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PROJECT DATA RESPONSIBILITIES FOR CARBON ASSESSMENT IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

The construction industry is a significant contributor to global greenhouse gas emissions, driven by both embodied and operational carbon emissions. In Sri Lanka, the lack of a national standard and limited availability of local data have constrained effective carbon measurement and reduction. This study explores stakeholder data responsibilities in carbon assessment, focusing on the Sri Lankan construction sector. Drawing on semi-structured interviews with 18 experts, the research identifies the process-based Life Cycle Assessment (LCA) method as the most appropriate for project-level carbon quantification. In contrast, the input-output method is recognised as a practical alternative in data-scarce situations. The study highlights the importance of stakeholder engagement across life cycle stages, with clients responsible for setting sustainability goals, consultants for conducting carbon calculations, contractors for collecting project data, and government bodies for establishing regulatory guidance. Key data types and stakeholder contributions are identified across construction stages, offering insights to enhance the accuracy and credibility of carbon assessments. The findings offer practical recommendations to promote more sustainable practices and enhance carbon accountability in Sri Lanka's construction industry.

Keywords: *Carbon Assessment; Construction Industry; Data Management; Life Cycle Assessment (LCA).*

1. INTRODUCTION

The global construction industry has a considerable impact on society and the environment (Crawford, 2022). Moreover, it is recognised as a major contributor to greenhouse gas (GHG) emissions, which in turn affects climate change and global warming (Labaran et al., 2021). While numerous studies have highlighted the significance of carbon assessment and emission-reducing policies for the built environment (Xu & Macaskill, 2023), developing countries are aiming to implement effective policies to reduce greenhouse gas emissions by 37% within the next decade (Berlie, 2018). Moreover, international policies have specified principles and guidelines for quantifying the carbon footprint (Kumari et al., 2022).

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Accurate carbon assessment in construction relies on the use of reliable data, which plays a significant role in reducing carbon emissions (Lai et al., 2023). According to Zhu et al. (2023) and Du et al. (2018), the most prominently used carbon assessment method in construction is life cycle assessment (LCA), which is further categorised as process-based analysis, input-output analysis (IOA) and hybrid analysis. In the Sri Lankan context, both process-based analysis and input-output analysis (IOA) approaches are employed, depending on the availability of data (Kumanayake & Luo, 2018a). When comparing them, the input-output method focuses on product groups in the economy, while the process-based method focuses on specific products and services (Han et al., 2022). However, due to a lack of embodied carbon coefficient data for SL, they often rely on international databases such as the Inventory of Carbon and Energy (ICE) or adjust such data for each condition to perform the carbon calculations (Kumanayake & Luo, 2018a). This emphasised a critical gap in the absence of a national database and a standardised method for data collecting, reporting, and management in the Sri Lankan context (Kumanayake & Luo, 2018a).

The effectiveness of carbon assessment is further influenced by the diverse roles and responsibilities of stakeholders involved in the project lifecycle (Xu & Macaskill, 2023). Therefore, clearly defined data responsibilities and data collection processes are crucial for facilitating reliable carbon assessments. However, currently there is no standardised guideline for stakeholder roles and responsibilities in carbon data management and reporting within the Sri Lankan construction industry (Kumanayake & Luo, 2018a).

Addressing this knowledge gap in existing literature, this study aims to explore the Project Data Responsibilities of stakeholders for carbon assessment in the Sri Lankan construction industry. It seeks to identify the carbon assessment methods currently used in the Sri Lankan construction industry, determine the roles and responsibilities of stakeholders in carbon assessment, and assess the specific data contributions of stakeholders throughout the building's life cycle. By clarifying stakeholder data roles and establishing standardised processes, this research aims to enhance the accuracy and reliability of carbon assessments, supporting Sri Lanka's efforts toward sustainable construction and effective climate change mitigation actions.

2. LITERATURE REVIEW

2.1 GLOBAL CARBON EMISSIONS

Carbon emissions have increased due to economic and population growth, with carbon dioxide being the dominant greenhouse gas (Xiong et al., 2024). Human activities, such as the use of fossil fuels and cement production, contribute to around 80% of global GHG emissions. The construction sector alone is responsible for 30–40% of these emissions (Zhang & Zhang, 2020). Both embodied and operational carbon emissions of buildings and infrastructures are responsible for these emissions (Mohebbi et al., 2021). Despite this impact, Yang et al. (2018) highlight that the construction industry has not prioritised emission management. Emissions are typically categorised into Scope 1, 2, and 3 for structured reporting (Kim & Kim, 2021). However, Jusoh and Hashim (2018) emphasise that having sufficient data on GHG emissions is essential to support the effective development of climate policies.

2.2 ACTIONS TOWARDS GLOBAL EMISSIONS REDUCTION

Since the late 20th century, international agreements such as the Kyoto Protocol and the Paris Agreement have been introduced to slow down climate change by reducing GHGs (Liu et al., 2022). The Kyoto Protocol focuses on all six major GHGs, while the Paris Agreement aims to limit global warming between 1.5°C and 2°C (Kuriyama & Abe, 2018). Therefore, achieving carbon neutrality by reducing CO2 emissions has become a global priority, with the introduction of net-zero goals to minimise climate change (Huang & Zhai, 2021).

In Sri Lanka, efforts to measure building-related energy use and CO_2 emissions have begun to emerge. Kumanayake et al. (2018) emphasise the importance of this data as a foundation for national mitigation strategies. Therefore, a detailed assessment of construction carbon emissions is very important for policy regulations and carbon emission reduction (Kumanayake et al., 2018; Hung et al., 2019).

2.3 CARBON ASSESSMENT METHODS IN THE CONSTRUCTION INDUSTRY

Several methods are used to calculate construction-related carbon emissions. Among them, Life Cycle Assessment process-based analysis (LCA) and Input-Output Analysis (IOA) are the most widely adopted (Xiong et al., 2024). LCA is more suitable for project-level evaluations, as it tracks emissions throughout the life cycle of a building. In contrast, IOA offers a broader view by analysing economic flows between industries, making it better suited for regional or national studies (Xiong et al., 2024). However, each method has limitations. IOA lacks specificity for individual projects, while process-based method can be data-intensive and time-consuming. To bridge this gap, some studies have used Hybrid LCA, which combines both approaches. This method enhances accuracy but increases complexity and data requirements (Luo et al., 2019).

Beyond the core methods, techniques such as the Emission Factor method and Real Measurement Method are also used in certain contexts. In Sri Lanka, LCA is the primary carbon assessment method used in the construction industry (Nawarathna et al., 2021). Nevertheless, local applications often rely on international datasets due to the absence of Sri Lanka-specific emission factors. This reliance compromises the accuracy and relevance of the results (Kumanayake & Luo, 2018a).

2.4 DATA TYPES USED FOR CARBON ASSESSMENT IN DIFFERENT LIFE CYCLE STAGES

Input data is generally divided into two types as data stored in databases (materials, construction activities, and energy sources) and user-entered data like material quantities, energy consumption, and project-specific information (Kumanayake & Luo, 2018a). These data are collected from various existing databases, standards, and reports. However, due to regional differences, climate, geography, and technology and construction practices the significant variations can happen in the LCA outcomes (Kumanayake & Luo, 2018a). This highlights the need for country-specific data to accurately reflect local energy and carbon emissions (Kumanayake & Luo, 2018a). Moreover, depending on the calculation method, the results differ even for the same building, as each relies on different data sources (Lu et al., 2024). Table 1 demonstrates the data types used in carbon calculations in each stage.

Table 1: Data types used for carbon assessment in different life cycle stages

Stage	Data type	1	2	3	4	5	6	7	8	9	10
Raw material supply	Material type	X							X		
	Energy use intensity	X									
	Carbon emission coefficients of materials				X			X		X	
	Material quantity					X		X	X	X	
	Material embodied carbon factor			X		X					
Transportation for production and distribution	Type of vehicle		X		X		X				
	Capacity of vehicle				X						X
	Fuel type				X						
	Transportation distance		X	X	X	X	X	X	X	X	X
	Weight of material					X	X	X		X	X
	Carbon emission factor				X		X	X	X	X	X
	Number of trips			X							
Manufacturing	Energy consumption	X			X						X
	Carbon emission factor	X	X		X		X		X		
	Material Qty		X	X	X		X				X
	Total no. of materials	X		X	X						X
	Types of machinery				X		X				
Construction	No. of construction activities			X	X				X		X
	Qty of construction activity				X				X		X
	Fuel/electricity use rate			X	X					X	X
	Carbon emission factors			X	X			X	X	X	
	Quantity of materials					X					
	Site waste					X					
	Machinery use							X	X	X	
	Working time of the machinery								X		
Operation stage	No. of energy sources				X						
	Average annual energy consumption			X	X		X	X	X	X	X
	Carbon emission coefficient			X	X						
	Life span of building			X	X				X	X	X
	Average life span of building material				X					X	X
	Material qty required for repairs and replacement			X						X	
	Repair/replacement rate for material			X	X					X	X
	Carbon emission factor of replacing/installing material			X						X	

Stage	Data type	1	2	3	4	5	6	7	8	9	10
End of life	Refrigerant consumption					X		X		X	
	Annual leakage rate					X					
	Performance of cooling systems						X	X			
	No. of demolition activities			X	X				X	X	X
	Quantity of demolition activity			X	X				X		X
	Carbon emission factor			X	X				X	X	
	Number of trips			X			X				
	Distance			X			X				X
	Area of the building						X	X			X
	Average waste amount per m^2						X				
	Energy consumption										X

[1] (Zhang et al., 2019), [2] (Royal Institution of Chartered Surveyors, 2012), [3] (Kumanayake & Luo, 2018b), [4] (Kumanayake & Luo, 2018a), [5] (Royal Institution of Chartered Surveyors, 2012), [6] (Zhang, X. & Wang, F., 2015), [7] (Zhao et al., 2024), [8] (Zhang, Z. & Wang, B., 2015), [9] (Shang & Geng, 2021), [10] (Chou & Yeh, 2015)

Carbon assessments rely on both database values (e.g., emission factors, material types) and user-entered data (e.g., quantities, distances, energy use) (Kumanayake & Luo, 2018a). Table 1 shows that stages like raw material supply, transportation, and operation require the most diverse data inputs. For instance, transport depends on fuel type, trip count, and distance, while the operation stage involves energy sources, building lifespan, and replacement rates. These variations show that different stages demand different data depths, and results can vary significantly depending on the method and data used (Lu et al., 2024). In Sri Lanka, the lack of local data often leads to the use of foreign databases, reducing the reliability of results (Kumanayake & Luo, 2018a). This risks misleading decisions and weakening carbon reduction strategies. Developing a national carbon data system is therefore critical to support accurate assessments and align with net-zero goals (Dong et al., 2023; Xu & Macaskill, 2023).

Developing countries like Sri Lanka face challenges due to the lack of reliable data and carbon-related studies, making it essential to develop national databases for accurate analysis (Kumanayake et al., 2018a). Without reliable data, stakeholders like governments, developers, and builders risk making incorrect assumptions, setting unrealistic targets, and implementing ineffective policies, potentially undermining net-zero goals (Xu & Macaskill, 2023). Therefore, in LCA, accurate data collection is foundational to avoid overestimating or underestimating emissions, which impacts the decision-making process in the construction industry (Andreux & Henrysson, 2023).

2.5 STAKEHOLDERS INVOLVED IN THE CONSTRUCTION CARBON ASSESSMENT

Stakeholders play a critical role in the successful adoption and implementation of relevant net-zero strategies and carbon reduction policies (Falana et al., 2024a). Collaboration among stakeholders has been identified as a key strategy in realising net-zero carbon buildings for the integration of carbon reduction practices in achieving green building objectives (Falana et al., 2024a). While green building principles recognise the importance of stakeholder contributions, especially in data management and emissions tracking, most countries still lack clearly defined stakeholder roles specifically for carbon assessment.

Green buildings target reducing carbon emissions during all lifecycle phases, with the contribution of stakeholders in minimising carbon impacts (Kaya & Scolaro, 2023). Therefore, those key Stakeholders were identified, such as clients, contractors, architects, engineers, manufacturers, facilities managers, governments and non-government organisations, who need to be actively involved in managing emission-related data across the building life cycle (Falana et al., 2024b). Despite the growing relevance of stakeholder engagement, existing studies rarely explore their specific responsibilities in emission tracking across life cycle stages, indicating a critical gap in both research and practice (Falana et al., 2024a).

3. RESEARCH METHOD

Research is a systematic approach that discovers new knowledge, verifying existing facts, analysing their relationship to formulate theories that explain phenomena (Bhagyamma & Ramesh, 2023). The choice of a suitable research approach among qualitative, quantitative and mixed approaches depends on the nature of the available information for the study (Pandey & Pandey, 2015). The qualitative approach is exploratory, suited for the discovery of new insights and the formulation of new theories, while the quantitative approach is basically used for measuring and analysing numerical data (Kothari, 2004; Taherdoost, 2022). The mixed method approach is a combination of both quantitative and qualitative approaches, which expand the findings of one method by using the other and then mix the data in analysis and get the results (Abutabenjeh & Jaradat, 2018). Therefore, to explore new insights of this novel concept in-depth, this study employed the qualitative approach.

Interviews provide a straightforward approach to gathering details in-depth, where there is less knowledge to explore. There are three types of interviews as structured, semi-structured and unstructured interviews. Out of them, semi-structured interviews are widely used as they allow flexibility to discover new ideas from experts. Therefore, the data collected through semi-structured interviews in this study. The qualitative data was analysed using thematic analysis with the aid of NVivo software to ensure the clarity of the data analysis. The profile of the experts who participated in the interviews is summarised in Table 2, providing an overview of their experience, qualifications and areas of expertise.

Table 2: Details of the experts

Int. code	Designation	Experience		Qualifications
		Cons.	Carb.	
E1	Senior Lecturer	12+	5+	GREEN SLAccP, Research publications in carbon assessment
E2	Senior Professor	0	12+	Research publications related in carbon assessment, Founder of carbon calculating software
E3	Senior Professor	25+	15+	Research publications in Carbon assessment, GREEN SLAccP

Int. code	Designation	Experience		Qualifications
		Cons.	Carb.	
E4	Researcher	7+	5+	Research publications in carbon assessment, GREEN SLAccP
E5	Senior lecturer	11+	5+	Research on embodied carbon-related emissions in buildings
E6	Lecturer	6+	5+	Facilities manager and Health and Safety officer in the manufacturing industry
E7	Researcher Assistant	5+	7+	PhD in sustainable built environment, construction LCA-based publications and sustainability manufacturing
E8	Lecturer	10+	5+	Research publications related to sustainable construction and building carbon emissions.
E9	Senior Lecturer	8+	6+	Research related to sustainable built environment, GREEN SLAccP, Carbon Assessment consultant
E10	Manager (Sustainability)	-	10+	Verification, certification, and advisory services for an organisation's carbon emissions
E11	Green Building Analyst	5+	5+	Master's in sustainable construction architecture, involved in LCA carbon assessment, IGBC Accredited Professional
E12	Project Lead	8+	7+	Visiting Lecturer and Project Evaluator, Former General Manager at GBSL, External Carbon Consultant, GREEN SLAccP, Civil Engineer
E13	Acting Chief Executive Officer	-	10+	Carbon verification in organisations and services, GHG auditing
E14	Executive Envir. Sustainability	5+	4+	LEED & Green Building Certification and Rectification
E15	Senior Engineer (Green projects)	9+	6+	Involved in Carbon footprint assessment and LCA of buildings, LEED Green Associate, IGBC Accredited Professional
E16	General Manager	25+	5+	Green auditing, GREEN SLAccP
E17	General Manager	30+	-	Involved in Green buildings and low-energy embodied materials selection, green accreditation practices
E18	Senior QS	30+	5+	Involved in sustainable construction practices

As presented in Table 2, 18 Experts were selected under three categories as academia, carbon analysts and construction professionals. Their selection criteria were having more than 5 years of experience in the construction industry and a carbon assessment to ensure their knowledge aligned with the objectives of the research.

4. RESEARCH FINDINGS

4.1 CARBON ASSESSMENT APPROACHES IN THE CONSTRUCTION INDUSTRY

The interview findings revealed that the primary carbon assessment methods are process-based LCA, input-output and hybrid approaches. The majority of the interviewees (E3, E4, E5, E6, E7, E9, E10, E16) highlighted the suitability of the process-based LCA method in the construction industry. They cited its ability to provide comprehensive and detailed emission calculations across all stages of a building's life cycle, including embodied and operational carbon. However, the E1, E3, E5, and E8 groups of experts suggested the input-out method as a viable option due to the practical availability of data. Additionally, E10, E11, E18, and E16 experts recommended the use of international standards, such as the GHG Protocol, ISO 14064-1, and ISO 14064-2, as well as methods specified in BRE and EN standards for carbon assessment. However, 70% of the interviewees selected the process-based LCA method as the most suitable carbon assessment approach for the Sri Lankan context. As identified, the reason for this preference was the ability to provide detailed and accurate emission calculations than the other methods. Five experts acknowledged the challenges associated with data availability and suggested applying input-output approach in cases where data is limited.

The literature findings summarise that the most used carbon assessment approach is life cycle assessment (LCA), according to the authors Xiong et al. (2024) and Zhang et al. (2019). Further studies confirmed that the process-based method is the most accurate LCA method suitable for single-building carbon emission assessment. In contrast, the input-output method is suitable for sector-level or region-level calculations (Liu et al., 2022). However, in the existing literature, no specific method has been suggested for Sri Lanka. Few studies by Kumanayake and Luo (2018a), Nawarathna et al. (2021) have been carried out in Sri Lanka using the LCA approach.

Through the expert interviews, both process-based methods and input-output methods were suggested for Sri Lanka, while some experts recommended the process-based method as the most ideal method due to its clarity few experts suggested input input-output method due to a lack of data in the current situation. Therefore, based on the literature findings and confirmation by the opinions of the majority of experts, the process-based method can be proposed as the most suitable approach for carbon assessment in the Sri Lankan construction industry.

4.2 STAKEHOLDERS' ROLES AND RESPONSIBILITIES IN CARBON ASSESSMENT AND CARBON DATA MANAGEMENT

The findings of expert interviews confirmed a significant gap in defining clear roles and responsibilities for carbon assessment and data management in the Sri Lankan construction industry. Most experts agree that the absence of defined roles and responsibilities among stakeholders, as well as inadequate regulatory requirements, has led to inefficiencies and inaccuracies in carbon reporting.

The client or developer is identified as the primary stakeholder responsible for initiating the carbon assessment by setting up sustainable goals. However, E3, E7, E11, and E13 highlighted that they are not directly involved in providing specific data for the calculations. E16 noted two primary responsibilities: setting the objectives and allocating funding. Consultants are identified as the key stakeholders in conducting carbon calculations and providing guidance. Contractors play a central role in data collection, collaborating with suppliers and manufacturers to gather data on materials and processes, as well as collecting on-site emissions data. The experts also highlighted that the government is responsible for setting out regulations and standards to promote the concept, though their current efforts are not sufficient. E16 highlighted the significance of government encouragement to make this a success, while E3 mentioned some government contributions, such as the Blue-Green economy and material rating systems in the Construction Industry Development Authority (CIDA). As identified, non-governmental organisations like the Green Building Council Sri Lanka (GBCSL) also carry a similar responsibility in promoting green building practices within the community through training and accreditation; however, according to the E10, their influence is constrained without stronger government support.

Although the previous literature has not defined any clear role and responsibility for stakeholders in carbon calculations and carbon data management, Fenner et al. (2018), and Kaya and Scolaro (2023) noted the stakeholder involvement in green buildings. Therefore, stakeholder roles were defined through expert opinions as the client and the consultants are responsible for doing the calculation, while the contractor plays a major role in providing and collecting data. Contractors should communicate with the other stakeholders, like manufacturers, suppliers and subcontractors, to acquire data and need to provide it to the consultant. Facilities managers are the key people to collect operation stage data, and at the end, demolition contractors or waste management authorities will be involved as per the requirements of the client.

4.3 DATA CONTRIBUTIONS OF STAKEHOLDERS IN LIFE CYCLE STAGES

The extraction of raw materials stage and the manufacturing stage are considered similar stages for carbon assessment due to the method of conducting carbon calculations. The manufacturer is identified as the primary stakeholder responsible for providing carbon-related data in both stages, according to the opinion of the majority of experts, where 11 experts suggested the extraction stage, and 13 experts suggested the manufacturing stage. The supplier is the next most important stakeholder, as they provide data on material transport and the embodied carbon of the product. However, as highlighted by experts E1, E11, and E15, suppliers and manufacturers typically pass this data to the contractor, who is responsible for collecting all the data and providing it to the consultant who is performing the actual carbon calculations. The key data types required for carbon calculations in these stages include emission factors, material quantities, and energy consumption. Experts such as E2, E8, E9, and E11 emphasised the use of Environmental Product Declarations (EPDs), while E3 and E4 mentioned databases like ICE to acquire carbon coefficients for materials. However, experts highlighted the importance of emission factors for fuel and electricity and proposed the use of recycled materials as a data type, which is less emphasised in existing literature.

During the construction stage, all experts noted that the contractor has a central responsibility for collecting carbon data, with the support of other stakeholders, including subcontractors, suppliers, and industry practitioners. Essential data types include energy consumption (electricity and fuel), machinery usage (number of working hours and construction activities), emission factor and waste generation. In the qualitative data analysis, the term “emission factors” is used to represent all carbon emission factors related to materials, fuel, and electricity for ease of presentation. As emphasised by E7, these data points can vary depending on the specific processes used on-site. The new data type identified through the interviews was water usage at the site.

The transport stage involves multiple phases, and Experts E3, E5, E7, and E16 emphasised that transportation can occur in various modes, such as direct supply to the site, like river sand or through intermediate manufacturing facilities. E16 further explained that the data types required for carbon assessment remain consistent across these modes. The contractor is identified as the main responsible stakeholder by the majority of interviewees for collecting transport-related data, while the suppliers, manufacturers and logistic companies also have a shared responsibility. The key data types in the transport stage include total distance, vehicle type, capacity, fuel type, and carbon coefficients of fuel. Total distance is taken by considering the number of vehicles and trips, and experts E7 and E11 argued that vehicle type is sufficient instead of capacity and fuel type. Even though only Kumanayake and Luo (2018a) have identified "fuel type", it is an important data type in this stage of calculations, according to the experts.

In the operation stage, almost all interviewees agreed that the facilities manager plays the key role in data collection and management. E17 noted that the client also has an indirect involvement in delegating the responsibility to the facilities manager. The significant data types in this stage are energy consumption (electricity, fuel, and water) and their emission factors. As additional data type, waste quantity, water quantity, and solar energy consumption were identified through expert interviews. Since the embodied energy is already calculated in the previous stages, the interviewees argued that "amount of original building materials" and "life span of building materials" data do not need to be collected in this stage.

The end-of-life stage is considered the most challenging due to the lack of reliable data. Facilities managers, Demolition contractors, and waste management companies are identified as the main responsible stakeholders for capturing data on demolition transport, waste quantities, and recycled materials in this stage. However, E11 mentioned that they rely on assumptions in practice due to the unavailability of data even in the global context. Energy consumption, particularly fuel use during demolition, and the quantity of recycled materials are critical data types. Moreover, experts argued that the quantity of demolished activity and the quantity of demolished material are similar, and there is no need to have both in calculations.

5. CONCLUSION

This research addresses the timely issue of carbon assessment within the local construction context by identifying Project Data Responsibilities in carbon assessment, which primarily clarifies stakeholder roles and data handling procedures. The research confirms that the process-based LCA is the most appropriate technique for detailed and accurate carbon assessment, but is hampered in practice by a lack of localised data and standard protocols. Not having precisely outlined duties for stakeholders related to this process has been identified as a major factor that negatively impacts the current carbon assessment procedure in the local context. The study offers a systematic approach to reliable data collection and carbon reporting, precisely outlining the responsibilities of clients, consultants, contractors, suppliers, manufacturers, facilities managers, and regulatory bodies throughout the project lifecycle. Its application will add credibility to carbon analyses, enable more realistic policy and project objectives, and allow effective emissions reduction strategies to be developed. However, this is limited to the Sri Lankan building projects, and this study provides a clear pathway to collect, report and manage carbon-related data needed for the calculations with their responsible stakeholders. Therefore, the findings facilitate the proper implementation of accurate carbon assessments to achieve sustainable construction goals in Sri Lanka and alignment with global climate objectives.

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