TRANSFORMING THE 21ST CENTURY BUILT ENVIRONMENT: SELECTED STUDENT PAPERS IN DOMICOLOGY

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TABLE OF CONTENTS

INTRODUCTION

Dear Readers,

For several decades, many U.S. cities have experienced significant economic and population decline that has resulted in large amounts of structural abandonment. This abandonment has pervasive social, environmental, and economic consequences that disproportionately affect already struggling communities. In response to this problem, scholars at Michigan State University have focused their efforts on understanding the complex circumstances that have led to blight in order to create potential solutions. One such research area has focused on altering our perceptions of the built environment from the traditional linear model to a cyclical system. Domicology examines the continuum from the planning, design, and construction stages through to their end of use, abandonment, deconstruction and reuse.

The following primer was developed during a Spring 2021 special topics course in the School of Planning, Design & Construction at MSU entitled "Transforming the 21st Century Built Environment: Advancing the Science of Domicology." The course was co-taught by Dr. Rex LaMore, faculty in the
Urban and Regional Planning Program and Director of the MSU Center for Community and Economic Development as well as Dr. George Berghorn, faculty in the Construction Management Program. The primer seeks to expand on the existing knowledge surrounding structural abandonment, explore various implications of "design for deconstruction" principles, as well as assess the social, environmental, and political factors involved in adopting domicological practices. This primer and the primers developed in 2017, 2018, 2019, and 2020 can serve as introductory readings for those seeking to explore the various concepts of sustainable development and the life cycle of structures. The research contained in this primer is by no means a complete work; as the built environment is a multifaceted area of study, so too are its implications.

Contributors to the primer include selected students of the special topics course and represent several disciplines in the built environment including planning, construction, environmental sustainability, and other disciplines. Special thanks to our editor, Jhovonne Fernandez. For more information on the study of Domicology, we invite you to visit https://domicology.msu.edu/ . We also welcome external research on the subject of the life cycle of structures, which can be submitted via the website.

We hope that you find these selected writings stimulating and informative as we seek to transform our understanding of the built environment.

Yours for stronger communities,

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Utilizing Salvaged Materials in Tiny Homes

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I. Introduction

Increasing at a troublesome rate compared to previous years, the US Environmental Protection Agency found that building construction and demolition contributed 145 million tons of construction waste to the landfills in 2018 (EPA, 2021). Demolition waste is responsible for approximately 90% of this alarming statistic (Sustainable Management, 2020). As it stands, not all construction debris sees a new life, and this waste has a profound impact on peoples' physical health, communities, land use, ecosystems, resource economy, and Earth as a whole. The following report is an investigation into the feasibility of new materials, processes for building, and deconstruction that can be derived from salvaged materials. Research into the means and methods of utilizing salvage materials in tiny home construction is relevant to the field of Domicology. Tiny homes that utilize salvaged material are a way that students, the ideal candidates for tiny home residency post- university, can contribute to Domicological field in their daily lives. Furthermore, they are viable alternatives to traditional housing from a financial and well-being perspective. The budding industry of alternative living merits consideration as the focus for this investigation because of its capacity for utilizing salvaged materials while avoiding some disadvantages of salvage use in other cases. The lightweight nature of tiny homes, for example, mitigates concerns about salvage materials' structural integrity. This investigation covers the types of materials that can be used in tiny home construction. Followed by identifying the economically and socially viable case for tiny homes that will present the potential impact that they can have on redirecting construction waste from the landfills. Large scale use of tiny homes has the potential to remedy several contemporary dilemmas at once. After all, construction salvage is no different from waste in the landfill if it is not used.

II. Analysis of Tiny Homes

The organization Tiny Life is one of the many outlets providing readily accessible content for little to no cost that provides all the information one would want on how to construct a tiny home (Mitchell, 2020). The organizations website offers a detailed guide on the tools, materials, and processes required for every step and section of a tiny home. The materials required for tiny homes are very similar to those of standard homes, however tiny homes often do not have a traditional foundation and have light structural requirements due to their size. The frame carries a smaller load; less water and air require conditioning; less energy is needed to operate. This opens many possibilities, particularly for the use of salvaged material for structural elements that would typically be challenging to reuse without intensive refabricating. Tiny Life's guide breaks down tiny homes into thirteen components: a trailer, foundation (weather protection, anchoring to trailer, and decking), wall framing, sheathing, fenestration, roof framing, siding, trimming, heating, and cooling, plumbing, electricity, insulation, appliances, flooring, and interiors (2020). Of these categories, a wide selection of deconstructed material can be used and combined with new materials as needed. Use of salvaged material is highly flexible and can cater to what is available at the time and location of construction.

Aside from the trailer and foundational components, it is best to use lightweight materials such as wood products, steel, aluminum, vinyl, and foam board, and to avoid masonry, iron, stone, and concrete. In many cases, premium household products derived from salvaged material, such as countertops, decorative flooring, cabinetry, or furniture, can be financially justified by the proportionally small amount needed to finish construction of the home. Other structural materials need little to no preparation for reuse in a tiny home. Often, the wear and tear look of salvaged material for items such as doors, windows, shingles, and siding, contribute to the overall aesthetic that many tiny home clients are looking for.

Using salvaged material in construction is inherently an individualized experience as there is far less predictability in the resource economy throughout the construction timeline. This can be both positive and negative. On the one hand, it can cater to the exact needs and wants of an individual and follow along with dynamic resource availability. However, it requires most individuals to be motivated to endure a non-streamlined process. Brad Kittel and his company, Texas Tiny Houses, is a case study as a tiny home construction company using salvaged material (n.d.). Brad builds extravagant and unique tiny homes incorporating reclaimed building materials. Best described as a work of art and those residing in these homes are a living example of how using salvaged construction material to build structures is possible and economically desired. Brad highlights the viability of constructing tiny homes using salvaged materials as:

> There's a whole virgin forest, the largest in the world, at our fingertips. Yet, Americans want to go buy new crap at Home Depot. That forest is hidden in the form of buildings, farms, and houses. It's already been cut up, sliced, diced, cured and is free of toxins, for the most part. (ibid.)

A negative of using salvaged materials in tiny homes could be seen implicitly through what the use of exclusively new materials can do. Great Lakes Tiny Homes of Blanchard, Michigan, is a tiny home construction company that offers a streamlined service to build select tiny home models (2016). This business model makes it challenging to use salvage material as they not only have to adhere to specific drawings and specifications, but also provide insurance for the long-term performance and quality. This option is more expensive than the do-it-yourself method, but it is a more practical and familiar way to approach acquisition. Despite the relatively high price tag, their largest and highest tier model is only 40.5% of the cost of the average home in Michigan and retains all the benefits of living tiny (Zillow, n.d.). A salvage-based construction company, such as Texas Tiny Houses, can still be an effective business, but it must be structured to cater to the individual. Additionally, custom salvage tiny home design and construction requires the skilled trade of obtaining and preparing salvage material, a design team flexible enough to incorporate it, and clientele that understand the benefits of, and hold desire for, salvaged material. Although not representative of the entire economy, Great Lakes Tiny Homes is successful as a business while Texas Tiny Homes had to close its doors in 2019.

III. Academic Analysis of the Viability of Tiny Homes

Deconstruction and material salvage and reuse are instrumental components in the study of Domicology. In a recent study conducted by the Michigan State University Center for Community and Economic Development on structural material reuse and recycling has identified a weak supply chain for material reuse in Michigan and recommendations to strengthen it (LaMore et al., 2017). The report begins by breaking down deconstruction materials into three categories: Re-use As-Is, Recycle Material, and Repurpose Material as illustrated in figure 1 (Structural Material Reuse and Recycling Market Study, Figure 1). Tiny homes utilize reused, as-is, and repurposed material for interior decoration including: furnishings, fenestration, shingles, siding, structure, and more. This study's spatial analysis presents the primary and secondary market sizes and locations of tiny homes in Michigan. This is highly useful for determining where material salvage would be best to obtain for tiny home construction. Weidenaar, Kurland, and LaMore conclude their report with a recommendation to improve the salvaged material supply chain is, "examin[ing] new material processes that salvage structural material in new and innovative ways, leading to the creation of more sustainable products" 1

(Structural Material Reuse and Recycling Market Study, Recommendations). Tiny homes can and are a new material process that does exactly that.

Tiny homes are a product that can take advantage of the growing salvage material economy. However, barriers to restricting tiny homes from expanding beyond sparse social passion projects and luxury secondary homes do exist. To address these barriers must be identified with real solutions to create a case for tiny homes to have a role in the macroscopic and long-term economy. Ryan W. Hebert of Illinois State University's Center for Community and Economic Development addresses tiny homes' viability and barriers in Strategic housing and vacant land development plan for a more viable Detroit (2016). Hebert identifies the success in Detroit's vast efforts to mitigate blight in downtown and midtown. The objective of this capstone project was to propose addendums to the city's Master Plan of Policies for Detroit and provide strategies for private market players to improve issues in Detroit vacancy, land development, and housing. This content focuses on housing and neighborhood development to address Detroit crises related to chronically vacant land.

Herbert's section on zoning describes current Detroit zoning laws as, "archaic and restrictive," and that "poor zoning laws can actually be worse than having no zoning laws reason for this conservative position on tiny zoning comes from nescient fears that tiny homes could depreciate nearby property value. This fear is unsubstantiated and is on a promising decline with efforts such as Cass Community, a nonprofit providing tiny homes for low-income people, with several accounts of critical acclaim at a national level such as FOX, PBS, and CNN. With public perception improving, Hebert proposes that reduction or elimination of Detroit's square footage requirements would allow for tiny homes to be built and placed within city limits. This would make it only the second major city in the US to allow for tiny homes within city limits, after Philadelphia. The second zoning amendment would be for specific area/s in Detroit to be designated as tiny communities, comparable to that of a cultural center like 'Greektown.'

The implementation of tiny homes within the city of Detroit would serve to benefit several party's: the local government would see increased revenue from property taxes; availability of affordable housing will reduce homelessness and the financial burden on low-income people; revitalization of blighted areas will improve Detroit's image and environmental quality, with the benefit of reducing climate change through low-energy housing.

Catherine Mingoya's graduate capstone for the Massachusetts Institute of Technology's Master's program in City Planning, building together: Tiny home villages for the Homeless, adds to the viability of tiny homes as a Domicological tool (2015). In addition to Detroit's Cass Community, Mingoya highlights five additional tiny home communities across the United States that demonstrate their ability to provide low-cost, or even free, housing to the homeless. Mingoya's report further supports tiny homes as viable housing solution and addresses how to overcome barriers that keep the movement from growing. In addition, Mingoya explains the complex relationship between tiny homes and funding. All five of the communities examined in the study where social programs aimed at addressing homelessness; this is only way tiny homes can be used. However, in these instances most of the funding for these communities comes from donations. Although donations have served well as a kick starter for the programs in this study, donation as a form of funding has several concerns about long-term success. Mingoya recommends that municipalities take on tiny home projects with donor funded villages as a model. A growing number of peer reviewed studies show that these municipalities would have greater success in aiding the homeless if they were to divert funding from social services to extremely affordable housing – requiring small and feasible amounts of rent that would generate more sustainable revenue than that from donations.

IV. Conclusion

Tiny homes are affordable, sustainable, versatile, and attractive alternatives to traditional residences. A substantial amount of evidence proves that tiny homes are an economically and socially viable form of housing, from premium to penniless. In addition, they are a process that can utilize salvaged material to save money and contribute to the aesthetic of the home. Looking towards the future, municipal governments across the United States have an unlimited potential to combat their local blight, better aid the homeless, and divert landfill waste. With benefits to people and communities of all demographics and boundless avenues for growth and development, tiny homes and their use of salvaged material are a meaningful subject of research. Peoples, nonprofits, businesses, and governments would find value in investment in this subject as salvaged tiny homes can offer sustainability, financial freedom, an unsaturated market sector, and a solution to blight, vacant land, and homelessness.

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Policy Considerations in Addressing Blight and Abandonment in U.S. Legacy Cities:

Detroit, Michigan

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I. Introduction

Decades of depopulation and deindustrialization primarily in older manufacturing cities in Michigan, Ohio, New York, and Pennsylvania – the region now referred to as the country's Rust Belt – have left behind widespread structural abandonment and blight (Schilling & Pinzon, 2016). These shrinking cities, once drivers of industry and wealth, have been left to grapple with the conundrum of addressing crumbling infrastructure, dangerous abandoned commercial sites, and half-vacant dilapidated housing stocks all while experiencing rapid disinvestment and disappearing revenues. In particular, the City of Detroit is notorious for its extreme population loss, down 60% from its peak of 1.85 million in 1950, with a 25% decrease in the last twenty years (Akers & Seymour, 2019). This incredible loss of population in a city once hailed for its historic achievements in industry now leaves the community with approximately 85,000 vacant parcels and structures spread across 139 square miles (Detroit Blight Removal Task Force, 2014).

The first wave of loss, brought on by globalization and massive outsourcing of blue-collar jobs, racist government policies that steered investments away from communities of color, and 'white flight' to suburban areas, was followed by a more recent exodus in the wake of the U.S. mortgage crisis and following recession (Akers & Seymour, 2019). Rampant predatory lending, followed by years of slow economic growth in an already impoverished city, caused thousands to default on mortgages with eventual foreclosure and repossession (ibid.). Indeed, since 2005, more than 70,000, or 30%, of the city's residential properties have undergone mortgage foreclosure (ibid). Following the housing bust – a new mechanism surfaced through which Detroiters continue to lose their homes – tax foreclosure (ibid; Cooney & Nothaft, 2019; Detroit Blight Removal Tax Force, 2014). Detrimental effects of declining economic opportunity, the mortgage crisis and recession, combined with chronic overassessment of property values to maintain tax revenues1, resulted in the tax foreclosure and subsequent Wayne County auctioning of more than 110,000 Detroit homes between 2002 and 2016 (Cooney & Nothaft, 2019).

II. Domicology

Blighted and abandoned structures are social, economic, and environmental impediments to the communities in which they're located. The presence of blight in a neighborhood significantly decreases property values while costing the municipality funds in the way of services to clean up trash, address rodent infestations, mow lawns, and respond to increased crime and fire (LaMore, 2021). The proliferation of blight, and the degree to which it is overrepresented in disadvantaged communities, indicates a number of shortcomings in the current built environment paradigm. Recognizing these shortcomings, the field of Domicology emerges, guided by three objectives, to shift our thinking we must:

1. Examine the life cycle continuum of building and infrastructure use and abandonment from planning, design, construction, building use, abandonment, demolition/deconstruction, and material reuse.
2. Identify potential innovative tools, models, policies, practices, and programs that can sustainably address structural abandonment.
3. Conduct research on the technical, economic and policy challenges present in structural abandonment and seek to reduce the negative social, economic, and environmental impacts associated with structural abandonment.

It is within this framework that the following information is presented. This discussion looks at previously implemented or newly recommended federal, state, and local policy initiatives which act both to prevent further abandonment and blight and address the deleterious and disproportionately felt negative effects of existing structural abandonment.

III. Federal Policy

Detroit is not alone in its challenge, legacy cities across the U.S. are home to nearly 17 million individuals and a collective economy of more than $430 billion (Lincoln Institute of Land Policy, 2021). Federal will and funding are needed if we are going to begin to remediate widespread structural abandonment. In 2010, the U.S. Treasury made available $7.6 billion to 18 states for foreclosure prevention through its Hardest Hit Funds (HHF) Program. Citing research that shows targeted demolition helps preserve property values and prevent foreclosures, Michigan reserved $175 million of its HHF dollars for blight elimination – with $107.3 million going to Detroit for demolition (Dynamo Metrics, 2015). A massive private-public undertaking began to document and categorize all residential and commercial blight in the City of Detroit with actual demolitions beginning in 2014. In less than two years, the Detroit Land Bank Authority demolished 5,800 homes in HHF zones with a plan to complete 7,000 total before funds are fully expended (ibid). Already, homes within 500 feet of HHF demos have risen in value by 4.2% and homes located in HHF zones have increased by an average of 13.8% (ibid). While this progress is remarkable, the HHF program can only address 15% of properties identified as in need of intervention in the City of Detroit – and there are no additional funds in sight.

The proven success and efficiency of blight elimination programs in raising home values and building wealth in historically disenfranchised communities should encourage the federal government to continue with their funding. Housing and racial justice advocates suggest funds be raised through the capping, elimination, or transformation of the Home Mortgage Interest

Deduction (MID) (Fernandez et al., 2018). In 2015, the federal government spent $71 billion on the MID; 92% of which went to homeowners earning more than $100,000 annually, with 15% of MID beneficiaries earning incomes in the top 1% (National Low Income Housing Coalition, 2017). This costly itemized deduction, is our nation's most costly itemized deduction and one of our largest tax expenditures, is not only inefficient in that it transfers a large amount of government spending to a relatively small number of wealthy Americans, but it is also a major driver of the U.S. racial wealth gap. While Black and Hispanic households represent 26% of the U.S. population, they only receive 6% and 7% of MID benefits respectively (ibid). White households receive nearly 80% of the deduction's benefits (ibid). Proposed reforms include converting the MID to a tax credit which would provide tax relief to all mortgaged homes regardless of income, or elimination of the MID entirely – with forgone funds being collected and reinvested in housing policy with proven positive impacts, such as the HHF (ibid).

IV. State Policy

The state of Michigan has used its authority to provide funding and relief to cities experiencing widespread blight and to homeowners in danger of losing their properties to tax foreclosure. The state has been commended for their 2014 authorization of Wayne County to cut interest rates on back taxes owed from 18% to 6% and to allow delinquent homeowners to set up payment plans (Pendal & Hedman, 2018). In September of 2017, less than three years after the authorization, Wayne County had 36,000 residents enrolled in repayment plans (Pendal & Hedman, 2018). In addition, another 'circuit breaker' program – dubbed property tax 'circuit breakers' because they kick in when taxpayers are overloaded – deployed in Michigan includes the Homeowners Property Tax Assistance Program (HPTAP). The HPTAP provides full or partial property tax exemption to homeowners living at or below the federal poverty line

(Cooney & Nothaft, 2019). Housing advocates applaud the intent of the HPTAP but are eager to address perceived shortcomings in its implementation. In the City of Detroit, between 2012 and 2016, nearly 40,000 owner-occupied homes were eligible for this exemption, but less than 5,000 applied (ibid). In studying this low utilization rate, researchers at the University of Michigan's Poverty Solutions (2019) found limited program awareness and a complex application process to be the main barriers in eligible homeowners applying.

To further prevent homes from entering tax foreclosure and feeding the cycle of blight, Michigan lawmakers may want to look to Texas's 2015 legislation requiring land contracts to transfer titles to homebuyers and for these transactions to be legally recorded (Pendal & Hedman, 2018). Predatory rent-to-own land contracts are frequently used by real estate investors to take advantage of disenfranchised individuals that are not able to access traditional forms of credit (Kurth, 2017). The home is bought at a nominal cost, often at auction, then sold to desperate or naive buyers at ten times the purchase price with high-interest rates and owners assuming all back taxes and upkeep, but as soon as the buyer is late on a payment, they're evicted – not only losing their shelter, but any money they've invested in the home in the form of repairs, tax payments, or upkeep (ibid). Rent-to-own real estate investors are not a new phenomenon. Data collected by housing advocates on the multi-generational detriments to Black families and communities caused by this practice helped end federally backed redlining in the 1970s (ibid). Today, the Black community in Metro Detroit once again disproportionately bears the brunt of this predatory speculative practice, even when controlled for socioeconomic standing (Akers & Seymour, 2019). Michigan would do well to pass legislation that brings these transactions above board.

V. Local Policy

America's legacy cities, while enduring some of our most difficult challenges, have displayed incredible resiliency and innovation. As mentioned earlier, the City of Detroit's convening of the Detroit Blight Removal Task Force (2014), although funded primarily through federal HHF funds, was an unprecedented bringing together of private, philanthropic, nonprofit, federal, and state partners. The Task Force surveyed, recorded, and made recommendations on every single blighted residential, commercial, and public structure in the city as well as all vacant lots – totaling nearly 85,000 parcels (ibid). This could not have been achieved without competent administration, skilled coordination, energizing leadership, and remarkable creativity. With the backing of state and federal government, Detroit has within its power the ability to bring about an equitable revival. Addressing speculative purchasing is a necessary step for any city attempting to stabilize its housing market after manmade or natural disaster. Speculation is the process of purchasing land or real estate with the intent to use it as a financial investment rather than a place to live (People's Action, 2019). Speculators buy large amounts of property at low prices (tax foreclosed properties in Wayne County sell in the second round of auction for a flat rate of $500) then sit on them for years, sometimes decades, with the hopes of selling once market values have increased. In the meantime, these properties sit vacant, decreasing surrounding home values and threatening the health and safety of neighbors. Between 2005 and 2015, 90% of homes sold in Wayne County's tax auction were purchased by real estate investors buying in bulk (Akers & Seymour, 2019). When speculators don't sit on properties, they often rent to low-income individuals, making no repairs, while consciously not paying taxes. This is a win- win situation for these "investors" as they easily recoup the $500 initial investment, make money off vulnerable people, then face no consequences for letting the property return to tax delinquency in worse and worse shape. It is estimated that starting in 2014, the City of Detroit has spent $34 million demolishing homes purchased by speculators in the Wayne County tax auction (Akers & Seymour, 2019).

Cities around the world, including Washington, D.C., have successfully implemented anti-speculation measures. The People's Action organization (2019), "one of the largest, multiracial people's organizations in the country," (p. 2) recommends the following local anti-speculation policy initiatives:

<u>Land Value Uplift Tax</u>

A tax levied at the point-of-sale on appreciation of a property's assessed value from point-of-purchase when no capital improvements have been made. This policy recommendation relies on the assumption that any increase in market value of a property without capital improvements is entirely based on surrounding activity.

<u>Out of State Transaction Tax</u>

A tax on the sale of any real property zoned for residential use to anyone who is not currently a resident unless the buyer commits to move to that state within 30 days and continuously reside there for the next full year.

<u>Scaling of Code Enforcement Violation Fines</u>

Code enforcement violation fines calculated as a percentage of the owner's (whether individual or corporate) income and assets.

Recently, the City of Detroit took a public health approach in holding owners responsible for their blight and abandonment. In February of 2020, the Mayor of Detroit, Mike Duggan, and Chief Public Health Officer, Denise Fair, declared property speculators' practice of "invest and neglect" to be a public nuisance and "dangerous to the public's health and safety" (Frank & Pinho, 2020). The city sued 3 landlords owning more than 1,000 blighted properties between them (Frank & Pinho, 2020). The city claims these speculators' business model risks lead poisoning due to flaking paint from these old homes in disrepair, as well as increases crime in areas surrounding their blight (ibid).

In addition to the above, municipalities should assess local ordinances for hospitability towards shared equity housing models – such as Detroit's first Community Land Trust (CLT) established by The Storehouse of Hope nonprofit organization (The Storehouse of Hope, 2021). CLT housing models have the community, often in the form of a nonprofit organization, owning the land in disenfranchised neighborhoods and leasing the housing to long-term residents. When the leased occupant moves or sells, the community still owns the land and can preserve affordability. CLTs are also able to step in and assist leased 'owners' in events that would typically lead the property to enter the foreclosure and blight cycle. This model allows for revitalization without displacement.

VI. Conclusion

While addressing extensive blight and abandonment may seem like a Herculean task, it has been done to varying degrees of success in many U.S. localities. The undertaking asks legacy cities and the federal government to put the needs of residents, often disenfranchised residents, and people of color, before the profits of corporations treating housing as a commodity. The above listed policy recommendations are but a few approaches available to sustainably address structural abandonment.

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Establishing a Global Supply Chain for Recycled Construction Materials

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I. Introduction

In 2007, 50.145% of the world's population lived in an urban area. This was the first time in recorded history that more people lived within cities than outside of them. Since then, this percentage has grown to 55% (World Bank, 2018). This rural-to-urban migration will inevitably attract construction for homes as well as industrial buildings to house and employ migrant workers. In the United States, blight in legacy cities such as Detroit and Baltimore can serve as historical examples on the effects of rapid economic growth that followed by the cycle of blight and abandonment. In these cases, the value of the homes dropped low enough that land and property owners felt no financial pressure to recover material from their blighted properties. The creation of a global supply chain for recycled materials will assign value to homes constructed as these cities grow and encourage Domicological principles such as design for deconstruction. A global supply model for reuse will rely on waste management practices as well as international trade to incentivize deconstruction by giving value to recycled materials from abandoned homes.

II. Michigan & Reuse

Michigan, being home to the cities of Detroit and Flint that have seen abandonment due to economic decline, provides an informational case study into the current market for material salvage. The enormous number of homes that have been abandoned represent materials that are being left to waste, rather than recycled. Construction materials, such as wood and concrete, are a business opportunity that has not been fully explored in the state. The MSU Center for Community and Economic Development estimates that the structural reuse industry currently employs 0.5% of the state's workforce to create $18 million in sales, where it has the ability to employ 3.5% of the workforce and total $80 million in sales (Weidenaar & LaMore, 2019). Structural reuse presents an economic opportunity with benefits to the environment through displacing waste as well as benefitting local communities through the creation of skilled trade labor. The growth of this industry would be beneficial to owners, employees, and citizens, but relies heavily on supply chain logistics to thrive. A comparative location, where waste recycling is being encouraged, is the Netherlands.

Although relatively larger than Michigan, the Netherlands provides some insight into what a sustainable industry for material reuse may look like. According to their Ministry of Housing, Spatial Planning, and the Environment, “almost all construction and demolition waste in the Netherlands is currently recycled” (OECD, n.d.). This relies on the well-developed recycling industry in the country that does not exist in Michigan. In the case of the Netherlands, their Ministry works with industry leaders to encourage adoption of the supply chain model that they create. Such direct collaboration between the government and business does not occur in the United States as a whole compared to the Netherlands but has proven beneficial in the reduction of waste and its environmental impact. Although the state government could intervene and encourage material salvage companies to take on more projects, funding them would require government money that is not currently allocated for the industry. However, one of the main lessons the Ministry shares from its chain method was that “for carrying out a project, the parties involved often look to the government for financial support” (ibid.). Demolition waste may have value, but with current technology, may not be a valuable enough product to encourage private sector investment. The success of recycling construction and demolition waste in the Netherlands suggests that government backing is an effective way to reduce waste, if not necessary to attract investment in the industry.

III. The Supply Chain of Design for Deconstruction

A global supply chain for recycled materials naturally relies on a strong supply of materials. Whether or not government funding is present at any stage in the reuse supply chain, greater availability of construction and demolition waste to be reused will benefit structural reuse businesses. A technological advancement that facilitates this can be found in the Netherlands. At the Delft University of Technology, research is currently being done into an Advance Dry Recovery (ADR) process that will allow concrete from buildings to be broken down and reused as cement for new construction (Deloitte, 2015). Concrete is an environmentally intensive material to produce, meaning that this technology's potential to displace new concrete production makes it both economically and environmentally sensible. Concrete's role in the global supply chain for material reuse will be key to connecting deconstruction projects with new construction. ADR also provides a method for buildings that were not originally designed with Domicological principles in mind to be reused as if they had been, albeit at a more expensive rate.

A global supply chain of reused construction materials will also encourage designers to now factor in the piecewise sale of their buildings after their useful life. Rather than focus on the initial sale of a home or other structure, owners will have a financial incentive to choose designers that use the Domicological principles of design for deconstruction that will create value for them in the future. Another feature of this is design for deconstruction's circular economic modeling. Design for deconstruction also involves designing from deconstruction. The use of recycled materials in construction acts as an investment in the development of the reuse market for the time when the building is deconstructed. As the Environmental Protection Agency states, "supporting the materials reuse market will also help create demand for more used materials" (2008). This increase in demand for more used materials is fueled by greater adoption of construction with recycled materials, innovative technologies that increase the supply of recycled materials, and supply chains that connect the supply with the demand.

IV. The Market of Design for Deconstruction

A well-developed market is the key to success for the deconstruction industry. Deconstruction is discouraged by the greater labor costs it poses when compared with demolition. However, a thriving material reuse market gives firms the opportunity to recoup these costs through material resale. In fact, "considering material sales and savings from avoiding landfilling, deconstruction projects cost less than traditional demolition projects" (Patterson & Leigh, 2006). The current state of the market for material resale in many places is not developed enough to induce firms to take on the risk of deconstructing at a loss of profit. Communication at the city-wide level is not only not strong enough to support the market, but there are simply not enough buyers of deconstruction materials. As described in the Journal of the American Planning Association, "sellers of salvaged materials cannot easily find buyers, while those who might be interested in such materials may not be able to identify a reliable supply (ibid.). A possible solution to this mismatch of buyers and sellers may be to open material reuse to the global stage. Increasing the size of the market means increasing the number of buyers and sellers. Ensuring a buyer for reused materials encourages firms to take advantage of the financial benefits of deconstruction.

Illustrating a global supply chain adds buyers and sellers of reused materials, but also introduces many other players. For example, materials must first be processed before being reused, they must be transported internationally, and businesses must operate in different currencies. Most of these issues are addressed in supply chains of other international industries, such as newly produced textiles. In studying current markets, researchers found that "global supply chain models need to address the composite supply chain design problem by extending models to include both internal manufacturing and external supplier locations" (Meixell & Gergeya, 2005). This raises an issue for a material reuse supply chain in that there is no clear 'internal manufacturer' of deconstructed materials. The owner of a property may entitle themselves as the owner of the materials that comprise the property, but the company that deconstructs it may be considered the manufacturer of material salvage. If a global supply chain assigns value to materials that are currently discarded as waste, then ownership of these materials will become an investment that property owners and deconstruction firms alike will seek out. This is the financial basis of the supply chain model's encouragement of design for deconstruction. Seeing a building for the value of all of its parts provides owners a new perspective on its role as an investment. Rather than construct for current needs and demolish when the building is no longer useful, owners will see each part of the construction as an investment.

V. Conclusion

The current market for deconstruction materials has seen moderate but geographically unequal success. It will rely on global expansion for growth around the world. Expanding the market to the global stage will address construction everywhere by connecting material sellers in places such as Michigan with buyers in places such as the Netherlands, where there is demand for reused materials. This connection will fundamentally change the way houses are initially constructed by encouraging designers to consider the end stage of their properties. Owners of these properties will then avoid abandoning them as abandonment will carry a financial burden in the form of missed profit. Worldwide cooperation and business partnership in the material reuse market will then reduce the environmental impact of construction as well as help to reduce its most negative social impact, blight. A global supply chain for material reuse will encourage property owners to see themselves as stewards of their buildings as well as investors in salvage materials.

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Education Implements for Designers Regarding Commercial Deconstruction

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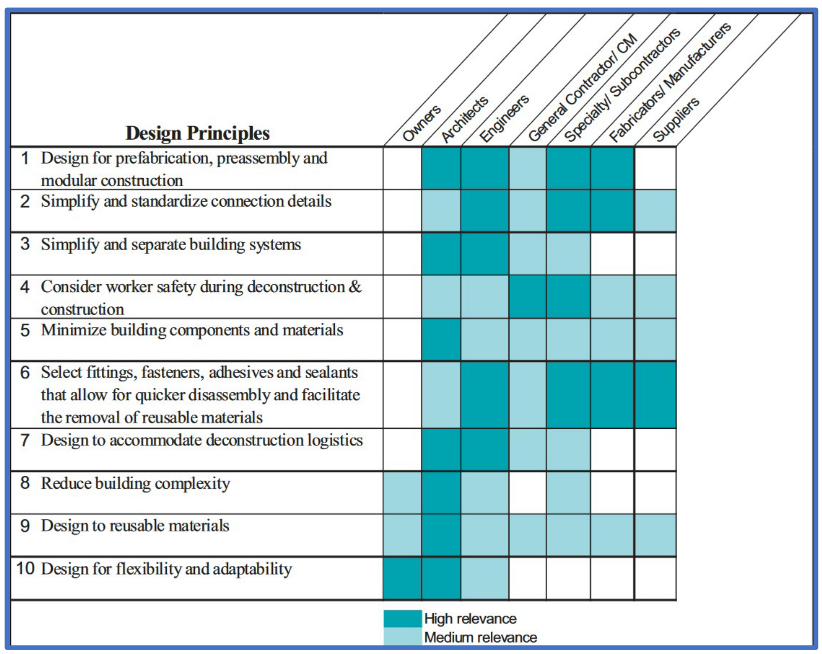
I. Introduction

Design for Deconstruction (DfD) is the future of architectural design. From the European Union to Canada and Montana, more and more governments and municipalities are mandating deconstruction, often with the cost of disassembly borne by the producer. (Bahorski 2019) With this coming paradigm shift in mind, there are a set of solutions to be considered. Many of them could be considered reactive, such as mandating producers pay to deconstruct already-built wind turbines, removal planning and materials management; while solutions like DfD, Inventory-Constrained Design, and BIM Systems are more proactive. Architects and engineers have been identified in surveys as particularly able to influence the architecture design process in favor of deconstruction. (Pulaski 1999) The purpose of this paper is to lay out a set of methods and standards that designers and engineers can incorporate to understand their full material inventories including salvaged and incorporate those materials effectively into design with the intent for deconstruction.



The focus of early work in Design for Deconstruction has mostly been in residential structures. There are distinct problems in residential design, and the relatively similar programs of these buildings makes DfD considerations for one or two typical residential configurations have implications for many potential structures (Bukauskus 2018). However, if DfD is to be part of the new construction paradigm, Domicologists need to offer solutions specific to commercial projects as well. Commercial projects hold several specific advantages including adaptability for many different uses, abatement of a different set of pollutants and hazardous materials. The analyses contained in this paper will focus on the impacts of data points for commercial projects.

According to Figure 1 demonstrates the shares of demolition waste that were generated in the year 2000 (Chini et al. 2003). At that time, nearly one third of all C&D Waste (CDW) was generated from non-residential demolition. The vast array of different uses, locations, and economies that these buildings occupy make them most likely to be demolished and have nearly all the waste immediately disposed of in a landfill.

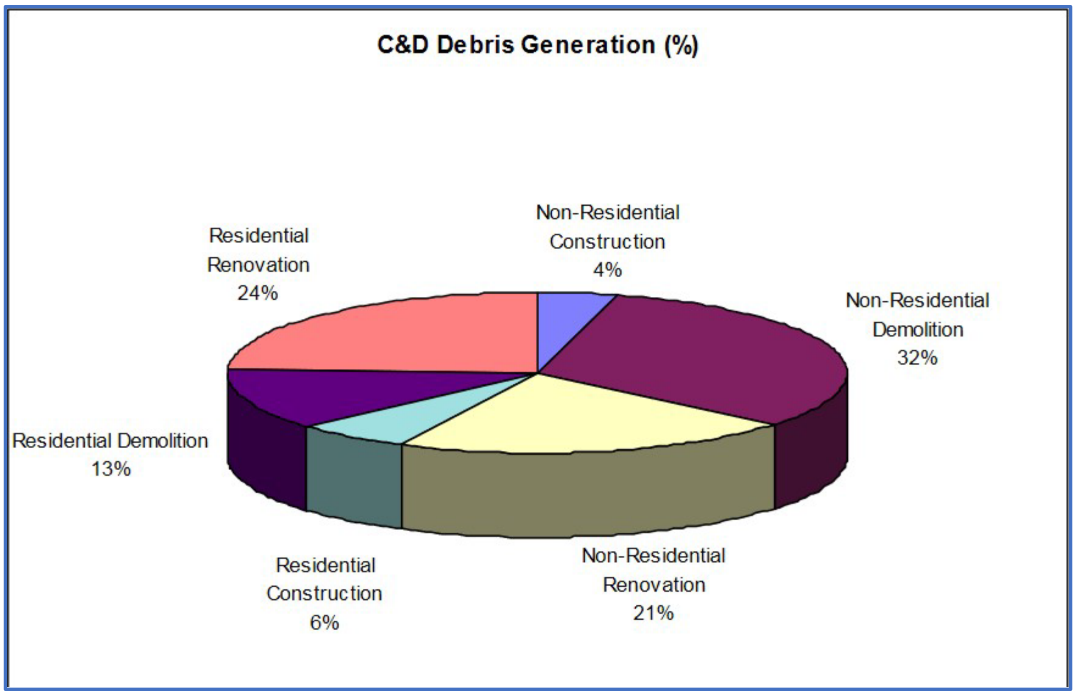


Figure 1 Construction and Demolition Waste Generation in 2000 (Chini et al., 2003)

II. Thesis

The next generation of designers and engineers will need to have a clear understanding of material salvage, testing, and reuse. They will also need to understand how they may leverage the full and complete value of everything on their sites in a sustainable, beautiful, safe design. A meaningful site inventory includes information on the structure, the deconstruction, and the salvage output that may be predicted for the building. This will need to be repeated at least once with an engineer, followed by the next phases of planning. Proposed below is a framework for the schematic design phase in which structural configurations are mimicked in the new design to maximize reuse, and designers will be encouraged to allocate for all reusable materials before adding freshly extracted materials to the site. These measures, once spread sufficiently within the community, will open the door for policy and economic instruments to accelerate the acceptance of these methods.

III. Material Reuse Inventory

The backbone of effective reuse is understanding what exists onsite before any work begins. A deconstruction and salvage project often begins with a walkthrough of the site to recognize any potential hazards, understand the structure, roughly estimate the scope of work, and what equipment will be needed. The architects should also create a customized document for their walkthroughs, based on the resale and salvage markets in their area. This document should be like a checklist that they will add to as they walk through if necessary, showing what materials are in the building, and in what dimensions they will be available (Guy 2003). Along with the materials the architect must include the cost/benefit ratio of extraction and the potential ratio of material that may be reused. Similar to the layout of Figure 2 with additional columns mentioned.

Item	**Cost/Benefit Ratio**
Doors	0.46
Cabinetry	0.35
2 x 6 lumber	0.29
Windows	0.29
Wood stair (as one piece)	0.16
6 x 8 lumber	0.07
3x10 floor beam	0.03
Ceiling and attic fans	0.03-0.04
Claw foot tub	0.08-0.10
2 x 8 lumber	0.27-0.32
1 x? Novelty siding	0.37-0.45
1 x 12 planking	0.15-0.24
4 x? lumber	0.13-0.24
1 x 3 bead board	0.32-0.71
Brick	0.33-0.72
1x3 T&G flooring	0.11-0.58

Figure 2 Example of material reuse inventory sheet

There are specific considerations to be made in commercial deconstruction projects that are not made for residential projects. For example, all past uses of a site ought to be considered. If at any point in the past 100 years the site was used for any sort of toxic use (chemical manufacturing, gas stations, paint shops, radiological transportation, or manufacturing) then a Phase One Environmental Survey must be administered to take samples of the building and the soils to determine what sorts of materials are present on the site. Without an environmental survey, the designers still must consider how the uses and practices on the site have impacted its conditions and look through documents from past sales to see if any problems were delineated with the structure or the soils (Guy 2003).

During research away from the site, a designer needs to compile information about the context of a site in social terms and economic terms. This includes people employed, or reasons users tend to visit the site. Given the information obtained from the walkthroughs, now a designer can start to understand how they ought to treat this site. If the structure is delicate, or highly unique in configuration, perhaps it would be better suited to a historic preservation reinforcement and renovation rather than a full deconstruction. However, a high-rise office building with an open floor plans, exposed structural elements and modular design with simplified connections, is highly suitable for deconstruction (Bertin 2020).

In a recent 2020 study, researchers analyzed a set of high-rise building (HRB) designs at various scales with steel frame construction with the similar conventional DfD principles noted above. This study modeled two different methods: designing from a stock, in which the building was essentially replicated at a smaller scale to account for loss from deconstruction, and design with a stock, where reused material is highly preferred but new elements are also added (Bertin 2020). The outcome of the study was essentially that design with a stock is better suited for older buildings without specific load-bearing requirements seen in some newer HRB constructions.

But these design options are a major tool in the kit of a designer. In any sort of building, many of the systems can be preserved, reinforced or replicated to facilitate maximum reuse and this will be a key to major carbon and economic savings.

The last item to consider in the material reuse inventory is the current strength of the structural system. In some abandoned buildings the structure is relatively healthy and undamaged, especially if they can be identified and deconstructed quickly. Perhaps parts of the structural system are dilapidated or otherwise compromised but that does not affect the rest of the system. Preservation of the structural system in the new design, or mimicry of it with added or subtracted elements, will lend the maximum reuse of structural elements.

IV. Inventor-Constrained Design

The concept of limiting your designs based on what is available in the site inventory is often not written about in DfD materials. Often those consist of a set of concepts that may be incorporated into any building project, even one on a site with no previous development. But the most efficient carbon and dollarwise would always be a plan for adaptive reuse or deconstruction. By prioritizing reused materials, a designer can deliver a more significant and special final product, often to the exact same or better standards of safety and quality, for cheaper than other options.

A model was created to try and show how a pin-jointed truss system could be disassembled and rebuilt with members of all different sizes at different levels of efficiency (Bukauskas 2018). The variable that was continuing to be optimized for was the "off-cut ratio" or how much wood is being cut off the average member in order to build the new structure. It was approached as a mathematical problem and as plotted in Figure 3 a & b.

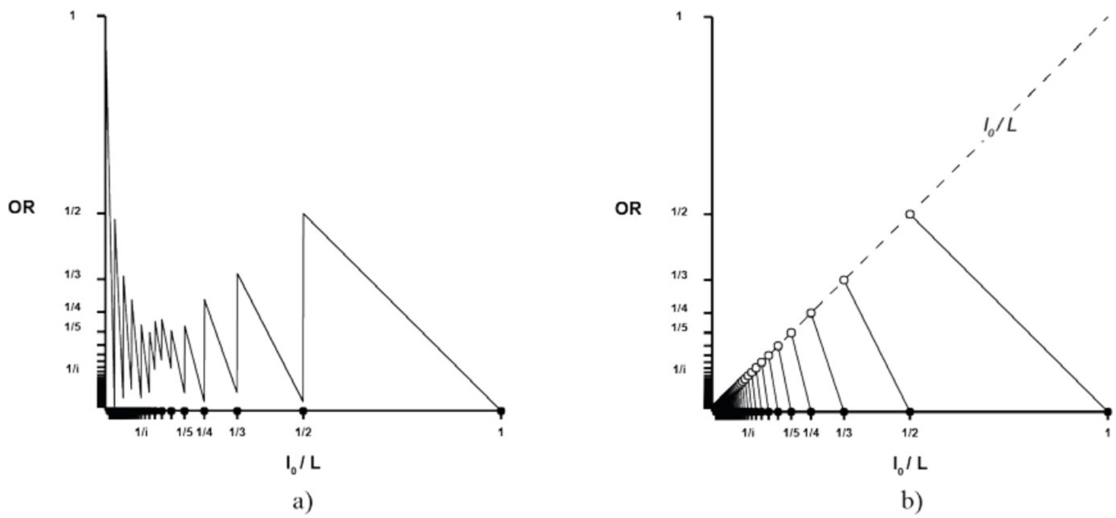


Figure 3 Off cut ratio

As shown above, thinner members yield less waste than thicker members. But the major takeaway here is that pin-jointed truss systems can be reused to a high degree of efficiency to rebuild essentially the same system, even compensating for losses and offcut due to nail connection points (Bukauskas 2018). If a structural layout is mimicked along with a pin-jointed truss system for the roof 60-70% of the old structure and roof to be reused. All the money that was budgeted for those elements to be built completely new can now be used in other ways on the site to benefit users and the environment.

V. Removal Plans

Every architect, as part of their usual process for creating a schematic design, must create a removal sheet. In the classroom, often these plans are an afterthought. Find a landfill near the site that accepts C&D waste, find how much per ton that landfill charges and calculate the cost of your entire demolition through this process. Often in professional practice, these methods that are familiar, reproducible, and often quicker and cheaper upfront than any sorting or recycling process (Chini et al., 2003). This is simply not compatible with the imminent changes to the building paradigm that are coming due to climate change, environmental changes, and changes to the value of products leaving construction sites.

Table 6: *Recovery Rate for Various Deconstruction Projects*

Location	Case Study	Reuse/Recycling Rate
San Francisco, CA	Presidio	87%
Fort McCoy, WI	US Army Barracks	85%
San Diego, CA	US Navy Motor Pool Building	84%
Marina, Ca	Fort Ord	80-90%
Twin Cities, MN	Army Ammunition Plant	60-80%
Baltimore, MD	Four Unit Residential housing	76%
Port of Oakland, Ca	Warehouse	70%
Minneapolis, MN	Residential Building	50-75%

Table 6 reflects the absolute best-case scenario in each state, rates of recycling upwards of 60% through deconstruction have been carried out across California, on the East Coast, and across the Midwest. These are all different types of buildings from homes to warehouses to the famously deconstructible U.S. army barrack. (Chini et al. 2003) With these numbers it's clear that deconstruction greatly increases the rates of salvage from existing buildings, all that material now ready to be evaluated and priced by a consumer. The materials we use in new construction are highly extractive and detrimental to the environment, and older materials are even more so. By planning for recycling at the schematic stage, architects can also screen the building for hazardous materials both before work and during the process, ensuring these materials are not carelessly transported to a landfill site.

Considerations for these removal sheets must go beyond simply planning for the reuse of materials and adding up projected costs. At the schematic phase, there must be documentation and if necessary, calculations, to support the reuse decisions an architect is making. Drawings and details showing how materials will be stored on the site and how they will be moved across the site will ensure worker safety and efficiency of time and costs onsite. These documents have the added benefit of demonstrating the full scope of work to contractors so that the architects may be sure that their plans may be carried out faithfully.

Not every building needs to be deconstructed. In fact, at this juncture many architects and researchers interested in this are primarily concerned with finding buildings with owners ready to accept deconstruction, so these characteristics are what an architect can look out for to make sure their clients can realize the cost benefits of deconstruction.

1. Wood framed buildings utilizing heavy timber.
2. Buildings that are constructed using high value specialty items such as hardwood flooring, architectural molding, etc.
3. Buildings constructed with high quality brick and low-quality mortar.
4. Buildings that are generally structurally sound and watertight will have less rotted and decayed materials.

Currently, when a designer is consuming a recycled material, they are most likely to do it from a manufacturer they already trust, and simply selecting for example a bench or a light post from a recycled product line at LandscapeForms (Chini et al. 2003). While it would be a success for the environment if these manufacturers only used recycled materials, it would not achieve the levels of reuse in the case studies above. The only way that truly sustainable building can be done is through custom, strategic reuse of existing components directly into a new building.

In the 1970's the architecture critic Martin Pawley wrote about the simultaneous problem of mass homelessness, and massive pollution due to CDW. He criticized the "tunnel vision" of western culture and design sensibilities for not accepting "waste materials" as a cost effective but sturdy building material that could be used to address the housing problem. He theorized that by developing second uses for both existing and new buildings, architects and designers would be able to merge western design sensibilities with the reuse of "waste material" by not completely abandoning the typical patterns of consumption in the building economy. Pawley's theory incorporates well into this new paradigm that is being forged, by allowing for the consumer choices and changes and customization that clients expect from architects, while not having to destroy the valuable components already there.

When assessing a site for reuse and what can viably be repurposed or reused, there are four typologies of reusing previously used materials (Gorgolewski 2018):

1. Reuse an existing structure for the site, possibly adding to it - often referred to as "adaptive reuse" this approach is common for heritage structures with recognized cultural value. Often a change in use is implied.

2. Relocate most or all of an existing building to a new location - sometimes occurs for pre-engineered buildings. Temporary structures offer lessons about design for this use.

3. Reuse individual components extracted from a different project in a new building - Sometimes referred to as component reuse. Structural components (beams and columns) or non-structural components (cladding, bricks, staircases) are taken from one building to another. This is not common except for heritage buildings, and there are always more opportunities for reuse in a building where considerations for such things were made in the design phase.

4. Use materials that were previously used for a different purpose - This may be a product or building with a designed second use (these are rare but becoming more popular) or it could be something that initially had nothing to do with building but is transformed into a window or interior piece.

There are great benefits to each of these approaches, and if an economy and supply chain locally can support it, these approaches should be used in tandem to ensure a sustainable and beneficial outcome for the community. When selecting components to be reused, there are six categories that they may come from:

1. Primary structure - heavy steel, timber, in situ concrete often will need to be crushed except in the case of an adaptive reuse

2. Building envelope - Thermal performance standards are significantly higher now than in even recent years, so it may be beneficial to layer many building envelopes

3. Services - Although specific machinery will often be outdated, infrastructure such as ducts and pipes may be salvaged by savvy contractors who are able to assess the site.

4. Interior finishes - often through a buildings life these components change. If they are all intact, they offer a high propensity for reuse.

5. Feature Components - Many times a feature component in a reused office building or business location will be kept for heritage purposes, it may be worthwhile to make an effort to expand what is considered heritage or a valuable feature component.

6. Landscaping - landscapes featuring reuse of previous landscape components have instant character.

As with anything in architecture, these plans are only worth as much as their execution. If a diverse set of engineers and contractors have not seen and approved these plans, they are not prepared for schematic design. A contractor or engineer's support goes a very long way with convincing contractors to bid and to be onboard with deconstruction projects.

VI. Material Management

This winter, MSU Center for Community Economic Development convened a Focus Group with two contractors (one from Georgia and one from Michigan) and a construction manager (with a large construction company in mid-Michigan) to discuss what the barriers and opportunities are that they can recognize in their local to regional business communities to greater reuse and recycling of building materials (Hall et al., 2021). In this discussion, all participants agreed that one of their top priorities was development of businesses further along the supply chain that could all network together and co-ordinate the materials supplied and demanded from their various projects. That, luckily for the architects, is not something they need to address in their work. However, architects were also identified in this focus group as a key player who can ensure from the beginning of these projects that there are budgets, time and expertise dedicated to deconstruction and material processing. The contractors specifically noted that they had walked into projects where deconstruction was very feasible and even profitable, but because of opposition from the design team or lack of planning early on, compromises had to be made in the retention of materials that all could have been avoided.

Another study was conducted on the other side of the world in Perth, Australia (Bullen, 2010). There are extreme differences in everything from the environment, the economy, the social situations and demographics, the building styles, and regulations between any town in the U.S. and Perth. However, not everything is different as demonstrated in Figure 4.

Profession	**Variables**						
	Commercial performance	**Building demand and function**	**Costs**	**Risks**	**Operational attributes**	**Suitability of building**	**Sustainability performance**
Architects	High	Medium	Medium	Medium	Low	High	Low
Property developer	High	High	High	High	Medium	Low	High
Property consultant	High	High	High	High	Medium	Low	High
Cost consultant	High	Medium	High	High	Medium	Medium	Medium
Project manager	High	Medium	High	High	Medium	Medium	Medium
Building manager	High	High	Medium	Medium	High	Medium	High
Planning Consultant	Medium	Low	Medium	Medium	Low	Low	Low
Town planner	Medium	Low	Medium	Medium	Low	Low	Low

Figure 4

This is a very similar incentive structure to what we can observe in the United States. Architects are interested in sustainability (in this case they were being interviewed about adaptive reuse), for managers and contractors adaptive reuse measures are recognized as valuable but if a tradeoff is to be made between sustainability and another component of the project that is necessary or will gain profit, sustainability may not win in that conversation. And least concerned with reuse are the property developers and planners who often would be happier to see the construction line item of the bill go down because they have not been faithfully educated on the value of their buildings and materials.

All of this can be addressed by the architect discussing early on with the client their plans for sustainability and material reuse, and regardless of what they client says, a material management plan must be developed for the sustainability of the project and budget down the line.

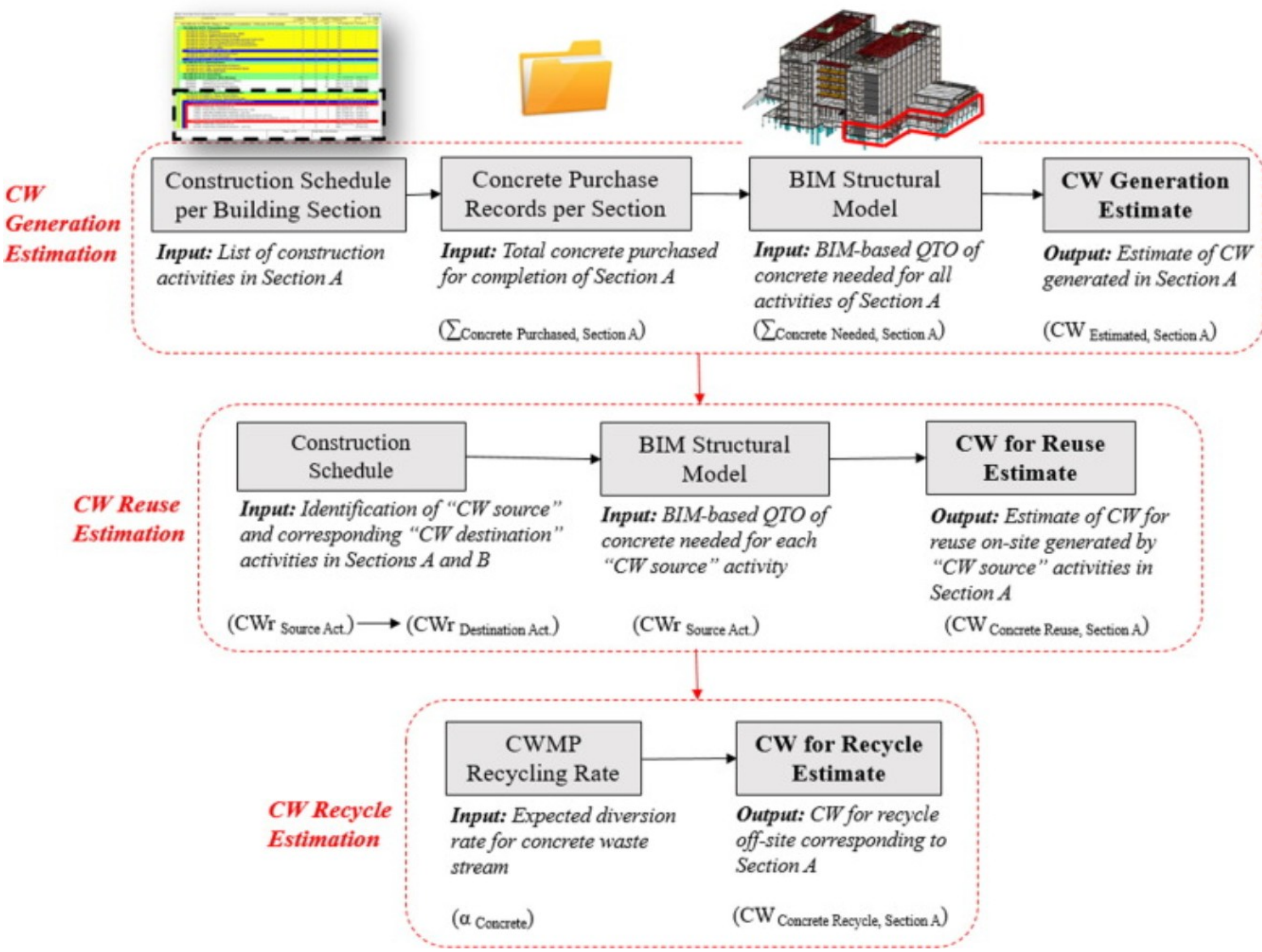
When creating a material management plan, ensure that uses for every component onsite are devised. However, there are better uses than others for every material. Consider the typologies of reuse discussed above. Best-case scenario for every project is to reuse major elements to eliminate the most extractive materials that would need to be manufactured for the new project. This requires careful planning of material sales and uses. Once all elements that are suitable for reuse have been identified, next identify consumers for as many materials leaving the site as humanly possible. These uses include CLT production of lumber, crushing of concrete for use as aggregate, sale of materials to a recycling facility, or transport of materials directly to another worksite. Only after these options have all been exhausted in the local and surrounding economy should the architect consider disposal of onsite materials. Even then, the architect should reach out to agricultural suppliers, building material manufacturers and local non-profit recycling centers to ensure that as much waste is diverted from the landfill as possible.

There have been some advancements in the financial instruments that may need to be developed to facilitate this kind of reuse. In Savannah, Georgia the non-profit Re:Purpose Savannah has been at the forefront of this development. When a contractor has waste in Savannah, they can contact Re:Purpose to consult on disassembly and safe extraction of building materials. Not only will Re:Purpose consult on these projects, they will also receive all viable materials as a donation and provide the contractors with a receipt. That receipt sets the value of the materials that were donated and will be the tax deduction value for the construction company at the end of the year. Re:Purpose Savannah then transports the materials to other construction sites with special attention to store materials as little as possible to ensure high volume of recycling.

If a project is subject to great pressure against deconstruction, it would be necessary to create a material management plan. The architects and the designers will get no influence or oversight of the recycling activities, so it will be even more important to ensure that the consumers of product leaving your site will take better care of the environment and community than a landfill would.

VII. BIM Systems

Building Information Modeling (BIM) is a highly popular development of the last decade in architecture, construction, engineering fields (Guerra et al. 2020). BIM reflects a major change in the expectations for a property owner or landowning institution like a university. In the very near future, it will be common for architects to catalogue each member or component going into a building and store it with the owners so that when the time comes for a renovation, or a disaster happens, the building will be much more resilient than if not. Beyond that, BIM systems increase the value of a property, with more value the more data and the more buildings monitored. A study by Guerra et al. found that they could incorporate temporal data into their BIM to streamline waste planning and minimize waste during construction (and therefore during deconstruction). This model utilized the R's to prioritize reduction, then reuse, then recycling for the project. Creative end-uses were developed for this model including concrete reuse for soil stabilization, grading, road bases, etc. and recycling drywall for soil amendment, Portland cement production, etc.



Above is the description of how this BIM worked and separated out its inputs.

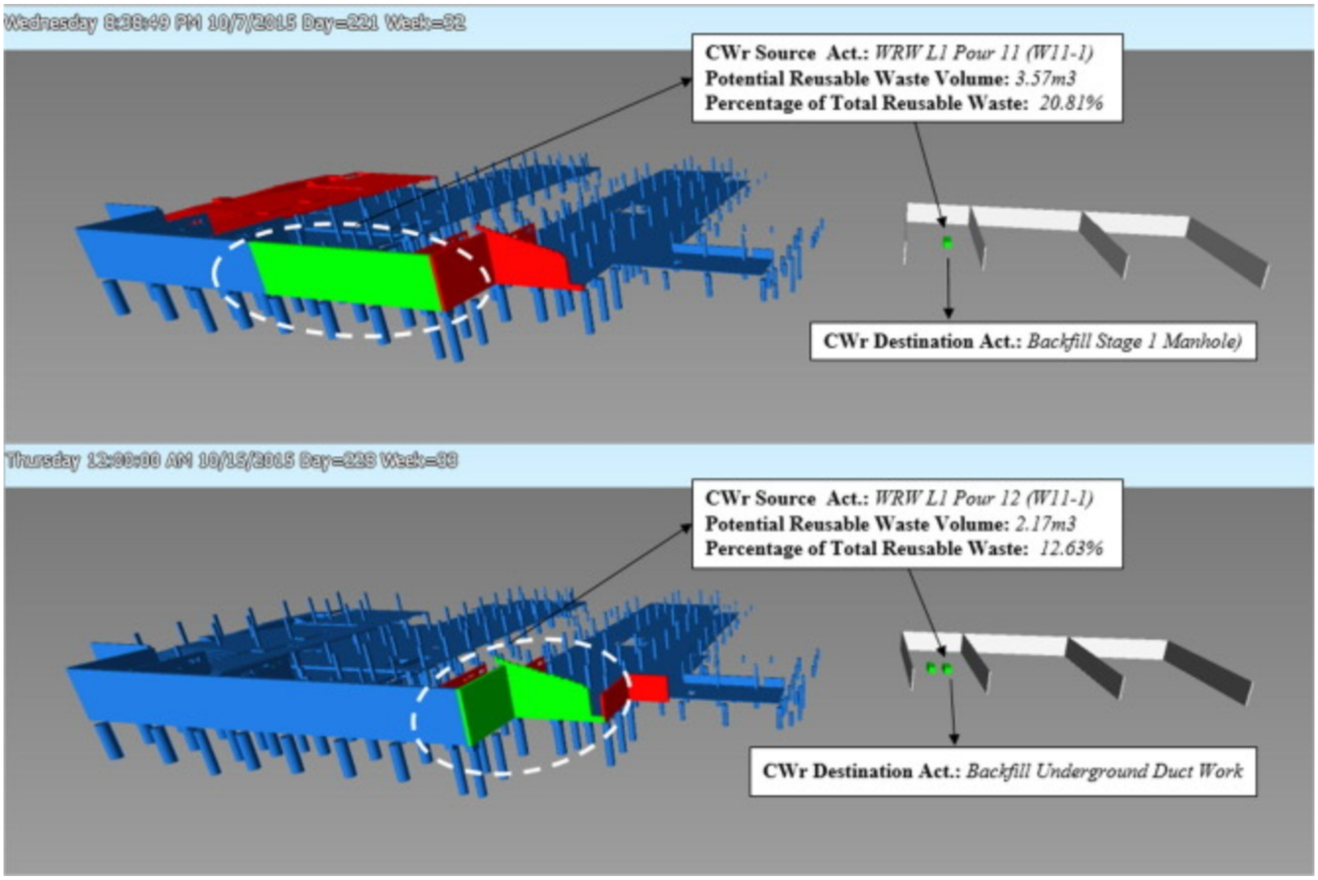


Figure 5 Output visualization

The output visualization illustrated in Figure 5 would be the architect responsible for the end of this structure's life. With information to catalogue each member in the structure and materials of those members, the deconstruction can be modeled to a highly accurate degree ahead of time. As demonstrated in this study, it is also an invaluable cost estimation tool. One of the major points of the CCED Material Reuse Focus Group was that contractors and designers need much more accurate cost estimation tools to ensure there are no problems and that they can maintain trust and healthy business relationships with clients interested in deconstruction (Hall et al., 2021).

VIII. Conclusion

We do not get a choice as to whether or not these methods get adopted. The research and architecture community have too much green momentum. The choice now is who will be in on the ground floor, developing standards and more efficient methods of deconstruction. The choice now is who will be ready to pivot into these modes of design once the real estate market catches up and recognizes these DfD principles and BIM as additional value. Much of the information Domicologists and contractors are talking about right now is not new, or even novel. Mostly, it is knowledge that we forgot due to unsustainable development. By adopting these principles, we can temper the progress we have already made with discipline to ensure longevity.

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