Review

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Towards Sustainable Construction Development: A Qualitative Review

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Abstract: The construction industry plays a crucial role in shaping the built environment and contributes to the global economy. However, the construction process is associated with negative impacts on the environment and communities. This paper examines the environmental impacts of construction and presents strategies for mitigating them, focusing on sustainable construction practices. The research draws on a comprehensive literature review, case studies, and expert interviews to fully understand the construction industry and its environmental effects. The findings indicate that the implementation of greater supervision of every construction project phase, using alternative design practices, and the use of sustainable construction practices can reduce the negative impacts of construction on the environment and society. The study concludes that sustainable construction practices can contribute to a better environment for a better quality of life and should be embraced by the construction industry. The recommendations for future work include the adoption of green building standards, the use of renewable energy sources, the reduction of waste, and the promotion of stakeholder engagement. Future research should focus on the evaluation of the effectiveness of these strategies and their scalability.

Keywords: sustainable construction; environment impacts; global economy; renewable energy; construction industry

Introduction and Literature Review

Construction, which combines different elements, using a detailed design and plan to create a structure for a certain location, is a fast-growing industry (Cover 2020; Omar and Muthusamy 2022). Construction not only allows the human right to housing, recognized in the Universal Declaration of Human Rights, but construction is critical to connecting communities and improving society overall. The construction industry serves as a community-building block and contributes greatly to a community's economic health (Quinn 2013; Iberdrola 2021). Though many benefits arise from construction, there are also disadvantages. One of the biggest disadvantages of construction is its environmental impact. Negative environmental impacts occur when there are negative changes to the natural environment from an activity, which causes adverse effects on many elements, such as air, water, land, and even the quality of human life. Some ways construction harms the environment include waste, air, water, and noise pollution (Muslemani et al. 2021). If the harmful impacts of construction continue with no solution or are lessened, there will be no habitable Earth for future humans to live on. However, not all hope is lost, due to the concerns of many architects and engineers worldwide.

One of the negative impacts of construction is waste. What exactly is construction waste? Waste can be defined as "…any materials by-product of human and industrial activity that has no residual value" (Nagapan et al. 2011). Construction waste may come in many forms, such as "…building debris from demolition process, rubble, earth material, concrete waste, steel waste, timber waste, and mixed site clearance construction materials, arising from different construction activities of the project including land excavation or formation on site, civil and building construction materials, site clearance waste, demolition activities waste, roadwork waste, and building renovation waste" (Gulghane and Khandve 2015).

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It can be assumed that construction waste may be generated throughout the entirety of the construction phases, whether they are adding or demolishing, considering how much material is needed. But what are the origins of construction waste? Researchers M. Osmani and J. Glass from Loughborough University suggest that construction waste starts when design changes frequently occur. They state that "…design changes (including variations) occurring whilst construction is in progress are key origins of construction waste production" (Osmani et al. 2008). This boils down to change orders. This occurs when there are unanticipated conditions at the job site, if specifications are inaccurate, and most importantly, if design changes may be decided by the project owner. This results in a change order, which is a document that entails changes to the scope of work, which then impacts the project's schedule, and cost. Ultimately, waste accumulates due to needing to add or demolish current parts of the project already built. Another unforeseen cause of waste can also be "…due to: 'poor communication' leading to mistakes and errors; and 'overlapping of design and construction', which further complicate the management of the design process and moves waste prevention issues to the bottom of the priority list" (Osmani et al. 2008). Thus, "Waste has direct impact on the productivity, material loss and completion time of project resulting in loss of a significant amount of revenue" (Hussin et al. 2013) (Figure 1).

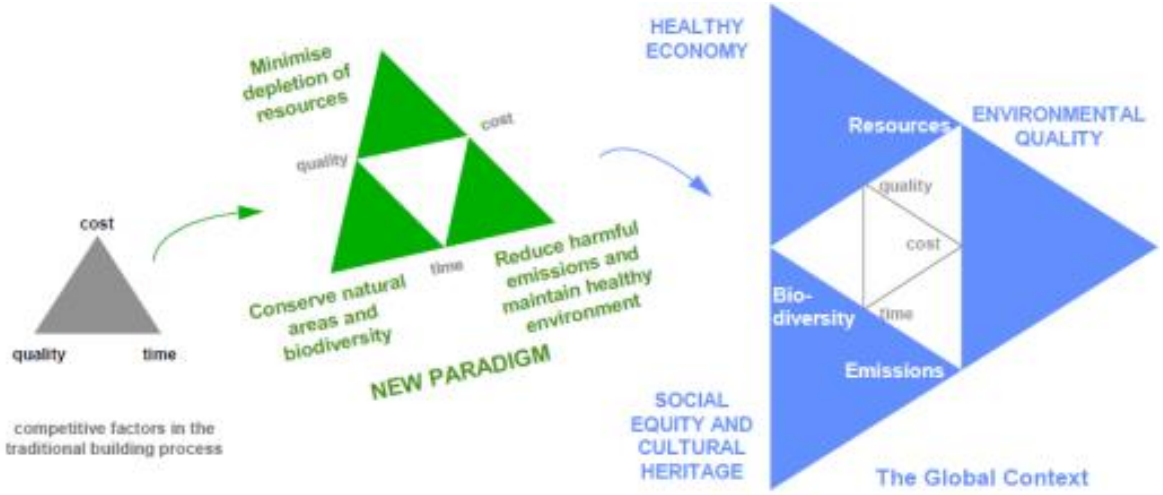

Figure 1. The evolution of sustainable construction (Hussin et al. 2013).

Not only does it hurt the overall project, but it also hurts the environment. Some negative impacts include "…soil contamination, water contamination, energy and natural resources consumption, environmental degradation, and landscape deterioration (Tafesse 2022) (Figure 2). This is because the waste and its chemical makeup seep into the Earth and may also runoff into the groundwater and nearby waterways, which in turn contaminates freshwater supplies and makes it undrinkable for communities. Furthermore, "It is very difficult to dispose of C&D waste as it contains hazardous matters such as asbestos, heavy metals, persistent organic compounds, and volatile organic compounds when compared to household waste" (Polat 2017), which is why is often dumped into landfills to protect communities from contaminants. However, even then, landfills also pose environmental problems because "According to statistical data, C&D waste constitutes nearly 10–30% of the waste received at many landfill sites around the world" (Polat 2017).

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Figure 2. Waste of Construction Materials (Tafesse 2022).

Another negative impact of construction is air pollution. Pollution from construction can be defined as contaminants from construction sites that are released into the environment and have harmful or poisonous effects. Throughout the entire construction project life cycle, harmful contaminants are released into the environment. This can occur from the beginning stages, such as the product stage, which includes potential harmful pollutants within the "…raw material supply, transport, or manufacturing" (Wieser et al., 2021 and Schuldt et al. 2021). To the construction process stage, where the construction activities occur. With all of the cutting, drilling, sanding, etc. with the construction equipment and machinery, lots of particulate matter is released into the air. Particulate matter (PM) are microscopic solid and "…is one of the most common air pollutants globally..." (Singh and Rout, 2018 and Wieser et al., 2021). This includes dust, dirt, or soot that is released into the air from the construction during the project. Because the particles are so small, inhaling particulate matter can cause long-term health issues such as respiratory illness. This not only the construction workers themselves but also the surrounding neighborhoods. Not only do the construction equipment and machinery release particulate matter, but many of those equipment and machinery use gasoline, which is a non-renewable resource. This means that once the gasoline has been used up, it cannot be replaced or regenerated. Because gasoline is a natural resource, it will be difficult to replenish at the same speed it was consumed, so it is not efficient. Furthermore, when gasoline is burned, it produces carbon dioxide. Too much carbon dioxide in the air causes air pollution and the global temperature to rise. Even the close-out and occupancy stage of a construction project can release pollutants because "Buildings consume a lot of energy in their use stage and emit pollutants throughout this period. Heating, ventilation, and air-conditioning (HVAC) systems thus also play an important role within the use stage and can affect especially indoor air pollution (Wieser 2021)."

Construction projects can also cause water pollution. With the leftover materials from a construction site, if there is a nearby body of water, those materials can run into that body of water and contaminate the water. This is especially a problem if nearby neighborhoods use that body of water as their drinking water. According to researchers Belayutham et al. 2016, "Sediment is the most significant pollutant from the construction site as it could potentially affect all the three dimensions of sustain-ability i.e., economic, environmental and social simultaneously". This, in turn, "…may cause flooding, clogging of the current drainage system, reduction of groundwater recharge and destruction to natural aquatic" (Belayutham et al. 2016). For example, researchers from the University of Texas at Austin researched extensively the environmental effects of highway runoff. In their research, they found that there are some considerable effects of highway runoff, including water

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pollution. If the highway is near a body of water, dirt, dust, and other harmful materials can find their way into that body of water. The researchers state that "Particulates and sediment in runoff also can cause problems by decreasing flow capacity in drainage ways, reducing storage volume in ponds and lakes, smothering benthic organisms, decreasing water clarity, and interfering with the respiration of small fish. Furthermore, toxic materials often are sorbed to and are transported by suspended solids. These toxins include metals, hydrocarbons, chlorinated pesticides, and PCBs, and they present acute and chronic threats to receiving water organisms" (Barrett 1995). Because highway construction is an enormous project, yet highly critical for transportation, solutions must be taken quickly, or the negative effects of the construction will become too difficult to control.

Lastly, construction projects can cause noise pollution. It is evident that while construction is occurring, the noise level is extremely high. This can be an annoyance to nearby neighborhoods, but there are many layers to this problem. For those who live in urban areas, such as New York City, this is an even greater problem, because of the other noise that already occurs, such as the traffic. The most negative effect of noise pollution is the health effects. The article states that, "Such levels have proven effects on health, including sleep disruption, hypertension, heart disease, and hearing loss (Bello, 2019)." Not only can the noise be harmful to surrounding neighbors, but to the construction workers as well, those who are in direct contact with the source.

The negative health impacts include "…loss of voice, unintelligible speech hearing impairment, stress, loss of attention, hypertension, enhanced blood pressure immunity effects, biochemical effects, cardiovascular disease, annoyance, sleep disturbance, and vascular system diseases". The construction workers are the most vital stakeholders of the project because they are the people who physically build the entire project from the ground up. These workers should be valued, and not the ones who have to deal with the most consequences of a project. Thus, solutions must be taken to protect both the neighbors and the most valued people on the job. One article suggests that "Noise can be mitigated at the receiver's end by, say, wearing earplugs or along the transmission path by, say, erecting sound barriers along major roads. These strategies do not, however, reduce noise emissions but instead put the burden of mitigation on the receiver.

Alternatively, noise can be mitigated at the source (such as by designing aircraft with quieter engines, acoustically treating night clubs, muffling jackhammers for roadwork, and stopping unnecessary honking" (Bello 2019) However, this is very difficult to do in a large urban area, where millions of citizens live. How can architects, engineers, and contractors help the millions of citizens in one enormous city? Sustainable construction hopes to lessen negative environmental impacts. It is defined as creating a healthy built environment using resource-efficient, ecologically based principles and aims to tackle economic, environmental, and social sustainability (Hussin et al. 2013; Oliver et al. 2014).

The objectives of this paper are to examine the environmental impacts of construction and to present strategies for mitigating them focusing on sustainable construction practices. The research draws on a comprehensive literature review, case studies, and expert interviews to fully understand the construction industry and its environmental effects.

Synthesis of Literature and Discussion

The rising amount of waste that ends up in landfills, and areas that affect human health have raised many concerns among professionals in the architecture, engineering, and construction industry. Thus, many solutions have been proposed and implemented to help mitigate waste in many projects around the world in both the environmental design and construction phases areas. The AEC industries have developed "Various approaches for managing construction wastes … and these project works can be grouped largely into three areas mainly classification of waste, management strategies for waste and disposal technologies for waste" (Gulghane and Khandve, 2015).

One solution is waste management, which refers to the action and process of attempting to control and mitigate waste from the planning phase to the final construction phase. This means that a waste manager or management team will oversee solely attempting to minimize the waste generation throughout the entire project. Effective strategies include "…reduce waste generation,

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maximize reusing, and recycling, reduce the intake of mixed construction waste at landfills" and "… the maintenance of a well-managed public filling program with sufficient facilities and access" (Gulghane and Khandve 2015). Furthermore, even some governments try to give incentives for construction companies to mitigate waste.

In Hong Kong for example, the construction waste charging scheme provided passed on 2005 provide "…financial incentives to C&D waste generators to reduce waste and encourage reuse and recycling (Gulghane and Khandve, 2015). Other government incentives from all over the world, including the United Stares include "…Landfill tax, higher tax for using virgin construction materials, tax credits for recycling, etc." (Gulghane and Khandve, 2015). If there is someone closely monitoring the waste at all time, there will be better effectiveness in controlling the amount of waste produced throughout the project as well as a better plan on how to get rid of that waste.). By implementing waste management, "…the implementation of waste reduction initiatives during construction work saves costs and reduces environmental impacts" (Tafesse 2022).

Another solution to waste falls more on the design phase of the construction project. Professors Osmani, Glass, and Price, have observed that thinking about waste management during the design phase of a project is often overlooked and not considered a priority. This is because waste is thought to have some correspondence with the physical building in the project. Although this is somewhat true, the professors have discovered that "…about one-third of construction waste could essentially arise from design decisions" (Osmani et al. 2008). If the architects do not design the project in a more sustainable way, which doesn't use as much waste, there may be in turn more waste overall. Thus, construction waste reduction by design should be a considered solution. Architects should consider reviewing waste reduction during designing by "…undertaking waste reviews at key design stages; waste reduction opportunities; use of reclaimed material; use of prefabricated and off-site preparation of materials; and use of standardized components" (Osmani et al. 2008).

This suggests architects need better overall coordination. Through coordination and communication, architects should be involved in all stages of the construction project. This includes being involved and knowledgeable when it comes to initial site surveying so architects can understand the possible waste that may occur and design around that. All in all, reducing waste requires cooperation from all stakeholders, and there must be cohesiveness among all to effectively carry out waste management from all phases of a construction project.

To help mitigate overall air pollution during construction, there needs to be better measures and initiatives taken throughout the entire life cycle of a building. This could include "…a reduction of transport activities together with better management of construction sites or construction schedules in a city to optimize distances and avoid traffic jams, which can contribute to higher emissions. Further measures include shortening the distances for the transport of building materials by using local enterprises and services and using regional building materials. Technical measures and improvements such as the humidification of tires on construction sites to prevent dust emissions or the optimization of construction site equipment to protect residents and neighbors from dust and noise can be helpful" (Wieser et al. 2021). As for particulate matter mitigation, "Identifying the sources of construction dust can assist project managers in adopting targeted effective measures to mitigate dust generation. For example, in an earthwork activity, by knowing the sources of dust generation, the project managers can pay intensive attention to the soil excavation and transportation" (Wu et al. 2016). In addition, all stakeholders should be involved in the mitigation process, and they must all cooperate in order for the process to be successful (Figure 3).

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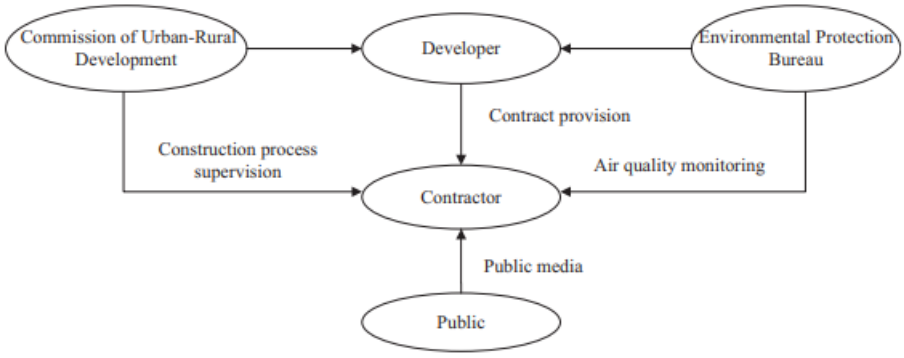

Figure 3. Framework for monitoring construction dust pollution (Wu et al., 2016).

The researchers have proposed that "The control of pollution from highway runoff can be accomplished by both source management and control measures. Examples of source management are transportation and land use planning and highway design and operation. Structural controls include vegetative practices, ponds, infiltration methods, wetlands, and filters" (Barrett, 1995). Though the use of cars is the main source of transportation in countries like the United States, it is not as efficient in terms of being environmentally friendly. Having one single-family drive one or multiple cars, increases the number of vehicles on the highway, therefore possibly increasing the risk of water pollution. The use of public or mass transportation, such as using the train or bus, can reduce traffic congestion and fuel consumption, which in turn, may reduce the total vehicles traveling on the highway. Therefore, there is a decrease in the amount of runoff of sediment. Governments need to push and popularize the use of public transportation or provide an incentive for the citizens to cooperate. Furthermore, improved highway design may also lessen the effects of water pollution by generating ideas on how to prevent sediments from flying off the highway into those body of waters.

In places like New York City, SONYC (Sounds of New York City) is a project that has been attempting to mitigate noise pollution. This project/system aims to create technological solutions to noise pollution in New York City by integrating sensors, machine listening, data analytics, and citizen science (Bello 2019). The goal of the project is to "…improve urban-noise mitigation, a critical quality-of-life issue, SONYC promises to benefit urban citizens worldwide. Our agenda calls for the system to be deployed, tested, and used in real-world urban conditions, potentially resulting in a model that can be scaled and replicated throughout the U.S. and beyond" (Bello 2019). SONYC serves as a pivotal moment of research in noise pollution, because noise pollution is often overlooked compared to air or water pollution. After all, it is not visible to the human eye. SONYC is one step closer to helping both neighbors and construction workers increase their quality of life.

Sustainable construction is the means of using recyclable and renewable materials in projects, along with minimizing energy consumption and waste at the same time. It involves creating a healthy built environment using resource-efficient, ecologically based principles. Sustainable construction can be applied to any of the negative impacts discussed: waste, air, water, and noise pollution. This approach aims to tackle economic, environmental, and social sustainability. It provides a holistic view of the entire construction process, from design to disposal, and promotes the use of materials that are environmentally friendly and socially responsible. While sustainable construction focuses on all aspects of the effects of sustainability, including the people and financial implications; the topic is much deeper. Green building practices on the other hand, focus more on the environmental impacts of construction.

For example, in the topic of the negative impact of waste from construction projects, the use of green building practices is better the overall environment because of its objectives to "… minimize the emission of toxic substances throughout its life cycle, harmonize with the local climate, traditions, culture and the surrounding environment. Green buildings are able to sustain and improve the quality of human life whilst maintaining the capacity of the ecosystem at local and global levels. Green buildings have many benefits, such as better use of building resources, significant operational

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savings, and increased workplace productivity" (Hussin et al. 2013). Green buildings utilize practices that are both environmentally friendly and resource-efficient. Architects analyze the link between each component and stage of the project: long-term costs, construction, building functions, and operation/maintenance.

The UC Davis Manetti Shrem Museum of Art serves as a great example of green building practices being used in real life. From the start of construction in 2014, to its completion in 2016, this 32,000 sq. ft. contemporary art building embodies what it means to be green. The United States Green Building Council, who oversees and facilitates the LEED ratings for buildings, rated the museum a platinum score, the highest tier of 86 points. They were given this rating due to its remarkable achievements in sustainability including a 58% reduction in energy use from baseline, a 44% reduction in water use through efficient fixtures, a 57% reduction in irrigation water use through drought tolerant plant species and drip irrigation, use of a reflective roof to reduce heat island effect while minimizing light pollution (Figure 4).

Figure 4. UC Davis Manetti Shrem Museum of ART (Source: U.S. Green Building Council).

Furthermore, "During construction, 81% of waste was diverted from landfill and 20% of the site's building materials were recycled. The museum also provides access to parking, fueling stations, and public transportation, as well as walking and biking access to campus core and downtown" (*UC Davis Manetti Shrem Museum of ART | U.S. Green Building Council*). This museum serves as a great example of when creativity meets innovation and serves as a legacy for green building projects. Thus, sustainable construction strategies offer viable solutions to reduce the environmental impact of construction activities. As such, it is necessary to continue exploring innovative approaches that align with sustainable construction principles, to create a more sustainable future for our communities and our planet.

Conclusions

The construction industry plays a crucial role in the development of communities and their economic growth. However, it also has a significant impact on the environment, particularly in terms of waste generation. The accumulation of construction waste can lead to soil and water contamination, energy and natural resources consumption, environmental degradation, and landscape deterioration. Additionally, the disposal of construction waste presents further environmental issues as hazardous materials are often included. This, in turn, affects the health and well-being of nearby communities, making it essential to address the negative environmental impact of construction. It is crucial to address the negative impact of construction on the environment and

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the health of nearby communities. Sustainable construction and waste management strategies offer viable solutions to reduce the environmental impact of construction activities. As such, it is necessary to continue exploring innovative approaches that align with sustainable construction principles, to create a more sustainable future for our communities and our planet. We need to continue to make the Earth habitable for our future humans.

Recommendations for Future Work

Mitigating the negative impacts of construction is crucial to ensuring sustainable development. Given by what was discovered in the scope and methodology, there are many recommendations for future work. First, there should be an increase in the use of renewable materials. These materials are sustainable and can reduce the amount of waste generated during the construction process. The second, is to implement green building practices. The construction industry should adopt green building practices such as reducing energy consumption, using sustainable building materials, and incorporating sustainable design principles. Third is to promote sustainable transportation: Transportation is a major contributor to carbon emissions, and the construction industry is no exception. Therefore, promoting sustainable transportation such as public transport, cycling, and carpooling can reduce the environmental impact of construction by reducing the amount of vehicle traffic. Finally, stakeholders need to be educated. Educating stakeholders such as architects, engineers, contractors, and clients about sustainable construction practices is critical. This can help to promote sustainable construction practices and create a culture of sustainability in the construction industry. All of these recommendations should be carefully researched to fully understand what it means to change the negative impacts of construction and find better ways to maximize the quality of life.

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