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DESIGN WASTE GENERATORS IN CONSTRUCTION PROJECTS

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ABSTRACT

The construction industry in the UK is by far the greatest waste producer among all industries, being responsible for 32% of total waste generated, which equates to three times the combined waste produced by all households. Consequently, the last few years saw the development of several government-driven waste related regulations, policies and consultation documents to reduce construction waste production and increase reuse and recycling rates. Equally, global research on construction waste has been conducted over the last decade ranging from 'soft' onsite waste management tools to 'hard' material and recycling technologies. However, there is an insufficient effort and no structured approach to examine the underlying generators of design waste. Hence, this research engaged the top 100 UK contractors and architectural practices through a questionnaire survey and 24 follow up interviews to investigate the direct and indirect root origins and causes of construction waste across all stages of the building design process that culminated in the development of a set of design waste maps. Respondents reported that designing out waste has never been a priority in the design process. Moreover, results reveal that design waste is affected by a wide practice of not embedding waste reduction in briefing, no waste reduction target setting, and lack of designers' understanding of design waste causes; hindered by incoherent coordination and communication between project members; and impeded by time constraints

Keywords: Construction waste; design waste mapping; architects; contractors; UK.

1. INTRODUCTION

The construction industry makes a vital contribution to the competitiveness and prosperity of the UK economy; with an annual turnover in excess of £100 billion, contributes 9% of GDP, and provides employment for over three million people. However; it is by far the greatest consumer of resources and waste producer of all industries in the UK being responsible for 32% of total waste generated, which equates to three times the combined waste produced by all households (DEFRA, 2007). Additionally, an estimated 25 million tonnes of construction and demolition waste ends up in landfill without any form of reuse or recovery, costing the industry £1 billion per year in disposal costs (Moon, 2008). Consequently, construction waste management and minimisation became a priority in the UK environmental policy programmes such the UK Strategy for Sustainable Construction-SSC (BERR, 2008), which contains a target to halve waste to landfill by 2012. A zero waste target was debated, but concerns regarding industry fragmentation and poor engagement led to its omission. More than 500 companies have signed the 'Halving Waste to Landfill' commitment, including 185 contractors and 64 designers, in addition to clients, professional institutions and government agencies. Additionally, a host of existing and forthcoming environmental legislation is expected to drive the resource efficiency momentum, and the issue of waste reduction is likely to rise in importance among all construction stakeholders. The SSC recognised the importance of considering construction waste minimisation during design; hence the notion of 'designing out waste', as espoused in recent guidance for building projects (WRAP, 2008; WRAP, 2010). Despite international academic endeavours over the last 15 years, design waste reduction research is limited and piecemeal; and as such "more work is essential to investigate C&D (construction and demolition) waste issues in project design (Lu and Yuan, 2010). Hence, the aim of this paper is to investigate the root causes construction waste during the design process. Building 'design waste' is defined in this paper as waste arising from building sites as a direct and indirect result of the design process, including opportunities to reduce waste by all project's stakeholders throughout the design stages.

2. INSIGHTS INTO CURRENT CONSTRUCTION WASTE MANAGEMENT RESEARCH

An ever-increasing construction waste related research has been conducted ranging from 'soft' mapping, management, and reduction tools and methodologies to 'hard' material and recycling technologies Yuan and Shen (2010) presented insights into the recent construction and demolition (C&D) waste management research trends. The study showed that there was no clear signposting on a single research direction by reporting that the bulk stream of publications was devoted to broad brush topics such as environmental regulations and cost benefit analysis. Similarly, Lu and Yuan (2010) developed a framework for understanding global construction waste management research.. They indicated that the majority of published papers were related to the construction and demolition stages, with very few attempts were devoted to investigate design waste. That said, Yuan and Shen (2010) and Lu and Yuan (2010) reviews were limited to a number of journals on the one hand; and they did not cover other academic work, such as doctoral studies; and industry and government publications on the other. For example, Gamage et al. (2009) and Gamage (2011) assessed the relationship between construction procurement systems and construction waste generation, which led to the development of a procurement waste minimisation framework for construction projects. As such, Osmani (2011) revealed that the current and on-going research in the field of construction waste management and minimisation can be broadly categorised into 13 clusters, including procurement waste. In terms of government publications, WRAP (2008) introduced a new guide to help architects reduce the amount of construction waste sent to landfill in the UK. The guide comprises five principles: design for reuse and recovery; design for offsite construction; design for material optimisation; design for waste efficient procurement; and design for deconstruction and flexibility. The latter is a step forward to engage architects in designing out waste; however, it did not associate the proposed principles with all parameters of the design process environment; including design stage sequencing and stakeholders' interactions and roles. More importantly, the guide failed to conduct a waste diagnosis across all design stages to map out the direct and indirect design waste sources and origins that are critical in informing and implementing designing out waste principles and strategies.

Emerging information technologies, bar coding systems, and GPS, GIS and the wide area networks (WAN), are being introduced into construction waste management and minimisation research (Cheng et al. 2011). Most recently; saw the emergence of Building Information Modelling (BIM) techniques (RIBA, 2012), which can be adopted to assist architects minimising waste in their design projects (Liu and Osmani, 2011). Similarly, a steering committee consortium, chaired by the author, is in the process of developing a new British Standard, BS 8895,that aims to provide principles and an implementation framework for waste prevention and minimisation during the design briefing stage of building projects. BS 8895 Part 1 forms the foundation standard for a suite of future British Standards and Codes of Practice intended to address specific and interrelated issues and processes of designing out waste in building projects (BSI, 2013).

The extant of literature suggests that all construction stages directly or indirectly contribute to construction waste generation. However, the level and severity of waste production varied from stage to stages depending on a number of variables that include type of procurement, project brief, stakeholders' engagement and commitment, etc. That said, it is widely argued that future waste efforts should focus on designing waste (Baldwin et al, 2006; Poon et al., 2004; Poon, 2007; Osmani et al, 2008; Osmani, 2011; Chen et al, 2011; Lu and Yuan, 2010).

3. METHODOLOGY

The research adopted a triangulated methodological approach, consisting of a desk study, quantitative and qualitative research methods. The quantitative research took the form of two sets of postal questionnaire surveys distributed to top 100 UK architectural practices and contractors respectively. The aim of the twofold questionnaire survey was to establish a general industry-wide perspective on causes and origins of construction waste. The qualitative data collection comprised 24 follow up semi-structured interviews that were conducted with 12 architects and 12 contractors to provide the qualitative research for the research.

The Statistical Package for Social Science (SPSS) software was used to analyse questionnaires' results. The qualitative data from the interviews were firstly recorded, which enabled full transcripts, and finally coded and analysed using NVivo.

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4. RESULTS

The response rates from the questionnaire were 40% and 49% from participating architects and contractors respectively; representing a 44.5% mean response rate. Both questionnaires' results led to a rating signposting of broad waste related causal parameters. However, there was a need to comprehensively map the root origins and underlying causes of design waste and establish correlation between onsite waste generation and the building design process. As such, interviewees were asked to identify the potential causes of design waste during each briefing, design development and detailing and specification. Results are summarised and discussed below

4.1 Construction waste sources

Respondents were asked to rate from 1 (lowest) to 5 (highest) waste sources in construction projects. Questionnaire results indicate that responding architects rated 'unused materials' as the highest waste generator with a mean value of 4.30; followed closely by 'offcuts' (4.15) and 'client-led changes' (4.00). Similarly, responding contractors accorded the highest and same mean importance rating (3.57) to both 'offcuts' and 'client-led; followed by an equal rating of 3.51 for 'design changes' and 'improper onsite material storing'.

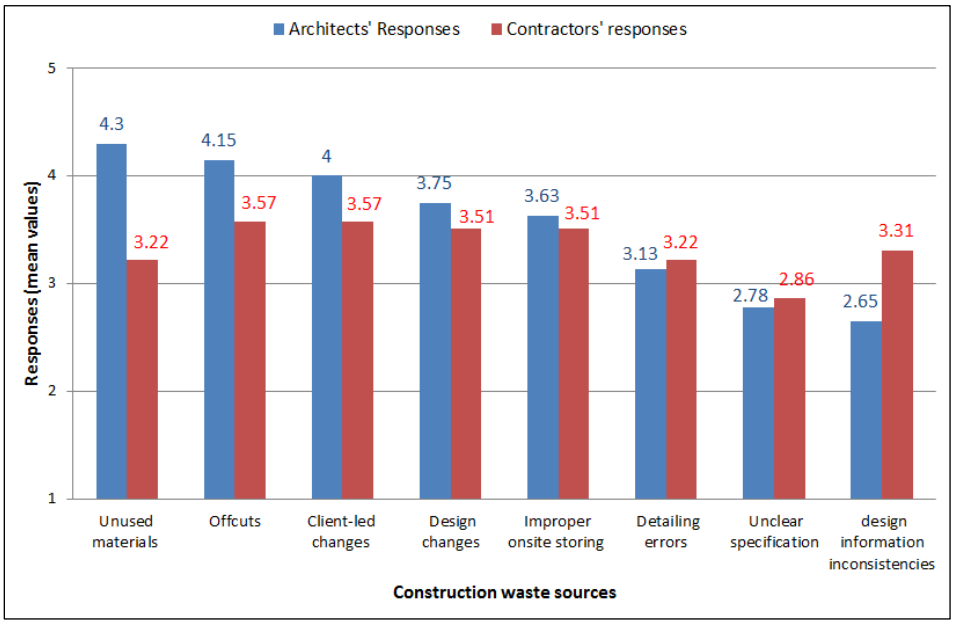

Figure 1. Sources of waste across a construction project life cycle

In-depth investigation was needed to examine the underlying design waste causes and sources during the design stages. As such, 24 follow up semi-structured interviews were conducted with 12 architects and 12 contractors from the responding architectural practices and contracting firms respectively. The results of the interviews are reported and discussed in the sections below.

4.2 Construction waste causes during design stages

4.2.1 Construction waste causes during project brief development

The interviews identified a number of design waste causes during the briefing stage. These are summarised in Figure 2 and discussed below.

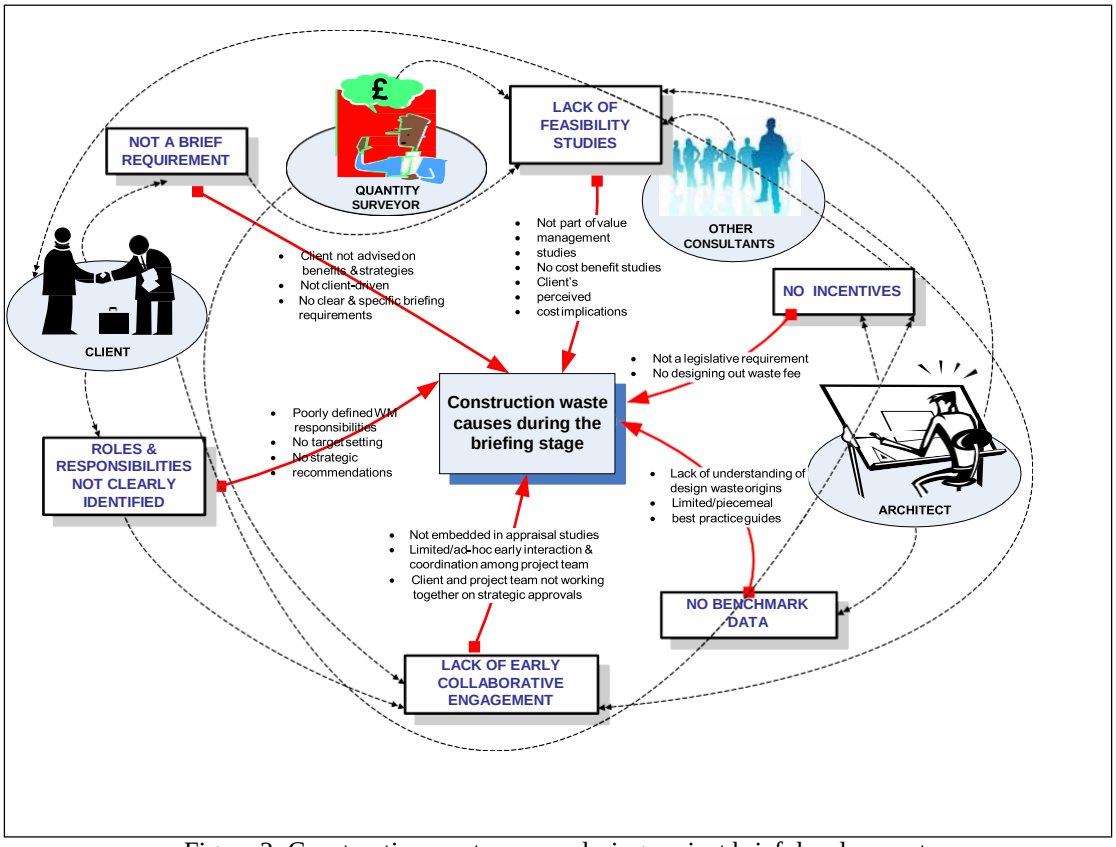

Figure 2: Construction waste causes during project brief development

4.2.1.1 Designing out waste is not a brief requirement

There was a consensus among participating contractors and architects that waste minimisation is generally not a brief requirement in most projects. The client being unaware of the benefits, especially associated costs with waste reduction measures, was raised by the majority of interviewees. It was emphasised by both architects and contractors that "this is the responsibility of the quantity surveyor to identify potential benefits and communicate this to the client", who should be taking the lead in making sure that all project stakeholders are informed about the importance and impact of waste minimisation throughout the project life cycle. When probed on reasons for the lack of architect, consultants, and contractors' engagement in advising the client regarding waste control and management; contractors were of the opinion that this is mainly due to time constraints imposed by clients. Similarly, architects reported that they work in accordance with a tight time schedule from start to end and there is "no time to look at best design"; and encapsulated their thoughts by stating that they "are not influencing the fundamentals of design after all". On the other hand, contractors argued that the client and design team "should be in a position to identify a waste minimisation target during the briefing stage, that's as far as they can go". On the other hand, architects rejected the argument by stating that architects "don't even know at that point what the building is going to be made of as the design brief is a broad brush stage".

4.2.1.2 Roles and responsibilities not clearly identified

Participants were asked whether the client should endeavour to define and allocate responsibilities for waste minimisation at the briefing stage. A representative response was forwarded by one contactor: "If waste minimisation is driven from the project outset and written into contracts, then responsibilities were made through the key stages of design that would help enormously".

4.2.1.3 Lack of early collaborative engagement

Little interaction among architects, consultants and contractors was a factor identified by all interviewees. The need for a whole team approach was considered important if waste minimisation was to filter through the entire process, as one contractor put it: "waste minimisation has to be introduced right at the start of the briefing stage so that the client and the design team have all got to collaborate to implement it".

4.2.1.4 No waste minimisation feasibility studies and benchmarking data

Most contractors were of the view that the briefing stage should comprise detailed research into how waste can be minimised through design. As such, one contractor argued that this is partially the client's responsibility; however, most of the time "the client will just give the architect an embryonic brief with broad requirements". This was seen as an opportunity for architects to conduct a waste minimisation feasibility study whereby information is assembled, waste reduction target is set, and a mechanism is put in place to monitor the process throughout the project life cycle. This should include working out rough ideas on materials, assess their resource efficiency suitability, and develop an initial cost plan with quantity surveyors. On the other hand, architects reported that currently waste minimisation is not a design priority and "feasibility studies during the briefing stage of a construction project will be looking at big issues on sites". One architect went further by stating that "the extent at which waste minimisation will be considered at these stages will depend on how it fits into the most critical design issues". However, by and large architects acknowledged that if the waste issue is not addressed at the project brief, then there is a potential to create a framework which will go on being wasteful all the way through the project life cycle. That said, both participating contractors and architects concurred that at present, waste minimisation endeavours are not considered during feasibility studies and the lack of waste related information, especially benchmarking data, makes it even more difficult to pragmatically assess the potential for waste reduction during the design and construction process.

4.2.1.5 No financial incentives for designers

The lack of financial incentives was raised as another key issue for the passive motivation by architects in investing extra time and effort required to design out waste. As such, one architect pointed out that, "the client should perhaps set aside an additional fee; for the architect to consider waste minimisation in the design process". Another architect stated that waste minimisation "is often a moral expectation from the architect", and argued that this is often not sufficient pressure to consider it in design. Conversely, most contractors agreed that design waste considerations should be part of architects' conventional work process without being paid extra for it. However, architects argued that financial incentives could objectively drive forward the waste agenda during the design process; and proactive actions in this matter will need architects to go "above and beyond their legal requirements". On the other hand, a responding architect compared the waste issue to health and safety considerations by stating that 10 years ago, architects did not think about health and safety too much because it was assumed to be the contractor's responsibility but now if it is routinely considered part of CDM Regulations (HM Government, 2007); and as such architects eventually will get at that stage with waste minimisation. He argued; however; for the moment "the idea has not permeate the architectural offices".

4.2.2 Construction waste causes during design development

Figure 3 summarises the interviewees' insights into the salient design waste origins and causes during design development, which are discussed below.

4.2.2.1 Lack of partnering commitment and coordination

Both respondents agreed that wastage can indirectly occur because of lack of coordination between members of the design team on one hand, and the architect and the client on the other. Interviewees went further by associating waste generation with weak linkages between designers and manufacturers and poor coordination and communication among designers.

4.2.2.2 Lack of architects' engagement

Contractors commented that waste minimisation is not considered a priority by architects. Responding architects They opined that even though design waste will be an initial consideration, other issues soon distract architects from implementing it, such as "getting through planning and other regulatory approvals" that require more urgent thoughtful attention.

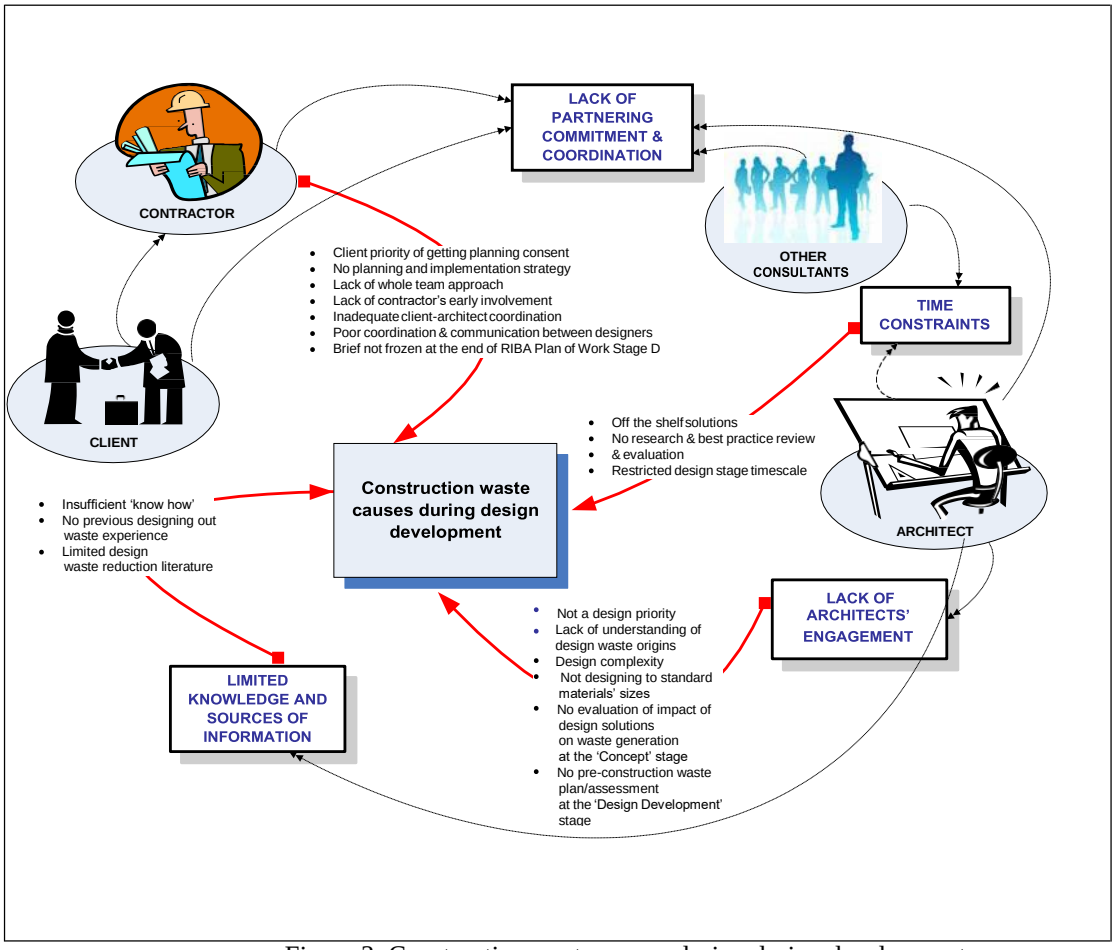

Figure 3: Construction waste causes during design development

The issue of design complexity fuelled greater debate among the respondents. This was particularly emphasised by contractors as a key source of waste resulting in unconventional shapes that are beyond traditional site personnel buildability skill sets. This often results in abortion of work or trimming off materials to fit their specific applications. Indeed, offcuts and rework are by and large indirect consequences of design waste as an architect stated: "every time more complexity is added, there is potential for more waste". For contractors, the key action for architects is to produce a more integrated and informed design process to avoid offcuts. However, they argued that the overtly complex design makes it difficult to specify materials to standard dimensions. Nonetheless, another architect identified the issue of design complexity as an opportunity to explore and promote the use of modern methods of construction: "when a certain level of complexity is a concern then there is a need to explore offsite fabrication and manufacturing". Responding architects commented that design waste can be reduced without compromising creativity and innovation: "if architects standardised everything they would automatically eliminate design, which is actually the most important element of architecture". An architect also added that it is possible to "manage the process to have a complex design but still minimise waste within the parameters of that particular project".

Architects attributed their lack of engagement in designing out waste to their limited involvement in design development. This is due to an increasing amount of specialist design, particularly in Design and Build (D&B) procurement. The restricted contribution of architects in the whole process especially in a supervisory role was also raised as a factor that could lead to design waste: "our role in onsite supervising work is diminished; therefore the level of experience that our technicians are getting, going out and seeing what is going on onsite is getting less". They concluded that current and up-coming architects will have little or no practical knowledge of site activities and will be unable to relate the impact of their design on what happens onsite. The prevalent practice that architects are not responsible for the entire design was raised. One contractor agreed that "architects rarely produce a design for

100% of the building" as most the specialised design work packages in D&B procurement, such as curtain walling are done by specialist contactors. This leads to lack of design coordination and ultimately design waste.

4.2.2.3 Limited knowledge and source of information

The lack of knowledge related to an effective waste reduction strategy during the design stage was raised by both architects and contractors as an indirect design waste origin. However, the majority of contractors pointed out that "having that background information of where waste comes from is important". They went further by stating that "a focussed education for architects needs to take place first, not only giving them the tools but also the understanding of how to use them". Similarly, most architects acknowledged a lack of knowledge and appropriate methods to minimise waste during the design process. Furthermore, the lack of robust technical knowledge of building materials and site processes was highlighted by most contractors as a serious impediment facing architects to design out waste. As such, one contractor opined that "architects will need to be aware of all standard sizes produced by manufacturers"; while another argued that "poor understanding of building materials" by designers tends to lead to uninformed design and material specification.
One of the recurring issues raised by all respondents was related to limited and incoherent accessible information that contributes to the lack of knowledge on designing waste. Accurate and available information, i.e. best practice guides, was seen as an enabler in design decision making, which could consequently lead to reduction in design waste.

4.2.2.4 Lack of early team interaction

Both architects and contractors consented that efficient design waste minimisation can only be achieved if it is pursued by all parties and driven by the client. Architects opined, however, that this "depends on the kind of contractor and the type of procurement route". On the other hand, contractors maintained that this should be firmly set during the early design stages and argued that "if waste is not considered or known about at the briefing stage, it will be extremely difficult to carry it further".

4.2.2.5 Time constraints

Insufficient time to consider waste minimisation is a common thread in most of the work stages. Due to time constraints, architects argued that they cannot adequately explore individual solutions and often make use of design and specification data from past projects. This was reinforced by one participating architect: "if there is no time to research systems, architects will keep defaulting and probably pull off what they have used or heard of before". Another architect suggested that if there was no sufficient time, issues are considered in order of importance. He went further to explain that "time is always short to do everything perfectly but it doesn't mean that one does not have a go at doing it, if it is considered important enough". Contractors also commented that clients want "buildings designed, built and occupied as quickly as possible". They added, however, that if longer periods were allowed for pulling project details together, then issues such as waste and alternative methods can be realistically considered. They went further by acknowledging that if designers are up against very tight deadlines, "they will go with what they know".

5. CONCLUSIONS

Quantitative and qualitative data collection that were captured from the major UK architectural practices and contracting companies allowed a holistic and detailed mapping of waste causes across design stages in construction projects. Design waste during the briefing stage is attributed to the lack of project strategic waste minimisation commitment driven by misinformed clients; absence of benchmarking data and legislative requirements for designers; and limited early interaction of project team members. The key waste causes during the design development stage are associated with limited knowledge on the underlying design-related waste origins and designing out tools and methodologies; and stilted client-architect, architect-material manufacturers; and architect-consultant coordination and communication.

Results suggest that design waste is affected by a wide practice of not having waste minimisation as a brief requirement, no baseline setting, and lack of designers' understanding of design waste origins; hindered by limited 'know-how' and incoherent coordination and communication between project members; and impeded by time constraints and disjointed design information; which cumulatively disallow due waste minimisation consideration, implementation and monitoring during the design stages.

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