BOARD #119: The Role of Educating the Future Construction Workforce in Sustainable Practices for Effective Disaster Recovery

Claudia Calle Müller, Florida International University

Claudia Calle Müller is a Ph.D. Candidate in Civil and Environmental Engineering at Florida International University (FIU). She holds a B.S. in Civil Engineering from Pontificia Universidad Católica del Peru (PUCP). Claudia has over 4 years of experience in structural engineering designing reinforced concrete residential and commercial buildings in Peru; over 2 years of experience in entrepreneurship; and over 4 years of teaching experience. Currently, she is a Graduate Research Assistant and Teaching Assistant at the Moss School of Construction, Sustainability, and Infrastructure at FIU where she focuses on multidisciplinary research on sustainability, equity, resilient and sustainable post-disaster reconstruction, engineering education, circular economy, and well-being. Claudia holds professional credentials in LEED Green Associate for sustainable buildings and ENV SP for sustainable infrastructures.

Mr. Mohamed ElZomor P.E., Florida International University

Dr. Mohamed ElZomor is an Assistant Professor at Florida International University (FIU), College of Engineering and Computing and teaches at the Moss School of Construction, Infrastructure and Sustainability. Dr. ElZomor completed his doctorate at Arizona

The Role of Educating the Future Construction Workforce in Sustainable Practices for Effective Disaster Recovery

Abstract

The construction industry is crucial for driving economic growth, advancing social development, and protecting the environment of communities globally. As such, it plays a key role in sustainable development. However, the environmental footprint of the built environment is significant, accounting for 40 percent of global energy consumption and 33 percent of greenhouse gas (GHG) emissions. Natural disasters further exacerbate this impact by causing widespread destruction, resulting in material waste, increased resource consumption, and emissions during reconstruction. Therefore, achieving environmental improvement and promoting sustainable construction practices, including circular construction and life-cycle assessments (LCAs), is critical for reducing the industry's environmental footprint and fostering a more responsible built environment. To achieve sustainability goals in the construction industry, it is essential to equip the future construction workforce with knowledge and skills related to sustainable construction practices. The goals of this study are to (1) understand the impact of natural disasters on communities, including damages and recovery efforts, and explore the potential for implementing sustainable practices, such as circular construction, in post-disaster recovery by interviewing 109 stakeholders in disaster-prone communities; and (2) investigate the knowledge gap among civil engineering (CE) and construction management (CM) students regarding sustainable construction practices, as well as the significance of integrating sustainable topics into CE and CM curricula through 121 student surveys. The results of this study underscore the benefits of incorporating sustainability in post-disaster recovery. Furthermore, they highlight the knowledge gap among CE and CM students regarding sustainable practices, including circular construction, as well as the benefits of equipping the future construction workforce with such knowledge and skills to enhance both professional success and tackle environmental challenges. The findings of this study contribute to the field of sustainable construction by advocating for curriculum revisions that integrate sustainable practices. By preparing the future construction workforce to adopt sustainable practices and focusing on their implementation in post-disaster recovery, this study addresses key sustainable development goals (SDGs) and supports efforts to create a more responsible built environment. Furthermore, these efforts benefit communities and stakeholders by fostering sustainable reconstruction that not only reduces environmental impact but also has the potential to reduce the cost of reconstruction.

Keywords: Built Environment, Circular Construction, Construction Industry, Education, Life-Cycle Assessment, Natural Disasters, Resilience, Sustainability, Sustainable Development Goals (SDGs)

Background and Motivation

The construction industry is essential for fostering social and economic growth while safeguarding the environment, making it a critical contributor to sustainable development [1], [2]. However, infrastructure requires vast amounts of resources and energy throughout its life

cycle. Additionally, it generates waste, consumes significant amounts of water, occupies land, and is ultimately demolished, further exacerbating waste production [3]. As a result, the construction industry has a substantial environmental footprint, accounting for 40% of global energy consumption, 30% of raw material use, 25% of solid waste generation, and 33% of greenhouse gas (GHG) emissions [2], [4], [5], [6], [7], [8], [9], [10].

Natural disasters further amplify these impacts and challenges. These destructive events cause widespread infrastructure damage, loss of life, and socioeconomic disruption, posing barriers to achieving sustainable development [11], [12], [13], [14], [15], [16]. Furthermore, they result in vast amounts of construction and demolition waste, along with increased resource consumption and emissions during reconstruction [17], [18], [19]. Consequently, the construction industry faces significant environmental concerns and immense pressure to minimize resource depletion and socio-environmental impacts while enhancing resilience to disasters, thereby reducing vulnerability and fostering long-term sustainability [7], [11], [12], [14], [20], [21], [22], [23].

The construction sector is deeply committed to pursuing a sustainable path by reducing emissions, material use, and energy consumption [1], [21], [24], [25]. Key strategies for achieving these goals include implementing sustainable practices such as (1) life-cycle assessments (LCAs), which evaluate and quantify the environmental impact of buildings throughout their entire life cycle; and (2) circular construction, which involves reducing the use of natural resources, reusing and recycling materials, recovering materials, and adopting effective waste management systems. These practices are essential for minimizing the industry's environmental impact and fostering a more responsible built environment [1], [2], [4], [6], [7], [20], [26], [27], [28], [29], [30].

Advancing sustainability efforts and achieving sustainable development goals (SDGs) in the construction industry necessitates significant changes in current industry practices [26]. Achieving these goals requires all stakeholders to understand the environmental impact of construction and become familiar with sustainable practices. For this reason, it is essential to equip the future construction workforce with knowledge and skills related to sustainable construction practices, as they will be key contributors to this transition. Educating civil engineering (CE) and construction management (CM) students in sustainable practices, including circular construction, sustainable materials, LCAs, sustainable technologies, and strategies to overcome barriers to sustainable construction, while incentivizing this critical shift, is paramount.

This study aims to (1) examine the effects of natural disasters on communities, focusing on damage and recovery processes, and assess the feasibility of incorporating sustainable practices, such as circular construction into post-disaster recovery efforts through interviews with over 100 stakeholders from disaster-prone areas; and (2) identify gaps in knowledge among CE and CM students concerning sustainable construction practices while assessing the importance of integrating sustainability-related topics into CE and CM curricula through student surveys.

Methodology

This study is guided by three research questions: (1) What are the impacts of natural disasters on communities, particularly in terms of damage and recovery processes? (2) How can sustainable practices, such as circular construction, enhance post-disaster recovery efforts, and what challenges must be addressed for their adoption? And (3) What knowledge gaps exist among CE and CM students regarding sustainable construction practices, and how do they perceive the importance of acquiring such knowledge?

To address these questions, this study (1) collected interview data from 109 stakeholders in disaster-prone areas to examine the impacts of natural disasters on communities and evaluate the potential and feasibility of adopting sustainable practices in post-disaster recovery; and (2) surveyed 121 CM and CE students to identify knowledge gaps related to sustainable construction practices and assess their perceptions of their importance. Purposive sampling was employed, using a judgmental approach to select participants deemed most relevant to the research objectives. The study employed a mixed-methods sequential explanatory approach to gather and analyze both quantitative and qualitative data.

Semi-Structured Interviews

The authors developed a semi-structured interview with open-ended questions to explore the impacts of natural disasters, recovery processes, the importance of sustainable practices like circular construction, and the challenges faced by stakeholders in implementing these practices. Participants included project managers, contractors, consulting engineers, forensic engineers, city code inspectors, sustainability professionals, insurance agents, lawyers, and homeowners. The interview data were analyzed using a qualitative content analysis approach. All interviews were transcribed into Word documents to ensure accurate documentation of participants' responses, providing a detailed record of the conversations. These transcriptions were carefully reviewed to identify key themes and insights. A structured table was developed to systematically categorize and organize the data under three main headers: (1) impact of disasters on infrastructure and communities; (2) challenges in recovery efforts; and (3) sustainable practices and barriers to adoption. Finally, the findings were synthesized to provide a comprehensive summary of the key insights shared by the participants.

Surveys

The study developed and administered a survey on the online platform Qualtrics. A mixed-methods sequential explanatory design was utilized to collect and analyze both quantitative and qualitative data. The survey included a demographic section and four questions. The first question, a yes/no format, examined students' awareness and familiarity with circular construction and sustainable practices. The second question invited students to mention a practice they believed could support the transition to sustainable construction in an open-ended format. The third question, a Likert scale question (1=not at all important to 5=very important), assessed students' perceptions regarding the importance of incorporating circular construction and sustainability topics into CM and CE curricula. Finally, the fourth question, also a Likert scale question (1=not at all important to 5=very important), aimed to identify effective teaching

methods for educating students on these paramount topics. Figure 1 presents the research overview.

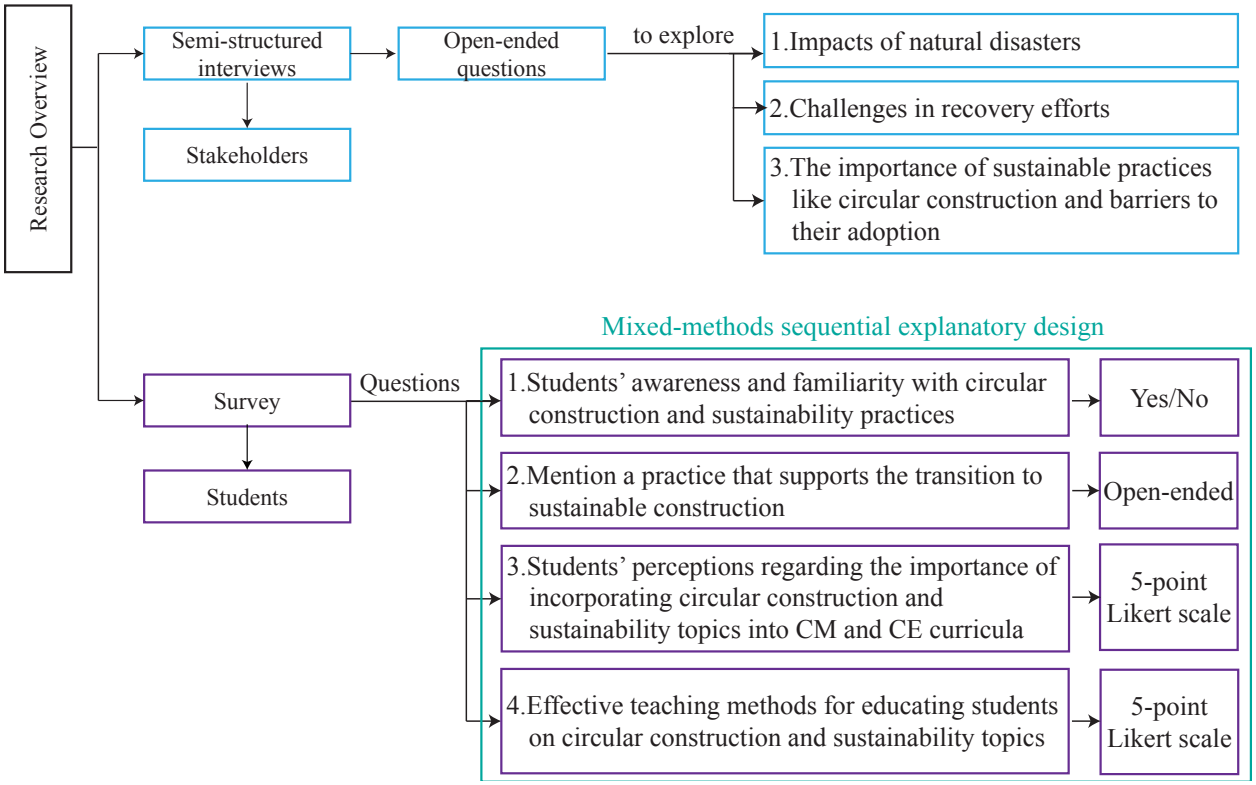

Figure 1. Research overview

Results and Discussion

This section presents the results associated with the responses of 109 stakeholders and 121 CE and CM students. The recorded data included a diverse group of students and stakeholders, as presented in Figure 2. Among stakeholders, the sample included (a) 25 females and 74 males, as well as a diverse group of professionals, including 29 consulting engineers, 24 contractors, 12 forensic engineers, 8 project managers, 4 sustainability professionals, 4 insurance agents, 4 lawyers, 3 city code inspectors, and 21 homeowners. Among students, the data included 19 civil engineering (CE) students and 102 construction management (CM) students, with 28 females, 77 males, 2 non-binary/gender fluid individuals, 1 individual who identified themself as other, and 13 students who preferred not to answer.

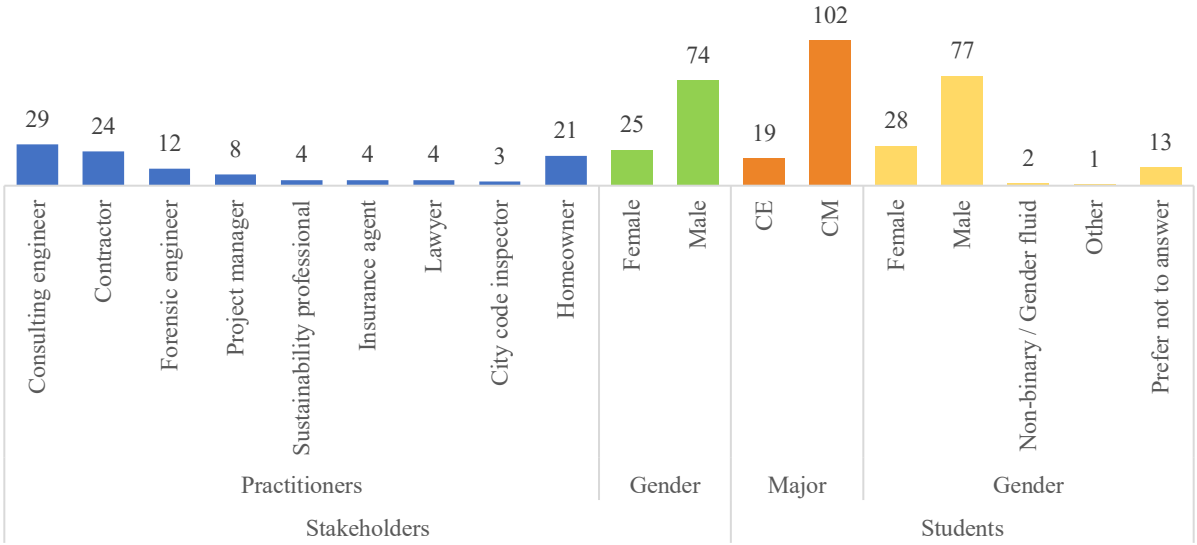

Figure 2. Sociodemographic background (n=230)

Semi-Structured Interviews

Insights from the interviews, which involved diverse stakeholders including project managers, contractors, consulting engineers, forensic engineers, city code inspectors, sustainability professionals, insurance agents, lawyers, and homeowners, reveal the following:

- **Impact of disasters on infrastructure and communities**
  Natural disasters often lead to widespread destruction of homes and critical infrastructure, severely disrupting daily life. Interviewees frequently mentioned damages such as roof collapses, structural failures, and severe flooding. These destructive events place significant financial strain on affected communities due to high repair costs, loss of livelihoods, and prolonged delays in receiving insurance payouts or financial aid. Additionally, communities face displacement, limited access to essential services like food, electricity, and water (FEW), and the exacerbation of mental health challenges, including stress and trauma.

- **Challenges in recovery efforts**
  Recovery efforts encounter several obstacles that hinder efficient and quick rebuilding. These include: (1) delays in government aid and insurance payouts, which can take several years, leading to prolonged recovery timelines; (2) material shortages and increased demand for construction materials, which drive up costs and slow reconstruction; (3) a shortage of skilled workers to execute reconstruction projects; and (4) vulnerabilities in poorly designed or inadequately maintained infrastructure, which exacerbate damages during disasters.

- **Sustainable practices and barriers to adoption**
  The interviews emphasized the transformative potential of sustainable practices, such as circular construction and deconstruction, with offer benefits such as material reuse, waste reduction, and lower reconstruction costs. Participants provided examples of effective

practices like recycling materials, implementing green infrastructure, and utilizing energy-efficient designs. However, significant barriers to adoption remain, including high initial costs, limited skilled labor, and a lack of cultural acceptance or policy frameworks to support circular construction practices. Additionally, concerns about contamination in reused materials and the safety of recycled components pose challenges that must be addressed to foster trust and wider implementation. Education about sustainable practices and their benefits for communities and construction professionals plays a pivotal role in overcoming these challenges and driving a broader adoption of circular construction.

Surveys

The first question assessed students' awareness and familiarity with circular construction and sustainable practices. The findings, presented in Figure 3, reveal significant awareness among students regarding the environmental impact of the construction industry, with 95% (115 individuals) acknowledging this impact. Additionally, 79% of students (95 individuals) are aware of the challenges and costs involved in transitioning to sustainable construction and 86% consider environmental improvement a critical goal for the construction industry.

However, despite this importance, the results also highlight critical gaps in knowledge and education, with 24% of students (29 individuals) unable to precisely describe sustainable construction and 71% (86 individuals) unable to precisely describe circular construction. Furthermore, 61% of students (74 individuals) reported that their academic institutions did not include education on circular construction, suggesting a need for enhanced curricula to bridge this gap.

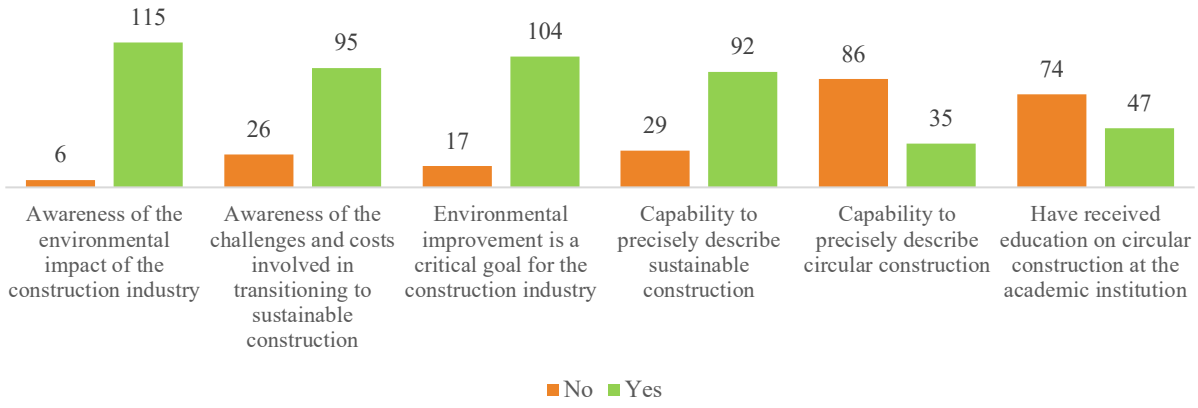

Figure 3. Awareness and familiarity with circular construction and sustainable practices

The second question prompted students to mention a practice they believed could facilitate the transition to sustainable construction. Students mentioned several practices including: (1) recycling and reusing materials as well as adopting green materials and construction techniques; (2) minimizing construction waste and implementing effective waste management strategies; (3) reducing carbon emissions from cement production; (4) employing LCAs to evaluate and mitigate the environmental impact of buildings across their lifespan; (5) repurposing unused or unfinished structures; (6) limiting reliance on diesel-powered equipment, promoting the use of electric vehicles and machinery, and integrating renewable energy sources like solar and wind

power; and (7) incorporating design strategies for disassembly. Notably, 60% of students (72 individuals) indicated that they were unfamiliar with any practices related to sustainable construction.

The following question assessed students' perceptions of the significance of integrating circular construction and sustainability topics into CM and CE curricula. According to the results of the study, shown in Figure 4, 48 students rated this as very important, 24 as fairly important, and 36 as important, indicating strong support for the inclusion of these topics. A smaller portion of students expressed lower levels of importance, with 9 rating it as slightly important and 4 as not at all important. This distribution highlights a generally positive attitude among students toward integrating sustainability and circular construction into academic programs, with the majority acknowledging its significance.

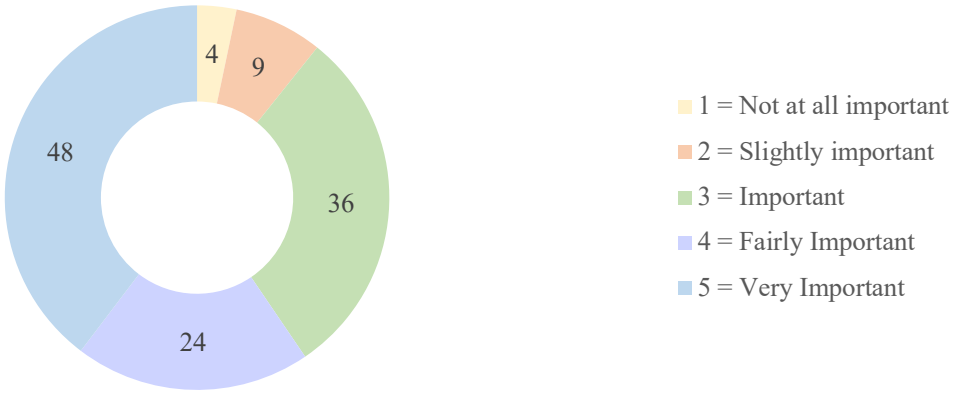

Figure 4. Importance of integrating circular construction and sustainability topics into CM and CE curricula

The last question sought to identify effective teaching methods for educating CE and CM students on sustainability topics, including circular construction. The results are presented in Figure 5 using box plots, where the box spans from the first quartile (Q1) to the third quartile (Q3). The median is represented by a horizontal line, the mean is indicated by an "x", and the whiskers depict the minimum and maximum values. According to the study results, the most effective teaching methods for educating students are: (1) hands-on experience, reflecting a mean of 4.50; (2) on-the-job training, with a mean of 4.45; and (3) problem-based learning, yielding a mean of 4.23. These integrative teaching methods provide practical, real-world learning opportunities that enhance students' understanding and application of concepts, fostering critical thinking skills and preparing them for industry challenges.

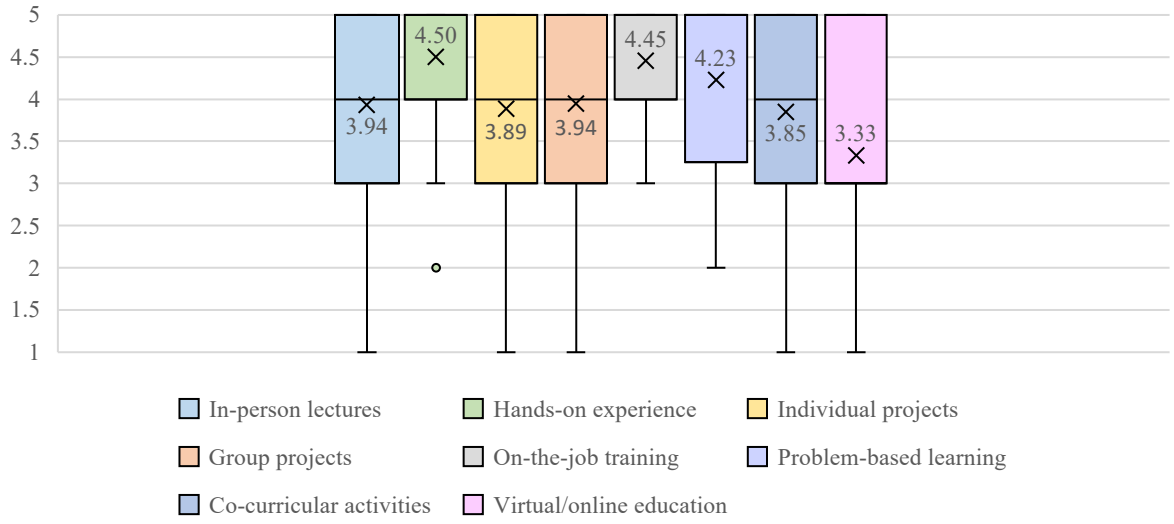

Figure 5. Effective teaching methods for educating CE and CM students on sustainability topics

Limitations and Future Work

This study acknowledges several limitations, including: (1) the potential influence of self-assessment and bias in the interviews and survey responses; (2) the interviews being conducted exclusively in the U.S., which limits the generalizability of the findings to other countries; and (3) the survey being conducted solely at Florida International University (FIU), a minority-serving institution (MSI) in the U.S., potentially narrowing the scope of the results. Future research could address these limitations by conducting studies across diverse countries and institutions to broaden the understanding of the challenges posed by disasters, the role of sustainable practices in disaster recovery, and the obstacles to implementing sustainability, as well as strategies to overcome these challenges. Such efforts would contribute to a more comprehensive and global perspective on sustainable disaster recovery practices and their effectiveness.

Furthermore, while demographic data were collected, the study did not perform a statistical analysis to determine how demographic factors may have influenced interview and survey responses. For instance, the predominance of CM students over CE students in the sample may have shaped responses related to sustainability knowledge and perceived barriers. Similarly, stakeholders' professional backgrounds could have influenced perspectives on the feasibility of adopting sustainable practices in disaster recovery. Future research should examine these relationships in greater depth and assess their impact on the findings.

Conclusion

This study highlights the significant environmental impact of the construction industry, which is further intensified by natural disasters. These destructive events not only cause widespread infrastructure damage but also generate significant construction and demolition waste, increase resource consumption, and heighten emissions during reconstruction. The findings from the

interviews with diverse stakeholders underscore the importance of adopting sustainable practices, such as circular construction, in disaster recovery efforts. These practices demonstrate potential benefits, including material reuse, waste reduction, and cost savings. However, significant barriers, including high initial costs, limited skilled labor, and a lack of cultural acceptance or policy frameworks to support these practices, hinder their implementation. Furthermore, the findings emphasize the critical role of education in addressing these challenges, with targeted efforts needed to equip the future construction workforce with knowledge and skills in sustainable practices.

The student surveys reveal substantial awareness of the environmental impact of the construction industry yet highlight critical knowledge gaps. A significant proportion of students are unfamiliar with circular construction and sustainable practices, and many indicated that their academic institutions did not educate them on these topics. Despite these gaps, the overwhelming majority support integrating sustainability-related topics into CE and CM curricula. Equipping CE and CM students with such knowledge and skills can enhance professional success and tackle environmental challenges. Effective teaching methods, such as hands-on experience, on-the-job training, and problem-based learning, are identified as key strategies for imparting these essential skills.

By addressing the identified knowledge gaps and barriers to sustainable practices, as well as emphasizing the need for curriculum revisions that integrate them, this study contributes to advancing sustainability in the construction sector. Incorporating sustainability topics into academic curricula and enhancing professional training can foster a more environmentally responsible construction industry, benefiting communities and stakeholders by reducing environmental impacts and promoting cost-effective recovery efforts. These efforts align with SDGs and pave the way for a more sustainable built environment.

Acknowledgments

This research was partially funded by the National Science Foundation Innovation Corps (NSF I-CORPS), Grant Number 2317424.

References

[1] A. F. Abd Rashid and S. Yusoff, “A review of life cycle assessment method for building industry,” 2015, *Elsevier Ltd*. doi: 10.1016/j.rser.2015.01.043.

[2] C. Calle Müller, P. Pradhananga, and M. Elzomor, “Pathways to decarbonization, circular construction, and sustainability in the built environment,” *International Journal of Sustainability in Higher Education*, 2024, doi: 10.1108/IJSHE-09-2023-0400.

[3] M. Buyle, J. Braet, and A. Audenaert, “Life cycle assessment in the construction sector: A review,” *Renewable and Sustainable Energy Reviews*, vol. 26, pp. 379–388, 2013, doi: 10.1016/j.rser.2013.05.001.

[4] C. K. Chau, T. M. Leung, and W. Y. Ng, “A review on life cycle assessment, life cycle energy assessment and life cycle carbon emissions assessment on buildings,” 2015, *Elsevier Ltd*. doi: 10.1016/j.apenergy.2015.01.023.

[5] W. Lu, V. W. Y. Tam, H. Chen, and L. Du, "A holistic review of research on carbon emissions of green building construction industry," *Engineering, Construction and Architectural Management*, vol. 27, no. 5, pp. 1065–1092, Jun. 2020, doi: 10.1108/ECAM-06-2019-0283.

[6] J. Mansuy *et al.*, *Transitioning to a circular economy Changing Business Models and Business Ecosystems*. ASP editions-Academic and Scientific Publishers, 2022.

[7] M. Arora, F. Raspall, L. Fearnley, and A. Silva, "Urban mining in buildings for a circular economy: Planning, process and feasibility prospects," *Resour Conserv Recycl*, vol. 174, Nov. 2021, doi: 10.1016/j.resconrec.2021.105754.

[8] OECD, *Decarbonising Buildings in Cities and Regions*. in OECD Urban Studies. OECD, 2022. doi: 10.1787/a48ce566-en.

[9] United Nations Environment Programme, "Buildings and Climate Change: Summary for Decision Makers," 2009. Accessed: Feb. 15, 2023. [Online]. Available: https://wedocs.unep.org/20.500.11822/32152

[10] United Nations Environment Programme, "Common Carbon Metric for Measuring Energy Use and Reporting Greenhouse Gas Emissions from Building Operations," United Nations Environment Programme: New York, NY, USA, 2009, 2009. Accessed: Feb. 15, 2023. [Online]. Available: https://wedocs.unep.org/20.500.11822/7922.

[11] C. Calle Müller and M. Elzomor, "Origami Housing: An Innovative and Resilient Post-Disaster Temporary Emergency Housing Solution," *Journal of Architectural Engineering*, vol. 30, no. 3, p. 04024025, Jul. 2024, doi: 10.1061/JAEIED.AEENG-1809.

[12] E. Hendriks and A. Opdyke, "The influence of technical assistance and funding on perceptions of post-disaster housing safety after the 2015 Gorkha earthquakes in Nepal," *International Journal of Disaster Risk Reduction*, vol. 73, p. 102906, Apr. 2022, doi: 10.1016/j.ijdrr.2022.102906.

[13] T. Cela, L. H. Marcelin, N. L. Fleurantin, and S. Jean Louis, "Emergency health in the aftermath of disasters: a post-Hurricane Matthew skin outbreak in rural Haiti," *Disaster Prevention and Management: An International Journal*, vol. 31, no. 4, pp. 398–410, Aug. 2022, doi: 10.1108/DPM-04-2021-0121.

[14] C. Kenny, "Why Do People Die in Earthquakes? The Costs, Benefits and Institutions of Disaster Risk Reduction in Developing Countries," *The Costs, Benefits and Institutions of Disaster Risk Reduction in Developing Countries (January 1, 2009). World Bank Policy Research Working Paper*, no. 4823, pp. 1–42, 2009, doi: https://doi.org/10.1596/1813-9450-4823.

[15] R. Rahat, P. Pradhananga, C. Calle Müller, and M. Elzomor, "Incorporating a Resilient Infrastructure Design Strategy, Safe-To-Fail, into Architecture/Engineering/Construction (AEC) Curricula," in *2022 ASEE Annual Conference & Exposition*, Minneapolis, MN, USA: ASEE, Jun. 2022. [Online]. Available: www.slayte.com

[16] C. Calle Müller and M. Elzomor, "Addressing Post-Disaster Challenges and Fostering Social Mobility through Origami Infrastructure and Construction Trade Education," *Sustainability*, vol. 16, no. 8, p. 3415, Apr. 2024, doi: 10.3390/su16083415.

[17] J. Talbot, C. Poleacovschi, and S. Hamideh, "Socioeconomic Vulnerabilities and Housing Reconstruction in Puerto Rico After Hurricanes Irma and Maria," *Natural Hazards*, vol. 110, no. 3, pp. 2113–2140, Feb. 2022, doi: 10.1007/s11069-021-05027-7.

[18] V. F. Medina, E. Martinez-Guerra, and S. C. Cosper, "Military Solid and Hazardous Wastes: The Army Corps of Engineers Disaster Debris Management Mission," in *Waste:*

A Handbook for Management, Elsevier, 2019, pp. 553–565. doi: 10.1016/B978-0-12-815060-3.00029-3.

[19] P. Pradhananga and M. ElZomor, "Revamping Sustainability Efforts Post-Disaster by Adopting Circular Economy Resilience Practices," *Sustainability (Switzerland)*, vol. 15, no. 22, Nov. 2023, doi: 10.3390/su152215870.

[20] M. van den Berg, H. Voordijk, and A. Adriaanse, "Information processing for end-of-life coordination: a multiple-case study," *Construction Innovation*, vol. 20, no. 4, pp. 647–671, Aug. 2020, doi: 10.1108/CI-06-2019-0054.

[21] D. William Dobson, A. Sourani, B. Sertyesilisik, and A. Tunstall, "Sustainable Construction: Analysis of Its Costs and Benefits," *American Journal of Civil Engineering and Architecture*, vol. 1, no. 2, pp. 32–38, Apr. 2013, doi: 10.12691/ajcea-1-2-2.

[22] C. Calle Müller, L. Lagos, and M. Elzomor, "Leveraging Disruptive Technologies for Faster and More Efficient Disaster Response Management," *Sustainability*, vol. 16, no. 23, p. 10730, Dec. 2024, doi: 10.3390/su162310730.

[23] E. Hausler, "Building earthquake-resistant houses in Haiti: The homeowner-driven model," *Innovations: Technology, Governance, Globalization*, vol. 5, no. 4, pp. 91–115, 2010, doi: https://doi.org/ 10.1162/INOV_A_00047.

[24] European Commission, "Energy performance of buildings directive." Accessed: Oct. 25, 2023. [Online]. Available: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

[25] IPCC Inter-governmental Panel on Climate Change, "Climate Change 2021: The Physical Science Basis," 2021. Accessed: Oct. 25, 2023. [Online]. Available: https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf

[26] A. S. Allam and M. Nik-Bakht, "From demolition to deconstruction of the built environment: A synthesis of the literature," Apr. 01, 2023, *Elsevier Ltd*. doi: 10.1016/j.jobe.2022.105679.

[27] Eurostat, *Sustainable development in the European Union: Monitoring report on progress towards the SDGs in an EU context*. Publications Office of the European Union, 2023.

[28] Eurostat, *Sustainable development in the European Union: Monitoring report on progress towards the SDGs in an EU context*. Publications office of the European Union, 2022.

[29] S. H. Ghaffar, M. Burman, and N. Braimah, "Pathways to circular construction: An integrated management of construction and demolition waste for resource recovery," *J Clean Prod*, vol. 244, Jan. 2020, doi: 10.1016/j.jclepro.2019.118710.

[30] Independent Group of Scientists appointed by the Secretary-General, "Global Sustainable Development Report 2023: Times of crisis, times of change: Science for accelerating transformations to sustainable development," New York, 2023.