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CARBON AND COST CRITICAL ELEMENTS OF BUILDINGS: A COMPARATIVE ANALYSIS OF TWO OFFICE BUILDINGS

ABSTRACT

Purpose: The aim of this paper is to identify and compare cost and carbon critical elements of two office buildings and help achieve an optimum balance between building Capital Cost (CC) and Embodied Carbon (EC).

Design/methodology/approach: Case study approach was employed to identify cost and carbon critical elements of two office buildings as it allows an in-depth and holistic investigation. Elemental estimates of CC and EC were prepared from Bills of Quantities (BoQs) of the two office buildings by obtaining rates from the UK Building Blackbook. Pareto Principle (80:20 rule) was used to identify carbon and cost critical elements of the two buildings and the significance hierarchies of building elements were compared.

Findings: Substructure, Frame and Services were identified as both carbon and cost critical elements responsible for more than 70% of the total CC and EC in both buildings. Stairs and Ramps, Internal Doors and Fittings, Furnishings and Equipment were identified to be the least carbon and cost significant elements contributing less than 2% of total CC and EC in both buildings. The hierarchy of cost and carbon significance varies between buildings due to the difference in the specification and design.

Originality/value: The increasing significance of dual currency (cost and carbon) demands cost and carbon management during the early stages of projects. Hence, this paper suggests that focusing on carbon and cost intensive building elements is a way forward to keep both cost and carbon under control during the early stages of projects.

Keywords: Carbon Hotspots, Capital Cost, Cost Hotspots, Embodied Carbon, Office Buildings.

Article type: Research paper

1. INTRODUCTION

Carbon management of the built environment is imperative to tackle the global climate change by reducing Greenhouse Gases (GHGs). Even though carbon (implies GHG) emitted during the operation of buildings (Operational Carbon – OC) is managed through statutory benchmarks, carbon emitted during the production, maintenance and demolition of buildings (Embodied Carbon - EC) are not regulated. However, EC management is becoming prevalent now. EC cannot be managed unless it is measured and EC databases are fundamental building blocks of EC estimating. A range of embodied carbon inventories are available to facilitate EC estimating at different stages of a building's life cycle including material production, construction, use and end-of-life stages. Inventory of Carbon and Energy (ICE) developed by Hammond and Jones (2011) is a cradle-to-gate (or production stage) inventory which assists is estimating EC of a building during the production stages. The UK Building Blackbook is another data source developed using ICE and data from manufacturers and suppliers, which assist in the production stage EC estimating. Construction and in-use EC are project specific as it depends on the method of construction and the type of fuel used, hence, carbon conversion factors for fuels are used to calculate the carbon footprint of business operations. Department for Environment Food and Rural Affairs (2015) in the UK maintains a repository of carbon conversion factors to facilitate operations related carbon footprint calculations. Similarly, end-of-life emissions are project specific and fuel conversion factors can be used to estimate EC during this stage too while a dataset developed by PE International assist in the end-of-life EC calculations for common framing materials. In addition, GaBi (developed by PE Internationals) and ecoinvent (developed by the Centre for Life Cycle Inventories) are international life cycle inventories, which are conversant databases but are not freely accessible as the other databases mentioned above. Apart from

these, businesses provide access to their data by integrating their data into third-party databases or national databases such as WRAP Embodied Carbon database in the UK (WRAP and UK Green Building Council, 2014).

The existence of a range of EC databases with different source data makes EC estimating non-uniform. Clark (2013) noted a difference in the EC estimates produced by different estimators for the same building. Commonly identified five factors affecting EC measurements include the system boundary of the analysis, the method of estimating, underlying assumptions, data sources used and the element classification (Dixit et al., 2010, Clark, 2013, Ekundayo et al., 2012, Victoria et al. 2015a). The most problematic factor of the five is the underlying assumptions of the estimate that are subjective to the estimator and cannot be standardised. Hence, these factors make it challenging to compare studies conducted in different parts of the world at different times. In fact, existing EC databases facilitates EC estimating during the detail stages of design while the reduction potential of EC is claimed to be high during the early stages of projects (RICS, 2014) similar to CC. Hence, there is a need for EC estimating and control mechanisms during the early stages of design. RICS (2014) suggests that focusing on intensive emission sources is a good approach to keep EC under control during the early stages of design, which are referred to as the carbon critical elements or the 'carbon hotspots' in this context. However, empirical research that explore EC datasets and control strategies for early design stages are limited. Hence, this paper proposes a method that can facilitate early stage EC estimating and controlling by focusing on carbon critical elements by employing two case study buildings. Furthermore, cost and carbon critical elements of the case study buildings were compared due to the increasing attention to both cost and carbon, which are referred to as the dual currency of construction projects (Ashworth and Perera, 2015; Victoria et al. 2015a).

2. CARBON HOTSPOTS

RICS (2014) defines 'carbon hotspots' as the carbon significant aspect of a project which can be building elements or other aspects in the supply chain. Ease of measurability and reduction possibility are two key features of carbon hotspots (RICS, 2014). Carbon hotspots may vary from one building to the other depending on the type or the function of the building (Ashworth and Perera, 2015). Monahan and Powell (2011) highlighted the importance of identifying hotspots in buildings by modelling a two storied residential building (in the UK) in three different scenarios, (1) timber frame and larch cladding, (2) timber frame and brick cladding and (3) conventional masonry cavity wall. Substructure and external walls were identified as carbon hotspots of the residential building and the potential for carbon reduction through alternative designs was highlighted (Monahan and Powell, 2011). Similarly, Shafiq et al. (2015) studied a two-storied office building in Malaysia by modelling six different scenarios for structural composition. Different grades or classes of concrete and steel were combined to generate different compositions that resulted in different material quantities producing varying EC impacts. Only a few elements were studied including foundation, beams, slabs, columns and staircases, which can be related to Substructure, Frame, Upper Floors and Stairs according to New Rules of Measurement (NRM) element definitions. Shafiq et al. (2015) found that it was possible to reduce up to 31% of EC by using different classes of concrete and steel to meet the given design criteria.

EC studies in different types of buildings highlighted above (Monahan & Powell, 2011; Shafiq et al, 2015) have different focuses and hence, limit the analysis to a few elements. However, the analysis of the whole building will provide a holistic picture of the EC contribution of each element and will unfold potential areas of carbon reduction. Table 1 presents a compilation of case studies of low, medium and high-rise office buildings in the UK. Superstructure is unanimously the predominant carbon hotspot while the contribution increases with the height of the building. Substructure EC is generally one fourth of the total EC, though, the contribution becomes significant with the inclusion of basements (see, the case study of Victoria et al., 2015). Finishes range from 1% to 15% highlighting the wavering nature of the element. Most case studies have not included Fittings EC while WRAP case study suggests that it can contribute up to 13% of the total EC. The contribution of Services EC seems to be underrepresented in the presented case studies as Services are said to be

accounting for 10-25% of the total EC (Hitchin, 2013; RICS, 2014). The identified low contribution of Services could be attributable to non-inclusion of all services as is evident in the case study reported by Victoria et al., (2015b) which covers only Disposal, Sanitary, Water and Lift installations. Accordingly, the comparison of case studies suggests that hotspots can vary for different classes of building such as low, medium and high-rise and no robust knowledge exist concerning the carbon hotspots of different types and classes of buildings.

Table 1: Case studies of office buildings from the literature

It is expected that EC planning will be embedded with cost planning process in the future with the increasing significance of dual currency of construction projects (Ashworth and Perera, 2015). However, research focusing on EC and CC relationships are limited. Langston and Langston (2008) analysed the relationship between initial embodied energy and CC of buildings in Australia and found a strong correlation at the project level but the relationship was insignificant at the elemental and material levels. However, the sample consisting of different types of buildings was a drawback of the study of Langston and Langston (2008) as carbon hotspots may vary for different types of the buildings resulting in different correlations. Further, embodied energy and carbon are not interchangeable as the material production process might emit or sequester carbon (Hammond and Jones, 2011, Brandt, 2012, Lélé, 1991). Hence, differing relationships might exist between EC and CC. This identified gap in the literature makes the case for exploring and comparing carbon and cost critical elements to contribute to the state-of-the art literature and to improve the early design stage decision-making of industry practitioners.

3. RESEARCH METHOD

This investigation can take either quantitative or qualitative form. Qualitative methods allow micro investigation of a problem and could possibly lead to the development of theories and hypotheses that can be tested through quantitative methods. Yin (2014) suggests that experiments, history and case studies are appropriate to deal with 'how' and 'why' form of research questions while surveys and archival analysis are good at answering 'who', 'what', 'where', 'how many', 'how much' types of research questions. This study seeks to answer 'what are carbon critical elements and how they compare to cost critical elements?'. According to Yin (2014), the proposed methods to answer the above research questions include surveys and archival analysis. However, this is a relatively new area of research and no past studies have empirically identified cost and carbon critical elements of buildings. Hence, case study approach was selected to study a few buildings in-depth (Fellows and Lieu, 2003) and holistically (Harling, 2002) which can lead to the development of hypothesis (for example, 20% of buildings elements are responsible for 80% of EC) that can be tested with a larger sample of data. Accordingly, two buildings were employed as cases of the study to investigate cost and carbon critical elements of those buildings and to study their interactions.

Case study buildings were selected using purposive sampling technique from a small dataset obtained from construction consultancy practices in the UK. Homogeneity of design parameters was the key selection criteria as cost and carbon intensity varies with the function and class of buildings (for instance, function encompasses residential, offices, warehouse and the like and class encompasses low, medium and high-rise buildings). Hence, both buildings were offices and have similar design parameters in terms of Gross Internal Floor Area (GIFA), building height, façade area and the building perimeter. Building A is 11,320m^2 and eight (8) storeyed with a basement; Building B is 15,120m^2 and seven (7) storeyed with two basements. Both buildings have a hybrid frame with raft foundation comprising concrete flat roof. Façade of Building A is made of pre-engineered stone concrete and glass while Building B has a curtain wall system. Both buildings have a combination of brick, block, dry lined and glazed internal partitions, finished with moderate types of finishes and accommodate highly sophisticated services including Building Management System (BMS).

EC and CC estimates were prepared using un-priced BoQs and the UK Building Blackbook (Franklin and Andrews, 2011). In addition, data were obtained from manufacturers and suppliers when EC and

CC rates were not present in the Blackbook. The UK Building Blackbook is a data book containing itemised CC and EC rates in accordance with the Standard Method of Measurements which was developed using the EC data from ICE. However, Blackbook data have a base date of 2010 2Q (price index - 218) and a location index of 100. Subsequently, costs were updated to 2016 1Q (price index - 276) and the location was index kept unchanged. Even though adjustments for CC was made, adjustments for EC was not made as EC is affected by processes (in this context process include manufacturing process of building materials). Therefore, an adjustment to EC data is not required unless the process is changed. This leads to a crucial assumption in EC calculations that the manufacturing process of materials has not changed radically.

Two key problems encountered in the data collection were the lack of detailed measurements (in BoQs) and the lack of EC and CC rates (in the UK Building Blackbook) for building services. The lack of EC and CC rates were overcome by obtaining CC benchmarks from Spon's price book (Davis Langdon Consultancy, 2014) and EC benchmarks developed from a specific dataset (consists of EC data of 28 offices in the UK) obtained from a UK consultancy practice. Consequently, EC and CC of services for the case study buildings were estimated using the EC and CC benchmarks to complete the estimate and present a holistic analysis of the case study buildings. The CC and EC rates used for the other types of services are roughly £371 to £386 per m^2 GIFA and 163 $kgCO_2$ per m^2 GIFA respectively. It should be noted that the estimates are subjective to the five key factors introduced in the literature review: it covers only cradle-to-gate (production) EC; manual estimating method was followed relying on the measurements presented in BoQs obtained from consultancy practices; assumptions were made on missing pricing information; the UK Building Blackbook was the major source of data used; and NRM element classification was adopted.

The next step in the investigation is to identify cost and carbon critical elements of the case study buildings by employing a structured approach. Munns and Al-Haimus (2000) highlighted that seminal texts in the cost management literature (Ashworth and Perera, 2015, Seeley, 1996, Ashworth and Skitmore, 1983) validates the applicability of Pareto Principle to identify cost significant items of buildings. The works of Munns and Al-Haimus (2000) and Tas and Yaman (2005) are examples of embracing 80:20 Pareto Principle to identify cost significant items from a BoQ. Hence, it is evident that 80:20 Pareto Principle is widely accepted as a popular method of identifying cost significant items of a building. Pareto Principle defines that 80% of the results (or consequences) are attributable to 20% of the inputs, which demonstrates the unequal relationship between the inputs and the outputs (Koch, 2011). Accordingly, it can be hypothesised that 80% of the EC of a building is caused by 20% of its elements. However, BoQ items have to be grouped (to minimise the complexity by reducing the number of items) either by work packages (trades) or functional elements to identify the cost or carbon significant items as done in previous studies (See, Munns and Al-Haimus, 2000, Tas and Yaman, 2005).

Accordingly, BoQ items were grouped by elements (to study the cost and carbon significance of building elements irrespective of trades) in accordance with the NRM elements classification system (RICS, 2012) which is the latest measurement standard prevailing in the UK. The sum total of EC and CC of each element group was obtained and the element groups were arranged in a descending order of their group totals. Cumulative percentage of the element group totals were calculated to identify the elements contributing up to 80% of the total EC and total CC separately for each building, which are referred to as the carbon or cost critical elements or the hotspots of the buildings.

4. DATA ANALYSIS AND DISCUSSION

The estimated total CC of Building A was £14,157,600 and Building B was £15,768,900; the estimated EC of Building A was 8,806,100 $kgCO_2$ and Building B was 11,574,500 $kgCO_2$. The CC and EC breakdown of the main elements of Building A and Building B are presented in Figure 1. Accordingly, Superstructure of Building A contributes almost equally towards CC (44%) and EC (49%) while Superstructure is the predominant carbon and cost significant element (hotspot) among others in Building A. Substructure is the second most significant carbon hotspot and the EC of the

Substructure (23%) is as twice as its CC (10%). Services are the second most significant cost hotspot in Building A, contributing up to 36% while Services (22.8%) and Substructure (23.1%) contribute almost equally towards the EC of Building A. Internal Finishes contribute up to 10% and 5% towards CC and EC, respectively. Fittings, Furnishing and Equipment are the least significant in terms of both CC and EC contributing less than 1%. Similar to Building A, Superstructure of Building B contributes almost equally towards CC (35%) and EC (39%), though, the contribution of Superstructure towards CC and EC in Building B is lower than the contribution of Building A. Substructure CC of Building B is as twice as the CC of Building A (the same is true for EC). This is mainly due to Building B having two (2) basements. Further, the EC of Substructure is almost equal to the EC of Superstructure of Building B, which signifies the importance of Substructure design. EC of Services is identified as the third important contributor towards the total EC of Building B while Services are the highest CC contributor of Building B. The contribution of Internal Finishes towards the total CC and EC of Building B are insignificant and almost equal whereas the CC and EC of Fittings, Furnishing and Equipment of Building B are negligible similar to Building A.

Figure 1: CC and EC contribution by elements – Building A and Building B

Similar and differing patterns were noticed when comparing the study findings of case studies presented in Table 1. Substructure EC of Building A is about a fourth of its total EC while Building B is more than a third of its total EC due to two basements, which validates the literature findings. Superstructure EC figures of both buildings are lower than the literature figures due to the inclusion of Fittings and Services in the analysis, which demonstrates the supremacy of holistic analysis. Finishes EC is within the range of the figures reported in the literature though lies in the lower end. EC of Fittings is negligible in both buildings similar to the findings of Victoria et al. (2015b) while Services accounts for approximately 23% in both case study buildings, which is higher than the literature figures and are in-line with the percentage proposed by Hitchin (2013) and RICS, (2014).

Building A and B have almost similar group CC and EC elemental profiles. Superstructure is identified as the most cost and carbon significant element in Building A, while Services is identified as the most cost significant and Superstructure is identified as the most carbon significant in Building B. Hence, in both the cases, Superstructure is identified as the most carbon significant element while there is a difference in cost significance. Findings also suggest that having an additional basement in a building can increase EC significantly, making Substructure as EC intensive as Superstructure. Even though the CC and EC of Internal Finishes do not highly influence the total CC and EC of Buildings A and B (as both buildings have moderate finishes), it can be a significant contributor in high-end office buildings with luxury finishes. Furthermore, the contribution of Fittings, Furnishing and Equipment towards the total CC and EC are almost negligible in both cases.

Table 2: Hierarchy of carbon and cost significance of building elements of the case study buildings

Table 2 presents the hierarchy of cost and carbon significance of building elements of the two case study buildings. The elements that are coloured in grayscale are the elements that contribute up to 80% of the CC and EC of the buildings and identified as cost or carbon hotspots. According to the significance analysis, cost hotspots of Building A and Building B are almost the same except for Ceiling Finishes, which has been identified as a cost hotspot in Building A. Services is identified as the most cost significant building element in both buildings while the cost significance of the Substructure and Frame is interchanged between the second and third positions in the hierarchy. External Walls including Windows and External Doors are identified as the fourth most cost significant element in case study buildings. However, the cost significance of the rest of the elements varies between the buildings. On the other hand, the same four elements have been identified as carbon hotspots in both buildings including Substructure, Frame, Upper Floors and Services, though, the carbon significance of elements wavers between the two. Similarly, carbon significance hierarchy of the rest of the elements varies, though, the three least carbon significant elements in both buildings remain the same including Stairs and Ramps, Internal Doors and Fittings, Furnishings and Equipment in the same order.

In addition, Substructure, Frame and Services are identified as both cost and carbon hotspots in both buildings, capturing the first three positions in the cost and carbon significance hierarchy. External walls are identified as cost significant while Upper Floors are identified as carbon significant in both case study buildings. The comparison of buildings showcases the elements that are both cost and carbon hotspots (Substructure, Frame and Services) and the elements that are almost insignificant (such as Stairs and Ramps, Internal Doors and Fittings, Furnishings and Equipment which captures the last three positions in the cost and carbon significance hierarchy and contributes less than 2% towards total CC and EC). However, there are elements that lie between these two categories, which are vague in nature and have the potential to become a cost or carbon hotspot such as, Upper Floor, External Walls, Windows and External Doors, Roof, Internal Walls and Partitions, Wall Finishes, Floor Finishes and Ceiling Finishes. These elements require special attention during the design phase though more attention should be given to the design of elements that are identified as both cost and carbon hotspots (Substructure, Frame and Services are identified as both carbon and cost hotspots in the case study buildings).

Furthermore, CC per GIFA and EC per GIFA (referred to as 'element rates') are also calculated for individual elements of Building A and Building B to get insights into the findings and presented in Table 3. Even though CC and EC demonstrate a similar pattern between the case study buildings when analysing at the main element level, differences were noticed at the individual element level. Clearly, Services is the most cost significant hotspot in both buildings and has similar element rates in Buildings A and B. However, Substructure element CC rate is doubled in Building B due to an additional basement in the building while Frame element CC rate is almost reduced to half in Building B compared to Building A which almost compensates for the increased cost in the Substructure. Further, element CC rates of External Walls, Internal Walls and Partitions, Roof and Internal Doors were very similar in both buildings while differences in element CC rates were noticed for the remaining elements due to the difference in element specifications. On the other hand, similar element EC rates were noticed in Roof, Internal Doors, Wall Finishes and Services while the element EC rates of other elements vary.

Table 3: Comparison of CC per GIFA and EC per GIFA of building elements of case study buildings

In addition, Table 3 highlights the magnitude of differences between CC and EC rates. For instance, External Walls are cost significant while the EC contribution of the same is very low. The reason for this could be the use of timber for windows and external doors where CC of timber is high while EC of timber is very low resulting in the identified difference in rates. This implies that cost and carbon significance hierarchies should be complemented by elemental EC and CC benchmarks to manage the dual currency effectively during the early design stages. Hence, the specification of building elements plays a major role in dictating CC and EC of buildings and their cost and carbon significance hierarchies.

5. CONCLUSIONS

The need to manage EC is at the forefront of the climate change propaganda of the built environment. Hence, this paper proposes an approach to control EC and CC (the dual currency) during the early stages of design by studying two office building in the UK. Pareto principle (80:20 rule) was adopted to identify cost and carbon critical elements of the case study buildings – elements that are responsible for 80% of EC and CC of the building. Substructure, Frame and Services were identified as both cost and carbon hotspots in both buildings responsible for more than 70% of the total CC and EC in both buildings. Likewise, Stairs and Ramps, Internal Doors and Fittings, Furnishings and Equipment were identified as the least cost and carbon significant elements responsible for less than 2% of the total CC and EC. Some of the remaining elements were identified as either carbon or cost hotspot, which are vague in nature and have the potential to be carbon or cost hotspots. Especially, Internal Finishes can be a cost and carbon significant element in high-end office buildings. The analysis clearly highlights the elements that need more focus during the design development which has high cost and carbon reduction potential over the others. Further, the hierarchy of cost and carbon significance of elements

varies even between buildings with similar design features due to the difference in the specification. Further, the comparison of element CC rates and element EC rates displays the complexity of achieving cost and carbon optimum design solutions.

Findings presented in the paper are based on two office buildings, and results might vary for buildings of different functions and storey heights. Hence, no inferences are drawn from the findings. However, the study has some key implications. The implication of carbon and cost significance analysis is that it informs designers of the elements whose design has a high impact on the CC and EC of a particular type and class of buildings. For instance, CC and EC of the substructure of Building B were as twice as Building A due to an extra basement. Assuming that the basement is primarily for parking if the likely EC and CC can be estimated during the early stages of design, then the design team can choose between one of the two options: (1) two basements or (2) one basement and a private parking space. There is clearly a trade-off between the convenience of employees and savings in dual currency in those two options. Further, this analysis also helps identify the elements that can be disregarded in the decision-making process during the early stages of design as its contribution to total EC and CC will be almost negligible, and no significant reduction can be achieved. In addition, the use of elemental CC and EC benchmarks to maximise the reduction was also highlighted, though, industry developed EC benchmarks does not exist at present. Hence, there is a need for industry developed EC benchmarks to facilitate dual currency management during the early stages of design. Further, the 80:20 ratio could not be tested statistically due to the qualitative nature of the study. However, this study acts as a forerunner for the development and testing of propositions and hypotheses on carbon significant elements of homogenous buildings with large samples. It is also believed that this study will facilitate life cycle cost and carbon analysis, which is a more holistic approach and superior to cradle-to-gate analysis though that could not be performed within the limited scope of the study.

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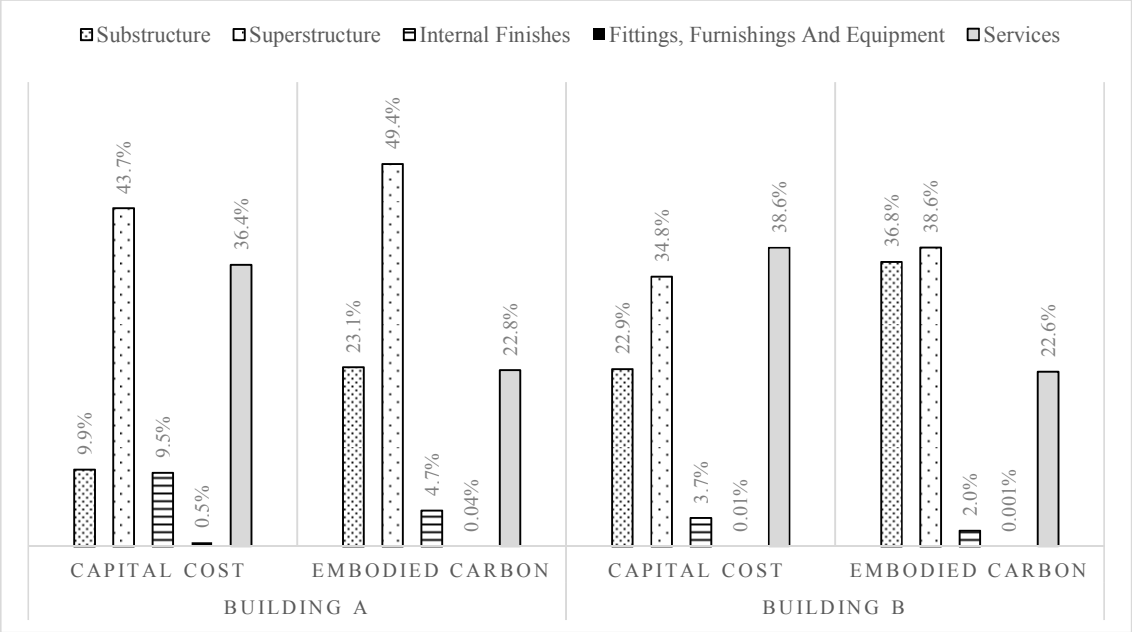

Figure 1: CC and EC contribution by elements – Building A and Building B

Table 1: Case studies of office buildings form the literature

	Halcrow Yolles (2010)			WRAP	Victoria et al. (2015)	Sturgis Associates (2010)	RICS (2012)
	Okehampton	Pool	Brunel			Ropemaker Place	Leadenhall
GIFA (m^2)	1,140	3,441	2,341	Unknown	33,663	56,020	86,450
Storeys (No)	1	2	2	Medium-rise	18	21	51
Basements (No)	0	0	0	0	2	0	0
Substructure	30%	22%	20%	16%	44%	25%	25%
Superstructure	52%	62%	72%	57%	55%	60%	74%
Internal Finishes	15%	12%	6%	10%	1%	10%	1%
Fittings, Furnishings & Equipment	-	-	-	13%	0.1%	-	-
Services	3%	4%	2%	3%	1%	5%	-

Table 2: Hierarchy of carbon and cost significance of building elements of the case study buildings

Cost Significance Hierarchy		Carbon Significance Hierarchy	
Building A	**Building B**	**Building A**	**Building B**
Services	Services	Frame	Substructure
Frame	Substructure	Substructure	Services
Substructure	Frame	Services	Frame
External Walls (Incl. Windows and External Doors)	External Walls (Incl. Windows and External Doors)	Upper Floors	Upper Floors
Ceiling Finishes	Internal Walls and Partitions	Internal Walls and Partitions	External Walls (Incl. Windows and External Doors)
Upper Floors	Upper Floors	External Walls (Incl. Windows and External Doors)	Roof
Internal Walls and Partitions	Roof	Ceiling Finishes	Internal Walls and Partitions
Floor Finishes	Floor Finishes	Roof	Floor Finishes
Roof	Ceiling Finishes	Floor Finishes	Wall Finishes
Wall Finishes	Wall Finishes	Wall Finishes	Ceiling Finishes
Fittings, Furnishings and Equipment	Internal Doors	Stairs and Ramps	Stairs and Ramps
Stairs and Ramps	Stairs and Ramps	Internal Doors	Internal Doors
Internal Doors	Fittings, Furnishings and Equipment	Fittings, Furnishings and Equipment	Fittings, Furnishings and Equipment

Table 3: Comparison of CC per GIFA and EC per GIFA of building elements of case study buildings

Building Elements	CC per GIFA (£/m^2)		EC per GIFA (kgCO_2/m^2)	
	Building A	Building B	Building A	Building B
Substructure	124.1	239.1	179.9	281.5
Frame	318.7	175.8	203.9	143.9
Upper Floors	50.9	23.9	97.5	63.0
Roof	24.3	20.9	16.4	18.2
Stairs and Ramps	6.1	0.9	4.7	1.0
External Walls (Incl. Windows and External Doors)	107.5	107.7	27.3	59.4
Internal Walls & Partitions	33.2	28.3	34.1	9.5
Internal Doors	5.7	6.0	0.7	0.7
Wall Finishes	21.4	11.4	5.3	4.1
Floor Finishes	29.9	14.0	13.8	8.0
Ceiling Finishes	67.6	12.7	17.2	3.4
Fittings, Furnishings & Equipment	6.4	0.1	0.3	0.1
Services	454.9	402.1	177.0	172.9