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Integration of Circular Economy Principles: Impact on Project Quality Assurance in Construction Industry of Pakistan

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ABSTRACT

The world's population is increasing at a very rapid rate, and it is resulting in increasing demand for housing and built environments. This increase in demand in causing resource depletion and increase in greenhouse gas emissions. The major cause of these problems is linear economic model of the construction industry. To cater the negative effects of linear economic model, the circular economy (CE) model has gained attention since 1970s. This research aims to identify the barriers and current trends in the integration of circular economy principles, assess the impact of circular economy principles on quality assurance, and propose recommendations for the implementation of circular economy for improved quality assurance in the construction industry of Pakistan. A questionnaire was developed to assess stakeholders' perceptions on different aspects of circular economy integration and its impact on quality assurance. The survey was conducted among 100 construction industry professionals. The results were statistically analyzed and the relative importance index (RII) for the perceived barriers and impacts of circular economy principles on quality assurance was calculated. Key findings reveal a generally positive outlook of circular economy integration on project quality assurance. Stakeholders acknowledged that circular economy integration can have significant improvement in overall project quality assurance, will have positive impact on durability and long-term sustainability of the construction components. Still, there is potential for improvement in terms of project cost optimization and resource efficiency. Key recommendations include development of quality control measures, integration of advanced technologies in quality assurance and providing knowledge about the circular economy principles to the stakeholders.

KEYWORDS: Circular economy, Quality Assurance, Resource Efficiency, Sustainability.

1. INTRODUCTION

The world population is increasing at a very rapid rate and is expected to peak at 9.7 billion by the year 2050 [1]. The population has increased so fast that demand for housing, infrastructure, and other built environment entities is rising fast and problems like resource depletion, straining ecology systems and soaring prices are arising. According to Rees (1999), the construction industry consumes over 32% of the total natural resources on the planet and accounts for 2.2 billion tons of waste (about one quarter of all the waste produced worldwide) per year [2] [3]. This tremendous amount of waste span from concrete to demolition debris and has put a load on landfills and poses

threats to the environment. According to Douglas (2006), the adaptive reuse of building materials is superior to new construction in terms of sustainability [4]. Hence to achieve sustainability in the construction industry, the waste produced from the construction industry should be reused in the construction to prevent resources from being used up and reduce the environmental impact of construction.

By the end of the 20th century, the increasing awareness about the climate change sparked interest in the scientific community about finding ways to reduce the carbon emissions, and the construction industry is no exception. These climate changes include rising temperatures, changing rainfall patterns and other aspects of the atmosphere. The construction industry accounts for 39 % of total global CO_2 emissions of which the production of building materials alone accounts for 2/3rd of total CO_2 emissions [5][6]. Hence reusing these materials and promoting sustainable construction practices will help to achieve sustainability in the construction industry.

Current construction industry is based on the linear economic model of "take, make, dispose of. The evidence indicate that the linear model is unsustainable, unbalanced, and is reaching its physical limits and is primary cause of problems related to construction waste generate and CO_2 emissions [4]. To reduce the negative impacts of the linear model, another model known as circular economy model is gaining attention since 1970s [7]. The construction industry is increasingly recognizing the importance of adopting a circular economy model. This model seeks to reduce the material costs, minimize waste generation, and improve resource efficiency [8] [9]. The circular economy approach involves designing buildings that can be easily dismantled and materials that can be recycled, using renewable energy sources, and promoting waste recycling [10].

The circular economy model works on three principles including design for disassembly, keeping materials and products in a closed loop and dematerialization [11]. According to Yu.et.al (2022), in CE model materials should be recovered and recycled as much as possible and kept in circulation for a longer period. The circular economy model not only mitigate the amount to construction waste and CO_2 emissions, but also result in reduction in the cost of the construction by utilizing low-cost waste materials in place of new materials. According to Sanchez & Haas (2018), the CE model has potential of improving the financial, environmental, and social performance of the buildings [11].

The global construction industry is vast in size and is projected to reach $17 trillion by 2030 and translates to roughly 6% of total global employment [13] [14]. Quality Assurance (QA) occupies a critical role within the landscape of the construction industry and project management. Quality assurance ensures that the projects meet predefined objectives, satisfy stakeholder expectations, and contribute to organizational success and helps in achieving sustainable project outcomes. Safety, reliability, and compliance with regulations are important throughout the life cycle of a project.

Extensive research has been conducted on the advantages of integrating a circular economy approach into the field of construction. According to Molchanova (2023), the circular economy principles reduce material costs, emissions, optimize design and reduce resource consumption in the construction industry [8]. Benachio et al. (2020) concluded that the adoption of circular

economy model in construction industry reduce the waste generation and resource extraction [9]. Smol et al. (2015) concluded that the circular economy systems promote resource productivity and waste elimination in the construction sector [10]. Ghufran et al. (2022) conducted a literature review and content analysis of existing literature and concluded that implementing CE principles drive innovation, economic growth, and competitiveness in the construction industry [17]. Leva et al. (2020) discussed the role of ICT based decision support tools in supporting circular economy and concluded the circular economy principles can reduce waste in the buildings [18]. Guerra et al. (2021) conducted a global scan of 81 companies implementing circular economy and concluded that construction industry can benefit from adapting circular economy principles [19].

The reuse of building materials in construction can have positive effects on quality assurance. Zihao et al. (2022) determined that integrating CE into project management frameworks has the effect of improving resource efficiency, reducing costs and increasing quality in building renovation. Jagan et al. (2022) determined that CE better guaranteed quality control procedures; the rational use of resources and a total system approach to quality management in construction. Among others Sanchez & Haas (2018) has demonstrated that the application of CE concepts helps to enhance many aspects of quality assurance, from matters such as material selection through waste reduction and project life cycle assessment [11]. On the other hand, Callun et al. (2021) concluded that quality assurance tools and frameworks could be introduced into CE practice to promote material recycling, reuse, and traceability through construction [16].

Numerous research studies have been carried out on measures for integrating the principles of the Circular Economy (CE) into the construction industry, a research gap becomes apparent when examining the specific challenges and opportunities in implementing CE principles for quality assurance in the context of the construction industry in Pakistan. the positive outcomes of CE adoption, such as reduced material costs, emissions, and enhanced resource efficiency, often drawing from studies conducted in diverse global contexts, including developed economies. However, limited attention has been given to the unique challenges and nuances that the construction industry in Pakistan may face in effectively implementing CE principles to ensure quality assurance. A more context-specific understanding of CE implementation and its impact on quality assurance in Pakistan is crucial for tailoring effective recommendations and strategies that align with the socio-economic and environmental characteristics of the local construction sector, addressing this significant research gap. The research objectives of this study are as follows.

1) To identify the barriers and current trends in the integration of Circular Economy (CE) principles into construction industry of Pakistan.
2) To assess the impact of CE principles on quality assurance.
3) To propose recommendations in the implementation of CE for improved quality assurance in construction industry of Pakistan

2. METHODOLOGY

This study aimed to identify the barriers and current trends, impact of circular economy (CE) integration on quality assurance, and stakeholders' perceptions regarding the application of CE

principles for improved quality assurance in the construction industry of Pakistan. To achieve these objectives a questionnaire, with Likert-scale ratings was developed on different aspects of CE implementation and impact on quality assurance.

As depicted in Table 1, the questionnaire utilized in this study comprises three sections. The initial part centers on prevailing trends, stakeholders' perceptions, and awareness levels regarding the integration of the circular economy in Pakistan's construction industry. Questions one through seven evaluate stakeholders' familiarity with circular economy principles, their perceptions of the impact of CE principles on sustainability (e.g., CO2 emissions), the importance they assign to CE principles for resource efficiency, the need for training or educational initiatives on CE principles in the field, the perceived significance of stakeholder awareness and involvement, the potential impact of lack of awareness on the willingness to adopt CE practices, and observations regarding industry perceptions of circular economy principles in recent years.

The second part focuses on the impact of CE principles on quality assurance. Questions eight through fourteen assess stakeholders' evaluations of the impact of CE principles compared to traditional construction methods, specifically exploring areas such as overall project quality and project quality parameters such as the durability and lifespan of building components, efficiency in resource consumption and waste reduction, overall project cost, and the identification and mitigation of risks associated with material performance and availability. Moreover, an examination was conducted on stakeholders' views regarding how the integration of CE influences the perception of project quality among clients, as well as the long-term sustainability of project quality.

The final part of the questionnaire seeks to identify barriers in the integration of CE principles. Five most common barriers were identified by systemic literature review. Questions fifteen through nineteen required stakeholders to rate the identified barriers. These barriers include deviations in product quality, the absence of penalties on illegal dumping, the role of education and awareness, the limited availability of circular materials, and the lack of standardized guidelines for CE integration. These factors are depicted in Table 2. The questionnaire format aligns with the research objectives, allowing for a comprehensive overview of stakeholder perspectives on sustainability, project quality assurance, and impediments encountered during the integration of CE principles within the construction industry of Pakistan.

Table 1: Detail of the parts of questionnaire.

Questionnaire Part	Questions	Focus
1	1-7	To review the current trends, stakeholders' perceptions, and level of awareness about integration of circular economy in the construction industry of Pakistan.
2	8-14	To rate the impact of CE principles on project quality assurance.
3	15-19	To rate the barriers in the integration of CE principles in construction industry of Pakistan.

A survey was conducted with 100 construction professionals (including project managers, contractors, consultants, and clients), and the questionnaire was distributed electronically. Responses included Likert-scale ratings from 1 to 5 (1- Little or no impact to 5- very high impact). The scores of the impact on project quality assurance metrics (Q 8-14) and the barriers in the integration of CE principles in construction industry of Pakistan (Q 15-19) received were statically analyzed. The Relative Importance Index (RII) was calculated to analyze the relative importance of these scores separately for project quality assurance and to rate the barriers. Figure 1 depicts the flowchart of the methodological process.

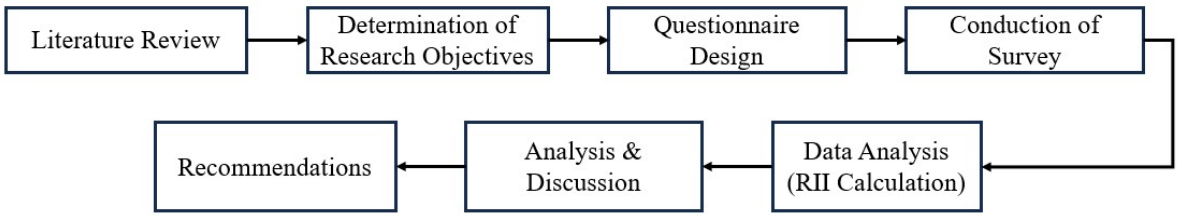

Figure 1: Flowchart of methodology

3. ANALYSIS AND DISCUSSIONS

Mean scores and standard deviations for various factors evaluated in the survey are presented in Table 2, providing insights into stakeholders' perspectives on circular economy principles and their implications for the construction industry. The first three factors focus on stakeholders' familiarity with circular economy principles, the impact of these practices on sustainability, and the perceived importance of integrating these principles for resource efficiency and waste reduction. Stakeholders, on average, reported a moderate level of familiarity (Mean = 4.0) with circular economy principles. This suggests a promising starting point for the integration of circular economy practices in the construction sector. Factors 4 and 5 delve into the educational needs and awareness requirements for stakeholders to effectively adapt to circular economy principles. Stakeholders express a moderate need for training or education (Mean = 3.0). Additionally,

stakeholders underscore the very crucial role of awareness and involvement for the effective implementation of circular economy practices (Mean = 4.0).

Factors 6 to 14 explore stakeholders' perceptions of the impact of circular economy integration on various aspects, including project quality assurance, durability of building components, efficiency in resource consumption, and waste reduction. Overall, stakeholders exhibit positive perceptions, foreseeing slight improvements in project quality assurance (Mean = 4.3) and recognizing the positive impact of recycled or reused materials on building component durability (Mean = 4.4). However, there is a range of opinions regarding the efficiency and cost implications of circular economy integration, as reflected in the diverse standard deviations for Factors 10 and 11.

Factors 15 to 19 assess perceived barriers to circular economy integration in quality assurance. While stakeholders acknowledge deviations in project quality (Mean = 3.8) and lack of penalties on illegal dumping (Mean = 3.4) as potential challenges, the lack of education and awareness is identified as a significant barrier (Mean = 4.5). This underscores the critical role of educational initiatives in overcoming obstacles to circular economy integration in construction. Table 3 provides interpretation of these factors based on mean score obtained. **Error! Reference source not found.** displays the mean scores in bar-chart form.

Table displays the Relative Importance Index (RII) for quality assurance metrics associated with the incorporation of Circular Economy (CE) principles in construction projects. Notably, stakeholders accord a high RII of 0.86 to factors such as the impact of CE integration on project quality assurance and the influence of CE principles on client or end-user perception regarding project quality. These results underscore the stakeholders' views in the positive influence of CE practices on the overall quality and external perception of construction projects. Additionally, the metric examining the impact of recycled or reused materials on the durability of building components receives a RII of 0.87, indicating a unanimous acknowledgment among stakeholders of the positive effect of choosing sustainable materials on quality assurance. While other metrics related to resource efficiency, project cost, and risk management have lower RIIs, they still signify a recognized importance in the context of CE integration on quality assurance.

Stakeholders generally anticipate positive impacts, as seen in the perceived benefits of CE integration on project quality assurance (rated as significantly better), the durability of building components (rated as positive impact), and the identification and mitigation of risks associated with materials performance and availability (rated as positive impact). However, the perception is more neutral when considering the impact on efficiency in resource consumption and waste reduction, as well as overall project cost. The stakeholders recognize a slightly positive influence on client or end-user perception regarding project quality and express a strong belief in the long-term sustainability of projects integrating CE principles, particularly considering environmental and economic factors.

Table delineates the Relative Importance Index (RII) for perceived barriers in Circular Economy (CE) integration within the construction industry of Pakistan. It is noteworthy that stakeholders attribute a substantial RII of 0.90 to the lack of education and awareness as a significant barrier to CE integration. This highlights the importance of knowledge dissemination and educational

initiatives in fostering the adoption of CE principles in the construction sector of Pakistan. Additionally, factors such as deviations in product quality and limited availability of circular materials receive respectable RIIs of 0.76, indicating a shared recognition among stakeholders regarding the challenges associated with maintaining product quality and sourcing sustainable materials. Moreover, the lack of standardized guidelines for CE integration is perceived as a notable barrier, with an RII of 0.67, emphasizing the need for clear and uniform frameworks to facilitate the seamless integration of CE practices in construction projects. Stakeholders express a considerable concern regarding deviations in product quality, emphasizing the need for stringent quality control measures for materials sourced through circular practices. Interestingly, stakeholders are neutral on the lack of penalties for illegal dumping, suggesting an opportunity to strengthen regulatory frameworks. However, the consensus on the very strong barrier of lack of education and awareness underscores the urgent need for targeted educational programs. Additionally, the perceived barriers of limited availability of circular materials signal the importance of promoting sustainable sourcing practices, while the neutral stance on standardized guidelines indicates a potential avenue for developing clear frameworks to streamline CE integration in construction projects. In essence, addressing these insights can significantly contribute to overcoming barriers and fostering successful CE adoption in the construction sector.

Table 2: Factors and statistical calculations

Question	Description	Mean	Std. Dev
1	Familiarity of stakeholders with circular economy principles	4.0	0.80
2	Impact of circular economy practices on sustainability	4.0	0.82
3	Importance of integrating circular economy principles for resource efficiency and minimizing waste	4.0	0.81
4	Need of training or education for stakeholders to adapt CE principles	3.0	0.82
5	Importance of stakeholder awareness and involvement for successful CE implementation	4.0	0.62
6	Influence of lack of awareness about CE on willingness to adopt circular economy practices	4.1	1.20
7	Observing stakeholders' observations on shifts in industry perceptions/trends regarding circular economy	3.2	0.70
8	Impact of CE integration on project quality assurance	4.3	0.75
9	Impact of recycled or reused materials on durability of building components	4.4	0.48
10	Impact of integrating CE principles on efficiency in resource consumption and waste reduction	3.4	1.10
11	Impact of implementing CE principles on overall project cost	3.2	0.42
12	Impact on identification and mitigation of risks associated with materials performance and availability	3.6	0.77
13	Influence of implementing CE principles on client or end-user perception regarding project quality	4.3	0.94
14	Stakeholders' perception of long-term sustainability when integrating CE principles considering environmental and economic factors	3.7	1.11
15	Deviations in product quality as a barrier to CE integration	3.8	0.38
16	Lack of penalties on illegal dumping as a barrier to CE integration	3.4	1.08
17	Lack of education and awareness as a barrier to CE integration	4.5	0.75
18	Limited availability of circular materials as a barrier to CE integration	3.8	0.38
19	Lack of standardized guidelines for CE integration as a barrier to CE integration	3.4	0.77

Table 3: Relative importance index (RII) for quality assurance metrics

Factor No	Description	RII	Stakeholders' Perception
8	Impact of CE integration on project quality assurance	0.86	Significantly better
9	Impact of recycled or reused materials on durability of building components	0.87	Positive Impact
10	Impact of integrating CE principles on efficiency in resource consumption and waste reduction	0.68	Neutral
11	Impact of implementing CE principles on overall project cost	0.63	Neutral
12	Impact on identification and mitigation of risks associated with materials performance and availability	0.73	Positive Impact
13	Influence of implementing CE principles on client or end-user perception regarding project quality	0.86	Slightly positive impact
14	Stakeholders' perception of long-term sustainability when integrating CE principles considering environmental and economic factors	0.75	Very sustainable

Table 4: Relative importance index (RII) for perceived barriers in CE integration in construction industry of Pakistan

Factor No	Description	RII	Stakeholders' Perceptions
15	Deviations in product quality as a barrier to CE integration	0.76	Significant Barrier
16	Lack of penalties on illegal dumping as a barrier to CE integration	0.68	Neutral
17	Lack of education and awareness as a barrier to CE integration	0.90	Very strong barrier
18	Limited availability of circular materials as a barrier to CE integration	0.76	Significant Barrier
19	Lack of standardized guidelines for CE integration as a barrier to CE integration	0.67	Neutral

Table 3: Interpretation of factors based on mean score.

Factor No.	Description	Factor Interpretation
1	Familiarity of stakeholders with circular economy principles	Familiar
2	Impact of circular economy practices on sustainability	Slightly positive impact
3	Importance of integrating circular economy principles for resource efficiency and minimizing waste	Important
4	Need of training or education for stakeholders to adapt CE principles	Moderate need
5	Importance of stakeholder awareness and involvement for successful CE implementation	Very crucial
6	Influence of lack of awareness about CE on willingness to adopt circular economy practices	Significant Influence
7	Observing stakeholders' observations on shifts in industry perceptions/trends regarding circular economy	Moderate shift
8	Impact of CE integration on project quality assurance	Slightly better
9	Impact of recycled or reused materials on durability of building components	Positive Impact
10	Impact of integrating CE principles on efficiency in resource consumption and waste reduction	Neutral
11	Impact of implementing CE principles on overall project cost	Neutral
12	Impact on identification and mitigation of risks associated with materials performance and availability	Positive Impact
13	Influence of implementing CE principles on client or end-user perception regarding project quality	Slightly positive impact
14	Stakeholders' perception of long-term sustainability when integrating CE principles considering environmental and economic factors	Very sustainable
15	Deviations in product quality as a barrier to CE integration	Significant Barrier
16	Lack of penalties on illegal dumping as a barrier to CE integration	Neutral
17	Lack of education and awareness as a barrier to CE integration	Very strong barrier
18	Limited availability of circular materials as a barrier to CE integration	Significant Barrier
19	Lack of standardized guidelines for CE integration as a barrier to CE integration	Neutral

4. RECOMMENDATIONS

Considering the comprehensive analysis conducted on stakeholders' perceptions, awareness, perceived barriers, and the relative importance index (RII) in the context of Circular Economy (CE) integration on quality assurance within the construction industry of Pakistan, several key recommendations emerge to facilitate a more effective adoption of CE principles construction industry of Pakistan:

Enhanced Quality Control Measures for Recycled Materials: To address concerns related to product quality (RII of 0.76), it is crucial to implement enhanced quality control measures. This involves developing standardized testing protocols to ensure that these materials meet or exceed industry quality standards.

Collaborative Development of Quality Assurance Standards: Industry stakeholders such as the government, construction, and material suppliers, should collaboratively work to develop comprehensive quality assurance standards for materials derived from circular practices.

Training Programs on Quality Assurance Best Practices & CE Principles: Thus, acknowledging education and awareness (RII = 0.82), it is necessary to organize specialized training for specific groups of interested persons to study quality assurance and CE principles.

Integration of Advanced Technologies in Quality Assurance: Embracing advanced technologies such as blockchain, sensors, and data analytics can significantly enhance the tracking and monitoring of material quality throughout the construction supply chain.

Promotion of Sustainable Material Sources: The high RII (0.76) for inaccessibility (limited availability) to circular materials highlights the importance of encouraging sustainable sourcing practices.

Financial Incentives and Policy Support: To actively promote CE, governments and related agencies should consider providing financial incentives such as tax breaks, subsidies, incentives for businesses and limitations on government projects.

Long-Term Sustainability Assessment: Given the positive perception of long-term sustainability (RII of 0.75), long-term sustainability evaluations should be included in project evaluations. This means not just looking at short-term economic calculations, but at long-term environmental and social impact of the principles of CE.

5. CONCLUSION

The research aimed to identify barriers and current trends, the impact of Circular Economy (CE) integration on quality assurance, and stakeholders' perceptions in the construction industry of Pakistan. The survey was conducted with 100 construction professionals using the questionnaire. The Likert-scale ratings obtained from the questionnaire were then statistically analyzed, and the Relative Importance Index (RII) was calculated to assess the relative importance of the scores for project quality assurance and perceived barriers. These barriers included deviations in product quality, lack of penalties on illegal dumping, limited availability of circular materials, lack of

standardized guidelines, and most significantly, the lack of education and awareness, which were identified by a systematic review of the existing literature. The Relative Importance Index (RII) analysis showed that the stakeholders highly value factors such as the influence of CE integration upon project quality assurance (RII of 0.86) and quality assurance metrics such as the influence of recycled or reused material content upon the durability of building components (RII of 0.87). Stakeholders acknowledged that CE integration can have significant improvement in overall project quality assurance, will have positive impact on durability and long-term sustainability of the construction components. These high RII values define the significance of ensuring quality control measures for recycled materials to uphold construction standards and guarantee the quality assurance. Recommendations for integration of CE include to improve quality assurance include the development of enhanced quality control measures, collaborative efforts to establish comprehensive quality assurance protocols, and the integration of advanced technologies for real-time monitoring of material quality throughout the construction process. Furthermore, the recommendations highlight the necessity of educational initiatives and awareness programs focused on quality assurance best practices in a circular economy context. By emphasizing the integration of circular design principles and the promotion of sustainable material sources, stakeholders can proactively address potential quality issues from the design phase onward, ensuring the compatibility and durability of materials.

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