Construction Industry As Net-Zero Enabler: Driving Circular Economy and Sustainability through Innovation and Change Management

This special issue aims to trigger serious debates about how innovation and change management could assist various stakeholders of the built environment towards uptaking circular economy (CE) principles and sustainability strategies. The bigger picture is to achieve Net-Zero targets. Whilst CE is expected to rise globally to $4.5 trillion by 2030 (World Economic Forum, 2019), indicating the seamless commercial opportunities in this domain, most construction businesses are still driven by traditional linear business models (Kaklauskas et al., 2020; Treptow et al., 2022). Further, recent growth in global aspirations towards achieving Sustainable Development Goals (SDGs) calls for significant change in traditional business models in all sectors of the economy. This is critical as all stakeholders align to address Environmental, Social and Governance (ESG) objectives (Cambridge University, 2023). A drawback for the construction industry in this is that the sector is overly driven by appetite for profit and an insatiable appetite to consume resources.

Therefore, this special issue brings means to the construction industry to rediscover itself and overcome its seeming traditional resistance to the change brought about by CE and sustainability principles. It is difficult for the industry to uptake the opportunities that come with the change without embracing the change itself. Whereas it provokes insights towards generating impactful solutions that would bring economic benefits to the built environment stakeholders, its broader goal was to promote the commitment of built environment industries towards achieving the objectives of applicable ESGs and SDGs. This is a timely need in a world influenced heavily by the changing priorities of Millennials and a Generation Z population.

Global partnerships are vital to achieve the ESG and SDG objectives. This, it is vital to understand the diverse challenges faced by various built environment stakeholders across the world. For example, Europe has pioneered global efforts towards Net-Zero targets. However, there are unresolved challenges requiring innovative solutions, particularly within the AEC (Architectural, Engineering and Construction) sector. Such situation cannot be better in other parts of the world where CE and SDGs have only attracted minimal commitments. Therefore, this special issue has provided an opportunity for scholars to discuss CE and sustainability strategies from multiple lenses, including the contexts of developing nations where rapid

development is a must to enhance economic prosperity and higher human development index (HDI).

There is hope for a circular construction economy as disruptive technologies become commonplace. In particular, Internet of Things (IoT) and Building Information Modelling (BIM) have been espoused to support circular economy protocols and practices (Abbasnejad et al., 2021; Rahnamayiezekavat et al., 2022; Ramanayaka et al., 2022). The challenge is that their widespread adoption is still slow, daunting and incipient. Whilst recent advances to standardization of technologies have shown the potential to transform the construction industry – *e.g.*, the deployment of ISO 19650, the international standard for digitizing and managing information about construction projects - there is limited awareness amongst academics and professionals of the practicality of disruptive technologies and infrastructures that support their deployment (Olatunji et al., 2021; Ramanayaka et al., 2022). On the other hand, these developments are generic. Therefore, another objective was to evaluate their appropriateness in the context of a circular construction economy.

Themed issues of some journals have triggered interest in this subject to some extent. However, the potential impact appears constrained by silo-like perspectives. This Special Issue brings multiple perspectives and applications of circular construction economy under one umbrella with a well-defined focus. Thus, it generates and pollinates synergies across various shades of scholarly and technical opinions on circular construction economy. It serves as a timely platform that the construction industry requires now to deliver novel solutions that deepens its capacity for a greater future through circular economy and sustainability.

Explanatory research is inadequate to fulfil this need (Holmström et al., 2009; Ramanayaka et al., 2022; Zhang & Van Burg, 2020). Thus, the main objective of this special issue was to invite original contributions, including and not limited to studies that report alternative exploratory methodologies which deepen theoretical and technical knowledge about circular economy and sustainability strategies. Of interest are industry-level applications that are relevant to challenges and gaps of a global scale. This special issue therefore address relevant connected areas and critical shortfalls therein.

The first paper of the special issue is from the United Arab Emirates (UAE) and promotes embodied water saving and hence sustainable water management in the residential

construction sector of UAE. While there is a large literature on operational water management of buildings, initial and recurrent embodied water management has been given little to no attention. Therefore, Rauf *et al* employed a life-cycle assessment (LCA) approach to analyze initial embodied water during the construction stage, and an input–output-based hybrid analysis to evaluate recurrent embodied water consumption for maintenance activities during the operational stage. As embodied water represents 70% of the total water demand of a typical residential building in UAE, this study encourages building designers and contractors to use alterative materials in lieu of 'water-hungry' construction materials (for example, concrete and steel) or find strategies to minimize their initial embodied water. Further, finishes contributes to a large portion of recurrent embodied water; it is vital to enhance their longevity. This study calls for partnership between academia, industry, and governments to achieve ESG and SDG objectives by establishing policies that promote the use of construction materials with low embodied water footprints.

The second paper is from Sri Lanka and also discusses the use of alternative construction methods in order to enhance sustainability in buildings. The study argues green walls have immense possibilities to promote ESG objectives, but majority of the built environment stakeholders prefer conventional wall construction. *Madushika and Ramachandra* argue a cost and energy performance comparison may change industry's attitudes and behavioral intention to use green wall constructions. The study was carried out in two stages: firstly, thermal performance of conventional and green walls construction was measured using onsite temperature measurements; and secondly, Life Cycle Cost (LCC) was calculated for each construction method and compared. They found green walls reduce cooling energy demand of buildings in tropical climates by 70% and a significant reduction in maintenance cost. The study argues that the greater initial cost of green wall construction could still negatively influence stakeholder's behavioral intention to use it. As initial capital cost could dominate decision making in many countries compared to asset operations and maintenance costs, they recommend that the industry must be encouraged to perceive building performance from both project and asset management perspectives.

While emphasizing the central role of LCC to sustainable decision making in the asset management stage, the third paper proposes a Reference Architecture-based approach to LCC analysis at a scale. Regardless of widespread adoption of LCC across many industries, its uptake is limited in the built environment mainly due to a generalization problems. To

address this challenge, Shaw *et al* bring the merits of both exploratory and explanatory research through a custom Design Science Research-inspired methodology to create a novel LCC analysis solution, refine proposed solutions and validate them using theory building research. The suitability of addressing the scalability challenge of theory building was substantiated. The study further emphasized directions of future research necessary to broaden the applicability of the LCC solution that the study suggested. Their Reference Architecture-based approach are appropriate for asset managers to realize Net-Zero emissions targets that align with extreme political ambitions for most parts of Europe.

Using an explanatory study in Ghana, the fourth study brings industry perspectives on how the Ghanaian built environment stakeholders prioritize CE principles through R-Frameworks. With *'reduce'* as the most effective CE principle of the framework, the practicalities of these R-frameworks are largely governed by the socio-economic and political factors. Thus, to evaluate this hierarchical preference in Ghana, Agyekum *et al* employed a questionnaire survey (N=162) and semi-structured interviews (N=8), analyzed via one-sample t-test and content analysis, respectively. As opposed to the well-established generic hierarchy, Agyekum *et al* find that *Recycle*, *Reuse*, and *Repair/Remanufacture* are in the top of the ladder and '*Reduce*' is the least preferred amongst the six R-principles considered. To make a significant difference in the current industry perceptions, interventions must go beyond merely increasing individual's awareness of the R-principles.

The fifth study is from the United States of America (USA). It also sees circularity but in the context of 'reusing' waste wind turbine blades. Wind energy is undoubtfully a major source of clean energy. However, decommissioned wind turbines have negative environmental impacts particularly due to their composite material structure that prevents them from being recycled. To find a solution to this, *Kio and Anumba* integrate CE and pedagogy in a state-of-art manner. As recycling is not an option, Architectural Engineering students undertook a coursework component where innovative architectural reuse methodology was the core of creative reuse of wind turbine blades as building elements. Aligned with the common beliefs of the R-framework's hierarchy, the quantitative analysis illustrates how creative reuse had positive impacts when compared to conventional recycling. Beyond preserving structural integrity, reuse of wind turbines assists in achieving Net-Zero emissions by reducing the carbon dioxide-equivalents. In addition, the coursework component became a means of enhancing student enthusiasm and awareness of CE principles.

Closely aligned with the fourth and fifth studies, our next research evaluates the impacts of Green Construction Procurement Practices (GCPPs) on CE success in the Ghanian context. To promote circularity through GCPP, *Kwasafo et al* launched a questionnaire survey from which responses from 100 procurement practitioners were analyzed for hypothesis verification/falsification using statistical techniques such as one-sample T-test and regression analysis. Whereas GCPP explains 12.8% of variance of CE success in Ghana, the study suggests the most preferred GCPPs. They include on-site systematic waste management, project stakeholders' commitment and support for green practices, and environmental requirements in technical specifications. The findings articulate the importance of policy making to support GCPPs in public infrastructure projects.

The seventh study evaluates innovative green construction (IGC) adoption using a modified theory of planned behavior (TBA). While sustainability and green construction are advocated widely, their adoption in the construction industry is largely governed by the designers and therefore, *Addy et al* investigate attributes that influence architect's attitudes, behavioral intention and actual adoption of innovative green construction methods. The data obtained from 61 architects were analyzed via Partial Least Square Method, where outcomes indicate that behavioral intention to adopt IGCs has no significant statistical influence towards actual adoption. However, they found behavioral control governs the actual adoption of IGCs. Therefore, it is vital that designers have confidence regarding their control over IGC adoption. To assist this, Addy *et al* highlight the importance of access to the right information and knowledge and funding sources for skill development. In summary, this research emphasizes the role of behavioral changes required in the context of ecological development.

The last study of this special issue focuses on Smart Cities. Domingos *et al* explain how sustainability and artificial intelligence are evolving concepts of smart cities developments. As a response to COVID 19 pandemic, the European Resilience and Recovery Plan intends to employ advanced technologies such as sensors, blockchain and big data to improve economic, social and environmental sustainability in Smart Cities. Regardless of these inspirations, Domingos *et al* find that extant Smart Cities literature is insufficient in terms of an interdisciplinary approach to integrate expertise from multiple knowledge domains. They argue that long-term performance and adaptability of smart cities are also questionable. As a solution, the authors established a novel smart building assessment framework in the context

of Smart Cities. The initial phase is a systematic literature review to understand the two key concepts of this research - Smart City' and 'Smart Buildings' - including bibliographic research on the role of public policies to further enhance the performance of smart cities. Then, the authors integrate an existing Smart Cities assessment framework with the outcomes of the bibliographic research methodologically to propose the initial version of the new assessment framework. Validated and refined after focused group interviews with field experts, the new framework suggests specific dimensions and sub-dimensions to assess the performance of smart cities while also providing a basis for strategy and policy developments to enhance the viability of smart cities.

In conclusion, the additionality of all the articles featured in this special issue is far reaching. Whether as theory-building or as empirical research, the implications of this collection draw insights for teaching and learning, policy development as well as science and industry. As contributions have come America, Europe and Africa, we are pleased to claim that this themed issue is a positive step that is scalable for an international impact. Finally, we appreciate the authors for their fabulous contributions, the selfless reviewers for their efforts and everyone who has contributed to the success of this issue.

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