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**SUSTAINABILITY IN PROJECT MANAGEMENT: BEST
PRACTICES FOR REDUCING ENVIRONMENTAL
IMPACTS IN MEGA PROJECTS**

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ABSTRACT: Mega projects are contributing to environmental degradation due to their complexity and large scale. Hence, it increases greenhouse gas emissions a lot to the environment. The study critically highlights the integration of sustainability principles in project management methods and focuses on determining the best practices which can reduce the environmental effect on large-scale infrastructure development. The use of a mixed approach helped in combining quantitative and qualitative data together for examining the existing formation for effective strategies like sustainable procurement, modular construction and prefabrication. This study aims to determine the sustainability impact of Balfour Beatty in managing large-scale projects. Modular construction helps in decreasing the energy consumption related to transportation procedures for delivering pre-assembled groups instead of multiple raw resources. Mega projects involve large-scale infrastructure development that causes significant ecological footprints, such as high carbon emissions and excessive resource consumption.

The “*mixed method of data collection procedure*” has been used by the researcher. The data was collected by sharing the questionnaire form that was created in Google form with the selected participants. Participants “who have at least 1 year of experience” in the “construction industry” are selected by the researcher to join and respond to the survey. Therefore “secondary qualitative data” has been collected from multiple sources like academic literatures, research papers, and online articles. A non-randomised sampling method was used by the researcher to collect appropriate data from the participants.

Moreover, the findings of the study highlighted that it is crucial to maintain engagement between all the stakeholders and follow early state sustainability planning processes in order to improve the sustainability measures followed by the construction sector. The research contributes a lot to developing green infrastructure and “provides actionable recommendations” for all the project managers to follow the construction process in a proper way for developing the environmental condition. Moreover, future research can be done by collecting qualitative information from primary sources. Interview sessions with all the workers in the construction sites can help in identifying the practical challenges they face and provide better insights about the research topic. Modular construction reduces the energy required to transport excess materials. Production of pre-fabricated materials in factories helps achieve better control over insulation installation. Balfour Beatty involves rating systems to benchmark their performance. The sustainability initiative of the organisation is comprehensive. It encompasses governance, social, and environmental aspects. Companies need to use green construction practices by following modular construction and prefabrication methods.

KEYWORDS: (Sustainability, sustainable practices, construction, mega projects, prefabrication, modular construction).

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Chapter 1: Introduction

1.1 Background

The study critically explores the adoption of sustainability for managing mega projects that can contribute to environmental degradation. As indicated by Orieno *et al.* (2024), incorporating sustainable practices helps in mitigating the negative impact of project management and promotes long-term viability. In this regard, modular construction and prefabrication are essential for reducing material waste and energy consumption. Both these techniques help to discuss how project management methods can be followed in an environmentally responsible manner. Sustainability helps in the process of social inclusion by encouraging development models that improve the quality of life and community lifestyle (Mirzoev *et al.* 2022). Economically, this supports the effective use of resources and also reduces the operational cost that leads to contributing to the financial sustainability of these projects.

Balfour Beatty is a top international infrastructure group in the UK. The organisation specialised in the construction, financing, development and maintenance of critical infrastructure projects. The organisation mainly operates in the US, UK and Hong Kong for delivering multiple projects.

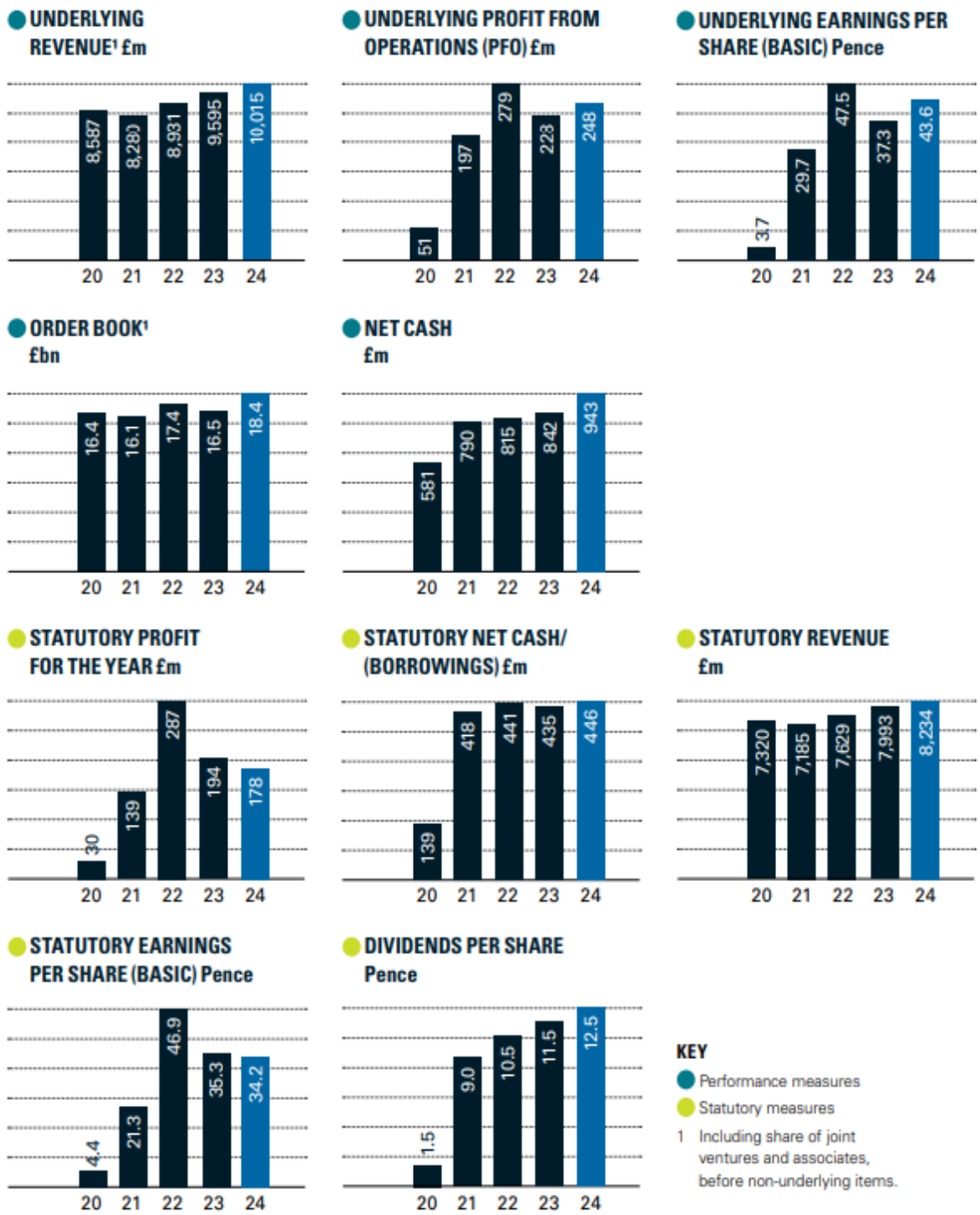


Figure 1.1: Financial Highlights of Balfour Beatty 2024
(Source: Balfour Beatty, 2024)

According to the annual report, the underlying revenue of the organisation has increased from £m9595 in 2023 to £m10015 in 2024. The underlying profit from

operating has increased from £m228 in 2023 to £m248 in 2024 (Balfour Beatty, 2024). This indicates the strong financial condition of the organisation. Moreover, in the year 2005, the organisation was fined £m 10 and Network Rail £2.5m for breaking the safety rule before the crash (Tran, 2005). As a result, 4 people were killed and the organisation paid a lot for legal costs. Furthermore, the Balfour Beatty community was fined \$65 million for defrauding the US military in 2021 (Shaver, 2022). The company was accused of falsifying repairs in military housing and that caused restitution and fines. All these issues highlight the challenges of the company in maintaining ethical standards with sustainability across all its operations. The organisation made notable progress in integrating sustainable practices and this highlights the need for diligence as well as development in corporate responsibility strategies.

1.2 Scope and Objectives

The research focuses on identifying the sustainability principles which can be effectively used for the management of mega projects in order to reduce the environmental impact. Mega projects involve large-scale infrastructure development that causes significant ecological footprints. This includes high carbon emissions and excessive resource consumption. As a result, it has a long-term ecological disruption. The research will highlight the strategies implemented by Balfour Beatty in order to deal with the sustainability challenges. Moreover, the aim objectives and research questions are as follows.

Aim: The aim of this study is to determine the sustainability impact of Balfour Beatty in managing large-scale projects.

Objectives

- To determine the implementation of sustainability initiatives by Balfour Beatty in large-scale mega projects
- To analyse the types of sustainability initiatives implemented in large-scale projects of Balfour Beatty

- To find out the impact of sustainability initiatives on large-scale mega projects in Balfour Beatty

Research questions

1. How does Balfour Beatty implement sustainability in large-scale mega projects and what type of sustainability initiatives is implemented in large-scale projects of Balfour Beatty?
2. What is the impact of sustainability initiatives on large-scale mega projects in Balfour Beatty?

1.3 Limitations

The research includes primary and secondary data in order to understand the sustainability practices for managing the mega projects. However due to the diverse nature of the mega projects hence the case study of Balfour Beatty may not be applicable in different regions. Interviews are not conducted that could present qualitative information and practical experience of the employees working in the organisation. Moreover, the study includes effective data but lack of time and budget are the major limitations in conducting the research in a more effective way.

1.4 Structure of study

“The study is divided into 5 chapters” hence the first chapter has discussed the background information along with the aim and objectives of the research. The second chapter will present the information published in other research papers similar to the topic. The main motive of the third chapter is to discuss the methods and techniques used by the researcher for collecting data while the fourth chapter will present the results along with the discussion section. The last chapter will be the conclusion chapter in which the whole research will be mentioned.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The study revolves around sustainable project management and the impact of Sustainable practices of Prefabrication and modular structure for decreasing energy in the construction sector. This study also analyses the impact of new and advanced technology on improving the outcome of a construction project along with the industry benchmarks in sustainability. Utilisation of different theories associated with sustainability such as triple bottom line theory, stakeholder theory and life cycle assessment helps in understanding the long-term benefits of sustainability.

2.2 The impacts of sustainable practices

2.2.1 The impacts of sustainable practices of prefabrication and modular construction to decrease energy in the construction sector

A significant impact of sustainable practices of prefabrication and modular construction to decrease energy in the construction can be observed which helps in increasing the level of sustainability. It also helps in mitigating the negative impact on the environment. Therefore, the impact of the sustainable practice of prefabrication and modular construction involves:

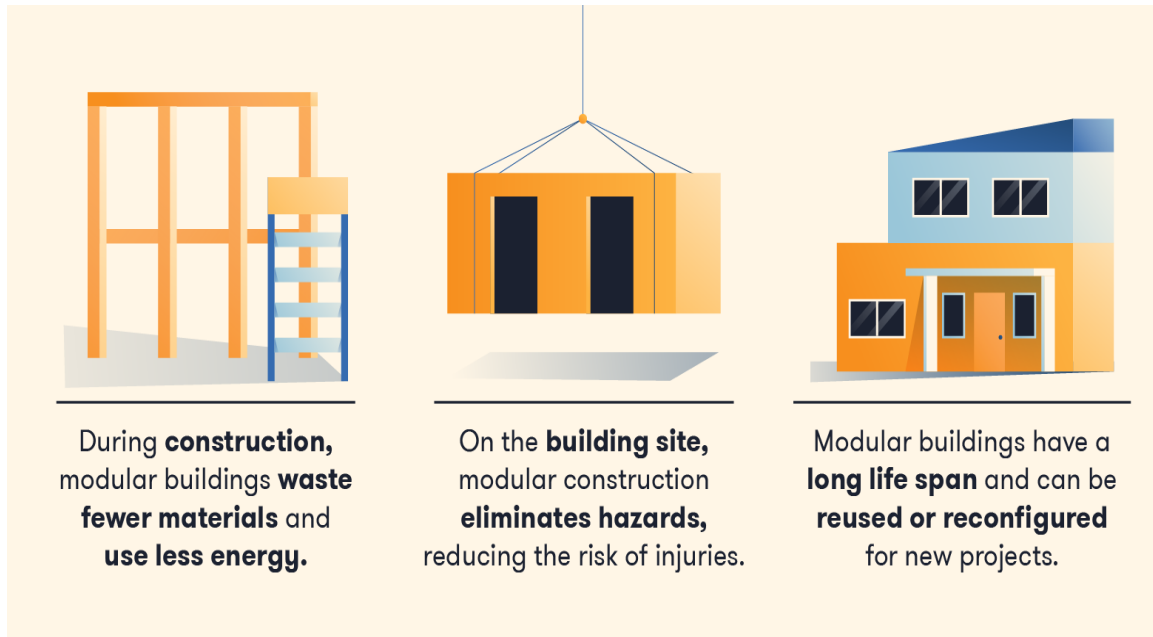


Figure 2.2.1: Modular construction types
(Source: Chaudhary *et al.* 2024)

2.2.2 Increasing efficiency in construction procedures

A significant decrease in the consumption level of energy can be observed as compared to the traditional procedure through prefabrication and modular construction. As the manufacturing procedures of these components occur in a controlled environment, an optimisation in the utilisation of energy and reduction in waste can be observed. The factory setting allows for the utilisation of machines that effectively and efficiently use energy and can be automated. As per the ideas of Chaudhary *et al.* (2024), the offsite construction method contributes to reducing the environmental effects through minimising material waste and develop energy efficiency in all megaprojects. Hence, it did not require on-site modifications which decreased the energy consumption level. The controlled manufacturing procedures help in assuring that the energy is effectively and efficiently utilised which contributes towards low consumption of energy per unit of the construction as compared to the conventional techniques related to building.

2.2.3 Decreasing waste material

An increase in waste material can be observed through traditional procedures of construction due to the inefficiencies in developing shapes and on-site cutting. It is said by Reichenbach & Kromoser (2021) that prefabrication helps in reducing the amount of waste as the resources are measured in a precise manner and optimised before the manufacturing process. On the other hand, as per the ideas of Ghaffar, Burman & Braimah (2020), modular construction helps encourage the utilisation of materials which are sustainable and can be reused. The controlled environment of the manufacturing procedure helps in ensuring that the excess resources are gathered and repurposed, unlike the on-site construction where the waste disposal increases the consumption level of the energy through the procedures associated with landfill and transportation.



Figure 2.2.2: Types of construction waste materials
(Source: Burman & Braimah, 2020)

2.2.4 Decreasing the level of carbon footprints with efficient transportation

Modular construction helps in decreasing the energy consumption related to transportation procedures for delivering pre-assembled groups instead of multiple raw resources. However, the structure of refabrication consolidates different components into fewer shipments which significantly optimises the logistic procedures and decreases the emission of carbon footprints. The centralised process of manufacturing helps in decreasing the requirements of several trips in order to acquire the materials. As a result, the consumption level of fuel decreases which helps in minimising the level of carbon footprints.

2.2.5 Conservation of water and materials

Sustainable procedures associated with prefabrication help in decreasing the consumption level of water in construction. Whereas, the traditional construction processes required excessive water utilisation in order to mix the concrete, clean the construction sites and prepare the materials. On the other hand, as per the ideas of Haller, Beuntner & Thienel (2024), modular construction helps limit the utilisation of water on-site by implementing techniques related to dry construction and pre-mixing of material. Additionally, the controlled setting of the factory helps in recycling the water and efficient utilisation of coatings and adhesives which decreases the overall waste amount. Therefore, prefabrication helps in promoting the conservation of water and material by optimising the management procedures of resources which also decreases the environmental impact and fosters sustainability.

2.2.6 Implementation of Renewable Energy Systems

Utilising prefabrication and modular construction helps in making the implementation procedure of systems associated with renewable energy easier which can decrease the consumption level of the energy. The modular construction is designed in a precise manner which can help in incorporating the solar panels, wind turbines and energy efficiency systems associated with cooling and heating in a seamless manner. In addition, modular construction also involves energy storage systems which helps in improving energy management. Therefore, prefabrication helps in decreasing the dependency on fossil fuels to improve sustainability levels in the construction sector.



Figure 2.2.3: Different Renewable Energy Integration Practices
(Source: Yang *et al.* 2021)

2.3 Sustainable procurement in construction

As per scholars, SPM (“sustainable procurement management”) consists of the ecological results of project purchase (Ershadi *et al.* 2021). In construction, sustainable procurement is a crucial element of diminishing the environmental and social effects of white skill projects. Incorporating sustainability into procurement involves more than choosing distributors or the materials depending only on the expenses; it also consists of considering the ecological, social, and economic elements to make sure that construction projects contribute well to sustainable development. The procurement process in construction consists of choosing materials, contractors, and services, along with managing the SC. When sustainability principles are incorporated into procurement practices, it can remarkably improve the ecological footprint, improve social value, and lead to economic efficiency.

Sustainable Procurement Strategy



Figure 2.3.1: Sustainable procurement strategy
(Source: Ershadi *et al.* 2021)

2.3.1 Incorporating sustainability into procurement

Sustainability can be embedded into procurement procedures with different strategies. The initial step is to define transparent sustainability objectives within the policy of procurement. These objectives can consist of diminishing the CO₂ emission of the materials, sourcing ethically manufactured goods, diminishing waste, or encouraging social equity. Arguably, among the current rules, sustainable procurement can enhance "construction and demolition waste management structure" (Shooshtarian *et al.* 2022). By creating sustainable targets, project groups can analyse procurement decisions not only depending on the expenses, but also considering the sustained ecological and social effects. Another primary approach is the adoption of the LCA ("life-cycle assessment") model. LCA analyses the overall ecological effect of materials and services from sourcing to production to their application and disposal.

By using this in procurement, construction projects can give importance to materials and items that have less ecological effect over the whole life-cycle, even in case they might be costly. Scholar, with their existing research, confirms that the construction sector plays a significant role in the adoption of practices of sustainable procurement towards achieving the SDGs (Ogunsanya *et al.* 2022). This approach assists the overall ecological footprint of the project, supports conservation of resources, and implements more accountable consumption. In contrast, collaborative procurement consists of involving suppliers in the initial planning process, making partnerships that are associated with sustainability goals. This collaboration can result in better creativity in the development of sustainable products, optimised use of materials, and less waste generation throughout the project life cycle.

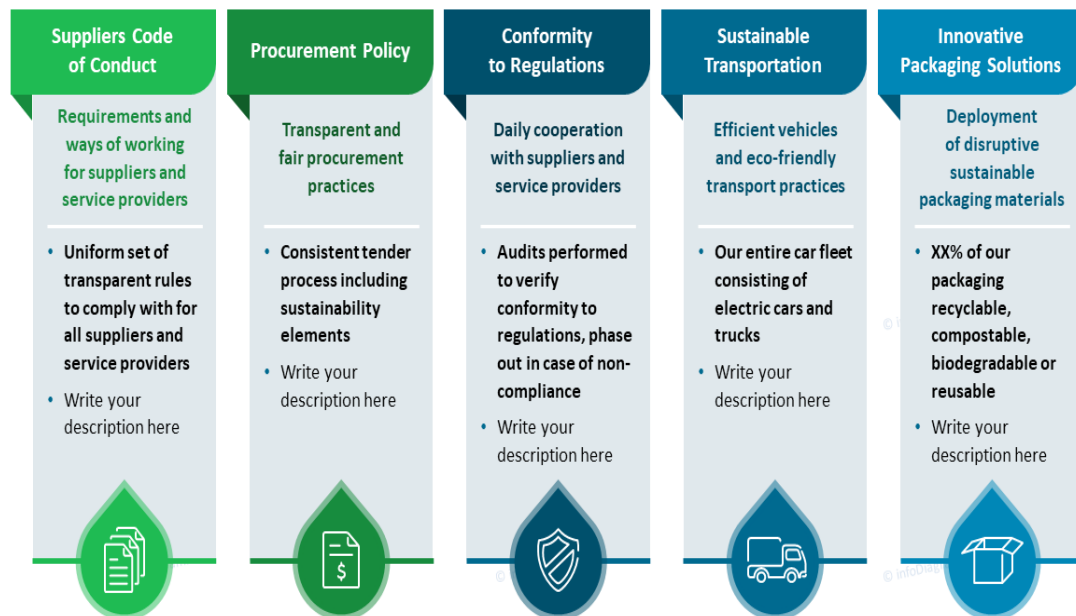
In many situations, sustainable procurement also consists of adopting the standards of green procurement, which may consist of sourcing items with popular ecological certifications, like FSC ("Forest Stewardship Council") for timbers or "Energy Star" for energy-empowered products.

2.3.2 Sustainable material sourcing and services

Sustainable sourcing alludes to the process of getting materials and services from distributors who abide by ethical, ecological, and social standards. In construction, sourcing materials like timber, metals, concrete, and insulation from a sustainable distributor is the primary part of diminishing the ecological impact of the project. Materials need to be chosen, depending on criteria like resource renewal, minimal pollution, and energy efficiency throughout the production. For instance, selecting recycling materials, or the items with a high level of recycled content, diminishes the need for raw resources, reducing the ecological impact linked with extraction and construction. Similarly, applying regionally sourced materials reduces emissions related to transport, thereby diminishing the CO2 footprint of the project.

Sustainable Procurement and Supply Chain Management

With Code of Conduct, Procurement Policy, Conformity to Regulations, Sustainable Logistics and Packaging



Get these slides & icons at www.infoDiagram.com

Figure 2.3.2: Sustainable procurement and SCM
(Source: Ogunsanya *et al.* 2022)

2.4 The impacts of New Technologies on enhancing Construction Project Results

Significant impact of utilising advanced technologies for improving the outcome of construction projects can be observed:

2.4.1 Enhancing the planning of the project with building information modelling

An improvement in project planning by providing a digital representation of the life cycle of a building can be observed through building information modelling. It helps the stakeholders to analyse, visualise and optimise the procedures of construction before implementing it in an actual manner. It is said by Yang *et al.* (2021) that building information modelling helps improve the accuracy of the design, decreasing clashes between various systems and improving the level of collaboration among the stakeholders. In addition, this modelling helps in minimizing reworks and errors which can contribute towards saving time as well as budget in an effective manner. The project managers can also make effective and informed decisions through 3D stimulation. This helps in decreasing the risk associated with construction and an overall improvement in the efficiency and sustainability level of the project can be observed.

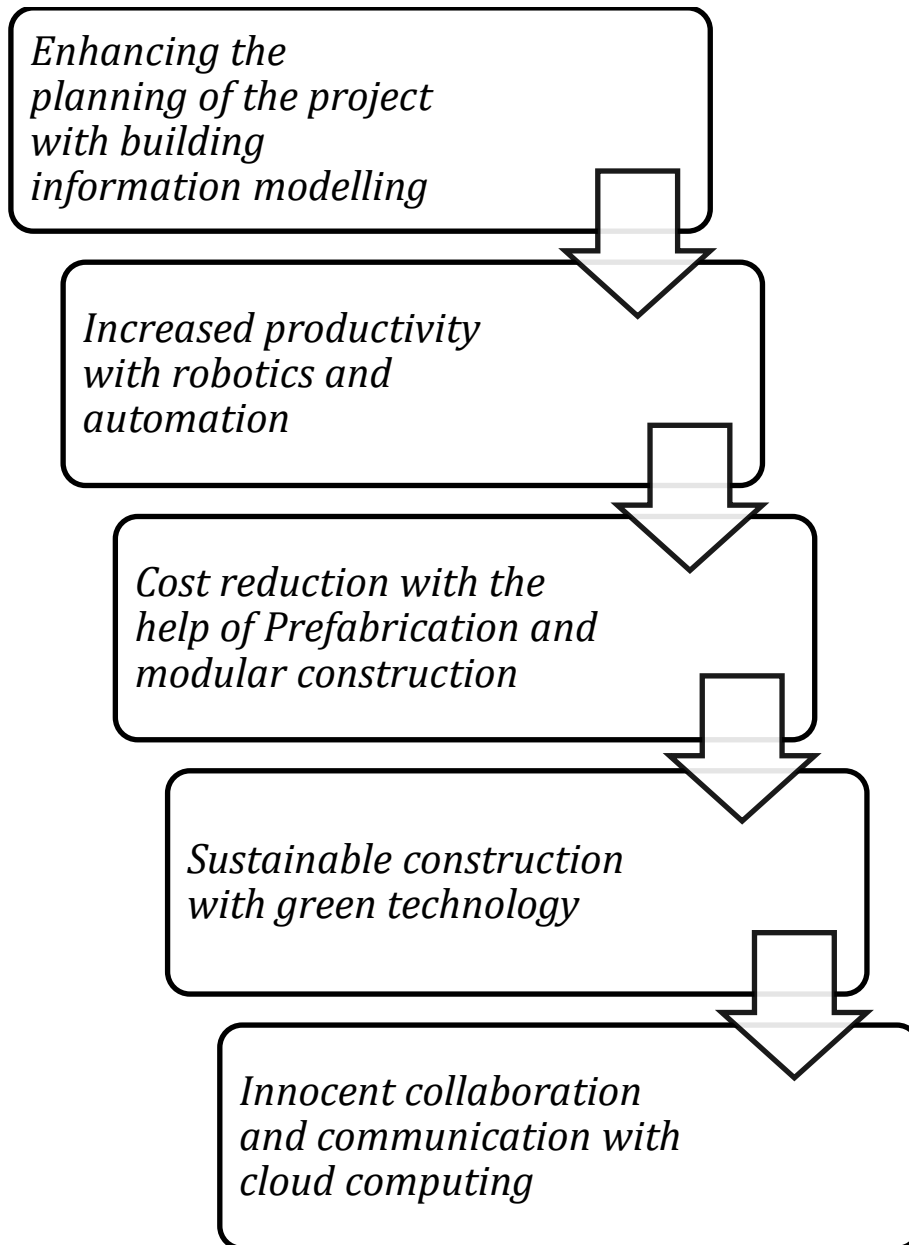


Figure 2.4.1: The impacts of new technologies on enhancing construction project results

2.4.2 Increased productivity with robotics and automation

A significant transformation in the construction sector can be observed through automation and robotics that help in decreasing manual labour and enhancing the efficiency level. Autonomous machines and robotic arms help in bricklaying, concrete pouring and assembling the components associated with prefabrications in a precise manner. It is said by Xiao, Chen & Yin (2022) that automation and robotics help in enhancing the speed of the construction procedure and decrease error. In addition, robotic arms can also work in hazardous situations which help in decreasing the number of injuries in the workplace. Furthermore, the automated machines help ensure uniformity in the quality of the construction and health in completing the project within the specific time period as compared to the traditional methods. Therefore, implementing automation and robotics in the construction project helps in achieving a high level of productivity which helps in completing the project in a specific time period without compromising the quality and safety standards.

2.4.3 Cost reduction with the help of Prefabrication and modular construction

Implementing advanced technology which has prefabrication and modular construction helps in utilising construction procedures which are cost-effective and energy efficient. The prefabricated structures are produced off-site and assembled on-site. This helps in decreasing the amount of waste in a significant manner along with labour costs. On the other hand, utilising computer-aided designs and 3D printing, the modules of prefabrication can be built in a precise manner which helps in assuring both sustainability as well as quality. This method also helps in decreasing the timeline of the project along with the overhead expenses. In contrast, molecular construction helps in decreasing the major disruptions which occur due to weather conditions and helps in maintaining the workflow. Therefore, implementing technology which is driven through

prefabrication can help in optimising the budget of the construction project while improving the management of the resources and achieving sustainability goals.

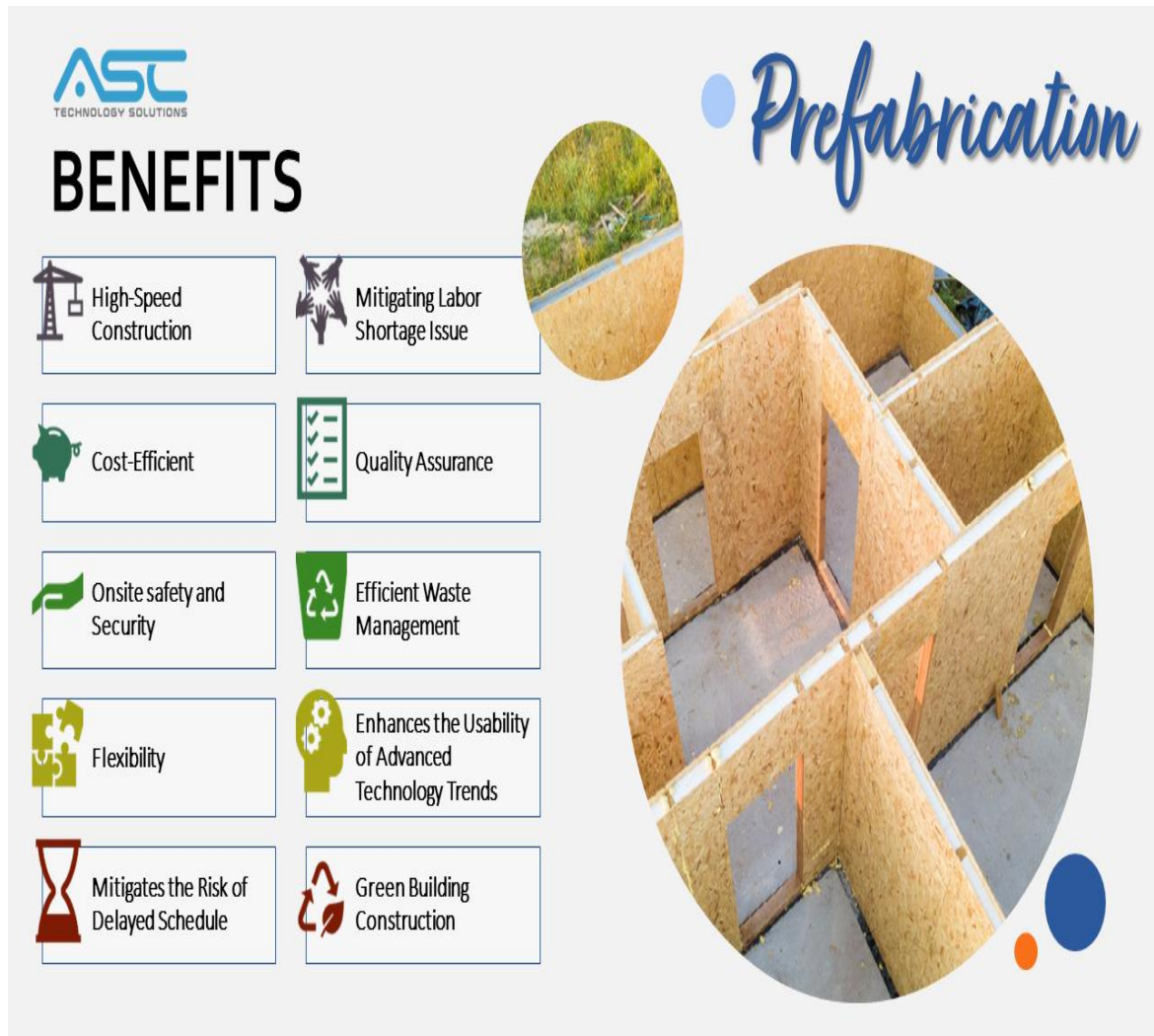


Figure 2.4.2: Benefits of prefabrication
(Source: Palomares *et al.* 2021)

2.4.4 Sustainable construction with green technology

Utilizing new and advanced technology which fosters sustainability by implementing eco-friendly materials and building techniques which are energy efficient. Advanced materials associated with insulation, smart lighting systems and energy-efficient solutions can help in decreasing the level of carbon footprint. Implementing green technology in construction like rainwater harvesting systems and solar panels can help in enhancing the efficiency and durability of the energy. According to the ideas of Palomares *et al.* (2021), drones and artificial intelligence-driven analysis help in identifying the areas which require enhancement for meeting sustainability. As a result, implementing green technology helps in decreasing the negative impact on the environment and decreases the long-term cost of operation while maintaining high performance and eco-friendly construction procedures.



Sustainable Construction: Methods and Benefits

Figure 2.4.3: Sustainable construction
(Source: Palomares *et al.* 2021)

2.4.5 Innocent collaboration and communication with cloud computing

Cloud computing helps improve the level of collaboration and communication with the construction team by offering real-time access to the documents and data related to the project. According to the ideas of Onungwaet *al.* (2021), platforms which are based on cloud computing allow the stakeholders to effectively share the blueprints and track the progress report of the project. It also helps in managing the project tasks in an effective manner. Clouding also helps in assuring seamless coordination between the team members as it provides remote access to the schedules and models associated with construction procedures. In addition, cloud storage helps in improving the security level of the data and mitigating the laws of important information and data. Hence, utilising cloud computing helps enhance the efficiency level of the workflow and reduce communication barriers. It also helps in maintaining the transparency level between the stakeholders which leads to successful completion of the project.

2. 5 Circular economy in construction

The construction sector is one of the biggest customers of raw material and a remarkable waste generator, generating almost 35% of the global landfill waste (Munaro and Tavares, 2023). As the worldwide concentration changes towards sustainability and conservation of resources, the notion of circular economy has achieved prominence as the alternative solution for diminishing investment and reducing ecological effect. Unlike the conventional linear economy that follows a “take, make, dispose” framework, the circular economy concentrates on diminishing, reducing, and recycling materials to make a more sustainable, regenerative way. By using principles of circular economy, construction practices can remarkably diminish waste, preserve resources, and contribute to create a more sustainable environment.

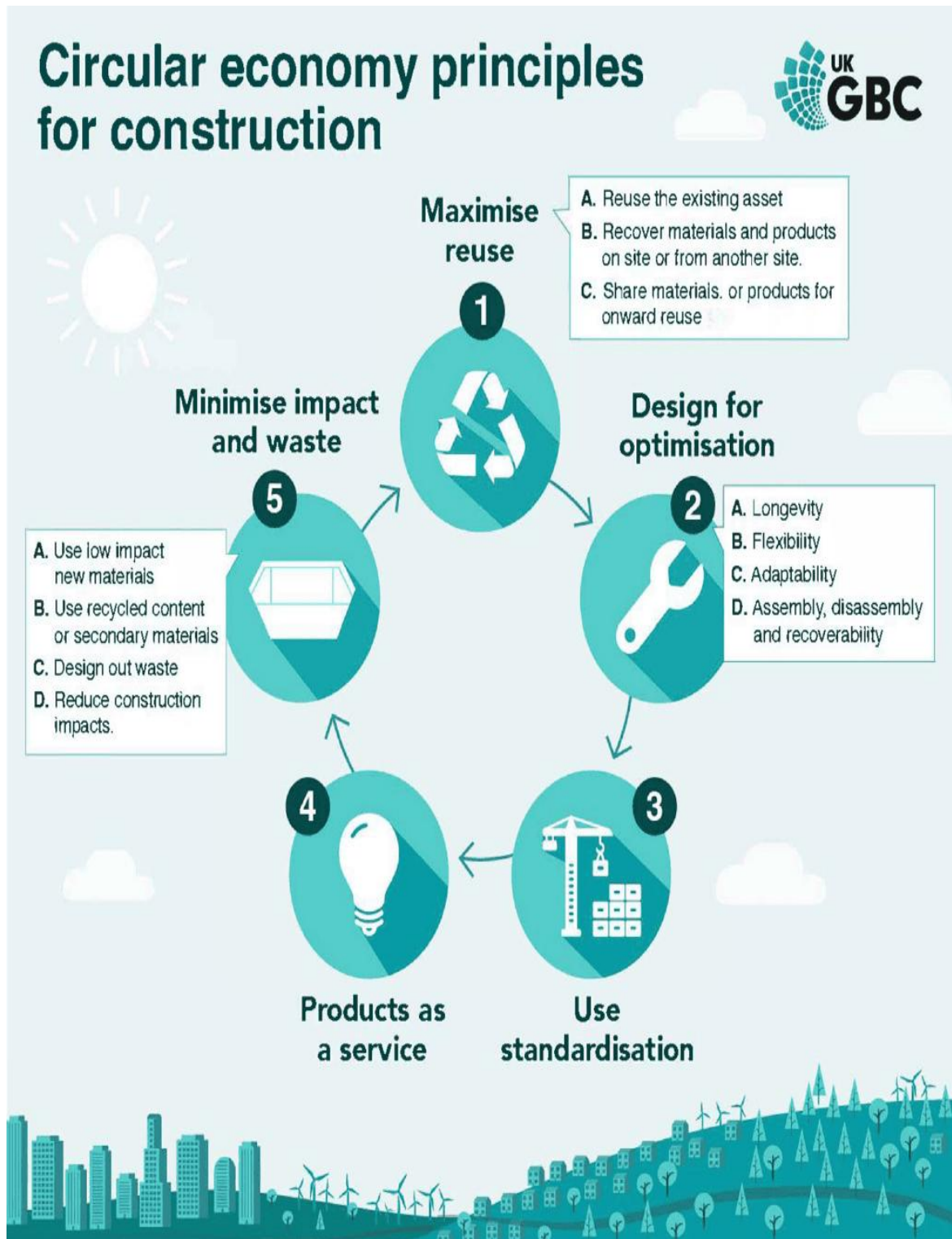


Figure 2.5.1: Circular economy
 (Source: Munaro and Tavares, 2023)

“The principles of circular economy in construction” consist of rethinking the way resources are applied and managed during the project life-cycle. The key goal is to keep the materials and items in “use as long as possible”, and extracting the highest value from them before they die. Circular economy attempts to add value to the raw materials that are traditionally discarded into the lands and make them applicable for the construction industry or other development (Purchase *et al.* 2021). This change can be used at different stages of the construction procedure. The design stage is important for executing principles of circular economy. By using practices of sustainable design, like selecting materials with maximum lifespan, and easy disassembly designing, construction projects can be the requirement for new materials and reduce waste.

Whereas, sourcing materials which are renewable, made from “recycled elements, and recyclable”, is a primary element of construction circular construction. Sustainable materials like recycled steel, “reclaimed wood, and non-toxic finishes” help in the ability of the building to be disassembled, reducing the ecological stress of production and extraction. A key notion of construction’s circular economy is DfD (“designing for disassembly”). It consists of making buildings that can be easily dismantled, or be used after they are done using. Regarding development of cities and urbanisation, to encourage a “circular economy in the construction industry”, building designing, and technology needs to be concentrated on reaching the highest level of diminish, material recycling, reuse, and practical strategies for energy cascade and symbolic resource exchange among various firms (Norouzi *et al.* 2021).

This practice makes sure that the materials and the elements applied in the construction are not wasted afterwards, but can be repurposed for future projects. As the construction sector creates a huge level of waste, with remarkable part coming from demolition processes, by using principles of circular economy, this much waste can be ignored, and redirected from the landfills. In past works of literature, the insufficiency of recovery facilities and infrastructure is taken as the biggest limitation encountered in the process of deconstruction (Charef *et al.* 2021). A few creative construction projects are using closed loop structures in which the materials from renovation are directly recycled and used back into other construction projects. This not only diminishes the overall

levels of waste, but also reduces the need for virgin materials, resulting in more sustainable application of resources.

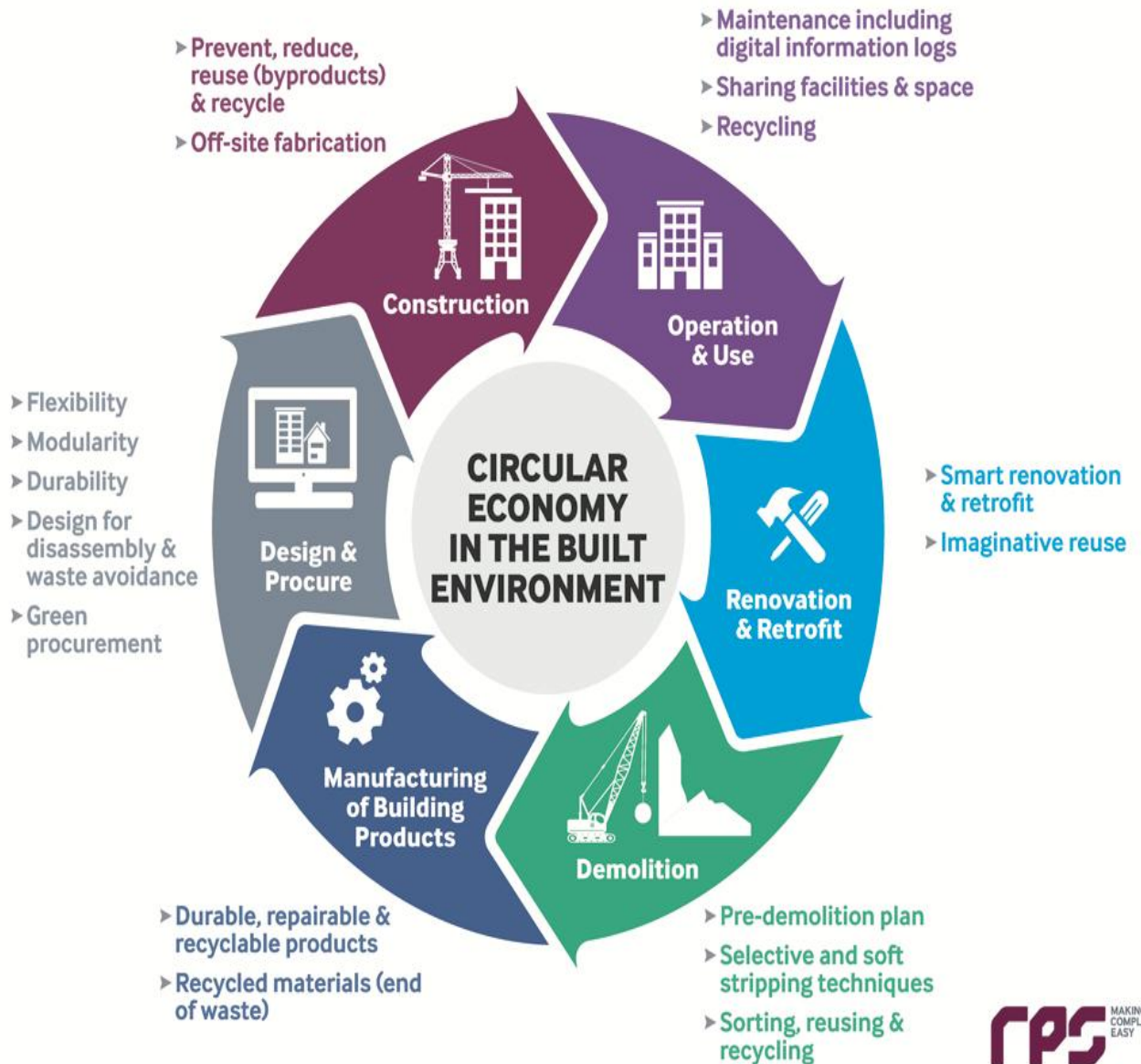
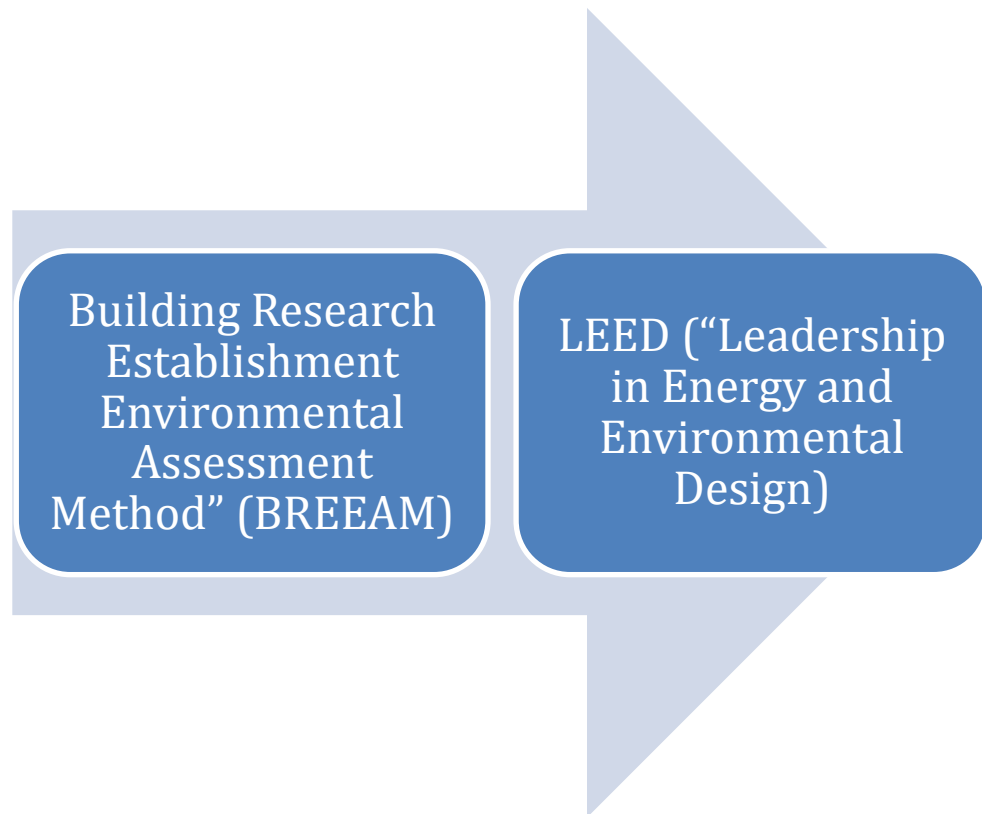


Figure 2.5.2: Build environment with circular economy
(Source: Charef *et al.* 2021)

2.6 Industry benchmarks in sustainability for construction projects

2.6.1 Sustainability in the construction sector

Sustainability within the construction structure is a focal point because of the growing concerns regarding resource depletion, environmental impact as well as climate change. Sustainability in construction projects is essential for adopting eco-friendly practices as well as using the resources effectively. In this regard, Korra (2021) explained the adoption of low-carbon building materials is crucial for achieving sustainable goals in large infrastructure projects. Green building certifications like "Building Research Establishment Environmental Assessment Method" (BREEAM) and LEED ("Leadership in Energy and Environmental Design") are widely identified standards in the construction sector. These are the benchmarks focused on multiple aspects like water conservation, energy efficiency, quality of the indoor environment and material selection. This encourages the use of different kinds of recycling materials and renewable energy sources. These benchmarks provide environmentally friendly methods. On the other hand, Belhadi *et al.* (2022) argued that the cost and the complexity of using these materials are a major concern that is impactful on the performance of construction organisations. The small construction companies find it difficult to afford all the certification processes as well as appropriately implement all these changes in the construction method. Hence, these benchmarks push the construction industry towards sustainability but it is favourable for only the large organisations that have more resources.



**Figure 2.6: Green building certifications
(Source: Inspired by Korra, 2021)**

2.6.2: Material efficiency

Sustainability within the construction sector is also associated with the efficiency of materials and promoting a circular economy. As represented by Ogunmakinde, Egbelakin, & Sher (2022) circular economy is essential for sustainable construction through aligning the strategies of the project with the UN SDG goals. The industrial benchmarks in this area consist of the use of different kinds of sustainable materials like low-carbon concrete, recycled steel as well as sustainably sourced Timber. A lot of projects adopted these principles where all the materials are consistently reused for new construction projects and it reduced the requirement for the virgin resources. Moreover, the material sourcing methods can cause conflicts due to economic factors. All the high-quality sustainable materials are more expensive than the traditional

alternatives. The availability of these high-quality sustainable construction materials is also a major concern for organisations.

Hence, a question is raised whether the advantages of sustainable materials can justify the cost of the projects where a tight budget is allocated. However, conducting a life cycle analysis is essential for utilising appropriate construction materials for the building process. Social responsibilities are also a major concern for the construction forms for creating value for the people in different communities (Wirba, 2024). Social responsibility includes developing the local community lifestyle and promoting the health and safety of the workers. In addition to this, providing affordable housing is also a major target for all organisations. Social responsibility within the construction sector involves the incorporation of all the public spaces that minimise inequality and enhance social well-being. Moreover, the adoption of appropriate sustainability benchmarks is crucial for balancing the financial viability and environmental goals. Sustainability of long-term cost saves in organisations due to the use of energy-efficient designs for the construction process. The government needs to make effective decisions for streamlining the certification process to provide more support to the small firms within the construction sector.

2. 7 Effect of climate change on constructions projects

Arguably, in construction projects, the insufficient knowledge and awareness of the impact of climate change situations affect the surrounding ecology and sustainability (Elhegazy *et al.* 2024). Climate change poses remarkable issues to the construction sector, specifically for broad-scale infrastructure projects. Increasing global temperature, extreme weather situations, and changing climate patterns are re-changing the way construction projects are developed, designed, and implemented. This effect not only impacts the physical structure but also results in new risks, both ecological and financial. In order to keep the resilience of the construction projects, the professionals need to adapt to the changing situations with climate-focused planning, risk assessment strategies, and designs. One of the most remarkable effects of climate change on the

project is the higher frequency and depth of extreme weather situations like floods, droughts, and heat waves.

REDUCING THE EFFECTS OF CLIMATE CHANGE IN THE CONSTRUCTION INDUSTRY

There are a number of measures businesses & companies within the construction industry can take to try reduce the impact on climate change from the construction industry.



REDUCE BUILDINGS CARBON FOOTPRINT: Many companies are implementing steps to reduce their own (& the buildings they construct) carbon footprint to minimise the impact of global warming.



USING GREEN BUILDING MATERIALS: Builders are now using "green building" materials in place of traditional construction materials which produce a lot of carbon and other greenhouse gases in their production.



CREATING URBAN GREEN SPACE: Companies are leading the way in Australia to create urban greenery or living infrastructure throughout cities.



FUTURE PROOFING BUILDINGS & INFRASTRUCTURES: We need to ensure that the projects we create have plans for future conditions.

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Figure 2.7.1: Climate change in constructions
(Source: Elhegazy *et al.* 2024)

These situations can result in delays, hinder the construction site, and even pose safety risks to the employees. Climate change and weather are mostly ranked as one of the most prevailing and detrimental causes for scheduled delays (Oruc *et al.* 2024). In order to reduce the risks, construction projects need to inculcate climate resilience into their planning, design and construction. For instance, infrastructure project in highly flooded areas needs to incorporate a flood-resistant approach, like heightened foundations or flood limitations, to secure against increasing sea levels and extreme rainfall., Buildings in locations that are subject to heat waves need to be designed to dim, manage the heat gain with materials that give better cooling results and isolation. Climate change also leads to the requirement for more sustainable energy-focused designs. Buildings and the infrastructure need not only witness the impact of climate change, but also determine their contribution.

This needs adapting technologies of green building and sustainable practices like using low carbon draw materials, renewable energies, and energy focused systems for cooling, lightning, heating. Integrating passive design approaches diminishes the energy consumption of the building, and its dependence on external sources of energy, contributing to both mitigation and adaptation of climate. Furthermore, in response to the increasing risk of climate change, governments globally are executing strict regulations and policies referring to building codes and construction. Various countries have recognised efforts to reduce climate change as executing commitments to diminish emissions or applying advanced technologies to restrict GHG emission (Yang *et al.* 2023). These regulations mostly need construction projects to fulfil the energy, efficiency, benchmark, water, conservation, and raw material sustainability.

2.8 Environmental Challenges in Mega Projects

2.8.1 Large-scale infrastructure development

Mega projects like large-scale infrastructure development or urban expansion have environmental implications. All these projects can exist for multiple years and can consume a lot of resources. Moreover, it can impact the ecosystem and may cause some environmental issues. For example, mega projects need extensive types of raw materials like Steel concrete and water. The transportation as well as extraction of all these materials can cause environmental degradation. Along with that, Centobelli *et al.* (2023) stated that circular and sustainable construction entails waste reduction and emission by reusing and recycling all the materials for future generations. Large-scale construction requires sustainable waste generation that includes demolition debris and hazardous materials. Furthermore, the operations of the mega projects can cause greenhouse gas emissions because of the transportation of heavy machinery as well as energy consumption.

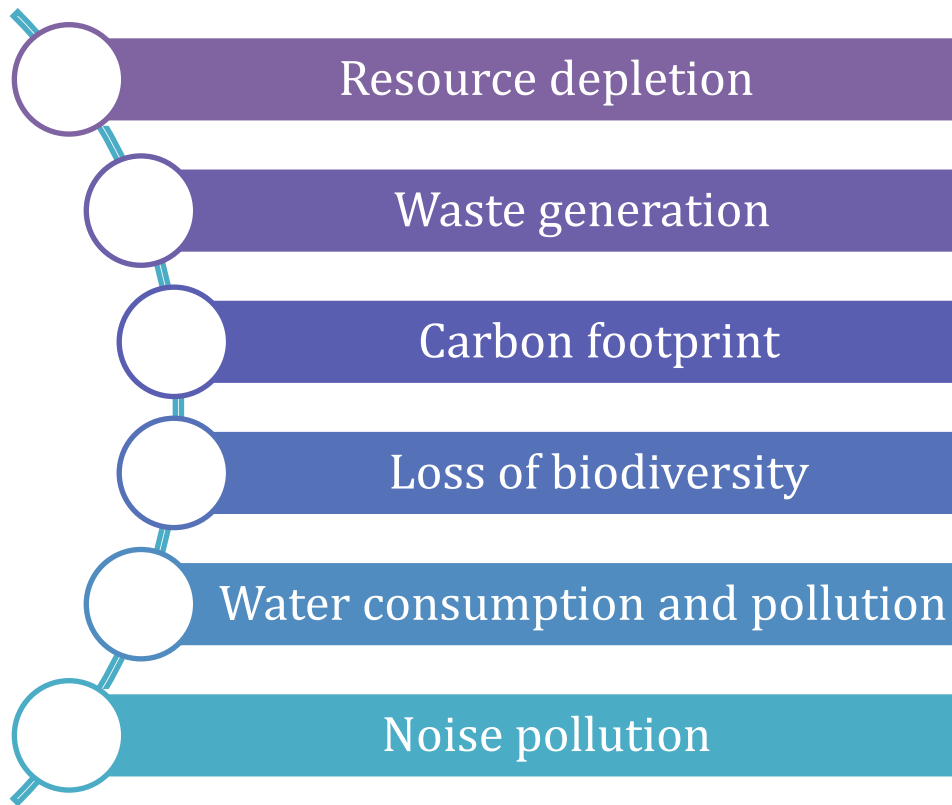


Figure 2.8: Environmental challenges due to construction

2.8.2 Greenhouse gas emission from construction project

As a result, an increase in carbon emission of greenhouse emissions can be observed that can contribute to air pollution and global warming. Conversely, Xiaolong *et al.* (2021) stated that economic boost, environmental protection and international relations are associated with the success of mega projects. Hence, public health and the environment can be negatively affected due to the mega projects' construction process. The large process needs appropriate land clearance and habitat destruction or deforestation. The displacement of wildlife and the destruction of wetlands are the common consequences that can be observed in the construction process. In some cases, soil erosion can also be observed if the environmental planning is poor in mega projects.

The mega projects need a specific amount of water to follow the operational process and construction. Hence, efficient use of water can cause resource depletion and the contaminated water bodies can impact public health in a negative manner. Noise pollution is also observed as a major challenge of the mega projects. As discussed by Hemmat, Hesam & Atifnigar, (2023) excessive noise from heavy machinery can be observed that can disrupt the wildlife and local communities. The noise of transportation and drilling can cause disturbance for the people living near the construction region. Moreover, megaprojects are exposed to different climate change challenges like extreme weather events, rise of sea levels and temperature fluctuation. In case the project is designed in a poor manner then long-term sustainability issues can be observed. Hence for mitigating all these environmental issues the project managers need to adopt ecofriendly and sustainable strategies for efficiently managing the waste and protecting the environmental condition.

2.9 Green Project Execution Tactics

2.9.1 Energy efficiency

The Green Project execution process involves the application of environmentally responsible as well as resource-efficient tactics for the whole life cycle of the project. The major strategy that can be applied by the project managers is the use of recycling and eco-friendly materials. Locally sourced materials are crucial for minimising environmental impact and carbon emissions. In this case, bamboo, recycled steel and fly ash concrete can be used for the construction process. Appropriately implementing an energy-efficient design like smart grids, passive cooling as well as renewable energy sources can reduce the carbon footprint caused by the mega projects. Ogunmakinde, Egbelakin & Sher (2022) mentioned that the circular economy must be contextualised for following the UN's SDGs in managing waste generated in the construction industry. Furthermore, a circular economy approach can be used by organisations to use construction waste. The waste management system is also important to be

implemented safely. The promotion of material recycling programs is essential for minimising resource depletion and landfills.

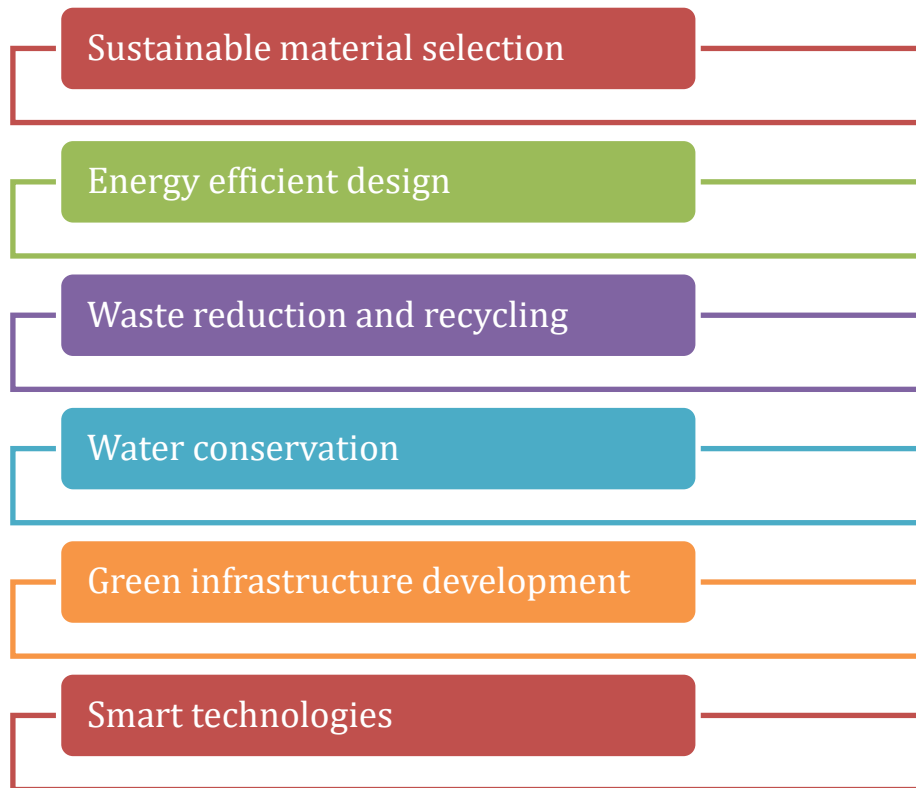


Figure 2.9: Green Project Execution Tactics

A rainwater harvesting system and water-efficient plumbing method are essential for minimising waste consumption in mega projects. The use of Smart technologies is also beneficial for identifying the energy requirement and monitoring the resources used. IoT and AI-driven technology are beneficial for efficiently using resources, boosting operational efficiency and reducing waste (Rane, 2023). The organisations need to make appropriate initiatives for incorporating vertical gardens and green roofs for helping to develop the air quality and restore the last biodiversity in the mega project area. Sustainable transportation processes are crucial in order to improve the environmental condition. Certifications like BREEAM and LEED are crucial for maintaining the successful and sustainable execution of the project. Integrated all these green execution methods are beneficial for achieving long-term sustainability and also maintain profitability and

efficiency. Following all these Green Project execution methods can help to improve the environmental condition and provide long-term benefits to the organisations.

2.10 Stakeholder Engagement and Corporate Social Responsibility (CSR) for mega projects

Stakeholder engagement as well as CSR is crucial for ensuring that the construction projects are ethical, sustainable and advantageous for the community. Hence appropriate collaboration between all the stakeholders associated with the project is essential for improving social and environmental outcomes. The stakeholders like the local communities Government and investors can influence the project's sustainability. Appropriate governance frameworks in mega projects can balance legitimacy, efficiency and accountability which is crucial for achieving sustainability (Brunet, 2021).



**Figure 2.10: Benefits of stakeholder engagement and CSR in building projects
(Source: Inspired by Brunet, 2021)**

Engaging all the stakeholders and local communities through appropriate awareness programs and consultations is essential for building trust and minimising opposition. Encouraging collaborative decision-making is essential for increasing the concerns of the

stakeholders about social and environmental issues. However, Ansu-Mensah *et al.* (2021) said that stakeholder involvement in CSR is crucial for implementing CSR programs that are relevant. The organisations associated with the mega project need to adopt appropriate CSR initiatives like educational sponsorships and afforestation programs to get positive results. Investing in a sustainable project can provide benefits to the community members and the organisations. All organisations need to follow an appropriate reporting process to ensure accountability in the project and also develop the project's sustainability.

2.11 Theoretical underpinning

2.11.1 Triple bottom line theory

A sustainability framework which helps in evaluating the performance level of a business beyond its financial success is known as the triple bottom line theory. Three different dimensions can be observed in triple bottom line theory which involves people, the planet and profit. According to the ideas of Heim, Vigneau & Kalyuzhnova (2023), the triple bottom line theory helps in emphasising maintaining a proper balance between economic growth with environmental responsibility as well as social well-being. Therefore, adopting this approach helps organisations maintain long-term sustainability by implementing ethical practices, decreasing environmental impact and contributing towards a positive society. Triple bottom line theory helps in encouraging an organisation to measure its success by considering both a sustainable future as well a profit margin. This theory alliance with sustainability and project management as it assures that the projects are developed responsibly.

The planet component of the triple bottom line theory helps in encouraging the utilisation of eco-friendly resources which helps in decreasing carbon footprint emissions and optimised utilisation of materials. On the other hand, the people's dimension pays more attention to the safety of the workers along with fair labour practices and community benefits. In contrast, the profit dimension of triple bottom line

theory helps in assuring feasibility in financial status without compromising the environmental and ethical standards. Therefore, implementing the principles associated with triple bottom line theory will help the construction projects to manage their resources efficiently which can help in achieving sustainability as well as the expectations of the stakeholders. This will also decrease the disc associated with rules and regulations through clear compliance with laws associated with labour rights and environmental considerations. As a result, following the principles of triple bottom line theory will help in attracting investors, giving more priority to sustainability and improving cost saving with the help of Sustainable resource management.

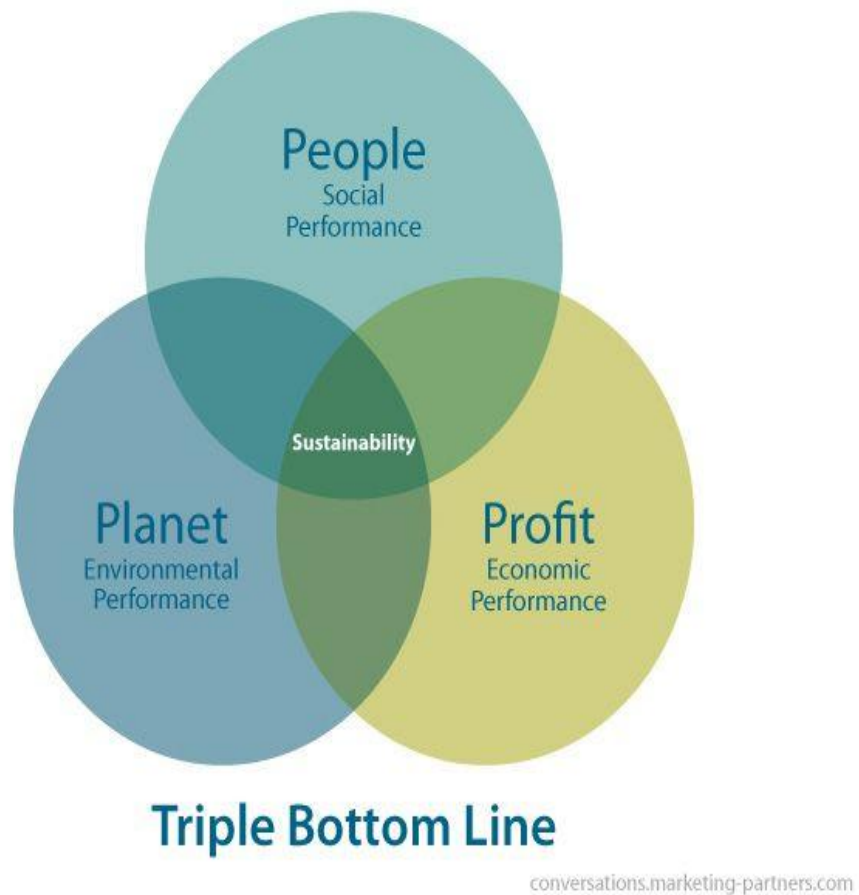


Figure 2.11.1: Triple Bottom Line Theory
(Source: Inchange, 2022)

2.11.2 Stakeholder theory

The stakeholder theory suggests that a business should consider the interest of every stakeholder during the decision (Barney & Harrison, 2020). Stakeholders involve customers, employees, suppliers, communities and regulators. This theory strongly emphasizes the ethical responsibilities as well as business practices associated with sustainability. It is crucial to balance the requirements of the stakeholders for a firm which promotes long-term sustainability, trust and social responsibility.

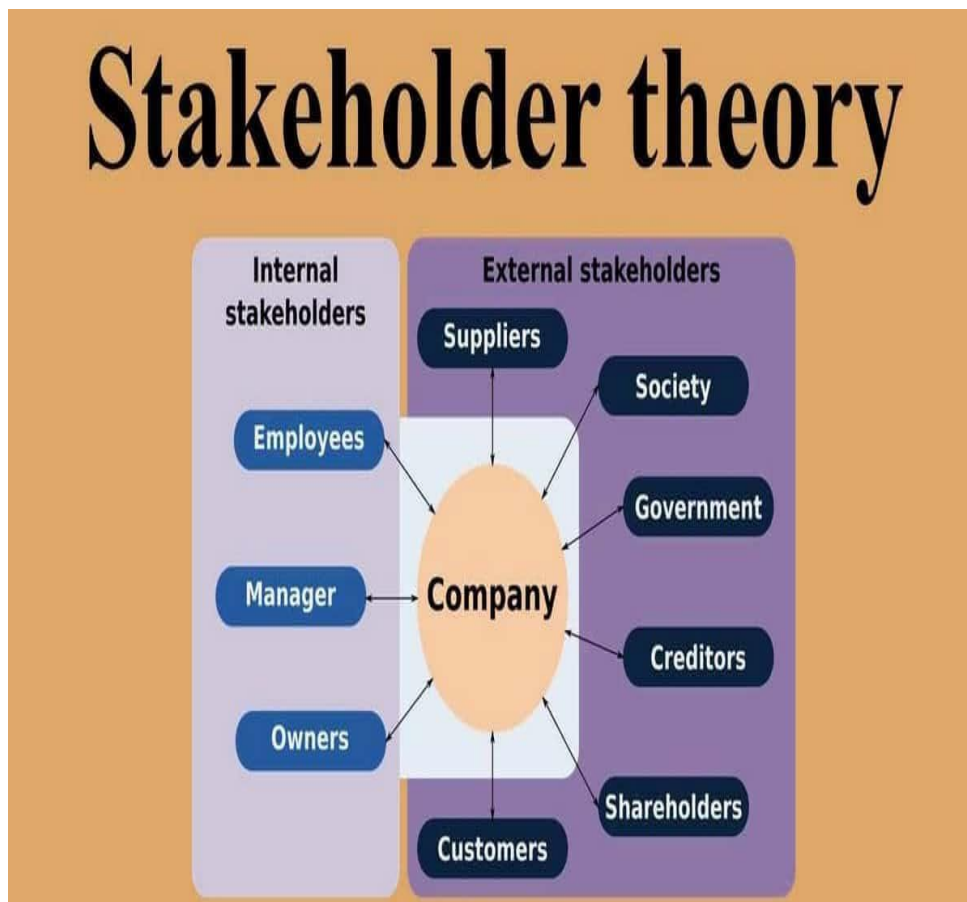


Figure 2.11.2: Stakeholder theory (Adapted by Barney & Harrison, 2020)

In sustainable project management, it is essential to effectively engage the stakeholders in order to balance social, economic and environmental goals. Therefore, implementing the stakeholders' theory helps ensure that the environmental impacts are effectively addressed by the project manager along with the safety of the workers and the community's well-being. Improving the efficiency level in the collaboration and communication level with the stakeholders helps in aligning the goals of the project with sustainable objectives that contribute towards informed decision-making.

2.11.3 Life cycle assessment theory

The life cycle assessment theory is an effective framework related to sustainability which is used for evaluating the environmental impact of a project throughout the entire life cycle. Life cycle assessment theory helps in identifying the areas which require improvement for decreasing the consumption level of resources and mitigating the emission of environmental footprint. Life cycle assessment theory helps in making informed decision making and gives more priority to sustainability and efficiency. Hence, utilising this theory will help in adapting solutions which are eco-friendly along with sustainable materials.

It will help in implementing effective strategies which align with the principles of the theory for assuring long-term environmental sustainability. It will help a construction project to identify and decrease their carbon footprint emission as well as the amount of waste. Moreover, a decrease in long-term costs associated with operations with the help of energy-efficient designs can also be observed. As a result, utilising this theory in a construction project helps in improving efficiency, sustainability and environmental responsibility for effectively utilising the energy and completing the project within time.

Hypothesis development

H1 (Alternative Hypothesis): Maintaining sustainability positively impacts Balfour Beatty in managing large-scale projects.

H0 (Null Hypothesis): Sustainability maintenance is having no impact on Balfour Beatty in managing large-scale projects.

2.12 Conceptual Framework

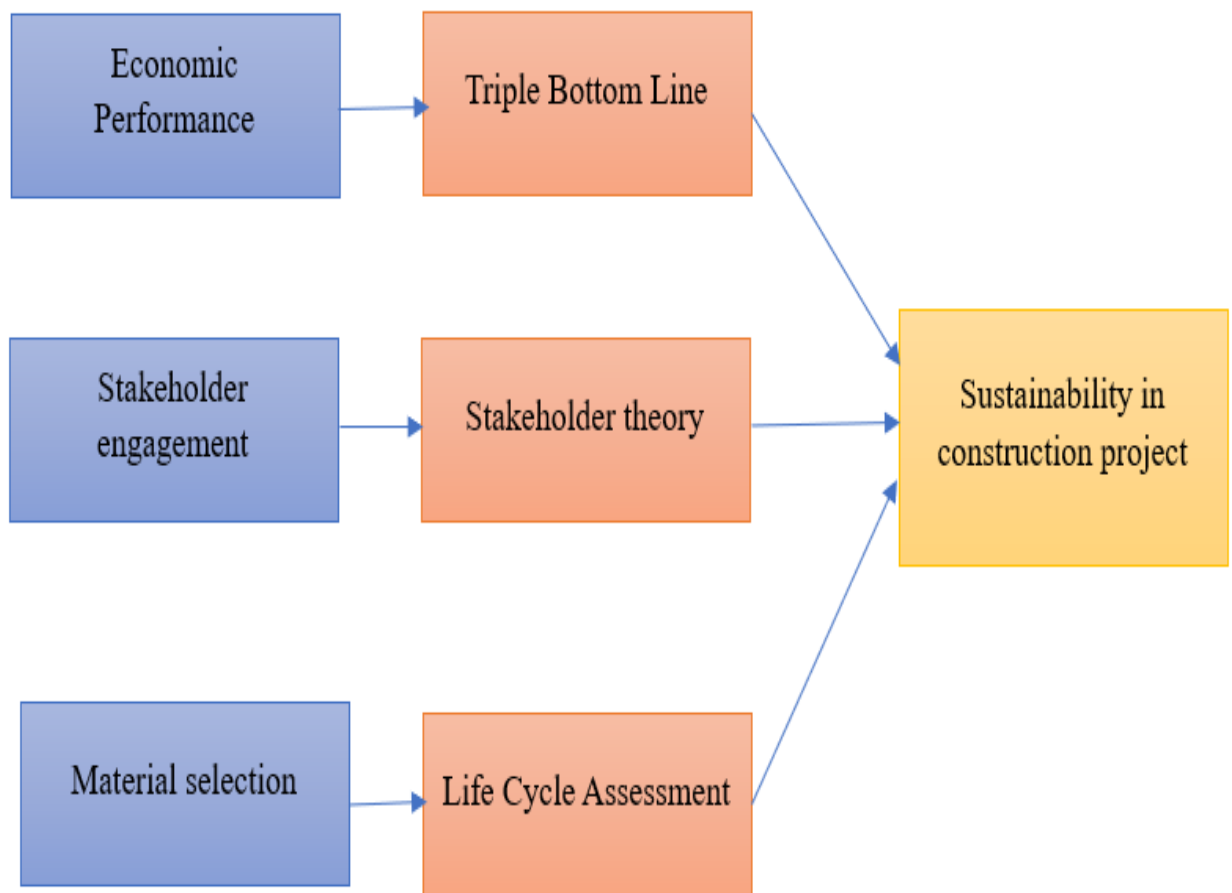


Figure 2.12: Conceptual framework

2.13 Literature gap

In spite of the comprehensive research on the triple bottom line theory, stakeholder theory and life cycle assessment in sustainable project management, significant gaps can be observed in the practical implementation. Many studies pay attention to theoretical benefits however they lack real-world case studies for analysing their effectiveness. In addition, conducting the research by implementing life cycle assessment with digital tools like artificial intelligence is limited. This study discusses molecular construction and prefabrication however a significant gap in a comprehensive analysis of their long-term sustainability impact can be observed.

2.14 Summary

Significant impact of prefabrication and molecular construction can be observed which involves increasing the efficiency level in construction procedure, decreasing the waste materials along with the level of carbon footprint. Utilising advanced technology also has a significant impact which helps in increasing the productivity level and improving the planning of the project. However, sustainability in the construction structure is crucial as an increase in the concerns regarding the environmental impact and climate change can be observed. Hence, sustainable project management depends on stakeholder theory, triple bottom line theory and life cycle assessment in order to maintain a proper balance between economic, social and environmental aspects.

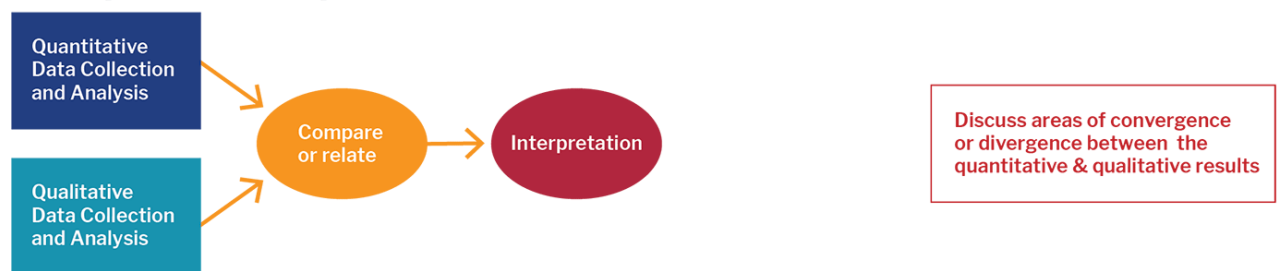
CHAPTER 3: RESEARCH METHOD

3.1 Mixed method

The “*mixed method of data collection procedure*” has been followed by the researcher for analysing the sustainable practices to manage the mega project. In this regard both quantitative and qualitative has been collected by the researcher from primary and secondary sources. “Primary quantitative data” has been collected by using Google form while “secondary qualitative data” has been collected from previously published academic literature, government publications and industry reports.

BASIC MIXED METHODS RESEARCH DESIGNS

Convergent Parallel Design



Explanatory Sequential Design



Exploratory Sequential Design



Figure 3.1: Mixed research method
(Source: Alharahsheh & Pius, 2020)

Methodology chapter of the research outlines the systematic techniques used in order to achieve the goal of the study. It clearly defines the data collection method, data analysis technique and the design of the research for ensuring validity and reliability. The chapter also highlights the reasons for selecting the research methods as per the objective of the study. Providing a structured framework is crucial for ensuring that the study is credible and replicable and allows meaningful analysis of the results. Hence a foundation for addressing the questions of the research in a systematic and effective way can be served by discussing all the crucial approaches followed by the researcher in this chapter. The following section in this chapter will represent the design of the study that will include the justification for selecting an appropriate philosophy, approach and design to complete the research paper. Apart from that, the data collection procedure to conduct the survey will be explained in detail in this chapter.

3.2 Research procedure

3.2.1 Research philosophy

Positivism refers to an appropriate philosophical choice that helps to complete a mixed method where primary quantitative and secondary qualitative data are collected. The positivism philosophy focuses on empirical evidence and objective reality. Therefore it helps in completing the research by allowing triangulation in the study. A paradigm refers to the inclusion of multiple components which can be divided into methods, epistemology, ontology and methodology (Alharahsheh & Pius, 2020). The study was completed by conforming the findings of multiple sources and it helped the researcher to make conclusions more objective and comprehensive. In this research, the positivism philosophy is beneficial for collecting numerical data and ensuring reliability as well as generalisability.

3.2.2 Research approach

The *deductive approach* refers to a top-down reasoning method that helps the researcher to test the hypothesis by the use of empirical data. As per Proudfoot (2023), Inductive/ Deductive is a thematic analysis which provides significant opportunities for the researcher. In this research, the study is conducted to check the usefulness of modern technology and sustainable methods for the construction project and reduce the environmental impact. Positivism philosophy is associated with the structured methodology and hence the deductive approach followed by the researcher. The primary quantitative analysis was the hypothesis testing method and the secondary qualitative analysis helped to support the findings in a systematic manner. In this regard deductive reasoning allowed the researcher to complete the study in a structured way. It provided a theory-based and systematic meaning to the research paper and ensured credible as well as rigorous research findings.

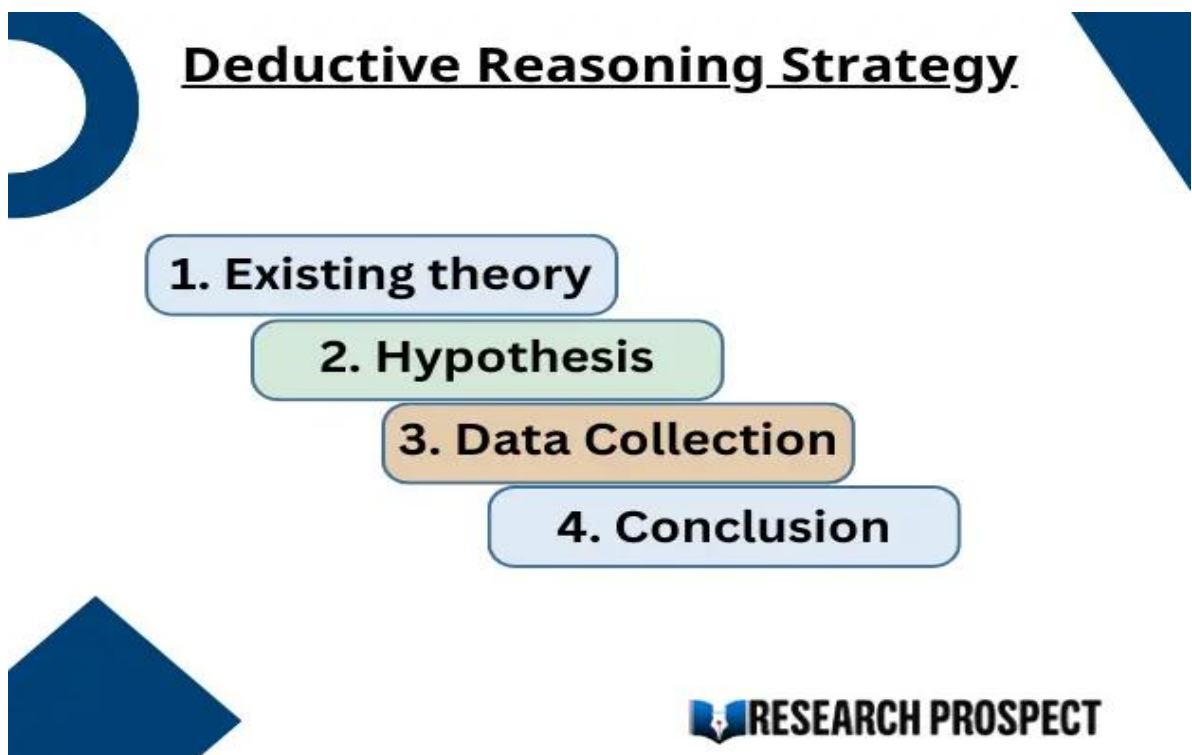


Figure 3.2.1: Deductive reasoning
(Source: Proudfoot, 2023)

3.2.2 Research design

Descriptive Research design refers to a systematic method that can be done by focusing on the qualities of a certain group, individual or situation (Ghanad, 2023). In this study, the descriptive design focuses on when, how and what rather than establishing a specific cause-and-effect relationship. Hence, the main aim of this design is to present accurate information about the real-world data. As the research is based on sustainable project management methods for reducing the environmental impact of mega projects, the cause of the sustainability issues found by construction organisations will be highlighted in this paper. Additionally, the Research design is also suitable for quantitative measurements and allows the researcher to follow a structured process for the data collection and analysis method. Descriptive design is beneficial for providing information about the patterns of the trends without any kind of subjective information. The mixed method followed in this study is beneficial for ensuring meaningful insights regarding the research topic. However, validity and reliability can be maintained by ensuring that the findings of the research can be applied to the border context. As the study aims to determine the main method for maintaining sustainability therefore the patterns and friends of the presented data will be useful to interpret the results of the study.

3.2.3 Selecting survey participants

In order to conduct the survey a close-ended questionnaire has been created in Google Form. The questionnaire form includes 12th questions and the link of the form was distributed among 51 numbers of participants. The questionnaire was prepared to complete the study in a cost-effective way and in a short time. Section A of the questionnaire included demographic questions about the job rules of the participants and the experience of the participants in managing large-scale projects.

All the participants who have at least 1 year of experience in the construction industry are selected by the researcher to join and respond to the survey. A non-

randomised sampling method was followed by the researcher to collect appropriate data from the participants.

Section B of the questionnaire form included questions about the modular construction process and section C discussed the impact of new technology for a better construction process. This section also explains sustainable materials for reducing the environmental impact. Section D of the form discusses the sustainability standards, measures and limitations of the industry for maintenance sustainability. Section E of the survey discusses the issues as well as recommendations for successfully implementing the construction process in a sustainable way. Hence objectives one and two of the research are considered by adding sections A to D of the survey. The last section will represent the third objective of the study. The participants will be contacted through social media applications like Twitter, Facebook and Instagram. The links to the survey are shared by them in their private chats and they are requested to join the survey and provide their valuable insights regarding the research topic.

3.2.4 Data collection

The data was collected by sharing the questionnaire form that was created in Google form with the selected participants. In addition to this, it has been informed to the participants that the survey will require 5 to 10 minutes to be completed. The quantitative data that has been collected in this research is beneficial to get effective and clear knowledge about the research issue. Hence the perspectives of the customers are crucial to meet the result of the study.

Method of data collection

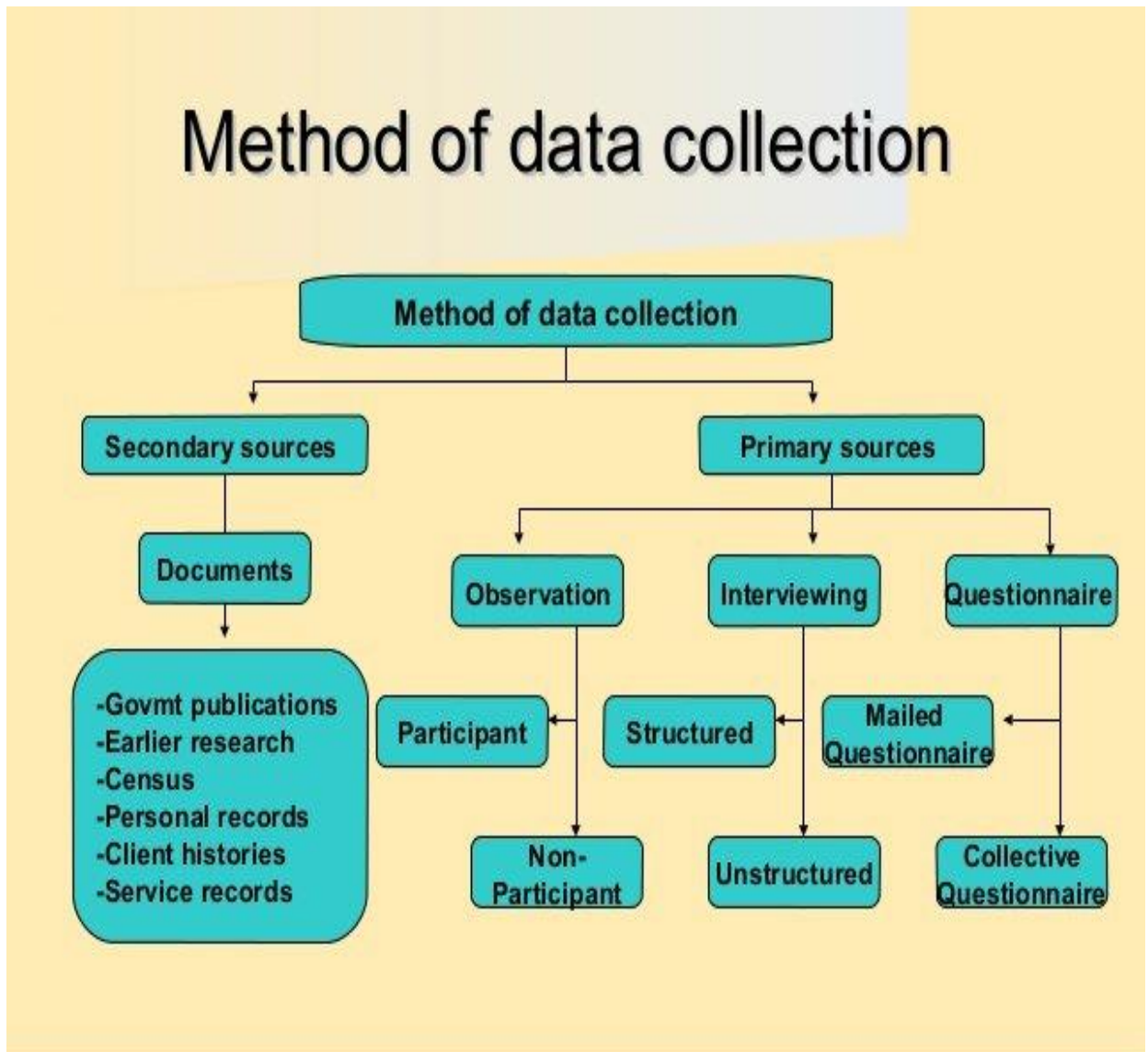


Figure 3.2.2: Data collection methods
(Source: Ghanad, 2023)

The secondary data is useful to complete the inside about the benchmarking as well as practices that are crucial for analysing the themes faster. Therefore secondary qualitative data has been collected from multiple sources like academic literature,

research papers, and online articles. The data published in the last 5 years has been collected by the researcher to provide recent and valuable information about the research topic. Google Scholar is used as a search engine for accessing the database of multiple journals. There are a lot of filters that can be applied in Google Scholar to include appropriate data required for meeting the results of the study. For example, articles published from 2021 to 2025 are included in the study. Additionally, other data inclusion criteria were articles published in the English language, availability of the full-text pdf and specific information about the research topic. The keyword search method has been applied by the researcher to include secondary qualitative data in this research.

The keywords are

- Sustainability in Project Management
- Mega Projects
- Environmental Impact
- Prefabrication and Modular Construction
- High-Tech Technologies

All these keywords are beneficial for this study as they help to focus on the core idea of the research which is sustainability in project management, especially in mega projects.

In order to collect secondary data the researcher used authentic and valid sources. Proper citation, as well as acknowledgement method, was followed by the researcher to avoid plagiarism issues. All the information was properly referenced by the researcher. Additionally, the data was presented without any kind of modification or manipulation. The ethical guidelines for securing the secondary data were successfully followed by the researcher and following the ethical norms allowed to maintain credibility, transparency and integration in this study.

3.2.5 Analysis of Results

The primary quantitative data collected from the survey was analysed by using a statistical method. Therefore it helps the researcher to complete the study in a

systematic manner. All the statistical tests are beneficial to interpret the results in a proper way and meet the objectives of the study. On the other hand, the secondary data was analysed by creating some themes. Identification of the common factors and ideas presented by authors in their journals helped the researcher to create the themes.

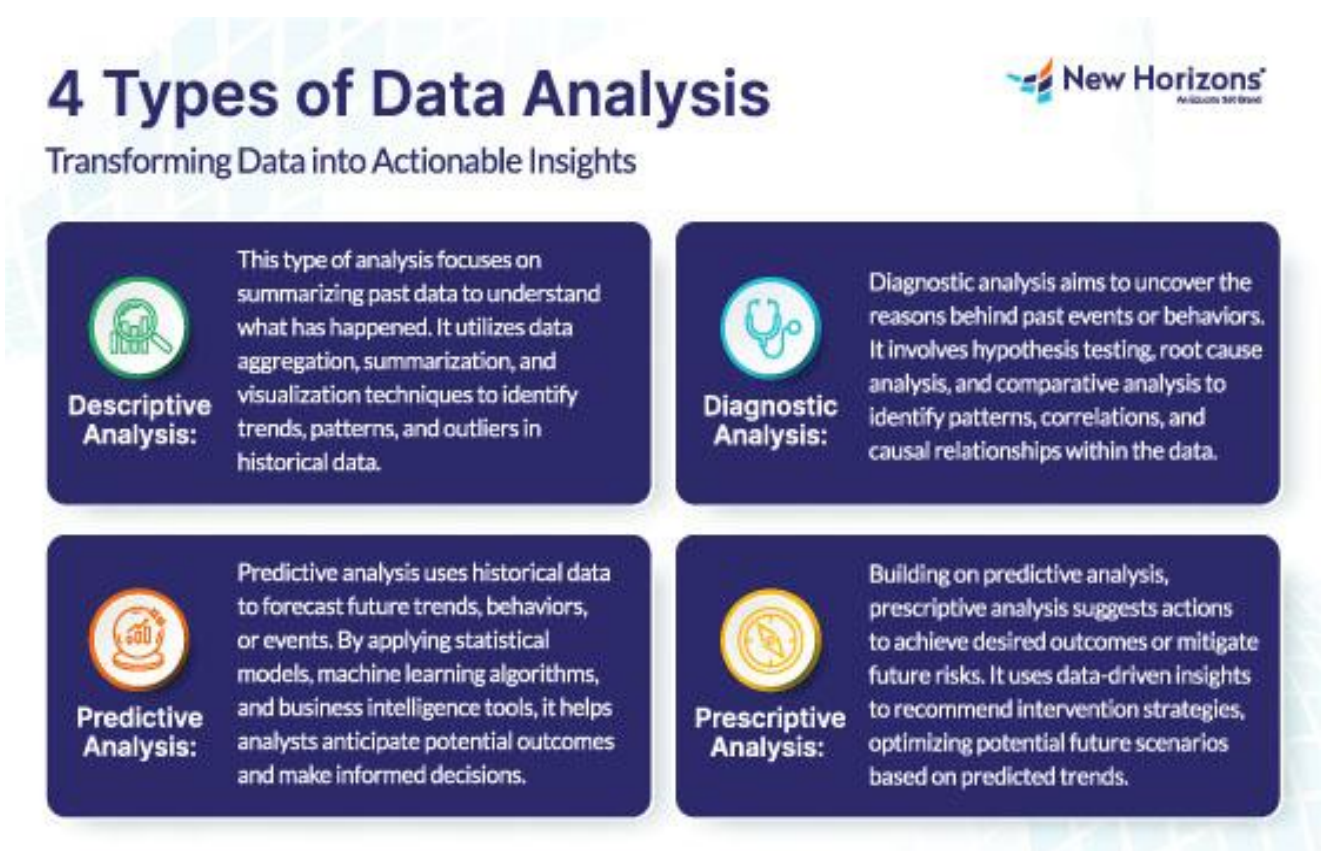


Figure 3.2.3: Type of data analysis
(Source: Braun & Clarke 2022)

Critical analysis has been followed by the researcher to discuss the ideas presented by each other under the themes mentioned above. Thematic analysis is selected for the secondary qualitative data where the mixed methodology is followed due to its flexibility. The thematic analysis process allowed the researcher to follow structured as well as systematic processes to interpret the qualitative information and also maintain an alignment with the deductive approach and positivist philosophy. Hence all the themes

that are created in this study will help to meet all the objectives of the research and also answer the questions of the research. As indicated by Braun & Clarke (2022) thematic analysis is beneficial for maintaining flexibility in the qualitative analysis process that provides better scope to the researcher in meeting the results of the study. Hence, thematic analysis has been selected by the researcher in this study to complete the research in an appropriate way.

Ethical considerations are important for ensuring credibility, integrity as well as responsibility in research (Kumavat, 2024). All the ethical guidelines were successfully followed in this study while conducting the survey process and collecting data from the secondary sources the participants were given an informed consent form where they were fully informed regarding the objective of the research procedure as well as they are right to withdraw their participation at any stage. The personal information of the participants is kept private and confidential. No participants were psychologically or physically forced to join and complete the survey. The data was collected in a secure way and all the regulations of the Data Protection Act were followed by the researcher.

The chapter has discussed the research methodology applied for the study and ensured a systematic and structured approach for the data collection as well as analysis process. The positivism philosophy was selected for focusing on objectivity as well as empirical evidence of the research topic. It aligned with the mixed method selected for the research paper that included both secondary qualitative and primary quantitative data. Additionally, the deductive approach was beneficial for providing a theoretical framework for the study and then empirical testing was performed. The use of descriptive design in this research paper allowed the researcher to systematically analyse the patterns and the trends without modifying the variables of the study. Hence all these methods ensured that the research is valid, reliable and also aligned with the objective of the study.

The upcoming chapter of the research paper will represent the findings of the study along with an appropriate discussion section. Hence the upcoming chapter of the research paper is the most crucial part of the study that helps to meet the objectives of the study.

CHAPTER 4: DATA ANALYSIS AND FINDINGS

This chapter will be used for data analysis and demonstrate the findings. In this chapter, the primary data and secondary data will be analysed. This chapter will help the researcher to meet the research objectives. The 3 developed themes will be analysed in this chapter by using a thematic analysis technique.

What is your job role in a project management company?

51 responses

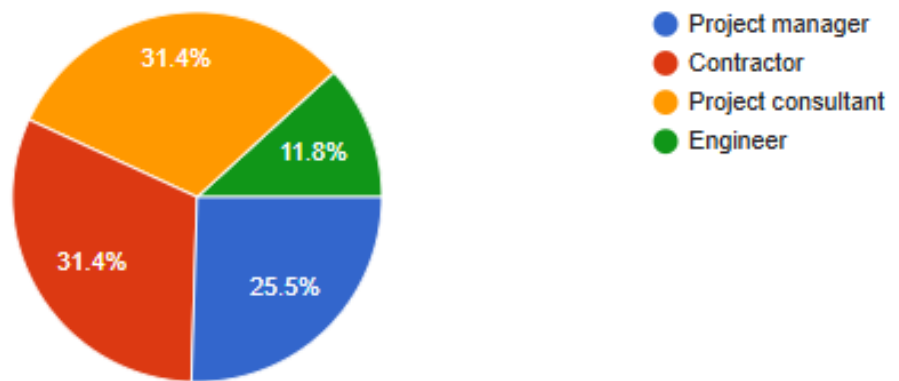


Figure 4.1: Job role

The above image represents the frequency of the first demographic question. Among 51 participants, 31.4% work as project consultants whereas 31.4% work as contractors.

How much is your experience in managing large scale projects?

51 responses

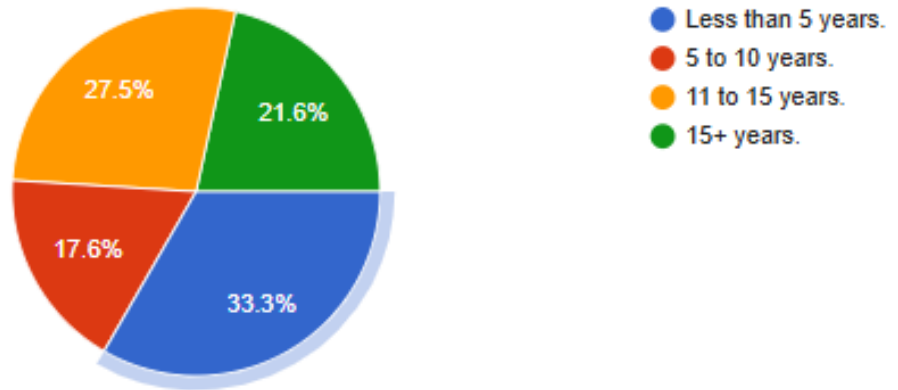


Figure 4.2: Job experience

The table above shows that 32 participants are working in a project management company for 5 to 10 years and 11 to 15 years. Only 6 respondents have worked for more than 15 years.

How often do you apply pre-fabrication and techniques of modular construction in your projects?

51 responses

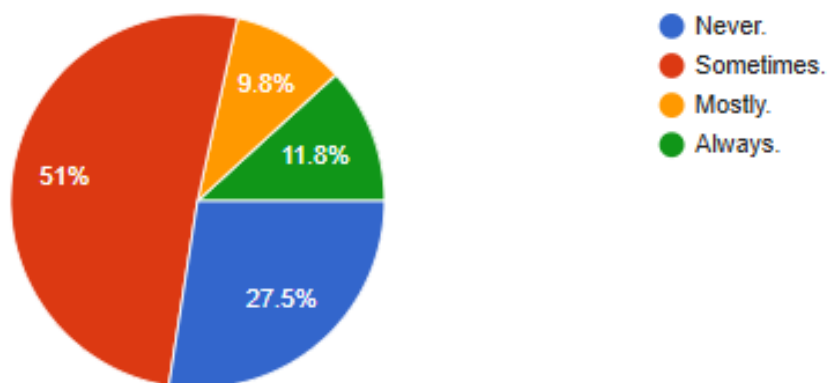


Figure 4.3: pre-fabrication techniques

The above figure shows that 14 participants have never applied pre-fabrication techniques in a construction project. 26 respondents have used these techniques sometimes.

How much energy does pre-fabrication technique save?

51 responses

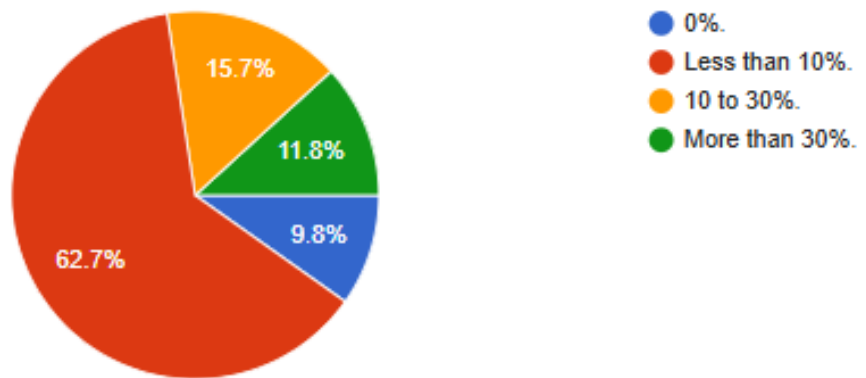


Figure 4.4: Energy saving in pre-fabrication techniques

32 respondents have found that the prefabrication technique can save less than 10% of energy. Only 5 respondents believe that the pre-fabrication technique does not save any energy. 6 respondents have found that pre-fabrication technique can save more than 30% of energy.

To which extent have you utilized the following technologies for improving project sustainability?

51 responses

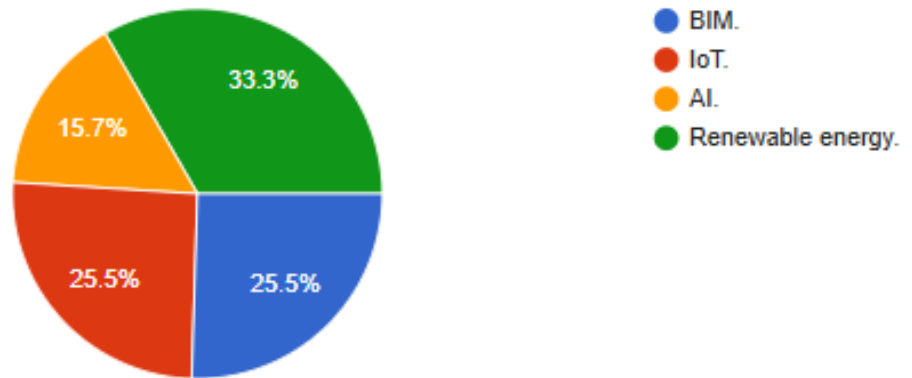


Figure 4.5: Technologies improving sustainability.

The figure shows that 13 respondents believe BIM and IoT technology can enhance the sustainability performance of the sector. 17 respondents believe that the use of renewable energy can improve sustainability performance.

How effective do you find sustainable materials in decreasing the environment impact of construction project?

51 responses

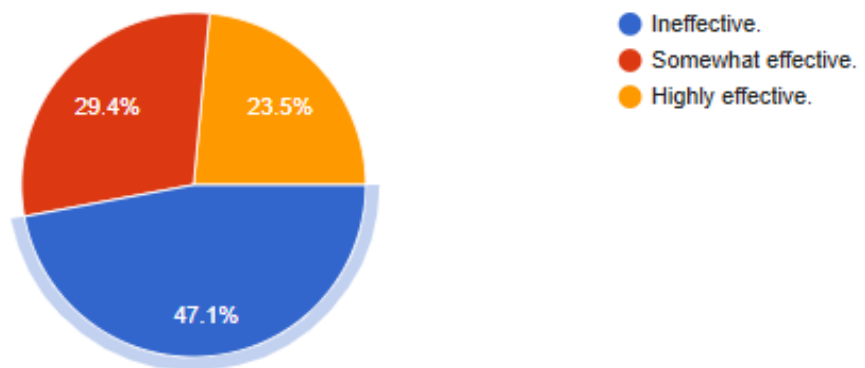


Figure 4.6: Decreasing environmental impact

How familiar are you with the sustainability standards or certifications like LEED or BREEAM?

51 responses

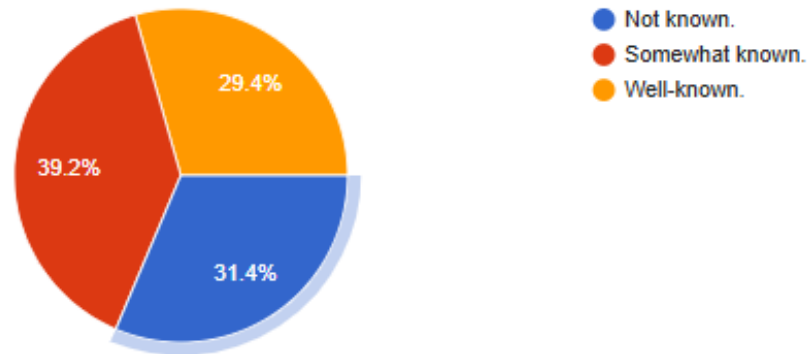


Figure 4.7: LEED/ BREEAM

The figure proves that 16 respondents are not familiar with sustainability standards and certifications such as LEED and BREEAM. 15 respondents are well-known for the sustainability standards.

Which of the sustainability measures do you apply into your project planning and implementation?

51 responses

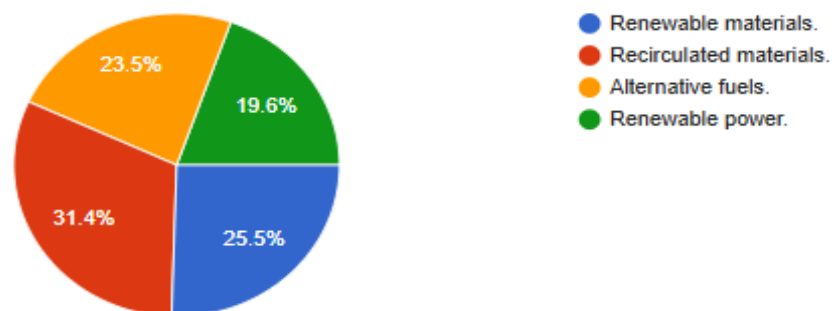


Figure 4.8: Sustainability measures

16 respondents apply recirculated materials in project planning and implementation as sustainability measures. Only 10 respondents use renewable power as a sustainability measure in project planning and implementation.

What limitations do you face when using industry standards for sustainability?

51 responses

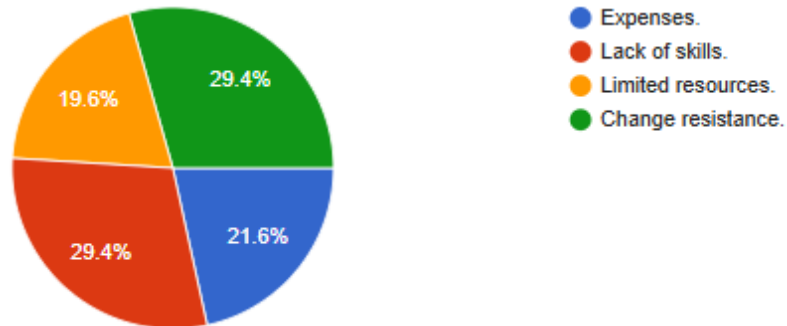


Figure 4.9: Industry standards

15 respondents have expressed that they face a lack of skills and resistance to change as major limitations to using industry standards. Only 11 respondents claim that expense is a major limitation for using the sustainability standards of the industry.

What challenges do you mostly face while executing sustainability in large scale projects?

51 responses

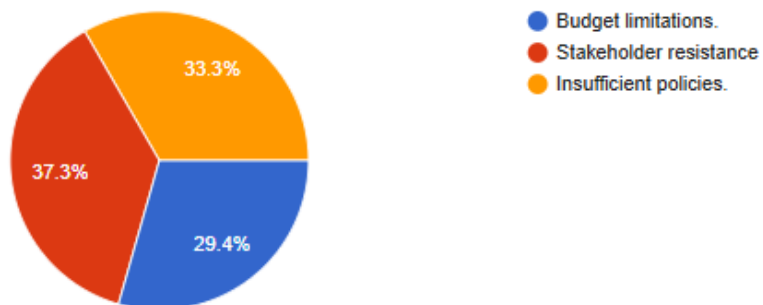
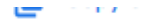


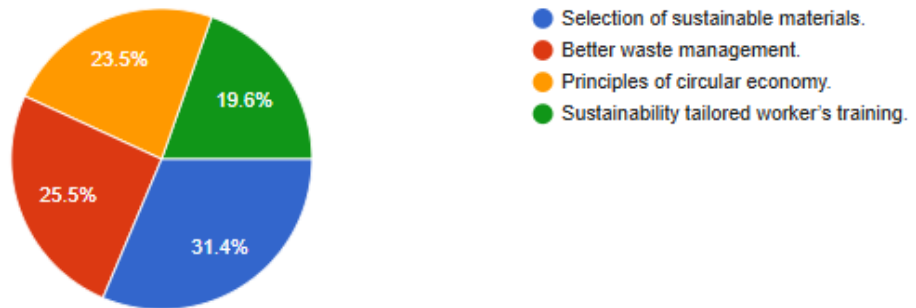
Figure 4.10: Sustainability in projects

Stakeholder resistance is faced by 19 participants when they are executing sustainability in large-scale projects. 17 respondents experience insufficient policies as a major challenge for executing sustainability.

What additional measures do you recommend for improving sustainability in large scale projects?



51 responses



16 respondents recommend a selection of sustainable materials to enhance sustainability in large-scale projects. On 10 respondents recommend that sustainability training can improve sustainability in large-scale projects.

What kind of compensation do you think is appropriate for construction companies to identify operational impacts?



51 responses

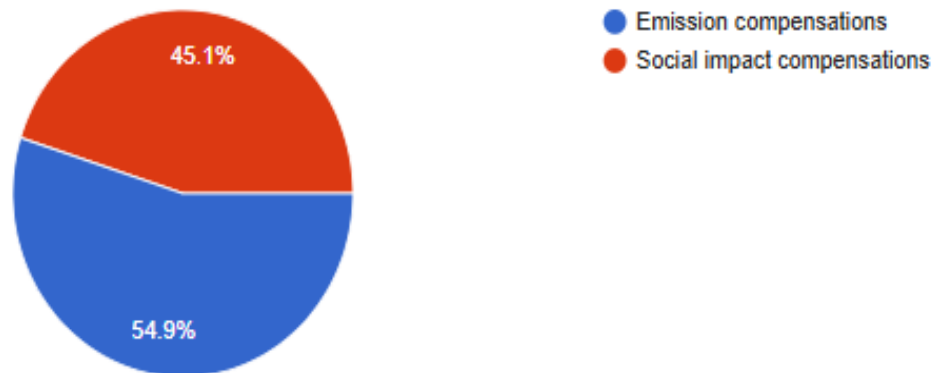


Figure 4.12: Compensation

28 respondents think that emission compensation is required to identify the operational impact of construction companies whereas 23 respondents believe that social impact compensation is necessary for identifying operational impacts.

The construction sector in the UK is criticised for having a negative impact on the environment. According to several scholars, modular construction can help foster sustainability credentials in this industry by improving resource efficiency (Shooshtarian *et al.* 2025). Again modular construction can shift the resource efficiency to any stage of the system. The environmental impact is particularly important as construction sector excavation and demolition activities generate 59% of all solid waste in the nation (Iacovidou *et al.* 2021). Offsite manufacturing of construction and manufacturing of pre-developed components that are delivered on-site are often noted as modular and pre-fabricated construction. In the words of some other researchers, modular construction is a type of pre-fabricated construction (Iacovidou *et al.* 2021). In the UK, four types of pre-fabricated construction are found, those are panelised units, volumetric construction, hybrid construction, and roof cassettes. Manufacturing of construction components in factories allows precise cutting and measurements. It reduces the energy required to transport excess materials.

Permanent modular construction is noted as pre-made buildings consisting of pre-fabricated parts or modules. Several scholars have indicated that shipping of modular houses has become more expensive when the distance from the factory to the site is more than 300 km (Agha *et al.* 2021). It means that when the distance increases, the consumption of energy also increases. In order to improve energy efficiency, it is necessary to reduce the volume of shipped materials and the factory-site distance. Therefore, modular or pre-fabricated construction can reduce the energy consumed for the shipping of excellent materials. Transportation by helicopter is a difficult way and very expensive. In the UK, accomplishing productivity, sustainability, and efficiency in energy consumption shapes the political agenda of the government (Iacovidou *et al.* 2021). Production of pre-fabricated materials in factory conditions fosters better control over insulation installation. Such production methods reduce heat gain or loss and lead to lower energy consumption for cooling and heating.

After the pandemic, the construction sector has become increasingly dependent on disruptive technologies. Workers are obliged to cope with the social distancing requirements and adapt to technology to perform work remotely (Lal *et al.* 2023). The industry players are now leveraging technologies like AI, AR, VR, Big Data, and others. This technology can improve the performance and productivity of construction workers. Construction employees are burdened by the stress of obtaining resources and the necessity to learn new technology (Pamidimukkala&Kermanshachi, 2021). The challenges of virtual work are exacerbated for the older workers of this sector who are struggling with technology usage. Technologies like VR enable construction project managers to identify risks and weaknesses in modular or pre-fabricated construction elements without human intervention. Thus, these technologies have reduced the chances of errors and bottlenecks in construction projects. BIM technologies can be used to share information between the members of the project team, while they can perform virtual inspections by using AR and VR.

New technologies have helped construction project managers to foster green innovation in construction projects. The green innovation is the feature of the product and services as a solution to environmental problems. Adaptation of green practices and technologies is no longer an option for construction project managers, rather, it has become imperative. Green logistic technologies have dramatically boosted the green efficiency of the construction sector (Sandra Marcelline *et al.* 2022). SDGs 7, 8, and 9 focus on attaining environment-friendly technologies and procedures to innovate new strategies. These technologies can help accomplish the performance goals of the industry and sustainable development goals. Automated machines and robotic technologies are able to perform lethargic and repetitive tasks that accelerate the efficiency of workers and reduce the chances of human error. Construction project managers can finish large-scale projects faster and deliver better outcomes to clients. Real-time information and data analytics can foster proactive decision-making.

Balfour Beatty strongly emphasises sustainability and uses multiple benchmarks to guide sustainability efforts, such as climate change, nature-friendly, supply chain integrity, resource efficiency, and community engagement. The construction sector needs to be updated on the changing regulations and incorporate them into their projects and implementation process. Non-compliance with these regulations results in fines, project shut down, and delay. Balfour Beatty is a UK-based construction company that is popular for its environmentally friendly construction projects (Ademoluet *al.* 2021). Balfour Beatty improves its sustainability performance by considering the health and safety of its workers. The company has set a carbon reduction target, validated by SBTi. This target aligns with the objective of reducing global warming. The managers and workers are performing towards net zero emissions from the construction projects. By improving focus on biodiversity, Balfour Beatty aims to create a positive impact on nature.

They collaborate with several organisations to foster biodiversity. The organisation's targets are to minimise waste from a production process and optimise resources in their large-scale construction projects. They work with the supply chain to demonstrate ethical and sustainable practices in the entire project.

The large construction projects in the UK require major contractors such as Balfour Beatty to increase their investment in off-site construction manufacturing known as modular or prefabricated construction (Sadabad, 2023). The initiatives taken by this company align with the industry benchmarks for resource efficiency and sustainability. Balfour Beatty strives to create a diverse and inclusive workforce in order to improve social values. By aligning their business performance with the industry benchmark, the company has successfully accomplished sustainability objectives. The offsite construction technique adopted by Balfour Beatty is recognised as a key enabler of industry productivity. The company participates in and helps different industry organisations promote sustainability, such as "The Institute of Environmental Management and Assessment (IEMA)" and "Considerate Constructors Scheme (CCS)".

Balfour Beatty involves rating systems to benchmark their performance. The sustainability initiative of the organisation is comprehensive. It encompasses governance, social, and environmental aspects.

Despite the growing sustainability concern, the use of pre-fabricated or modular construction is low in the UK. 14 participants have never applied pre-fabrication techniques in a construction project. Modular construction fosters sustainability credentials in this industry by improving resource efficiency. In the UK, the construction sector is responsible for generating 59% of the solid waste. Panelised units, volumetric construction, hybrid construction, and roof cassettes are used in pre-fabricated constructions (Iacovidou et al. 2021). Modular construction reduces the energy required to transport excess materials. Production of pre-fabricated materials in factories helps achieve better control over insulation installation. Shipping of modular houses has become more expensive when the distance from the factory to the site is far.

The construction sector in the UK is increasingly dependent on disruptive technologies. According to 13 respondents, BIM and IoT technology can enhance the sustainability performance of the sector. The use of renewable energy can improve sustainability performance, as mentioned by 17 respondents. After the pandemic, construction workers are struggling to cope with the social distancing requirements and adapt to technology to perform work remotely (Lal et al. 2023). VR technologies enable construction workers to identify risks and weaknesses in modular or pre-fabricated construction. Automations and robotic technologies can perform repetitive tasks and reduce the chances of human error.

16 respondents have used recirculated materials in project planning and implementation as sustainability measures. Renewable power in project planning and installation is used by only 10 respondents. The implementation of sustainability practices at large-scale projects is noticeable in the UK. 10 respondents recommend that sustainability training can improve the sustainability performance of large-scale projects.

Balfour Beatty shows its sustainability performance by considering the health and safety of its workers (Ademolu et al. 2021). The organisation aims to minimise the impact of its activities on the environment. Thus, the organisation uses its industry benchmarks to promote sustainable construction project management. Even though 90% + of the building's materials can be used, only 20%-30% of the resources are reused after the useful life of the building (Munaro and Tavares, 2023).

The respondents of the survey share their opinions. A number of the respondents have never been familiar with the pre-fabrication and modular construction. Panelised units, volumetric construction, hybrid construction, and roof cassettes are the major components of modular and pre-fabricated constructions. Technologies such as IoT and BIM technologies can improve the performance of the construction sector. Balfour Beatty responsibly uses industry benchmarks to execute sustainability initiatives. Modular construction improved the sustainability performance of this industry by improving resource efficiency. Modular construction reduces energy consumption.

CHAPTER 5: CONCLUSION

5.1 Discussion of results

5.1.1 Summary

According to the results of the survey it has been identified that most of the participants who joined the survey were either the project consultants or the contractors. A lot of project managers also joined the survey. The results elaborated that most of them said they use free fabrication and techniques of modular construction sometimes in their project. Less than 10% of energy can be saved for the pre-fabrication process. Along with that popular tools like BIM, artificial intelligence, IoT and renewable energy sources are used to improve the sustainability of projects. Sustainable materials are essential for decreasing the environmental impact of the construction project. Moreover, most of the population thinks that they have knowledge about BREEAM and LEED as the certifications and sustainability standards. Sustainability measures that can be applied for the project planning and the implementation process are recirculated materials and renewable materials. Along with that renewable power and alternative fuels are also used for the process. Moreover, the major limitations that everyone faced were using the industry's standards for the sustainability process the limited resources and lack of skills. However, developing the skills of the construction workers and the project manager is crucial in order to improve the sustainability project management methods for handling large-scale projects and infrastructure development. Failing to do this process can cause several issues in the construction project.

The major challenges faced by the employees in the organisations are stakeholder resistance and insufficient policies. Hence, it is crucial for the organisation to improve stakeholder engagement by appropriately communicating with them in order to make informed decisions that can provide ultimate benefits to handling construction projects. However, better waste management policies can help to improve

sustainability in large-scale projects. Along with that, the selection of sustainable materials can also help to develop the efficiency level of large-scale projects. Both the primary and secondary data that are collected in this study have highlighted the importance of sustainability measures in developing the construction sites of the country. However, a lack of skills and limited knowledge about the prefabricated construction project is a major challenge for organisations in modern days. However, transportation by helicopter is a major issue and is costly for organisations. After the pandemic situation, it is important to use disruptive technology for organisational development. However, the use of big data AI, IoT and other technologies can help in improving the construction work in an effective way.

5.2 Recommendations

- Adopt green construction practices: organisations need to use green construction practices by following modular construction and prefabrication methods. Low-carbon materials can also be used to minimize emissions and waste.
- Integrate sustainability for the project planning process: while starting the project planning process the organisation needs to consider the sustainability principles and design the stages according to that. This will help in assessing the risk of the environment and performing a life cycle analysis before initiating the project.
- Develop supplier collaboration and supply chain transparency: as found in the study lack of communication and collaboration between the suppliers can cause significant challenges for the organisations. In this regard, it is crucial for the companies dealing in the construction industry to maintain transparency with all the stakeholders and maintain collaboration with all the suppliers.
- Invest in employee training and awareness: appropriate training can be provided to all the employees of the company to educate them about the best practices

of the construction projects and belong long-term benefits of sustainable project management practices. This will help in developing their skills and abilities.

5.3 Suggestion for future research

In future, the study can be done by exploring the organisational barriers and behavioural issues to adopt sustainability practices in the construction sites. Examining how the sustainability measures followed by the organisations after completing the project especially for the infrastructure can help in identifying more details. However, in future interviews can be done to analyse the practical experiences of all the employees working in the construction sites.

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Appendix 1: Google Form Questionnaire (5 point Likert scale)

Section A: demographic information

1 What is your job role in a project management company?

- A. Project manager
- B. Contractor
- C. Project consultant
- D. Engineer

Literature context: different stakeholders hold different perspectives on sustainability practices. For example, project managers mostly give importance to cost and project scheduling, while the constructors concentrate on resource efficiency.

2. How much is your experience in managing large scale projects?

- A. Less than 5 years.
- B. 5 to 10 years.
- C. 11 to 15 years.
- D. 15+ years.

Literature context: the experiences in PM affect the knowledge of strategies and sustainable practices to be used.

Section B: Modular construction and prefabrication

3. How often do you apply pre-fabrication and techniques of modular construction in your projects?

- Never.
- Sometimes.
- Mostly.
- Always.

Literature context: past works of literature mentioned that modular construction diminishes the consumption of waste and energy, resulting in lower ecological effect.

4. How much energy does pre-fabrication technique save?
- A. 0%.
 - B. Less than 10%.
 - C. 10 to 30%.
 - D. More than 30%.

Literature context: pre-fabrication helps in energy saving by reducing on site activities.

Section C: Effect of new technologies

5. To which extent have you utilized the following technologies for improving project sustainability?
- A. BIM.
 - B. IoT.
 - C. AI.
 - D. Renewable energy.

Literature context: sustainability technology such as BIM streamlines designs that are energy efficient, while IoT allows real-time energy usage monitoring. Also, as mentioned by Pan *et al.* (2022), the significant role of AI and robotics in increasing creativity to transform and digitize constructions has been highlighted in different policies.

6. How effective do you find sustainable materials in decreasing the environment impact of construction project?
- A. Ineffective.
 - B. Somewhat effective.
 - C. Highly effective.

Literature context: various past works of literature pointed out the increasing importance of sustainable materials in strengthening sustainability.

Section D: Industry standards

7. How familiar are you with the sustainability standards or certifications like LEED or BREEAM?
- A. Not known.
 - B. Somewhat known.

C. Well-known.

Literature context: the rural roads, mostly incur huge environmental and social expenses throughout the construction period (Zhou *et al.* 2021). Hence, green certifications like LEED or BREEAM can help make the benchmark for sustainable constructions and are broadly identified for their positive ecological effects.

8. Which of the sustainability measures do you apply into your project planning and implementation?

A. Renewable materials.

B. Recirculated materials.

C. Alternative fuels.

D. Renewable power.

Literature context: abiding by the measures makes sure that the project meets the sustainability goals.

9. What limitations do you face when using industry standards for sustainability?

A. Expenses.

B. Lack of skills.

C. Limited resources.

D. Change resistance.

Literature context: issues like expenses or knowledge, caps destruct, the broadspread acceptance of sustainability standards.

Section E: Issues and recommendations

10. What challenges do you mostly face while executing sustainability in large scale projects?

A. Budget limitations.

B. Stakeholder resistance.

C. Insufficient policies.

Literature context: in the last 20 years, different scholars have investigated means of using sustainable materials in road constructions to help conservation (Bamigboye *et al.*

2021). Yet, issues in sustainable PM mostly appear from external stress, restricted policies, and stakeholder resistance.

11. What additional measures do you recommend for improving sustainability in large scale projects?

- A. Selection of sustainable materials.
- B. Better waste management.
- C. Principles of circular economy.
- D. Sustainability tailored worker's training.

Literature context: the suggestions from research participants can help finish the academic findings, and make industry focused solutions highlighting the practical needs.

12. What kind of compensation do you think is appropriate for construction companies to identify operational impacts?

- A. Emission compensations
- B. Social impact compensations

Literature context: In the past works of literature, it is suggested by scholars that the construction companies need to take into construction any of these two compensations to improve their brand reputation

