Geospatial and temporal analysis of studies on construction projects' decarbonisation drivers

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Abstract

The decarbonisation of built environment projects is becoming increasingly significant in realising net zero goals in many countries. Even though construction contractors responsible for bringing design to fruition have been touted to be slow in adopting strategies that can facilitate this ambition. Therefore, it is vital to understand the drivers that could motivate these stakeholders to decarbonise the carbon footprint within their control. While equally investigating the geographical spread and temporal distribution of studies that have contributed to this development. In achieving this, a systematic review of the literature approach was adopted and identified studies were examined through content analysis. The result of the analysis yielded thirteen drivers from 20 eligible studies. Also, studies on the drivers of carbon reduction began to appear in literature in 2008 and overall, the UK, USA and Australia tend to dominate this research area. These findings suggest that there seems to be sparse research conducted in this knowledge area and more studies are required across the globe if the world is to mitigate the effect of climate change and attain its net zero ambition. Lastly, the outcome of this study might be beneficial for construction stakeholders and policymakers in developing strategies to support research and practice to decarbonise the built environment.

1. Introduction

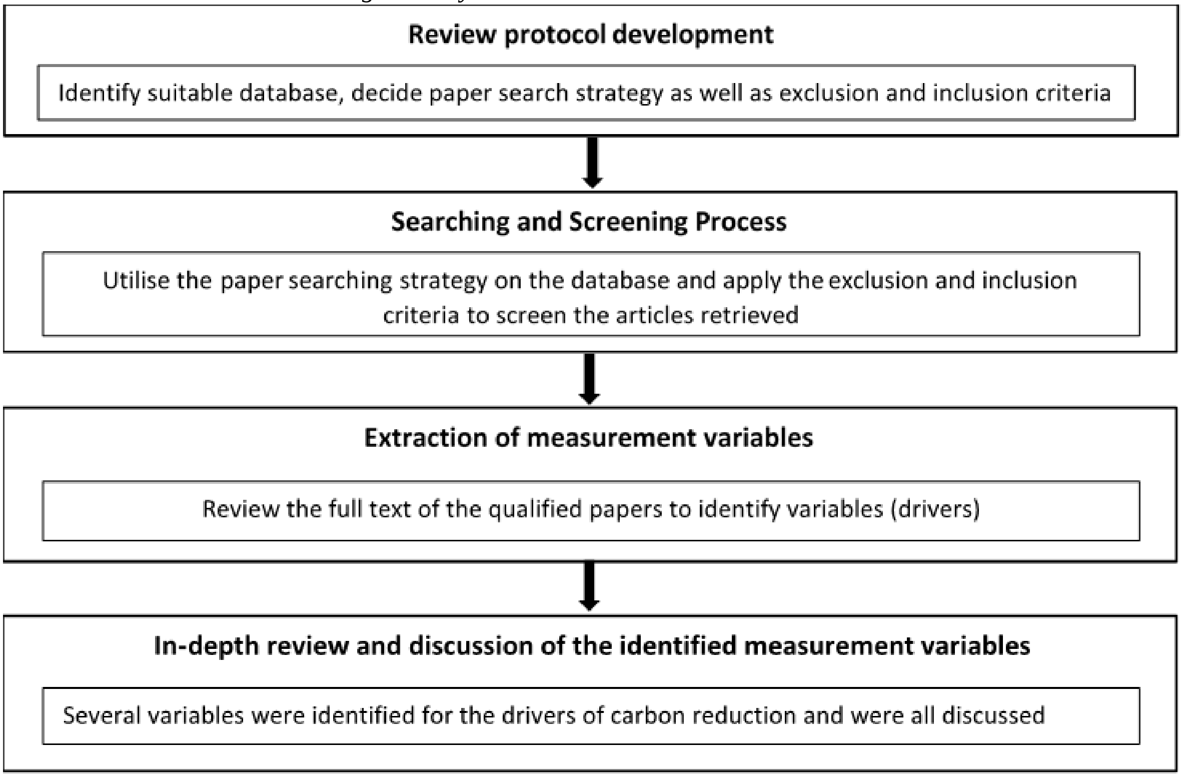
The construction sector accounted for 13% of the global GDP in 2020 with the expectation of rising to 13.5% in 2030 (Robinson *et al*., 2021). This makes the sector one of the largest in the world and has a reported annual spend on construction-related goods and services totalling around USD 10 trillion (Barbosa *et al*., 2017). The outcome of this huge spending by the construction industry is the enormous consumption of material resources, energy and water (Ajayi, S. O. and Oyedele, 2018) which then makes the industry a major contributor to climate change (Arogundade *et al*., 2023; Giesekam *et al*., 2018). According to the United Nations Environment Programme (UNEP), in 2019, the built environment sector was responsible for 38% of the world's total energy-related emissions (United Nations Environment Programme, 2020). In line with this, the World Green Building Council reported that in 2018, about 11% of all global carbon emission are embodied carbon (World Green Buiding Council, 2019). This might continue to grow because the International Energy Agency and UNEP estimated that between 2017 and 2050, half of the entire carbon footprint of new construction will be embodied carbon (UN Environment and International Energy Agency, 2017). Furthermore, the impact of the likely increase in embodied carbon is global since the world is set to add about 230 billion m^2 of new floor area by 2060 (UN Environment and International Energy Agency, 2017). Therefore, it is imperative to deploy strategies that can reverse this likely trend especially since the built environment sector has been touted to be vital in achieving global net zero (Arogundade *et al*., 2021b). However, the industry rate of innovation adoption is slow and the move towards project decarbonisation is sluggish and filled with challenges (Wuni and Shen, 2019). Thus, it is necessary to investigate the factors that can motivate construction stakeholders particularly contractors to implement measures that could minimise construction carbon footprint. The focus on contractors is owing to their role in bringing building design to life and because they are the major stakeholder involved in executing construction projects (Wong *et al*., 2013). Moreover, due to the global widespread of the built environment decarbonisation challenge and given the urgency required in attaining net zero, it is useful to examine the geographical spread and temporal distribution of studies done around decarbonisation drivers for contractors. Hence, this paper aims to examine the geospatial and temporal distribution of construction projects' decarbonisation drivers' studies while also highlighting the numerous carbon reduction drivers identified in those studies. The systematic review of literature was performed in achieving the study's goal and this is detailed in the next section followed by the analysis and discussion of the findings after which the conclusion was then presented. The findings of this study will be significant to both construction researchers and stakeholders as it provides a basis for further research and could influence decarbonisation policies targeted to the delivery of construction projects.

2. Methodology

A systematic review of the literature approach was adopted in achieving the study's goal. This is because Charef *et al*. (2018) noted that it applies auditable steps and gives extensive reports on subject matters. Moreover, Kitchenham and Charters (2007) stated that the usage of a systematic review approach provides reliable scientific value to a research study. In this study, a four-step process which was adapted from Ershadi *et al*. (2020) was employed in carrying out the comprehensive literature review (Figure 1).

The review commenced by developing a protocol that comprises database selection, defining a search strategy, and establishing inclusion and exclusion criteria. Although numerous databases exist this study utilised Scopus due to its extensive coverage of peer-reviewed work and because it is considered to be the world's most comprehensive database (Saad *et al*., 2023). Upon deciding on a database, appropriate papers related to the research focus were identified through the use of keywords (Deng and Smyth, 2013) with the assumption made as needed (Dikert *et al*., 2016).

Figure 1: Systematic Literature Review Process



Source: Adapted from Ershadi et al. (2020)

Since this could impact the number of literatures gathered for the study, before beginning the systematic review, an initial broad and targeted review of the literature was carried out as practiced by Charef *et al*. (2018) as well as consultation with professionals with construction carbon knowledge. Some of the keywords utilised for the final search performed on the 11th of July 2023 are *"driv*" OR "motivat*" AND "carbon reduction" OR "emission* reduc*" OR "GHG emission* reduction" OR "reduc* carbon" OR "low carbon" AND "contractor*"*.

Regarding the inclusion and exclusion criteria, papers written in English and related to the study's objective published in journals and conference proceedings were included in this study. While studies in book chapters or books and those without full-text availability were excluded. Upon applying the exclusion and inclusion criteria, the identified studies were screened for relevance through an in-depth text review. Also, the snowballing method was used to determine if other pertinent papers could be found to boost the overall number of articles to be included in this current study. However, none was found. Hence, based on the search strategy adopted in this study, only twenty articles were discovered to be eligible (Table 1) and they were thought to be appropriate for the study since the number of papers was comparable to the 22 articles used in the systematic review study done by Cheng *et al*. (2022). The temporal and geospatial analysis of the twenty eligible papers was conducted using Microsoft Office suites.

Table 1: Publication platforms for the eligible studies

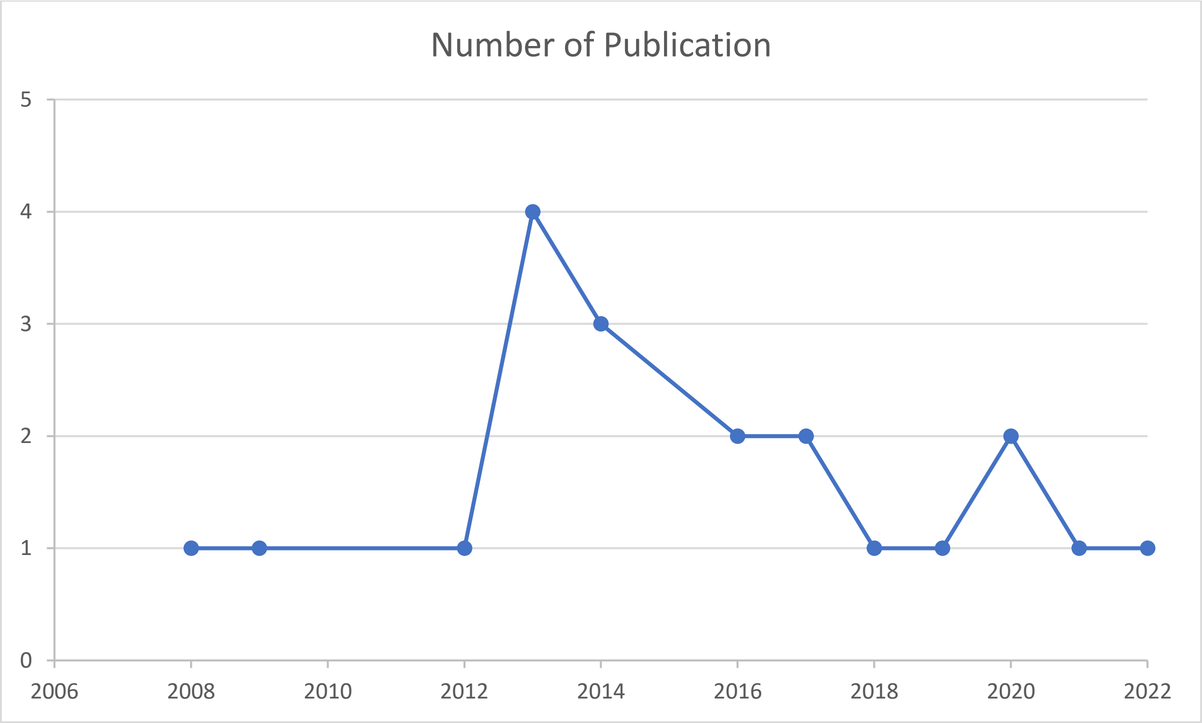
Eligible Studies Publication Outlet	Number of Relevant Studies
Climate Policy	2
Energy Research and Social Science	1
Energy Efficiency	1
Nature Climate Change	2
Journal of Cleaner Production	1
Energy Procedia	1
Energy Efficiency	1
Building Research and Information	3
Smart and Sustainable Built Environment	2
Energy Policy	1
Transportation Research Part A: Policy and Practice	2
International Journal of Project Management	1
Transportation Research Record	2
Total	20

3. Results and Discussion

3.1 Temporal Distribution of Studies Included for Carbon Reduction Drivers

In view of the small sample size of the papers eligible for the study, it might be beneficial to analyse the temporal distribution of the articles in a bid to understand how far back research has been conducted on drivers that could aid stakeholders, especially contractors to reduce the carbon footprint of construction projects. This was also necessary to determine if such efforts are being sustained given the urgency to decarbonise the built environment as the world race to achieve net zero. As seen in Figure 2, research into the drivers of carbon reduction only began to surface in literature in 2008 even though no restriction was placed on the time boundary during the literature search. This does not appear surprising since studies related to carbon emission in general only began to increase significantly in 2007 as highlighted in the work of Abeydeera *et al.* (2019) on mapping of global carbon emission research (Arogundade *et al*., 2021b). However, unlike the growing trend of global carbon emission research (Abeydeera *et al.*, 2019), those related to carbon reduction drivers in construction projects seem to be plummeting or have not picked up. The low number of articles vis-à-vis the seemingly declining nature of research into understanding the drivers of carbon reduction relating to construction projects can be attributed to the belief that the carbon emission linked to the construction process is relatively low and can be ignored. (Sattary and Thorpe, 2016; Wu *et al*., 2019).

Figure 2: Temporal Distribution of Eligible Studies for Carbon Reduction Drivers

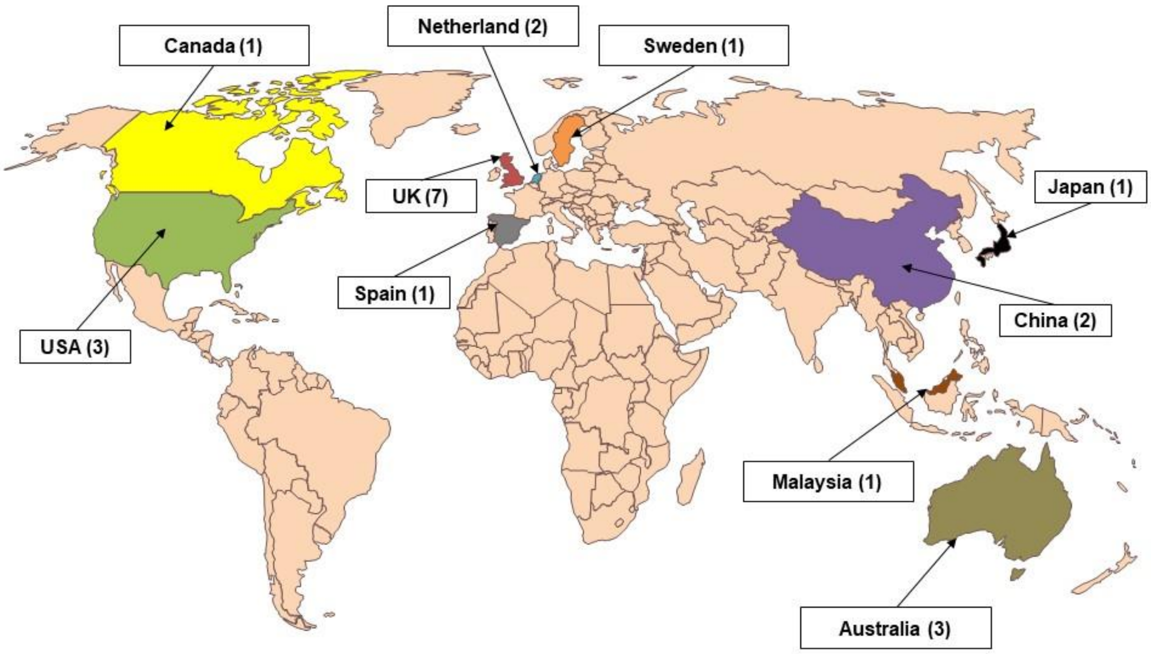


Most of the research within this area seems to have been done from 2013 to 2018 and this coincides with the period when IPCC released its Climate Change report on the need to tackle the risk associated with GHG emission (Arogundade *et al*., 2021a; Pomponi and Moncaster, 2016). According to Abeydeera *et al*. (2019), research into carbon emission equally saw a boost during this period as carbon emission publications suddenly went from 189 studies in 2013 to 479 in 2018. Similar findings were observed by Arogundade *et al*. (2021a) in their study on mapping research trends to understand the time distribution of studies that have been carried out on carbon reduction during building construction projects. Although, as depicted in Figure 2, only five papers have been published from 2019 to 2022 related to carbon reduction drivers in construction projects, there is a possibility of research to pick up within this area in the coming years. This is due to the increasing push to decarbonise the construction sector and achieve net zero carbon by 2050 (World GBC, 2016). Also, the rising adoption of the global standard in managing infrastructure carbon, PAS 2080 within the UK construction sector, for instance, will draw attention to construction stage carbon and the need to minimise its emission. This is because PAS 2080 breaks down construction projects into eight different work stages (of which construction is one of them) and all stakeholders involved in construction projects have to demonstrate how they work and collaborate to reduce carbon in each work stage. Based on this, construction project stakeholders especially asset owners who are majorly public clients and are at the forefront of the global decarbonisation agenda might begin to want to understand what can motivate contractors and indeed other stakeholders to reduce the carbon footprint of construction projects.

3.2 Geospatial Distribution of Studies Included for Carbon Reduction Drivers

The empirical research of the articles included in this study has been done in the context of different countries, with only two papers (Beckage *et al*., 2018 and Mundaca *et al*., 2019) being analysis of review articles and climate modelling respectively. Also, the works of Berry *et al*. (2014); Bolderdijk *et al*. (2013), and Niamir *et al*. (2020) were all carried out in two countries while Skippon *et al*. (2012) investigation examined case studies in the USA and Europe (the 27 European Union nations). All these have been separated while plotting Figure 3. That is, for instance, the USA and EU case studies of Skippon and colleagues have been reported as one paper each for ease of analysis and to avoid ambiguity. The UK has the highest number of papers (31.82%) in which drivers of carbon reduction variables were extracted, followed by Australia and the USA with three papers each (13.64%) and China and the Netherlands which have two papers each (9.09%). Spain, Japan, Canada, Malaysia, and the European Union (EU) all have one paper each (4.55%).

Figure 3: Geospatial Distribution of Carbon Reduction Drivers Studies



The UK having the highest number of papers is quite astonishing because the UK was reported to have just one paper that was eligible during the systemic review of literature on carbon reduction during building construction projects which was conducted by Arogundade *et al.* (2021a). This sort of contrast could be attributed to the boundary utilised during the literature search by the authors. It was discovered that Arogundade *et al.* (2021a) restricted their search to '*building construction*' while this current study looks at the whole of construction projects including infrastructures and buildings. Furthermore, the USA and China have low research output, 13.64% and 9.09% respectively, despite the two countries being reported to have contributed significantly to global carbon emission studies (Abeydeera *et al.*, 2019). This shows that there might be little attention being paid to construction-stage carbon emission probably due to the assertion that the carbon emission linked to it is nominal (Abouhamad and Abu-Hamd, 2021; Pacheco-Torres *et al.*, 2014). Hence, this could slow the pace of decarbonisation that is expected from the construction sector. Consequently, researchers, practitioners, and even governments might need to devote resources to this area if the global decarbonisation agenda is to be achieved by 2050 which is a few years from now.

3.3 Drivers for Carbon Reduction

Extant studies have identified multiple factors that can aid the reduction of carbon emissions within the construction industry as a whole and associated sector. For instance, Mundaca *et al*. (2019) identified the need for a policy initiative that will serve as a 'command-and-control' system in driving decarbonisation in the building sectors in China. Likewise, Grubb *et al*. (2020) highlighted various policy instruments that can influence carbon minimisation during the production and consumption of different construction materials. Nishida *et al*. (2016) and Wong *et al.* (2013) discussed the need for the introduction of 'more stringent standard' in achieving better energy efficiency and performance in buildings. In line with this, researchers (Hamdi-Cherif *et al*., 2021; Niamir *et al*., 2020; Nishida *et al*., 2016) seem to agree unanimously that a single policy is inadequate in achieving decarbonisation goal. Therefore, other measures such as incentives (Sanchez *et al*., 2014), rewards (Wong *et al.*, 2013), education (Berry *et al*., 2014; Hayles *et al*., 2013; Wong *et al*., 2013), cap and trade program (Millard-Ball, 2008; Nishida *et al*., 2016), penalty (Wong *et al*., 2013) to mention but a few are equally important in attaining carbon reduction. Based on the systematic review of the literature conducted in this study, the identified drivers for carbon reduction during construction projects are presented in Table 2. The carbon reduction drivers listed in Table 2 suggest that various strategies are required to aid the minimisation of the construction process's carbon footprint. Therefore, construction stakeholders including clients, contractors and policymakers need to pay attention to these drivers, and equally adopt and implement policies that will enable the promotion of these drivers.

Table 2: Carbon Reduction Drivers

Code	Drivers	References
D1	The introduction of standards such as PAS2080	Beckage *et al.* (2018); Grubb *et al.* (2020); Hamdi-Cherif *et al.* (2021); Hickman *et al.* (2009); Marsden and Docherty (2013); Mohareb and Kennedy (2014); Mundaca *et al.* (2019); Niamir *et al.* (2020); Skippon *et al.* (2012); Wong *et al.* (2013)
D2	Integrate carbon emission management into the assessment criteria of contractors	
D3	The introduction of a carbon reduction policy by the government targeting the adoption of low-carbon technology during construction projects	
D4	The infusion of carbon reduction requirements into the bid evaluation process	Liu *et al.* (2017)
D5	Higher cost of electricity/fuel	Al-Marri *et al.* (2017)
D6	Carbon trading programmes/emission trading schemes that bring about cost for carbon emission	Millard-Ball (2008); Nishida *et al.* (2016)
D7	Incentives for contractors within the bidding process to have a plan for reducing carbon	Sanchez *et al.* (2014)
D8	Exposure to carbon reduction training	Berry *et al.* (2014); Wong *et al.* (2013); Mustaffa *et al*. (2022); Hayles *et al*. (2013)
D9	Sharing knowledge and best practices related to carbon footprint reduction	
D10	The education and training support on carbon reduction from different stakeholders such as the government, clients, professional institutes and building authorities	

D11	Having the intention/willingness to preserve the environment	Bolderdijk *et al.* (2013)
D12	Employment of carbon tax once carbon emission surpasses a certain threshold during construction projects	Wong *et al.* (2013)
D13	Introduction of tax rebates and subsidy schemes	Wong *et al.* (2013)

4. Conclusion and Contribution of the Study

The study seeks to understand the geospatial and temporal distribution of studies carried out related to drivers of carbon reduction during construction projects. This was accomplished through a systematic review of the literature approach. Based on the result of the systematic review, limited studies were found to have documented carbon reduction drivers as only twenty papers were discovered to be eligible for this current study. Also, the analysis of the eligible papers showed that research in this area only became apparent in scholarly work in 2008 and this is yet to become mainstream. Hence, researchers and construction stakeholders might need to collaborate and focus efforts in this direction to ensure an adequate understanding of the motivating factors that could induce carbon reduction behaviour during the delivery of built environment projects. Moreover, the geographical spread of studies on carbon minimisation drivers is limited to ten countries and the EU. Other countries would need to explore what would motivate construction stakeholders especially contractors to lessen the carbon impact of construction projects. This is especially important to developing countries given that most of the studies obtained for this research (86%) were carried out in developed countries. Furthermore, since the identified drivers are geographically diverse and context-free, further studies could be conducted using the drivers established in this study to domesticate and identify significant drivers capable of prompting contractors to lessen construction carbon. This is because of the peculiarities in policies, level of sustainability knowledge, and level of the construction sector development which might vary in different regions of the world. The findings of this study might be valuable to sustainable construction researchers as it provides the theoretical foundation that could be useful in investigating studies related to construction carbon drivers. Equally, clients and policymakers may find it beneficial to comprehend the factors that may be utilised in motivating contractors to reduce construction carbon footprints.

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