Contractors' carbon reduction behaviour: UK construction professionals' perspective

Abstract

Purpose: The decisions of contractors could impact the reduction of construction carbon footprint. These decisions are linked to the belief of contractors which equally affects how they behave while delivering projects. This study investigates the behavioural tendencies of contractors that could lead to carbon minimisation during the execution of construction projects.

Design/methodology/approach: An industry survey was performed amongst 41 UK construction professionals. Spearman correlation and factor analysis were used to analyse the data.

Findings: The result of the Spearman correlation gave rise to 14 contractors' carbon reduction behaviour variables and their factor analysis yielded two distinct factors namely, contractors' consummate carbon reduction behaviour and contractors' pragmatic carbon reduction behaviour. The findings suggest that in the UK, contractors are willing to take voluntary practical steps to decrease the carbon footprint of construction projects.

Practical implications: This finding might be unexpected to construction stakeholders especially construction clients who may believe that infusing strict carbon reduction obligations in contracts is sufficient in nudging contractors to lessen the carbon impact of projects.

Originality/value: The study attempted to quantitatively derive contractors' carbon reduction behaviour thereby extending the breadth of knowledge in the construction carbon reduction domain.

Keywords: contractors' behaviour, carbon reduction behaviour, sustainable construction, consummate behaviour, pragmatic behaviour, construction management

Introduction

Due to the global consensus on the considerable contribution of the construction industry to greenhouse gas (GHG) emissions (Harmouche *et al*., 2012; Wong *et al*., 2014), the need to decarbonise the sector to achieve net zero carbon by 2050 is undebatable. For instance, in the UK, the parliamentary Environmental Audit Committee warned that the sector needs to reduce its emission if the UK is to meet up with its 2050 net zero commitment (Environmental Audit Committee, 2022). In line with this, scholars like Röck *et al*. (2020) called for the government to legislate policies that will drive attention to reducing embodied carbon emissions from construction activities (Wong *et al*., 2014). Equally, Manidaki *et al*. (2016b) noted that contractors have a responsibility to take leadership and implement carbon reduction strategies while delivering projects. Likewise, Wong *et al*. (2014) also link contractors' decisions with carbon emission reduction during construction. This is due to their responsibility in bringing construction design to fruition (Cheung *et al*., 2012). However, a challenge exists where contractors are slow in adopting carbon reduction measures while on site (Wong *et al*., 2013). This has been assumed to be a behavioural issue (Wong *et al*., 2013). The impact of contractors' behaviour becomes evident in influencing key processes such as alternative material selection (Giesekam *et al*., 2016), and construction waste management (Al-Sari *et al*., 2012). It also impacts project performance (Liu *et al*., 2019). However, the overall understanding of the behaviours that may predict contractors' tendency to minimise their carbon footprint remains scarce in existing research efforts. Conceivably, these arguments align with Zhang and Zhou (2016), who encourages studies on contractors' behaviour towards minimising carbon emissions during construction.

Previous studies have proposed several carbon reduction behaviours of contractors. For example, in the research conducted by Wong *et al*. (2013, p.1054) to understand how contractors respond to policies related to carbon reduction during construction projects, the authors have chosen contractors to study carbon reduction behaviour due to perceiving them as being "at the front line of producing construction facilities. Thus, their performance has a direct impact on the intended output”. Wong and colleagues argue that contractors’ carbon reduction behaviour (CCRB) may be interpreted through the uptake of carbon reduction measures as this shows their commitment to minimising construction carbon. In a similar study, Zhang and Zhou (2016) adopted the same process in examining the effect of carbon minimisation regulations on CCRB. Based on this, the authors (Wong *et al*., 2013; Zhang and Zhou, 2016) failed to examine the behavioural factors that might predict if contractors implemented carbon reduction strategies during the execution of construction projects. Furthermore, the study conducted by Jiang *et al.* (2023) highlighted the carbon reduction intention of contractors without exploring their actual behaviour in minimising construction carbon footprints. As noted by Jiang *et al.* (2023), the comprehensive understanding of the actual carbon reduction behaviour of contractors is essential to allow for the examination of factors that could influence them. Based on the foregoing, this study aims to fill this research gap by investigating the relationship between several behavioural tendencies exhibited by contractors in delivering a reduced construction carbon footprint and their adoption of various strategies to lessen the carbon impact of construction projects. The findings of this study will assist construction stakeholders in understanding the appropriate behavioural factors that could predict CCRB. This will complement existing sustainable construction research and provide policymakers and clients with valuable insights into devising useful strategies for motivating contractors to minimise the carbon footprint of projects within their control.

Contractors’ behaviour

The study on contractors’ behaviour as it relates to carbon reduction during construction projects seems to be sparse in the literature. This is not surprising as Anvuur and Kumaraswamy (2012) noted that within construction management research in general, there is paucity of studies focusing on behavioural themes. Most research conducted within the construction management field regarding contractors’ behaviour has largely been around how they behave when responding to tender (Asgari *et al*., 2016; Konno and Itoh, 2018); while accounting for weather risk (Chan and Au, 2007); while managing construction waste (Al-Sari *et al*., 2012; Begum *et al*., 2009); during price negotiation with suppliers (Chen, 2012; Leu *et al*., 2015) and in handling contractual claims dispute (Zhang *et al*., 2019). This suggests that contractors' behaviour is an arbitrary term that could be modified based on the subject being discussed.

In line with this, some scholars tend to describe contractors' behaviour based on the relationship and interactions that exist between contractors, their clients and suppliers (Yin *et al*., 2021; Liu *et al*., 2019; Zhang, Fenn and Fu, 2019; Zhang, Fu and Kang, 2018; Xu *et al*., 2018; Yan, 2015). For instance, Liu *et al*. (2019) and Zhang *et al*. (2019) noted that if a contractor performs a construction task according to the specification of the contract, this kind of action is termed obligatory behaviour. Yin *et al*. (2021) capture this phenomenon aptly by stating that a contractor will exhibit obligatory behaviour when the contractor completes work specified within the contract fully, correctly and according to drawings as well as meeting agreed targets. The authors suggest that with a contractor's obligatory behaviour, the requirement of the contract relating to project performance could be achieved since contracts typically would set out project performance goals (Yin *et al*., 2021). Putting this into consideration, it is reasonable to suggest that if the goal of meeting carbon reduction targets is integrated into the contract as part of the specification for project performance and agreed upon with the client, the contractor would strive to ensure that this obligation is met. Although, meeting such obligations might be influenced by various internal and external factors such as having the required skills, availability of appropriate technologies and suitable materials, cost, incentives probably embedded within the contract, having a need to develop or deepen the relationship with the client (Liu *et al*., 2019), risk allocation and trust (Xu *et al*., 2018).

Similarly, Zhang *et al*. (2018), Liu *et al*. (2019) and Yin *et al*. (2021) opined that the voluntary actions taken by the contractor in realising or surpassing the goal of carbon reduction that might be stated in the contract in the spirit of 'mutual trust and cooperation' can be described as consummate behaviour. Additionally, Xu *et al*. (2018 p.15) stated that this voluntary action ‘is beyond the scope of the contract’ and is not overtly compensated for by the client. Nevertheless, due to the uncertainty and complex nature of construction projects, consummate behaviour might be necessary to improve project performance as the contract might miss some salient stipulations that could affect the project quality (Zhang *et al*., 2018; Xu *et al*., 2018). Therefore, when it comes to reducing carbon during construction projects, a contractor might need to ‘inform the client of possible ways to minimise carbon if omitted from the contract’ by demonstrating consummate behaviour (Yin *et al*., 2021; Zhang *et al*., 2018; Xu *et al*., 2018).

You *et al*. (2018) and Zhang *et al*. (2018) elucidated that another form of contractor behaviour is one driven by the asymmetry of information between clients and contractors which serves in favour of the contractor due to their many years of experience working in a related environment or field. Hence, a contractor uses information to its advantage, making profits off contract loopholes, not fulfilling obligations and exhibiting other putative behaviour (Liu *et al*., 2019). Furthermore, contractors’ relational behaviour is borne out of a situation where the content of the contract is set aside and both the contractor and the client then rely upon mutual understanding to make concessions (Zhang *et al*., 2019). This concession could either be obliging (fulfilling the concern of the other party) or compromising (meeting each other halfway to reach an acceptable solution) (Zhang *et al*., 2019).

While, contractors’ competitive behaviour is such that a contractor might decide to yield to market pressure and reduce the price or agree to challenging carbon targets during the bidding process just to secure the project (Yan, 2015). Asgari *et al*. (2016) stated that such behaviour is outside the control of contractors as they simply respond to the level of competition in the marketplace which is fuelled by several factors like the contractors’ ‘need for work’ and financial power.

Carbon Reduction Measures

Several researchers (Kumari *et al*., 2020; Sandanayake *et al*., 2017; Sattary & Thorpe, 2016) and industry networks (Ko, 2010) have identified different strategies that can be adopted to minimise the carbon footprints of construction projects during their execution. Although, a lot of factors contribute to and influence the actual emission of carbon during the construction phase thereby prompting the adoption of certain carbon reduction measures. For example, the type of construction method to be utilised for a construction project will determine not only the quantity of carbon to be emitted during construction but will equally shift the concentration of carbon emission linked to the different processes involved while executing the construction task. This will then impact the choice of reduction measure to be implemented during that project. Thus, contractors might need to take pragmatic steps in ensuring a broad understanding of minimisation strategies that would enable them to implement measures capable of lessening carbon footprints (Wong *et al*., 2014). This could enable them to reduce emissions within their control. Moreover, contractors' decisions have been noted to directly influence the decarbonisation of the construction process (Wong et al., 2014).

In this study, the carbon minimisation factors identified through the comprehensive literature review conducted by Arogundade *et al.* (2023) was utilised (see Appendix). Based on the scope of the current study focusing on contractors who are responsible for the construction process, the carbon reduction measures were grouped into transportation and construction-installation stages to fit into phases A4 and A5 (construction process stage) of the lifecycle stages defined in the European Standard EN 15978 as it relates to carbon emission (World Green Building Council, 2019). This classification adopted for the carbon reduction measures is the same as that posited by Arogundade and colleagues (Arogundade *et al.,* 2023).

Research Methodology

This research study adapted the methodological sequence used by Chan *et al*. (2004) and it is based on a literature review, questionnaire development, pilot study and empirical research (see Figure 1).

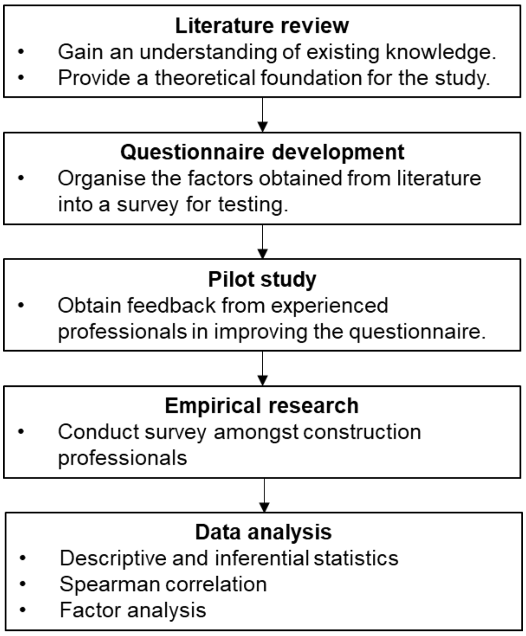

Figure 1: Research framework for the study (Source: adapted from Chan *et al.*, 2004)

This study commenced with a comprehensive review of two streams of relevant literature capturing contractors' behaviour and construction process carbon reduction measures. This approach was adopted based on the recommendation of scholars (Charef *et al*., 2018; Kitchenham and Charters, 2007) who opined that a comprehensive literature review is fair, thorough, provides a wide-ranging report on a subject matter and offers scientific value to a study. The comprehensive review of literature was performed to provide a theoretical foundation for the study and develop the questionnaire survey (Chan *et al*., 2004; Darko, 2019).

All the factors identified from literature depicting contractors' behaviour and carbon reduction strategies were considered in developing a list of variables to be tested empirically in this study. These variables were put together in a questionnaire with an additional section to understand the background of the respondents and a pilot study was carried out with 10 individuals with knowledge of construction management. These ten individuals included an early career researcher, two professors with demonstrable years of experience in construction management research and seven industry professionals who have engaged in carbon reduction in construction projects in the UK. Furthermore, the sample size of ten for the pilot study was considered adequate due to the argument posited by Ajayi (2016) who noted that a sample size of 10 – 30 is satisfactory for a pilot study. The questionnaire was scrutinised for vagueness, appropriate use of terms, comprehensiveness and relevance. The comments received from the pilot study were used to improve the questionnaire and a total of 33 contractors' behaviour variables and 59 carbon reduction strategies were finally included in the wider questionnaire survey. An extract of the final questionnaire is provided in the Appendix.

The survey was conducted using an online survey tool termed Google Forms due to its ease of usage and has been utilised by other researchers for data collection (Ajayi, 2016). The respondents were asked to rate their level of agreement with the behavioural tendencies and carbon reduction measures listed in the questionnaire according to a five-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree). Construction professionals who have engaged in projects where carbon reduction was implemented or considered were the primary target for this study. Hence, a qualifying question asking respondents about their participation in construction carbon reduction was used to strategically exclude respondents with no knowledge about carbon minimisation during construction activities. This is important in ensuring that the opinion of respondents captured through the empirical survey represents the industry's perception as it relates to carbon reduction. Such approach has been practised by other scholars (Chan *et al*., 2004). After the qualifying question, the questionnaire contained three sections. First section explored the background information of the respondents. The second section is related to the contractors' behaviour factor and the last section comprises of the carbon reduction strategy factors.

The link to the questionnaire was shared via email with prospective respondents and posted on LinkedIn. Professional industry associations such as the Institution of Civil Engineers (ICE) and National Federation of Builders were also approached for data collection. The sample utilised for this study was a non-probability sample and this has been used by other researchers within the construction management field (Darko, 2019; Wilkins, 2011; Zhao *et al*., 2015). After 12 weeks of numerous reminders being sent, a total of 48 responses were obtained. From the 48, six responses were omitted as they did not fulfil the major criteria of having participated in a construction carbon reduction project in the UK. Also, one response was considered invalid since the respondent did not complete almost 75% of the questionnaire. Therefore, the study ended up with 41 valid responses which is sufficient for statistical analysis since the central limit theorem holds once the sample size is beyond 30 (Zhao *et al*., 2016). Also, Akadiri (2011) noted that a sample size of more than 30 should be regarded as an acceptable sample especially as the UK construction sector has been well known for poor responses to questionnaire surveys. Similarly, the sample size for this study can be considered to be adequate when compared to other sustainable construction research which utilised a sample size of 32 (Hwang *et al*., 2017), 30 (Zhao *et al*., 2016) and 39 (Shen *et al*., 2017).

Based on the 41 valid responses, approximately 54% work within sustainability/carbon/environmental function, about 63% have carbon reduction work experience of up to five years, around 85% have more than five years of industry experience and 73% work for contracting organisations while 27% work for consultancy firms. The profile of the respondents suggests that the responses reflect the view of the industry.

Data Analysis and Findings

The data analysis was performed using the IBM Statistical Package for Social Sciences (SPSS) version 26. Both descriptive (mean ranking) and inferential statistics (Wilcoxon signed rank test, Kendall's *W,* and Spearman's correlation analysis) were carried out on the data collected after which factor analysis was conducted to establish the underlying relationship among the CCRB. Prior to conducting these analyses, the Cronbach's alpha and Shapiro-Wilk tests were first carried out to determine the reliability and normality of the data respectively. Yee (2012) noted that reliability measurement is vital in gauging how valid the result of a questionnaire is. While Kim (2015) stated that the normality test is essential to know the probability distribution of variables and determine if the data will be suitable for a parametric or non-parametric statistical analysis method (Hwang *et al*., 2018; Kim, 2015). The result of the Cronbach's alpha test for the contractors' behaviour and carbon reduction measures variables suggests that the data collected is suitable for statical analysis since the coefficient of alpha value is 0.891 and 0.960 respectively surpassing the acceptable minimum threshold of 0.7 (Bowling, 2014; Shen *et al*., 2017; Zhao *et al*., 2015; Yee, 2012). Likewise, the result of the Shapiro-Wilk test for all the variables contained in both the contractors' behaviour and carbon reduction measures construct have *p*-values lower than 0.05 indicating that the data are not normally distributed (Tables 1 and 2). Thus, a non-parametric method of analysis was deployed.

Upon establishing the normality and reliability of the data, the mean analysis, Wilcoxon signed rank test and Kendall's *W* test was performed on the contractors' behaviour and carbon minimisation strategies data individually to determine the most important and significant variables for both constructs. The results are presented in Table 1 and Table 2 respectively. After this, the significantly important variables for both constructs were then subjected to Spearman's correlation to investigate the behavioural tendencies that correlate to a significantly positive reduction in carbon during the execution of construction projects. The set of behaviours resulting from the correlation analysis is then termed contractors' carbon reduction behaviour since they have a significant degree of association with the implementation of carbon minimisation measures while delivering a built environment project in the UK. Lastly, factor analysis is performed on the CCRB variables to determine the intrinsic factors of the variables.

Mean Ranking and Significance of the Contractors' Behaviour

The survey responses for the contractors' behaviour (CB) variables were analysed and ranked based on their mean score and standard deviation (SD) as shown in Table 1. The mean value for the CB variables ranged from 2.83 – 4.49 with 4.49 being the highest-ranked value (Table 1). SD was used to segregate the rank of variables with the same mean score. Thus, variables with smaller SD were ranked higher than those with larger SD values.

The Kendall's coefficient of concordance test performed on the variables returned a value of 0.161 at an associated significance level of 0.000 suggesting that there is a level of agreement amongst the respondents on their rating of the variables. Also, one-sample Wilcoxon signed-rank test was conducted on the CB items to establish their statistical significance. The test result revealed that five variables were found to be statistically insignificant with *p*-values greater than 0.05. The non-significant variables include 'the contractor tends to avoid carbon reduction responsibility especially when it is not specified in the contract but which can actually be achieved' (CB22); 'the contractor will volunteer to make an extra effort beyond contractual provisions in reducing carbon associated with construction activities' (CB4); 'contractor trains sub-contractors on carbon reduction strategies' (CB14); 'contractor patronise suppliers having low carbon footprint' (CB29); and 'the contractor tends not to act in accordance with the contract or supplementary agreements as it relates to reducing carbon during construction' (CB21).

CB29 and CB21 have mean values less than 3.00 depicting that construction professionals in the UK disagree with these behavioural tendencies as it relates to emission reduction during construction project execution. Although, the disapproving viewpoint of CB21 by the respondents is not surprising since their agreement would be tantamount to showing dissent to a contractual obligation. Whereas, surprisingly, CB29 was widely disagreed upon even though the variable connotes a positive behaviour towards minimising construction process carbon footprint. According to the science-based target initiative (SBTi) for example, it is acceptable for contractors to present evidence of trying to influence their suppliers in towing the route of carbon minimisation (SBTi, 2021) since this will show the commitment of the contractor in reducing carbon. Hence, it would have been expected that behavioural tendencies such as CB29 will be promoted as it can display a contractor's devotion to a built environment project decarbonisation.

Table 1: Contractors' Behaviour Ranking and Significance (Source: Table created by Author)

Code	Mean	Standard Deviation	Rank	Shapiro-Wilk (p-value)	Wilcoxon Signed Rank Test (p-value)
CB1	4.49	0.675	1	0.000	0.000*
CB26	4.20	0.715	2	0.000	0.000*
CB2	4.17	0.629	3	0.000	0.000*
CB15	4.17	0.771	4	0.000	0.000*
CB3	4.15	0.727	5	0.000	0.000*
CB11	4.10	0.735	6	0.000	0.000*
CB30	3.98	0.790	7	0.000	0.000*
CB25	3.88	0.812	8	0.000	0.000*
CB23	3.85	0.823	9	0.000	0.000*
CB9	3.80	0.954	10	0.000	0.000*
CB16	3.76	0.888	11	0.000	0.000*
CB31	3.73	0.837	12	0.000	0.000*
CB8	3.73	1.073	13	0.000	0.000*
CB17	3.71	0.955	14	0.000	0.000*
CB7	3.68	0.986	15	0.000	0.000*
CB27	3.63	0.968	16	0.001	0.001*
CB10	3.61	0.919	17	0.000	0.000*
CB33	3.59	1.117	18	0.001	0.004*
CB28	3.54	0.951	19	0.001	0.001*
CB32	3.54	0.977	20	0.000	0.002*
CB6	3.54	1.075	21	0.001	0.004*
CB5	3.54	1.164	22	0.000	0.010*
CB13	3.44	0.950	23	0.000	0.006*
CB24	3.41	0.894	24	0.000	0.006*
CB18	3.41	0.974	25	0.002	0.012*
CB20	3.39	0.997	26	0.002	0.018*
CB12	3.39	1.070	27	0.003	0.024*
CB22	3.34	1.296	28	0.001	0.070
CB19	3.32	0.907	29	0.001	0.034*
CB4	3.22	1.173	30	0.003	0.200
CB14	3.17	0.892	31	0.000	0.220
CB29	2.95	1.071	32	0.004	0.821

CB21	2.83	1.046	33	0.002	0.326
Cronbach's Alpha	0.891				
Kendall's *W*	0.161**				
Chi-Square	211.526				

NOTE: **p-value < 0.05; **p-value ≤ 0.001*

The remaining three insignificant CB items have mean values greater than 3.00 implying that UK contractors tend to agree with them but not to an appreciable extent to make them very important. This could be because their fundamental attributes place the responsibility of carbon reduction on the main contractor who wins a job and might require them to be accountable for it. Literally, this may not be a challenge, but it could become one if the contractor is required to allocate financial resources for its accomplishment. Therefore, since it has been argued that UK contractors trade with low-profit margins (Akintoye and Skitmore, 1991; ICE, 2018), any additional responsibility that will put a strain on the profit will tend to be avoided. Having highlighted that five of the CB variables were non-significant, the remaining 28 variables which are statistically significant were used for the Spearman correlation analysis.

Overall, the five most highly ranked and significant CB items are 'contractor having a need to meet carbon target stated in the contract' (CB1); 'contractor tries to avoid possibility of rework' (CB26); 'contractor meets the carbon reduction performance expectations of the client' (CB2); 'the contractor tries to procure construction materials locally' (CB15); and 'contractor completes construction task while conforming with the carbon target set out in the contract' (CB3). It is not surprising that these variables are the most significant and important CB variables because they are akin to obliging to contractual requirements, local spending and expenditure. All these factors are vital to the continued profitability, reputation and success of a construction firm. For instance, Liu *et al*. (2019) stated that a contractor must take contract terms seriously, adhere to its stipulations and ensure the level of performance agreed upon is achieved to maintain a good reputation and build long-term cooperation with clients to bring about sustained patronage.

Likewise, beyond the carbon impact of sourcing materials locally, its social value impact is equally indispensable especially for main contractors who bid for public infrastructure projects. Battle (2023) noted that it is required by law in the UK that public sector clients infuse social value requirements into all their procurement, and these have weightings up to around 20% during bid evaluation. Therefore, having a social value strategy could improve work winning which might affect profitability positively. Lastly, the conscious effort to avoid rework by a contractor can boost its reputation with clients (Zhang *et al*., 2019), reduce construction activities as well as minimise related costs which again can enhance profit (Barbosa *et al*., 2017; Grindheim, 2022; Jones, 2020).

Mean Ranking and Significance of the Carbon Reduction Measures

As stated earlier, the carbon reduction strategies (CRS) were divided into transportation and construction-installation stages since both stages make up the construction process phase which contractors are responsible for. Therefore, the mean analyses presented in Table 2 mirror this pattern. The Kendall's *W* test gave a value of 0.140 at an associated significance level of 0.000 implying that there is a level of coherence in the respondents' rating of the CRS variables. Hence, based on the mean score, the variables were ranked within the construction process sub-categories as well as across them (Table 2). Overall, the mean score of all the 59 CRS variables was not less than 3.00 and only four were found not to be significant according to the one sample Wilcoxon signed rank test result. The four insignificant variables were split equally between the transportation and construction-installation stages. The non-significant variables for the transportation stage are 'utilisation of large disposal trucks' (TCR11) and 'adoption of driving techniques that maximise transport vehicle's engine efficiency during construction waste transportation' (TCR10). Though insignificant, their mean score value of 3.32 and 3.27 respectively shows that construction professionals in the UK still recognise their importance in reducing the carbon footprint of built environment projects.

Table 2: Carbon Reduction Strategies Ranking and Significance (Source: Table created by Author)

Code	Mean	Standard Deviation	Rank	Overall Rank	Shapiro-Wilk (p-value)	Wilcoxon Signed Rank Test (p-value)
Transportation						
TCR9	4.24	0.699	1	3	0.000	0.000*
TCR1	4.05	0.740	2	12	0.000	0.000*
TCR8	4.00	0.866	3	20	0.000	0.000*
TCR7	3.98	0.821	4	23	0.000	0.000*
TCR2	3.93	0.787	5	26	0.000	0.000*
TCR4	3.85	0.989	6	32	0.000	0.000*
TCR6	3.78	0.759	7	42	0.000	0.000*
TCR12	3.63	0.968	8	47	0.000	0.000*
TCR3	3.59	1.072	9	51	0.001	0.002*
TCR5	3.37	0.994	10	55	0.001	0.031*
TCR11	3.32	1.011	11	56	0.002	0.059
TCR10	3.27	1.073	12	57	0.002	0.136
Construction -Installation						
CCR22	4.32	0.567	1	1	0.000	0.000*
CCR41	4.24	0.663	2	2	0.000	0.000*
CCR11	4.24	0.699	3	3	0.000	0.000*
CCR16	4.22	0.690	4	5	0.000	0.000*
CCR21	4.20	0.749	5	6	0.000	0.000*
CCR3	4.17	0.543	6	7	0.000	0.000*
CCR10	4.17	0.667	7	8	0.000	0.000*
CCR32	4.15	0.792	8	9	0.000	0.000*
CCR14	4.12	0.872	9	10	0.000	0.000*
CCR13	4.05	0.669	10	11	0.000	0.000*
CCR47	4.05	0.893	11	13	0.000	0.000*
CCR9	4.05	0.893	11	13	0.000	0.000*
CCR18	4.05	0.921	13	15	0.000	0.000*
CCR40	4.02	0.821	14	16	0.000	0.000*
CCR2	4.02	0.987	15	17	0.000	0.000*
CCR30	4.00	0.806	16	18	0.000	0.000*
CCR15	4.00	0.837	17	19	0.000	0.000*
CCR23	3.98	0.612	18	21	0.000	0.000*
CCR17	3.98	0.758	19	22	0.000	0.000*
CCR36	3.98	0.961	20	24	0.000	0.000*
CCR42	3.95	0.805	21	25	0.000	0.000*
CCR43	3.93	0.932	22	27	0.000	0.000*
CCR35	3.90	0.917	23	28	0.000	0.000*
CCR8	3.88	0.781	24	29	0.000	0.000*

CCR38	3.88	0.842	25	30	0.000	0.000*
CCR19	3.88	1.077	26	31	0.000	0.000*
CCR27	3.85	0.989	27	32	0.000	0.000*
CCR25	3.83	0.803	28	34	0.000	0.000*
CCR33	3.83	0.946	29	35	0.000	0.000*
CCR34	3.83	0.972	30	36	0.000	0.000*
CCR20	3.83	0.998	31	37	0.000	0.000*
CCR29	3.80	0.782	32	38	0.000	0.000*
CCR1	3.80	0.843	33	39	0.000	0.000*
CCR6	3.80	0.872	34	40	0.000	0.000*
CCR5	3.80	0.954	35	41	0.000	0.000*
CCR26	3.73	0.895	36	43	0.000	0.000*
CCR46	3.73	0.949	37	44	0.000	0.000*
CCR44	3.68	1.011	38	45	0.000	0.000*
CCR39	3.66	0.965	39	46	0.001	0.000*
CCR31	3.61	0.862	40	48	0.000	0.000*
CCR7	3.59	0.948	41	49	0.000	0.001*
CCR4	3.59	0.948	41	49	0.001	0.001*
CCR24	3.56	0.950	43	52	0.001	0.001*
CCR28	3.49	0.746	44	53	0.000	0.000*
CCR37	3.49	1.052	45	54	0.002	0.007*
CCR45	3.15	1.315	46	58	0.001	0.324
CCR12	3.00	1.072	47	59	0.005	0.966
Cronbach's Alpha	0.960					
Kendall's *W*	0.140**					
Chi-Square	332.433					

NOTE: **p-value < 0.05; **p-value ≤ 0.001*

For instance, Ko (2010) reported that drivers trained in safe and fuel-efficient driving improved their driving techniques and this led to an efficiency of more than 10% in the miles per gallon usage of fuel by the vehicle without affecting travel time. Furthermore, Coyle (2007) argued that once a 44-tonne truck load exceeds 17 tonnes, its fuel efficiency is enhanced compared to a 32-tonne truck. This suggests that the usage of large disposal trucks and improved driving technique could lead to minimal fuel usage thereby decreasing carbon emissions. Thus, this could be responsible for the level of importance accorded to the TCR11 and TCR10 variables by the respondents.

For the construction-installation stage, the insignificant CRS variables are ‘reducing thickness of the wall’ (CCR45) and ‘reducing the usage of cranes on-site’ (CCR12). Their mean scores are 3.15 and 3.00 respectively. Their mean values are quite low and close to the neutral point on the Likert scale used for measurement. This indicates some level of indifference in the opinion of the respondents. Perhaps, this could be due to the indispensability of crane usage on-site in the case of CCR12. However, Gottsche *et al*. (2016) have noted that while it might be impractical to eliminate the usage of cranes on-site, minimising the duration of usage even if it is by two hours when possible every day, will contribute to decreasing construction carbon emissions. Whereas the low mean value for CCR45 might be because of the supposed inability of contractors to fully influence work specifications during the delivery of construction projects since specifications are done during the design stage of a project (Fox *et al*., 2011; Sanchez *et al*., 2015). Hence, early contractor involvement (ECI) has been noted to be one of the strategies capable of lessening construction carbon footprints (Arogundade *et al*., 2021; Sanchez *et al*., 2015).

The remaining 55 CRS variables have mean scores ranging from 3.37 – 4.32 and those with equal mean values were differentiated in rank by using SD, similar to the contractors' behaviour. According to the mean score ranking analysis, the top five construction process CRS considered to be significantly important in decarbonising construction operation in the UK are 'utilisation of recycled material' (CCR22); 'utilisation of prefabrication method of construction' (CCR41); 'replacing diesel oil machineries with electric ones' (CCR11); 'reusing and recycling material on-site' (TCR9); and 'reusing materials (including carbon-intensive material) on-site' (CCR16) (Table 2). Four out of these highly ranked CRS are related to the construction-installation stage while only one variable, TCR9 belongs to the transportation stage. While TCR9 is a transportation CRS, its underlying feature seems to be affiliated with construction installation since it involves repurposing material usage on-site to reduce waste that will require transportation off-site for management. Also, interestingly, all the top five CRS are linked to the minimisation of waste generation except CCR11 which is related to eliminating fossil fuel usage. This result demonstrates the criticality of construction waste generation and its management as well as the usage of alternative fuels in decreasing the carbon footprint of construction projects in the UK. Thus, construction stakeholders in the UK are urged to pay attention to these areas and adopt practices that would reduce or eliminate waste from construction operations. Furthermore, UK policymakers should consider making laws and approving government expenditures that will promote the usage of alternative fuels within the UK construction industry.

Lastly, in congruence with the previous section, only the 55 statistically significant CRS variables were utilised for Spearman's correlation analysis.

Carbon Reduction Behaviour: UK Contractors' Perspective

Since correlation analysis is employed to determine the direction and degree of association between two variables (Pallant, 2020), the CCRB amongst UK construction professional were investigated using Spearman's correlation. This was achieved by examining the relationships between the CB variables and the construction process carbon reduction measures. In this study, the CB variables with positive and significant ($p < 0.05$) relationship with the CRS were noted to be the acceptable behavioural standard amongst UK contractors that is likely to lead to the minimisation of carbon during project execution. This is similar to the procedure adopted by Huang *et al*. (2020) in classifying the academic performance of students. Huang *et al*. (2020) used the number of significant features from Spearman correlation to determine the factors influencing predictive performance of classification methods. Also, according to Pallant (2020) and Field (2005), a negative correlation suggests an inverse relationship and in this study, behavioural tendencies that have a positive connection with carbon minimisation measures are what is desired. In conducting the correlation analysis, only the significant CB and CRS variables established in the preceding two sections were utilised. The result of the Spearman correlation is presented in Table 3. From the 28 CB variables, only three (CB18, CB19 and CB20) resulted in a negative correlation with the CRS variables. The negative correlation of CB19 and CB20 albeit weak is expected since *apriori* the variables have a pessimistic underlying characteristic. However, for CB18, the converse relationship is surprising since the reuse of waste materials on-site have been cited as one of the effective approach in minimising construction carbon footprint (Kumari *et al*., 2020). Therefore, it would have been expected that such behavioural disposition as CB18 would be associated with the adoption of construction decarbonisation strategies. Out of the remaining 25 CB variables, 11 correlated positively with CRS but were not statistically significant. Hence, the level of confidence in the CB – CRS relationship of these 11 variables is low (Pallant, 2020). Thus, the remaining 14 CB variables that have a positive and significant relationship with the construction process CRS are adjudged to be the carbon reduction behaviour of contractors in the UK and this is based on the recommendations of Huang *et al*. (2020), Pallant (2020) and Field (2005) as discussed above. Furthermore, the exclusion of variables which are not significant prior to conducting factor analysis is similar to the process adopted by Chan *et al.* (2022) and Olawumi and Chan (2022) in selecting the key drivers and barriers to the implementation of smart sustainable practices in construction projects. The contractors' carbon reduction behaviour variables are explored further in the succeeding section.

Table 3: Spearman's Correlation Analysis (Source: Table created by Author)

Contractors' behaviour	Carbon reduction strategies	
	Transportation	Construction-installation
CB1	0.135	0.024
CB2	0.175	0.092
CB3	0.185	0.146
CB5	0.507**	0.525**
CB6	0.439**	0.394**
CB7	0.360*	0.335*
CB8	0.217	0.148
CB9	0.323*	0.206
CB10	0.202	0.277*
CB11	0.272*	0.179
CB12	0.300*	0.215
CB13	0.237	0.218
CB15	0.355*	0.200
CB16	0.234	0.124
CB17	0.087	0.091
CB18	-0.075	0.064
CB19	-0.066	-0.063
CB20	0.019	-0.181
CB23	0.214	0.242
CB24	0.290*	0.287*
CB25	0.134	0.252
CB26	0.170	0.189
CB27	0.034	0.026
CB28	0.274*	0.348*
CB30	0.388**	0.427**
CB31	0.209	0.328*
CB32	0.200	0.379**
CB33	0.308*	0.397**

**Correlation is significant at the 0.01 level (1-tailed). *Correlation is significant at the 0.05 level (1-tailed).

Factor Analysis of Contractors' Carbon Reduction Behaviour

The 14 CCRB variables were subjected to a factor analysis (FA) test to determine their underlying factors. Before performing the FA, the reliability and suitability of the data were examined through Cronbach's alpha test. The Cronbach's alpha value for the CCRB variables is 0.887 indicating that the data is reliable for analysis. Also, the appropriateness of factor analysis for factor extraction needs to be established. This was done by carrying out the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity while eigenvalue was used to determine which factors to retain. To retain a factor, the eigenvalue has to be above 1 based on Kaiser's criterion (Ma *et al*., 2021; Pallant, 2020). The KMO value was 0.746 and it is greater than the acceptable threshold of 0.5 (Haupt and Akinlolu, 2021) while the Bartlett's test gave a chi-square value of 288.055 at a significant level of 0.000. Based on the Bartlett's test and KMO results, it is established that the correlation matrix is not an identity matrix (Pallant, 2020; Zhao *et al*., 2015) and the FA would likely produce reliable and distinct factors.

Having established the appropriateness of FA, factor extraction and rotation were then conducted using principal component analysis with varimax rotation since it is the most widely utilised approach in construction management research (Chan *et al*., 2004; Wong *et al*., 2016). The initial analysis generated three factors with eigenvalues greater than 1. However, one variable (CB15) was loading on more than one factor. This was removed and the analysis was repeated. The ensuing outcome gave rise to a variable (CB24) having a low communality value of 0.290 and two factors extracted with a total variance of 56.888%. Thus, the CB24 variable had to be removed since according to Pallant (2016 p.220), a low communality value of less than 0.30 suggests a lack of fit of the variable with other items and could impact the cumulative variance explained as seen from the result. Furthermore, several scholars (Chan, 2019; Hair *et al*., 2014 p.109) noted that a value of 60% is an acceptable minimum for the total variance. Hence, CB24 was taken out and the factor analysis was repeated. The result yielded a two-factor solution with a cumulative variance of approximately 60% (Table 4) and a KMO value of 0.744. The two groupings labelled based on their inherent attributes are consummate and pragmatic carbon reduction behaviours.

Discussion of factor analysis results

Contractors' consummate carbon reduction behaviour

This cluster explains almost 44% of the total variance (Table 4) and signals the importance of taking voluntary actions by contractor's in lessening the carbon footprint of construction projects.

The underlying characteristics of this group denote the readiness of contractors in tackling construction process carbon emission at their own volition. According to Yan and Guo (2020), contractors will perform optimally without nudge if they are not shortchanged within a contract. For instance, in delivering the UK's first box slide bridge, contractors worked with clients in adopting such innovative technique to minimise traffic disruptions, disruption to residents at night as well as decrease the project's carbon footprint through the use of fewer materials such as concrete (HS2, 2023; Smulian, 2021). The project was equally delivered ahead of schedule (HS2, 2023). This is consistent with the assertion made by Liu *et al*. (2019) who noted that contractors' consummate behaviour has the potential of improving project performance. Additionally, Teller *et al*. (2014) and Liu *et al*. (2019) opined that contractors taking initiative to internalise project risks serves as an assurance for enhancing project success. Furthermore, the consummate carbon reduction behaviour of contractors could ensure that some contract loopholes related to project carbon minimisation are taken cared of (Yin *et al.*, 2021). This also improves trust between clients and contractors which could lead to repeat business thereby strengthening the contracting company's sustainability.

Table 4: Factor Analysis for Contractors' Carbon Reduction Behaviour (Source: Table created by Author)

		Factor Loading	
Code	**Contractors' carbon reduction behaviour**	**1**	**2**
Grouping 1: Consummate behaviour			
CBR1	The contractor develops and implements carbon management plan for construction projects	0.819	
CBR2	Contractors having a defined carbon reduction target	0.809	
CBR3	The contractor sets carbon targets for sub-contractors	0.756	
CBR4	The contractor is concerned about the source of fuel used for transportation	0.706	
CBR5	The contractor tends to ensure fuel/electricity used on-site is from a renewable source	0.690	
CBR6	The contractor will try to ensure that all relevant staff/operatives working on construction site are trained on carbon reduction	0.665	
CBR7	The contractor will take the initiative to propose carbon reduction strategies to the client	0.660	
CBR8	The contractor will voluntarily inform the client of possible ways to reduce carbon if omitted from the contract	0.626	
Grouping 2: Pragmatic behaviour			
PB1	The contractor plans the site layout before construction to ensure easy movement of material on-site		0.818
PB2	The contractor will be conscious of the impact of construction waste on the environment		0.763
PB3	The contractor adopts a work sequence that reduces equipment idle time		0.660
PB4	The contractor carefully plans the work sequence to avoid wastage of materials		0.631
Eigenvalues		5.264	1.900
Variance (%)		43.867	15.830
Cumulative Variance (%)		43.867	59.696

The implementation of carbon management plans while executing construction projects and other variables within this cluster can also have a similar effect since clients are increasingly prioritising carbon reduction in infrastructure projects in the UK (HS2, 2022; UK Government, 2021). If a contractor had to sub-contract part or all of the construction activities to sub-contractors, the main contractor might need to 'coordinate carbon reduction efforts amongst the subcontractors including supporting the training of relevant staff working on the site on carbon minimisation (Yin *et al*., 2021). Economic-wise, project cost could be minimised when contractors display genuine interest in a project thereby suggesting ways (e.g. use of alternative materials, design optimisation) in which the project could be accomplished with a minimal budget (Liu *et al*., 2019; Xiaowei *et al*., 2018). This aligns with the suggestions of Yan and Guo (2020) who noted that contractors exhibit consummate behaviour by voluntarily taking initiatives during project implementation without recourse to the contract as long as the contract is not skewed against them. In addition, Yin and colleagues opined that mega-project performance can be significantly improved if contractors are motivated to to display consummate behaviour (Yin *et al*., 2021).

The finding suggests that contractors' consummate carbon reduction behaviour could boost the attainment of low-carbon construction. Therefore, clients and policymakers might need to prioritise practices and standards that can induce the likelihood of contractors to exhibit consummate carbon reduction behaviour.

Contractors' pragmatic carbon reduction behaviour

This group demonstrates the willingness of contractors to take practical steps in reducing construction process carbon. It explains about 16% of the cumulative variance and comprises four variables (Table 4). According to Garcés (2022), pragmatic behaviour entails a self-directed course of action and encompasses a fourfold process. The process involve showing an indication to take-action, interpreting the indication into a meaningful strategy, then formulating a procedure for the action, and lastly, carrying out the eventual action. Hence, contractors' pragmatic behaviour towards diminishing construction carbon is essential to the decarbonisation agenda of the built environment since according to Wong *et al*. (2014), contractors are responsible for bringing construction design to fruition. This has been emphasised by Manidaki *et al*. (2016b) who stated that contractors will need to show leadership and adopt strategies capable of minimising the carbon footprints of infrastructure projects.

Moreover, Manidaki *et al*. (2016a) argued that the display of pragmatic behaviour by contractors during construction has the tendency to accelerate construction carbon-saving opportunities. This view was supported by Richards (2021) who recounted that the replacement of fossil fuel with low carbon alternatives on construction sites managed by a particular UK contracting organisation was made possible through the premiership of the contractor and engagement with its supply chain partners. A similar observation was mentioned in a report by the National Federation of Builders (NFB) in the UK where it was stated that a contracting firm reduced project carbon intensity by almost 16% within a year through their proactiveness and supply chain involvement (NFB, 2020). Also, Savić *et al*. (2022) emphasised the potency of lived experience on pragmatic behavioural practices and contractors are likely to possess enormous amount of lived experience on decarbonisation practices due to the nature of their job which exposes them to varying ways of doing things as they constantly procure and deliver construction projects. This validates the potentiality of pragmatic carbon reduction behaviour of contractors.

Thus, contractors might need to jettison the indifference nature which characterises their disposition to the adoption of novel strategies and practices during construction project delivery (Arogundade, 2021; Wong *et al*., 2014; Wuni and Shen, 2019). While clients and policymakers would need to create an enabling environment and reward contractors who expediently work in decreasing construction carbon. This would result in a win-win for all stakeholders since the government and client need to meet their decarbonisation targets

(Environmental Audit Committee, 2022; HS2, 2022) and contractors would want to sustain a cordial relationship with their clients for the possibility of winning more work (Zhang *et al*., 2019; Teo and Loosemore, 2001).

Contributions of the study

Theoretical implications

To a great extent, this study draws on the seminal work of Whetten (1989) to justify its theoretical contribution. Firstly, the study quantitatively derived CCRB thereby extending the breadth of knowledge in the construction carbon reduction domain. This represents a notable extension of the works of Wong *et al*. (2014) and Zhang and Zhou (2016) by exploring the relationship that exists between the behavioural tendencies exhibited by construction professionals during the execution of construction projects and their implementation of carbon minimisation strategies on such projects. To the best of the knowledge of the authors, this study is the first to establish the contractors' carbon reduction behaviour being exhibited by UK contractors during the delivery of built environment projects. Secondly, the study categorised these contractors' carbon reduction behaviours into two clusters to enable a better comprehension of their distinctiveness. This classification could serve as a piece of foundational knowledge and form the basis for further empirical research toward deepening the understanding of carbon reduction behaviour within the built environment research area.

Practical implications

This study provides insight into the specific behavioural tendencies of contractors capable of leading to the lessening of construction process carbon emissions. This could be particularly beneficial to construction clients as they could use this to develop strategies on how to better engage contractors during the tender and project delivery stage. Also, policymakers can utilise this research result in understanding more competent ways to tailor embodied carbon reduction regulations especially those linked to contractors. In general, this may lead to the development of policies that could enhance the identified CCRB to boost the attainment of built environment sector decarbonisation.

Conclusion and limitations

The carbon reduction behaviour of UK contractors was examined in this study through Spearman's correlation analysis by investigating the relationship that exists between significant CB and CRS variables. The CB and CRS variables' significance was ascertained based on the result of one-sample Wilcoxon signed-rank test. The CCRB variables were then classified into consummate and pragmatic carbon reduction behaviour through FA. The contractors' consummate carbon reduction behaviour construct consisted of variables with intrinsic features indicating the keenness of contractors to tackle construction process carbon emission at their discretion without being compelled to do so. Whereas the contractors' pragmatic carbon reduction behaviour construct portrays the inclination of contractors towards the implementation of suitable measures that could lead to carbon minimisation. This implies that contractors prefer taking voluntary and actionable steps to lessen the impact of carbon during the execution of construction projects. This could be thought-provoking for construction stakeholders especially construction clients who might believe that infusing strict carbon reduction obligations in contracts is sufficient in nudging contractors to minimise the carbon footprints of projects.

Having achieved the objective of the study, the research has few limitations. Firstly, even though the sample size was satisfactory for conducting statistical analysis, it is noted to be small. Due to the scope of the study, construction professionals who have engaged in projects where carbon reduction was implemented or considered were the primary target for the research. Hence, a qualifying question asking respondents about their participation in construction carbon reduction was used to strategically exclude respondents with no knowledge about carbon minimisation during construction activities. While this is important in ensuring that the opinion of respondents captured through the empirical survey represents the industry's perception as it relates to carbon reduction, this might have impacted the response rate of the survey. Future studies may utilise a larger sample size to replicate the results. Secondly, construction professionals in the UK were the only respondents examined in this study. Therefore, interpretation of the findings was made within this context. Thus, similar research could be carried out in other climes and findings juxtaposed with those presented in this study. This is because contractors' outlook in certain geographical areas might be influenced by existing laws and policies as well as access to carbon reduction technologies and knowledge.

Disclosure statement
No potential conflict of interest was reported by the authors.

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