Article

Advancing Circular Economy in Construction Mega-Projects: Awareness, Key Enablers, and Benefits—Case Study of the Kingdom of Saudi Arabia

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Abstract: The implementation of a circular economy (CE) in the construction sector faces several challenges that hinder its progress. Research on the awareness, key enablers, and potential benefits of CE in Saudi Arabia’s construction of mega-projects that could contribute and promote a successful transition is still at its early stages and remains limited. This study delves into CE awareness and understanding, identifying the key enablers that could support its successful adoption in Saudi Arabian mega-projects and the potential benefits associated with it. To achieve this, a comprehensive literature review was conducted, followed by 18 semi-structured interviews across three case studies, which involved the main stakeholders in building, urban development, and infrastructure projects. The findings, which are thematically analysed, revealed that CE awareness mostly focuses on reuse, recycle, and waste reduction. A significant gap in the knowledge of circularity throughout projects’ lifecycles has been identified. As such, this study concludes that the key enablers for CE include establishing regulatory frameworks, enhancing professionals’ awareness and education, promoting the use of advanced technology, ensuring a mature market, and supporting CE initiatives. Moreover, the potential environmental and socio-economic benefits of CE, such as cost reduction, environmental impact reduction, and better-improved quality of life are crucial for encouraging a wider implementation of CE in the construction of mega-projects in Saudi Arabia.

Keywords: circular economy; CE awareness; enablers; benefits; construction; mega-projects

1. Introduction

The construction industry continues to grow and significantly support socio-economic development. However, for decades, the sector has faced criticism for waste generation, natural resource consumption, and other ecological challenges [1,2]. The industry generates more than 25% of solid waste and consumes approximately 32% of raw materials worldwide [3]. Therefore, the construction industry shifting from the current linear economic model towards a circular economy (CE) that aims to reduce material and energy consumption is essential [3,4]. The CE is recognised for its effectiveness in optimising resource use and waste reduction [5,6], promoting a closed-loop system for materials throughout their lifespan [7,8]. A circular economy is defined in the literature as a “system where materials never become waste and nature is regenerated” [9] Therefore, the CE could reduce dependence on raw materials.

The circular economy is underpinned by several fundamental principles, mainly focused on reducing, reusing, and recycling [10]. However, the literature indicates that the application of reducing, reusing, and recycling might not be sufficient for fully achieving a closed-loop system [11,12]. Consequently, the 3Rs are expanded to more comprehensive...
frameworks, including the 5Rs, 9Rs, and 10Rs, tailored to the requirements and applications of the industries [13]. For example, Geissdoerfer et al. [14] propose the 6Rs—reuse, recycle, redesign, remanufacture, reduce, and recover—as the appropriate model for the manufacturing sector. While, within the construction sector, Ping Tserng et al. [15] and Reike et al. [16] propose the 5Rs—rethink, reduce, reuse, repair, and recycle—as the appropriate set of CE principles for the sector.

Previous research has investigated CE awareness and enablers [17,18]; however, the focus of these investigations remains generic and primarily covers buildings. This study attempts to enhance the scope by focusing on mega-projects under construction in Saudi Arabia. Mega-projects are characterised by their substantial cost, high risk, significant impact, and variety of stakeholders [19].

The construction sector in Saudi Arabia contributes approximately 6% of the GDP and provides over 2.9 million jobs [20]. It is also responsible for generating about 55 tons of waste per 1000 m² of construction [21]; although, according to a study by Ouda et al. [22], the content of construction waste that gets recycled and reused is less than 14%. Therefore, adopting CE principles is vital for the Saudi national economy, especially as it aligns with the strategic plan of Vision 2030. This study aims to assess the current awareness and understanding, identify the key enablers, and the potential benefits of CE (environmental, social, and economic) in the construction of mega-projects in the KSA based on semi-structured interviews and analyses of three case studies (mega-projects), referred to as Project A (building), Project B (urban development), and Project C (infrastructure).

This study examines both the awareness and understanding of professionals about CE, the key enablers, and the benefits of implementing CE in the construction of mega-projects. This study is in contrast to previous research which assessed quantitatively (via surveys) CE awareness and enablers in Saudi Arabian buildings [17]. Unlike previous works, this study intends to fill a notable gap by qualitatively examining CE awareness, enablers, and potential benefits in the context of mega-projects and uses semi-structured interviews to gain deeper insights. Furthermore, this research uniquely selected three different project types to have a comprehensive understanding of the CE. This approach provides a broader perspective and a more comprehensive understanding of the circular economy in the context of mega-project construction, which could provide invaluable insights for professionals, academics, stakeholders, and policymakers while informing the decision-making of local governments and similar developing countries for transitioning into a circular economy.

Research Questions:
1. What is the current level of awareness and understanding of the CE within construction mega-projects in Saudi Arabia?
2. What are the key factors enabling the adoption of CE in construction mega-projects in Saudi Arabia?
3. What are the potential environmental, social, and economic benefits of CE implementation in construction mega-projects in Saudi Arabia?

This study is divided into five sections. Section 1 provides an overview of the construction industry and the concept of a circular economy and discusses the significance of the study in the context of mega-projects in Saudi Arabia. Section 2 reports on a thorough literature review of circular economy awareness, its key enablers, and the potential benefits of implementing CE in construction projects. Section 3 explains the adopted research methodology. Section 4 presents the key findings and expands the discussion of the results. Section 5 addresses the overall implications of the study including limitations and identifies further research avenues.

2. Literature Review
2.1. Circular Economy: Concept and Awareness

The circular economy, as defined by Ellen MacArthur [3], is “a restorative and regenerative industrial system, by intention and design. It replaces the ‘end-of-life’ concept
with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models”. Expanding on this, Kirchherr et al. [7] describe CE as an “economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, [……], with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations”. Accordingly, CE is a transformative system that shifts the industry towards more sustainable systems that minimise waste and maximise material efficiency. Despite the clarity of such definitions, the lack of awareness and knowledge delays the transition of the construction sector into CE [23,24].

The challenges faced by the transition into circular economy within the building sector exhibit a considerable variation across nations, due to the regulatory and socio-economic contexts of each country. The variability in awareness and adoption of CE in developed and developing countries highlights a global challenge. A study conducted in the UK by Adam et al. [25] demonstrates that while awareness of CE in developed countries is relatively high among professionals in the building sector, it is not uniformly extended to an industry-wide level, which highlights the need for enhanced training and education to achieve a more uniform understanding. Similarly, in the USA, Guerra and Leite [26] note a significant variation in the understanding of CE principles within the building sector, since recycling and prefabrication are more recognised and implemented in contrast to other circularity practices which are not widely acknowledged or adopted. In Australia, a state-wide exploration of CE awareness by HO et al. [27] finds that there is a limited understanding of CE, as the current practice focuses on waste management rather than other aspects, such as redesign. Likewise, Kevin van Langen et al. [28] demonstrate that the understanding of CE among stakeholders across the EU and neighbouring countries is fragmented. Such a level of variability underscores the need to enhance educational programmes and an appropriate policy framework to bridge the gap and promote more circular practices.

With regard to developing countries, Nie et al. [29] examine the United Arab Emirates’ transition towards a circular economy and point out that although there is a recognition of its importance, there is also variability in the level of understanding of CE principles among professionals in Dubai, particularly in relation to design for deconstruction. This finding is also observed by Siraj Ahmed et al. [30], who conclude that there is a lack of knowledge and understanding of circularity among project parties—clients, consultants, and contractors. In Ghana, Amudjie et al. [18] surveyed 162 built environment professionals and discovered a moderate awareness of the 6Rs principles (repair, recycle, reuse, renewable energy usage, reduce, redesign). Furthermore, Aljaber et al. [17] explored the awareness of stakeholders in building projects in KSA, reporting a low awareness level, without delving into specific aspects of engineering practice.

To address the limitations noted in previous research, this study uses semi-structured interviews and multiple case studies. These methods are applied across various project types to examine in depth the level of awareness of CE in mega-projects, which are characterised by their complexity and large scale. The existing literature on CE awareness highlights a need for educational programmes. These programmes should not only enhance the depth of professionals’ understanding but also encourage them to adopt CE throughout the project lifecycle. This approach aligns with the identified barriers to CE implementation, as the lack of education and training in circular economy principles is considered a primary obstacle, mainly within the context of the three mega-projects [23].

2.2. Enablers for Circular Economy Adoption in Construction Projects

Despite the barriers that hinder the successful transition towards circularity, several researchers identify key enablers that can facilitate the implementation of CE in the con-
These enablers are essential to drive the sector towards circular principles and have been investigated within developed and developing countries. In the UK, Adam et al. [25] examined the adoption of CE in the building sector, identifying the significant enablers, and confirmed the need for a business case to support CE. It also highlights the importance of demonstrating the economic advantages of CE practices. Furthermore, the study encourages design for deconstruction and other recovery methods that facilitate the reuse of materials while emphasising the critical role of legislation in raising the awareness of CE within the construction industry.

In the USA, Guerra and Fernanda [26] investigated the CE in the construction industry and found that there are four main enablers for circularity strategies that facilitate the transition. These include education and cultural change, availability of reliable data, and policies and incentives. They demonstrated, accordingly, the importance of education in raising awareness, the role of accessible and reliable data in decision-making, and the benefit of having regulatory frameworks. Another study conducted in the Pacific Northwest by Izquierdo et al. [35] identifies several enablers for CE practices in the built environment through interviews with industry professionals. The study concludes that regulatory support and contractual requirements are essential for promoting circularity practices. Additionally, aligning CE practices with project goals and leveraging the necessary technology can facilitate its adoption. The study emphasises the importance of training professionals and the existence of a robust supply chain system for successful implementation.

A study conducted by Giorgi et al. [34] encompassing five EU countries highlights that CE transition can be facilitated through different drivers. The study discusses the importance of regulatory support including national initiatives and programmes and private sector efforts to stimulate market competition and demonstrates the need for integrating environmental assessment tools to support circular strategies.

In Australia, a survey conducted by Shooshtarian et al. [33] on 132 professionals in construction revealed that CE can be facilitated by enabling the research and development of proper technology as a primary enabler of the transition. In addition, offering training to the main stakeholders of the projects about CE adoption strategies and associated benefits is crucial as it results in raising their awareness. The survey refers to the crucial role of tangible evidence that can prove the economic and environmental importance of CE to support the transition and justify its need. Moreover, incentives and regulations are identified as essential drivers of CE implementations.

In developing countries, a study conducted by Mhatre et al. [36] about the CE in the built environment sector in India uncovers the need for robust regulatory frameworks that mandate and facilitate the adoption of CE through clear and practical policies. Furthermore, the study reaffirms the significance of enhancing the knowledge of professionals, suggesting that a high awareness of CE among professionals can contribute to the adoption of CE initiatives. Moreover, there is a need to have the appropriate technologies and infrastructure related to circularity.

In Gulf Corporation Countries, Al Hosni and Amoudi [37] explore the drivers of CE in Oman and found that the key drivers are related to regulation and vision, raising public awareness, and establishment of supportive infrastructure for circularity processes. On the other hand, in Saudi Arabia, Aljaber et al. [17] quantitatively investigated the enablers of CE in building projects and found that the existence of material storage and recycling facilities, the use of BIM, technology tools, CE policy, and material certifications are the top five enablers in the building sector. Although Aljaber et al. [17] identify crucial enablers, their study is limited to building projects, overlooking different types of projects. Additionally, their reliance on surveys might not capture stakeholders’ in-depth experiences. In contrast to but also building on that insight, this study offers a novel approach by examining the CE implementation across three distinct construction mega-projects in Saudi Arabia (building, urban development, and infrastructure). It examines multiple case studies including semi-structured interviews with key stakeholders (client, consultant, and contractor). This method not only offers a broader insight, but also introduces practical implications for deci-
sion makers involved in the construction of mega-projects, contributing significantly to the CE body of knowledge. Table 1 provides a referenced summary of the CE implementation enablers identified through the literature review.

Table 1. Summary of the enablers for implementing CE as identified in the literature review.

<table>
<thead>
<tr>
<th>Code</th>
<th>Enabler</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Supportive Law and Legislation</td>
<td>[8,17,31–37]</td>
</tr>
<tr>
<td>E2</td>
<td>Incentives</td>
<td>[8,17,25,26,32,33]</td>
</tr>
<tr>
<td>E3</td>
<td>Education and Training</td>
<td>[8,17,26,31–33,37]</td>
</tr>
<tr>
<td>E4</td>
<td>Technology and Innovation for Circularity Practices</td>
<td>[8,17,25,31–33,35–37]</td>
</tr>
<tr>
<td>E5</td>
<td>Awareness Raising</td>
<td>[8,25,31,32,36,37]</td>
</tr>
<tr>
<td>E6</td>
<td>CE Case Studies</td>
<td>[8,17,25,32,33]</td>
</tr>
<tr>
<td>E7</td>
<td>Material Certifications</td>
<td>[8,17,32]</td>
</tr>
<tr>
<td>E8</td>
<td>CE Initiatives</td>
<td>[8,34,36]</td>
</tr>
<tr>
<td>E9</td>
<td>Market Creation</td>
<td>[8,17,31,32]</td>
</tr>
<tr>
<td>E10</td>
<td>Data Availability</td>
<td>[8,26,32]</td>
</tr>
<tr>
<td>E11</td>
<td>Cost Reduction and Saving</td>
<td>[32]</td>
</tr>
<tr>
<td>E12</td>
<td>Cultural Supports</td>
<td>[8,32,37]</td>
</tr>
<tr>
<td>E13</td>
<td>Use of BIM</td>
<td>[17,25,33,34,38]</td>
</tr>
<tr>
<td>E14</td>
<td>Stakeholders’ collaboration</td>
<td>[33,34]</td>
</tr>
</tbody>
</table>

According to the literature review, researchers have visualised some common enablers, such as the regulatory framework, education, and technology advancements. However, a notable limitation is the tendency to base criteria on project types or regional contexts, limiting the generalisation. Furthermore, there is still a significant gap related to large-scale projects and case studies in investigating circularity.

2.3. Environmental, Social, and Economic Benefits of Implementing Circular Economy

The following sections address potential benefits linked to the environment, society, and economy.

2.3.1. Environmental Benefits

A circular economy transition in the construction industry could yield significant ecological benefits, including the mitigation of global warming, reduction of CO₂ emissions, construction waste minimisation, and natural resource preservation. A study by Minunno et al. [39] revealed that adopting design for deconstruction and reusing structural elements can significantly reduce the GHGs emissions by more than 80% compared to emissions resulting from recycling alone. They also observed that other environmental indicators like landfill waste and pollution are lowering, which is partially attributed to the reduced production of new materials and better practices put into place for managing waste. In a separate study by Eberhardt et al. [40], it was found that adopting circularity practices such as reuse and design for disassembly helps to mitigate environmental challenges such as global warming, resources depletion, and GHGs emissions. Their study found that reusing concrete structures can reduce CO₂ emission in amounts ranging between 15% and 20%. Moreover, a study by Ritzen et al. [41] found that incorporating CE in new construction projects can significantly reduce the embodied carbon emissions and energy by more than 87% and 60%, respectively. Also, Aguilar and Rodrigues [42] analysed different CE hypothetical scenarios that revealed that CO₂ emissions could decrease by around 24%.

A circular economy can fundamentally transform the value chain by shifting from the current linear economy towards circularity practices, such as optimising the use of materials and minimising waste and pollution [43,44]. According to Suleman et al. [45], the potential benefits of CE adoption are around preserving natural resources, minimising environmental impacts, and reducing materials disposal in the landfill. Furthermore, Ghisellini et al. [44] argue that the primary goal of CE is to decouple economic growth from the harm of the ecosystem, as CE reduces the ongoing pressure on natural resource demands. Additionally,
a circular economy is expected to reduce waste and CO\textsubscript{2} emissions, mitigate environmental degradation, and conserve the natural resources [43,45,46]. As such, adopting CE practices such as reuse, recycling, and recovery can subsequently reduce the environmental impact and landfill waste.

2.3.2. Social and Economic Benefits

The socioeconomic aspect is vital in the construction of mega-projects [47]. The benefits associated with CE are not limited to creating new market, reducing construction costs, and improving public health and well-being. A study by Minunno et al. [39] highlights that CE can offer benefits beyond environmental impacts, such as establishing new markets for reclaimed materials and reducing operation and maintenance costs. Other studies emphasise the role of CE in preserving local biodiversity and improving public well-being [26,45]. As per several studies [4,45,48], CE practices in the building sector diminish the need for new raw materials, which not only lowers the cost but creates new market opportunities. Moreover, the transition to CE can encourage job creation, economic growth, and improved social inclusion [4,48,49]. Overall, CE practices can provide socio-economic advantages and foster a more sustainable construction sector. Table 2 summarises the benefits found in the literature, associated with the implementation of CE-based practices.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Potential Benefit</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Reduce greenhouse gas and CO\textsubscript{2} pollutions</td>
<td>[39–46]</td>
</tr>
<tr>
<td></td>
<td>Support climate change and global warming mitigation</td>
<td>[40]</td>
</tr>
<tr>
<td></td>
<td>Conserve natural resources</td>
<td>[40,43,45,46]</td>
</tr>
<tr>
<td></td>
<td>Protect soil and ground water</td>
<td>[45,50]</td>
</tr>
<tr>
<td></td>
<td>Minimise waste generation</td>
<td>[39,43–45]</td>
</tr>
<tr>
<td></td>
<td>Less consumption of materials and energy</td>
<td>[44,45]</td>
</tr>
<tr>
<td></td>
<td>Environmental degradation reduction</td>
<td>[43,45,46]</td>
</tr>
<tr>
<td></td>
<td>Enhances material efficiency</td>
<td>[43,44]</td>
</tr>
<tr>
<td>Social</td>
<td>Improve public health and well-being</td>
<td>[26,45,51]</td>
</tr>
<tr>
<td></td>
<td>Improving social inclusion</td>
<td>[4,48,49,51]</td>
</tr>
<tr>
<td>Economic</td>
<td>Job creation</td>
<td>[4,48,49]</td>
</tr>
<tr>
<td></td>
<td>Potential decreases in building’s operation and maintenance costs</td>
<td>[39,45]</td>
</tr>
<tr>
<td></td>
<td>Creating new market</td>
<td>[4,39,45,48,49]</td>
</tr>
<tr>
<td></td>
<td>Reduces construction costs</td>
<td>[39]</td>
</tr>
<tr>
<td></td>
<td>Potential economic growth</td>
<td>[4,42,48,49]</td>
</tr>
</tbody>
</table>

3. Methodology

3.1. Research Approach

Considering the exploratory nature of this research, a qualitative methodology was selected, involving the use of semi-structured interviews along with multiple case studies. As emphasised by Yin [52], semi-structured interviews were deemed necessary for collecting data in case studies, facilitating open discussion with interviewees, and enabling an in-depth exploration by the interviewer. This means that semi-structured interviews allow the researcher to thoroughly explore the awareness of the circular economy within construction mega-projects, as well as the enablers and benefits of its implementation. Previous studies in similar fields, such as [10,29,30,53], have also used semi-structured interviews.
interviews to gather the views of professionals on the research phenomena. This method has been able to help researchers to collect reliable data effectively.

Once interviews were identified as one of the most appropriate qualitative methods to collect data, we established a systematic process and criteria for selecting participants who could contribute to covering the research objectives. Different perspectives from the various stakeholders involved in the targeted construction mega-projects were considered. Clients, consultants, and contractors were selected, given their key roles in managing, controlling, and decision-making throughout the construction lifecycle. Top management and expert engineers, with a minimum of 5 years of experience, in the three construction mega-projects were interviewed and provided broader insights into the transition to a circular economy. Figure 1 summarises the methodology of the study.

Figure 1. Summary of the study’s methodology.

3.2. Sample Strategy

The interviewees were selected using a non-probability sampling technique, specifically purposive sampling, focusing on top management and expert engineers involved in three mega-projects. This method allows the researcher to identify and select the key professionals responsible for the delivery of these construction mega-projects. Purposive sampling has been proven effective for gathering concise data from a specific subset of the population, particularly when exploring complex phenomena [54].

The case studies were selected based on the criteria set for mega-projects outlined by Ashkanani and Franzoi [55] and Fkyvbjerg [56]. According to this, the projects have to cost
more than $1 billion, take over 5 years to complete, and involve high risks and associated impacts. Applying these criteria, we selected a building (project A), an urban development (project B), and an infrastructure project (project C). The outlined diversity of case studies, organisational roles, and participant positions aims at enhancing the scope and validity of the results. Recognising the distinction between project types adds depth and insight to the CE enablers and their associated benefits while accepting that enablers and associated benefits might differ across the projects, as reflected in the collected opinions.

According to the literature review, there is no specific sample size to work on. However, it is understood that capturing diverse opinions and perceptions is essential to represent the reality of the phenomena. Morse [57] asserts that at least six interviews are needed to investigate phenomena and reach the so-called saturation point, since conducting more interviews will not add any new information. Conversely, Cresswell [58] suggests a sample of between 5 and 25 interviews to achieve saturation. Guest [59] indicates that twelve interviews can help to reach saturation. In case studies, the number of interviews typically ranges between 4 and 10 per case [60]. This debate highlights the lack of agreement about the required number of interviews needed to reach the saturation point. In this study, we conducted six interviews per project. This number is an average of the recommendations of Cresswell and Plano Clark [60], distributed among the three main parties (client, consultant, contractor) to provide a reasonable view of the phenomenon. Thus, a total of 18 interviews were conducted, noting that, for this study, the saturation point was reached after the 15th interview; hence, no additional information was added from the participants past this point. Table 3 shows the general details of the interviewees.

Table 3. Participants' details.

<table>
<thead>
<tr>
<th>Participant Code</th>
<th>Position</th>
<th>Years of Experience</th>
<th>Organisation Role</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Senior Design Lead</td>
<td>23</td>
<td>Client</td>
<td>Project A</td>
</tr>
<tr>
<td>C1-PD1</td>
<td>Senior Project Director</td>
<td>21</td>
<td>Client</td>
<td>Project A</td>
</tr>
<tr>
<td>C2-PM1</td>
<td>Project Manager</td>
<td>12</td>
<td>Client</td>
<td>Project B</td>
</tr>
<tr>
<td>C2-PM2</td>
<td>Project Manager</td>
<td>10</td>
<td>Client</td>
<td>Project B</td>
</tr>
<tr>
<td>C3-PM1</td>
<td>Project Manager</td>
<td>15</td>
<td>Client</td>
<td>Project C</td>
</tr>
<tr>
<td>C3-PM2</td>
<td>Project Manager</td>
<td>17</td>
<td>Client</td>
<td>Project C</td>
</tr>
<tr>
<td>CS1-PD1</td>
<td>Project Director</td>
<td>18</td>
<td>Consultant</td>
<td>Project A</td>
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<tr>
<td>CS1-SE1</td>
<td>Senior Sustainability Specialist</td>
<td>12</td>
<td>Consultant</td>
<td>Project A</td>
</tr>
<tr>
<td>CS2-ARE1</td>
<td>Assistant Resident Engineer</td>
<td>25</td>
<td>Consultant</td>
<td>Project B</td>
</tr>
<tr>
<td>CS2-RE1</td>
<td>Resident Engineer</td>
<td>32</td>
<td>Consultant</td>
<td>Project B</td>
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<td>16</td>
<td>Consultant</td>
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<td>CS3-SPE1</td>
<td>Senior Project Engineer</td>
<td>14</td>
<td>Consultant</td>
<td>Project C</td>
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<td>CT1-PD1</td>
<td>Project Director</td>
<td>18</td>
<td>Contractor</td>
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<td>27</td>
<td>Contractor</td>
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<td>CT2-CM1</td>
<td>Construction Manager</td>
<td>15</td>
<td>Contractor</td>
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<td>CT2-QM1</td>
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<td>CT3-PM1</td>
<td>Project Manager</td>
<td>16</td>
<td>Contractor</td>
<td>Project C</td>
</tr>
</tbody>
</table>

3.3. Data Collection

The interviewing questions were developed based on the past works about circular economy in construction projects discussed in the literature. According to Bryman [61], the research questionnaire should be developed after a thorough review of previous studies, considering the research aims and objectives. We have followed this rule for the present
study, which enabled us to add questions to encourage the participants to freely express their opinions and knowledge about the circular economy in construction mega-projects.

Both face to face and online Zoom interviews were conducted based on the participants’ availability and preferences. The content of the semi-structured interview guide underwent validation following several steps. Initially, two professors with expertise in construction and circular economy reviewed the content. Subsequently, feedback was sought from six industry professionals to assess the clarity and comprehensiveness of the questions. Following this, pilot interviews were conducted with three professionals. Based on the feedback received at each stage, adjustments were made to the questions to eliminate ambiguity and improve clarity.

At the beginning of each interview, the interviewer introduced the topic and outlined the purpose and scope of the study to the participants. Prior to the interview, participants signed a consent form to confirm their understanding of their rights, be ensured the data were going to be managed safely, and be informed of the research’s ethics. The interview questions were structured to address all research objectives. Initially, the participants are asked for general details about their background, including their experience and role/responsibilities. This was followed by a discussion of the study objectives concerning awareness, enablers, and benefits of CE. All interviews were audio recorded, with each session typically lasting between 40 and 55 min.

Following the interview transcription using MS Word (version 16.81), all interviews underwent a thematic analysis using NVivo14, a software utilised to easily manage and visualise data. The analysis followed the procedure outlined by Braun and Clarke [62]. Next, the transcripts and main findings were shared with the participant to validate the accuracy and reliability of the text and its analysis, seeking their feedback. Additionally, feedback on the analysis procedure was sought from two colleague researchers, one other civil engineering professor, and a qualitative analysis expert to mitigate potential bias in the analysis process and validate the findings.

4. Results and Discussion
4.1. Awareness and Understanding of CE within Construction Mega-Projects

To cover the first objective of CE awareness in construction mega-projects, the 18 interviews were analysed thematically. The findings are grouped into three main themes namely Knowledge and Familiarity with CE, Principles of Circular Economy, and Materials Efficiency and Sustainability Links, which are illustrated in Figure 2 and discussed in the following paragraphs.

![Figure 2](image_url)

**Figure 2.** The themes and subthemes of CE awareness and understanding in the construction mega-projects.

4.1.1. Theme 1: Knowledge and Familiarity with CE

The study demonstrates a lack of awareness of the term circular economy amongst participants, with more than half of them demonstrating a basic or lower level of understanding. The term CE turned out to be new to some of them, or they acknowledged that the term is rarely referred to in the construction industry. For example, a project manager from Project B client stated the following:
“Frankly, I do not hear the term itself before, but when you invite me for the interview, I read about it...” (C2-PM1)

Similarly, a project manager of Project C client mentioned the following:

“The word itself is not mentioned widely during ... the daily routine. Not like sustainability”. (C3-PM1)

These findings align with other research findings on the level of awareness of the CE among professionals. For instance, the study conducted in the UAE by Siraj Ahmed et al. [30] demonstrated a significant lack of awareness, while the research by Adam et al. [25] in the UK, showed relatively high CE awareness. In Ghana, Amudjie et al. [18] found a moderate awareness among professionals.

4.1.2. Theme 2: Principles of Circular Economy

Despite the unfamiliarity with ‘circularity’, the participants demonstrated good recognition of some of its principles and defined it as the vehicle to cover the 4Rs: redesign, reduce, reuse, recycle, in the construction lifecycle. The most cited principles were “reuse of materials”, “recycling”, and “waste reduction”, as they were dominantly used to define circular economy by the interviewees. The reuse, recycle, and waste reduction were mentioned 15, 14, and 9 times, respectively, which indicates a good recognition of these principles. An example of this literacy is illustrated with a quote by the project manager of the contractor at Project C who stated the following:

“Circular economy is related to how can we reuse the material again or .. recycle it...”. (CT3-PM1)

However, the application of circularity in the design stage has only been mentioned twice, indicating a lack of consideration of CE in the early stages of the project. The identified variation in the understanding of CE principles is consistent with a study conducted by Guerra et al. [26] in the USA, who found that professionals’ understanding of CE strategies varied, apparently because strategies like recycling and prefabrication are perceived to have higher awareness compared to design for disassembly. In contrast, in developing countries like Ghana, Amudjie et al. [18] points out that awareness of the 6Rs is moderate among professionals.

4.1.3. Theme 3: Materials Efficiency and Sustainability Links

A moderate level of awareness related to sustainability and materials efficiency was observed. The interviewees showed some recognition of the CE and its role in waste reduction and sustainability in the sector as seven participants linked CE to sustainability and sustainable development. For instance, the designer of Project A stated the following:

“I think, it is very important topic for me, because I believe in sustainability and during all my career, I’ve done a lot of research and a lot of design to correlate sustainability into the construction sectors...”. (C1-D1)

Similarly, the project director of the client at Project B stated the following:

“I can also connect it to sustainability and the sustainable material..”. (C2-PD1)

On the other side, participants demonstrated even less recognition of the role of CE in materials efficiency, while they emphasised its role in reducing and managing waste in construction projects. This has been asserted by previous studies which concluded that professionals focus on waste reduction but fail to consider CE as an integral system, see for example [26,30].

The general understanding of CE is mostly made up of knowledge of sustainability and waste management, which makes it evident that the circular economy has not been fully grasped yet. Interviews demonstrated that CE understanding in the construction mega-projects is mainly associated with reuse and recycling, and waste management in general. However, the knowledge and understanding of CE implementation principles such
as 4Rs, 5Rs, and 9Rs are still not well achieved, and defining CE as a system rather than a tool to manage waste is not demonstrated yet. Therefore, raising awareness and enhancing knowledge of CE in construction mega-projects is necessary, considering it a transformative system capable of reshaping the sector rather than a mere waste-management tool.

4.1.4. Awareness across Projects

In examining the awareness of CE within the three construction mega-projects, the integrated analysis underscore minor variations in thematic emphasis. Participants from the three projects demonstrate a focus on reuse and recycling as the most frequently discussed themes. Furthermore, the participants across the three projects show a level of unfamiliarity of the term ‘circular economy’. Unlike the participants of Projects B and C, the participants from Project A link CE with sustainability and consider these to fall under the same umbrella. Notably, materials efficiency is overlooked by most participants in project A, while a couple of interviewees from projects B and C define CE as a tool to seek materials efficiency. On the other side, CE in design and prolonging themes received less attention, as they were mentioned by only one participant. Table 4 shows the distribution of perceived awareness of circular economy across the three construction mega-projects.

Table 4. The distribution of perceived awareness of circular economy across the three construction mega-projects.

<table>
<thead>
<tr>
<th>Code</th>
<th>Theme and Sub-Themes</th>
<th>Project A</th>
<th>Project B</th>
<th>Project C</th>
</tr>
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<tr>
<td>B.2</td>
<td>Prolonging and restoring</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>B.3</td>
<td>Recycle</td>
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<tr>
<td>B.4</td>
<td>Reuse Materials</td>
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<td>4</td>
<td>6</td>
</tr>
<tr>
<td>B.5</td>
<td>Waste Reduction</td>
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<td>4</td>
<td>3</td>
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<tr>
<td>C C.1</td>
<td>Link CE to Sustainability</td>
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<td>1</td>
</tr>
<tr>
<td>C.2</td>
<td>Materials Efficiency</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

4.2. Enablers to Implement CE in Construction Mega-Projects

The identified enablers have been grouped into five themes, namely: regulatory, knowledge, technology, market and economic, and culture. The findings will thematically be presented in the following section. Figure 3 shows the main themes and subthemes of CE key enablers in the construction mega-projects.

4.2.1. Theme 1: Regulatory Enablers

The transition to the circular economy in the construction mega-projects is related to the existence of clear laws and regulations. The interviews underscore the importance of having proper regulation, materials certifications, incentives, government and private initiatives, and existing successful examples of CE adoptions in the sector. The subthemes below discuss the regulatory enablers that facilitate the transition to circularity practices in the construction of mega-projects.
4.2. Enablers to Implement CE in Construction Mega-Projects

The identified enablers have been grouped into five themes, namely: regulatory, knowledge, technology, market and economic, and culture. The findings will thematically be presented in the following section. Figure 3 shows the main themes and subthemes of CE key enablers in the construction mega-projects.

Figure 3. The themes and subthemes of CE enablers in the construction mega-projects.

1. **Law and Legislation**

Law and legislation are a major agent for the transition to the CE in the construction of mega-projects. Most participants emphasized the difficulty of adopting CE due to the lack of mandatory obligations for the main parties in the projects through legislation. Legislation should, therefore, be referred to in contracts with clear roles and responsibilities of each party. In this regard, a project manager of Project B stated the following:

“Also regulations, ... very important the clear regulations. It’s very important for everybody in the projects, so they will understand their role, they will understand what to do ...”. (C1-PM2)

This view was supported by the contractor of Project A who confirmed that clear legislation will help the contractor adopt CE principles in the project and will protect him, as it is stated in the clauses of the contract. Their statement reads as follows:

“... we need legislation to support the contractor to do that ... because the contractor he cannot request anything from client to accept this kind of reusing or recycling material because he do not have a specific clue or a specific statement in ... his contract enhancing this. So he don’t want to go to the headache by requesting that ....”. (CT1-PD2)

The participants see legislation as an enabler to solve other obstacles to CE transition, such as culture and awareness. They think that the existence of CE is supportive to the spread of CE as a new method and raise awareness about it. This is confirmed by the project director of Project A, who says the following:
“I think you’ll have to start with regulation. When I talk about the awareness or a culture of people, it can be changed by regulation only. So since we have regulations that stop us from doing some wrong practices that will push everybody to use reused material or recycled . . .”. (CS1-PD1)

The number of times that laws and regulations were mentioned by the professionals of the three projects and the different stakeholder representatives (client, consultant, contractor) underscores the significance of the need for a robust regulatory framework to mandate the incorporation of CE in the construction of mega-projects. This finding is repeatedly presented in both developed and developing countries, as the regulation is a backbone for the circularity adoption. For instance, in the UK and Australia, Adam et al. [25] and Shooostarian et al. [33] emphasise the importance of regulations being in place to help raise awareness of CE within the sector. Similarly, in developing countries such as India [36] and Oman [37], researchers confirm the need for mandatory obligation from project parties through robust regulations and policies. Conversely, in the Saudi Arabian building sector, Aljaber et al. [17] rank CE policy as fifth, which indicates less priority for some regulatory frameworks compared to this study.

2. Governmental and private Initiative

Governmental and private initiatives are critical for the transition to CE in the building sector. Six participants emphasised the need for initiatives with clear indicators and potential prizes for organisations to encourage CE practices in their projects. They cite the local content initiative as an example, which imposes a specific percentage of domestic materials in government contracts with the private sector. For instance, the client project manager at Project C states the following:

“Also, I can say we have good example of local content initiative. So having circular economy initiatives similar to a local content idea, this will help to achieve the needed circular economy practices. . . .”. (C3-PM2)

Therefore, the existence of successful initiatives in the country will encourage organisations in the sector to integrate CE practices into their projects. This is asserted by two studies in developed countries, USA [34] and Australia [33], as they argued that government or private initiatives are a driving factor towards circularity.

3. Case Study (Show Example)

According to our findings, one of the primary enablers for CE implementation is the availability of case studies/previous examples that incorporate the circularity principles in its practice, particularly with regard to cost-saving and best practices across the board. Furthermore, quantifying the benefits and existence of empirical evidence can promote the adoption of CE in the building sector. For instance, the client project manager at Project B stated the following:

“I can also add a very important enabler in my opinion, let say clients or investors . . ., if they start with one project .. do it based on circular economy concept like for example using recycled materials in the project. Then they said this is the benefit, this is the saving that we have and this is how we build it based on these sequences and this procedure. This . . . will help everybody to follow even the private sector they might follow us to do the same . . .”. (C2-PM2)

The participants highlight the significance of showcasing the tangible benefits of CE adoption. Additionally, it shows the importance of practical procedures and benchmarks in the sector which can help promote CE. As such, this can provide robust evidence of the potential benefits associated with this principle. This is supported by studies in developed countries by Adam et al. [25] in the UK and Shooostarian et al. [33] in Australia, who emphasise the need for tangible evidence to prove the socioeconomic and environmental advantages of a transition to circularity. Whereas, in developing countries, it is either mentioned as less important or overlooked.
4. **Incentives**

Incentives for CE transition are critical; the primary incentives relate to fiscal support, such as an exemption from tax for the procurement of local materials, which not only enhances CE but also supports the economy of the country. Furthermore, prioritising loans for monetary support and simplifying the process of hiring foreign experts were considered effective measures to support the transition towards a more circular construction sector. For instance, a designer of Project A mentioned the following:

“Also, the incentives, first incentive should be for the developer who is doing the right thing. .. give them some kind of tax free to source material locally. Give them priority to get bank loan, give them priority to get the knowledgeable people to come in the country easily to work for them”. (C1-D1)

The incentives can change the culture in the sector and raise awareness. Furthermore, rewards offered by the public authority can motivate organisations to align their practices with CE principles and motivate other organisations to shift towards more circular practices. Studies by Guerra et al. [26] and Shooshtarian et al. [33] assert that CE in the construction sector needs incentives from governments to encourage the main parties to transition towards circularity.

5. **Certification**

Despite the benefits of using reclaimed materials in construction, four participants expressed the need for quality assurance to ensure the best materials selection. The participants expressed the need for the materials verification process and called for governmental oversight and the establishment of standards and certification systems, such as what the Saudi Standards Metrology and Quality Organisation (SASO) did for other materials. The certification theme is thus emerging as a critical factor for enabling the shift to reclaimed materials. The existence of standards and certifications provided by governmental authorities enhances the reliability of reclaimed materials and items. For instance, the contractor of Project A stated the following:

“... they have to make ... some specifications for that and make some like certification. For example, SASO the standards for material ... in the kingdom. They have to give some testing certificates of the material, ... material take certificates from SASO, that means very good material in a very good condition” (CT1-PD2)

This statement highlights the significance of having specific standards and certifications in place for reclaimed materials. The project director underscores the importance of the Saudi Standard, Metrology, and Quality Organisation’s (SASO) role in providing the required tests and certificates for such materials. This viewpoint is supported by a study by AlJaber et al. [17], which ranked materials certifications among the top five enablers in Saudi Arabian building projects. This indicated that certification provision by local authorities is essential to mitigate the risks associated with the use of reclaimed materials, as it can enhance their utility and acceptance in the market by verifying their quality.

4.2.2. **Theme 2: Knowledge Enablers**

1. **Awareness**

The awareness of CE and the associated benefits of its adoption are highlighted across multiple participants. It is considered key to the integration of circularity in the sector, as it educates professionals, stakeholders, and the public about the implementation of CE in the construction of mega-projects. The sustainability engineer of the consultant at Project C said the following on this point:

“Firstly, is the awareness of stakeholders in the sector. I see awareness is very important because it needs many efforts to raise it among workers and increase the commitment from client and contractors. . . .” (CS3-SPE1)
By elucidating the circularity principles and their advantages for professionals in the sector and the public, a well-known community will help accelerate the adoption of CE and ensure broader acceptance of the CE system. This is confirmed by studies from both developed and developing countries [26,33,36,37].

2. Education and Training

Education and training are also key factors for fostering circularity in mega-projects, as they help raise awareness and gain the support of the main stakeholders. Educating and training professionals in the construction field is essential, as they facilitate the practical adoption of CE and enhance the common understanding of the term among the sector parties. For instance, a C3-PM2 stated the following:

“In my opinion, if we want to implement circular economy, we have to start with the . . . education. The concept itself does not exist in a common way. Especially, . . . in construction, it’s rarely discussed or rarely known”. (C3-PM2)

This can show the insufficient awareness of CE principles, highlighting the significance of appropriate training and educational programmes.

Furthermore, the participants affirmed the importance of the early-stage incorporation of circularity and sustainability in engineering school curricula for students and junior engineers. The CS1-PD1 mentioned the following:

“Well, this started by teaching the engineers or engineering students . . . that raise awareness of the engineering students by teaching them about circularity and sustainability principles during design and during construction that will bring to us educated students who can enhance later the sector and improve the sustainability and circularity practices in the construction. So, the new engineers should be aware of these things.” (CS1-PD1)

This has been confirmed by studies in developed and developing countries [26,33,35–37], which emphasise the need for education and training programmes, considering them as essential driving tools in promoting circularity and equipping professionals and the public with the needed knowledge and skills to understand and adopt CE in the construction of mega-projects.

4.2.3. Theme 3: Technology Enablers

1. Technology

Technological advancements are essential for effective resource management, reuse of materials, and recycling, which are considered to be essential for the CE transition. The feasibility of dismantling or recycling construction elements and materials is heavily dependent on the adequacy of the existing technology in the factories. Furthermore, the advancement of technology in terms of the sorting, cleaning, and recycling of materials highly contributes to the efficiency of the reclaiming processes. For instance, a designer at Project A stated the following:

“... you don’t have resources to do that. Resources in terms of technology. You know, when you .. remove or when you recycle this material, there is a way to dismantle things and you need to have the right technology and the right knowledge to do it in a normal way....”. (C1-D1)

Thus, technological advancement is a pivotal enabler for CE adoption in the construction sector, as asserted in studies conducted in developing [17,36] and developed countries [33,35].

2. Data

A client in Project C mentioned that the transition to CE will be easier if reliable data are available, affirming the absence of shared data on waste quantity or dismantled elements. The project manager 2 of Project C stated the following:
“... that there is no data and no organisations that specifically giving us the information of the amount of waste materials to be reused...” (C3-PM2)

Therefore, enhancing waste data transparency and accessibility by collecting data and analysing it for stakeholders can establish a data-driven sector and ease the decision-making related to the recycling and reuse of materials; this is also highlighted by the study by Guerra et al. [26] in the USA.

4.2.4. Theme 4: Market and Economic Enablers

1. **Market and Supply Chain**

   A key enabler for the CE transition is the existence of effective engagement with competent suppliers in the market. Seven participants indicate an initial challenge in establishing the proper network with suppliers with knowledge of sustainability in the market. Furthermore, ensuring a reliable supply chain for reclaimed materials and having a more mature market to sell and buy reclaimed materials are crucial in the CE transition. In this regard, the director of the contractor at Project A stated the following:

   “We have now the local content initiative for example, this localisation program starting from seven years ago, and it’s gonna gradually use local materials in KSA market. ... we need to have market, good one, and this can be gradually built by government or other party”. (CT1-PD1)

   Thus, the presence of credible suppliers who can deliver the needed materials with reasonable cost and quality, as well as an initiative to have a mature market can facilitate the incorporation of CE practices into the construction sector. This matches the findings of Giorgi et al. [34] in the EU, Al Hosni and Amoudi [37] in Oman, and Mhatre et al. [36] in India, which emphasise the need for market-salvaged materials and logistics to adopt circularity.

2. **Cost**

   The cost of reclaimed materials can be a pivotal enabler as it contributes to cost reduction and provides incentives to project stakeholders to implement CE. A participant in this research emphasises the mutual benefits derived from this heading which are shared between the main parties in the project:

   “... I can say something that it have to be mutual benefits between different parties. Because contractor need ..., like a benefits from doing that. For example, if they state something like this, we need to build this project but if you reuse like 10% recycled or reused material, we will give you these benefits okay, ... and the cost in total will be less but the contractor is still getting some benefits and similar margin. So, the contractor getting benefits and the client getting benefits of reducing the total project cost”. (CT1-PD2)

   Likewise, the transition towards CE in the sector will benefit the national economy, as the country is an importer of construction materials. Decision makers are encouraged to support this strategy, as it helps reduce exports. The CT1-PD2 stated the following:

   “... it will improve many things in terms of the construction itself and also for the country itself. You know, we are importing many things. So, if we do that, it will help us to improve the construction and save a lot of money”. (CT1-PD2)

   Cost-effectiveness is pivotal to enabling the implementation of CE in the sector. Adopting circularity can offer economic benefits at both the project and national level and facilitate its practical integration. This aligns with the findings in the review of CE drivers by Wuni [32].

4.2.5. Theme 5: Culture Enablers

1. **Culture**

   Cultural norms can enable the adoption of CE, as observed by the participants, who note that both top management and the public reject the idea of using second-hand materials
in their projects. Overcoming this by changing the attitude of the main stakeholders can significantly facilitate the adoption of CE in mega-projects. The client project manager of Project B stated the following:

“The culture of the project managers and the clients, they do not like the used material from the other projects, even if the construction materials are good and it’s not used …… they do not want to use it in their projects. They think this is my project, I don’t want to have a material that is purchase or used for any other projects”. (C2-PM1)

As such, providing materials certificates, quality assurance, and raising awareness about the CE and reclaimed materials can accelerate the transition towards a more sustainable and circular sector. This has been confirmed in the findings of studies in the USA by Guerra et al. [26] and the findings of studies in Australia [33] and Oman [37].

4.2.6. Enablers across Projects

Emphasis is put on law and legislation across the three projects, indicating the importance of appropriate CE regulations. In addition to this, the participants agree on the role of education and training programmes in raising awareness of CE and confirm that it can significantly contribute to the transition to CE in the construction sector. Government initiatives, education, and advanced technology are also emphasised across the three projects. Notably, other important enablers garnered less emphasis across the projects, for instance, certifications, incentives, and culture, despite their contributions. Table 5 shows the distribution of the perceived enablers of the circular economy across the three construction mega-projects.

Table 5. The distribution of perceived enablers of the circular economy across the three construction mega-projects.

<table>
<thead>
<tr>
<th>Codes</th>
<th>Theme and Sub-Themes</th>
<th>Project A</th>
<th>Project B</th>
<th>Project C</th>
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<td>C1</td>
<td>Culture</td>
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<td>1</td>
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</tr>
</tbody>
</table>

4.3. The Benefits of CE Implementation within Construction Mega-Projects

4.3.1. Environmental Benefits

The reduction of CO₂, the environmental impact, and the global warming mitigation are noted as direct benefits of CE practices in the construction of mega-projects. The
participants highlighted the advantage of using reclaimed content for minimising the manufacturing and transportation process, which subsequently reduces emissions. For instance, the project director of Project A stated the following:

“... Now this comes to the port and then you will do much more processing and then you transfer this. So, more CO₂ emissions this by using 50% recycled content they are actually 50% saving”. (C1-PD1)

Furthermore, data revealed a board awareness among the participants in the construction mega-projects on the need to preserve natural resources from depletion, contributing to utilising materials efficiently. Meanwhile, the participants expressed their concerns over climate change and its relationship with the mass consumption of natural resources, noting that a circular economy could mitigate these issues by reducing the demand for finite materials. The construction manager of contractors at Project B stated the following:

“Circular economy is beneficial... as it optimise resources consumption and also leave it for the new generations with new mind and new ideas to make use of the natural resources. We need to include circular economy in our all the mega projects so that we make use of the resources and not deplete them or not go scarce we may finish off the resources”. (CT2-CM1)

The adoption of circularity in the construction of mega-projects promotes ecological sustainability and ensures that future generations inherit a more sustainable sector. This is confirmed by previous research findings on the environmental benefits, such as [39–41,43–46]. Two participants of this study emphasise the importance of CE in reducing some materials’ scarcity, especially since the Saudi construction sector is considered the key sector that relies heavily on imported materials.

4.3.2. Social and Economic Benefits

This study highlights the benefits for future generations and the enhancement of the quality of life as the main social advantages of shifting towards a circular economy in the construction of mega-projects. The participants shed light on the importance of embracing circularity in the construction of mega-projects in Saudi Arabia and other sectors, as it benefits the younger generations and promotes a more sustainable lifestyle that can positively influence the region. Furthermore, the study reveals how CE benefits the environment, health, and life quality in society, signifying an interconnection between them. Interviewees demonstrated that CE practices in construction mega-projects can improve the quality of life by reducing environmental degradation, which can, in turn, enhance public health and well-being. The project manager 2 Project B mentioned the following:

“... these strategies will improve the environment which will improve people life and have better health”. (C2-PM1)

This relationship between the environment and society is what can establish a robust foundation for advocating for a circular economy to enhance the quality of life. On the other hand, the study also revealed a significant economic benefit associated with the transition towards circularity in the construction of mega-projects. The results demonstrated the potential of a substantial cost reduction achieved through the recycling of steel bars or the reuse of structural elements, which significantly reduces the need for raw materials, thereby reducing the manufacturing and transportation costs. Furthermore, by adopting circularity practices, the national Saudi economy will be improved since the sector that depends on importing materials will rely on local recycled or reused materials, and this will lead to the creation of a new sector and jobs for people. The project director at Project A stated the following:

“You know Saudi Arabia is imported country .... by less importing of material, they will reduce the imported amount and that will improve the economy in general”. (CT1-PD2)

These multifaceted socio-economic advantages of CE will not only reduce the cost of construction but will foster sustainable economic development. This finding aligns
with previous research conclusions on the socio-economic potentials of a circular economy, emphasising its role in the creation of new market opportunities, and offering jobs and good life for people [4,48,49].

4.3.3. Benefits across Projects

Themes encompassing cost reduction, environmental impact reduction, and good life received significant attention across the three projects, this indicates the awareness of professionals in the construction of mega-projects in Saudi Arabia about the associated benefits of implementing circularity principles in different aspects: environmental, social, and economic. An agreement is noted on the fact that the CE transition can contribute significantly to the preservation of natural resources and the reduction of CO\(_2\) emissions. Noteworthy, other benefits have been overlooked among the mega-projects. For instance, future generations would benefit and help with material scarcity, as shown in Table 6.

Table 6. The distribution of perceived benefits of the circular economy across the three construction mega-projects.

<table>
<thead>
<tr>
<th>Codes</th>
<th>Theme and Sub-Themes</th>
<th>Project A</th>
<th>Project B</th>
<th>Project C</th>
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5. Conclusions

As the circular economy is gaining momentum as a system that helps to minimise waste and efficiently use resources, there remains a need for more work to facilitate its adoption in the construction of mega-projects, especially in developing countries like Saudi Arabia, where the sector significantly contributes to the national GDP and the portfolio of mega-projects under construction. Therefore, this study has aimed to assess the awareness of CE in the construction of mega-projects in three distinct mega-projects. It examined the main enablers and associated benefits of circular economy adoption from the perspective of professionals in the sector.

The findings of CE awareness within the mega-projects in Saudi Arabia suggest a substantial need for awareness-raising campaigns through education and training programmes. Despite the basic knowledge of CE principles among professionals, especially reuse and recycle, as well as waste reduction, there is a noticeable gap in the understanding of CE practices throughout the projects’ phases. This study finds that approximately half of the professionals are either not aware of or unfamiliar with the circular economy, indicating that awareness is shallow and limited to the waste management of materials. This
emphasises the importance of embedding education and training programmes to foster a holistic understanding of CE within the construction mega-projects.

Furthermore, the successful transition towards CE in the construction of mega-projects in Saudi Arabia depends on several enablers, as identified by professionals from the case studies. First, building a robust framework for CE legislation will set the roles, responsibilities, and guidelines that can help foster its adoption. Second, raising awareness for stakeholders and educating the professionals can help in the transition, allowing them to learn the best practices and potential benefits of such a transition. Moreover, the existence of technological advances, a mature market, and a credible supply chain can ease the use of reclaimed materials. Lastly, government or private initiatives are essential to encourage the transition towards CE; therefore, fostering the acceptance of these practices in the sector is a key factor. These enablers together can offer an easier transition towards circularity in the construction of mega-projects in Saudi Arabia. Moreover, the adoption of circular economy principles in the construction of mega-projects is attributed to potential environmental, social, and economic benefits. The participants emphasise that CO₂ reduction, environmental impact reduction, and natural resource preservation are prominent environmental advantages. Meanwhile, a good quality of life and well-being have also been related to the environment and, subsequently, to circularity. From an economic perspective, reducing cost, improving the national economy, and creating new sectors are also considered as the primary benefits.

This study contributes significantly to the existing literature on CE implementation in mega-projects by employing semi-structured interviews coupled with multiple and distinct case studies: buildings, urban development, and infrastructure in Saudi Arabia. Opposite to previous studies that mostly concentrated on the building sector and quantitively identifying the enablers, this study expands its focus to include three case studies of mega-projects encompassing various types of projects to enrich the existing literature by obtaining the insights from the project’s professional lens. This study can enhance stakeholders’ comprehension regarding the current understanding as well as the key enablers and benefits for CE adoption. Additionally, policymakers can use the findings of this study to build the needed regulations and policies to contribute to the successful adoption of CE. Furthermore, the findings of this research can contribute to the awareness-raising of CE among professionals and academia, advocating the incorporation of CE principles in training and educational programmes.

Although this study brings valuable insight towards CE awareness and enablers within mega-projects in Saudi Arabia, it is noteworthy that the generalisability of the findings to mega-projects in other developing countries requires further exploration. Future research could focus on the CE adoption methods and indicators in an aim to promote the advocacy for circularity within the sector.

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