IMPROVING THE CIRCULAR ECONOMY OF CONSTRUCTION WASTE

RECOMMENDATIONS FOR CREATING MORE SUSTAINABLE CONSTRUCTION PROCESSES

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ABSTRACT

Using different commercial and residential construction jobsites within California and Arizona, this project highlighted the different methods of waste management used within the construction industry and steps to become a zero-waste industry. This paper analyzes the ground view perspective of industry professionals utilizing the current methods in place for waste management in the construction industry. The project differentiates the policies for Construction and Demolition debris (C&D) recycling and waste management between the two states to better form a plan for an Arizona waste management plan. Utilizing the methods and standards from construction sites, interviews, and common themes from industry professionals (specifically, project managers), this project outlines potential strategies to improve current waste management methods in both California and Arizona. Finally, the paper provides recommendations to state and local municipalities on how best to establish waste management techniques that benefit both the environment and industry professionals.
# Table of Contents

ABSTRACT .......................................................... 1

INTRODUCTION ...................................................... 3

LITERATURE REVIEW ............................................. 4

METHODS ............................................................. 6

DATA AND MEASURES ............................................ 6

RESULTS ............................................................. 9

SURVEYS ............................................................ 10

SITE STUDIES & INTERVIEWS .................................... 13

COMMON THEMES ................................................ 14

RECOMMENDATIONS ............................................. 16

CONCLUSION ....................................................... 19

REFERENCES ....................................................... 21

APPENDICES ....................................................... 22
INTRODUCTION

Construction waste and debris continue to dominate landfills. Initiatives like adaptive reuse construction, government policies to limit construction waste, and policies that ensure recycling, reduction, and reuse of construction materials are not being mandated thoroughly on a federal level to create plans for all jurisdictions to follow and are failing to counteract the waste issue. With city and state ordinances in place to maximize the recycling and reuse of construction waste, it should be an industry close to zero waste or have a circular economy framework established. In Europe or our western neighbor, California, studies have been conducted to minimize the amount of construction waste. According to a 2014 report on the solid waste stream in California, construction and demolition material (C&D) accounted for 25 percent of the disposed waste stream.\(^1\)

Moving forward with their circular economy incentive, California has diminished their C&D waste drastically into the teens.\(^2\) The United States seems to be 20 years behind. Is this a cultural problem? Policy issue? Or possibly ignorance at the lower levels of the construction industry (stakeholders)?

Figure 1. 2018 C&D Recycling Statistics

Since construction contributes so much to the built environment, research was conducted at the lower levels of the construction industry. Innovative technology and different techniques have been adapted to minimize construction waste over the last 30 years. In California, it is mandated by the state's waste orders that 65% of any

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\(^2\) California Recycle, 2
construction site’s waste must be recycled. There may be other alternatives that contribute in more effective and drastic ways, but this is a start to build policy momentum in the United States. According to the Environmental Protection Agency (EPA), in 2018, 600 million tons of Construction and Demolition (C&D) material were produced within the United States. Of that 600 million tons, more than 200 million tons were not recycled and disposed of throughout landfills. Many of these efforts stem from the commercial construction industry due to the high volume of waste and the ability for state and city governments to enforce these regulations. Yet more common, smaller residential construction projects are often unregulated due to owner-builders and their lack of visibility to city inspectors. There are multiple factors and problems that hinder solving the construction waste dilemma, and communication breakdowns between designing and building can even cause multiple builds on one project. To accurately find out why construction waste continues to be an issue regardless of the ordinance, policy, or laws, I pose two research questions:

1. Is it achievable for the construction industry to become zero-waste?
2. Do stakeholders within the construction industry knowingly or unknowingly dispose of construction waste improperly?

LITERATURE REVIEW

Construction waste is a problem, and it is not going away. Gillian Foster found through an extensive literature review that decision-makers lack the knowledge of environmental

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3 Cal Recycle, 3


benefits that adaptive reuse could bring to our economy. She strongly suggests that having a comprehensive circular economy would increase the lifecycle of buildings and construction. Foster describes the circular economy (CE) as eliminating waste. Waste from one project could be reused as material for another project, thus, eliminating the number of materials that must be made, produced, or mined to provide new materials for new or adaptive reuse construction.

We have a finite number of resources on our planet. Building materials like metals and inerts (concrete) will eventually run out. How can we extend the lifespan of our buildings or create more material with debris that we already have? Construction is one of the greatest contributors to the United States’ growing waste management problem. Introducing a circular economy of waste management for the industry will allow us to tackle many issues at once, like recycle building materials and prevent more waste entering full landfills.

California already has an ordinance at the state level to recycle building materials. This ordinance states that fifty percent of jobsite waste on any construction site must be recycled. The unfortunate part about this is the number of loopholes that site managers can jump through. By hiring a waste management company to pick up construction debris, that company takes responsibility for that material. The waste management service does not have to report to the California government how they dispose of the collected materials.

In further research, the easiest materials to recycle are brick, concrete, metals, and wood. Masonry materials are ground up and put into concrete as aggregate. Metals are melted down to their original block form and recycled as their specific materials. This is a very energy-consuming process, but it is more efficient and environmentally

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6 Foster 2

7 California Recycle 4


9 Tam 2
friendly than mining new materials from the earth. Wood is broken down into smaller pieces, compressed, and formed into newer alternative wood forms. This process of recycling wood is more efficient than running a logging industry, but there are still pros and cons to both. All recycled materials factor into the overall objective of creating a circular economy of building materials.\textsuperscript{10}

An older study from 2003 showed that the United States generated 170 million tons of C&D waste.\textsuperscript{11} Of the 170 million tons, only 48 percent were recycled or reused in a circular fashion. The recycling industry is constantly battling to keep up with newer and better technology to raise the annual percentage of recycled material.

Osmani describes the main obstacles to creating a circular economy with zero construction and demolition waste as improper reporting of waste and illegal dumping of waste.\textsuperscript{12} This defines the second research question that this paper is trying to answer: whether the stakeholders are complying with rules and regulations.

\section*{METHODS}

\section*{DATA AND MEASURES}

To structure and capture as much information as possible, the research is driven by three factors found in survey questionnaires and data collection from a Green Business Certification Inc. (GBCI). This design is cross-sectional deriving quantitative and qualitative data from October 2021. As well as drawing on data taken in October, the research frequently considers proven methods to reduce construction waste like CE and waste minimization techniques.

\footnotesize{\textsuperscript{10} Foster 3}


\footnotesize{\textsuperscript{12} Osmani 2}
Data collected is a combination of both primary and secondary data. The primary data collection was gathering survey results from project managers currently in charge of ongoing construction within San Diego, California, and Tucson, Arizona (Appendix 1). The primary data collected was the most difficult to collect due to a lack of participation by the industry professionals. Despite sending the survey to more than 30 individuals, there was only a response rate of over 50 percent. Other primary data collected were interview results (Appendix 3). Standardized interviews with the project managers and superintendents on the sites studied were scheduled to record common themes amongst the different stakeholders and jobsite controllers.

The secondary data collected came from 2 construction sites in San Diego, California, and 1 construction site in Tucson, Arizona. The data collected was the pounds of debris collected at those specific sites during October 2021 (Appendix 2). The data was broken down into specific categories of waste type and then weighed. SCOR Industries, the company that collects and recycles from construction sites, separates the debris, and generates a report that describes how much of the waste could be recycled by them.

The research study site of San Diego County in Southern California was chosen. San Diego has a unique construction and demolition recycling program named Cal Green.\(^{13}\) Cal Green is a state-wide program that incentivizes and governs municipalities from the state level. First implemented in 2016, the program diverts 65% of construction waste away from landfills.\(^{14}\) The ultimate reason for conducting site analysis in California was to grasp the concepts of the C&D recycling methods. Asking the hands-on experts, project managers and superintendents of construction sites would give a clear view into answering the research questions listed above.

\(^{13}\) Cal Recycle 5

Common questions to be answered on site were:

1. How does the recycling initiative work?
2. Are all site employees aware of the difference of materials recycled?
3. Is the separation of materials being followed?

Once the site reviews were logged and annotated, the research could be conducted similarly on sites in Tucson, Arizona. Arizona does not have state policies that mandate recycling C&D materials. Taking the lessons learned from the San Diego sites, recommendations could be provided after considering hazards, issues, or problems that were visually noted on the several Tucson sites.

It is interesting to note that there are many policies in place in the state of California that do not apply in Arizona to divert construction waste from landfills. Research conducted outside the Tucson and Arizona areas can bring light to programs and initiatives to eventually help Tucson put specific policies into effect to protect the environment that it is always trying to save.
The methods were broken down into five different phases (Figure 4). The literature review in the first phase was to collect background information about construction waste. Keywords like “construction waste,” “adaptive reuse” and “construction waste management” were typed into Google Scholar. Finding articles that were recently published was difficult. A 20-year timeframe was allowed to filter through more articles regarding research conducted on Construction Waste.

Next, the goal was to look at differently sized jobsites to determine if these companies were utilizing a green certified waste manager or disposing of their jobsite waste and debris in other ways. The goal of the survey was to find out the percentage of respondents (companies) that seemed to have a viable waste management program.

Phase 3 allowed a collection of secondary data from job sites. If the companies utilized a service that disposed of their waste, weight receipts would be given. Analyzing how much waste is produced and recycled will show an exact number in pounds per job. This number in pounds can then be shown in a percentage per job site of the amount of material recycled.

RESULTS
SURVEYS

The results concluded two major findings that can be attributed to construction waste and how it can be mitigated or minimized in the future. The data set from SCOR Industries points out that during October (2021), they collected approximately 108,000 lbs. of construction debris from 1 site in Camp Pendleton, California. Of that total number, they could recycle 96% of that material and debris. Approximately 96,000 lbs. of construction debris were recycled. What SCOR did not provide in the shareable data is what for or where the debris is used. This aspect of the debris data limited the ability to answer the initial research question. Overall findings showed that the GBCI companies benefited the ground user (contractors) but did the ground user prefer to use them? Logistically, it is viable and convenient for the job site to use them. It takes away the hassle of taking materials to waste deposit sites. The downside is discussed in the second question, “Is there a willingness from the project managers or ground level contractors to use GBCI companies to recycle? And if not, did they know that there were such services available for them to use?”

Figure 5 shows that of the 17 project managers surveyed, 11 of them used a GBCI recycling service, and 6 did not. This directly shows that construction companies are using recycling services that are proven to divert waste from landfills. With a majority using these services, we can assume that there is general compliance with how the materials are being recycled. If data were to hold across other job sites, then it can be inferred that 64% less debris from construction sites is directed to landfills. These numbers would have to be clarified through every jobsite waste report.
To assess the viability or willingness to use GBCI recyclers for on-the-ground workers or stakeholders within the construction (2nd research question), a survey was distributed to 35 project managers within the construction industry in San Diego, California. The survey was given to professionals that worked on job sites to determine ground-level workers’ willingness to comply or use these companies. An unwillingness to use these GBCI companies would directly affect the amount of debris and waste added to the landfills in San Diego County annually. Hiring a GBCI like SCOR Industries is not cheap. For any company within any industry or organization, competitive price points must exist to economically use certain services. If they do not see an economic benefit or cannot afford the GBCI recycler, the construction company will not use it. Instead, they will divert to past construction methods of ordering roll-off dumpsters to fill and send directly to landfills.
Data collected from the survey shows that nearly 53% of respondents agreed that their site would benefit from a GBCI recycling program. The 11 percent difference shows a staggeringly low number of respondents compared to the 64% that are using them. An assumption to this data could stem from not wanting to use GBCI programs. These programs are being used are more expensive than the older traditional methods of sending all materials and debris to the landfills in Southern California.
Findings in Figure 7 show that there is still a lag in the information on green recycling services to inform project managers of their services. Although waste recycling is nearly mandatory in California, there need to be programs that show statistical data to the on-the-ground workers that grab their attention about the harms and concerns of improper waste disposal.

SITE STUDIES & INTERVIEWS

Over two weeks at the end of January and beginning of February 2022, interviews were conducted with 2 construction sites in San Diego, CA. In general, both sites were similar in size and were non-residential projects. The first site was located next to Cal State University San Marcos, a new site for a restaurant on the bottom floor of a multi-use building. The second site was a new dining facility on Marine Corps Base Camp Pendleton. This site was a ground-up construction build that is replacing an existing structure. The importance of highlighting that the site is replacing an existing structure is that the entirety of the existing structure must be demolished. If the site was an additional building attached to the existing structure, the amount of C&D would be significantly less in overall weight and volume.

The data collected was primarily based on interviews with industry professionals within the construction industry. All sites were chosen based on familiarity with the project managers who were willing to be interviewed. The basis for the interview with each project manager was to find out their techniques within the industry to recycle C&D debris in their respective region.

For the sake of time and respect to all project managers, only 6 questions were asked to pull as much information possible from them promptly:
1. What method of Construction and Demolition (C&D) removal does your current jobsite have?
2. What method of C&D removal do you prefer, Recycle or Landfill, why?
3. Are there any incentives within your county/state for your company/client to take advantage of to utilize construction material recycling companies?
4. Are you required to recycle a certain percentage of waste materials?
5. What more could be done at any level to increase your participation of recycling debris?
6. As a project manager, are you FOR or AGAINST utilizing construction recycling companies vs. contributing to the landfill?

COMMON THEMES

The themes from both interviews were similar upon analyzing the data. Both Interview 1 and Interview 2 had regulations to follow and were mandated by the Cal Green Ordinance to recycle 65% of their site’s C&D materials. This shows that Cal Green is enforced at the municipal level. Programs and incentives are offered to offset the costs of recycling. The recycling services are not free, but the application and site overview are at no costs to the users.

Both project managers within San Diego were ultimately focused on staying on budget with their projects. According to Cal Green the costs associated with C&D recycling are more than what it would be to drop materials at a landfill. At Site 1 in Camp Pendleton, the project manager accounts for recycling when bidding costs are submitted to clients. For him, this is a method to maintain a budget for the project and meet the 65% requirement from the State of California and the City of San Diego.

Leadership in Energy and Environmental Design (LEED) projects offer a different insight into how companies go about recycling services. Within the LEED checklists, there is a portion of points that will be deducted if there is waste, C&D and other materials that are
not recycled. This could make a difference in certain levels of LEED performance. As the superintendent from Site 2 remarked, “On a LEED certified project, budget is usually too much of an issue since the building and project are most likely near the 50-to-100-million-dollar status. Most owners understand that a thousand dollar per month LEED recycling service is not going to tip the bill. If they do not understand, it is easy to persuade them in that direction.”

The project at Site 1 budgets only for generic recycling services. A GBCI company collects its dumpsters weekly and separates materials at their facility in Orange County, CA. “If the client/owner wants to recycle more, that bill is submitted directly to them,” the project manager from Site 3 states. There are many ways around this problem. Many companies and contractors have recycling services included in their bids for services. “Contractors who do not incorporate trash services into their bids are often very new to the industry,” states the project manager from Site 1.

These techniques show that stakeholder initiatives in recycling waste carry weight when proposing them to clients. If the bid for the contract already includes the prices to recycle near 100%, it may have a greater effect on having the client/owner recycle. On the other hand, if the costs for debris recycling are external to the bid (extra costs), it could be a reason for the client not to recycle.

Question 5 posed what could be done more to recycle more. The responses showed that it would require more incentives on the state/city end. The current 65% minimum recycling of C&D is a high number for most. Both project managers alluded to yearly tax incentives or legal kickbacks from the state level. “If there are more incentives for our companies to recycle C&D, we are obviously going to take advantage of them,” stated the project manager from Site 3.

Motivation to recycle on the stakeholder level comes in the form of the “what's in it for me?” mentality. Policy dictates what standard we want to set, and what standard we need to set for our safe future.
RECOMMENDATIONS

Recommendations from the findings of this study are specific to the Tucson, Arizona, sites. The following recommendations are taken from areas that have already implemented initiatives for recycling construction materials. California and Illinois provided examples of which strategies were successfully modeled. The end state of this recommendation is to show that in 10 years, growth towards a successful circular economy of construction in Tucson is completely possible if the policy is established and followed meticulously.

The 4 pillars to obtain a zero-waste construction industry in Tucson come down to creating a policy that must be followed, responsible demolition, properly recycling the materials at updated construction recycling facilities, and adapting the way we construct buildings to increase building lifecycles.

Creating Policy

Establishing, correcting, and adopting policies that mandate construction recycling in Tucson will lead to long-term success. It is proposed as a crawl-walk-run approach. The
Cal Green construction recycling initiative was not implemented until the year 2016.\textsuperscript{15} The state of California still only mandates 65% of material recycling. Policy establishment should allow for a multi-year startup phase after implementing a yearlong trial and test period for end-state companies (contractors) to fully build these new processes into their business plans and operations.

Once the year trial phase is over, the city can analyze and review how the trial period succeeded and where it needs to be fixed. The second phase will consist of a year period where 30% material recycling must be in place. The percentage increases every 3 years until a 90% material recycling is hit at the beginning of year 8. Figure 6 represents the end state goal.

![Figure 9 Recommended Policy Outline for Material Recycling Implementation](image)

**More Recycling Companies**

Trends and themes transcribed from the professional interviews were taken into serious consideration for this section. A theme amongst all project managers was “the cost of recycling vs. roll off dumpster.” To address the price related to recycling construction materials means that the city of Tucson needs more of these companies.

\textsuperscript{15} Cal Recycle 6
Economically, a rise of more businesses within an industry brings down the costs for services. By focusing on creating and increasing the amount of construction recycling business in Tucson, the more economic benefits will occur with new companies aligned with the direction the city is moving toward. With an increase in the demand for future recycling, these businesses will be able to share the load of demand, setting a fair and equitable price point for the service.

**Long Lasting Construction (Masonry and Steel)**

Arizona debatably has the harshest climate and environment in the United States. With average temperatures often above 100 degrees Fahrenheit.¹⁶ The summer months cause intense sun-degrading effects to new construction techniques like stick frames and vinyl side paneling. Building lifecycles need to increase to ensure tear down and reconstruction happen less often.

Two materials that have proven to withstand the high desert environment over the last century are masonry and metal products.¹⁷ If you consider the oldest neighborhoods and structures that are still standing in Tucson, they were constructed with a double layer of concrete masonry unit (CMU) block and brick.¹⁸

Going forward, block, brick, and metal need to be the basis of our construction here in Tucson. With an increase in concrete and masonry material recycling, it can directly


decrease the price of concrete while creating buildings that last longer than conventional stick frame buildings.

**Significance of Findings**

Looking back on what could have been done to improve this study, there can be a lot done differently. First, to gather and collect more concrete data, there needs to be more time in the field collecting numerical (quantitative) data. What would have improved this research is having 5-10 construction sites agree to host me throughout the month to observe and collect numbers and question and interview workers. Having multiple sites instead of my single site for data collection would mean a larger population for the study and more concrete data to observe. My biggest challenge was to approach private companies as an undergraduate student attempting to collect data or observe. Many companies are not willing to share construction data or methods. This research relied heavily on family and friends in the construction industry in San Diego. This shows that inside sources are much more advantageous to collect data. Future work would benefit from conducting more interviews. Proving that there is a disconnect between an unwillingness to recycle construction materials due to the cost of recycling can be done through further qualitative research (professional interviews).

**CONCLUSION**

Adopting a new policy to implement a construction waste management plan is vital to creating zero-waste for the industry. Three major takeaways were discovered when conducting this study. First, responses from construction industry professionals showed common themes that the stakeholders on the ground do not care about recycling: recycling is seen as expensive, time-consuming, and a hindrance to completing jobs faster.

Secondly, it is possible to create effective and easy to follow policy. The California model of construction recycling shows that at a minimum, 65% of jobsite debris can be
recycled. Creating policy like this allows more businesses to be created and jobs to open as the recycling industry will grow within Tucson. The only job the onsite workers have is to separate specific materials into their own dumpster. This takes the pain away from construction companies as it is hired out to GBCI recycling companies. The common theme of costliness should no longer an issue due to the calculation of the recycling services in the bidding.

Lastly, achieving zero-waste within the industry will not happen overnight. The process in California is still at 65%, and it is in its sixth year of implementation. The crawl-walk-run phase is not in full stride until the 8th year of implementation. It is a painstaking process that will take time to come to fruition, but the plan needs to be implemented sooner than later to end the constant battle of creating new material.
REFERENCES


### APPENDICES

<table>
<thead>
<tr>
<th>Question 2 - How much debris/waste is your site producing monthly?</th>
<th>Q3 - Do you currently use a Green Business Certification company to collect...</th>
<th>Q4 - Would your project benefit from a LEED certified company to properly recycle...</th>
<th>Q5 - Have you been cited for improper waste at your current jobsite?</th>
<th>Q6 - Were you aware that there are LEED companies that specialize in construction...</th>
<th>Question 1 - Are you currently managing/working on an adaptive reuse construction site?</th>
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**Total Waste Diverted:** 100000.4 lbs

Appendix 2 Site 1 Waste Report
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<th>Question 1</th>
<th>Interview 1 (San Marcos)</th>
<th>Interview 2 (Camp Pendleton)</th>
<th>Interview 3 (Tucson)</th>
<th>Themes/Pattems</th>
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<tbody>
<tr>
<td>Method of Trash/Debris Removal</td>
<td>Utilizes a GBCI recycler</td>
<td>Utilizes a roll off dumpsters</td>
<td>Roll off dumpster</td>
<td>Dumpsters</td>
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<td>Personal Preference of Method</td>
<td>Easier to utilize recycling company to collect debris due to restrictions of landfill use.</td>
<td>Best to utilize what is best for the job. Sometimes it’s easier to utilize roll off dumpsters that take debris directly to landfill if it means that it can leave the site within the day. Majority of the time, recyclers take some time to get to a site.</td>
<td>Whatever is the cheapest and most effective method for debris removal on the job site.</td>
<td>Didn’t really care</td>
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<td>Incentives to recycle within State/County</td>
<td>There are recycling incentives that apply to recycling materials, but they contribute to the owner not the builder.</td>
<td>Refundable recycling deposits, but you must use certified recyclers that are on the City’s website</td>
<td>Possible LEED</td>
<td>Owner incentives</td>
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<td>Is there any requirement?</td>
<td>In California there is no actual mandates at the state level. Although certain counties can have ordinance that follow Cal Green Building Initiative. In San Diego it is 65% of waste must be recycled and diverted from landfills.</td>
<td>65% although this site is above 90%</td>
<td>LEED Requirement Almost zero waste</td>
<td>none</td>
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<td>What could be done to facilitate your sites to recycle more or near 100%?</td>
<td>Contractor rating system. Maybe end of year tax incentives for the business.</td>
<td>Tax incentives</td>
<td>More incentives</td>
<td>Incentives</td>
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<td>For or against? Why?</td>
<td>Doesn’t really care. If the client is willing to pay for a recycling service than that is on them.</td>
<td>For. It allows our industry to stay healthy and provide services that will keep us in business. We always bid jobs that utilize recyclers.</td>
<td>Didn’t care</td>
<td>2 don’t care 1 for</td>
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Appendix 3 Interview Results