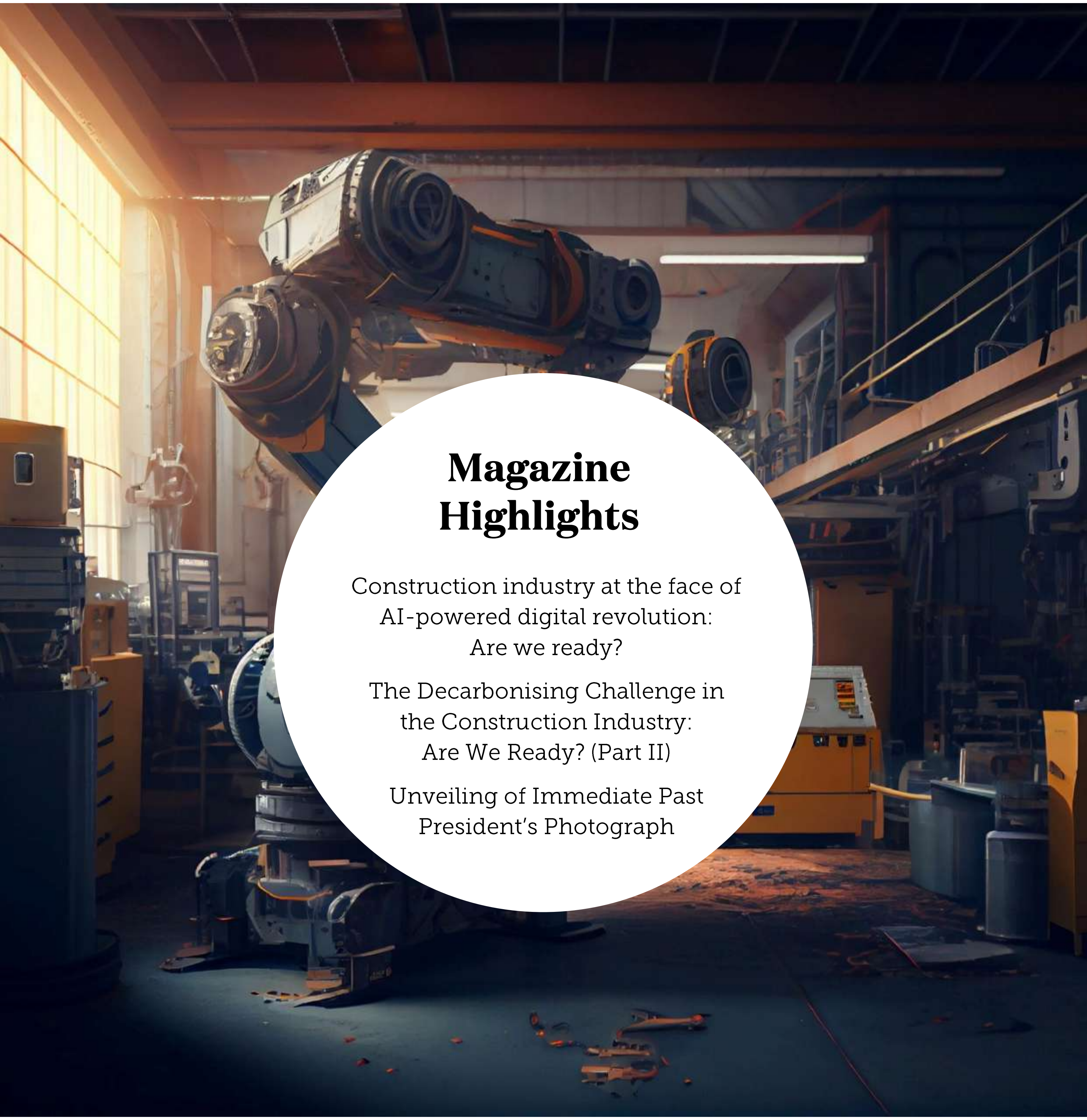
FOCUS

Quarterly E-Magazine of the
Institute of Quantity Surveyors, Sri Lanka
Volume 17: Issue 03, May 2024



Magazine Highlights

Construction industry at the face of AI-powered digital revolution: Are we ready?

The Decarbonising Challenge in the Construction Industry: Are We Ready? (Part II)

Unveiling of Immediate Past President's Photograph

Published by:
Institute of Quantity Surveyors Sri Lanka (IQSSL)

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Research Article

Construction Industry at the Face of the AI-powered Digital Revolution: Are We Ready?

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Introduction

The fourth Industrial Revolution refers to an intellectualised society with various technologies, such as Artificial Intelligence (AI), big data, blockchains, and robotics (Heo et al., 2021). This paper is focused on AI among technologies in this AI-powered digital revolution and its impact on defining future construction industry.

The construction industry's growth is significantly hampered by a variety of complications, including cost and schedule overruns, safety and health concerns, production issues, and lack of labour (Alawag et al., 2024). According to the authors, the construction sector is one of the least computerised in the globe, making it challenging to address the issues it is now facing. According to Oprach et al. (2019), data in the construction industry is heterogeneous, organisations do not work closely together, and construction software is highly specialised for individual users and applications. As a result, knowledge from previous construction projects is often not shared, linked, or transferred to subsequent projects. Additionally, the manual work on-site leads to long and unstable design and construction processes. Consequently, the construction industry struggles to increase productivity, time management, working effectiveness, and quality due to a lack of awareness of the use of new technologies that are widely used in other disciplines (Prabhakar et al. 2023).

AI is a cutting-edge digital technology that is presently impacting several sectors, including manufacturing, commerce, and communications (Alawag et al., 2024). Automation, knowledge-based platforms, machine learning, robotics, optimisation technologies, genetic algorithms, Artificial Neural Networks, Deep Learning, computer vision, machine learning, and Building Information Modeling and optimisation are only some of the areas of artificial intelligence that have been effectively used in various sectors to improve their bottom lines, operations, and security. Recently, the emergence and rapid adoption of advanced Large Language Models (LLM) e.g. OpenAI's GPT, Google's PaLM, and Meta's Llama, have shown great potential and sparked considerable global interest. However, despite rapid advancements in AI transforming many industry practices, construction largely lags in adoption (Ghimire et al. 2023). Contradictorily, Rane (2023) argues that generative AI, including ChatGPT is reshaping the construction industry across a multitude of domains. Deep Learning, especially in combination with Artificial Neural Networks, is becoming increasingly popular in the construction industry (Chen & Ying, 2022).

Applications

AI has promising applications in many areas of construction industry practice. The word cloud presented in Figure 1 integrates the possible applications proposed by recent eleven research papers i.e. Abioye et al. (2021); Arroyo et al. (2021); Kyivska and Tsiutsiura (2021); Regona et al. (2022a); Regona et al. (2022b); Jallow et al. (2023); Rane (2023); Li et al. (2023); Oluleye et al. (2023); Saka et al. (2023); and Rafsanjani and Nabizadeh (2023). The papers published beyond 2020 were selected which have analysed the context comprehensively using the judgemental sampling technique.

Figure 1 – The word cloud of AI applications in Construction Industry

Figure 2 – The word cloud of challenges for AI application in Construction Industry

Challenges

The analysis identified more than 250 AI applications. Accordingly, management is predicted to be the mostly intervened by AI obtaining a 71 times frequency. Moreover, optimising, regulation, design, planning, and compliance are predicted be the most AI inferred actions whilst the highest influence is placed at the project level whereas the frequency of appearance falling between 26 to 20 times. The next significant applications of AI are predicted to be related to the fields of material, risk, demolition, safety, schedule, cost, and communication, obtaining frequency of appearance between 20 and 10. Though the promising applications are available, Bolpagni and Bartoletti (2021) state that the application of AI in the most advanced construction practices is still limited, and most applications cover process automation and process optimisation during design.

Multifaceted challenges for construction industry AI intervention were revealed by research hence selected seven papers i.e. Bolpagni and Bartoletti (2021); Heo et al. (2021); Rampini et al. (2022); Na et al. (2023); Rane (2023); Wang et al. (2023); Liang et al. (2024). The papers published beyond 2020 were selected which have analysed the context comprehensively, using the judgemental sampling technique. The findings were used as input to generate the word cloud presented in Figure 2.

The analysis identified around 100 challenges for AI applications. Obviously, the biggest initiating challenge is predicted to be the data availability that is the key for any AI implementation. The amount of training data needed depends on elements e.g. problem type, model complexity, number of features, and error tolerance; While no fixed rules exist, the popular guideline is having ten times or more examples than features (Stupak, 2023). Hence, Building Information Modelling (BIM) would come as a forerunner in construction industry to record data thereby AI models can be started training in localities. Moreover, ethics, safety, acceptance, trust, knowledge, capital, cost, training, and expertise are predicted be some more critical challenges.

Way forward

AI is becoming a game changer across industries. Hence construction organisations should change traditional work culture to foster AI adoption therefore organisations should look at introducing learning tools and skills to develop employees on AI knowledge whilst top management should include employees when working on AI adoption strategies (Tjebane et al. 2022). Hence scientific knowledge of integrating AI to practice is essential, thereby complementing Emaminejad and Akhavian (2022)'s study which stated that researchers and industry professionals should increasingly study and deploy AI.

However, as a starting point, ChatGPT and its generative AI counterparts have the potential to revolutionise the construction industry, rendering processes more efficient, sustainable, and resilient as suggested by Rane (2023). Moreover, BIM adoption would be complementary in assuring the data availability for AI model training in construction sector. Nevertheless, the careful implementation and management are essential to harness the full potential of AI while addressing the associated challenges within the construction sector.

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Research Article

The Decarbonising Challenge in the Construction Industry: Are We Ready? (Part II of II)

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Introduction

The global construction industry is facing a burning requirement of decarbonising due to its numerous direct and indirect contributions to greenhouse gas (GHG) emissions. As the second article of two related articles, this article discusses the decarbonising challenge faced by the construction industry, the approaches to life cycle thinking for decarbonising, and conducting building life cycle assessments. The first article was published in Volume 16 (Issue 02) of the Focus E-Magazine in May 2023, emphasizing the significance of achieving net zero carbon in the construction industry and introducing different approaches to achieving carbon neutrality in the construction industry. Importantly, it highlighted the importance of life-cycle thinking as the pathway for decarbonisation. Both articles are predominantly based on the key concepts, facts, and figures presented at the online Continuing Professional Development (CPD) session delivered by Professor Shiromi Karunaratne on the 16th of December, 2022 on the topic of "Decarbonising Challenge: Are We Ready?" for the CPD programme of the Institute of Quantity Surveyors Sri Lanka (IQSSL). The two articles were written with the intention of disseminating knowledge on the decarbonising needs and status in the Sri Lankan construction industry to a wider community.

1. Decarbonising Challenge

The United Nations Framework Convention on Climate Change (UNFCCC) sets out the basic legal framework and principles for International Climate Change Cooperation. The aim is to stabilise atmospheric concentrations of Green House Gases (GHGs) to avoid “dangerous anthropogenic interference with the climate system." Now it has come far away, and the most recent intervention is the “Paris Agreement” adopted at the 21st Conference of the Parties (COP 21) to UNFCCC that was held in Paris, France, in December 2015. The Paris Agreement is a legally binding international treaty on climate change and a landmark in the multilateral climate change process (United Nations Climate Change, n.d.). This necessitates all parties to identify, plan, and regularly report on their Nationally Determined Contributions (NDCs) aimed at mitigating climate change. To date, Sri Lanka has submitted its initial NDC along with two subsequent revisions, totaling three versions, with the most recent revision being submitted in September 2021 (Ministry of Environment, Sri Lanka, 2023). In this document, Sri Lanka has established a target of reducing greenhouse gas (GHG) emissions by 14.5% within the period of 2021–2030 across various sectors including power (electricity generation), transport, industry, waste management, forestry, and agriculture (Ministry of Environment, Sri Lanka, 2023). As a country, our pledge is clear, but our readiness is questionable. In COP 27 (in November 2022), countries agreed to recognise the need for finance to respond to loss and damage associated with the adverse effects of climate change. As construction professionals, it is our responsibility to convince policymakers to make the necessary changes to achieve the targets. To keep global warming to no more than 1.5 °C, emissions need to be reduced by 45% by 2030 and reach net zero by 2050.

Many countries embarking on the journey towards achieving net zero emissions have established robust policy frameworks. These effective policies serve as catalysts for research and development in materials and energy, compelling policymakers and industry professionals to adapt design and construction practices accordingly. However, waiting for all prerequisites to be met is not feasible. Therefore, the first crucial step should involve quantifying the problem, enabling us to assess our progress in the decarbonisation process. When quantifying, primary emphasis should be placed on evaluating environmental impacts, with carbon emissions serving as a key parameter for measurement. Consequently, the following impact categories can be assessed to benchmark these impacts:

- Climate change (characterisation factor – GWP (Global Warming Potential) (CO2 equivalents))
- Ozone layer depletion
- Resource depletion
- Eutrophication potential
- Acidification potential
- Ecotoxicity.

While there are indeed immediate benefits to quantification in the context of the decarbonisation challenge, the primary focus remains on "climate change", given its status as the most urgent global issue currently. The methods and tools for quantifying the environmental impact of buildings can be categorised into three main groups as:

5. Passive tools (e.g., green building rating systems, guidelines, checklists) – Passive tools do not exactly quantify the environmental performance of buildings. Instead, they help enhance environmental performance.

6. Energy and ventilation modelling tools – They optimise the building performance during the operation and maintenance stages.

7. Whole Building Environmental Life Cycle Assessment software tools (WBELCA-ST) – WBELCA-ST model the full environmental life cycle assessment of buildings from cradle to grave. Life Cycle Assessment tools (LCA) are the most versatile tools that allow quantifying any performance indicators.

3. Life cycle thinking for quantification of environmental impact

Life cycle thinking provides a comprehensive approach to quantifying environmental impacts by considering the entire life cycle of a product or process, from raw material extraction to end-of-life disposal or recycling. This approach allows for a holistic assessment of environmental impacts across all stages of the life cycle, rather than focusing solely on a specific phase. Generally, in the construction industry, the primary focus is always on the design and construction stages. However, these two stages are the shortest compared to a building's life span. On the other hand, decisions made in the design and construction stages determine end-of-life behaviour. Thus, professionals must pay attention to the whole life cycle of a project instead of focusing primarily on the design and construction stages. The ideal scenario is to put all the life cycle stages within the system boundary, and it is very important to define the system boundary. Figure 01 presents the detailed stages of a building life cycle as per "BS EN 15978: Sustainability of Construction Works – Methodology for the Assessment of Environmental Performance of Buildings", along with different elements associated with each life cycle stage.

In order to enhance the life cycle performance of buildings, changes are needed at all stages of the whole life cycle in terms of (using low/no CO2 emitting material, i.e., less material, and using low/no CO2 emitting energy):

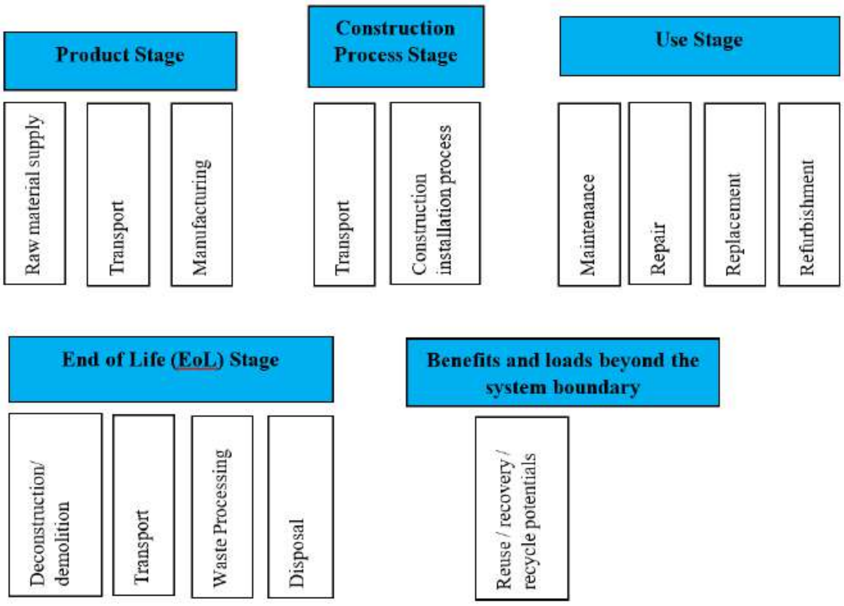

Figure 1 – Stages of building life cycle (source: Karunaratne, 2022)

- buildings being designed as life cycles, not just projects
- buildings using efficient construction technology, standards
- buildings being operated to high efficiency standards
- buildings achieving purposeful deconstruction.

In another two or three decades, most of the building materials will be locked in constructed buildings and infrastructure, allowing urban mining. Hence, recycling will be more economical than obtaining virgin materials. Deconstruction is a better approach compared to demolition as it allows the extraction of more resources, such as doors, windows, and roofing material. Land filling should be the last option only if there are no ways to recycle / reuse / reprocess the demolished / deconstructed material.

4. Building Life Cycle Assessments

LCA is a tool to assess / quantify the environmental impacts of a product, process, or activity throughout its life cycle, from the extraction of raw materials to processing, transport, use, and disposal. Building LCA is the most reliable way to assess how sustainable a building is. This is because it deals with actual values (not approximated or estimated values), which are generated based on scientific approaches. It is the best mechanism to understand the environmental (ELCA), financial (ICCA), and social impact (SLCA) associated with all the phases of a building. The process is very data-intensive, which has advantages as well as disadvantages. Building LCA allows us to understand a building's impact in a quantifiable manner.

One major value of an LCA is its advanced visibility and decision-making in regards to the supply chain. LCAs can be used to justify business decisions, from obtaining raw materials to modifying a specific operation process. There are various international and local standards in this regard, such as ISO 14040 (Principles and framework for LCA), ISO 14044 (specifies requirements and provides guidelines for LCA), ISO 14067 (specifies principles, requirements, and guidelines for the quantification and reporting of the carbon footprint of a product), ISO 14020, ISO 14021, ISO 14024, ISO 14025, and ISO 14026 (set out principles, requirements, and guidelines for the development and use of environmental labels and declarations, as well as for the communication of footprint information), and ISO 15686.5 (2017) (building and constructed assets – services life planning – part 5 – life cycle costing).

Importantly, system boundaries and what is included and excluded in an LCA should be defined explicitly. Thus, it should be a fully transparent process. The generated data would not be useful without that declaration. Also, the category of environmental impact that is taken into consideration should be defined. By including all the impacts, it is possible to quantify the ultimate impact of the building. However, this manuscript focuses only on climate change – GWP, as that is sufficient for carbon crediting and carbon trading.

The process adopted in an LCA consists of the following four steps:

1. Goal and scope: Identify the goal, scope, and system boundary
2. Life cycle inventory: Collect the life cycle inventory (e.g., include building materials/products like solar cells as inputs)
3. Impact assessment: Calculate the associated impacts of the inventory (e.g., if solar panels have been included as inventory, the impact of 1 solar panel is calculated using the databases). If the impact of a certain material is known through material/product level LCAs, they can be accounted for in this stage of building LCA. Thus, assessing the impact of a building is complicated as it contains thousands of materials/products.
4. Interpretation: Interpret the quantified impacts with respect to the bottom lines of environmental, economic, and social aspects.

There are mainly two types of LCAs: Processed-Based LCA and Input-Output Analysis (IO Analysis). Figure 02 demonstrates a comparison between these two types of LCAs. Process-based LCA focuses on analysing the environmental impacts associated with individual processes or activities within the life cycle of a product or service. It involves identifying and quantifying the inputs (e.g., energy, materials) and outputs (e.g., emissions, waste) of each process. This approach requires detailed data on the inputs and outputs of each process, often obtained from industry-specific databases, literature, or direct measurements. Input-Output Analysis (IOA) is an economic modelling technique that examines the interdependencies between different sectors of the economy by quantifying the flow of goods and services among them. IOA utilises national or regional input-output tables, which provide comprehensive data on the transactions between industries and final consumers within an economy. Instead of focusing on individual processes, IO Analysis assesses the environmental impacts associated with the entire economy by tracing the flow of resources and emissions throughout production and consumption chains.

In building LCA, generally, these two types are combined to create a hybrid version because, a building is a complicated product that contains thousands of other individual products.

The purpose of conducting LCA during the design stage is to inform decisions regarding material selection, design optimisation in terms of energy and water usage, among other factors. Therefore, dedicating a significant amount of time to conducting LCA may not be feasible. Hence, software tools represent the most practical option. LCA Software Tools (LCA-STs) are extensively utilized in today's manufacturing industries to assess the environmental impacts of products and processes, facilitating product design enhancement, characterisation, and benchmarking. These tools vary in capabilities and accuracies, catering to diverse audiences such as architects, engineers, etc. Additionally, in Sri Lanka, factors like cost and suitability for assessing local projects impose further restrictions. There are generic LCA tools designed to evaluate various products like electronic goods, food items, building materials, and packaging.

Conversely, specialised tools target specific industries or sectors such as buildings, agri-food, or automobiles. Although generic tools have been applied to specific applications like buildings, specialised tools offer more efficiency. Therefore, employing specialised LCA-STs is essential.

Attributes such as comprehensiveness of analysis, user-friendliness, associated databases (LCA is very much a data incentive, and quality of the output and accessibility of data are determined by the associated databases), and contribution to sustainable design should be considered when selecting a suitable specialised LCA-ST. Among widely used tools, OneClick stands out in the international market due to its adherence to these criteria. However, tools like Athena IE, which was developed in the USA and is very expensive, despite being well established, have limitations, such as the inability to accurately represent Sri Lankan locations, rendering its results unreliable for Sri Lankan buildings. Some freely available STs, like Eco Quantum, are restricted to specific countries. The majority of these tools originate from Europe, with some available in languages other than English. Tools like Tally, ELODIE, Eco bat, and Greencalc are tailored for early design stages, particularly for architects. While most tools are user-friendly, some require advanced skills, such as Tally ST, which demands proficiency in Revit.

It is in this context that Building-SAT was developed in Sri Lanka as a specialised LCA-ST by a team of researchers to enable quantification of project-level Global Warming Potential (GWP) throughout a building's life cycle in kg of CO2 – eq per m2/year (Team Building-SAT, 2022). Data in Building-SAT has been sourced from International Environmental Product Declarations (EPDs), as EPDs reflect material-level data pertaining to different countries where similar materials can be found in Sri Lanka. This was supplemented by research-generated data in standard formats as well, ensuring relevance to Sri Lanka's context. Building-SAT offers users the capability to analyse a wide range of building types, including apartment complexes, office buildings, residential structures, and various construction types such as new constructions, refurbishments, and existing buildings (Team Building-SAT, 2022). It systematically guides users through the process of conducting an Environmental Life Cycle Assessment (LCA) on a selected building, accounting for both the materials used and the processes involved in a user-friendly manner (Team Building-SAT, 2022). This is facilitated by allowing users to input necessary data obtained from a Bill of Quantities (BOQ) and relevant construction or structural drawings across three phases: construction, operation, and demolition (Team Building-SAT, 2022). Building-SAT integrates multiple databases covering materials, machinery, transportation vehicles, etc., which are regularly updated to ensure accuracy and relevance (Team Building-SAT, 2022). Further information about the Building-SAT specialised LCA-ST can be found at http://building-sat.com/.

5. Carbon markets and carbon credits

When the quantification of the environmental impact of a product, process, or something is done and ready, the relevant entity can enter the carbon market. A carbon market operates within the framework of carbon trading systems, which are designed to reduce greenhouse gas emissions and combat climate change. It is a platform where carbon emissions are traded, typically in the form of carbon credits or allowances. The primary goal of the carbon market is to create economic incentives for entities to reduce their emissions by putting a price on carbon. Sustainable buildings allow the earning and trading of carbon credits, which motivates us to go forward with decarbonisation.

A carbon credit, also known as a carbon offset, represents a permit or certificate that allows the holder to emit a certain amount of carbon dioxide or other greenhouse gases. One credit permits the emission of one ton of carbon dioxide or the equivalent in other greenhouse gases. Carbon credits are a key component of carbon trading, and they aim to mitigate greenhouse gas emissions. The Sri Lanka Climate Fund, which is a government body under the Ministry of Environment, has established the Sri Lankan Carbon Crediting Scheme (SLCCS) for trading carbon credits within Sri Lanka. SLCCS is the national offset scheme to support local clean projects to benefit from climate finance for GHG emission reduction. As a voluntary initiative, it allows entities to register carbon removal projects, trade carbon credits, and offset verified emissions. It can estimate the project-based contribution and ultimately the construction industry's contribution as a whole. This will enhance credibility, transparency, and the quality of emission reduction in Sri Lanka. Based on the verification report, Certified Emission Reductions (CER) shall be issued in the name of the client. The client is allowed to use credits for internal offsetting or trading. Accordingly, this scheme facilitates carbon trading opportunities by providing data.

Acknowledgement

The authors would like to express their sincere gratitude to Professor Shiromi Karunaratne at the Sri Lanka Institute of Information Technology for the online session delivered on the topic of "Decarbonising Challenge: Are We Ready?" for the Continuing Professional Development (CPD) programme of the Institute of Quantity Surveyors Sri Lanka (IQSSL) on the 16th of December, 2022. This article was predominantly prepared based on the key concepts, facts, and figures presented at this CPD session with the intention of further elaborating, clarifying, and disseminating the knowledge on the decarbonising needs in the Sri Lankan construction industry with a wider community. Our thanks also go to the organisers of the IQSSL's CPD programme as well as the participants of this specific CPD session, who generously shared their knowledge and perspectives with everybody.

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Unveiling of Immediate Past President's Photograph

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1. ☐☐☐☐☐☐☐☐☐☐☐☐ 2. ☐☐☐☐☐☐☐☐☐☐☐☐ ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

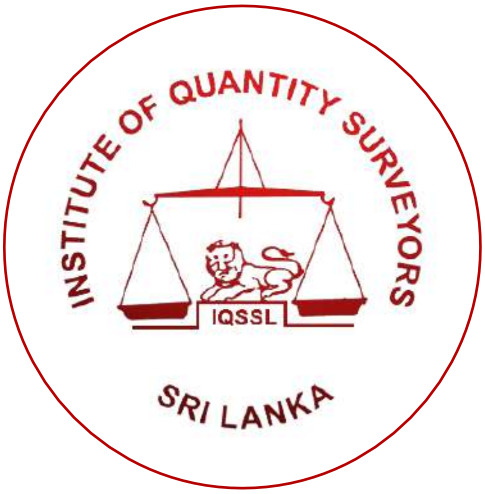
I hereby authorize the use of my credit card to debit the amount mentioned above:

CARD HOLDER's SIGNATURE **DATE**

Change of Address:

Mail to: INSTITUTE OF QUANTITY SURVEYORS SRI LANKA
The Professional Centre,
2nd Floor, No.275/75, Prof. Stanley Wijesundara Mawatha
Colombo 07.
E-mail : Scan the form and e-mail to: iqssl@sltnet.lk

* **Note: CVV #,** is the three (03) digits, printed on back of the Credit



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