLAS.ti, to capture non-numerical key words and patterns. To prevent associating the context to a specific interviewed candidate and to maintain their privacy, the candidate’s name and company name was not included in the analysis.

The quantitative data in this research was collected from reports and studies published by independent government agencies such as The United States Environmental Protection Agency (US EPA) and the United States Census Bureau which is the nation's leading provider of data for the United States people and economy. The goal was to find a relationship between the data as it relates to the amount of residential and multi-family construction and the construction wood waste generated. Thematic analysis techniques were used to evaluate the transcribed data.

RESULTS AND ANALYSIS

The following are the interview questions and a summary of the responses from the respondents:

Q1, Based on your experience in residential and multi-family construction, which lumber category produces the most waste during construction and which the least?

This specific question was asked to determine which wood material may potentially be contributing the most to wood waste on construction projects in order to investigate the causes and methods practiced in the field. Between all candidates interviewed, the three wood materials categories that produce the most waste were sheathing materials, dimensional lumber, and bracing material. Thematic analysis of responses resulted in the creation of figures depicting summary of the data, as shown in Fig 1. Due to space limitations for this paper, only one figure is shown to demonstrate the analytical processes used in developing conclusions for the study.

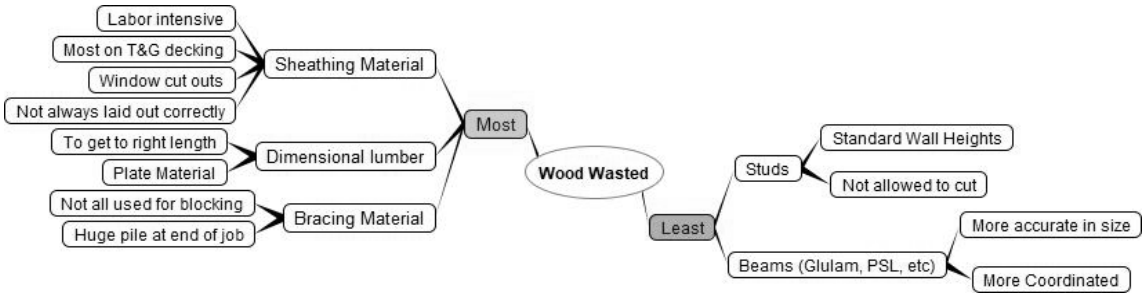

Fig 1: Materials producing most construction waste.

Q2, How does labour cost impact your company's decision to practice wood waste minimization?

5 of the 8 respondents stated that the cost of labour negatively impacts their decision to recycle. Another respondent stated they only consider recycling when disposal costs in dumpsters become prohibitive. Only one respondent mentioned that they always recycle. Regardless of the cost of labour, some explained it is a standard for their company to reduce wood material of a certain length from making its way to the dumpster through methods such as using the waste as wall blocking.

Q3, When providing a turnkey framing installation, as opposed to providing labour only, what type of waste minimization methods are practiced?

The main difference between a turnkey framed project and one that is not, could be that is rests on the ownership of the materials during construction. All respondents indicated there is little or no accountability when the framer is not required to supply material. The result is an increase in waste because the framer has no economic incentive to conserve material. Therefore, the framing method that rendered characteristics with greater challenges in material management and contributes more to generated waste is the non-turnkey framing approach. The obvious solution to this problem is in material procurement for the framing contractor's scope of work.

Q4, Based on your experience, from lumber purchased for a project, what percent normally ends up as waste and how does that change by project type?

There was a wide range answers for this question. For projects that did not include turnkey framing, the waste was estimated by the respondents to be 30%. For turnkey framing jobs the average was estimated to be 10-12% provided crews were well trained. However, the consensus of the respondents was that wood waste can vary widely based not only by project size and crew training but also by project design and geometry.

Q5, Can you describe how best to minimize waste of construction materials?

The answers to this question revealed the major factors contributing to wood waste. By far the most common answer was that the specifics of project design was the factor

most effecting wood waste. This was followed closely by time and schedule, labor vs material costs and lack of qualifications/skills/training of framing crews.

Q6, What are some material management techniques you use out on the construction site that helps reduce the number of scrap material created after wood members are cut to size?

All respondents stated that they used scrap wood as blocking in walls. Five of the 8 respondents stated that by having material delivered in bundles that corresponded to the wall section or work section minimizes waste. This is a material management approach in which the lumber material is not delivered all at once, but deliveries are scheduled to match the construction sequence. This method reduces errors in the field by limiting the amount of material available to the framers to draw from at any one time. Five of 8 respondents also responded that good estimating resulted in less waste. Tighter estimating resulted in less material being purchased that will end up as waste to be disposed at the end of the project.

Q7, Are you familiar with a framing technique called Advance Framing or Optimum Value Engineering framing techniques?

These optimized framing methods have been available in some form since the 1960's. However, only one respondent mentioned using advanced framing techniques once in the past. Another stated that the techniques were once presented as part of a value engineering package to help reduce cost, but the non-traditional framing methods were not accepted and as a result not implemented.

Q8, Do you use any software to help cut lumber and to minimize waste?

Unfortunately, among the eight respondents, only one explained how he uses AutoCAD to generate his layouts and lumber list for pre-cutting at the lumberyard. As he explained, using this method allows him to hand a "beautiful" package for his foreman and crew to follow during the construction phase.

Q9, Project metrics normally give priority to cost, schedule, quality and safety. What are your thoughts about the idea of including minimization of lumber waste on this priority list?

The consensus of the respondents was that while wood waste minimization is a good idea, the costs associated with it are prohibitive. They viewed the concept as a virtue, not a business practice.

The perception of the majority of the respondents were that the increase in wood waste corresponded to the increase in construction. However, the quantitative research does not support this conclusion. Data from the United States Census Bureau indicates that residential construction remained steady for the years of 2013-2017. Likewise, data from the US EPA (2015, 2016, 2018, and 2019) indicates that wood waste generated by construction also remained steady. It should be noted that these were the latest years from which complete data was available. It would be interesting to ask these same questions to respondents when the cost of lumber increases.

CONCLUSIONS

Based on the qualitative data gathered, there are numerous methods that are available that can help reduce construction wood waste. These methods include recycling, reuse of wood from demolished structures advanced framing techniques, more intense material management and more accurate material estimating, as shown in Fig 2.

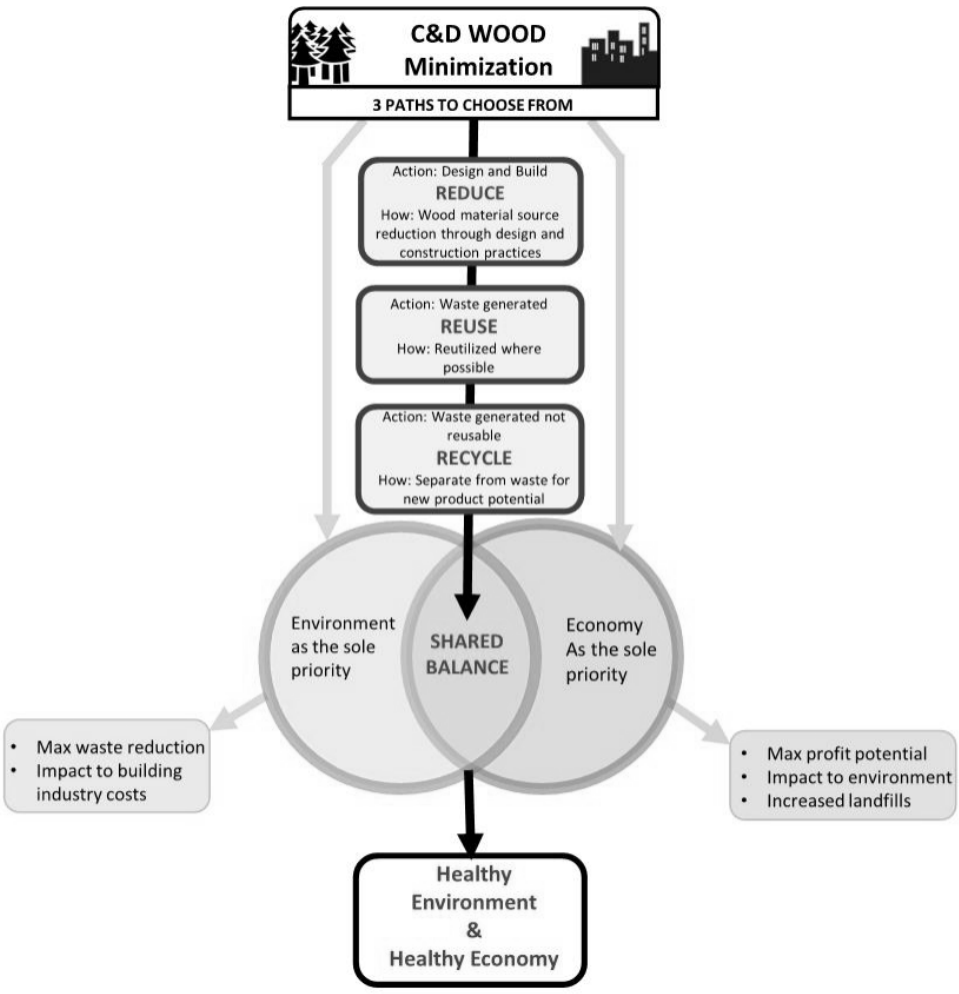

Fig 2: Research conclusions on ways to minimize wood waste

However, all these methods include increased cost and/or require contractors to shift the paradigm as to how they manage their operations. In the case of recycling, the perception is that the cost of implementing an effective recycling program costs more that the monetary benefit realized by contractors. Using scrap lumber as blocking and bracing in walls is an effective way to minimize waste. The practice is currently utilized by most of the industry professionals that responded to the survey. However, this accounts for the reduction of only a fraction of the wood waste generated on most projects. In order for a recycling program to be effective, all wood waste must be segregated in dedicated dumpsters on site and taken to a recycling centre for reuse. While this process seems simple, there are still labour costs involved in order to segregate wood waste and additional costs for dumpster fees. The use of advanced framing techniques and framing software are two areas that show promise to minimizing wood waste. However, industry has been slow to adopt these practices because of the significant retraining of both designers and wood crews that would be required to implement these practices. This problem is exacerbated by the existing shortage of skilled labour and an overall resistance to change. Intensive material management practices such as better estimating and having materials delivered in sections show promise and are currently being used by the majority of the construction professions interviewed. However, these practices alone are insufficient to eliminate wood waste on construction projects as evidenced by the large amount of wood waste still being generated on projects.

It is realized that there are costs associated to many of these methods and, as a result, they can be perceived as impractical from an economic standpoint. However, not practicing these waste reducing methods is damaging to both the environment and economy. In the long term, a healthy economy relies on what a healthy environment. Making significant reductions in wood waste will require a holistic approach from both government entities and the construction industry. It is unrealistic to think that the construction industry will implement all of the waste minimization practices on its own. If that were the case, the industry would have already done so. The same is true for reducing construction waste in general. Companies who attempt to implement all of the wood waste reduction strategies would place themselves at an economic disadvantage when compared to their competitors. Therefore, companies who make a concerted to reduce wood waste on their projects are unable to do so from an economic standpoint.

Government at the national, state and local level must take a leading role in solving the problem by implementing rules and regulations that require the reduction of wood waste on construction sites through better designs and project site practices. Requiring all construction contractors to abide the same set of rules will eliminate any competitive disadvantages for companies that are environmentally responsible. Also, as these practices become standardized throughout the industry, innovation in the private sector will minimize costs. In addition to government and the construction industry, education also has a role to play in solving this problem. Institutions who train and teach craftsmen and the next generation of construction professionals have a responsibility to include the latest technology such as advanced framing, improved framing software, and best practices for waste reduction in their curricula.

In the interim, the industry should consider focusing on methods that can support the minimisation of waste while not impacting the project budget. Special consideration should be focused on educating all workers and subcontractors on job site waste management methods that minimize waste going to the landfill.

Future research should focus on expanding qualitative input from a larger pool of industry professionals to address possible gaps in methods to minimize wood waste on construction sites. The research can also be expanded to include all forms of construction waste.

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