Considerable Factors in Determining the Sustainability Benefits of the Demolition of an Existing Structure for a New Build and of the Renovation of an Existing Structure

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The decision between whether to demolish or renovate a building comes down to which one will satisfy the owner’s needs and objectives while remaining within budget. This project will identify factors in determining sustainability benefits between a completely new construction project that demolishes the existing structure prior to rebuilding and a renovation project that reuses some or all of the existing structure. Research on construction data, interviews conducted with leading industry members, and journals that reported on both these strategies are presented. This project will examine considerations that reduce the demolition’s negative impact on the environment and improve the overall lifecycle of the building, which includes the use of a construction and demolition waste plant to turn that waste into recycled aggregates. The new construction after demolition allows for the installation of modern energy systems that use sustainable and efficient building designs and lead to a long-lasting building lifecycle. Demolition provides higher cost savings and sustainability benefits to the building and its operations due to the ability to reduce the negative impacts of waste by recycling and being equipped with modern technology to improve energy savings through its design and its mechanical, electrical, and plumbing systems. A design that foresees future upgrades or renovations will improve the lifecycle of a building, leading to greater cost reduction and sustainability benefits by making future improvements more feasible and cost-effective.

Key Words: Demolition, Renovation, Construction, Building Lifecycle, Sustainability.

Introduction

Building standards and construction methods have significantly changed and adapted to modern technology and knowledge, which is important to meet increasing government regulations and energy efficiency standards. In the United States in 2022, the Biden Administration approved a novel federal building performance standard which requires any building space owned by the federal government to cut energy use by 30% (White House, 2022). The Administration has also launched the National Building Performance Standards coalition, a group of over 30 state and local governments that have committed to reducing the emissions of existing buildings. Residential and commercial buildings in the United States are directly responsible for 35% of carbon emissions and over $190 billion in energy costs (Whitehouse, 2022). Government entities in the United States are trying to reduce the environmental damage caused by the construction industry starting with Denver’s local government making new buildings codes that ban natural gas furnaces and water heaters in new commercial construction from being permitted in 2027 (Weiser, 2023).
Building owners will fund construction projects, so having the building’s systems up to code in anticipation of regulation changes is a major consideration for them. The owner does not want to change out the entire energy system due to the associated high costs and extra construction and demolition waste (CDW) produced. That is why it is important to determine if the energy systems are up-to-date or can easily adapt to become code-compliant if codes change in the future. This will help limit any long-term costs associated with maintaining the building and ensuring it is up to code for the lift of the building. Another reason owners want to design and build more environmentally friendly structures is because of the cost savings and other company benefits from decreased operational costs, increased employee productivity, and limitation of the overall impact on climate change in the long term (Jagarajan, 2017). Factors that can deter a potential contractor from partaking in a renovation project include issues with the existing building’s poor health and safety, layout inefficiencies, commercial risk, and uncertainties (Bullen 2010).

The decision to demolish a building is based on the value of the existing building and the potential hardships involved in retrofitting the building. Redesigning and modifying the existing building promotes sustainability without having to build an entirely new building from scratch. Renovations, retrofitting, or adaptive reuse projects all involve fixing and adding value to an existing structure without fully demolishing the structure. Adaptive reuse is when an existing building is fixed and renovated to accommodate a different type of business or company than its former owners and occupants (Richards, 2022). An owner must analyze if the building can be fully optimized to provide financial, environmental, and social benefits for the building’s overall performance.

Alternatively, new modern buildings are equipped with energy systems that reduce the energy usage of the building through both a new energy-efficient design/layout and new technology that makes the energy systems more efficient. Energy systems in the building can make the building invaluable if they are out of date and hard to replace.

Investigating this topic is important since a significant number of buildings in the United States are reaching the end of their lifecycles which would require significant costs and energy to renovate. Reflecting the Biden administration’s implementation of new sustainability standards for buildings within the last few years, more building owners are prioritizing sustainability as an objective. Not only are there tax benefits related to energy-efficiency upgrades, but multiple studies found that buildings with above-average energy performance yield higher occupancy and higher rent or sale prices on the property (Boston Green Ribbon Commission, 2012). Success in sustainability goals will ultimately lower operational costs for the building owners in the long term. Choosing between a complete demolition and rebuild or a renovation or adaptive reuse is not easy – there are numerous factors for owners to consider. This research project aims to identify considerable factors in determining the sustainability benefits of demolition versus renovation.

**Literature Review**

**Waste Considerations**

CDW refers to the solid waste generated in construction projects. The United States generates over 600 million tons of CDW yearly with 75% of that being recycled or reused (Qiao, 2022). Waste landfills use up large amounts of land and they can bring harm to the surrounding environment through hazardous pollution. Renovation is a better method of reducing waste because it utilizes the
existing structure and its major components to improve the building without extensive change (Bullen, 2010).

Instead of renovation, owners may demolish the old building and replace it with a completely new building on the property. This allows for the design to directly benefit the building’s overall performance since they can start a new build without any existing components limiting the new building’s design and performance. Although the building’s performance will benefit in the long term, there is the issue of the negative environmental impact of the extraction of raw materials that will be used in the new building. One of the issues the construction industry has faced over the past several years revolves around materials acquisition (Beiser, 2022). Waste is a huge concern in terms of sustainability because of the huge amounts of environmental damage associated with mining and excavating raw natural resources to replace non-recycled CDW materials discarded into landfill. With the onset of the COVID-19 pandemic and global supply chain issues, lead times for sourcing materials have increased dramatically. This shortage is further bolstered by the scarcity of materials commonly used in construction. For example, sand stands as one of the world’s most consumed resources with over 50 billion tons of aggregate used annually (Beiser, 2022). This represents a larger issue because sand is a vital ingredient in the recipe for concrete and therefore shortages of sand represent a shortage in a material that is the very foundation of construction itself. When it comes to demolition, material shortages can be lessened or prevented altogether through the recycling of construction and demolition waste. The construction industry is responsible for consuming 50% of the world’s extracted resources. In the United States, since 75% of all CDW is recycled and turned back into aggregate, it can help alleviate material shortages and the pilfering of the natural environment (Qiao, 2022). When renovating, less waste is created, decreasing the need to recycle materials in the first place (EPA).

Lifecycle Considerations

Understanding the lifecycle of a building can help achieve long-term energy and cost benefits. The lifecycle is crucial for analyzing the costs and environmental impact of a building over its entire life, beginning from the production of raw materials to the demolition of the building. The lifecycle of a building is divided into four distinct stages: (1) the production stage, (2) the construction stage, (3) the use stage, and (4) the end-of-life stage. The use stage is analyzed by monitoring the environmental impact caused by the users, energy and water use, and waste generation (TU Delft, 2020). The building service life data from the use stage are used to decide the type of activities required to maintain, repair, and replace the building materials and systems (Rauf, 2015). When the building is older and its physical components cannot be easily repaired or updated, the building is at the end-of-life stage and demolition would be more efficient in terms of costs and sustainability (TU Delft, 2020). The average year for structures built in the United States is 1979 (United States Census Bureau, 2022). About one third of all commercial buildings were built before 1970 and before the 1970’s oil embargo, meaning that energy costs and internal systems were significantly different and less efficient (Baker, 2019).

Another study found that the average U.S. commercial building lifespan of a commercial building ranges from 50 to 60 years (Feldstein, 2022). Commercial buildings include but are not limited to, stores, offices, schools, religious institutes, gyms, libraries, warehouses, hospitals, and other places where commercial activities take place (Michigan, 2022). A newly built building will have a lifecycle of 100 years or more, and a heightened focus on its design to improve its long-term sustainability to allow for future renovations and upgrades to be completed in an easy and efficient manner to allow for that expended lifecycle (Marsh, 2017). It will also reduce the costs associated with facility ownership and operating costs throughout its long-lasting lifecycle.
Growing Trends

Cost research demonstrates that it is only financially beneficial to demolish an existing structure if it is in such a poor condition that expensive non-energy-related fixes would have to be completed to be up to the owner’s standard. There is a growing trend of construction projects dealing with old and outdated buildings and increased discussion on how to deal with them. As shown in Figure 1, companies are putting their money into existing structures for renovations and projects that utilize the existing building (Richards, 2022). The major reason behind this trend is that owners want the positive benefits that include reducing the carbon emissions associated with extracting raw materials for a whole new building. Owners want a renovation project to simply update the interiors and change the function of the building. The need to update energy systems makes up a small percentage of reasons noted for choosing a renovation (5.4%) because it costs more to engage in a green retrofit (Mortice, 2022).

It is important to determine the construction method as early as possible. Once demolition or renovation is chosen it is not possible to change the type of project unless there is a special and rare situation. Hence, it is recommended that an owner, when considering a renovation, makes a proper pre-inspection and works together with the design team and engineer at the preliminary stages to see what major costs would offset the benefits of utilizing the existing building. A renovation could benefit the project a lot in the short term with their provisional patch-up job, but it will limit any long-term benefits that could have been attained when there are no major energy system replacements or green building components to replace the old ones. Therefore, the design team must identify all potential expected problems and properly analyze the risks for both methods, to reduce costs and ensure the use of the best long-term sustainable building strategy for the project.

Figure 1. Example of Industry Trends
Source: Historical Data from AIA Firm Survey Reports, 2021 Estimate from April 2022 Work-on-the-Boards survey (Richards, 2022).

Sustainable Methods of CDW and RA

When an owner approaches a contractor and/or designer with a project that places an emphasis on sustainability, demolition and renovation offer two completely different paths to achieving a sustainable project that meets all of the owner’s expectations. One of the most common sustainability
practices in construction revolves around taking discarded concrete, concrete prefabricated components, and concrete subgrades and crushing said concrete into aggregate to form what is called recycled aggregate (RA). Research lists methods and their respective benefits that assist recycled aggregates to attain better environmental performance when mixed into concrete (Xing, 2022). It is important to understand the key impact materials of adhesive glue and cement when used in the recycling CDW plant’s processes to create quality concrete, masonry bricks, and other materials. Using RA, one can avoid using freshly ground aggregate mined from a quarry that potentially both pollutes and destroys the environment. By recycling waste material, one reduces the need for newer materials, thus protecting the natural landscape from industrial destruction. This in turn can create cost savings, reduces energy consumption, conserves energy, and reduces waste production associated with demolition (Silva, 2017). This allows for reducing the negative impacts that demolitions cause in the demolition stage of the project with CDW. Recycling aggregates is an important method to promote sustainability in a demolition project, but this depends on whether the materials can be recycled through both an efficient and environmentally friendly system (Silva, 2017).

Although demolition is seen as a more wasteful and environmentally unfriendly process these issues can be offset by recycling construction demolition waste to create recycled aggregates and then recycled concrete aggregate (Xing, 2022). Recycling discarded concrete, discarded prefabricated components, and concrete subgrades to form RAs is a common method of sustainability when demolishing concrete structures. The RA can substitute natural aggregates (NA) to reduce energy consumption, conserve resources, achieve cost savings, and diminish waste production. RA has a reduced compressive strength compared to NA because of the weak bond between the old materials together but can be resolved by using adhesive glue (or other additives) or cement slurries that will improve their performance strength (Qiao, 2022). Cement and adhesive glue involved in the RA manufacturing process contribute to environmental pollution, high costs, and carbon emissions. This negative environmental impact is nothing in comparison to the extraction and crushing of NAs because the process produces large amounts of carbon emissions and uses up many depleting raw materials like sand (Qiao, 2022). The use of recycled aggregates from construction & demolition waste can reduce carbon emissions by 15.6 to 20.4 kg per functional unit of masonry bricks and permeable bricks (Qiao, 2022). This shows that CDW can turn into recycled aggregate while reducing their project’s carbon footprint and cost.

Having access to an existing CDW recycling plant is very important when considering a large demolition job. The operation and transport-related impacts associated with CDW plant processes are very small compared to using natural aggregates and other raw materials. The CDW plant process generates 90% less CO2 emissions and requires 85% less energy compared to the operation and transportation of natural aggregates (Silva, 2017). If a CDW plant poorly monitors the washing of the CDW when it is delivered it can lead to groundwater pollution. The manufacturing plant will also include the typical factory facility risks of dust production, noise and vibrations, gas emissions, and pollution caused by internal combustion engines and lubricants (Silva, 2017). A CDW plant must adapt and constantly enforce environmental protection of the local area and require a management control plan to limit any alternate non-environmentally safe practices and pollution discharges into the local ecosystem. With these RAs and other recycled items, there will be an overall more significant sustainability factor and improved efficiency in their construction application.
Methodology

A qualitative methodology was chosen for the study using structured interviews with construction industry experts and experienced workers involved in projects that considered either construction method. Questions focused on the positive and negative aspects of their construction methods through resource consumption, measuring the long-term sustainability, and waste produced. Research participants were limited to contractors working on commercial building projects in an urban setting. Participants were asked a series of questions to learn their company’s involvement in renovations and/or demolition projects, their individual experience and position they held, if they work on commercial projects or other project types, the typical project location, and their company size based on typical project cost. The more in-depth and informative questions asked were as follows:

- What factors have influenced your company to perform a demolition rather than a renovation or vice versa?
- Do time constraints influence the company's decision to choose either a demo or renovation approach on a project?
- Do owners have a heavy influence on either demolition or renovation occurring? Or does the construction company influence that more?

These questions were used to understand their experiences in the industry currently and to see if the typical major considerations in construction, the owner’s wants and timeline, will significantly influence one method over another. Interviews were conducted through phone calls, with recorded responses compared through charts made to organize the responses into relative categories. The responses from the structured interview questions were reviewed in comparison with the information learned from the other sources. This research paper utilized the data and statistics presented in journals and articles written by experts to verify and make connections with the information from interviews to enhance the findings. The other articles and databases used were for supplemental information to support the critical significance of this research and its relevance to the current world today and the industry.

Results and Analysis

Fifteen industry experts with over 265 years of combined experience in the construction industry were interviewed. The interview participants included superintendents, project managers, owners and owner’s reps, estimators, architects, and general contractors. To help narrow the focus, all of those interviewed work on both demolition and renovation projects in the commercial sector of the industry. The interviews were short with an average of about 20 minutes, with the responses recorded by copying and pasting the responses or by writing them down on scratch paper.

Reasons for Demolition

Multiple interviewees noted structural issues and asbestos (caused by poor annual maintenance), functional obsolescence (the building is no longer suitable for the intended use), and end-of-life cycle were reasons for demolition. The area being developed is the most common reason for demolition because the land value has increased, and the original building is no longer providing the highest level of value for that location. This is common in cities and downtown areas that were once lower-class neighborhoods and are now being gentrified because the existing buildings are at a point of functional obsolescence. An owner with over 25 years in the industry stated how buildings with outdated design features could be too costly to retrofit to meet the desired purpose.
According to the research, the reasons for choosing a demolition seem to match the data gathered from interviews. Demolitions are often selected over renovations despite adaptive reuse significantly reducing waste production and reducing the excavation of raw materials. A virtual design and construction engineer with over 20 years of experience noted that the first step is to do value engineering to see if preservation is economically feasible. Value engineering analyzes components and materials to lower the cost of goods and services with a tolerable loss of performance. Once performed, value engineering will influence a company’s choice to renovate or demolish a structure.

In an interview with an architect from Perth, Australia, they said “Generally old buildings particularly those from the 70s are just not equipped to deliver what is required in terms of natural light and have cramped conditions” (Bullen, 2010). The lifecycle of the average commercial building is nearing its end due to deterioration and the lack of functionality for the occupants’ modern needs.

**Reasons for Renovation**

All research participants agreed that a renovation project has the most potential to save costs. During the interviews when trying to discover the best construction considerations they discussed cost savings, time, and value engineering associated with the renovation as their main considerations. A superintendent with five years of experience in the commercial industry stated that budgets play a big role, and it is often less expensive to renovate an existing building rather than demolish it. He continued to discuss how lifespan or lifecycle is the biggest factor they consider. An adaptive reuse strategy is seen as preferable to demolition when the objectives of environmental sustainability and reduced energy consumption can be achieved. Renovations reduce the environmental and financial costs associated with bringing in natural aggregates and large amounts of other raw materials. Using existing infrastructure helps to avoid using unnecessary materials by utilizing the project site’s existing roads, powerlines, water supplies, and structure.

When asked if time factored into the decision between choosing a renovation or a demolition approach, 80% of those interviewed said “no” or mentioned how finances and budget is the bigger consideration as written (see Figure 2). Even before the question was asked, cost consideration was the most frequent answer for the first question of “What factors have influenced your company to perform a demolition rather than a renovation or vice versa?” In one interview with an industry member with 30 years of experience being an estimator, planner, and project manager, they listed cost as the focus for the owner with the desired outcome second and time third. In the interviews, cost was emphasized as being the most important consideration followed by the structure’s existing condition as written (see Figure 3). The cost consideration would involve analyzing the existing building’s condition to see if there are concerns. It is important to consider the condition of the existing structures to determine if it has any significant structural problems or issues that would lead to higher costs while renovating.
In an interview with a superintendent, the biggest consideration is the existing structure on the property being developed. This included the condition of the physical components and lifespan of the building with the most important item to analyze is whether the existing building’s size and layout will meet the owner’s wants. When considering the strategy of adaptive reuse, it is important to analyze and examine the building’s layout and its capacity for change. A lot of owners and developers want more square feet and if an existing building limits an addition to expanding the overall square feet of the building, they are less likely to renovate it (EIA, 2012). As written (see Figure 4) there is a clear and steady trend of buildings being built having more square feet than in years past. This demand for more space is a major concern for the owner when deciding whether to try to retrofit their existing building to enhance the existing small area or to demolish it and start from scratch.
Figure 4. Display of Commercial Buildings’ Size Over the Last Century

Lifecyle Analysis of CDW Recycling

Cement has the largest environmental impact of all concrete components through its impact on climate change and oxidant emissions (Xing, 2022), increasing the need for lifecycle assessment. Analyzing the lifecycle assessment of natural aggregates and recycled aggregates includes monitoring the extra additional cement added to a mixture with RA. The solution to promoting sustainability in the process of RAs becoming concrete is through using the Equivalent Mortar Volume (EMV) method and Particle Packing Method (PPM) to reduce up to 21% of the overall environmental impact (Xing, 2022). The EMV method and PPM allow for the improvement of the recycled concrete aggregate’s strength but also minimize the amount of cement content required. The processes for recycling CDW into quality and productive construction materials have grown to be sustainable and will continue to advance in production methods as more companies utilize CDW recycling plants.

In the interview with a superintendent with five years of industry experience they said in their experience with CDW recycling, the job required the demolished material to be at least 70% recycled into recycled aggregate. This was a method by the owner to reduce the waste produced from demolishing over four buildings due to requirements for green building in the local jurisdiction. Such requirements are increasingly found in other local jurisdictions in order to further promote the recycling of CDW.

Conclusion

An extremely important task for the developer or owner when deciding whether to reuse or demolish an existing structure is figuring out the building’s usable life, desired goals of performance, and sustainability with energy savings. This brings in other factors that need consideration like the longevity of the building, methods to limit the need for maintenance and more renovations in the future, and the long-term sustainability throughout the building’s entire lifecycle.

As there are many ways to eliminate the negative impacts involved in a demolition, there are many positive and smart reasons for choosing to perform a demolition of an existing structure. Longer
lifecycles may be attained from the implementation of modern MEPs, materials, and design features. The negative environmental impact of the waste produced from the demolition and natural aggregates being extracted for the new materials can negatively impact the sustainability of the project in the short-term. This negative impact can be properly mitigated through the recycling of CDW on the project with a qualified CDW plant that utilizes the EMV method and PPM. A demolition project should be considered when the building cannot be renovated in an efficient manner. For example, to adapt to new building regulations, new energy systems and components, and changing owner/occupant needs. When a building is nearing the end of its estimated lifespan, performing renovations and repairs can be an unsustainable and costly strategy for managing the buildings.

The interviews conducted all put one thing first, which is coming within or under budget while meeting the owner’s considerations. After careful analysis of cost considerations, particularly with focus on recycled aggregates and waste, the owner determined that all their goals are most achievable through demolition. This was determined to be the most feasible option to get the owner what they want under budget. This is because of the benefits seen by the design team including the reduction of short-term environmental damage and the long-term benefits associated with having a new build. The benefit of having a new build is it allows for the focus on designing an environmentally sustainable building that has a longer lifecycle, saves on annual maintenance costs, and will better suit the occupants’ or owner’s desires (Jagarajan, 2017). However, renovations can work a step ahead of recycling by reusing the existing structure, thereby eliminating a large amount of waste produced. If the project demolishes the building and focuses its design plan to allow for easy future adaptive reuse, it will increase the overall sustainability factor of the building through its lifecycle.

Something that developers or owners often fail to do is to consider the lifecycle of the building and when it will need to undergo renovations again and how to decrease significant costs and the environmental impact of future renovations (TU Delft, 2020). There is a need to conduct more research on how to enhance the design of a building to allow for future system upgrades and renovations to be easily applied. A building’s lifecycle is significantly lower if its design fails to consider adapting to future modernizations, preparing for changing environmental and health regulations, and other significant changes in the future. The designer and owner can better prepare by analyzing future markets and new applicable technology to have the building designed to be able to easily adapt to new performance technologies and the changing needs of the owner and their occupants.

Often, based on a review of considerable factors determining sustainability benefits, the demolition method is the preferred strategy. The demolition of functionally obsolete older buildings and the building of a new structure using a sustainability strategy that mitigates negative short-term impacts and promotes the building’s longevity, will reduce the need to demolish it in the future and rebuild from scratch.
References


