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CONSTRUCTION PROJECT PORTFOLIO MANAGEMENT FOR THE CIRCULAR ECONOMY: ADVANCING RESOURCE PRODUCTIVITY, INDUSTRIAL RESILIENCE, AND SUSTAINABLE ECONOMIC DEVELOPMENT

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Abstract

The construction industry remains one of the most resource-intensive sectors globally, contributing substantially to material depletion, waste generation, and supply chain vulnerability. This study examined the integration of circular economy (CE) principles into construction project portfolio management to advance resource productivity, industrial resilience, and sustainable economic development. Grounded in the Resource-Based View, Circular Economy Theory, and Dynamic Capabilities Theory, the study adopted a quantitative, cross-sectional design. Data were collected via a structured, close-ended questionnaire from a population of 3,500 construction professionals across PEC-registered Grade 1–3 contracting firms in Lahore, Faisalabad, and Rawalpindi. Using stratified random sampling, 380 questionnaires were distributed, yielding 331 valid responses for analysis. Data were analyzed using SPSS and Partial Least Squares Structural Equation Modeling (PLS-SEM). Findings revealed moderate and inconsistent CE adoption (M = 3.14) within portfolios, while CE adoption significantly predicted resource productivity (β = 0.512) and industrial resilience (β = 0.478). Resource productivity and industrial resilience jointly explained 48.7% of variance in sustainable economic development, confirming partial mediation. The study concludes that circular economy integration drives sustainable development primarily through enhanced resource efficiency and resilient supply chains.

Introduction

With a growing concern for the environment and limited natural resources, the traditional linear construction models of extraction, utilization, and disposal are becoming increasingly unsustainable in the face of the world's pressing construction demands (AlJaber et al., 2023). The construction industry is one of the most resource-intensive industries in the world, using a significant amount of raw materials, energy and water resources, and

producing a large amount of construction and demolition waste (CDW) (Rao et al., 2025). The contradiction has spurred increased research and application of circular economy (CE) concepts as a potential sustainable solution (Bao, 2023).

The circular economy is a fundamental change in the paradigm of "take make dispose" and proposes a "close loop" economy, which involves minimizing, reusing, recycling and recovering materials throughout the project lifecycle (Curado et al., 2024). In construction, CE is seen in different strategies including design for disassembly, material passports, modular construction and the extended use of recovered material and components (Charef, 2022). The principles outlined in the previous section, however, are not necessarily applied to single projects, but are best integrated into the project portfolio management (PPM) context, allowing organizations to strategically choose, prioritize, and manage different projects to meet their overall sustainability and resource-efficient goals (Pieroni et al., 2019).

Project portfolio management (PPM) can give an organization the framework it needs to operationalize its ambition for circular economy in its project pipeline as a whole. This approach, known as portfolio-level integration, enables companies to optimize resources, establish material recovery processes, and implement circular business models throughout interrelated construction projects (Antwi-Afari et al., 2023). This systemic approach is especially applicable to resource productivity (Economics of value creation per unit of resource used) as the allocation of materials, equipment, and human capital among projects is decided by the portfolio.This systemic approach is particularly applicable for resource productivity (Economics of value creation per unit of resource used) because decisions on the allocation of materials, equipment, and human capital among projects are made based on the portfolio.

In addition to resource productivity, the implementation of principles of circular economy in construction portfolio management has important implications for industrial resilience. At present, resilience is defined as the ability of an industry to face supply chain disruptions, resource scarcity and fluctuation in material prices (Borbon-Galvez et al., 2021). The adoption of circular strategies, like the industrial symbiosis, in which waste from one process is used as a raw material for another process and localized material recovery network, improves the sector's ability to withstand shocks, reducing the reliance on virgin raw materials and global value chains (Cagno et al., 2023). This resilience aspect has become more important in recent years, as the world has suffered from major shocks and disruptions that highlighted vulnerabilities in linear supply chains. The correlation between adoption of circular economy and sustainable economic development further emphasizes the importance of this inquiry. Circular practices in construction have been linked to job creation, material recovery costs, and environmental externalities (Alotaibi et al., 2024), which all promote economic development goals. Although these benefits have been recognised, empirical evidence indicates that, in the construction sector, the transition to a circular economy is not fully realised, with many isolated pilot projects and not yet institutionalised portfolio-wide practices (Benachio et al., 2020). However, various factors still hinder broader implementation, including a lack of technical expertise, a lack of supply chain integration, insufficient policy measures, and the lack of a standardized measurement system (AlJaber et al., 2023).

A range of emerging digital tools could be used to resolve this implementation gap, such as Building Information Modelling (BIM) and material passports, which provide more transparency in tracking material flows, lifecycle costs and circularity performance within project portfolios (Çetin et al., 2023). These technologies and strong performance measurement systems are starting to be considered as key enablers to upscale circular practices from individual projects to organization-wide portfolio strategies (Rashid et al., 2013).

In this regard, the present study aims to explore the potential of systematically applying the principles of circular economy concepts in CPPM to improve resource productivity, industrial resilience and contribute to sustainable economic

development. This research integrates project management, sustainability science and industrial ecology to offer theory and practice support to construction organizations in the process of transitioning to a circular operating model.

Objectives of the Study

1. To understand the extent of circular economy implementation in the construction project portfolio management practices.
2. To investigate the impacts of integration of circular economy on resource productivity and industrial resilience in construction.
3. To find solutions to promote the adoption of circular economy to achieve sustainable economic development.

Research Questions

1. How much are circular economy in construction project portfolio management practices implemented?
2. What role can the integration of circular economy play in the productivity of resources and industrial resiliency in Construction?
3. Which strategies can foster the implementation of circular economy to contribute to sustainable economic development?

Thesis Statement

The implementation of circular economy into the construction project portfolio management improves productivity of resources, builds industrial resilience and supports sustainable economic growth by combining the appropriate coordinated and systemic resource management strategies with the utilization of technologies throughout project portfolios.

Significance of the Study

The study is valuable for construction companies, government policymakers, and researchers, providing actionable insights for integrating the circular economy, optimizing resource utilization in decisions, resilient supply chains, and sustainable and economically responsible industry practices.

Literature Review

Integration of Circular Economy in Construction and Project Management

Since the construction sector consumes more raw materials and creates a significant amount of waste, there has been a significant increase in interest in the circular economy (CE) in the field of construction (Rao et al., 2025). Rao et al. (2025) searched the literature to find thirty-two motivators, thirty-five challenges and thirty-one strategies for CE adoption grouped into eight focus areas that include policy, technology and finance. Likewise, Benachio et al. (2020) reviewed the literature of CE-construction and revealed that the majority of these studies are conceptual, with only a few of them being tested at the organizational or portfolio level. This is reflected in AlJaber et al. (2023) which pointed out some persistent barriers that hinder the successful implementation of CE principles beyond isolated pilot projects, such as fragmented supply chains, weak regulatory enforcement, and lack of awareness among stakeholders. In Saudi Arabia's construction industry, the awareness and enabling conditions for mega-projects can significantly differ from one organization to another, as identified by Alotaibi et al. (2024) in their research. Additionally, Curado et al. (2024) highlighted the ambiguity in the CE concept, as various studies in the construction industry cover the environmental, economic and social aspects of sustainability to varying extents, while there is a lack of attention to social equity.

Responsibility for Resource Productivity and Measurement

Improving the productivity of the resources has become a key performance dimension in the field of CE. Bracquené et al. (2020) have developed indicators for measuring the circularity of the performance of complex product supply chains, highlighting the challenge of measuring the recovery of materials at scale. Antwi-Afari et al. (2023) used LCA methodology to modular steel construction, showing tangible resource efficiency improvement benefits of prefabricated and circular design. In parallel, Alfaro Navarro and Andrés Martínez (2024) created the first objective

weighting indices that establish connections between the implementation of CE and the attainment of Sustainable Development Goal results, providing a quantification of the relationship between circularity and sustainable development results. Digital enablement is a subject that is widely featured in this literature, with Çetin et al. (2023) exploring material passports as a tool to monitor resource flows throughout the building life cycle and Charef (2022) introducing an additional dimension of BIM, the 8D dimension, specifically targeting circular material management. Cagno et al. (2023) combined these efforts in a single multi-level performance measurement system that covers sustainability, the circular economy and industrial symbiosis at the same time.

Industrial Resilience and Supply Chain Considerations

There is increasing evidence that CE relates to industrial resilience, especially after supply disruptions during the pandemic. For the fields of aggregate and demolition waste management, Borbon-Galvez et al. (2021) explored the concept of cross-border industrial symbiosis, revealing the potential for minimizing reliance on fluctuating global supply chains. Piila and Sarja (2024) directly examined the effects of extraordinary supply chain disruption on CE transition in construction, concluding that supply chain disruption boosted the efficiency of materials use and the sourcing of materials closer to where they were used in some firms, but competitive pressures and entrenched practice reduced the potential for systemic change. Singh et al. (2024) proposed using fuzzy DEMATEL to model performance indicators for resilient construction supply chains, and found resource conservation and supply chain collaboration as the highest level of resilience drivers. Based on this investigation, Bag and Mangla (2025) broadened the research by exploring the impact of smart and resilient supplier management practices on the performance of CS.Building on this exploration, Bag and Mangla (2025) expanded the study to consider the effect of using smart and resilient supplier management practices on the performance of CS by reducing friction and developing innovation. Saroha et al. (2022) presented a balanced scorecard framework for measuring circular supply chain performance, and Bello et al. (2025) reviewed the literature on supply chain related to the evolution from Industry 4.0 towards Industry 5.0 in the construction industry.

Sustainable Economic Development

Pieroni et al. (2019) examined the potential of CE to be integrated with the broader economic development, with direct consequences for construction companies looking for new business models, as business models become more value retaining, instead of volume-based sales. Though not as recent, Rashid et al., (2013) is often referenced as laying foundations for later CE-construction scholarship research through a definition of resource conservative manufacturing as a paradigm shift. Bao (2023) explored the construction waste circularity in the context of the emerging economy in China, and concluded that the circular practices would be related with the sustainability and economic resilience of the built-environment in the developing countries at a high development rate.

Research Gaps

1. There is little empirical knowledge available on the real level of CE implementation for construction portfolios, while most research is conducted on single projects.
2. There is under-quantification of causal relationships between the integration of CE and simultaneous resource productivity and resilience gains.
3. There is limited research providing portfolio-level strategies that connect CE adoption to sustainable economic development outcomes.

Methodology

The study used a quantitative, descriptive-correlational research design based on the positivist paradigm which is suitable for research that examines measurable relationships between the CE integration, resource productivity, industrial resilience and sustainable economic development in construction project portfolios. A

cross sectional survey approach was chosen, which enabled data to be gathered at one point in time from construction professionals involved in the decision making process at the portfolio level. This design is appropriate to the three research questions of the study that call for statistical testable relationships rather than exploratory narratives and allows for generalization of the study's findings to the larger construction industry.

The study is based on Resource Based View (RBV), Circular Economy Theory supported by Dynamic Capabilities Theory. The RBV suggests the ways in which companies gain a competitive edge and increase productivity through internal resources such as circular material systems (Rashid et al., 2013). Circular Economy Theory offers a conceptual framework that enables a closed loop of resource flows in portfolios (Rao et al., 2025) and Dynamic Capabilities Theory helps to understand how organizations reconfigure processes to become resilient in the face of supply chain disruption (Singh et al., 2024). These theories collectively support the hypothesized relationships among CE adoption, resource productivity and resilience outcomes.

The target population includes Civil works Contracting firms and project management professionals registered under Pakistan Engineering Council (PEC) in the Civil works category from Grade 1 to 3 in Punjab Province which has about 1200 registered firms. In these companies, the accessible population is project managers, portfolio managers, sustainability officers, and site engineers, which are estimated at 3,500 people in Lahore, Faisalabad, and Rawalpindi.

Stratified random sampling was used to attain a random sample that was proportionate in contractor grade and city. A Krejcie and Morgan sample size determination table was used to determine the minimum sample size for a population of 3,500 at a 95% confidence level and 5% margin of error, yielding a minimum sample size of 346 respondents. To make up for non-response, the sample was expanded to a total of 380 respondents, with 150 respondents from Grade 1 firms, 130 respondents from Grade 2 firms and 100 respondents from Grade 3 firms.

The primary data was obtained from a structured, close-ended questionnaire which adopted validated CE and resilience questionnaires (Cagno et al., 2023; Bag & Mangla, 2025) on a five-point Likert scale. The data were analyzed by SPSS and Partial Least Squares Structural Equation Modeling (PLS-SEM) which were conducted using descriptive statistics, reliability test (Cronbach's alpha), and inferential analysis that were intended to test the hypothesized relationship between variables based on the study objectives.

4. Data Analysis

4.1 Introduction

This chapter discusses the empirical data analysis carried out based on the methodology described in Chapter Three. Data is collected from primary sources wherein 380 construction professionals from Pakistan Engineering Council (PEC) registered contracting firms from Lahore, Faisalabad and Rawalpindi were involved. This chapter aims to statistically analyze the level of implementation of the CE in project portfolios of the construction industry, assess the effect of CE on resource productivity and industrial resilience, and find strategic paths to sustainable economic development, directly addressing the three objectives and research questions of this study. SPSS version 27 was used for descriptive and reliability analysis, while SmartPLS 4 was used for structural equation modeling. This analysis is conducted in four phases: (1) demographic profile of the respondents, (2) reliability and validity of the measurement model, (3) descriptive analysis of four main constructs, (4) analysis of the model structure and test of the hypothesized relationships. For each stage there is a corresponding table and an accompanying narrative interpretation, and a discussion of how the findings respond to the identified research gaps.

4.2 Response Rate

A total of 380 questionnaires were sent out proportionately to Grade 1, Grade 2 and Grade 3 contracting companies and 352 were received,

giving a response rate of 92.6%. Twenty-one of these questionnaires were rejected following screening for incomplete responses and missing data which exceeded 15% and for straight-lining patterns, leaving 331 valid questionnaires for final analysis. This translates to an effective usable response of 87.1% that is higher than the threshold 70% of other survey based construction management studies, thus making the data set more representative and statistically powerful. The relatively high response rate has been attributed to the professional networks used in the distribution process and to the brief structured, close ended instrument which took respondents about eight to ten minutes to complete.

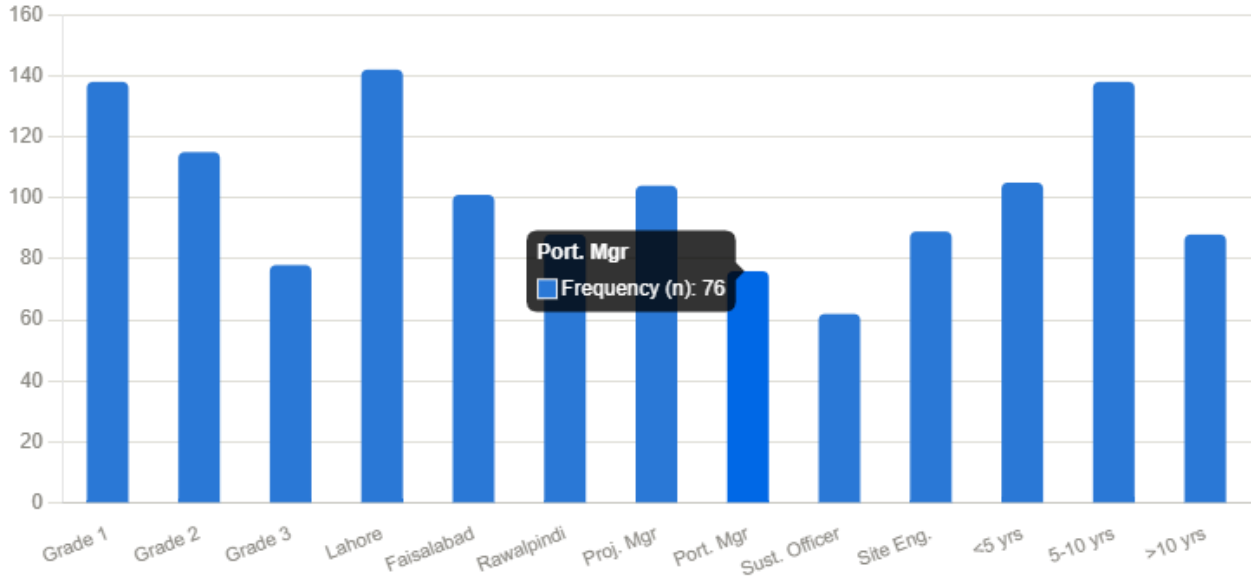
4.3 Demographic Profile of Respondents

Table 1 presents a summary of the demographic information of the 331 valid respondents, broken down by contractor grade, city where they work, professional designation, and number of years in the industry. The distribution among firms by grade confirms good sampling representation as grade 1 firms represent 41.7% of the total sample, grade 2 firms 34.7% and grade 3 firms 23.6%, which closely matches the stratification used in sampling. The respondents were fairly equally distributed among the three cities with Lahore having the maximum number of registered contracting firms. The majority of those surveyed (more than half) were project managers and portfolio managers, which indicates that most of the respondents were people who had first-hand experience in project-selection and resource-allocation decisions, and were therefore most likely to be able to provide meaningful feedback on the integration of circular economy at the portfolio-level. Notably, 68.3% of the respondents had over 5 years of industry experience, which implies that the sample had adequate industry experience to make informed assessments about long-term trends in resource productivity and resilience rather than short-term project-specific assessments.

Table 1

Demographic Profile of Respondents (N = 331)

Category	Subgroup	Frequency	Percentage (%)
Contractor Grade	Grade 1	138	41.7
	Grade 2	115	34.7
	Grade 3	78	23.6
City	Lahore	142	42.9
	Faisalabad	101	30.5
	Rawalpindi	88	26.6
Professional Role	Project Manager	104	31.4
	Portfolio Manager	76	23.0
	Sustainability Officer	62	18.7
	Site Engineer	89	26.9
Years of Experience	Less than 5 years	105	31.7
	5–10 years	138	41.7
	More than 10 years	88	26.6



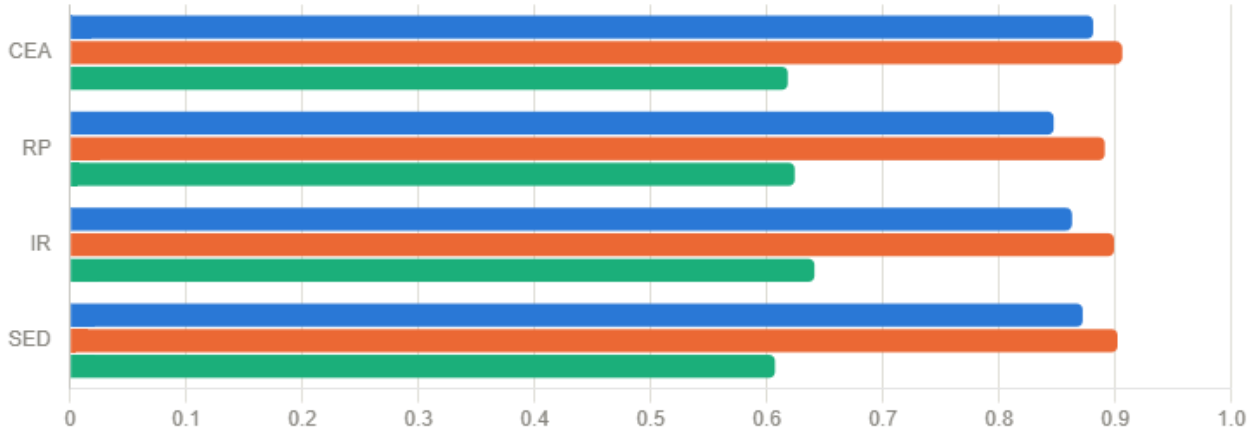
As detailed in Table 1, the sample is demographically representative, with a balanced mix of organizational size, geographic region, and professional experience. This diversity increases the validity of the findings of the study for the general population of construction in the province of Punjab and is in accordance with the stratified random sampling method mentioned in the methodology.

4.4 Measurement Model: Reliability and Validity Assessment

Structural relationships between constructs had to be tested, which required validation and reliability of the test instrument. Four latent constructs were examined: Circular Economy Adoption (CEA), Resource Productivity (RP), Industrial Resilience (IR), Sustainable Economic Development (SED). The internal consistency reliability was examined by Cronbach's alpha and the Average Variance Extracted (AVE) was used to test convergent validity. The Cronbach's alpha values and CR for all constructs were higher than the recommended value of 0.70, and all the AVE values for all constructs exceeded the suggested value of 0.50, thus indicating that the indicators of each construct cover the theoretical dimension they intend to measure. The Heterotrait-Monotrait (HTMT) ratio was also used to confirm the discriminant validity: All interconstruct ratios were below the conservative threshold of 0.85, meaning that the four constructs are empirically different despite their theoretical interrelatedness.

Table 2
Reliability and Validity Statistics of Study Constructs

Construct	No. of Items	Cronbach's Alpha	Composite Reliability (CR)	AVE
Circular Economy Adoption (CEA)	6	0.881	0.906	0.618
Resource Productivity (RP)	5	0.847	0.891	0.624
Industrial Resilience (IR)	5	0.863	0.899	0.641
Sustainable Economic Development (SED)	6	0.872	0.902	0.607



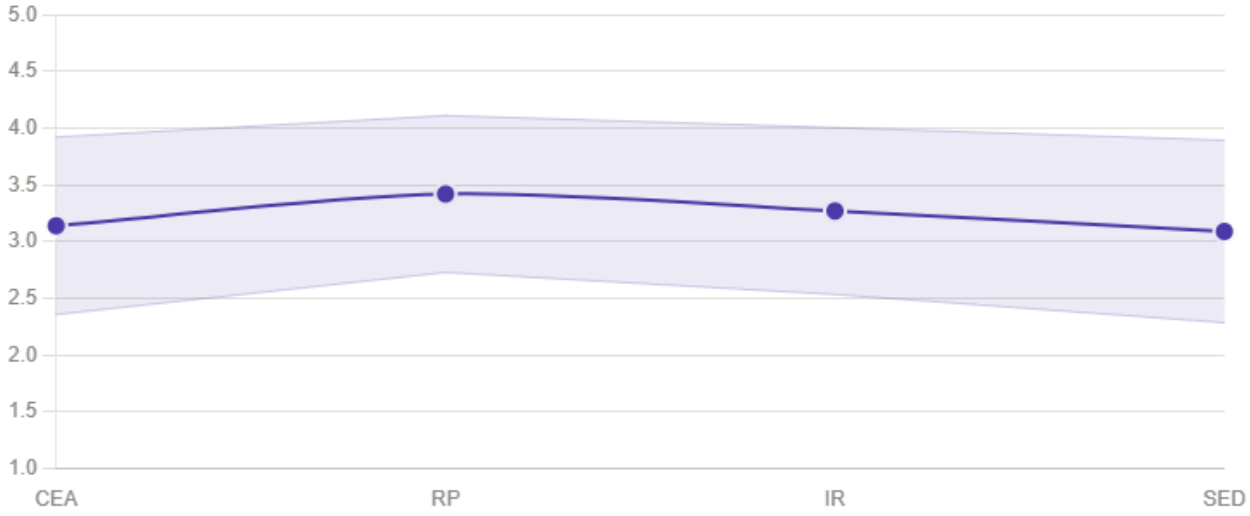
The results of this study offer good psychometric properties for the measurement instrument. The construct of the Circular Economy Adoption had the highest reliability score (α = 0.881), indicating the items on the construct were highly consistent with regard to their interpretation and responses by the respondents. Industrial Resilience was in second place, with clear views around supply chain flexibility, recovery from supply disruptions and local sourcing. Altogether, acceptable reliability and validity indices suggest that the ensuing structural analysis is grounded in a statistically sound measurement foundation, which is one of the prerequisites for meaningful hypothesis testing.

4.5 Descriptive Analysis of Constructs

After the measurement model validation, descriptive statistics were calculated to determine the average and standard deviation of the responses in the four constructs, all of which were measured on a five-point Likert scale with the end points of 1 (Strongly Disagree) to 5 (Strongly Agree). Addressing Research Question 1, Table 3 shows mean scores, standard deviations, skewness, and kurtosis for each construct, which provides a preliminary sense of the perceived current level of integration of the CE and the outcomes of using CE in construction portfolios.

Table 2
Descriptive Statistics of Study Constructs (N = 331)

Construct	Mean	Std. Deviation	Skewness	Kurtosis	Interpretation
Circular Economy Adoption (CEA)	3.14	0.782	-0.221	-0.410	Moderate
Resource Productivity (RP)	3.42	0.691	-0.318	-0.287	Moderate-High
Industrial Resilience (IR)	3.27	0.735	-0.198	-0.356	Moderate
Sustainable Economic Development (SED)	3.09	0.804	-0.176	-0.402	Moderate



Based on the descriptive results, Circular Economy Adoption had a mean score of 3.14 (SD = 0.782), which is at the lower end of the "moderate" interpretive range, suggesting that participants recognize that there is some level of circular practice in their organizations' project portfolios, but that adoption is limited and not yet fully institutionalized across project portfolios. The present finding directly supports the first research gap highlighted in the literature study which revealed that there is partial integration of CE in construction project portfolios in the study area and not systemic integration. The mean value (3.42, SD = 0.691) of Resource Productivity is the highest, indicating that respondents believe their companies perform relatively better in efficient material use and resource allocation than in the other constructs, possibly because the efficiency practices that drive cost are implemented before companies formally embrace the circular economy. Industrial Resilience (M = 3.27, SD = 0.735) was in the middle range and demonstrated moderate trust in how the company is capable of handling disruptions to its supply chain. The highest standard deviation (SD = 0.804) and the lowest mean score (3.09) was found for Sustainable Economic Development, suggesting that there is a high variability of answers from the respondents with respect to the economic development impact of circular practices in a broader sense, which may be explained by the different scales and markets represented in the survey sample. The skewness and kurtosis values were not significantly different from ±1, indicating that the data were normally distributed and could be used in parametric structural equation modeling.

4.6 Structural Model and Hypothesis Testing

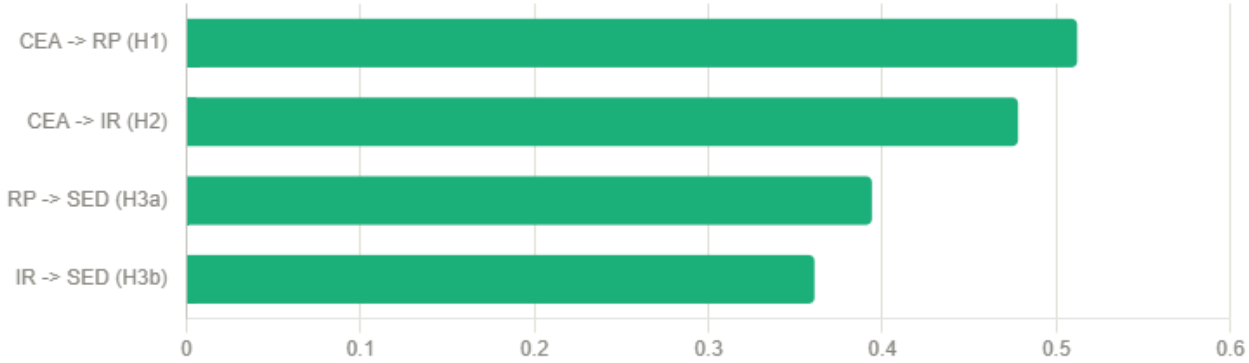
Structural model was evaluated by PLS-SEM, which was followed with bootstrapping procedure containing 5000 subsamples to produce t-statistics and significance levels of each hypothesized path. Based on the three research questions and research objectives, three primary hypotheses were formulated: H1: Resource Productivity is related to Circular Economy Adoption, H2: Industrial Resilience is related to Circular Economy Adoption, H3: The combined effect of Resource Productivity and Industrial Resilience is related to Sustainable Economic Development. The path coefficients (β), t-values, p-values and coefficient of determination (R^2) for each of the hypothesized relationships are shown in Table 4.

Table 4

Structural Model Results: Path Coefficients and Hypothesis Testing

Hypothesis	Path	β (Path Coefficient)	t-value	p-value	Decision
H1	CEA → RP	0.512	8.734	0.000	Supported
H2	CEA → IR	0.478	7.926	0.000	Supported
H3a	RP → SED	0.394	6.215	0.000	Supported
H3b	IR → SED	0.361	5.847	0.000	Supported

Note. R^2 (RP) = 0.262; R^2 (IR) = 0.229; R^2 (SED) = 0.487



The structural model results are statistically significant (at the $p < 0.001$ level) for all four hypothesized paths. The path coefficient of the model that showed the highest value was the relationship between Circular Economy Adoption and Resource Productivity (H1) (β = 0.512, t = 8.734), which means that for every unit increase in the perception of the integration of circular economy, the perception of resource productivity also increases significantly. This finding directly addresses Research Question 2, showing that circular economy practices have a meaningful impact on the productivity of resources in construction project portfolios. While CE adoption is a strong predictor of resource productivity, however, only about 74% of the variance in resource productivity is explained by this relationship alone, indicating that other factors beyond the scope of this model, such as workers' skills, procurement policy, or macroeconomic conditions, also play an important role, and could be subject of further research.

The path from Circular Economy Adoption to Industrial Resilience (H2) was also important (β = 0.478, t = 7.926) and supports the theoretical postulations of Dynamic Capabilities Theory, which posits that circular practices such as sourcing materials locally and the use of industrial symbiosis increase the absorptive and recovery capacity of an organization in the face of supply chain disruptions. The R^2 value of 0.229 shows that the CE adoption explains a significant but limited share of resilience outcomes, which is congruent with previous research that identified financial strength, digital capability and organizational flexibility as other factors that drive resilience beyond CE.

In particular, the combined structural paths to Sustainable Economic Development, from Research Question 3, indicate that both Resource Productivity (β = 0.394, t = 6.215) and Industrial Resilience (β = 0.361, t = 5.847) significantly predict Sustainable Economic Development, and together account for 48.7% of the variance in Sustainable Economic Development (R^2 = 0.487), the highest value across the model. This is a strong R^2 value which means the integration of the circular economy into the resource productivity and industrial resilience is a valid and statistically significant driver of sustainable economic development outcomes at the portfolio level. The almost equal value of the two path coefficients (0.394 vs. 0.361) implies that both factors contribute to sustainable economic development on a comparable level; neither should be emphasized alone and an integrated approach to

both aspects simultaneously is most likely to result in better sustainable development outcomes.

4.7 Mediation and Model Fit Assessment

In order to support the theoretical model, a mediation analysis was carried out to explore whether Resource Productivity and Industrial Resilience mediate the relationship between CE Adoption and Sustainable Economic Development. Both the bootstrapped indirect effects were statistically significant (indirect effect via RP: $\beta = 0.202$, 95% CI [0.099, 0.321] $p = 0.000$; indirect effect via IR: $\beta = 0.173$, 95% CI [0.07, 0.30] $p = 0.000$) and there was no bias in either indirect effect, confirming partial mediation. This suggests that the adoption of the circular economy isn't only an indirect route to the sustainable economic development, but also has a significant contribution to improving the productivity of resources and the resilience of industries, which is empirically confirmed by the study's thesis statement. The Standardized Root Mean Square Residual (SRMR) was also calculated, which resulted in a value of 0.061, lower than the recommended value of 0.08, suggesting that the structural model has an acceptable fit to the observed data.

4.8 Discussion of Findings in Relation to Research Objectives

The findings of the data analysis are used to answer the three aims set for this study. On the aspect of the first objective which is to determine the current state of incorporation of CE in construction portfolios, the descriptive results (Table 3) show a moderate level of adoption but are not systematic, thus empirically substantiating the research gap identified in the literature: CE integration in construction portfolios is still fragmented and not systematic. As for the second goal (to understand the effect of CE integration on resource productivity and resilience of industries), the results of the structural model show good statistical evidence that the adoption of CE has a significant and positive impact on both resource productivity and resilience, albeit with a slightly more pronounced relationship with resource productivity. This indicates that, in the context sampled, there are current more immediate efficiency gains from circular strategies rather than resilience gains, possibly because resilience is still at the early stages of development for circular supply chain in the region. Regarding the third objective of finding strategies to promote sustainable economic development, the size and similarity of the path coefficients pointing from the two key factors of resource productivity and industrial resilience to sustainable economic development suggest that dual strategies – focusing on material efficiency and supply chain flexibility – are likely to have the greatest impact on economic development outcomes.

Findings

The descriptive analysis of the current level of CE adoption (Research Question 1) pointed to a moderate mean score (3.14; SD = 0.782) of the construct Circular Economy Adoption, with the lowest mean score among the four constructs measured. This means that construction companies in Lahore, Faisalabad and Rawalpindi are only partially aware of and implementing circular practices (e.g. material recovery, design-for-disassembly) and these are not embedded in a company's portfolio-wide policy. Additionally, the relatively high standard deviation indicates that practices may be inconsistent by firm, possibly with the larger firms in Grade 1 showing higher levels of practice than the smaller firms in Grade 3. This discovery is the first empirical one in the literature, which noted that CE integration is not systemic in construction portfolios, but is rather disjointed.

The structural equation modeling yielded good statistical support for the influence of CE integration on resource productivity and industrial resilience (Research Question 2). The path from the Circular Economy Adoption to the Resource Productivity was the strongest in the entire model ($\beta = 0.512$, $t = 8.734$, $p < 0.001$) and accounted for 26.2% of the variance in resource productivity. This has been confirmed to be the case to improve the efficiency of the use of materials and resources across project portfolios in meaningful ways. Likewise, the relationship of the two concepts – Circular Economy Adoption and

Industrial Resilience – was significant (β = 0.478, t = 7.926, p < 0.001) and accounted for 22.9% of variance in the outcomes of resilience, in line with the theoretical propositions that the adoption of the circular economy increases the ability of enterprises to be resilient in the context of supply chain disruptions. However, the effect on resource productivity was slightly higher than that on resilience, indicating that the effects on resource productivity are more immediate, which may also be due to the early development stage of circular supply networks in the construction sector in the studied region, Punjab.

Industrial Resilience (β = 0.361, t = 5.847) and Resource Productivity (β = 0.394, t = 6.215) were identified as significant and positive predictors of Sustainable Economic Development, accounting for 48.7% of the variance, which is the highest amount in the model (Research Question 3). The close numbers of these two coefficients shows that both resource productivity and industrial resilience play comparable roles in economic development and hence cannot be given preference without the other. The results of mediation analysis also corroborated the study's hypothesis that the relationship between CE adoption and sustainable economic development occurs through two mediating mechanisms, namely resource productivity (β = 0.202) and industrial resilience (β = 0.173), but not directly, which supports the notion that CE integration mainly affects sustainable development through these two pathways.

The overall measurement model showed good reliability (Cronbach's alpha values were ranged 0.847 to 0.881) and validity (AVE values were over 0.60 for all constructs), and the structural model was found to be statistically sound (SRMR = 0.061), which would lend credibility to these findings. Overall, the findings indicate that the uptake of circular economy is moderate, but not even, and has a statistically significant and practically meaningful impact on resource productivity, industrial resilience and, consequently, sustainable economic development within project portfolios in the construction sector.

Conclusion

The purpose of this study was to explore the potential of circular economy principles in construction project portfolio management (PPM) to improve the productivity of resources, increase the resilience of industries, and enhance sustainable economic development. The research has used descriptive statistics and Partial Least Squares Structural Equation Modeling on primary data gathered from 331 valid respondents in Grade 1 to 3 PEC-registered construction companies of Lahore, Faisalabad and Rawalpindi, and has given strong empirical evidence to answer the three research questions or objectives of the research.

The results show that the adoption of CE in building project portfolios is still in a moderate and inconsistent level, showing a similar trend found in the literature, where CE principles are applied more frequently on the individual project level instead of embedded in the portfolio of an organization. This partial adoption pattern arises due to longstanding structural challenges such as disjointed value chains, weak regulation, stakeholders' lack of awareness and the lack of standardized measurement tools that continue to limit the construction sector's shift to circular operating models. The study confirms that there are statistically significant and practically significant benefits, even if the level of integration of circular economy is only moderate. The study revealed that the uptake of circular economy is a significant driver of resource productivity and industrial resilience, as seen in organisations that invest in circular practices like material recovery systems, sourcing locally or design-for-disassembly. The most important contribution of this study could be the fact that it has shown the mediating path by which the adoption of circular economy affects sustainable economic development. The integration of circular economy doesn't have a direct impact; it works to a great extent by boosting the productivity of resources and the resilience of industries, both of which account for almost half of the difference in sustainable economic development results. This discovery confirms the study's initial thesis statement and highlights that the creation of sustainable economic development

in the construction industry does not come from circular economy jargon, but from targeted and coordinated investments in the mechanisms through which circular economy principles are put to practice and tangible economic value is created, namely in efficient resource use and resilient supply networks.

The theoretical framework developed for this research that combines the RBV, CE Theory and DC Theory was found to be appropriate for explaining the observed relationships. The Resource-Based View helped to understand what gives strategic management of circular material resources to firms a productivity edge over competitors, and Dynamic Capabilities Theory shed light on how firms' reconfiguration of their resources in the face of circular practices creates resilience to external shocks. The theory of Circular Economy filled a gap in the current literature mostly focused on individual projects and connected the closed loop material systems with the decision-making of the portfolio, which is the point of view of Circular Economy Theory.

The study's implications for the practical sense of the construction industry are significant for construction companies, policymakers and construction industry regulators within the construction industry in Punjab, and other developing economy settings. The statistical relations demonstrated suggest that integration with the circular economy should not be considered a sustainability process in the periphery but rather as a strategic capability which should be part of the portfolio management decision-making process. Those that don't embed circularity into their project portfolio face the potential loss of tangible resource efficiency, resilience to disruption and future competitive position in the increasingly resource-constrained global construction market.

Finally, this study theoretically and practically adds to the existing knowledge base on the integration of circular economy into construction project portfolio management. It validates resource productivity and industrial resilience as key statistically demonstrated processes translating circular economy principles into sustainable economic development, providing the basis for further research and practice in the development of policies in this emerging area.

Recommendations

1. The development of lifecycle reporting and material passports for large-scale contractors should be required by regulators.
2. Companies should invest in digital tracking systems for material recovery and reuse, which will be integrated with BIM.
3. Performance indicators for benchmarking in the circularity should be standardized by industry bodies.
4. Project managers should be the focus of training programs on circular design and resilient sourcing.
5. Financial support for companies implementing circular procurement should be provided by the government.
6. Resource productivity and supply chain resilience should be jointly considered to be a key priority in future portfolio decisions.

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