The Role of Contractors in Reducing Carbon during Construction – A Preliminary Study

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Abstract

Construction contractors have been touted to be a major player in reducing carbon emissions during the construction process due to their role in bringing building designs to life. Also, various carbon reduction strategies have been highlighted in assisting contractors in reducing the carbon emitted while carrying out construction activities. However, it is believed that contractors are quite reluctant to adopt these strategies for several reasons, such as a possible increase in cost and being contradictory to their existing construction procedures. This paper, therefore, aims to highlight the report of a preliminary study done through the adoption of a systematised review approach in synthesising literature to understand what the evidence is as regards how contractors contribute towards the reduction of carbon during building construction activities. The findings reveal that there is a paucity of research in this research area as only 12 papers were found relating to the focus of this study. The analysis of these papers revealed eight possible ways (e.g. adoption of lean management principles, adoption of eco-hauling concept, and utilisation of modern digital tools) in which contractors contribute to carbon reduction during building construction projects. The findings of this study will benefit contractors looking for a suite of measures to implement in reducing their building construction project carbon footprint while also serving as a piece of foundational knowledge in the research area of carbon reduction during building construction projects. Lastly, a future study area worth exploring is proposed.

1.0 Introduction

Construction contractors have been touted to be a major player in reducing carbon emissions during the construction process due to their role in bringing building designs to life (Wong *et al*., 2014). This is extremely important given the recent call by the Intergovernmental Panel on Climate Change (IPCC) in its *Global Warming of 1.5^{o}C* report that the world needs to reduce global warming to 1.5^{o}C in order to avoid major catastrophes both to human and natural systems (IPCC,

2018). Therefore, in identifying sectoral contribution to global carbon emission so as to serve as a guide in knowing where efforts should be directed in reducing greenhouse gas (GHG) emission and avert its impact, the construction industry was found to be a vital sector to focus attention on. This is largely because the sector has been recognised as one of the major contributors to GHG emissions (Giesekam *et al.*, 2018). To put this in context, a report by Global Alliance for Buildings and Construction *et al.* (2019) stated that globally, the building and construction sector alone emitted almost 40% of the total carbon dioxide (CO_2) emissions in 2018. And in the UK in 2014, the UK Green Building Council (UKGBC) reported that 42% of the UK's total carbon footprint was from the built environment, with new construction alone contributing 48 Mt CO_2eq (UKGBC, 2021).

Based on this backdrop, scholars have started devoting time to identifying carbon reduction strategies that can assist in minimising the pollution from new construction operations (Wong *et al*., 2013). Since construction contractors have been identified as the stakeholder responsible for bringing building design to fruition (Wong *et al*., 2014), it is therefore important to investigate their role in reducing carbon emission during construction activity. Although previous work has been done on the reduction of carbon emission during the lifecycle (from initiation to completion) of a construction project (Agung Wibowo *et al.*, 2018) and on assessing the impact of energy reduction measures on carbon emission during construction (Gottsche *et al*., 2016), but until now and to the researchers' knowledge, no study has been done in examining the role of contractors in reducing carbon emission during the construction phase of a building project through the synthesis of literature. Hence, a need for this present study and to fulfill the aim of this research, the research question to be explored is 'what are the evidence from literature regarding how contractors can contribute towards the reduction of carbon during building construction activities?'

It is therefore hoped that the findings of this study will present construction stakeholders and policy makers a further insight into what is obtainable in the construction industry, especially as it relates to minimising carbon emission arising from the construction phase of building projects as managed by contractors. Equally, this present study hopes to contribute to the construction research body of knowledge relating to carbon reduction during building construction projects.

2.0 Building Construction Projects Lifecycle Stages

The need to understand the lifecycle stages of a building construction project has become quite significant, especially as it relates to the study of carbon reduction in construction projects. This is because the intensity of carbon emission related to construction projects varies during the different lifecycle stages. Therefore, to understand a building's construction lifecycle stages, this study adopts the European standard EN 15978 (Figure 2.0) classification since, according to the

World Green Buiding Council (2019), it has been largely adopted in assessing lifecycle stages of buildings.

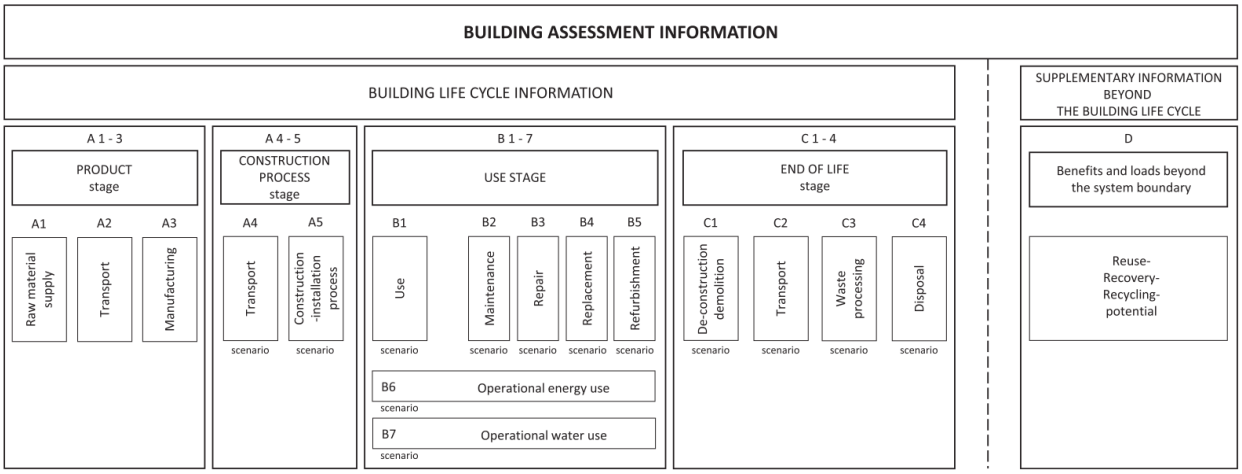

Figure 2.0: Lifecycle Stages of Building (Source: European Committee for Standardisation 2011)

As depicted in Figure 2.0, the lifecycle stages of buildings can be divided into four broad modules, namely: product and construction process stage (A1 – A5); use stage (B1 – B7); end of life stage (C1 – C4); and beyond the building lifecycle stage (D). Since the focus of this study is related to the construction phase of a building, we shall limit the explanation of the lifecycle stages in this paper to module A while further insight into the detailed explanation of each module can be obtained from the European Committee for Standardisation (2011).

Now, according to the European standard EN 15978, module A is categorised into two, and they are product stage (A1 – A3) and construction stage (A4 – A5). The product stage involves processes related to the materials and overall utility employed in building construction, from raw material extraction to when the material is manufactured and ready for use (cradle-to-gate). While the construction stage involves the transport of materials to the site from the gate of the factory till the end of construction work, including construction equipment transportation to and from the construction site (European Committee for Standardisation, 2011).

Carbon emissions associated with the construction stage of a building project have been reported by researchers to be small (Kong et al., 2020; Zhang, et al., 2016). However, if human activities such as transportation to and from the site, electricity usage, etc. are included, this could drive construction phase-related carbon emission further up by almost 45% (Hong et al., 2015). Thereby making the construction phase of building projects an important lifecycle stage to be examined.

3.0 Research Methodology

Since this study is a preliminary research in gaining insight into how contractors contribute to the reduction of carbon emission during construction projects, a review of literature was conducted to assess scholars contribution to this research area and to serve as a foundational knowledge (Snyder, 2019) in understanding the current dynamics that have influenced progress in this area. A systematised review approach was adopted in analysing literatures for this study due to its reliability in espousing what works and its dependability on minimising bias while generating a robust response to a dedicated research question (Mallett *et al*., 2012).

In selecting the appropriate articles for this study, the Scopus database was chosen and this is based on the fact that the database has an enormous archive of engineering, management, psychology, business, and construction research publications (Darko and Chan, 2016) as well as owing to its reliability when compared to other databases like Google Scholar and Web of Science (Charef *et al*., 2018). On Scopus, a keyword search was conducted to identify relevant papers as done by other authors (Deng and Smyth, 2013). The selection of keywords to be used was a bit challenging, however, since a study cannot in itself address all the possible complexities associated with research keywords (Darko and Chan, 2016) in identifying the role of contractors' in reducing carbon during building construction projects, an assumption was made on the keywords. The two strings of keywords assumed and used are as follows:

i) "carbon reduction" OR "reduc* carbon" OR "carbon emission* reduction" OR "CO2 reduction" OR "CO2 emission* reduction" OR "GHG reduction" OR "greenhouse gas emission* reduction" OR "GHG emission* reduction"
ii) "contractor*" OR "contracting organi*" OR "contracting firm*" OR "building contractor*"

Upon deciding on appropriate keywords, the full search was conducted on the 22nd June 2021, and the search was done using the 'title-abstract-keyword' section of Scopus with no limitation to the date range. The search returned 51 papers and after removing subject areas not related to construction like medicine, agriculture, mathematics, etc; limiting the search to articles published in journals and conferences; as well as those published only in English language, we were left with only 41 papers. The abstract of these 41 papers were reviewed, and articles that did not meet the objective of this research, but which only mentioned any or some of the keywords in their abstract or titles were removed (Darko and Chan, 2016; Charef *et al*., 2018). This then left us with just 19 papers plausible for full-text analysis. Of these 19 papers, the full text of two papers was not found, and upon scanning through the full text of the others, three papers did not fit the purpose of the research, while two papers were irrelevant to the scope of the present study. Therefore, we were left with 12 papers (Figure 3.0) which are in line with the question posed in this study (Charef *et al*., 2018). It is important to note that two papers (Krantz

et al., 2019; Sanchez *et al*., 2015) out of the 12 papers focused on road and transport infrastructure but were included in this study due to their relevance to this study as observed during their analysis. This sort of deviation, according to Charef *et al*. (2018) is tolerable in a review study once it is done for a valid purpose.

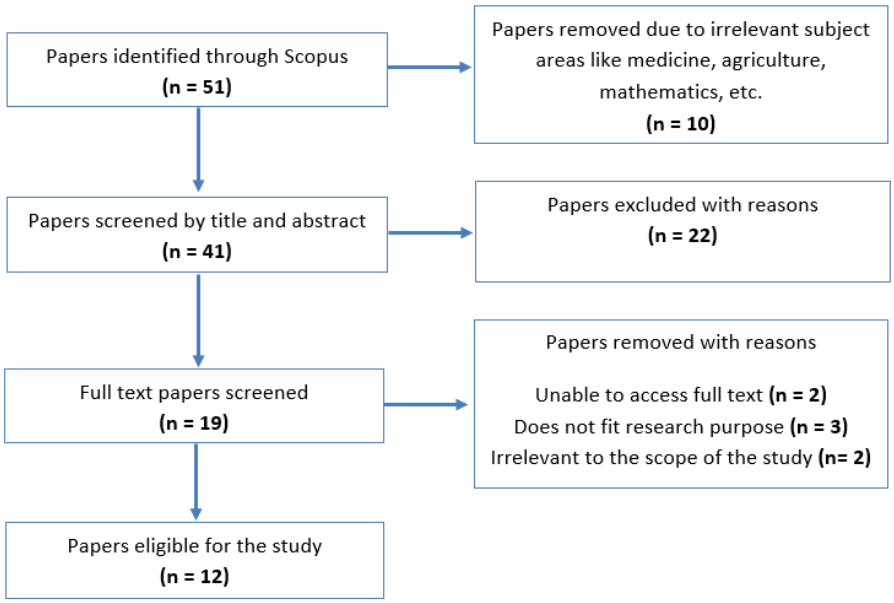

Figure 3.0: Flowchart Summarising the Systematised Review Process.

4.0 Result Analysis and Discussion

In contributing to carbon reduction during building construction projects, contractors will need to utilise some carbon reduction strategies to bring about the desired outcome.

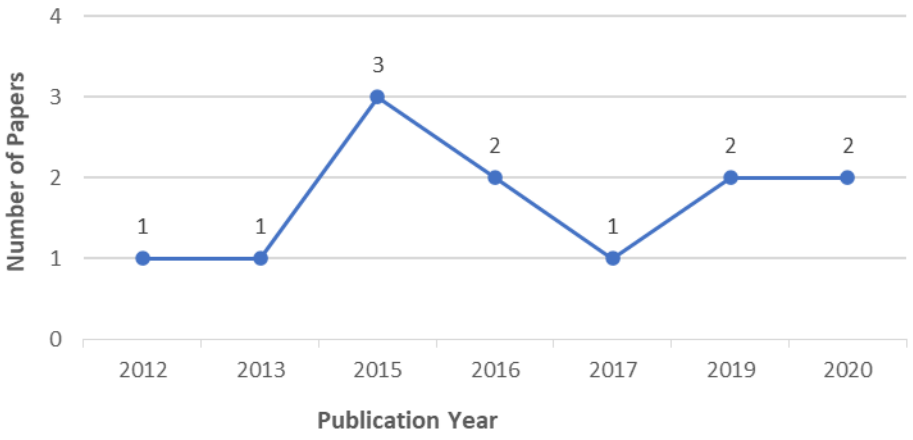

Figure 4.0: Annual Publication of Papers Selected for the Study

However, it was observed during the review of literatures for this study that the uptake of these strategies by contractors' have not been well documented in literature since only 12 papers was found across the years, as depicted in Figure 4.0, even though the search does not have time boundary as explained in Section 3.0.

This might not be unsurprising given that research into carbon emission generally just began to rise significantly in 2007, according to Abeydeera *et al.* (2019) in their work on mapping global carbon emission research. Also, as highlighted by Wong *et al*. (2013), the adoption of strategies is a behavioural issue, and according to Anvuur and Kumaraswamy (2012), issues bothering on behaviour is one of the fundamental challenges in the construction sector, and the authors equally noted that research focusing on behavioural themes in construction management (CM) is rare. Therefore, the low number of papers obtained for this study mirrors what is in the literature. Thus, the research community, especially those with interest in building construction decarbonisation need to pay attention to this area of research so that there would be an opportunity for shared knowledge within the sector, particularly amongst contractors in order to drive the decarbonisation agenda in meeting the 2050 net-zero carbon buildings target.

Table 4.0: Distribution of Methods Utilised by Selected Papers for Data Collection

Method Used for Data Collection by Papers	Number of Papers	Percent of Total
Case Study	7	58
Literature Review	1	8
Mixed Method	2	17
Survey	2	17

As seen in Table 4.0, most of the papers analysed in this study collected their data using case study method (58%), and this corroborates what is in the literature regarding the increased adoption of this method within the CM field (Taylor *et al.*, 2009). Although, critics have highlighted biasness, inability to generalise, and lack of rigour as some of the issues surrounding the use of case study as a research approach (Wedawatta *et al*., 2011). However, scholars have identified tactics such as validity and reliability test to eliminate these issues (Wedawatta *et al*., 2011) and that its use enables researchers to retain the meaningful and complete characteristics of actual events being studied (Sutrisna and Abbott, 2002) which is the feature of most construction projects examined in CM research.

Other methods used in collecting data in the papers selected for this study are mixed method (17%), survey (17%), and literature review (one paper). The papers that utilised mixed method approach combined both survey, direct observation, and case study methods together. This is typical of mixed method approach since its other terminology is methodological triangulation, and it has been known to utilise the strength of other methodologies in studying a specific phenomenon in detail (Darko *et al.*, 2017).

4.1 Contractor's Role in Reducing Carbon during Building Construction Projects

In the papers analysed in this study, eight strategies were identified as steps taken or to be done by contractors' in reducing the carbon footprints of building construction projects. These strategies are presented in Table 4.1.

Table 4.1: Contractors' Contribution to Carbon Reduction during Building Construction as Culled from the Selected Papers

Contractors' Contribution to Carbon Reduction during Building Construction	References
Utilisation of modern digital tools such as BIM	Goyal and Rai (2020); Hao *et al*. (2020)
Adoption of lean principles during construction (e.g, site layout management and delivery management such as just-in-time approach)	Fu *et al*. (2015); Wu (2015); Wu *et al*. (2013); Wu *et al*. (2012)
Adoption of eco-hauling principles	Krantz *et al*. (2019)
Adoption of necessary regulation	Zhang and Zhou (2016)
Adoption of low energy management practices	Gottsche *et al*. (2016)
Adoption of the appropriate construction schedule and material procurement while utilising the concept of 'trade-off analysis'	Gan *et al*. (2017)
Adoption of appropriate cooperation models between the main contractor and subcontractor in delivering construction projects	Jiang *et al*. (2019)
Client adoption of early contractor involvement contract model	Sanchez *et al*. (2015)

4.1.1 Utilisation of Modern Digital Tool

The use of building information modelling (BIM) to simulate environmental performance, including the understanding of carbon footprint and its potential reduction in building construction projects, have been noted by scholars as a measure that can assist contractors in reducing carbon emission during building construction (Goyal and Rai, 2020; Hao *et al*., 2020). Amongst other things, some of the benefits that BIM could provide in reducing carbon emission during building construction activity include the reduction of construction waste and energy management (Raza *et al*., 2019; Goyal and Rai, 2020).

4.1.2 Adoption of Lean Principles during Construction

Lean principles adoption during the building construction process has been identified as one of the ways in which contractors can reduce the carbon emission associated with a building construction project (Fu *et al*., 2015). During a case study carried out by Fu *et al*. (2015) on the construction of the secondary trusses of the roof of a steel structure building, the authors found out that the application of lean principle to this part of the construction process reduced the carbon footprint of both the equipment used and the transportation associated with material

movement and waste disposal by around 56%. Wu *et al*. (2013) and Wu (2015) equally noted that the carbon emission from the installation of a precast concrete column during the construction of a high-rise building could be reduced by about 71% if lean management principles such as just-in-time and uninterrupted workflow (e.g. appropriate site management layout) are adopted. This is expected since lean construction has been said to enhance construction process reevaluation in a bid to reduce waste linked to activities that consumes resources but end up not generating any value (Goyal and Rai, 2020).

4.1.3 Adoption of Eco-hauling Principles

Eco-hauling is the term given to the adoption of eco-driving concept in reducing carbon emission during earthmoving operations by Krantz *et al.* (2019). The authors (Krantz *et al.*, 2019) defined eco-hauling as strategies to be adopted at company, project, and task, as well as equipment operator level in minimising activities that could yield carbon emission during earthmoving operation. These strategies include the purchase of fuel-efficient equipment; steady maintenance of equipment; optimisation of equipment utlisation and earthmoving plan; etc. While the authors highlighted the benefit of this principle in reducing carbon emission, they equally noted the need for contractors to balance productivity and cost when utilising eco-hauling concept. Furthermore, Krantz *et al*. (2019) stated that having up-to-date information about a site and careful planning is crucial when implementing the eco-hauling principle. Based on the aforementioned, the eco-hauling concept advanced by Krantz *et al*. (2019) has some similarities with the lean management principle; hence, it will be useful if contractors can combine both principles that is lean management and eco-hauling in minimising carbon during building construction projects. This is because eco-hauling has more to do with earthmoving operation, which is part of the task involved during a building construction ground works activity as categorised by Acquaye and Duffy (2010), and lean management has to do with how the overall activity on a building construction site is carried out so as to eliminate waste and drive down cost.

4.1.4 Adoption of Necessary Regulation

Contractors' have been documented to improve their carbon reduction behaviour when there are appropriate government regulations instructing them to do so. For instance, in the studies conducted by Wong *et al*. (2013) and Zhang and Zhou (2016) in understanding the impact of government regulations on contractors' uptake of carbon reduction strategies during construction (termed as carbon reduction behaviour by the authors), the authors found out that indeed, government regulations do have some impact on contractors' carbon reduction behaviour. Albeit, in both studies, the authors argued that this carbon reduction behaviour could be strengthened by other factors such as organisational culture and incentives.

4.1.5 Adoption of Low Energy Management Practices

Energy consumption through the usage of fuel and electricity have been highlighted as one of the major emitters of carbon during building construction projects (Hong *et al*., 2015). Consequently, contractors' have been encouraged to adopt low energy management practices when handling a building construction project. Gottsche *et al*. (2016) demonstrated how this could reduce carbon emission during an action research study carried out on two building construction projects in Ireland. During the action research, the contractor implemented only 10 energy reduction measures (such as office equipment switching off; reduction of heating usage; night-time electricity management; and machine idle time reduction) out of the 27 specified by Gottsche and her colleagues and was able to achieve a 24% reduction in carbon emission and saved an estimated 5.5% of the profit believed to be made from the project. This clearly shows that if the contractor had implemented all the energy management strategies stated by the researchers, more carbon emissions could have been reduced, including the possibility of making more profit.

4.1.6 Adoption of Appropriate Construction Schedule and Material Procurement while Utilising the Concept of 'Trade-off Analysis'

Construction projects and their delivery have been known to be complex, fragmented, and sometimes with strict schedules (Sutrisna and Abbott, 2002; BIS, 2013; Gan *et al*., 2017). Therefore, understanding the specific feature of a building construction project together with its many intricacies is important in adopting an appropriate construction schedule that will optimise the construction process, including reduction of its carbon footprint. A part of this process is material procurement. As highlighted in the work of Gan *et al*. (2017), the strategies adopted in procuring materials for a building construction project can influence the amount of carbon emission associated with that part of the construction process. Some of the considerations put forward by the authors (Gan *et al*., 2017) in making decisions on material procurement to reduce carbon emission include construction time, material availability, and sources of materials. The authors appreciate that juggling between these considerations in making the right decision will involve trade-offs; hence, they developed a carbon accounting tool (see Gan *et al*. (2017) for details) that would ease the decision process in procuring material sustainably, thereby reducing its carbon footprint and cost.

4.1.7 Adoption of Appropriate Cooperation Models between Main Contractor and Sub-contractor in Delivering Construction Projects

Building construction projects implementation involves many stakeholders due to the different processes involved in bringing its design to life. Thus, it is common to have several sub-contractors working on-site at the same time, with the main contractor being the lead of the project. Due to this fragmentation, there is a possibility of having a lower opportunity to reduce waste and carbon emission, including the cost of a building construction project (BIS, 2013).

Hence, it is important for all these stakeholders to cooperate favourably if they want to maximise their gains and reduce the carbon emission of the activity under their watch. In establishing the appropriate cooperation model between the main contractor and sub-contractor that could lead to their increased reduction of carbon during a construction project, Jiang *et al*. (2019) conducted a simulation study using game theory and Shapley value method to understand carbon reduction impact under a co-opetition, pure cooperation, and pure competition environment. The authors (Jiang *et al*., 2019) found out that only an atmosphere of co-opetition and pure cooperation can deliver carbon reduction during the execution of a construction project. Therefore, it is imperative for contractors involved in a building construction project to identify the right cooperative strategy that can deliver the carbon emission goal of the project they are implementing early on during the construction phase.

4.1.8 Client Adoption of Early Contractor Involvement Contract Model

Although this approach in reducing the carbon emission of contractors during a building construction project has to do with the client's decision, however, it has been included as a foresight strategy that can be advanced by contractors if they have a good working relationship with their clients. The study conducted by Sanchez *et al*. (2015) proved that if a contractor is integrated early on during the planning phase of a construction project, there is an increased potential to reduce the carbon footprint of such project. Kadefors *et al*. (2021) equally echoed the same finding based on the case study research they carried out in five countries, including the UK on the implementation of procurement requirements to reduce carbon during the construction of infrastructure projects.

5.0 Conclusion

This study aimed at investigating the role of contractors in reducing carbon emission during construction projects through the synthesis of the literature. 12 papers were identified through the systematised review approach adopted in selecting the articles for this study. The analysis of these papers revealed eight strategies that contractors usually adopt or could adopt in reducing the carbon footprint of building construction projects. Some of these measures taken by contractors include adoption of low energy management practices while on-site, adoption of lean management principles, adoption of eco-hauling concept, and utilisation of modern digital tools such as BIM. The findings of this study will be beneficial for contractors looking for a suite of measures to adopt in reducing the carbon footprint of the building construction project in which they are involved. Equally, it will serve as foundational knowledge in the research area on carbon reduction during building construction projects.

Although these strategies have been identified from research conducted in various contexts and climes, however, further research can still be done in exploring contractor's agreement to these measures and to find out if there are limitations to their adoption in certain climes and building

construction contexts. Also, another study can be carried out to understand the cumulative effect of the application of these strategies on carbon reduction during the erection of a specific building construction project.

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References

Abeydeera, L. H. U. W., Mesthrige, J. W. and Samarasinghalage, T. I. (2019). Global Research on Carbon Emission: A Scientometric Review. *Sustainability*, 11 (14), pp. 1–25.

Acquaye, A. A. and Duffy, A. P. (2010). Input-Output Analysis of Irish Construction Sector Greenhouse Gas Emissions. *Building and Environment*, 45 (3), pp. 784–791.

Agung Wibowo, M., Uda, S. A. K. A. and Zhabrinna (2018). Reducing Carbon Emission in Construction Base on Project Life Cycle (PLC). *MATEC Web of Conferences*, 195, pp. 1–11.

Anvuur, A. M. and Kumaraswamy, M. M. (2012). Measurement and Antecedents of Cooperation in Construction. *Journal of Construction Engineering and Management*, 138 (7), pp. 797–810.

BIS. (2013). *Supply Chain Analysis into the Construction Industry*.

Charef, R., Alaka, H. and Emmitt, S. 2018. Beyond the Third Dimension of BIM: A Systematic Review of Literature and Assessment of Professional Views. Journal of Building Engineering, 19 (May), pp. 242–257.

Darko, A. and Chan, A. P. C. (2016). Critical Analysis of Green Building Research Trend in Construction Journals. *Habitat International*, 57, pp. 53–63.

Darko, A., Zhang, C. and Chan, A. P. C. (2017). Drivers for Green Building: A Review of Empirical Studies. *Habitat International*, 60, pp. 34–49.

Deng, F. and Smyth, H. (2013). Contingency-Based Approach to Firm Performance in Construction: Critical Review of Empirical Research. *Journal of Construction Engineering and Management*, 139 (10), p. 04013004.

European Committee for Standardization (2011). *BS EN 15978:2011 Sustainability of Construction Works - Assessment of Environmental Performance of Buildings - Calculation Method*.

Fu, F., Sun, J. and Pasquire, C. (2015). Carbon Emission Assessment for Steel Structure Based on Lean Construction Process. *Journal of Intelligent and Robotic Systems: Theory and Applications*, 79 (3–4), pp. 401–416.

Gan, V. J. L., Cheng, J. C. P., Lo, I. M. C. and Chan, C. M. (2017). Developing a CO2-e Accounting Method for Quantification and Analysis of Embodied Carbon in High-Rise Buildings. *Journal of Cleaner Production*, 141, pp. 825–836.

Giesekam, J., Tingley, D. D. and Cotton, I. (2018). Aligning Carbon Targets for Construction with (Inter)national Climate Change Mitigation Commitments. *Energy and Buildings*. Volume 165: 106-117.

Global Alliance for Buildings and Construction, International Energy Agency and the United Nations Environment Programme. (2019). 2019 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. [Online]. (Accessed 16 February 2021). Available from: https://webstore.iea.org/download/direct/2930?fileName=2019_Global_Status_Report_for_Buildings_and_Construction.pdf.

Gottsche, J., Kelly, M. and Taggart, M. (2016). Assessing the Impact of Energy Management Initiatives on the Energy Usage during the Construction Phase of an Educational Building Project in Ireland. *Construction Management and Economics*, 34 (1), pp. 46–60.

Goyal, L. K. and Rai, H. S. (2020). BIM Approach for Sustainable Design of Flat Slab Buildings: A Review. *IOP Conference Series: Materials Science and Engineering*, 955 (1).

Hao, J. L., Cheng, B., Lu, W., Xu, J., Wang, J., Bu, W. and Guo, Z. (2020). Carbon Emission Reduction in Prefabrication Construction during Materialization Stage: A BIM-Based Life-Cycle Assessment Approach. *Science of the Total Environment*, 723, p. 137870.

Hong, J., Shen, G. Q., Feng, Y., Lau, W. S. T. and Mao, C. (2015). Greenhouse Gas Emissions during the Construction Phase of a Building: A Case Study in China. *Journal of Cleaner Production*, 103, pp. 249–259.

IPCC. (2018). Global Warming of 1.5°C. *An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

Jiang, W., Lu, W. and Xu, Q. (2019). Profit Distribution Model for Construction Supply Chain with Cap-and-Trade Policy. *Sustainability*, 11 (4), p. 1215.

Kadefors, A., Lingegård, S., Uppenberg, S., Alkan-Olsson, J. and Balian, D. (2021). Designing and Implementing Procurement Requirements for Carbon Reduction in Infrastructure Construction–International Overview and Experiences. *Journal of Environmental Planning and Management*, 64 (4), pp. 611–634.

Kong, A., Kang, H., He, S., Li, N. and Wang, W. (2020). Study on the Carbon Emissions in the Whole Construction Process of Prefabricated Floor Slab. *Applied Sciences (Switzerland)*, 10 (7).

Krantz, J., Feng, K., Larsson, J. and Olofsson, T. (2019). 'Eco-Hauling' Principles to Reduce Carbon Emissions and the Costs of Earthmoving - A Case Study. *Journal of Cleaner Production*, 208, pp. 479–489.

Mallett, R., Hagen-Zanker, J., Slater, R. and Duvendack, M. (2012). The Benefits and Challenges of Using Systematic Reviews in International Development Research. *Journal of Development Effectiveness*, 4 (3), pp. 445–455.

Raza, Muhammad Saleem, Kumar, D. and Nawab, H. (2019). Building Information Modelling (BIM): An Approach for Reducing Carbon Emissions of Buildings. *First International Conference on Carbon Neutral Built Environment (CNBT–I) "A Step Towards Sustainable Future"*, (December).

Sanchez, A. X., Lehtiranta, L. M. and Hampson, K. D. (2015). Use of Contract Models to Improve Environmental Outcomes in Transport Infrastructure Construction. *Journal of Environmental Planning and Management*, 58 (11), pp. 1923–1943.

Snyder, H. (2019). Literature Review as a Research Methodology: An Overview and Guidelines. *Journal of Business Research*, 104 (July), pp. 333–339.

Sutrisna, M. and Abbott, C. (2002). Presenting Case Studies of Construction Projects To the Construction Industry Audience.

Taylor, J. E., Dossick, C. S. and Garvin, M. J. (2009). Constructing Research with Case Studies. In: Ariaratnam, S. T. & Rojas, E. M. ed., *Building a Sustainable Future*, *2009*. Seattle, Washington: American Society of Civil Engineers, pp. 1469–1478.

UKGBC. (2021). Climate Change. [Online]. (Accessed 17 February 2021). Available from: https://www.ukgbc.org/climate-change/.

Wedawatta, G., Ingirige, B. and Amaratunga, D. (2011). Case Study as a Research Strategy: Investigating Extreme Weather Resilience of Construction SMEs in the UK. pp. 1–9.

Wong, P. S. P., Ng, S. T. T. and Shahidi, M. (2013). Towards Understanding the Contractor's Response to Carbon Reduction Policies in the Construction Projects. *International Journal of Project Management*, 31 (7), pp. 1042–1056.

Wong, P. S. P., Owczarek, A., Murison, M., Kefalianos, Z. & Spinozzi, J. (2014) Driving Construction Contractors to Adopt Carbon Reduction Strategies - an Australian Approach. *Journal of Environmental Planning and Management*, 57 (10), pp. 1465–1483.

World Green Buiding Council (2019) *Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon.*

Wu, P. (2015). Monitoring Carbon Emissions in Precast Concrete Installation through Lean Production – A Case Study in Singapore. *Journal of Green Building*, 9 (4), pp. 191–212.

Wu, P., Feng, Y. and Zhong, Y. (2012). Identification and Reduction of Non-Value Adding Activities in the Precast Concrete Construction Projects in Singapore. *Association of Researchers in Construction Management, ARCOM 2012 - Proceedings of the 28th Annual Conference*, 2 (September), pp. 763–773.

Wu, P., Low, S. P. and Jin, X. (2013). Identification of Non-Value Adding (NVA) Activities in Precast Concrete Installation Sites to Achieve Low-Carbon Installation. *Resources, Conservation and Recycling*, 81, pp. 60–70.

Zhang, L. & Zhou, J. (2016) The Effect of Carbon Reduction Regulations on Contractors' Awareness and Behaviors in China's Building Sector. *Journal of Cleaner Production*, 113, pp. 93–101.

Zhang, Y., Zheng, X., Zhang, H., Chen, G. & Wang, X. (2016) Carbon Emission Analysis of a Residential Building in China through Life Cycle Assessment. *Frontiers of Environmental Science and Engineering*, 10 (1), pp. 150–158.