FACTORS INFLUENCING THE EXTENT OF WASTE MANAGEMENT ON CONSTRUCTION SITES

The adoption of net-zero carbon goals and the increasing calls for sustainable management of waste, has resulted in construction companies developing diverse sustainable practices towards the reduction, reuse, and recycling of waste from construction projects. Several factors influence the nature and adoption of such practices, and consequently the extent of sustainable waste management on site. Adopting a multiple case study approach involving 9 live projects, this research investigates the factors influencing the extent of waste management practices on sites through interviews, documentary analysis and observations. The study provides new evidence to suggest that, irrespective of the drivers of waste management, factors such as: site space, approach of senior management towards waste; early involvement of contractors in the design process; incentives for site teams; identification of alternative use of materials; attitude of site teams; level of waste management education; level of planning at the front-end; type of technology adopted; and complexity of design forms are important determinants of waste management on projects. Whilst some of these factors are shaped by organisational policy, the vast majority are project specific in nature. This indicates that construction companies must be flexible and focus on empowering site teams to develop effective project specific strategies.

Keywords: Construction and demolition waste, sustainable management, waste management, net-zero carbon goals

INTRODUCTION

The construction industry the world over struggles with the challenge of excessive generation and management of construction and demolition waste (CDW). The generation of CDW results in negative impacts such as: environmental pollution, misuse of natural raw materials, and increased cost of construction projects (Lu and Yuan, 2011; Loizou et al., 2021). To overcome these impacts, governments, clients, and construction companies have sought to adopt different measures towards the management of waste with a focus on sustainable strategies for managing waste (see Adjei et al., 2018). Research on waste management in the construction industry suggests that there is still a long way to go in achieving sustainable waste management (WM). Studies by Ajayi et al (2015), Kabirifar et al (2020) and Shooshtarian et al (2022) all indicate that though the construction industry has made some progress, the industry is still far from managing its waste using a sustainable WM strategy. The amount of CDW disposed of can be reduced greatly if better management of materials is practiced on construction sites (Ajayi et al., 2017). In this regard, several measures, including but not limited to the application of lean principles, use of waste hierarchy, deconstruction, waste source separation, and the adoption of modern methods of construction are adopted by construction companies to sustainably manage waste from their sites (Tingley and Davison, 2011; Loizou et al 2021). The adoption of the EU Waste Framework Directive 2008/98/EC which proposes the reduce, re-use, recycle and recovery approach to waste management is seen as a milestone of modern waste management (Zhang et al., 2022).

The different measures notwithstanding, the levels of waste minimisation, reuse and recycling differ from one project to the other (Ajayi et al., 2015). This suggests that the measures put in place to manage waste are influenced by factors other than the broad strategic measures. Manewa et al (2007) for example report that even when systems do exist on site to support waste management, factors such as worker awareness and management commitment contributes in so many ways to make it work. This research argues that, identifying and paying attention to the success factors and adopting measures focusing on same will go a long way in achieving sustainable waste management on construction sites. However, relatively limited studies have focused on such factors and the extent to which they influence WM. This research investigates success factors that influence the extent to which sustainable WM is achieved on construction project sites.

APPROACHES TOWARDS WASTE MANAGEMENT ON SITE

Diverse strategies have been proposed for WM. They include design to reduce waste (Wang et al 2015; Ajayi and Oyedele, 2018), design for de-construction (Tingley and Davison 2011), use of waste hierarchy, waste reduction through the application of lean principles (Udawatta et al., 2015), pre-fabrication and off site manufacturing (See Tam et al., 2007), adoption of effective material control on site; incorporation of source separation as a WM option, and strategic/early planning for WM. The call for the use of sustainable and ecological friendly construction technology demands a change in the traditional construction models to enhance the capacity of recycling and reuse of waste from construction activities. Lachimpadi et al. (2012) compared construction methods and conclude that Industrialised Building Systems (IBS) have a waste usage efficiency of over 94% compared to conventional methods. Other studies such as Loizou et al (2021) confirm the advantage of modern construction methods in ensuring better WM. For demolition waste, there is evidence to suggest that deconstruction has the added advantage of leading to salvaging a lot of the materials which can either be reused or recycled for other activities (Guy et al., 2006; Tingley and Davison, 2011).

These measures and practices are driven by factors such as cost, government legislation, environmental concerns, changing industry perspective on waste, and client demands (Adjei et al., 2018). This research argues that beyond the drivers, there is the need to identify project specific success factors that influence the extent of waste management on construction projects.

INFLUENCES ON WASTE BEYOND THE DRIVERS

The extent of waste management is influenced by an awareness of WM; availability of technologies for WM; training of site personnel; procurement of reusable/recyclable materials; active participation of management; cost considerations; close collaboration between designers, managers, and the supply chain; poor performance of workers; improper storage space and methods; and effective material control (Teo et al., 2000; Manewa et al., 2007; Kabirifar et al., 2020; Ajayi et al., 2017; Zhang et al., 2022). Although this is well discussed in the literature, there is not much research on the extent to which these factors influence the waste generation and management levels

on construction sites. The focus of this research is to investigate the extent to which these factors influence waste generation on sites and their implications for WM efforts

RESEARCH METHODOLOGY

To investigate the factors and extent to which they influence WM on site, this research adopted a multiple case study approach (Yin, 2009). The use of multiple case studies helped to identify different cases with different characteristics that could influence waste management on project sites (Stake, 2013; Gustafsson, 2017). A total of 9 different projects with varying sizes and characteristics were purposely selected as the basis for data collection. 38 semi structured interviews were conducted with project managers, site supervisors, tradesmen, and operatives. See Tables 1 and 2 for summary. These interviewees were purposely selected (Noor, 2008) due to their experience on projects and the relationship of their roles to WM on project sites. The roles and experiences of the interviewees varied significantly, and this was specifically designed to capture views from the strategic and operational levels on these projects.

The interview questions, which were based on the current literature, focused on the approach to WM on the projects and factors that may have influenced the extent to which the approaches achieved the required results. Data collected and analysis continued until data saturation was achieved (See Guest et al., 2020). This research adopted a thematic approach to analysing the data collected and thus following the recommendations by Saldana (2012). The research began with 5 predefined themes based on the existing literature. A total of 150 open codes were initially generated. Through axial coding, the themes and codes were then grouped into categories which ultimately formed the basis for the sub-themes of this reported in the results section.

In addition to the interviews, additional data was collected in the form of observations and documentary analysis (Noor, 2008). This allowed for the triangulation of the data (Yin, 2009) where outcomes of the observations and project documents helped to enrich the interviews.

Table 1 Characteristics of case study projects

Case Study	Project Client	Project Type	Cost	Duration
A	Education Funding Agency	School replacement project	£22 Million	7.5 months
B	Developer	Redevelopment Apartments and shops	£400 Million	39 months
C	Education Funding Agency	New Build with part refurbishment school	£12 Million	8 months
D	Developer	New Build Leisure centre and retail Park	£35 Million	23 months
E	Education Funding Agency	New Build University Project	£8 Million	17 Months
F	Education Funding Agency	New Build - Technology college on an existing site	£12.5 Million	12 months

G	Health Trust	New Build Hospital - Rapid Response Unit	£36.5 Million	18 months
H	Developer	New Build Retail Park	£20 Million	8 months Investor
I	Developer	Retail Park, fuel station &shopping mall	£45 Million	27 months

Table 2 Profile of research participants

Role	**Project Managers**	**Site Managers**	**Waste Managers**	**Sub-contractors**	**Skilled Operatives**
Participants	7	8	7	10	6
Years of Experience	5-17	3-12	5 - 12	3 - 12	10 - 15

RESULTS AND DISCUSSION

From the analysis of the interviews, documents and observations, there is evidence to suggest that beyond the drivers known to influence waste on sites, several factors influence the extent to which WM strategy achieved results on sites. These influences are grouped into three main themes: project characteristics, management efforts, and personal factors. The impacts of these factors and the extent to which they influence sustainable WM is discussed below.

Project Characteristics

Project characteristics such as the size of the project, stage of project, availability of space on site, complexities of the design forms/ standardisation of components on the project, and the construction technology used influence how well teams managed waste on site.

Project Size

Data from all the case study projects indicate that the size of project has an influence on the extent of WM. Whereas small sites are seen to be lacking adequate WM provisions, due to limited number of waste streams and resources to manage waste, the complexity of big projects restricted the extent of WM due to the sheer number of people and teams involved. The Assistant Site Manager for Project E explained this below: “It’s very frustrating when you see things happening on a job and you know there’s better ways of doing it, but the problem with big jobs like this is that it’s very difficult to change things quickly as there are so many people involved, so many people want their say, it’s very difficult to make it happen”.

Type of construction technology

Construction technologies such as steel framed construction, off site prefabrication and modular construction (low waste construction technologies) were identified to positively affect WM on projects as they led to low waste generation. On project 2 for example, precast columns seen during the site visits, according to the assistant site manager, saved on materials and time. He explained “these come in off the back of a wagon, we pick them up and drop them into place, fix the steeling - off you go - little to no waste generated, pre-cast is the way ahead.”. Prefabrication and modular construction have been suggested in previous research as low-waste construction

technologies for reducing C&D waste (Tam et al., 2007; Loizou et al., 2021; Lu et al., 2021).

Availability of space on site

Availability of space on site affected the reuse and recycling of materials. Site space affected the segregation of waste and storage of materials for reuse. On projects with less space to have different skips for segregation or store materials, a large percentage of materials which could be used on site had to be taken off site. On projects with the availability of space, site teams were able to store materials, including bricks and concrete on site for crushing and reuse. The analysis of site layout planning documents supported this observation and views from interviewees.

Design decisions

Design decisions such as material choices, buildability of components, the integration of site teams in design, and shape of structures or components had an influence on how well site teams could manage waste. The general notion on site is that site teams belong to the tail end of the spectrum with no input into the processes and decisions of designers that are actually the root causes of waste on site. Almost all interviewees cited design decisions as a factor influencing WM on site and suggested that standard/ simpler shapes and styles will go a long way to benefit WM. Previous research has identified design decisions as key to achieving sustainable WM (Guy et al., 2006; Ajayi et el., 2018;)

Complexity of design forms and components

Closely following design decision was the complexity of design forms and components which dictate waste generation and management. The specification or design of very irregular shapes or components was identified to affect WM on projects. It was identified that client choices affected such decisions. An environmental manager explained “you get clients who just don’t understand the concept and design - a circular building - and want BREEAM very good and sign up to the fact that if they don’t get BREEAM very good, they’re not getting the funding for the project. So, when you say ‘well, you’ve got a circular building, there isn’t a straight line in here, there’s no way you can achieve that on the waste.’ …they just don’t get that interface at all.” During the observation, he showed a cutting shed with offcuts and explained they occurred as a result of making complex shapes. Ajayi and Oyedele (2018) provide similar results and suggest that construction waste could be significantly reduced by designing for standard materials size and by designing for modern method of construction.

Time allocation on project and stage of project

Availability of time on projects was identified to influence the extent of WM. The project manager on project 4 for example explained this as follows: “due to limited time, the site team may be more centred on building and finishing the work and WM (segregation of waste does get in their way).” This was confirmed by other interviewees. According to the environmental advisor on project 5, "sometimes it is not possible to concentrate so much on WM when time and cost are not in the favour of the site team". This was identified to be responsible for the high levels of wastage at the closing stages of projects. This means the stage of project can also influence WM. From all 9 sites visited, it was evident that most waste (different waste types) is generated at the groundworks (during excavations and earthworks), as well as the fit-out stage where there are many packages being brought to site and there is the pressure to hand over the project.

Management influences on waste management

Management influences on WM were identified to include: the approach by senior level staff towards WM, extent of planning at the initial stage of the project, Construction / works programme, material delivery patterns, use of incentives for site level staff, and supply chain arrangements.

The approach of senior management towards workforce

Evidence from the site visits and interviews suggests that the approach of senior management towards waste influenced WM. Where senior management prioritise WM, this influenced the effort of the site teams. Projects with waste champions or waste managers were identified to have better WM performance. Maintaining a close relationship with the site team was also identified to influence WM as identified on projects A,B,D,F,H and I. The site manager on project H for example suggested that close relationship allows you to understand the site team and why they do certain things. He explained that: "A director, years ago - he said to me 'if you can look after the people, the job will look after itself' and I think there's a lot of truth in that. It's technical and there's detail, but if you keep the people happy, then they'll be happy to work for you. It's about building relationships." Management commitment was identified in the literature to contribute in many ways to make WM work (Manewa et al., 2007). Approaches identified include: the use of incentives, building relationship between site team and supply chain, and WM planning.

The use of incentives - carrots and sticks system

Managers, supervisors, and operatives, all confirmed that the use of incentives improved WM on sites. For this reason, on project 2, the site management team run an incentive system called "don't walk by" which uses a carrots and sticks approach to reward people who perform well with coupons whereas those who perform poorly are punished. The sustainability manager on project A2 explained this "…what we do is we issue prizes and rewards for people based on the Don't Walk By. One of the most successful things is breakfast vouchers, which don't cost us very much, but what you can do is you can say to someone 'well done, you're doing a good job, thanks for doing that' and you can give them a voucher to go and get a free breakfast. And then, the other side of the coin is that we operate something like a driving licence, so if you get nine points on this site, you're excluded, you're not allowed back on site.

Relationship between the Site team and Design team

For design and build projects, the relationship between site teams and design teams was identified as a key factor impacting on WM. As gathered from the interviews, a good relationship or coordination between the design team and the site helps to enable the site teams to make inputs into the process from the practical or buildability point of view where real waste occurs. For some members of the project team, certain design concepts are naturally susceptible to waste generation on site, increasing the burden on site teams. Early involvement of the site teams at the design stage helps the design phase to benefit from the practical experience of site teams.

Proper planning at the initial stages of the Project

Linked to the relationship between design and site team was the amount of planning at the initial stages of the project which is one factor that was evident to affect WM to a very large extent. Among other things, site teams suggest it prevents issues such as rework. As the Senior Site Manager on project 5 suggested, "more can be done outside the site; people's decisions prior to the site team arriving on site have a big

role to play on the success of WM; people like designers." According to the Project Manager on Project H, "if we spend a lot more time planning and getting things done properly from the start, we'd build a lot quicker, we'd built a lot more efficiently and we'd have then reduced the waste." Documents such as WM plans were identified to play a key role in this process. Planning, coordination and communicating between the design team and the building team on site helped impact WM on site.

Relationship between site team and suppliers (Manufacturers)
Supply chain arrangements such as take-back schemes helped reduce waste on site. This works where delivery of materials implements schemes where suppliers could take back some waste from site. Suppliers take-back schemes for pallets for example, was identified as a common practice that influenced on WM.

Personal Factors

Individual characteristics from site team members such as attitudes towards waste, understanding of WM, ability to identify avenues for WM, and level of waste management education also influenced WM approach.

Attitude of site team towards WM
The attitudes of site teams have a major influence on WM at the site level. This operated at two main levels: the attitude of senior (high) level management, and the attitude of operatives (trades). In cases where high senior management have a positive attitude to WM, this reflects on the activities of the site team driving WM. The reverse is the case where management on site do not pay so much attention to WM issues. On Project 7, the Senior Site Manager explained that management leading by example influences the attitudes of site teams towards waste. On project D, almost all interviewees suggested that their attitude towards waste has been influenced by the attitude of the project manager who takes WM very seriously and had in most cases suggested WM strategies or measures that worked positively.

The attitudes of labourers and operatives influenced the level of waste generated or segregated as operatives are in touch with materials and their activities generate the waste. Teo et al (2000) also report that the attitude of operatives has a very big impact on WM.

Ability to identify alternative use potential of materials
Being able to identify alternative uses for materials (waste) on or off the project was also a factor that affected sustainable WM. This was closely linked to the amount of planning on the project. The project manager on project F gave an example of savings made on the project: "ability to identify a chance to reuse material from the temporary roads was able to save the project about 800 tonnes of stone". Ability to predict waste is seen as the first step in waste minimisation (Hobbs et al., 2011).

Level of WM education
As explained by the project manager on Project D, "ability to get the WM message into the minds of site teams affects WM success as it helps them get into a routine". From all the interviewees, education/training of the site team was the main means by which people are made aware of their responsibilities regarding WM. The willingness of site teams (especially operatives) depends on their understanding of the demands and the real benefits of WM. The ability to sell a common interest such as cost savings and how having a tidier site to the site team affects WM." Education, regular toolbox

talks with pictures displayed in the canteens and common places on site were identified to act as aide memoire to site teams.

Motivation of site teams

As gathered from the interviews, majority of site team members (especially operatives) do not see the real benefits of managing waste especially segregation of the waste. For this reason, education and incentives play a key role to make such people see the need for WM. A brick layer on Project 5 suggested that it is easier to throw things away than manage them. In his response to the role of incentives he made this known: "It would be far easier to say to someone 'when you've finished with that, throw it all into that lump, away you go,' and we move on. But there's nobody giving you any prizes at the end of the week for your WM attitude, so if they really want to get it up and going and fight for the environmental thing, there must be a few little tickles, a few prizes at the end of the day." A Site Manager on project F suggested that regardless of the education you give people on site, incentives make things easier. "If I were to be brutally honest, I think no matter how much you choose to train some people, if they can't see pound notes going into their pocket off the back of it, they won't do it. I'm not saying that we should pay people to do it, it's a very short-sighted incentive and sometimes that's the only incentive that seems to work."

The factors (characteristics) influencing sustainable WM are summarised in figure 1

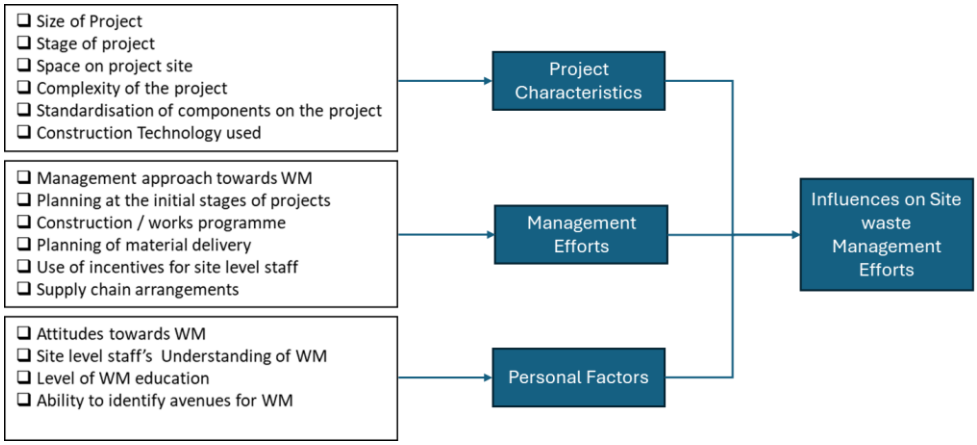

Figure 1 Influences on the Extent of waste management on construction projects.

Implication of research findings

The findings from this research extend the argument on the drivers for WM on construction projects (See Lu and Yuan, 2011; Adjei et al., 2018; Kabirifar et al., 2020) to determine the extent to which several factors influence the extent of WM. It is evident from the results that a one-size fits all approach to WM will not work, even for projects from the same company as the factors influencing the extent of WM goes beyond company policies. The findings imply that beyond the factors reported in the literature as driving WM (the reason for managing waste), the identified characteristics from this research influence the extent of WM. As summarised in figure 1, the characteristics of the project itself, the management on the project, and the site team characteristics will all influence waste generation and management levels. For example, waste source separation is a very good strategy for managing waste on site and commonly reported in the literature (Ajayi et al., 2017). This research suggests that the ability to use this approach to manage waste will be enhanced or hindered by the availability of space on site alongside other mediating factors. Although education is identified from the literature to influence attitudes

towards waste (see Teo et al, 2000; Ajayi et al., 2015; Wang et al., 2015) this research indicates that incentives to motivate site teams has a better influence on the extent of WM, presenting project managers more factors to consider in designing WM strategies.

CONCLUSIONS

Broadly, the result from this research demonstrates strong evidence to suggest that project characteristics, management approach and personal factors influence the extent of waste management on construction sites. These factors are largely interrelated and require careful planning from one project to the other considering the nature of the project and the opportunities or threats it offers to WM, management measures that can be put in place to take advantage of these, and the level of training of the teams. This illustrates the importance of integrating WM strategies from the front end of the project through to the handover stage as decisions made at the front-end of projects have an influence on WM at the execution phase. Thus, whereas project characteristics may not be within the control of construction site teams, the awareness of these factors could help in making inputs during the early stage of construction projects. Design teams should integrate the knowledge of the construction team in the design phase to assist in reducing and managing wastage at the construction phase. For management level factors, this presents opportunities for managers on construction projects to identify ways to influence site teams to sustainably manage waste. For personal level factors, the use of simple incentives and improved education can lead to better WM efforts. The adoption of simple measures can influence the attitudes of site teams who ultimately have the responsibility to manage waste.

This research concludes that, although the industry is not fully efficient regarding WM, there is increasing awareness of the need for sustainable WM. There is the need to pay more attention to the measures that influence the extent of WM on project sites, making the right investments to achieve the needed results.

REFERENCES

Adjei, S.D., Ankrah, N.A., Ndekugri, I. and Searle, D., 2018, September. Sustainable construction and demolition waste management: Comparison of corporate and project level drivers. In Proceedings of the 34th Annual ARCOM Conference ARCOM (pp. 99-108).

Ajayi, S.O. and Oyedele, L.O., 2018. Critical design factors for minimising waste in construction projects: A structural equation modelling approach. Resources, conservation and recycling, 137, pp.302-313.

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A., Owolabi, H.A. and Kadiri, K.O., 2015. Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements. Resources, Conservation and Recycling, 102, pp.101-112.

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A. and Owolabi, H.A., 2017. Critical management practices influencing on-site waste minimization in construction projects. Waste management, 59, pp.330-339.

Guest, G., Namey, E. and Chen, M., 2020. A simple method to assess and report thematic saturation in qualitative research. PloS one, 15(5), p.e0232076.

Gustafsson, J., 2017. Single case studies vs. multiple case studies: A comparative study.

Guy, B., Shell, S. and Esherick, H., 2006. Design for deconstruction and materials reuse. Proceedings of the CIB Task Group, 39(4), pp.189-209.

Kabirifar, K., Mojtahedi, M., Wang, C. and Tam, V.W., 2020. Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: A review. Journal of Cleaner Production, 263, p.121265.

Lachimpadi, S.K., Pereira, J.J., Taha, M.R. and Mokhtar, M., 2012. Construction waste minimisation comparing conventional and precast construction (Mixed System and IBS) methods in high-rise buildings: A Malaysia case study. Resources, Conservation and Recycling, 68, pp.96-103.

Loizou, L., Barati, K., Shen, X. and Li, B., 2021. Quantifying advantages of modular construction: waste generation. Buildings, 11(12), p.622.

Lu, W. and Yuan, H. (2011), A framework for understanding waste management studies in construction, Waste Management, vol. 31, no. 6, pp. 1252-1260.

Lu, W., Lee, W.M., Xue, F. and Xu, J., 2021. Revisiting the effects of prefabrication on construction waste minimization: A quantitative study using bigger data. Resources, conservation and recycling, 170, p.105579.

Manewa, R.M.A.S., Rameezdeen, R., Amaratunga, R.D.G. and Ginige, K.N., 2007, March. Towards the sustainable construction through minimizing site waste in Sri Lanka. In Proceedings of 7th International Postgraduate Conference in the Built and Human Environment.

Noor, K.B.M., 2008. Case study: A strategic research methodology. American journal of applied sciences, 5(11), pp.1602-1604.

Saldana, J. (2012). The coding manual for qualitative researchers (No. 14). Sage.

Shooshtarian, S., Maqsood, T., Caldera, S. and Ryley, T., 2022. Transformation towards a circular economy in the Australian construction and demolition waste management system. Sustainable Production and Consumption, 30, pp.89-106.

Stake, R.E., 2013. Multiple case study analysis. Guilford press.

Tam, V.W., Tam, C.M., Zeng, S.X. and Ng, W.C., 2007. Towards adoption of prefabrication in construction. Building and environment, 42(10), pp.3642-3654.

Teo, M.M., Loosemore, M., Masosszeky, M. and Karim, K., 2000, September. Operatives attitudes towards waste on a construction project. In Annual Conference–ARCOM (Vol. 2, pp. 509-517).

Tingley, D.D. and Davison, B., 2011. Design for deconstruction and material reuse. Proceedings of the institution of civil engineers-energy, 164(4), pp.195-204.

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G., (2015) Improving waste management in construction projects: An Australian study. Resources, Conservation and Recycling, 101, pp.73-83.

Wang, J., Li, Z. and Tam, V.W., 2015. Identifying best design strategies for construction waste minimization. Journal of cleaner production, 92, pp.237-247.

Yin, R.K., 2009. How to do better case studies. The SAGE handbook of applied social research methods, 2(254-282).

Zhang, C., Hu, M., Di Maio, F., Sprecher, B., Yang, X. and Tukker, A., 2022. An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. Science of the Total Environment, 803, p.149892.