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RESEARCH ARTICLE

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Addressing the challenges of integrating carbon calculation tools in the construction industry

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Abstract

The construction industry is facing growing pressure to reduce carbon emissions. An important first step is to quantify emissions from construction projects enabling designs to be changed and emissions reduced. Whilst progress has been made in the development of carbon calculation tools, the uptake of these tools has been slow. This paper seeks to understand the reasons for the slow implementation of carbon calculation tools in the construction industry and provide guidance on how to overcome these challenges. We find there are specific issues that prevent tools being used such as data security and usability, but more general issues such as a lack of education or regulation also pose a challenge. Our findings suggest that despite the benefits that can come from using carbon calculation tools to reduce emissions, the use of tools on their own will be insufficient to achieve the needed carbon reduction and wider emissions-related change. Instead, carbon calculation tools need to be looked at within and across construction organisations through training, industry-wide standards and regulations as well as organisation-wide requirements and collaboration. The construction industry has a reputation for being slow to react to change, but if this industry waits for regulation before taking action, then the timescales involved may be too long given the pressing need to reduce emissions now. We recommend that for carbon calculation tools to be successfully integrated, the industry must work together to achieve more immediate change.

KEYWORDS

barriers to change, carbon calculators, carbon management, construction industry, emission reduction, enabling change

1 | INTRODUCTION

Climate change is 'the greatest challenge of our time' (Fanelli, 2014, p. 15), and to prevent global average temperature rise exceeding the 1.5°C target set in the Paris Agreement (UN, 2015), a significant reduction in greenhouse gas (GHG) emissions is needed. An often overlooked sector for achieving such a reduction in carbon emissions is the construction industry. Directly or indirectly, the construction and use of infrastructure assets accounts for over half of the United Kingdom's (UK's) total carbon emissions (Enzer, Manidaki, Radford, & Ellis, 2013) requiring reduction by 50% by 2025 (HM Government, 2013). Although growing attention has focused on how to reduce carbon emissions in this industry, only little change and reduction of emissions has been achieved so far (Xavier, Naveiro, Aoussat, & Reyes, 2017). One method that has recently been encouraged to enable greater change is the use of carbon calculation tools (also called carbon calculators) to allow this complex industry to identify emissions hotspots more easily and make required adjustments. These calculators assign a carbon emissions factor to each material used in the construction of an asset allowing the simulation of different scenarios to determine the most carbon efficient design. These tools promise to realise the famous 'what gets measured, gets managed' promise—often credited to Peter Drucker—by providing a baseline against which an asset's emissions performance can be evaluated.

Although it has been shown that environmental actions, such as using carbon calculators, can contribute positively to business performance (Oberhofer & Dieplinger, 2014), the use of carbon calculation tools in the construction industry is still relatively low. It is unknown why the uptake of these tools has been slow and what change is required to achieve their implementation throughout the industry. It has been tentatively argued that the industry's general resistance to change (Lines, Sullivan, Smithwick, & Mischung, 2015) and slow adaptation to new innovations (Robinson, 2018) might play a role. This alone however cannot explain the slow uptake of calculators as climate change pressures have led to other changes in the industry such as the implementation of circular economy practices (Adams, Osmani, Thorpe, & Thornback, 2017). A better understanding of the reasons for the slow transition of construction organisations towards carbon calculation tools and to enable associated change is therefore needed (Wittneben, Okereke, Banerjee, & Levy, 2012). It is to that end that we aim to answer the following research questions: why has the implementation of carbon calculation tools been slow in the construction industry, and how can organisations in the construction industry improve the implementation of carbon calculation tools to reduce emissions?

To answer these questions, we identify the barriers preventing the implementation of carbon calculation tools in the construction industry, and develop recommendations for increasing the uptake of such tools. We propose how construction organisations need to improve their strategic decision making to allow lowering of GHG emissions. We use a case study approach to examine the development and piloted implementation of a carbon calculation tool within a UK-based construction organisation through qualitative data collected over a 3-year period. In doing so, we fulfil the need to explore the barriers preventing the implementation of carbon calculation tools in the construction industry (Jackson & Brander, 2019) and fill the gap of qualitative studies investigating low-carbon techniques within the construction industry (Giesekam, Barrett, & Taylor, 2016).

This paper is structured as follows: First, we discuss carbon calculation tools and their value before showing how achieving carbon emissions reduction in the construction industry is challenging and discuss what can be learned from other industries and disciplines to ease this. We suggest three propositions based on this. Second, we present our methodology. Third, we present our findings on how carbon calculation tools can be integrated within an organisation followed by fourth, a discussion of those findings against our propositions. Finally, we conclude by stating that to reduce carbon emissions in the construction industry, carbon calculation tools must be implemented through individuals' training, industry-wide standards and regulations as well as organisation-wide requirements and collaboration.

2 | LITERATURE REVIEW

2.1 | Carbon calculation tools and their value

Measurements can help increase productivity and assist decision makers to make informed judgments (BEIS, 2017). However, it is widely acknowledged that measurements are only useful if they are based on techniques that deliver accurate data and data that add value for the decision makers. Gathering and showing sustainability-related performance measures, for example, can encourage higher revenue growth and provide opportunities to achieve competitive advantages over rival organisations (Tan, Ochoa, Langston, & Shen, 2015). Traditionally, within organisations, this takes place via environmental management systems (EMS) (e.g., Bansal & Bogner, 2002; Delmas, 2002; González-Benito & González-Benito, 2005), which provide a framework that organisations can follow to improve environmental performance. This has also found use in the construction industry (e.g., Abd Elkhalek, Aziz, & Omar, 2015; Tse, 2001). However, whilst EMS looks at how to improve an organisation's overall environmental performance, fewer studies have looked at how to measure carbon performance and create efficiencies on individual construction projects. Capturing and measuring carbon emissions can be complex (Dalsgaard, 2016) and making comparisons between different low-carbon processes can be difficult. Particularly, decisions made prior to the build phase of projects could have serious ramifications for carbon emissions during an asset's lifetime. As Jackson and Brander (2019) highlight, emission savings during the build phase of a high-speed rail project were quickly offset by increased emissions during the operation and use phase of the asset. If the designers assign a higher value to reducing emissions during the construction of the asset then overall emissions could increase rather than decrease. For this reason, PAS 2080 (BSI, 2016)—the first standard for carbon management in infrastructure—places high importance on measuring the carbon impact of an asset throughout its full lifetime. Carbon calculation tools have thus been developed to show the baseline emissions of designs and low-carbon alternatives aimed at reducing both cost and carbon emissions and help decision makers to make choices on reducing emissions and increasing efficiency. As carbon calculation tools are designed to highlight where performance can be improved and where efficiencies can be made, the implementation of these tools within the construction industry will enable carbon emissions to be minimised on construction projects.

Proposition 1. The implementation of carbon calculation tools in the construction industry will lead to a reduction of emissions on construction projects.

2.2 | Carbon emissions reduction and the construction industry

Research on the implementation of carbon calculation tools and the impact of measuring carbon emissions in the construction industry has been scarce. Most research has looked at broader technical issues, for example, the choice of building materials (e.g., Giesekam et al., 2016), low- or zero-carbon building designs (e.g., Kershaw & Simm, 2014) or critiquing embodied measurement practices within the industry (e.g., De Wolf, Pomponi, & Moncaster, 2017). So far it has been tentatively argued that for carbon calculation tools to be implemented within the construction industry, transformational change is required to allow new innovative technologies to be implemented and successfully used (BSI, 2016). However, no empirical studies on how carbon calculation tools can be implemented within construction organisations exist and what such transformational change should look like. It is however known that technical/technological capabilities and knowledge (Chang, Soebarto, Zhao, & Zillante, 2016; Pinkse & Dommisse, 2009), lessons on best practice, and case studies showcasing positive achievements (Chang et al., 2016) are all needed to achieve change more generally in sustainability-related performance.

Nevertheless, successfully integrating carbon calculation tools may be challenging given the construction industry's reputation of being resistant to change (Lines et al., 2015) and slow to implement new technologies (Robinson, 2018). The industry is often perceived to be lagging behind other industries in terms of implementing innovation, reacting to market tends, improving quality of products (Hoonakker, Carayon, & Loushine, 2010) and showing signs of lower levels of productivity compared to other industries (Yuventi, Levitt, & Robertson, 2013). The lack of change in this industry has been attributed to four main issues: first, the fragmented nature of supply chains often including a large number of stakeholders making collaboration difficult (Jacobsson & Linderoth, 2010; Yuventi et al., 2013); second, an absence of accountability between different phases of a construction project (e.g., work-winning and project delivery), which limits efficiencies and makes it hard for teams to understand what is happening outside their area of expertise (Yuventi et al., 2013); third, a procurement process that encourages a 'race to the bottom' with work often being awarded to the bidder offering the lowest price (Yuventi et al., 2013); here, other considerations such as the sustainability of products or carbon emissions are often overlooked; fourth, contractors using temporary project-based models so that new processes and knowledge accrued often fail to be transferred from one project to another (Miozzo & Dewick, 2002). However, this does not explain why other climate change-related issues, such as the circular economy, have been more dominant.

Proposition 2. Traditional working practices and a lack of collaboration hinder the implementation of carbon calculation tools within the construction industry.

2.3 | Barriers to achieving emissions reductions

Research on new construction processes (e.g., Vennström & Eriksson, 2010), appropriate use of new technologies (see Porwal & Hewage, 2013) and integration of sustainable practices (Pinkse & Dommisse, 2009) show that there are various barriers that hinder the implementation of change in the construction industry. Such barriers can be grouped at the level of the individual as well as the organisational and the institutional levels. Individual barriers include the behaviours and attitudes of individuals and their views on change. Organisational barriers are to do with processes within organisations and competitive pressures that develop between organisations. Institutional barriers incorporate factors that impact the whole industry such as laws, standards and procurement processes. For example, Studer, Welford, and Hills (2006) identified the top three barriers preventing environmental engagement in organisations generally to be a lack of government incentives (institutional), a low degree or awareness and training (individual) and limited resources within the company (organisational). An individual's resistance and attitude to change (Lozano, 2013; Porwal & Hewage, 2013; Vennström & Eriksson, 2010) influence how sustainability-related performance can be improved. Such barriers can be overcome through educating individuals on the issues and their benefits (Studer et al., 2006). Organisational barriers preventing, for example, emissions reductions can include an organisation's leadership not engaging with such issues thereby resulting in strategies and processes that do not address emission reductions (Arnold & Hockerts, 2011; Dahlmann & Roehrich, 2019) This in turn can reduce an organisation's overall environmental capabilities (Kesidou & Demirel, 2012). At an institutional level, a lack of regulation (Paulraj, 2009) and a lack of government support (Sajjad, Eweje, & Tappin, 2015) have been described as reasons for organisations not to engage in activities that reduce environmental impacts. Likewise, organisations are unlikely to adopt new practices if there are no incentives or demands by clients to do so (Davies & Osmani, 2011; Tse, 2001). Similarly, competitive pressures from other organisations can influence the organisation's behaviour (Cai & Li, 2018), so if competitors are not acting, then there is little need for the organisation to act.

Proposition 3. Individual, organisational and institutional barriers hinder the implementation of carbon calculation tools.

3 | METHODOLOGY

A case study approach (Baxter & Jack, 2008) was used to answer our research questions. The case study followed the development and implementation of a carbon calculation tool, the Carbon Infrastructure Transformation (CIT) Tool, within a U.K. contractor organisation. The CIT Tool quantifies and reports emissions prior to the start of the build phase (see BS 15978, BSI, 2011; and PAS 2080, BSI, 2016) and allows construction estimators, planners and designers to collaborate on carbon reduction practices to minimise carbon emissions and associated costs on large infrastructure projects. Thus, carbon emission reductions can be identified and initiated before the construction phase begins and can both reduce emissions and increase profitability. The CIT Tool was being developed alongside this research so the findings could help shape how the tool was developed in future iterations. Given the exploratory nature of the research (Blumberg, Cooper, & Schindler, 2011), a qualitative approach was used to gather data. The data collection can be divided into three phases:

The first phase of data collection for this case study gathered an industry-wide perspective of the challenges involved in integrating the CIT Tool within the construction industry. To get the widest possible reach, one workshop (Workshop 1) was organised with 23 participants working for 21 organisations across the construction industry: seven participants from contractor organisations, seven from client organisations, four from environmental consultancies, two from engineering consultancies, two from regulatory bodies and one participant from a technical consultancy. The selected participants were associated with environmental or sustainability roles within their organisations in order to have knowledge of current environmental practices within the industry and of carbon-related tools and initiatives. Participants were divided into four focus groups for three breakout sessions, addressing first, barriers to the CIT Tool's implementation; second, how to overcome such barriers; and third, to identify other carbon management practices that are currently being used within the construction industry. Each session was recorded and transcribed and posters were used to allow participants to write their key comments from each session. Workshops were used as they allow for a particular subject to be explored in depth (Bryman, 2008), revealing various barriers and challenges faced when developing and implementing carbon calculation tools for infrastructure projects.

The second phase of data collection captured the practitioners' (see Table 1) perspective (construction employees who would use the tool if implemented). This was done in two stages: first, four semistructured interviews (lasting on average 39 min) were carried out with practitioners from one contractor (Contractor A). These were recorded and transcribed. Next, a second workshop (Workshop 2) was organised with 13 practitioners from two contractors (Contractor B and Contractor C) who have previously trialled the CIT Tool. The content of these workshops was designed to gain an understanding of how carbon calculation tools were perceived throughout the industry and within each selected organisation. The practitioners were also asked to discuss the preliminary findings from Workshop 1 on barriers to and enablers of the tool's implementation. Once again, the workshop was recorded and transcribed, and posters were used for participants to map the barriers and enablers in the tool's implementation.

TABLE 1 Job titles of interview participants

Contractor A (Interviews 1–4)	Contractor B (Interviews 5–14)
Trainee Quantity Surveyor	Group Head Supply Chain
Business Development Manager	Head of Supply Chain—Rail
Quantity Surveyor	Business Development Manager
Planner	Knowledge Manager—Group Work Winning
	Piping Designer—Water
Client A	Planning and Technology Manager
Head of Carbon Neutrality	Estimating Manager
	Business Improvement Director
Supplier A	Group Carbon Manager
Commercial Development Manager	Sustainable Engineering Manager
Sustainable Construction Manager	Finance Director

The final phase of data collection explored the current operating practices and processes around carbon management within Contractor B. During this phase, 10 semistructured interviews (one group and nine individual interviews, averaging 45 min) were conducted to investigate the level of understanding within different teams and at different job levels (see Table 1). During this time, one researcher—as an observer—also joined a number of low-carbon working groups and conducted open interviews (recorded via field notes only) with a client (Client A) and supplier (Supplier A) of Contractor B.

4 | FINDINGS

Through each phase of our data collection, our participants reflected positively about the development of the carbon calculation tool and were aware of the potential benefits such a tool could create. However, our investigations revealed that the participants were clear about barriers that would hinder the implementation and integration of carbon calculation tools. We show why much praised carbon calculation tools alone are not sufficient to reduce emissions due to the interlinkage of (1) the sensitive nature and potential socio-economic risks of emissions data and (2) the complex construction industry's supply chain with traditional economic assumptions about competition. We then developed these considerations with our participants to examine how to increase the implementation and use of carbon calculation tools. We therefore reveal in this chapter how to decrease emissions through the use of carbon calculation tools.

4.1 | The sensitive nature of emissions data and the complex construction industry

Through the initial workshops, we identify barriers that prevent the use of carbon calculation tools within the construction industry. The most voiced challenge was that of standardisation. Several participants raised concerns around the need for a standard approach to using carbon calculation tools. The scopes that carbon calculation tools measure, for example, are different across different tools as well as the methods they used to calculate emissions and the carbon libraries they use as inventories:

> If the carbon library is something each company still has to go away and develop, that governance piece about how it is put together is always going to be a big issue. (1K1)

The participants see this as a concern as all actors of an industry and economy are impacted equally by emissions, but reduction efforts are carried by individuals. Hence, many believe efforts should be measured equally too. If a tool and an associated database are to be used throughout an industry, it needs to measure inputs and outputs in comparable ways across actors.

This shared understanding of using tools for a coherent monitoring, reporting and reduction of emissions is closely linked to the ownership of carbon calculation tools. Several participants raised the issue that if a carbon calculation tool for construction organisations was to be developed, there would be a question regarding who would own the data that would be collected and registered through this tool.

> We mentioned before, the need to share commercially sensitive information which seems wrong to me. … You should, as the user, be able to select what you keep confidential. (2D1)

Even if privacy settings and ownership could be clarified, the participants were still concerned about the sensitivity of the data in case this would be leaked. The participants understood that this is a concern that all data-dependent software has to address but feel that leaked emissions data could mean more socio-economic risks for their organisations than other data would. This also leads the participants to highlight that supplier and subcontractors would not want to share accurate data on their emissions performances with each product. A member of one contractor organisation during a nontranscribed discussion went as far as to say that even if the tool developed was beneficial, their organisation would not use it because it was developed by their competitor.

This highlights the fragmented, highly competitive nature of the construction industry where low levels of cooperation between competitors has been noted for sustainability-related challenges. This raised the issue of where and when in the long chain of construction projects carbon calculation tools would be used. Often by the time a contractor is awarded the work of building an asset, the design of that asset has already been developed. The participants stated that the carbon calculation tool would only achieve emissions reductions if it was used from the designing of an asset:

> I think if we can get in at an early stage, with an influence on the design, with the used of the tool, then it would have much more impact and I think that is arguably where the benefit comes. (Interviewee 10)

Nevertheless, the participants highlighted that there are a large number of carbon calculation tools that actors in the construction industry could use. Most of these tools cover a different range of life cycle stages, and there is no standard methodology stipulating what should and should not be accounted for. This gives the participants several choices of what tool to use and what to measure. The participants stress that this number of options requires a variety of skill sets, having to learn new tools regularly and having to evaluate which tool would be most suitable.

> There are hundreds of tools used across the industry on this topic. When we say the adoption of this tool, are you suggesting you want those people using those other tool's, to get rid of their tool's and to use this tool? (1R1)

Participants felt that the best way to integrate carbon calculation tools throughout the industry was for all industry actors to use the same tool and library to ensure consistency. However, as explained by the participant, if an organisation is already using a carbon calculation tool then they would have to retrain to use a new process—ultimately being reluctant to do so.

4.2 | Implementing carbon calculation tools through individual, organisational and institutional change

The linkage of the sensitive nature of emissions data and the complex yet traditional interactions in the construction industry means that the implementation of a carbon calculation tool is insufficient to create a reduction in carbon emissions. Instead, our participants highlight that carbon calculation tools need to be looked at within and across a construction organisation through other means than just through the lens of tool provision and training. They suggest implementing and addressing carbon calculation tools through the individual, the organisation, and institutional perspectives.

4.2.1 | Individual change

One of the key challenges to overcome from the individual's perspective is to determine and minimise the extra time and effort that is required to use the carbon calculation tools. Several participants raised concerns that using the tool would add to their existing workloads. They would need to learn new skills around emissions, understand the associated software but also require extra time to add data to the tool and integrate outputs to their decision making. As one participant stated:

> People are resistant to change … I do not think you can go in there and say 'right, from now on we will just be rolling out the tool' because it just will not work, people will push back. You have to target someone who is keen who can start to influence others within the team. (Interviewee 6)

The following participant explains the need to show users the benefits the tool can bring to the individual as well as to the organisation:

> No one particularly likes change because it means more work, but as long as there is a recognition of the benefit I think that is the key. Providing benefit for the individual and not just the organisation. If you can communicate that there is a clear benefit, a win-win, then you can overcome the resistance. (Interviewee 11)

Our data also show evidence that individuals are reluctant to engage more generally with the need to reduce carbon emissions, seeing it as the latest 'buzzword' that organisations are concerned about:

> Do you not think in three or four years' time there will be something else to measure? … Now the buzzword is carbon but in three or four years' time it will be something else … It may be your initial driver for this year but I guarantee in two years' time it will not be. It just will not be. It just will not. (2K1)

Overcoming this fear of additional efforts associated with carbon calculation tools could be solved by educating every individual within the construction organisation about the economic benefits to the organisations in measuring and reducing carbon emissions as well as for the environment more generally. As one participant suggested:

> One of the main things would be demystifying carbon … so making it as simple as possible with regards to what it is, why we do it and the benefits of doing it. So a clear strategy, not overly complicated, a clear route or storyline of where we are going with it and why. (Interviewee 12)

Delivering training to staff on the importance of reducing carbon emissions will be a key driver in overcoming an individual's resistance to change and successfully integrating carbon calculation tools into working practices.

4.2.2 | Organisational change

One of the major criticisms was the construction industry's level of fragmentation within organisations. The participants explain this by highlighting that the tool can be used to encourage improvement with the level of fragmentation between teams and that greater collaboration should be encouraged. Participants stated:

> You could have the most amazing tool in the world, but unfortunately, if there is not cross-collaboration between sectors, or between disciplines, the tool falls flat on its face. (Interviewee 12)

> The tool will be treated great and it will work with the right will, but actually in order to get the best of it, you have got to do something about how fragmented everything is. (1D1)

To do so, the participants encouraged collaboration for carbon calculation tools that starts within each construction organisation. Here, the primary issue that the participants want to see addressed is the number of different teams (e.g., designers, planners and estimators) within each organisation working in their own ways. They suggest that a joined up approach to carbon calculations needs to be established. The participants explain that to solve this 'silo mentality' for carbon calculation tools there needs to be sharing by each team within a construction organisation of what it is doing to reduce emissions and a base level of understanding of associated needs has to be created.

> If I'm honest, in the organisation, we struggle with a bit of a silo mentality, and people do things with the best intent within their own silo not aware of what else is going on in the business. (Interviewee 11)

Currently the participants perceive that anything related to carbon or GHG emissions was classed within its own 'silo'. One participant explains that any carbon related issue is currently seen as part of the environmental team's remit only instead of being relevant for each team across the organisation:

> In terms of where it [carbon] sits within [the organisation], it is one specific area of the environmental team rather than spread across the business. (Interviewee 6)

As such, opportunities for reducing carbon emissions are being missed throughout the organisation. There is also a view that carbon reduction is an afterthought or a 'tick box' exercise to make sure that work-winning bids were compliant when required. Hence, carbon emissions are not used to actually reduce emissions, but just to meet a minimum baseline. One of the participating environmental managers explains:

> I feel like a minister without a portfolio. No one really quite knows what my purpose is, yet they could learn stuff from what I do. (1D1)

The participant here suggested that the solution is to integrate carbon calculation tools within each team to avoid a duplication of effort and also to create incentives to consider emissions from the design stage and across all decisions. Rather than the designer developing a plan and a carbon manager then running an analysis to check its expected emissions, the designer could quickly find out the carbon impact of the design and make appropriate changes. Breaking down the carbon 'silo' and integrating carbon calculation tools within each discipline, whilst encouraging open communication between each team would help the organisation in developing a joined up approach to effectively reduce carbon emissions and drive change throughout the organisation.

4.2.3 | Institutional change

The identified linkage between the sensitive nature and potential socio-economic risks of emissions data and the construction industry's traditional ways of working with competitors, suppliers and contractors highlights the industry's level of fragmentation between organisations. To overcome some of the challenges stated above regarding integrating carbon calculation tools throughout the construction industry, measuring and using carbon calculation tools needs to be standardised. However, given how the industry operates, it can be difficult for one organisation to take steps forward without motivation to do this. As one participant stated:

> It is a very slow changing industry and that is due to the nature of the works that we do. It can be risky so we cannot go our own way, go off on one and do something completely different. (Interviewee 12)

As a result of this, there needs to be joined up approach throughout the industry for integrating carbon calculation tools and their measurements. In order to achieve this, organisations need to first be motivated to implement carbon calculation tools and the participants agree that this can only be achieved through regulation. As one participant stated:

> I think a tool like this, and thresholds for carbon reduction, need to be mandated, need to be driven from the government … if BIM wasn't mandated a couple of years back I think supply chains, contractors, consultancies just would not have adopted it. (Interviewee 4)

Here, the participant stated that had it not been for regulation requiring the industry to implement Building Information Modelling (BIM), then it would likely not have been implemented. This shows that this complex and fragmented industry achieves change mainly through standards and regulation. Regulation will be especially required in order to mandate the use of carbon calculation tools during the work-winning process and to enable emissions-related decisions from the design stage. However, to ease this transition, these regulatory requirements should be stipulated within the clients' calls for contracts—articulating in detail the emissions limitations that contractors need to pitch against/for. It is therefore the clients that need to ask for carbon calculations to be included in the work-winning process, and it is at this point where carbon considerations need to start within the construction process. One workshop participants stated:

> I have a commercial background, a big user of the NEC form of contract. I've never seen carbon mentioned in a contract before. (1D1)

The participants further explain that in order for contractors to engage in carbon emissions measurement, it has to be part of the commercial process, for example, awarding a contract based 70% on cost and 30% lowest carbon solution. This would then increase the uptake of carbon calculation tools. One participant explains that they observed some of these requirements beginning to take place in the construction industry:

> If you look at the leadership that is coming from the likes of Client A, Client B, Client C, Client D, a lot of the [carbon reduction] requirements are starting to be mandated as part of that leadership, their role is really important. Without them saying change is needed, change will not happen. (Interviewee 5)

However, there are still challenges because not all clients are mandating that carbon should be quantified as part of their commercial process. One participant was concerned with the lack of consistency:

> It's a bit hit and miss at the moment, it is driven by what the client wants so on some jobs we do it and on some jobs we do not. (Interviewee 10)

Developing an industry standard where carbon was an integral part of the procurement process would allow for a consistent approach where contractors would have to use carbon calculation tools to show how designs have been optimised to reduce emissions on a project. Both contractors and clients need to be included in the development of those regulations to ensure the regulations fit their complex systems.

5 | DISCUSSION

Our paper revealed how carbon calculation tools should be integrated within construction organisations to reduce emissions. We provided insight into the barriers preventing the implementation of carbon calculation tools and the associated steps to enable greater emissions reductions by answering two research questions: why has the implementation of carbon calculation tools been slow in the construction industry, and how can organisations in the construction industry improve the implementation of carbon calculation tools? We revealed that the much-praised carbon calculation tools alone are not sufficient to reduce emissions due to the interlinkage of (1) the sensitive nature and potential socio-economic risks of sharing emissions data and (2) the complex construction industry's supply chain with traditional economic assumptions about competition. Instead, introducing carbon calculation tools should take place simultaneously with implementing much needed—and long overdue change—on individual, organisational and institutional levels. On the individual level, education of the economic benefits of carbon reductions and the usage of carbon calculation tools within the construction organisation is needed. Delivering training to staff on the importance of reducing carbon emissions is needed to overcome individuals' resistance to change and successfully integrate carbon calculation tools into operations. On the organisational level, integrating carbon calculation tools within each discipline whilst encouraging open communication between each team is needed. On the institutional level, an industry standard on carbon emissions within the procurement process and regulations on minimum requirements are needed. We will now discuss those findings in relation to our three propositions to suggest how to enable the implementation of carbon calculation tools in the construction industry and lower carbon emissions.

5.1 | Proposition 1: The implementation of carbon calculation tools in the construction industry reduces carbon emissions

Carbon calculation tools have been developed to help decision makers to make choices on reducing emissions and increasing efficiency. However, on construction projects, the use of carbon calculation tools is still relatively low. Our findings reveal that construction stakeholders agree with the proposition that the implementation of carbon calculation tools in the construction industry reduces carbon emissions. However, our findings also reveal that often those tools do not get implemented in a way that allows for emission reductions to take place—'what gets measured' does not necessarily 'get managed'. First, taking action on carbon emissions measurements is not as easy as carbon calculation software might suggest. Emissions data without the knowledge of how to interpret and act upon such data just results in business as usual. Second, such a lack of knowledge and associated training hinder an organisation's employees to make comparisons and thus informed judgments within their organisations. To achieve the hoped-for changes in emissions performance through carbon calculators, we suggest that carbon calculators need to be implemented whilst simultaneously implementing organisation-wide education initiatives on the economic benefits of carbon reductions across each discipline of an organisation. Through this better understanding of the reasons for construction organisations to implement and pursue such calculators, construction organisations with their decision makers and employees can better act on the acquired information and manage performance. In addition, our research found that each team/division within a construction organisation needs to be required to use the calculators for the same purposes and with the same scrutiny/requirements. At present estimators, designers and planners all have their own tools and practices and work independently of each other, whilst any carbon-related issues these teams might experience are dealt with by someone external to this team such as an environmental or carbon manager. We propose that it is of great importance that this 'environmental silo' is broken down and carbon is integrated throughout each team. Developing a carbon calculation tool that allows each of these teams to work together on emissions challenges and to develop low-carbon decisions would be needed, rather than each team repeating a carbon assessment (see Studer et al., 2006).

5.2 | Proposition 2: Traditional working practices and a lack of collaboration hinder the implementation of carbon calculation tools within the construction industry

Our paper discussed how the construction industry is suffering from complex supply chains with a lack of collaboration throughout the industry embodied in traditional working practices and slow adaptation to innovation and change. In light of these challenges, we proposed that traditional working practices and a lack of collaboration hinder the implementation of carbon calculation tools within the industry. Our findings revealed that differences in standards on emissions measurement metrics across supply chains/partners and competitors hinder organisations from making carbon emissions measurements in the first place. If emissions measurements are taken, they are then not comparable across organisations, the supply chain and competitors. In addition, the general lack of collaboration across the industry prevents the sharing of data that are required for the carbon calculation tools to be used successfully. We recommend that carbon calculation tools need to be implemented via an industry-wide conversation about data sharing on carbon emissions. The target of this conversation should be to establish an industry standard on carbon emissions within the procurement process (see Carballo-Penela, Mateo-Mantecón, Alvarez, & Castromán-Diz, 2018).

Our research also revealed that the industry's traditional project based model limits the impact of carbon calculations by only allowing carbon emissions to be considered after a project is designed (see Williams & Dair, 2007). We recommend that carbon emissions calculations and judgments have to be made in the initial design stage of a project before they go to competitive tender. This would allow all parties to look at how emissions could be reduced and would encourage organisations to share the input and output data from the carbon calculation tool to identify and reduce the highest emitting points on a project.

5.3 | Proposition 3: Individual, organisational and institutional barriers hinder the implementation of carbon calculation tools

Due to the absence of empirical studies on how to integrate carbon calculation tools in organisations, we drew on the literature around barriers to the integration of other environmental and sustainability practices. We proposed that individual, organisational and institutional barriers could prevent the implementation of carbon calculation tools. Our research confirmed this proposition. For example, at an individual level, our findings revealed that individuals' absence of understanding the benefits of reducing emissions could hinder the implementation of carbon calculation tools within organisations (see Kaesehage, Leyshon, Ferns, & Leyshon, 2019). We propose that specific training is given to individuals using carbon calculation tools within organisations highlighting the benefits of these tools and their measurements (see Chang et al., 2016). Focusing on a broader transition, driven by education and skill development, would overcome the general absence of required change with using new tools within the industry (Porwal & Hewage, 2013). In addition, and perhaps most importantly, all barriers and suggested recommendations are closely linked to the need for governmental regulation. In the absence of incentives or governmental requirement to integrate carbon calculation tools construction, organisations are unlikely to use them. Regulation on BIM for example provided the support that organisations needed to successfully integrate BIM within the industry (Porwal & Hewage, 2013). These findings are heavily supported in the wider literature with several other scholars pointing to the need for standards or regulation (e.g., Sajjad et al., 2015) or client driven incentives/expectations (e.g., Davies & Osmani, 2011). Looking more broadly at these issues, we find several areas of overlap with the literature on integrating EMS within the construction industry. For example, Tse (2001) and Abd Elkhalek et al. (2015) both found a lack of government pressure, lack of client requirement or support and expensive implementation costs to be major obstacles to implementing EMS in construction industry. Given that there is almost 15 years between these papers, and a further 5 years since the latter, it is noticeable that despite time to address these issues, the construction industry still struggles with implementing new methods and that stakeholders in the industry are still pointing to a lack of regulation and client support as reasons not to implement carbon calculation tools. To that end, we challenge the construction industry not to be as dependent on regulation, to start mandating change and suggest that the industry can come together to develop and share best practice to initiate their own change. As part of this, they should also lobby government so that needed regulation is not only more timely but also properly compatible with the needs and constraints of the construction industry.

6 | CONCLUSION

In this paper, we have investigated the reasons for the scarce implementation carbon calculation tools within organisations in the construction industry. We find that the development and implementation of carbon calculation tools in itself is insufficient to achieve carbon reduction and wider emissions-related change. The much-praised carbon calculation tools alone are not sufficient to reduce emissions due to the interlinkage of the sensitive nature and potential socio-economic risks of emissions data and the complex and traditional construction industry's supply chain. The linkage of the sensitive nature of emissions data and the complex yet traditional interactions in the construction industry means that the implementation of a carbon calculation tool is insufficient to create a reduction in carbon emissions. Instead, carbon calculation tools need to be looked at within and across construction organisations through training, industry-wide standards and regulation as well as organisation-wide requirements and collaboration. At one level, there are several issues with the tool to overcome including data consistency, data sharing and usability. At another level, there are perhaps more serious challenges in general that prevent the implementation of carbon calculation tools, including existing processes within organisations, the need for regulation or incentives to drive the organisation to implement calculators, or the need for better collaboration amongst organisations. These issues must first be addressed before carbon calculation tools can be successfully implemented. Developing an industry standard where carbon is an integral part of the procurement process would allow for a consistent approach where contractors would have to use carbon calculation tools to show how designs have been optimised to reduce emissions on the project.

6.1 | Suggestions for policy makers

Our research shows that carbon calculation tools and their associated measurements are not sufficient to change emissions performances. Aiming to reduce emissions in the construction industry reveals a more deeply rooted struggle within this industry to react to and create change. More so than ever does this work therefore raise the need for regulation that is agreed and created in close collaboration with industry needs, so that climate-related standards and expectations can be met. With this research, we thus challenge the construction industry and policy makers to have a joint conversation about the metrics and minimum standards that realistically should and can be met. This could help improve issues around collaboration by uniting the industry on a challenge that is common to all organisations. The construction industry has a reputation for being slow to react to change, but if they are waiting until they are regulated to change, then timescales for change will be long. We also recommend that for carbon calculation tools to be successfully integrated, the industry must collaborate internally to achieve change and challenge itself to act before harsh and potentially inappropriate regulation is imposed. After all, the construction industry can hope that 1-day emissions get managed, but only if they first get measured.

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