CIRCULAR ECONOMY IN CONSTRUCTION INDUSTRY

CIVIL ENGINEERING DEPARTMENT

BALOCHISTAN UNIVERSITY OF ENGINEERING & TECHNOLOGY, KHUZDAR, PAKISTAN

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SUBMITTED BY:

Mohammad Tashfeen (Group Leader)	19CE05
Mohammad Sulaiman	19CE77
Amanullah	19CE52
Sufyan Tariq	19CE54
Shoaibullah	19CE70

BATCH 2019-23

SUPERVISED BY.

ENGR. SYED ABDULLAH SHAH HASHMI

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DEPARTMENT OF CIVIL ENGINEERING
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DEDICATION

Dedicated to our parents and adored siblings whose tremendous support and cooperation led us to this wonderful accomplishment.

BALOCHISTAN UNIVERSITY OF ENGINEERING ANDTECHNOLOGY, KHUZDAR

DEPARTMENT OF CIVIL ENGINEERING

Certificate

This is to certify that the work presented in this project report / thesis on "**Circular Economy in Construction Industry**" is entirely written by the following students themselves under the supervision of Engr. Syed Abdullah Shah Hashmi

Mohammad Tashfeen (Group Leader)	19CE05
Mohammad Sulaiman	19CE77
Amanullah	19CE52
Sufyan Tariq	19CE54
Shoaibullah	19CE70

This Project is submitted in partial fulfillment of the requirement for the award of "Degree of Bachelor of Engineering" in Civil Engineering Discipline

Project Supervisor Head of Department

Date: ________________

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ABBREVIATIONS

AI	Average Index
B&R	Building and Roads
BUETK	Balochistan University of Engineering & Technology Khuzdar
CCD	Construction Change Directive
CCDC	Canadian Construction Documents Committee
CII	Construction Industry Institute
CLP	Construction Labor Productivity
C & W	Construction & Works
CO	Change Order
DAE	Diploma of Associate Engineer
DG	Director General
DHA	Defense Housing Authority
GDP	Gross Domestic Product
UP & D	Urban Planning & Development
MD	Managing Director
MS	Microsoft
NHA	National Highway Authority
PD	Project Director
PHE	Public Health Engineering
SDOs’	Sub Divisional Officers
SPSS	Statistical Package for the Social Sciences

VO	Variation Order
WCDs’	Work Change Directives
XEN	Executive Engineer
CI	Construction Industry
RII	Relative importance index
VOS	Visualization of Similarities
SPSS	Statistical package for social sciences
GDP	Gross domestic products
CP	Construction productivity
FY	Fiscal year
PKR	Pakistani Rupees

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ABSTRACT

The Circular Economy offers a promising solution to the environmental challenges faced by the building industry. By prioritizing waste reduction, material reuse, and recycling, this approach addresses both ecological concerns and economic opportunities. This study provides a comprehensive review of the theoretical approaches, methods, and implementation cases of the Circular Economy in construction, as well as future development proposals. The study highlights specific sustainable practices that the building industry can adopt to implement the Circular Economy, these applications such as designing buildings for disassembly, using recycled materials, using Material Passport and implementing closed-loop systems. However, the study also acknowledges some challenges that the building industry may face in transitioning to a Circular Economy model, such as lack of awareness, resistance to change, lack of collaboration between stakeholders, and regulatory barriers. In analyzing these prospects and challenges, the article employs methods like VOS Viewer and questionnaire surveys. Overcoming these challenges will require concerted efforts from all stakeholders involved, including policymakers, industry leaders and consumers, these experienced engineers and stakeholders suggested that using KPI for measuring success of CE, investing in training and educating about CE, implementing circular business model and collaboration with stakeholders to promote CE for better implementation of CE in construction industry. Overall, this article suggests that the Circular Economy has the potential to revolutionize the way we conceive, construct, and sustain our built environment, and drive sustainable development for a more sustainable future.

CHAPTER-1
INTRODUCTION

1.1 Background

Recent years have seen a rise in interest in the concept of Circular Economy (CE) as a potential solution to the problems caused by our existing production and consumption paradigm based on unending expansion and ever-increasing resource throughput. The building industry is increasingly viewing the CE idea as a major legislative agenda item and a testing challenge. The building industry is responsible for a significant portion of global garbage. Fortunately, the Circular Economy can reduce some of the negative effects of the building industry on the environment[1]. The report reviews previous research on the theoretical approaches, methods, and implementation cases of the Circular Economy in the construction industry. Future development proposals are also mentioned in this study .For the building industry, the Circular Economy (CE) is rapidly becoming a top priority on the policy agenda and a formidable obstacle to overcome. It's a way of running the economy that seeks to maximize efficiency and minimize waste. Unlike the linear economy's 'take, make, dispose of' model of manufacturing, this regenerative approach actually adds to the resources available. By slowing down, shutting, and reducing energy and material loops, circular systems reduce resource input as well as waste, emissions, and energy leakage. Sustainable practices such as designing for longevity, repairing and reusing items, remanufacturing and refurbishing materials, recycling and up cycling, and reducing waste all contribute to this goal[2]. The Circular Economy is defined as “In circular economy we recycle and reuse products again and again”[3].“Circular economy is an economy where we can recycle and reuse the manufactured items as per requirements”[4]. One of the biggest consumers of raw materials is the construction industry (CI). In the past and currently, the CI has relied on a linear economic system that is not sustainable based on the "take, make, dispose of" paradigm. Construction facilities cannot be demolished and rebuilt using the linear method. That's why they're useless once the building's lifespan is up. Sustainability and worldwide greening programs have made it clear that this approach is no longer viable[5]. In practice, it means eliminating as much waste as possible. Recycling helps keep a product's materials in the economy when it reaches the end of its useful life. These can be used repeatedly to their full potential, adding value[6].

Projects cycles:

1. The proto protocol

Figure 1 The Proto Cycle

[7]

2. Circular economy for PET products

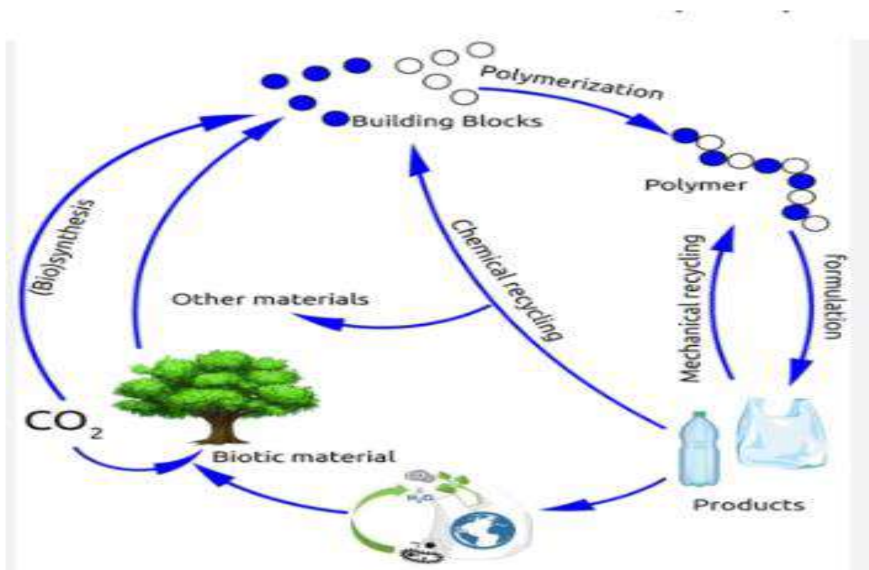


Figure 2 : Circular Economy for PET products

[8]

3. Textile circular economy

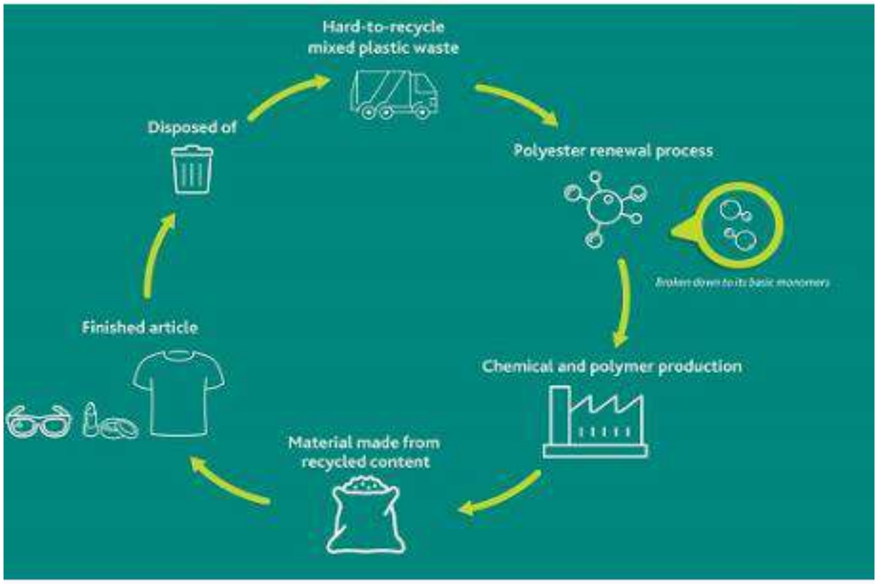


Figure 3: Textile Circular Economy

[9]

4. Cisco circular economy

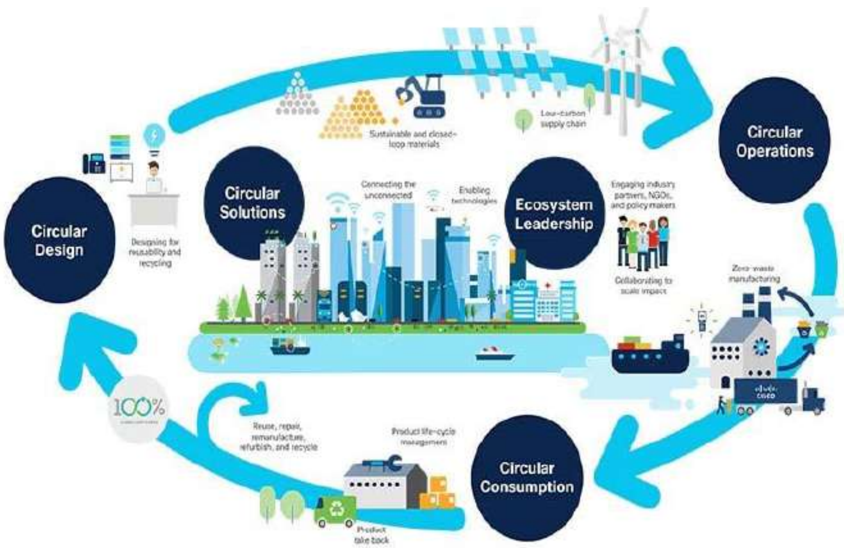


Figure 4: Cisco Circular Economy

[10]

1.2 Research justification

The construction industry plays a crucial role in environmental degradation and the depletion of global resources. In response, the concept of a circular economy has emerged as a potential solution for these challenges. Despite its potential benefits, the incorporation of circular economy principles within the construction sector is still in its early stages, especially in developing nations like Pakistan. This research seeks to examine the feasibility of implementing the circular economy in Pakistan's construction industry, aiming to uncover opportunities, identify obstacles, and propose strategies for its adoption. The research findings aim to enhance the existing body of knowledge on circular economy practices, providing valuable insights for policymakers, industry professionals, and researchers. Employing a mixed-methods approach encompassing literature reviews, case studies, and surveys, the research seeks to gather comprehensive data. With a team comprised of experienced researchers and industry experts, the study guarantees the quality and reliability of its outcomes. In essence, this research is both timely and pertinent, holding the potential to significantly impact the sustainable development of Pakistan's construction industry.

1.3 Problem Statement

Transitioning toward more sustainable sociotechnical systems is an urgent necessity[11]. Economic difficulties, such as supply uncertainties, ownership structure issues, deregulation in markets, and flawed incentive systems, have been causing more frequent financial and economic instabilities. These challenges impact both individual companies and entire economies[11]. Consequently, numerous essential material resources are projected to become scarcer and more expensive to utilize, potentially resulting in significant losses for future generations[12].

The construction industry is a significant user of natural resources, consuming a substantial 3 billion tons of raw materials each year. According to a survey conducted by the World Resources Institute, the construction sector is responsible for a remarkable 40% of the total global waste generated [15]. To address the inefficient use of resources and the negative ecological impact, it is imperative to embrace Circular Economy (CE) practices in the construction industry (CI). It is important to note, however, that the concept of circular construction is still in its early stages of development, rendering it more vulnerable to inherent risks compared to conventional construction methods [15]. Moreover, construction and demolition activities produce a substantial amount of waste, totaling 821 million tons in Europe in 2012. This figure represents one-third of the overall waste generated [16]. The successful integration of circular economy principles in the construction sector encounters various challenges. These include issues within the supply chain, inadequacies in support services and standards, economic uncertainties, and reservations regarding the quality and quantity of recycled materials[17].

The need for transitioning to more sustainable sociotechnical systems is imperative due to economic challenges and the growing risk of resource scarcity and environmental damage [13][14]. The considerable consumption of resources and generation of waste within the construction industry underscore the need for embracing Circular Economy practices to address and alleviate these challenges [15]. Nevertheless, the transition to circular construction presents challenges, including those associated with waste generation and supply chain complexities [16][17].

1.4 Aim of the study

This study sets out to address this knowledge vacuum by offering a thorough assessment of the existing literature on the circular economy its applications, barriers, challenges and the suggestions for its implementation.

1.5 Objectives of the study

To achieve the aim of the study, three objectives of the study are set.

- To identify the applications of Circular Economy (CE) in the construction industry.
- To investigate the barriers and challenges associated with the adoption of CE in the construction industry.
- To propose suggestions for the effective implementation of CE in the construction sector.

1.6 Scope of the study

The data will be collected from public/private sector Departments such as: NHA, C&W, Irrigation, Local Gov.t, PHE, B&R Department, QDA, MC offices etc.

1.7 Significance of the study

This thesis conducts a thorough analysis of the potential of the circular economy within the construction industry, marking a significant step toward sustainable development in the nation. The study, pioneering in nature for construction projects, aims to contribute to existing circular economy literature by presenting findings that illuminate applications, barriers, and challenges. Additionally, it offers recommendations for the implementation of Circular Economy (CE) in the construction industry, contributing to the creation of a more sustainable environment. This transition holds significant promise for positive impacts on the environment, society, and the economy.

1.8 Thesis Structure:

- This thesis is organized into five chapters.

Chapter 1: This chapter introduces the study, presenting the problem statement, aims and objectives, the significance of the research, and the scope of work.

Chapter 2: The chapter includes complete review of literature.

Chapter 3: This chapter describes the introduction of research, research design, area of the study, data collection, questionnaire administration, and method of data analysis.

Chapter 4: This chapter provides details about the respondents involved in the questionnaire survey, analyzes the responses from the questionnaire, discusses the findings, and proposes suggested remedies.

Chapter 5: This chapter offers a comprehensive summary of the entire study, highlighting the major findings and valuable outcomes. Additionally, it includes recommendations based on the study's findings.

CHAPTER-2
LITERATURE REVIEW

2.1 Introduction:

This chapter encompasses the findings and a review of previous studies conducted on the circular economy within the construction sector. In order to fulfill the study objectives, a comprehensive literature review explores the application of circular economy principles, emphasizing their potential in mitigating environmental impacts and reducing resource consumption. The chapter also delves into the barriers hindering the adoption of circular economy practices in construction, shedding light on challenges that impede widespread integration. Concluding with practical suggestions for implementation, it provides valuable recommendations to facilitate the seamless incorporation of circular economy practices in the construction industry. Serving as a foundational element, this literature review contributes to the existing discourse on circular economy in construction, drawing from various research papers to encompass a broad range of factors.

2.2 CE Applications in Construction Industry:

Amidst the dynamic dynamics of the construction industry, the emergence of the Circular Economy (CE) stands out as a guiding light for sustainable transformation. With increasing global apprehensions about resource depletion and environmental impact, the adoption of CE principles holds the potential to overhaul conventional practices. This section delves into the various applications of Circular Economy within the construction sector, covering a range of innovative methodologies, thorough assessments, and strategic approaches to material recycling. Through these applications, the profound potential of Circular Economy principles in revolutionizing the construction industry becomes evident.

The research focused on the reuse of materials in the construction industry can be categorized into three distinct levels. The micro-level encompasses studies that examine applications or methods for reusing specific materials[13]. Secondly, at the meso-level, the research encompasses studies that explore applications of reuse throughout entire buildings, not limited to specific materials or elements[14], The study involves an analysis of real-case buildings that incorporated reused materials in their construction. Additionally, it explores the potential applications of reuse during the operational phase of buildings. Furthermore, a developed method is presented to measure the level of material reusability at the end of the building's life stage[12]. Lastly, the macro-level focuses on evaluating the overall reuse potential of materials within the Construction Industry [15]. The study analyzes the prerequisites necessary for materials to be reused in the built environment. It also assesses the potential benefits of reuse in reducing carbon emissions within the industry. Additionally, the research identifies both the barriers and opportunities for material reuse specifically in Norway[1].

The modern understanding of the Circular Economy and its practical applications in economic systems and industrial processes has developed through the integration of diverse elements and contributions from various concepts that converge around the idea of closed loops. Several influential theoretical frameworks have shaped this understanding, including cradle-to-cradle[16], ecological principles[17], "looped" and "performance economy" [18], “re-generative design”[19], “industrial ecology design”[20], “bio-mimicry”[21], and “the-blue economy design”[22].

Foremost among these, the Ellen MacArthur Foundation's formulation stands as renowned, defining the Circular Economy as "an industrial economy that is restorative or regenerative by intention and design" (2013b: 14). Likewise, Doberstein and Geng in 2008, focused on its implementation in China, characterize the Circular Economy as the realization of "a closed loop material flow in the whole economic system". Webster in 2015-2016 added that "a circular economy is one that is restorative by design, aiming to maintain products, components, and materials at their peak utility and value consistently". Correspondingly, Yuan in 2008 emphasize that "the essence of the Circular Economy lies in the circular (closed) flow of materials and the efficient utilization of raw materials and energy across multiple phases". Bocken in 2016 categorize the Circular Economy's attributes, defining it as "design and business model strategies that decelerate, close, and narrow resource loops"[23].

However, instances of applying circular economy principles are gradually emerging, predominantly concerning material selection and design considerations. This observation aligns with survey results that underscore the absence of incentives for designing products with their end-of-life in mind. While previous research has focused on improving resource efficiency in construction products and supply chains (AIS, 2012; Dunster, 2014; Hobbs and Ashford, 2013; Smith, 2013a, 2013b), there is a noticeable lack of clarity regarding the precise actions that various segments of the construction sector can take to promote circularity. The versatility of circular economy applications is likely contingent upon project circumstances and supply chain intricacies, a factor where the guiding principle of systems thinking becomes pivotal. It aids in recognizing synergies, divergences, and potential unintended consequences. Collaboration emerges as a vital component in advancing The concept of the circular economy has been discussed by Chamberlin et al. (2013) and Preston (2012), making it necessary to investigate its implications in procurement, supply chain management activities, and the information-sharing capabilities of Building Information Modeling (BIM).

To propel circularity within the construction industry, embracing a comprehensive whole life cycle costing approach stands as an additional avenue for integration into CE models. As posited by Albuquerque et al. (2019), This approach tackles sustainability concerns associated with business operations by integrating externalities into life cycle costing models. Harts et al. (2019) support this perspective, identifying whole life cycle costing as a catalyst for implementing Circular Economy (CE) in the built environment. Additionally, Chen and Huang (2019) emphasize the profound significance of life cycle assessment for circular economy applications in products and services[24].

Initiatives to incorporate sustainable development practices within the Architecture, Engineering, and Construction (AEC) sector encompass the use of diverse tools and techniques[25]. Critical methodologies comprise Life Cycle Assessment (LCA), Energy Certificates, Material Flow Analysis (MFA), and Environmental Product Declarations (EPD). Specifically, Life Cycle Assessment has garnered significant attention for its comprehensive evaluation of the environmental impacts associated with buildings and the built environment throughout their entire life cycle[26]. In the context of resource efficiency through reuse and recycling, Material Passports (MP) have gained considerable attention. These tools are being explored by initiatives such as the EU-funded Horizon 2020 project 'Buildings as Material Banks' (BAMB) and other similar endeavors. As per

BAMB, a Material Passport is defined as an electronic dataset detailing material characteristics in products, thereby enhancing their value for recovery or reuse[27].

Madaster (2019) provides a definition of the Material Passport as a digital document that records the identity of construction materials used in a building. The Madaster platform, functioning as an online repository for built environment materials, seeks to minimize waste by assigning materials a distinct identity. A significant advancement introduced by Heisel and Rau-Oberhuber (2020) is the development of a circularity indicator. This indicator was utilized in the analysis of the extensively documented 'UMAR' (Urban Mining and Recycling) unit within the NEST research building, illustrating its potential application.

The process of generating a Material Passport necessitates a comprehensive understanding of building geometry and material composition, particularly focusing on material quality and separability. The Material Passport evaluates factors such as total mass, recyclable mass, waste mass, recycling potential, and environmental impacts. It serves as a valuable resource for tasks like ascertaining a building's material value, planning thermal renovations, managing sustainable waste streams, and facilitating public access to material information. As an illustration, an analysis of the exterior walls and foundation in a particular use case demonstrated that materials with higher density and larger area have a notable impact on the results. Additionally, the layer thickness was identified as a contributing factor in the outcomes. Leveraging Building Information Modeling (BIM) for precise quantity extraction and data required for the Material Passport is highly recommended. Incorporating element IDs for building components within the Material Passport streamlines information mapping from diverse sources"[28].

In Pakistan, the construction sector is advancing and exerting a significant impact on its economic growth. The construction industry contributed 4.7% to the GDP in 2016, which saw an increase to 5.2% in 2017. Notably, the China-Pakistan Economic Corridor has emerged as a key driver of this economic expansion. However, this upward trajectory in construction activities comes with associated challenges such as increased fuel consumption, energy usage, resource depletion, waste generation, and environmental degradation. Consequently, there is a pressing need to implement measures that enhance construction practices[29].

Improving the overall quality of construction while mitigating its adverse effects holds the potential to enhance project performance. Globally, the adoption of green procurement practices has proven effective in achieving these goals. Green procurement, a vital aspect of the green supply chain system, stands as the initial stride towards achieving sustainability in construction. By incorporating environmentally friendly materials, it facilitates better financial and environmental outcomes[29].

The impact of green procurement extends to the construction material supply chain, significantly reducing its environmental footprint while also yielding improved financial performance. However, the successful implementation of green procurement necessitates active engagement from all stakeholders [10]. Its positive outcomes are evident across various countries. While the adoption of green procurement practices in the building sector is gaining momentum due to its evident benefits, its progress in developing nations like Pakistan remains gradual. Therefore, it is essential to integrate green procurement strategies and practices to accelerate the advancement of construction project performance. This study delves into the pivotal factors that can catalyze the integration of green procurement in Pakistan's construction industry, contributing to the broader application of Circular Economy principles[29].

2.2.1 Applications of CE in Recycling of Various Materials:

Various materials are discussed below in the lights of circular economy:

Bricks

Bricks, a fundamental building material globally, contribute significantly to construction waste, often discarded due to damage or poor handling. Their inherent durability makes them environment-friendly, as they can be repeatedly reused and recycled. Demolished bricks, after mortar removal, are readily reusable for restoration or new projects. Salvaged bricks can be employed as pavers, landscape features, or artistic elements. If direct reuse isn't feasible, bricks can be broken down into aggregates or chips, serving as robust construction materials. These recycled products can become base materials for roads, construction fill, or lightweight concrete. Additionally, inadequately or excessively burned bricks can be repurposed for precast elements like pavers, kerb stones, and interlocking tiles, enhancing sustainability in various applications[30].

Figure 5: Bricks used as pavement

Concrete

Concrete, comprising cement, aggregates, and water, confronts scarcity of natural resources. Recycled concrete aggregates (RCA) from Construction and Demolition (C&D) waste offer an alternative. Demolished concrete is crushed into RCA at recycling plants. Precast elements from demolition can also become recycled aggregates. Blending recycled and natural aggregates can mitigate resource shortages, while RCA finds applications in road base, concrete production, and construction fill, promoting sustainable practices[30].

Figure 6: Concrete Used as Aggregates

Tiles

Tiles pose challenges in extraction for reuse due to potential damage and variations in type, lifespan, and condition. Despite this, even broken tiles offer artistic possibilities for murals and decorative pieces. Crushed broken tiles can serve as aggregate. Salvaged tiles, if intact, can be reused after removing mortar and gluing with appropriate adhesives, creating artifacts, table tops, and decorative features. Nek Chand's Rock Garden in Chandigarh exemplifies such innovative reuse. Crushed tiles can further replace gravel and crushed stone in concrete, extending their usefulness[30].

Figure 7: Tiles used as Artifacts

Metals

Steel and Aluminium stand as prominent metals in the construction realm, generating waste during both construction and demolition phases. Structural steel from demolitions or leftovers can be directly reused after resizing. Aluminium can be solid-bonded for reuse, with design-driven deconstruction plans enhancing its recoverability for household appliances. Reusing steel in its existing form is energy-efficient compared to remelting it. Steel generates minimal waste during construction and is ecologically sustainable for products like furniture and fire hydrants.

Aluminium's recyclability is a key advantage, capable of multiple cycles while preserving the environment. Recycling scrap aluminium demands significantly less energy than producing new aluminium. Its infinite recyclability enables diverse applications, making it ideal for premium uses even after repeated recycling[30].

Figure 8: Alumunium used for Sunroom

Timber

Timber waste arises from building demolition and wooden construction, each with distinct recycling systems. Timber products possess a characteristic of enduring service lives that often exceed the lifespan of the building they are a part of. Recovered timber, including items like doors and windows, maintains its quality and durability across multiple uses. The prolonged lifespan of timber contributes to its environmental friendliness. In instances where timber becomes unusable, recycling options include transforming it into particleboard, fiberboards, animal bedding, or renewable energy sources. Recycling demands clean, uncontaminated wood free from concrete, metal, and other debris. Quality wood waste generates wood chips, used by particleboard, paper, and pulp industries. Shredded wood finds uses in sewage sludge management and pallets, contributing to sustainable practices[30].

Figure 9: The trees were harvested in the early 1900's, they were 400 years old: 37" * 42" * 48' timbers from Welland Canal Lock.

Plastic

Recovered scrap or waste plastic undergoes reprocessing, yielding diverse and useful products. Unlike materials such as glass or metals, recycling plastic polymers requires intensive processing. High-density polyethylene (HDPE), a commonly recycled plastic, transforms into durable products like plastic lumber, tables, benches, and road curbs. It's also utilized in road construction, creating durable, rain-resistant surfaces by mixing shredded, melted plastic with bitumen[30].

Figure 10: This Road is from Thuna to Sehore in Madhya Pradesh, India: its 1.67 Km long and 20mm thick

2.3 Barriers and Challenges in the Adoption of Circular Economy (CE) in Construction Industry (CI):

This part of study initiates an inquiry into challenges obstructing Circular Economy (CE) adoption in the construction industry. Employing a literature review and questionnaire survey methodology, we aim to dissect key hurdles. By synthesizing academic insights and industry perspectives, we'll unravel regulatory, technological, and cultural impediments. This combined approach seeks to offer a comprehensive understanding of the barriers constraining CE in construction, paving the way for targeted interventions and sustainable solutions.

While numerous successful initiatives have embraced the concept of Circular Economy (CE) in the Arab region, significant obstacles persist within Arab countries. These hurdles manifest as cultural disparities, legislative and regulatory constraints, marketing limitations, and technological challenges[4]. It's worth noting that CE principles should ideally permeate all stages of the product life cycle, spanning from raw material procurement to eventual disposal. Nevertheless, the guidance specific to integrating circular economy within various industries remains inadequate. This deficiency extends to the absence of universally accepted international standards governing this sector. Furthermore, the public's understanding of CE remains deficient.

The legal framework for CEs and their applications is largely absent across the region, and these novel systems still necessitate substantial investments. Despite the Arab region's abundance of natural resources, its robust economic growth trajectory exposes it to challenges akin to those faced by rapidly developing economies. Notably, the processes of urbanization and crude oil extraction are prominent contributors to waste generation and environmental degradation[23].

Scarce agricultural land and water supplies compound the predicament in the Arab region. Traditional farming methods are unable to bolster food production, exacerbating reliance on food imports. According to the UN Food and Agriculture Organization, the Middle East and North Africa witness the generation of 250 kilograms of food waste per person annually, amounting to over USD 60 billion in value. Moreover, recycling rates in the Arab region remain disappointingly low [23].

The central objective of this study is to devise an "index" that can gauge the extent of CE integration and recycling rates in the Arab region. The intention behind this index is to effectively manage resource waste, curtail adverse environmental impacts, and concurrently enhance the value added to Arab economies. In essence, this study seeks to develop a regional benchmark for quantifying the progress of CE implementation across countries within the Arab world[23].

Numerous barriers and challenges characterize the adoption of circular business models. These intricacies span different aspects of circularity[11], where companies often make claims of promoting circularity but limit efforts to specific areas[3]. Circular models require validation through the sale of recirculated products[31], unlike linear models that gain validation through product sales.

Barriers encompass technical, economic, institutional, regulatory, and social aspects[32], impeding business model innovation[33]. A lack of means to measure circularity further hinders progress [34]. Certain circular models are context-dependent [35], some entail retained ownership, magnifying resource risks [31], and trade-offs and linear lock-ins pose ongoing challenges[36].

The central objective of this study is to devise an "index" that can gauge the extent of CE integration and recycling rates in the Arab region. The intention behind this index is to effectively manage resource waste, curtail adverse environmental impacts, and concurrently enhance the value added to Arab economies. In essence, this study seeks to develop a regional benchmark for quantifying the progress of CE implementation across countries within the Arab world[23].

This compilation of research explores Circular Economy implementation in the Construction Industry. Studies delve into barriers, challenges, and prospects across different countries' built environments. While awareness of Circular Economy is positive, integration is gradual due to practical complexities [37][38].

The attribute implementation gaps to supply chain complexities and short-term company goals[38]. Pomponi and Moncaster (2017) introduce a six-dimensional framework for Circular Economy in Construction, bridging gaps in prior research by emphasizing buildings' role[39].

The absence of standardized practices hinders adoption [40], including waste management in developing countries [41]. Authors concur on governments incentivizing Circular Economy practices[40][42].

Exploring real cases, studies illustrate Circular Economy benefits[43][44][45]. Lack of standardized practices for material reuse is a recurring obstacle[46][40][42]. Further research is needed to understand barriers in developing Building Material Passports, given limited academic contribution in this area[1].

In the realm of the construction industry, implementing circular economy principles faces a series of intricate challenges. Technical hurdles at the levels of materials, products, and buildings must be surmounted to enhance material circularity at optimal value [47]. A lack of incentives to design for end-of-life considerations, inadequate market mechanisms to facilitate enhanced recovery, and an unclear financial rationale compound the challenges[48]. Moreover, the construction industry's fragmented structure, alongside the ambiguity in end-of-waste regulations and the absence of legislation tailored to circular economy principles, contribute to the complexity[48]. Respondents from client and manufacturer backgrounds highlight significant issues pertaining to knowledge gaps and disinterest in circular economy principles[48]. This multifaceted set of challenges underscores the intricate path toward embedding circularity within the construction sector[46].

It is crucial to recognize the pressing issues and obstacles that currently characterize construction waste management in Malaysia. The authors have pinpointed four primary challenges that demand attention in order to establish a robust construction waste management framework: the escalating volume of waste, the resultant environmental consequences, the prevalent problem of illegal dumping, and the lack of support from top-level management[41]. Alongside these issues, three key hurdles have been identified as critical to surmount in the pursuit of effective construction waste management implementation: the need for enhanced regulations, a transformation of awareness and mindset, and the availability of tools for comprehensive data collection on construction waste, including its sources and composition. Nevertheless, the research landscape still lacks comprehensive investigations into waste minimization throughout the entire construction lifecycle in Malaysia, spanning planning, design, procurement, construction, and demolition stages[41]. This underscores the necessity for a circular approach that proactively addresses waste control from the very inception of the construction process, rather than focusing solely on reactive end-of-pipe strategies that manage waste post-generation[41].

The successful implementation of circular principles in construction faces various challenges and barriers that must be navigated to drive sustainable change. Foremost among these is the glaring gap in research at both the organizational and systemic levels. While individual studies have explored circular strategies at the building level, a crucial transformation is the translation of such research into broader standardization and more effective market mechanisms. It is imperative not to confine circularity to the mere re-use and recycling of construction materials; instead, a comprehensive understanding of circular principles, must guide the endeavor[49].

Furthermore, the complexity escalates when considering the multidimensional and interconnected nature of circular systems. A vital step is to foster interdisciplinary research that spans various viable systemic levels, from micro (project-focused) to macro (city or regional-focused) scales. The author underscore the intricacy arising from involving actors across this spectrum[50]. This complexity is compounded by the need to address life cycle impacts across diverse dimensions, necessitating dynamic impact models that account for technological advancements and innovations[51].

In addressing these barriers, it's crucial not to adopt a one-size-fits-all approach. Instead, the implementation should accommodate various assessment methods that align with the specific systemic level. This nuanced strategy acknowledges the multifaceted nature of barriers and the diverse solutions required to surmount them effectively. By embracing a multilevel perspective and fostering interdisciplinary collaboration, the construction industry can pave the way for comprehensive circular principles that extend far beyond material reclamation, ushering in a paradigm shift towards sustainable practices.

2.3.1 Challenges and Strategies for Implementing Circular Economy in the Construction Industry:

Efficient implementation of Circular Economy (CE) principles in the construction industry remains in its early stages. Comprehensive studies focusing on system approaches, methodologies, indicators, and frameworks are scarce. Most existing research primarily addresses construction waste minimization and recycling within CE frameworks. This article highlights key limitations and gaps in various aspects such as design, materials selection, supply chain, business models, uncertainty, and risk. Furthermore, potential solutions are proposed to facilitate successful CE integration in the construction sector[5].

Design

A significant challenge in CE adoption is integrating end-of-life considerations during the design phase. This involves addressing issues of materials' ownership, sustainable waste management integration, and uncertainty in waste handling. To unlock material reuse potential, changes in building elements' configuration and interaction are crucial. Circular building concepts require synergies between circularity and adaptability, as well as guidelines for design-for-adaptability. Utilizing tools like Building Information Modeling (BIM) and life cycle assessment optimization can aid effective CE implementation during the design stage[5].

Materials Selection

Integrating bio-materials like wood into the CE framework holds promise for a circular bio-economy. Challenges include technical difficulties in material recovery, quality of recycled products, and uncertainties in subsequent material cycles. Establishing guidelines for recycled products and modular design can mitigate these challenges[5].

Supply chain

Supply chain barriers include inadequate incentives for circular practices, differing interests among supply chain actors, supply uncertainties, and divergent perceptions. Effective supply chain collaboration, emphasizing the business model, is vital for CE adoption[5].

Business Model

Lack of suitable business models for circular building is evident, despite existing CE frameworks. Challenges related to life cycle cost, implementation of new models, absence of refurbishment product standards, high recycled material costs, and insufficient economic incentives hinder progress. Developing economically viable cases and exploring business model innovations are necessary[5]. There is no single good economic case for CE implementation in the construction industry[37].

Policy

Resource policies primarily focus on resource efficiency rather than demand reduction. Public procurement can promote CE by setting criteria for extended product life and material-efficient practices. To strengthen CE strategies, relevant policies should be enforced by local and central governments[52].

Collaboration

Collaboration among stakeholders is crucial for successful CE adoption. Enhanced communication through workshops, seminars, and collaborative tools can bridge gaps and stimulate demand for CE. Leadership skills and stakeholder management are also pivotal[5].

Stakeholder Knowledge

Awareness and understanding of CE concepts among stakeholders are limited. Education, training, and visionary thinking are essential to transform attitudes and behaviors towards re-manufactured products[5].

Budget and Upfront Costs

One of the most pervasive challenges identified is the budget constraints and upfront costs associated with implementing circular strategies. Some strategies demand initial investments to enable future material and component reuse. Additionally, lack of in-house expertise and the need for external consultants can further escalate costs. Notably, varying budget constraints across different owners pose a significant challenge, with some entities more willing and able to invest in sustainability compared to others[2].

Schedule and Project Timeline

Construction projects often face tight schedules, and this constraint can directly impact the feasibility of certain circular strategies. While strategies like prefabrication align with tight schedules, others like selective demolition or deconstruction might be impeded due to time limitations. Balancing circular goals with project timelines becomes a pivotal challenge in realizing circular strategies[2].

Lack of Awareness

A lack of awareness and understanding of circular strategies within the construction industry was cited as a prominent barrier. Some strategies, especially those novel to the U.S. context, suffer from limited recognition, hindering their widespread adoption. Additionally, the resistance to change, a common characteristic of the construction sector, further impedes the integration of new technologies and methodologies[2].

Lack of Regulations and Implementation Guidelines

The absence of clear regulations and guidelines is a critical barrier to circular strategy implementation. Local regulations, particularly in the realm of Construction and Demolition (C&D) waste management, play a crucial role. While some progressive regions enforce sustainable practices through regulations, others lack the incentive for circular strategies. Disparities in regulations create challenges, necessitating industry reliance on educated and risk-taking clients[2].

Efforts to implement circular strategies in the construction industry are undoubtedly promising, but these endeavors encounter several hurdles. Overcoming barriers related to budget constraints, project schedules, awareness gaps, entrenched business models, and regulatory disparities requires a collaborative approach. Stakeholders, policymakers, and industry players must unite to address these challenges, fostering an environment conducive to the successful implementation of circular strategies in construction projects.

2.3.2 Barriers to Circular Economy Implementation in the Construction Industry:

Technical Barriers

- **Lack of Standardization**

The absence of standardized practices in the construction industry poses a challenge to circular economy implementation, given the diverse materials, designs, and construction methods employed[53].

- **Complexity of the Built Environment**

The intricate nature of the built environment presents difficulty in designing structures that are easily disassembled and reused, hampering circular economy practices[53].

- **Limited Availability of Data**

Insufficient data on the environmental impact of construction materials and processes hinders informed decision-making for circular economy strategies[53].

- **Limited Technological Innovation**

Slow technology adoption within construction constrains circular economy development by not leveraging innovative solutions[53].

Organizational Barriers

- **Fragmented Supply Chain**

The lack of coordination among stakeholders in the construction supply chain complicates circular economy implementation[53].

- **Lack of Collaboration**

Absence of collaboration between various stakeholders impedes circular economy efforts within the construction industry[53].

- **Short-Term Thinking**

The industry's short-term focus, prioritizing immediate profits, obstructs the integration of circular economy principles[53].

- **Resistance to Change**

Industry-wide resistance to adopting new practices acts as a barrier, inhibiting the successful incorporation of circular economy strategies[53].

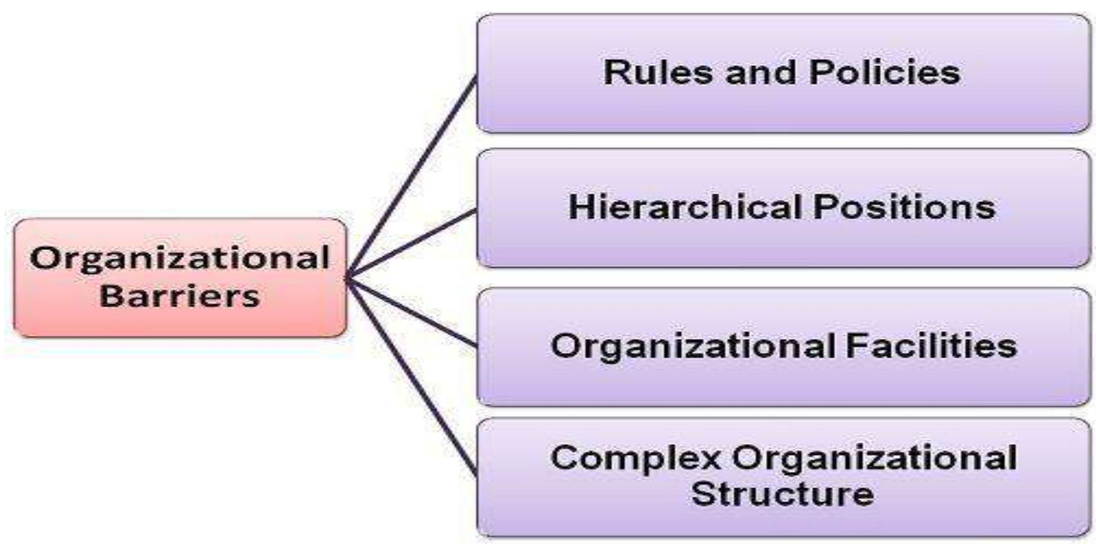


Figure 11: Organizational barriers

Political Barriers

- **Lack of Government Support**

The absence of government backing for circular economy initiatives in construction hampers their effective implementation[53].

- **Inadequate Policies and Regulations**

The lack of supportive policies and regulations tailored to the circular economy in construction limits its incorporation and progress[53].

By acknowledging and addressing these barriers, the construction industry can make meaningful strides toward implementing circular economy practices and contributing to a more sustainable and resource-efficient future.

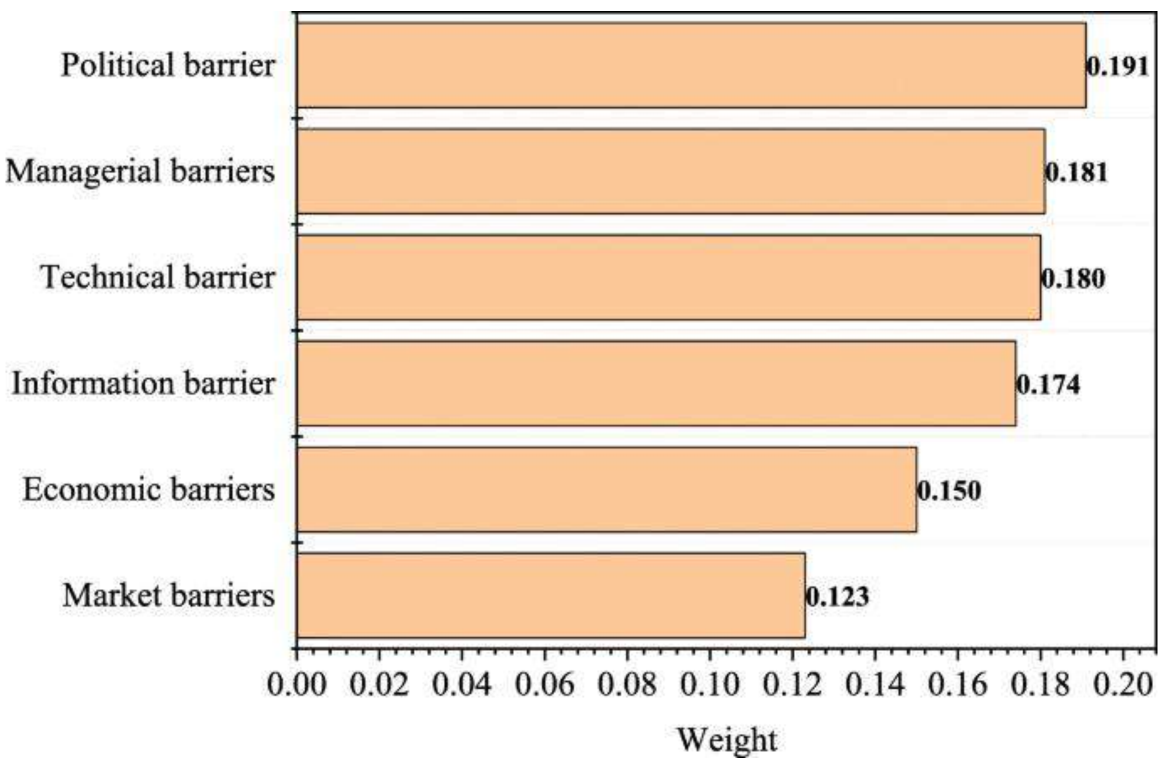


Figure 12: Yemen Facing following barriers in the adoption of sustainability

2.4 To Provide Suggestions for the Implementation of CE in the Construction Industry:

The application of the Circular Economy (CE) principles within the construction industry has been explored by various scholars. Geng and Doberstein (2008) emphasized the Chinese context, defining the Circular Economy as achieving a closed-loop material flow throughout the economic system[54]. Webster (2015) expanded upon this, describing a Circular Economy as a concept that prioritizes restoration in design and aims to maintain products, components, and materials at their highest utility and value continuously[55].

Yuan et al. (2008) highlighted the core of the Circular Economy as the establishment of a closed circular flow of materials, along with the efficient utilization of raw materials and energy across multiple phases[54]. Bocken et al. (2016) contributed to the discourse by categorizing the attributes of the Circular Economy, framing it as a fusion of design and business model strategies[11].

Significantly, the engagement with the Circular Economy concept gained momentum from both Chinese and European scholars, with China taking substantial regulatory steps starting from 2009. This proactive stance is evident through the keyword prominence of "China" in scholarly works, showcasing the country's commitment to the implementation of Circular Economy practices[56]. Consequently, a surge of publications from various authors, including those contextualizing geographical settings and jurisdictional performances, reflects the rising interest among companies and policymakers in these regions[11].

The growing recognition of the Circular Economy as a pivotal theme is evidenced by the surge in research interest. While the origins of the concept can be traced back to Europe, the recent upsurge has been significantly propelled by Chinese scholars following the implementation of regulatory controls within China. The topic has resonated with both Chinese and European researchers, leading to an exponential growth in publications. This collective engagement signifies the heightened attention from corporate entities and policymakers in these geographical areas[57].

The construction industry has become a focal point for the application of Circular Economy principles, with scholars emphasizing the closed-loop material flow and restorative design to ensure sustained value and utility of materials and products. This theme has gained substantial traction, particularly in response to regulatory measures in China, triggering a surge of research and interest from both Chinese and European scholars, as well as various stakeholders.

The implementation of the circular economy involves intricate considerations, including the definition's alignment with its core principles. Instances where CE implementations diverge from the priority of 'Reduce' can inadvertently perpetuate unsustainable business-as-usual practices. A critical point emerges from our coding analysis, revealing that merely 13% of definitions encompass all three dimensions of sustainable development. This is concerning as an incomplete CE understanding, lacking a comprehensive view, might lead to unsustainable implementations, particularly if social considerations are disregarded[11][56][58].

Contrary to claims by some scholars, our coding challenges the notion that CE discussions are predominantly focused on environmental quality. While environmental concerns are prominent (37%–38% of definitions), the most prevalent goal of CE is economic prosperity (46% of definitions). Practitioners, in particular, view CE as a means to drive growth and economic advancement (53% of definitions), highlighting its potential as a catalyst for positive change[11][56][58].

However, a distinction must be drawn between authentic CE definitions and subverted interpretations. A dominance of subverted definitions could result in incremental improvements rather than the promised transformative change. Vigilance is essential in identifying and addressing such deviations. Providing concrete examples of successful CE implementation, rooted in historical practices and contemporary innovations, can enhance comprehension among both scholars and practitioners. These exemplars should detail how obstacles were overcome, offering valuable insights for those navigating similar challenges[59][58]–[60].

To strengthen the field, future research should address overlooked dimensions like the consumer perspective. A deeper exploration of this aspect could uncover pathways to amplify consumer contributions to CE. As research progresses, a clear and deliberate conceptualization of CE is imperative to foster cumulative knowledge and drive meaningful advancements in the field[4].

2.4.1 Enhancing Circular Economy Implementation in the Construction Industry: Strategies, Challenges, and Future Directions

The implementation of circular economy principles in the construction industry offers significant potential for sustainable practices and resource optimization. The circular economy (CE) concept centers on minimizing waste, promoting reuse, and regenerating natural systems. In construction, CE can revolutionize the life cycle of buildings – from design and construction to operation and eventual decommissioning. Key implementation strategies in the construction industry include:

Design for Disassembly and Reuse:

CE advocates for designing buildings with the capability for easy disassembly and component reuse. This approach reduces waste, conserves resources, and lowers costs. Modular construction techniques exemplify this principle, enabling components to be reused across various projects[61].

Material Recovery and Recycling:

CE emphasizes material recovery and recycling during a building's end-of-life phase. Techniques like deconstruction enable careful separation of materials for reuse or recycling, leading to reduced waste and new business avenues. Incorporating recycled concrete aggregates in new projects illustrates this approach, diminishing the demand for virgin materials[61].

Energy Efficiency and Renewable Energy:

CE encourages energy-efficient building design, utilizing renewable energy sources like rooftop solar panels and passive solar design. These measures decrease energy consumption, enhance comfort, and lower costs. Integrating passive solar techniques and solar panels, for instance, reduces artificial lighting needs and generates renewable energy[61].

Water Conservation and Reuse:

CE advocates water conservation through water-efficient fixtures and the reuse of rainwater and greywater. Incorporating low-flow fixtures and rainwater harvesting systems exemplifies this, contributing to water savings and reduced strain on resources[61].

To advance CE in the construction industry:

Research and Innovation: Continuous research is crucial to developing innovative strategies that integrate CE principles seamlessly into construction practices. Focusing on material sourcing, modular construction, and advanced deconstruction techniques can yield groundbreaking results[61].

Stakeholder Collaboration:

Engaging diverse stakeholders, including architects, builders, regulators, and consumers, is essential for successful CE implementation. Collaborative efforts can ensure holistic and effective integration of circular principles[61].

Educational Initiatives:

Raising awareness and providing education about CE's benefits can inspire industry professionals and consumers to adopt sustainable practices. Training programs, workshops, and certifications can equip stakeholders with the knowledge needed to implement CE strategies effectively[61].

Policy Support:

Governments and regulatory bodies can play a pivotal role[61].

The integration of sustainable development principles into the Architecture, Engineering, and Construction (AEC) sector has been facilitated by a range of tools and methods[25].

These include established techniques such as Life Cycle Assessment (LCA), Energy Certificates, Material Flow Analysis (MFA), and Environmental Product Declarations (EPD). Notably, Life Cycle Assessment has gained substantial traction due to its ability to evaluate the entire environmental impact of buildings and their surroundings over their lifecycle[26].

In parallel, the drive for resource and material efficiency, particularly in terms of reuse and recycling, has led to the exploration of Material Passports (MP) as a valuable tool. Prominently championed by initiatives like the EU-funded Horizon 2020 project "Buildings as Material Banks" (BAMB), MP offers an electronic dataset detailing material characteristics that enhance their recoverability and reusability[27].

Additionally, Madaster (2019) defines MP as a digital record of all construction materials used in a building, contributing to waste reduction through material identification.

Addressing the need for circularity, Heisel and Rau-Oberhuber (2020) introduced a circularity indicator, demonstrated on the "UMAR" experimental unit of the NEST research building[62]. Despite the potential of these tools, the effective modeling and prediction of reuse and recycling rates remain challenging, particularly due to the limited information on existing building stock[63]. A mere 3% new construction rate across Europe (Euroconstruct, 2018) underscores the importance of optimizing end-of-life strategies, given that only 20–30% of construction and demolition waste is recycled or reused[64].

It is worth noting that the end-of-life stage contributes significantly to Construction & Demolition waste (CDW), accounting for over 50% of waste in a building's lifecycle[65]. Yet, estimating reuse and recycling rates remains unreliable due to time pressures during demolition and inadequate building documentation[66]. Present high-tech solutions lack the ability to penetrate beyond surface materials, leaving concealed materials unaccounted for[28].

This brings us to the challenge of urban mining in the building stock domain. Existing research predominantly relies on general assumptions, lacking a standardized method for investigating the existing building stock. Prevailing sustainability evaluation tools focus primarily on energy consumption and environmental impact, while studies on Material Passports (MPs) primarily center around their application during the design phase[28].

To bridge these gaps, the development of comprehensive methods for analyzing urban building stock is imperative. This calls for an in-depth examination of materials, building geometry, and the creation of a shared knowledge repository for buildings. This comprehensive approach would not only aid in addressing the challenges of the existing stock but also enhance Circular Economy strategies in the AEC industry.

The concept of Circular Economy (CE) has captured the spotlight, especially within the construction industry, as an essential strategy for sustainable development. Within the realm of built environments, the magnitude of waste generation is undeniable, making CE implementation not just a strategy but a responsibility. In this discourse, we delve into the heart of CE integration in the construction sector and explore its diverse benefits that resonate across various sectors[67].

The journey to implement CE within the construction industry is a complex tapestry woven from environmental, economic, technological, societal, governmental, and behavioral threads. Tackling this multifaceted challenge is akin to orchestrating a symphony involving numerous stakeholders across a supply chain that spans vast geographies and time frames. Yet, within these complexities, lie opportunities for groundbreaking solutions to address the intricate challenges of CE in construction[67].

At the crossroads of this endeavor lies the integration of Information and Communication Technologies (ICT). Recognized as an indispensable element of the journey towards CE, ICT-based solutions illuminate the path forward. The synergy between ICT and CE paints a picture of revolutionary environmental, health, and societal transformations, revolutionizing waste management practices and reshaping the very fabric of sustainability[67].

The theoretical exploration of CE within the built environment has ignited a tapestry of perspectives. Pomponi and Moncaster (2017) illuminated CE's fundamental dimensions within the built world[39], while Adams et al. (2017) offered a panoramic view of CE's challenges, awareness, and facilitators across industries[46]. Ghisellini et al. (2018) delved into the application of 3R principles to Construction and Demolition Waste (CDW) management, addressing the crux of waste concerns[68].

To grasp the contemporary nuances of CE application in construction, Benachio et al. (2020) distilled six research themes, unveiling the pulse of innovation[1]. López Ruiz et al. (2020) orchestrated a theoretical framework interlacing 14 CE strategies for CDW management[69], while Hossain et al. (2020) erected an integrated framework nurturing CE's adoption in construction[61]. Furthermore, Munaro et al. (2020) offered a panoramic vista into the convergence of CE concepts and the built environment[70].

In this endeavor, the rewards of embedding CE into the construction fabric are boundless and manifest across myriad sectors. Foremost among these is the reduction of waste generation, a vital undertaking given the industry's sizeable contribution to waste production. The symphony of CE principles, when harmonized, breathes life into a renewed approach, where materials find new purpose through reuse and recycling, illuminating the very essence of sustainability.

The UK has established a Resource Efficient Construction approach to encourage construction actors to redesign wastes, develop products from efficient resources, minimize waste, and maximize reuse[41]. The Netherlands has also outlined a blueprint for integrating CE into the construction industry to create products for future generations. Additionally, a pilot study in Denmark has shown high possibilities for sharing, optimizing, and looping the construction process based on the Resolve framework. These CE implementations are expected to provide benefits such as reducing waste generation, addressing resource scarcity, and creating a sustainable future[41].

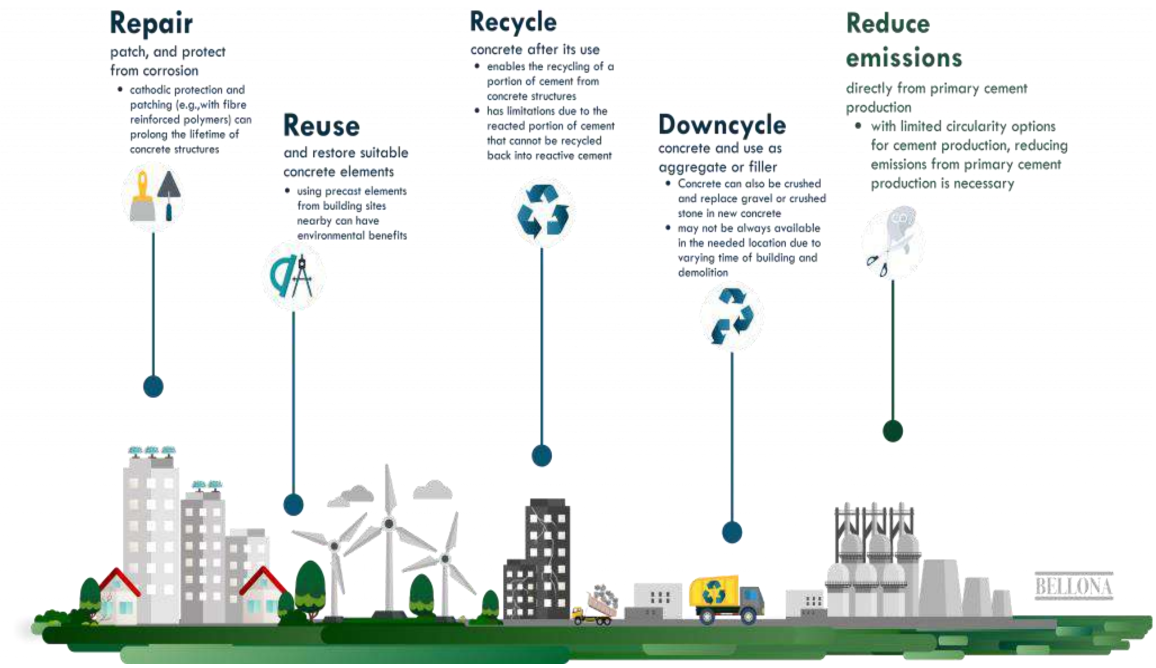


Figure 13: 4R

2.4.2 Building a Sustainable Future: Exploring Circular Economy Implementations in Construction

It explores a range of Circular Economy (CE) implementations within the construction sector, showcasing how this approach is transforming the industry. Some of the key implementations discussed include:

Re-use and Recycling of Construction Materials:

The re-use and recycling of materials play a pivotal role in minimizing waste and conserving resources. By repurposing materials from existing structures or recycling them for new projects, the industry can significantly reduce its environmental footprint[51].

Regenerative Solutions for Energy and Biodiversity:

The adoption of regenerative solutions involves creating structures that contribute positively to the surrounding environment. This includes strategies like generating renewable energy on-site, enhancing biodiversity through green roofs or native landscaping, and implementing systems that restore ecosystem services rather than deplete them[51].

Digital Technologies for Resource Optimization:

The integration of digital technologies, such as Building Information Modeling (BIM) and Internet of Things (IoT) devices, enables precise monitoring and management of resources throughout a building's lifecycle. This helps optimize material usage, energy consumption, and waste generation, resulting in both economic and environmental gains[51].

These implementations collectively yield various benefits:

Reduced Environmental Impact:

CE implementations strive to minimize the negative ecological consequences of construction activities, thereby contributing to a healthier planet[51].

Increased Resource Efficiency:

By reusing materials, optimizing resource use, and generating energy on-site, CE practices ensure that resources are utilized efficiently, reducing strain on finite resources[51].

Improved Economic Performance:

CE strategies often result in cost savings through reduced waste disposal expenses, lowered energy consumption, and improved operational efficiency[51].

Enhanced Biodiversity and Ecosystem Services:

Regenerative solutions promote harmony with nature, fostering biodiversity, and enhancing ecosystem services that benefit both the environment and communities[51].

The article underscores how the adoption of CE principles in construction is fostering innovation and driving positive change. These varied implementations collectively form a tapestry of strategies that contribute to a more sustainable and resilient built environment.

2.4.3 Circular Economy Innovations in Construction: Strategies and Benefits for Sustainable Building Practices

Certainly, here is the list of CE implementations along with their associated benefits, presented as bullet points and paraphrased to ensure originality:

Enhancing Energy Efficiency in Building Design:

Reduces energy consumption and greenhouse gas emissions, leading to lower operating costs and improved indoor comfort and air quality[71].

Extending Building Lifespan through Design:

Diminishes the need for new construction and associated resource consumption, resulting in decreased waste generation and improved economic advantages[71].

Designing for Disassembly:

Simplifies the retrieval of valuable materials and components, leading to decreased waste generation and enhanced resource efficiency[71].

Standardized Designs for Efficiency:

Enhances construction process efficiency and diminishes waste, facilitates disassembly and reuse, and brings economic benefits[71].

Incorporating Recycled Materials in Construction:

Reduces reliance on virgin materials, lessens waste generation, and bolsters resource efficiency[71].

Prefabricated Components for Waste Reduction:

Cuts down on waste generation, streamlines efficiency, and reduces construction duration and costs[71].

Modular Design for Facilitated Disassembly and Reuse:

Supports the recovery of valuable materials and components, reduces waste generation, and enhances resource efficiency[71].

Utilizing Renewable Energy Sources for Building Operations:

Decreases energy consumption and greenhouse gas emissions, resulting in lower operating costs and enhanced energy security[71].

Implementing Circular Business Models:

Elevates resource efficiency, curtails waste generation, and strengthens economic advantages[71].

Adopting Culturally Sustainable Indigenous Design Practices:

Safeguards cultural heritage, diminishes environmental impact, and fosters positive social outcomes[71].

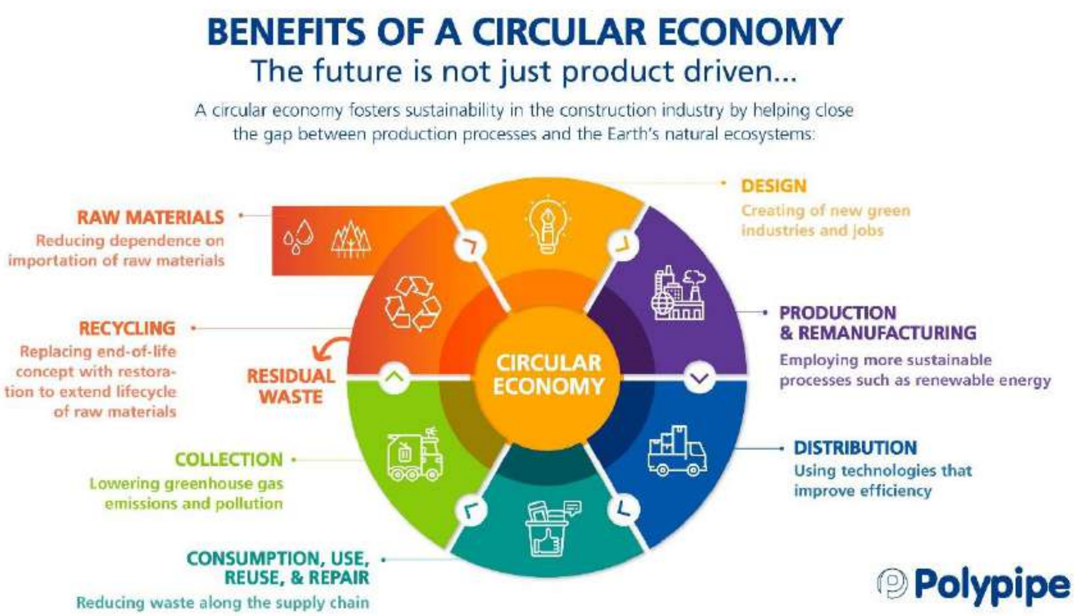


Figure 14: Polypipe Model , Middle East

2.4.4 Empowering Circular Economy in Construction: A Holistic Approach to Implementation and Collaboration

The drive to revolutionize the construction industry through Circular Economy (CE) principles has garnered the support of the EU-funded Horizon 2020 project BAMB (Buildings as Material Banks). This initiative seeks to infuse the industry with CE practices, primarily leveraging Material Passports (MPs) as a cornerstone. These passports encapsulate material characteristics within products and buildings, embodying the essence of Urban Mining to enable sustainable resource extraction. Alongside, Life Cycle Assessment (LCA) stands as a pivotal method, offering a lens to scrutinize environmental impacts throughout the lifecycle (International Organization for Standardization, 2006a)[72].

Forging the Path Forward with Collaborative Stakeholders:

Unveiling the prospects of CE implementation requires an understanding of the key stakeholders catalyzing this transformation. Past research by Honic et al. (2019) highlights the linchpins steering the ship of MPs and CE in the construction domain. By dissecting use cases and engaging with consortium partners including demolition firms, material industries, planners, and construction companies, the instrumental stakeholders in the creation of MPs and CE strategies were identified[72].

At the forefront, "AEC organizations" comprising designers, planners, construction companies, and MP consultants wield immense influence over material choices in construction. Their decisions hold the potential to amplify the use of recyclable materials with minimal environmental impact. Simultaneously, the "industry," represented by material and product manufacturers, acts as a wellspring of eco-inventories and environmental product declarations—vital inputs for LCA and MP[72].

Yet, the orchestration of CE also requires the steady hand of "regulative bodies" and "Public Policy" to set industry standards and regulations, playing a pivotal role in shaping the future of sustainable construction. Notably, regulations such as the European Commission's call for a minimum of 70% recycling of construction waste by 2020 can serve as a powerful catalyst for CE solutions[72].

The Confluence of Technology and Collaboration:

Conceptualized as both a technological marvel and an economic construct, the Digital Platform for Circular Economy (DEEP) emerges as a nexus that interlinks stakeholders, organizations (AEC companies), and meta-organizations (institutions). DEEP's mission is two-fold: augmenting value creation along the building project lifecycle and bestowing societal benefits through CE implementation. This intricate interplay, facilitated by digital design technologies and data repositories, charts a course toward resource optimization from inception to decommissioning[72].

Turning Vision into Reality:

The viability of these ideas is substantiated by a spectrum of research projects. The BIMaterial project, with its focus on BIM-based Material Passports, showcases a semi-automated workflow for their generation, steering the construction realm towards new horizons. Meanwhile, SCI_BIM underscores the significance of scanning and data capture in achieving integrated resources and energy assessment through Building Information Modelling[72].

In this pursuit, a compelling case study unfolds within a prominent Austrian design and planning company, DPC. Here, a digital ecosystem thrives, fostering innovation and sustainability hand in hand. The BIMaterial project, having established the framework for governing and managing MPs, underscores the roles of AEC, industry, and regulative bodies in realizing CE aspirations[72].

2.4.5 Unveiling Insights from Pioneering Research

The quest for a sustainable construction industry has spurred groundbreaking research that delves into the core of Circular Economy (CE) implementation. These studies offer profound insights into harnessing the potential of CE strategies to reshape the landscape of construction waste and resource utilization. Let us explore some of these seminal studies and their impact on shaping a greener, more responsible construction sector.

Tam (2008): A Paradigm Shift in Waste Management

Tam's investigation into the effectiveness of waste management plans within Hong Kong's construction sector reverberates as a pioneering step toward waste reduction and repurposing. The study underscores the significance of on-site material reuse, casting the spotlight on prefabricated components as a linchpin measure for waste reduction. By championing the use of these components, the construction industry embarks on a transformative journey that not only minimizes waste but also optimizes resource utilization[73].

Osmani et al. (2008): Architects' Crucial Role in Design-Driven Waste Minimization

Osmani and colleagues' revelations challenge preconceived notions about waste generation. Contrary to the prevailing belief that waste mainly emanates from on-site operations, this study unveils the significant impact of design decisions on construction waste—accounting for a substantial one-third of waste production. The study illuminates architects' pivotal role in driving waste minimization through informed design choices. However, a knowledge gap and the misconception that contractors are solely responsible for waste reduction act as barriers. Bridging this gap holds the key to unlocking CE's full potential[74].

Jaillon et al. (2009): Prefabrication's Power and its Limits

The study by Jaillon and team showcases the prowess of prefabrication in fostering a cleaner, safer, and more efficient construction environment. The revelation that prefabricated materials lead to a remarkable 52% waste reduction underscores the transformative potential of this method. Yet, the study also acknowledges a significant truth: while prefabrication drastically curtails waste, it cannot eliminate it entirely. The construction industry stands at a juncture where technological innovations intersect with sustainable practices to chart a path of reduced waste and increased efficiency[75].

Nunez-Cacho et al. (2018): Crafting a Blueprint for Comprehensive Evaluation

The seminal work by Nunez-Cacho and collaborators unveils a comprehensive evaluation system tailored for construction projects adhering to Circular Economy principles. The dimensions of this evaluation—the backbone of Circular Economy implementation—unfold a strategic roadmap. Energy management, water management, waste management, and the application of 3Rs principles (Reduce-Reuse-Recycle) emerge as the cornerstones. Additionally, the study underscores the significance of addressing emissions, materials, and the transitional facets of CE. This blueprint empowers entities involved in construction to navigate the intricate terrain of CE with purpose and precision[76].

Table 1: Literature Review

S. No	Authors	Year	Description
1.	Molchanova et al	2023	This literature review explores the concept of circular economy in the construction industry, highlighting its potential to reduce environmental impacts and resource consumption[77].
2.	Asante et al	2022	This study investigates circular economy (CE) practices in an emerging economy's construction and demolition industry, prioritizing reduce and recover principles, using a hybrid methodology[71].
3.	Zeng, X. et al	2022	This paper discusses the challenges and opportunities of implementing circular economy policies globally, emphasizing the need for international collaboration and addressing toxic material flows[78].
4.	Schumacher et al	2022	This article focuses on transitioning the U.S. textile industry from a linear to a circular economy, emphasizing reuse and recycling. It highlights the rapid growth of textile production, especially fast fashion, and its environmental and social impacts. The article suggests collaborative efforts and policy changes to promote circularity in U.S. textiles[9].
5.	Yu, Y. et al	2022	This study explores how ICT tools like BIM, GIS, and RFID support Circular Economy in construction, addressing waste reduction and material tracking, with future research recommendations[67].

6.	Othman et al	2022	A Circular Economy Index is presented to assess the Arab region's transition towards sustainable circular economies[23].
7.	Ghufran et al	2022	The study explores the implementation of Circular Economy (CE) principles in the construction industry, emphasizing sustainability. They use system dynamics to model and simulate enablers for CE, highlighting the importance of policy support and organizational incentive schemes[79].
8.	Corvellec et al	2021	This article discusses the critiques of the circular economy and its limitations in terms of theoretical, practical, and ideological grounds. It argues that the circular economy depoliticizes sustainable growth and presents uncertain contributions to sustainability[3].
9.	Guerra et al	2021	This study examines Circular Economy adoption in the U.S. construction industry, assessing stakeholder awareness, barriers, and enabling factors, contributing to sustainability discussions in the sector[2].
10.	Khahro et al	2021	The article explores factors influencing the implementation of green procurement in the Pakistani construction industry, highlighting its importance for sustainability[29].
11.	Charef, R. et al	2021	This article examines the challenges and obstacles hindering the adoption of the circular economy (CE) principles in the architecture, engineering, and construction (AEC) sector. The study conducts a comprehensive review of existing journal papers to identify and classify these barriers into six categories. The research aims to provide insights and strategies for stakeholders in the AEC sector to overcome these barriers and transition towards a more sustainable CE approach[53].

12.	Honic, M. et al	2021	This study explores the concept of Material Passports (MPs) for buildings' end-of-life stages, aiming to enhance recycling and reduce resource consumption. It assesses the recycling potential and environmental impact of materials in a demolition case study, highlighting the importance of MPs in supporting circularity and sustainability in construction[28].
13.	Sparrevik, M. et al	2021	This article explores the application of circular economy principles in the construction sector, emphasizing environmental performance assessment methods at various systemic levels[51].
14.	Fořt, J. et al	2020	This study assesses the environmental aspects of waste brick recycling in the construction industry, examining scenarios like cement replacement and alkaline activation to achieve circular economy goals. Environmental impacts vary, with partial cement replacement showing promise for decarbonization[80].
15.	Chizaryfard et al	2020	This article explore the circular economy (CE) as an evolutionary process, proposing a framework based on development blocks to understand industrial transformation toward sustainability[19].
16.	Iva Kovacic et al	2020	The paper discusses the potential of digital technologies to support Circular Economy (CE) in the Architecture, Engineering, and Construction (AEC) industry. It explores the integration of Building Information Modeling (BIM) and Material Passports to optimize resource use and recycling in construction, proposing a Digital Platform for Circular Economy (DEEP) to facilitate data exchange and collaboration among stakeholders[72].
17.	M. U Hossain et al	2020	This review analyzes the implications of implementing the circular economy (CE) concept in the construction industry. It highlights challenges, trends, and proposes an integrated CE framework for sustainable construction[61].

18.	Osobajo et al	2020	This systematic review identifies current trends and research gaps, highlighting the need for broader exploration of circularity in construction beyond waste management[24].
19.	Benachio et al	2020	This article reviews the shift from a linear construction model to Circular Economy practices, addressing resource extraction and waste issues. It analyzes 45 articles, highlighting trends and knowledge gaps in adopting Circular Economy principles in construction[1].
20.	Zils, M. et al	2020	This article explores the circular economy's value creation and capture through four building blocks: circular design, business models, reverse network management, and system enablers, using real-world examples[81].
21.	Afshari, A. R et al	2019	It explore Circular Economy (CE) in the construction sector, focusing on its potential to reduce waste and environmental impact. They discuss CE theoretical approaches, strategies, and implementation cases while offering future development suggestions[82].
22.	Manelius et al	2019	This paper discusses a construction project in Roskilde, Denmark, where approximately 90% of building materials were reused, designed for disassembly. The case study focuses on the transformation of a former industrial building and highlights end-user engagement and the role of city administrators in promoting circular economy practices in construction[14].
23.	Van Breugel, K. et al	2018	The paper discusses the role of models in science and technology and their potential for sustainable solutions in the construction industry. It highlights how models have contributed to impressive growth but also points out the sustainability challenges. The paper emphasizes the need to rethink current approaches for sustainability[83].
24.	Zhao et al	2018	The study reveals that Chinese croplands experienced a net increase in soil organic carbon (SOC) due to enhanced organic inputs driven by economics and policy changes, despite regional variations[40].

25.	Kirchherr et al	2018	This article discusses the challenges of defining and conceptualizing the Circular Economy (CE), highlighting the lack of consensus among scholars. It recommends a clear, comprehensive definition for future research[4].
26.	Esa, M. R et al	2017	This article examines circular economy principles for managing construction and demolition waste in Malaysia, proposing a framework for waste reduction throughout the construction cycle[41].
27.	Winning, M. et al	2017	This article discusses the development of the Environmental Global Applied General Equilibrium (ENGAGE-materials) model to analyze the circular economy and resource efficiency in the iron and steel industry, highlighting its potential economic and environmental benefits[84].
28.	Geissdoerfer et al	2017	This article reviews the relationship between the Circular Economy and sustainability, offering conceptual clarity by distinguishing the terms and their various relationships. The study examines their similarities, differences, and eight relationship types[11].
29.	Environmental Services Association	2017	The UK's transition to a Circular Economy, driven by cooperation among various stakeholders, requires a responsive planning system to facilitate waste management infrastructure development, generate jobs, and boost the economy[85].
30.	Adams, K.T. et al	2017	This study explores the awareness, challenges, and enablers of implementing circular economy principles in the UK construction sector, addressing material efficiency and waste management[37].
31.	Gharfalkar, M. et al	2016	This article investigates inconsistencies in reuse options, including repair, remanufacture, and refurbish, emphasizing the importance of standardized definitions to enhance resource recovery and sustainability[86].

32.	Moncaster, A. et al	2016	This article discusses the role of the built environment in the transition to a circular economy, highlighting the need for interdisciplinary research and a focus on individual buildings. It reviews existing tools and techniques for circular economy research in the built environment and provides a valuable framework for future research initiatives[39].
33.	Stahel et al	2016	The article advocates for a circular economy, emphasizing reuse and recycling of goods, which can reduce emissions and create jobs. The author shares personal experiences and discusses two business model categories for this approach, promoting sustainability[6].
34.	Xu, Xin, et al	2014	The article investigates how ICT service innovation and strategic approaches like service leadership and technology leadership influence customer loyalty and brand equity in the consumer technology market[87].
35.	Volk, R. et al	2014	The paper reviews Building Information Modeling (BIM) in the context of existing buildings, highlighting challenges in implementation and research. It emphasizes the need for BIM in maintenance and deconstruction processes[47].
36.	Bansal, S., et al	2013	This article explores a sustainable approach to managing construction and demolition waste. It emphasizes the importance of reusing and recycling materials from these processes to reduce environmental impact and enhance sustainability in the construction sector[30].

CHAPTER-3
RESEARCH METHODOLOGY

3.1 Introduction:

In this chapter research methodology of the study is explained in detail. This research was based on the collection of data through a literature review and using a specific emphasis is placed on incorporating VOS Viewer software, a recognized tool for efficiently visualizing and analyzing complex bibliometric networks and by constructing questionnaires and then analyzing the collected factors by using SPSS. The survey of the questionnaire was obtained from professional and experienced people from different private and public construction sectors.

3.2The Research Design:

This Research employs a mixed-methods approach. Qualitative approach is used to investigate and identify the applications and highlight the challenges and barriers faced by construction industry in the adoption of CE and enable us to provide suggestions for the implementation of CE in the construction industry.

In the quantitative approach, questionnaire surveys are circulated among the qualified construction participants to evaluate the challenges and barriers faced by the construction industry and also their suggestions are of great values for the implementation of CE in the construction industry and provide information about the current prevailing trends and situations in the construction industry. VOS VIEWER software is also used for the mapping of various research papers investigated for the applications of CE in construction industry. SPSS is also used for statistical analysis of the both the questionnaire surveys of barriers and challenges of CE in construction industry and their suggestions for its implementations.

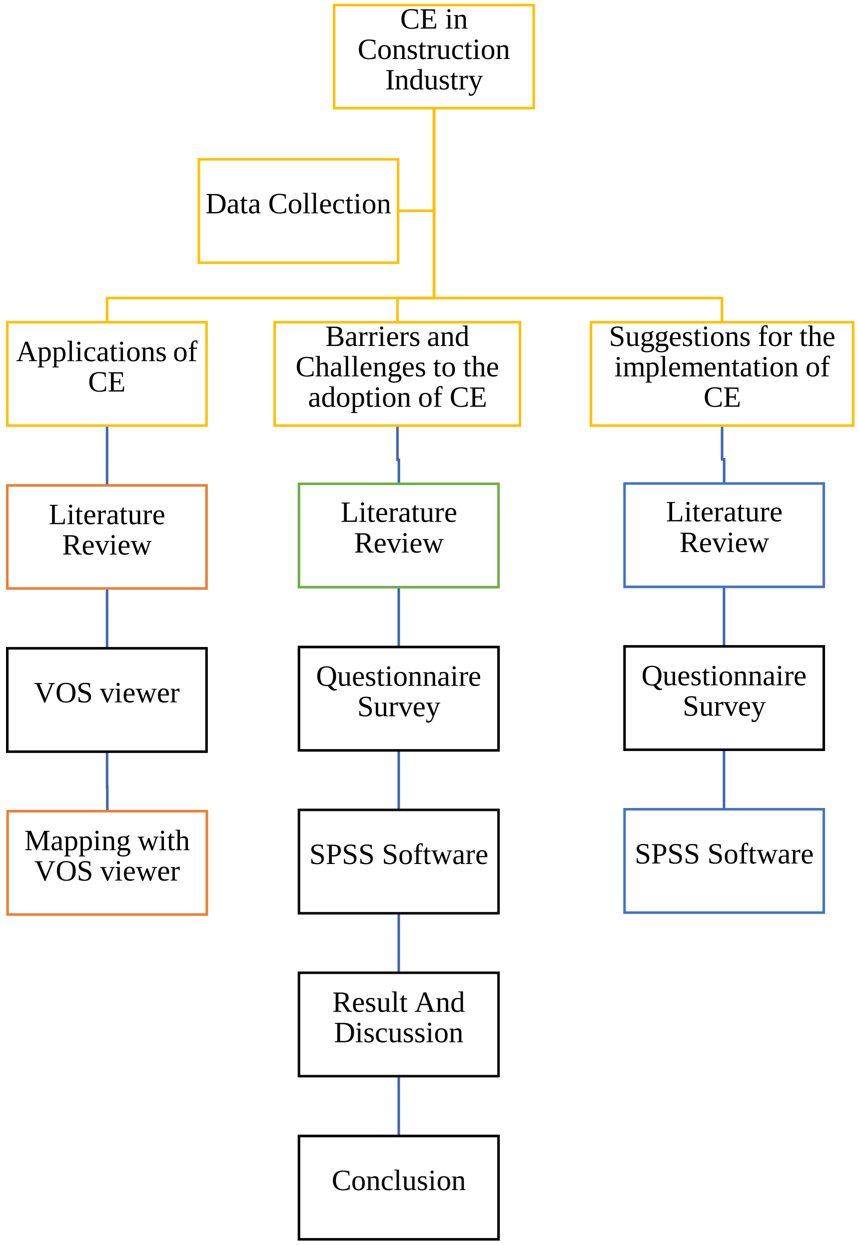


Figure 15: Research Methodology

3.3 Data Collection:

Data was collected from different sources as discussed below.

3.3.1 Primary Data.

The collection of primary data for this study involved distributing questionnaires to professionals and stakeholders in various public and private sector engineering departments of Pakistan specific to this project. The subsequent analysis and research findings were heavily reliant on the data thus obtained.

3.3.2 Secondary Data.

The secondary data for this research was collected through a literature review. The literature review was done through books, research articles, the Internet, construction management, and engineering journals, and many More methods are applied to get the data.

3.4 Questionnaire Design:

To collect data and to satisfy the objectives of the research study, two questionnaires were carefully designed and developed. From the study of the literature review, 10 questions were identified for the preparation of each questionnaire. The questionnaires consists of two sections, one for the demography of the respondents and the second with the questions with 5-point Likert scale questions like Significantly, Fairly, Adequately, Slightly, Insignificantly and Very actively, Actively, Moderately, Not Actively, Not at all. The questionnaire was drafted based on the results of the literature review and discussed by several times with the project supervisor and academic experts to identify and remove any ambiguity. After confirming and establishing that these questionnaires were enough for data collection, the questionnaires were finalized and then approved by the project supervisor with slight modifications. After that the questionnaires were provided to construction professionals, Engineers and, contractors. For the online questionnaire survey, the same questionnaires were transferred into electronic files and soft forms, and links of the online surveys were generated by using google forms and distributed among different social platforms and through emails.

3.5 Questionnaire Administration:

Diverse construction professionals, engineers, and experienced contractors completed the questionnaires, distributed in both private and public construction sectors. The data collection spanned approximately five weeks. To enhance this process, face-to-face discussions and an online Google Form were employed for an inclusive approach.

3.6 Method for Data Analysis:

The first objective is completed with VOS viewer mapping of common keywords found in different article which were analyzed for the applications of CE in CI, while the other two objectives were completed after successfully achieving the key milestone of data collection, a comprehensive analysis was conducted using both qualitative and quantitative methods. The data obtained from the questionnaire survey were compiled, organized, and then entered into the Statistical Package for Social Sciences (SPSS-23) software for rigorous statistical analysis. The ranking of the analyzed factors was determined by calculating their average means. The detailed results of this analysis are elucidated in chapter four.

CHAPTER-4
RESULTS AND DISCUSSION

4.1 Introduction:

This chapter details the utilization of VOS viewer for article mapping and the statistical analysis of data obtained through questionnaire surveys. The subsequent discussion provides a thorough exploration of the analysis results, accompanied by maps, graphs, charts, and tables that elucidate the findings from the questionnaire and align with the research study objectives. The results and analysis of the research study are presented in an organized manner based on specific objectives.

4.2 Objective 1:

To accomplish the objective 1 of this study, we employed VOSviewer software to conduct a comprehensive review of articles focusing on the applications of Circular Economy (CE) within the construction industry. Initially, a rigorous RIS form was created, specifying a minimum occurrence threshold of 3 and selecting 28 key terms. The application of VOSviewer enabled a methodical analysis, empowering us to identify meaningful patterns and relationships within the literature. The resulting insights make a substantial contribution to the synthesis of knowledge in this specific domain, underscoring the uniqueness and originality of our study.

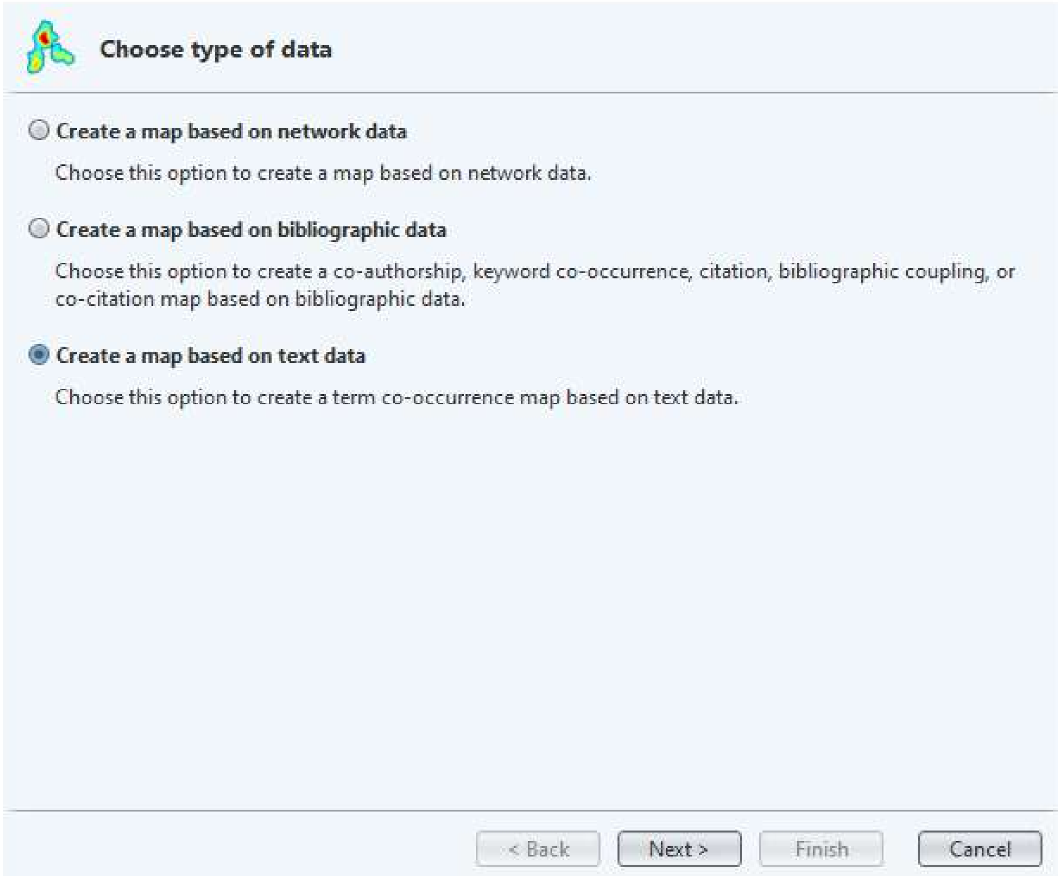


Figure 16: Choose VOS VIEWER Type Data

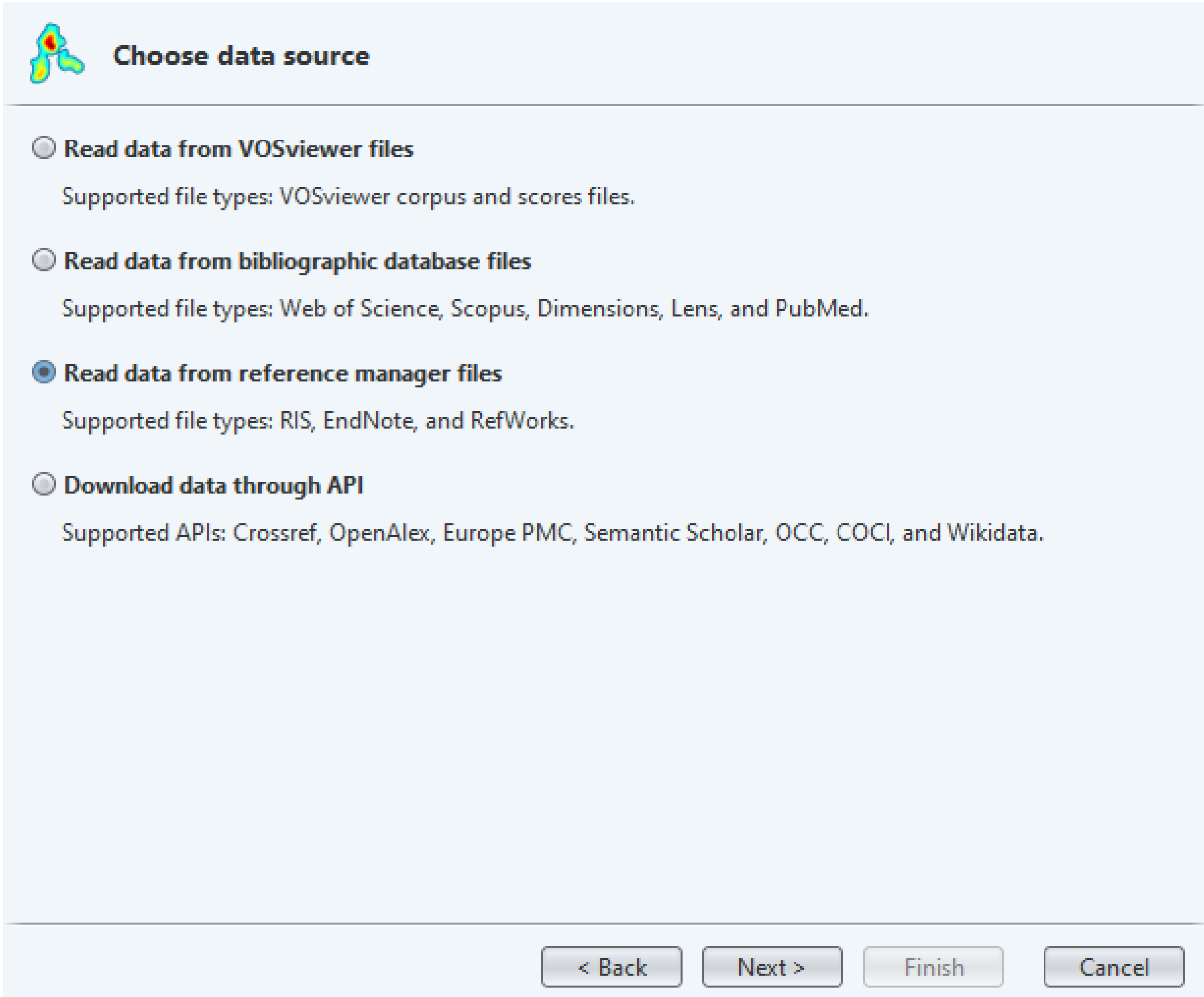


Figure 17: Choose VOS VIEWER data source

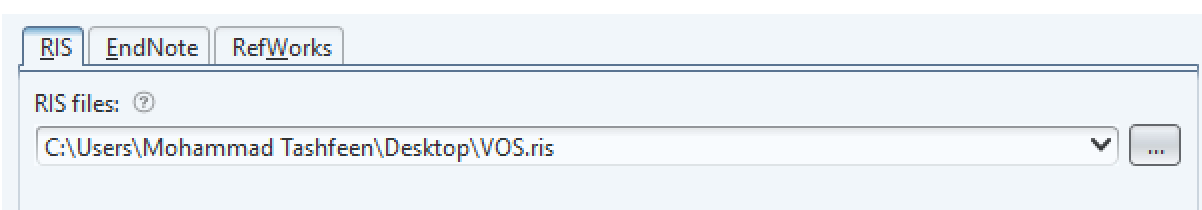


Figure 18: RIS File

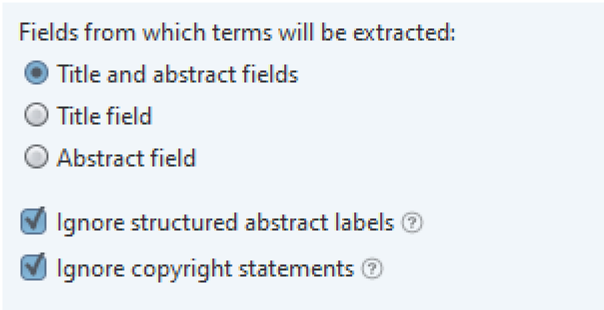


Figure 19 : VOS viewer fields for extraction

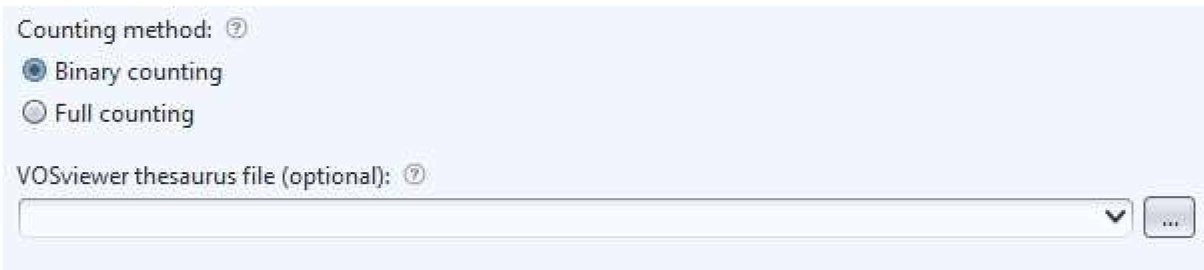


Figure 20: Binary Counting in VOS VIEWER

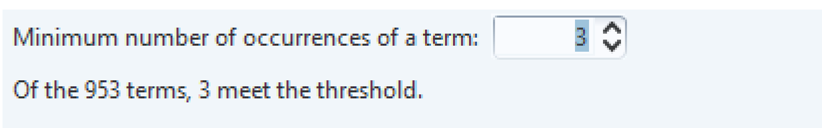


Figure 21: Threshold

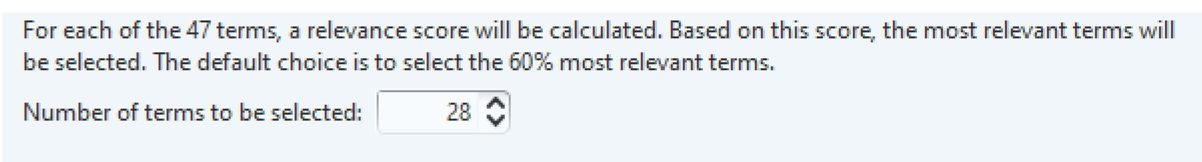
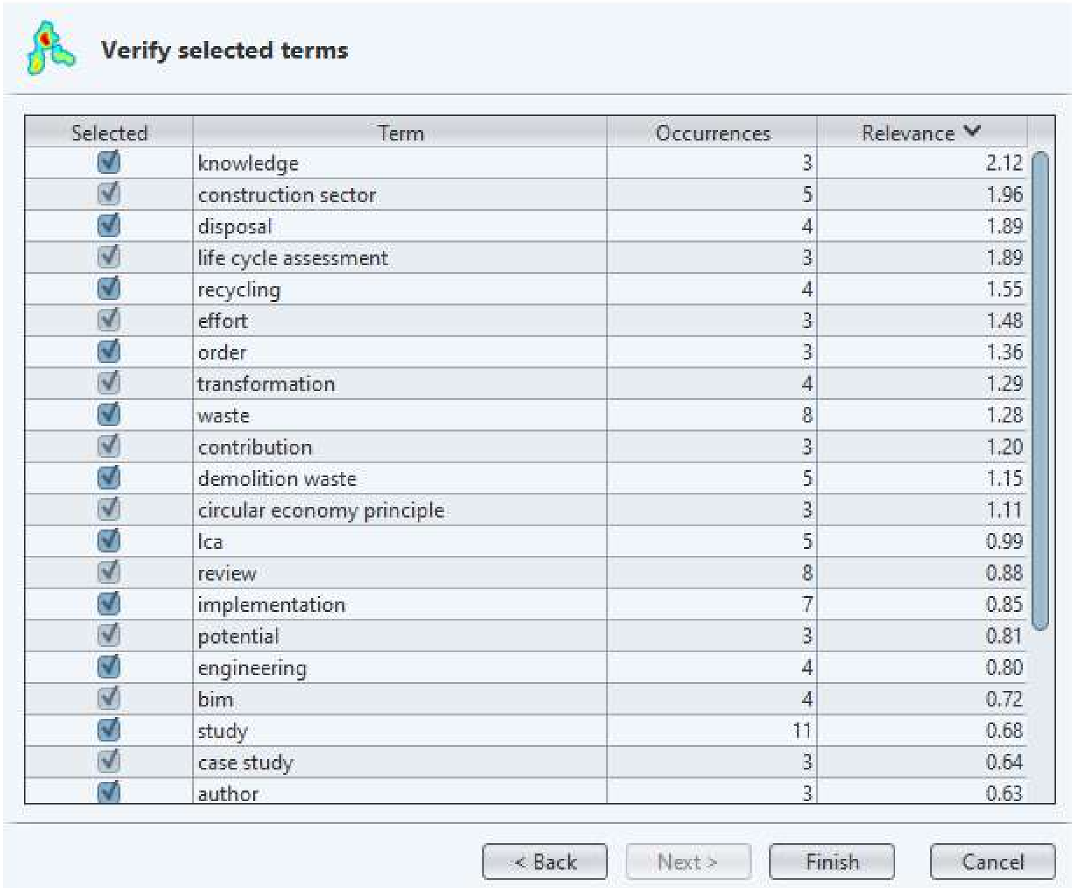


Figure 22: Number of terms



Verify selected terms

Selected	Term	Occurrences	Relevance
☑	knowledge	3	2.12
☑	construction sector	5	1.96
☑	disposal	4	1.89
☑	life cycle assessment	3	1.89
☑	recycling	4	1.55
☑	effort	3	1.48
☑	order	3	1.36
☑	transformation	4	1.29
☑	waste	8	1.28
☑	contribution	3	1.20
☑	demolition waste	5	1.15
☑	circular economy principle	3	1.11
☑	lca	5	0.99
☑	review	8	0.88
☑	implementation	7	0.85
☑	potential	3	0.81
☑	engineering	4	0.80
☑	bim	4	0.72
☑	study	11	0.68
☑	case study	3	0.64
☑	author	3	0.63

< Back | Next > | Finish | Cancel

Figure 23: VOS VIEWER Selected terms

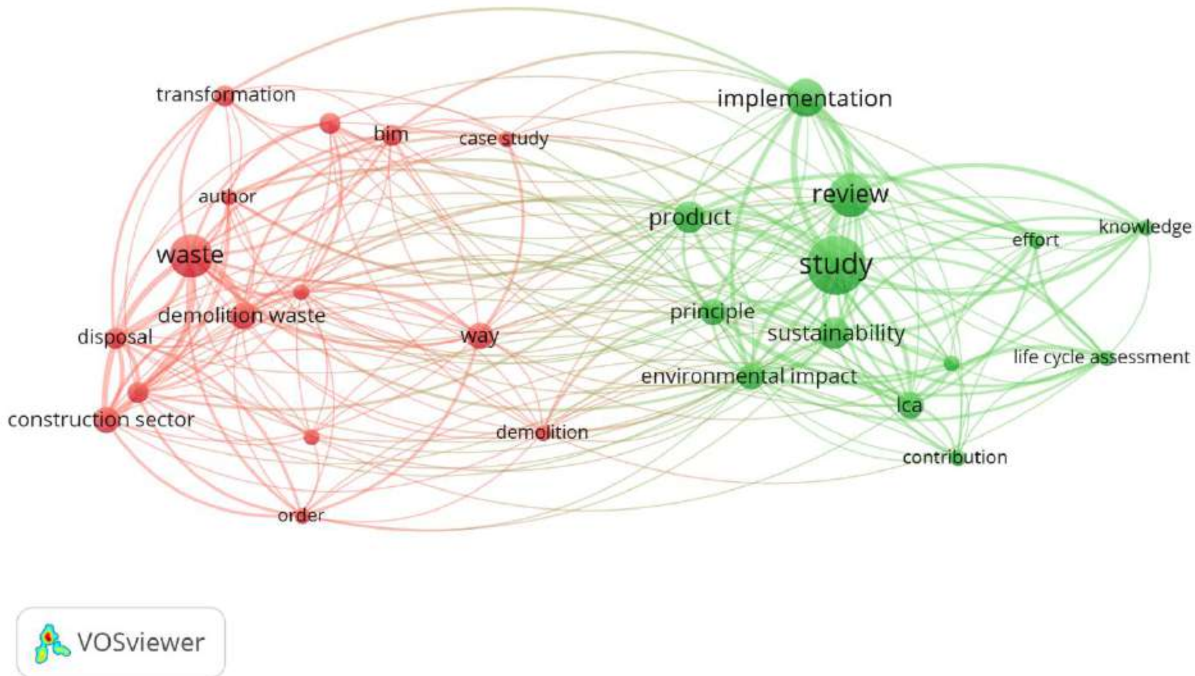


Figure 24: Network Visualization By VOS VIEWER

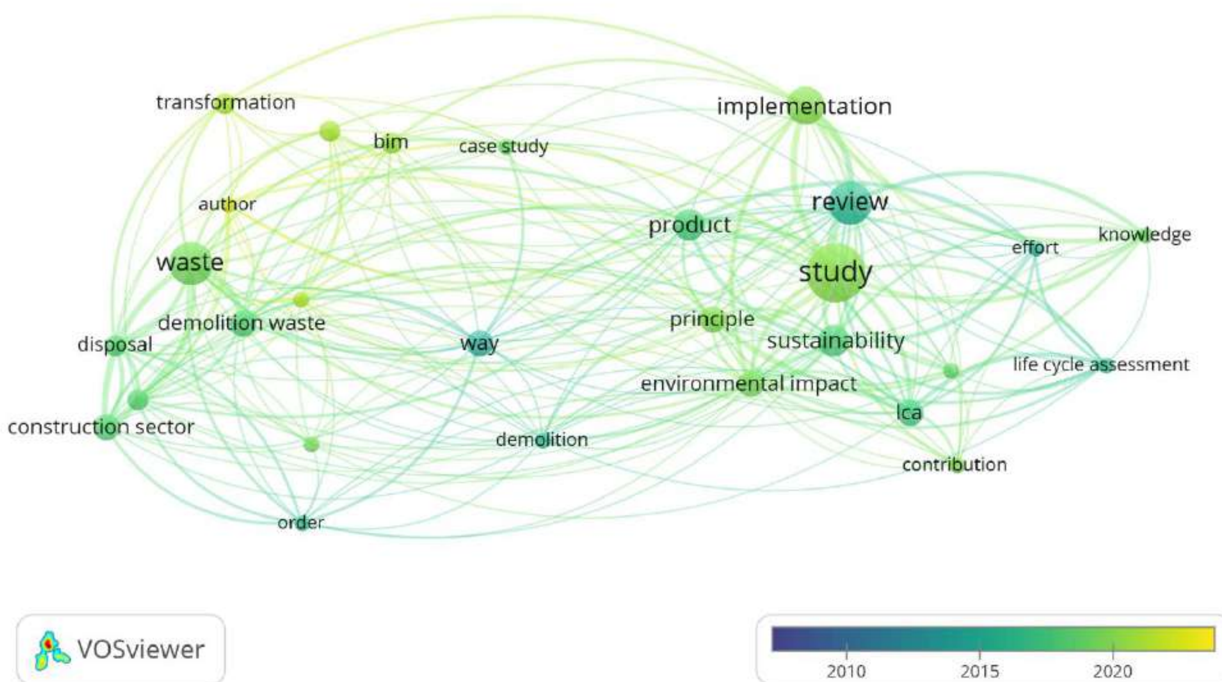


Figure 25: Overlay Visualization by VOS VIEWER

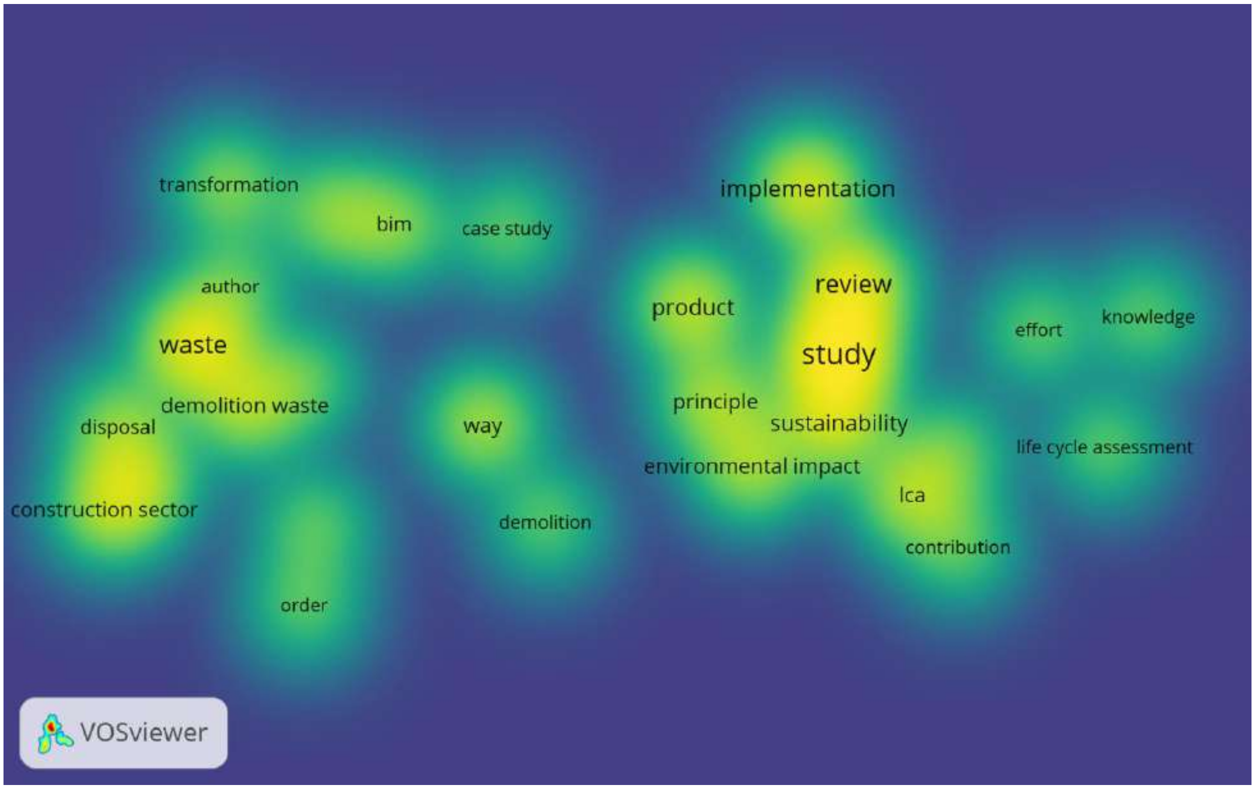


Figure 26: Density Visualization By VOS VIEWER

4.3 Objective 2:

To achieve the objective 2 of research a questionnaire survey was conducted. The questionnaire was consisting of two sections, one was a demographic section and the second was consisting of questions regarding barriers and challenges. The questionnaire was consisting of 10 questions as described in the previous chapter and a total of 120 questionnaires were distributed to the professionals of the construction industry and 101 were filled and received.

4.2.1 Demographics of respondents:

From the total 101 responses, 87 responses were received from Govt./ public organization, 14 to private sector organizations. The respondents worked for B & R (Building and Roads) which also includes C & W (Constructions and works), Irrigation department of Balochistan, NHA (National Highway Authority), Local government of Balochistan, , UP

& DD (Urban Planning & Development Department) Balochistan, and private consultancies and firms.

The respondents were working at various professional levels, the majority of them almost 2 were assistant Engineer, 44 were SDO,19 were XEN and DD, 5 were Chief Officers and Secretary, 16 were Sub Divisional Engineers, 15 were contractor. The age of respondents were that 48 were aged above 40 years, 6 of them were between 35 to 40 years, 21 of them were between 31 to 35 years and 27 of them were between 25 to 30 years.

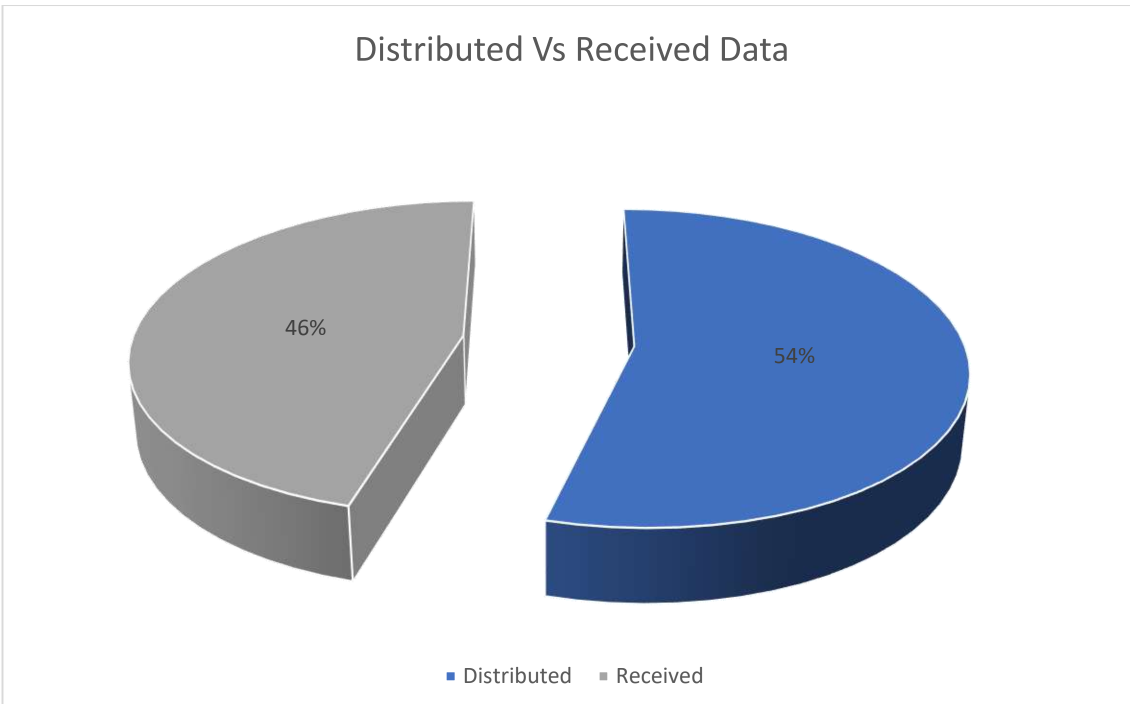


Figure 27: Distributed Vs Received Data

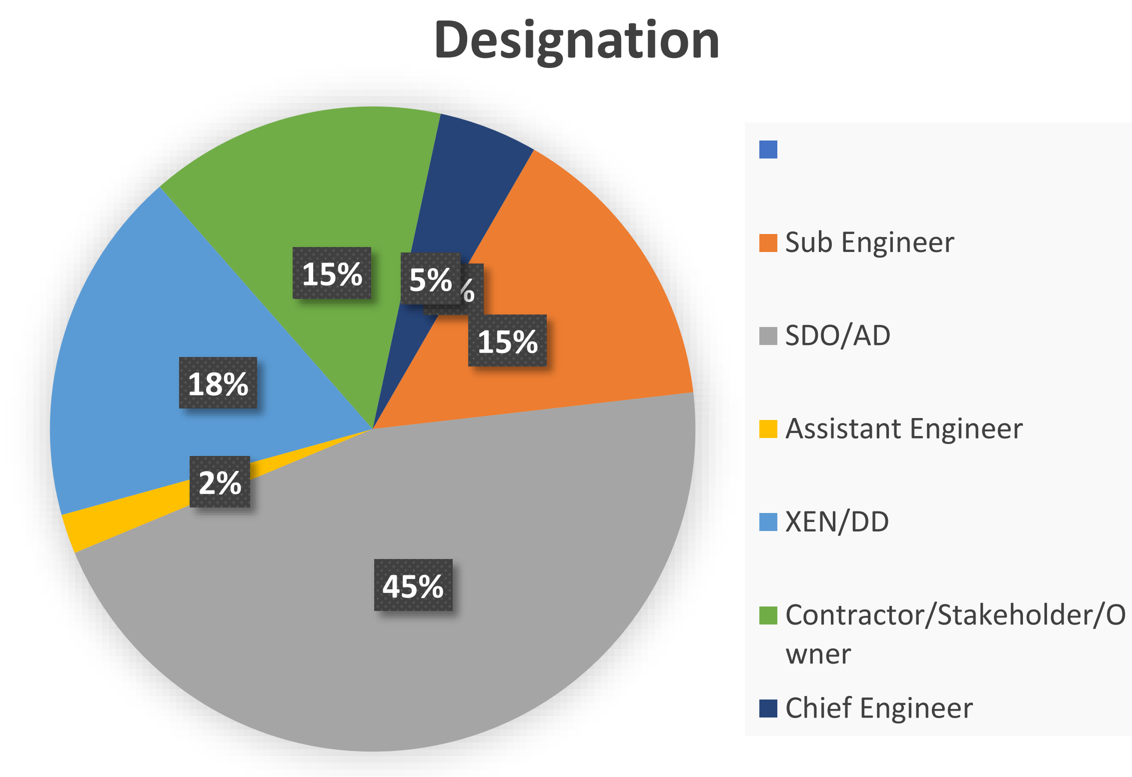


Figure 28: Designation of respondants

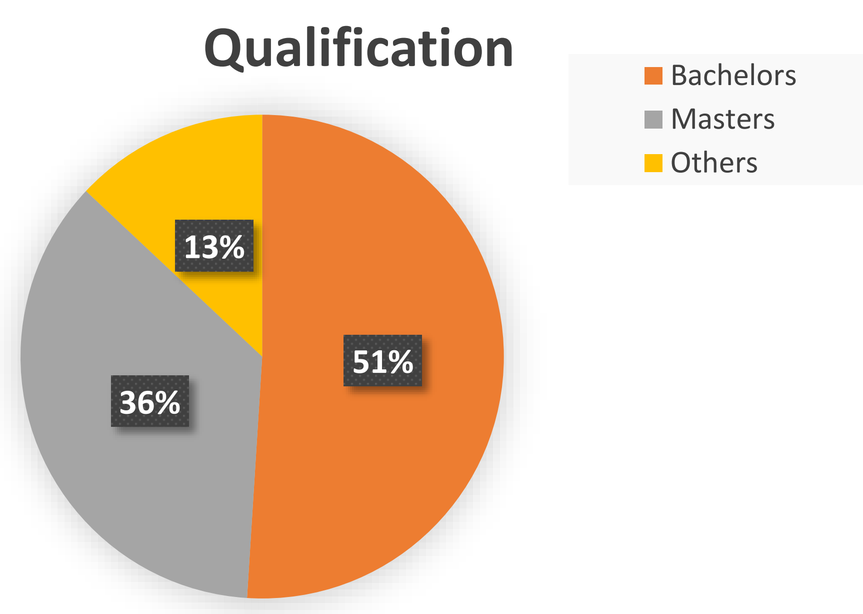


Figure 29: Qualification of Respondants

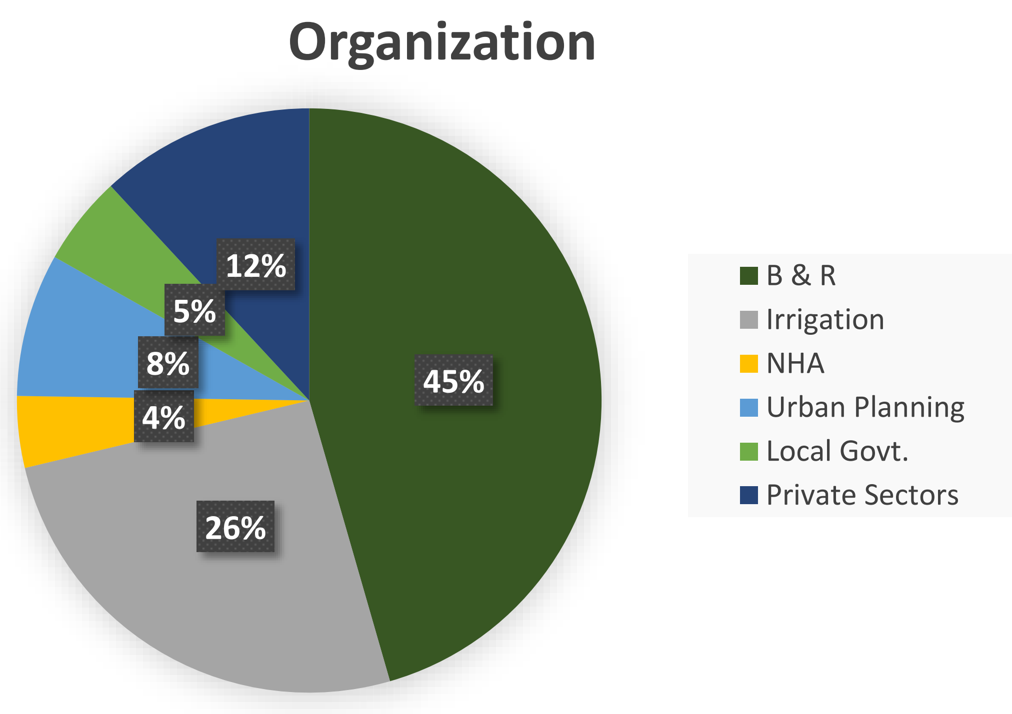


Figure 30: Organization of Respondants

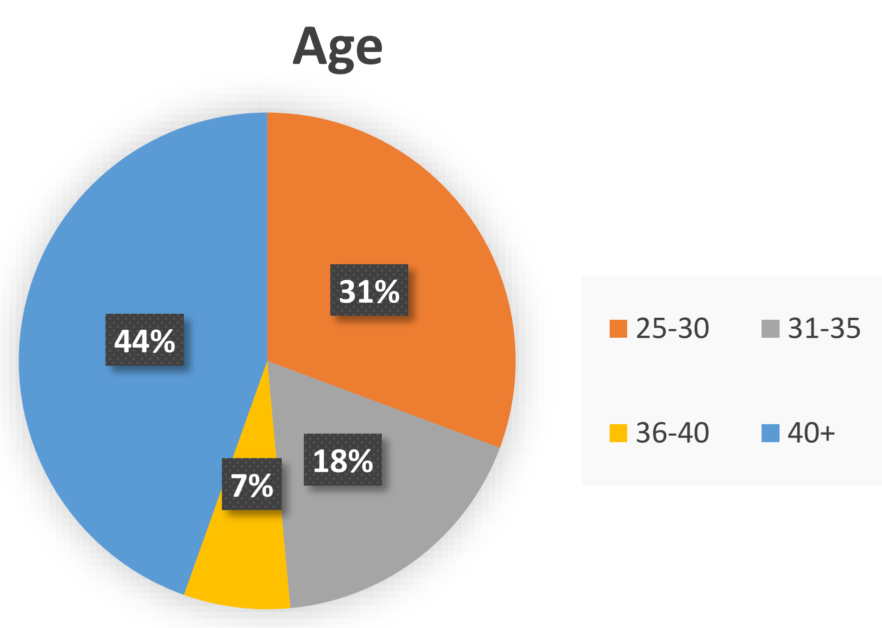


Figure 31: Age of Respondants

4.2.2 Results and Discussion:

A questionnaire consisting of 10 questions to identify the barriers and challenges in the adoption of CE was designed and distributed to know the top ranking barriers which affect the adoption of CE. Questions based on the mean scale were initially analyzed using SPSS software, then these were further analyzed using MS excel. The overall results of the SPSS software, MS excel, and presented in the Tabular, Pie chart, and Bar charts form.

Table 2: Result of Questionaire Survey 1

Sr. No.	Barriers & Challenges in Adoption of CE	Mean	Ranking
1	Progress Regarding Recyclable Building.	2.80	1
2	Resistance in adopting new CE practices	2.44	2
3	Lack of Collaboration between stakeholders.	2.24	3
4	Short term focus on immediate profit.	2.23	4
5	Impact of inadequate policies.	2.21	5
6	Limited Government Support.	2.19	6
7	Slow Adoption of Technology within construction.	2.12	7
8	Incomplete Supply Chain.	2.07	8
9	Lack of information about materials.	2.03	9
10	Lack of clear rules to adopt clean energy.	1.93	10

4.2.3 Mean of Barriers & Challenges:

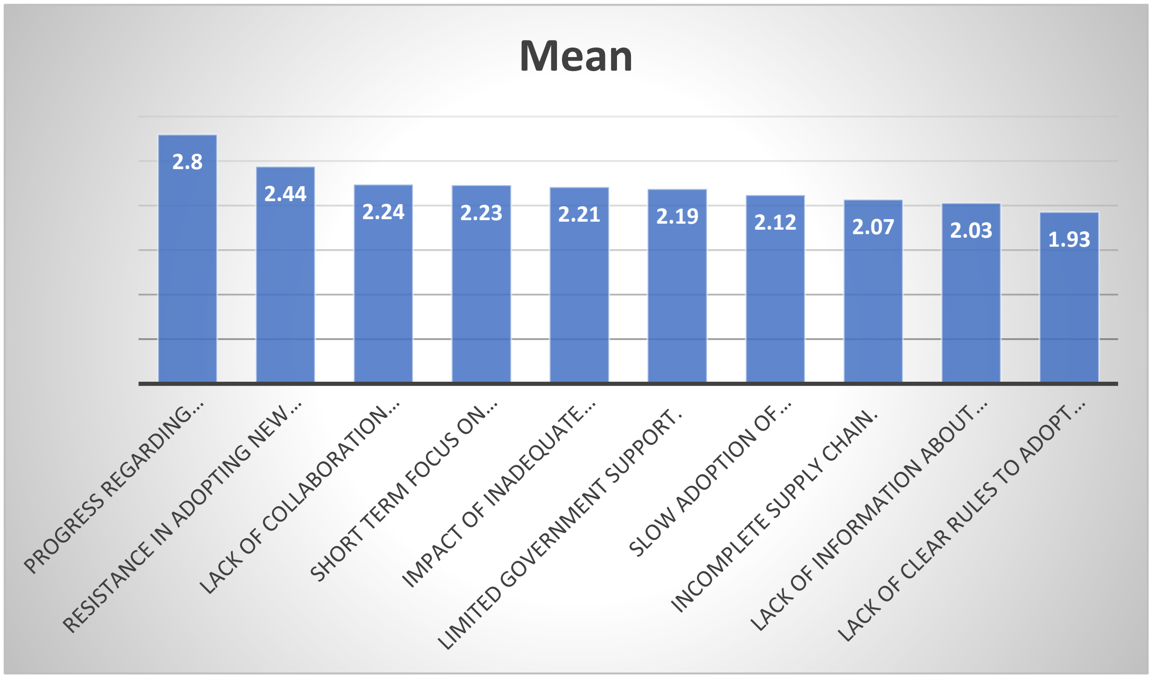


Figure 32: Mean Chart of Questionaire Survey 1

The above bar graph is the result of MS excel analysis, which shows the top 10 based on the highest mean at the first which shows the barriers and challenges in the adoption of CE in the construction industry.

4.4 Objective 3:

To achieve the objective 3 of research a questionnaire survey was conducted. The questionnaire was consisting of two sections, one was a demographic section and the second was consisting of questions regarding implementation of CE in construction industry. The questionnaire was consisting of 10 questions as described in the previous chapter and a total of 120 questionnaires were distributed to the professionals of the construction industry and 94 were filled and received.

4.2.4 Demographics of respondents:

From the total 94 responses, 80 responses were received from Govt./ public organization, 14 to private sector organizations. The respondents worked for B & R (Building and

Roads) which also includes C & W (Constructions and works), Irrigation department of Balochistan, NHA (National Highway Authority), Local government of Balochistan, , UP & DD (Urban Planning & Development Department) Balochistan, and private consultancies and firms.

The respondents were working at various professional levels, the majority of them almost 2 were assistant Engineer, 42 were SDO,17 were XEN and DD, 4 were Chief Officers and Secretary, 15 were Sub Divisional Engineers, 14 were contractor.

The age of respondents were that 46 were aged above 40 years, 7 of them were between 35 to 40 years, 18 of them were between 31 to 35 years and 23 of them were between 25 to 30 years.

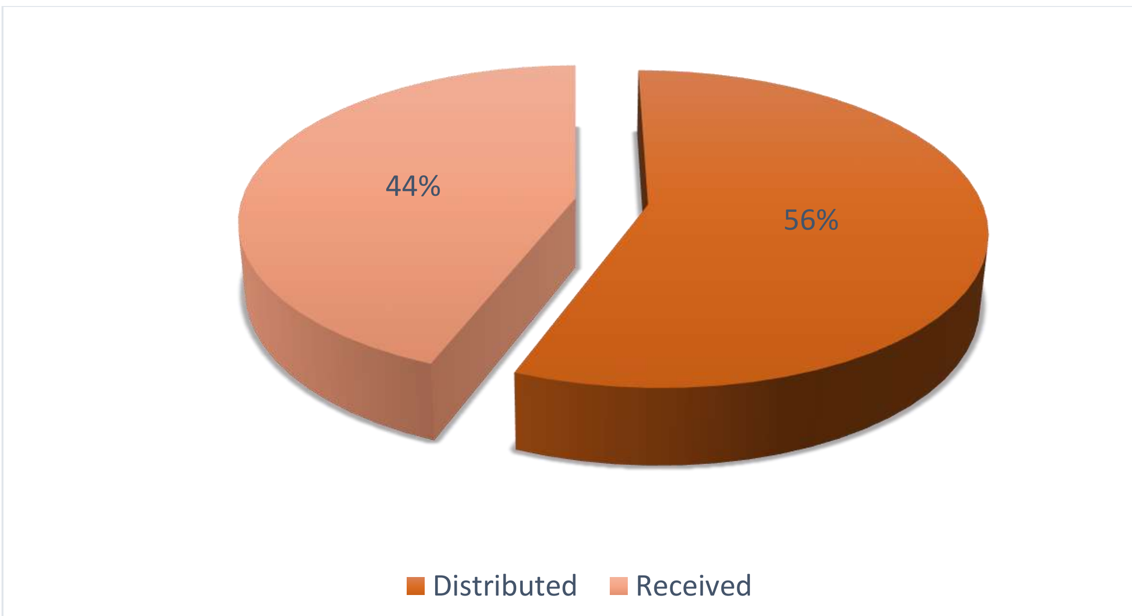


Figure 33: Distributed Vs Received Data

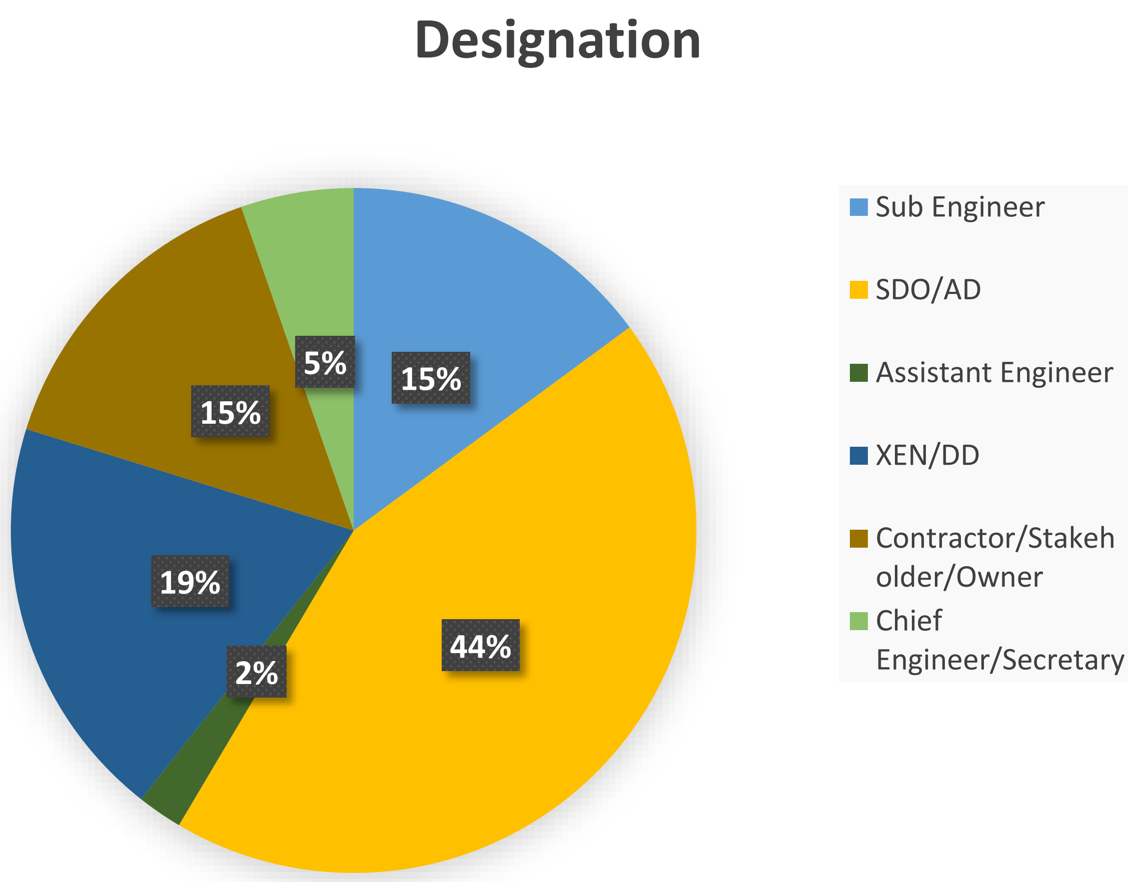


Figure 34: Designation of Respondants

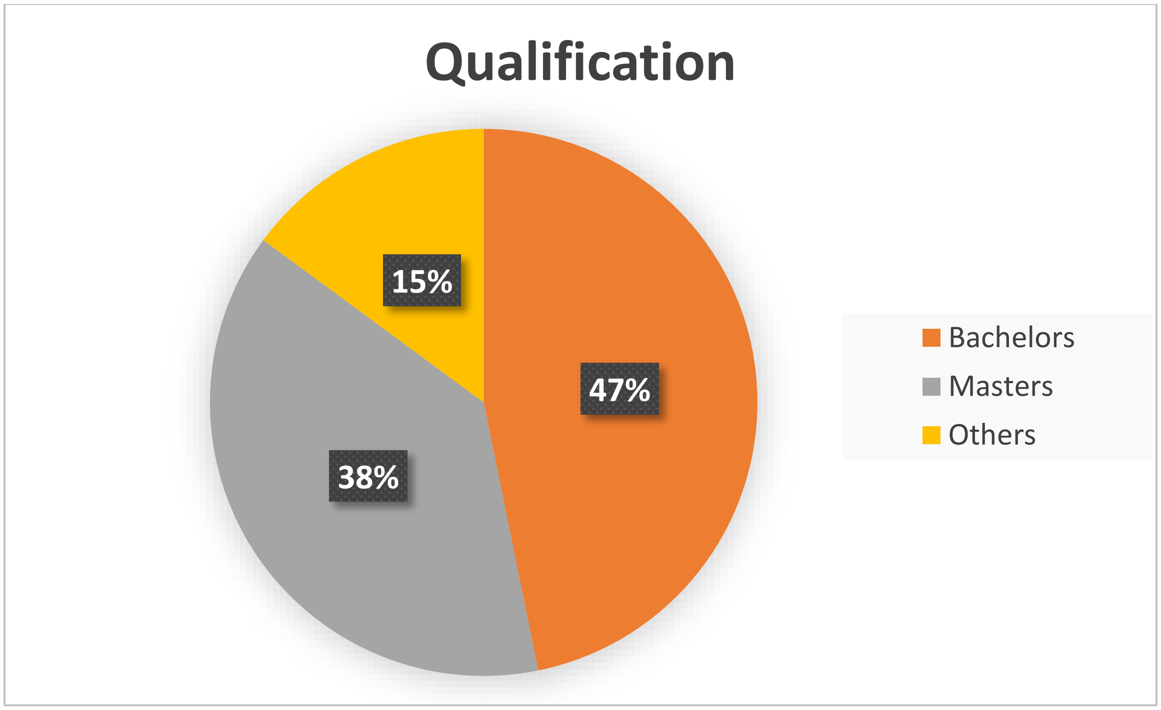


Figure 35: Qualification of Respondants

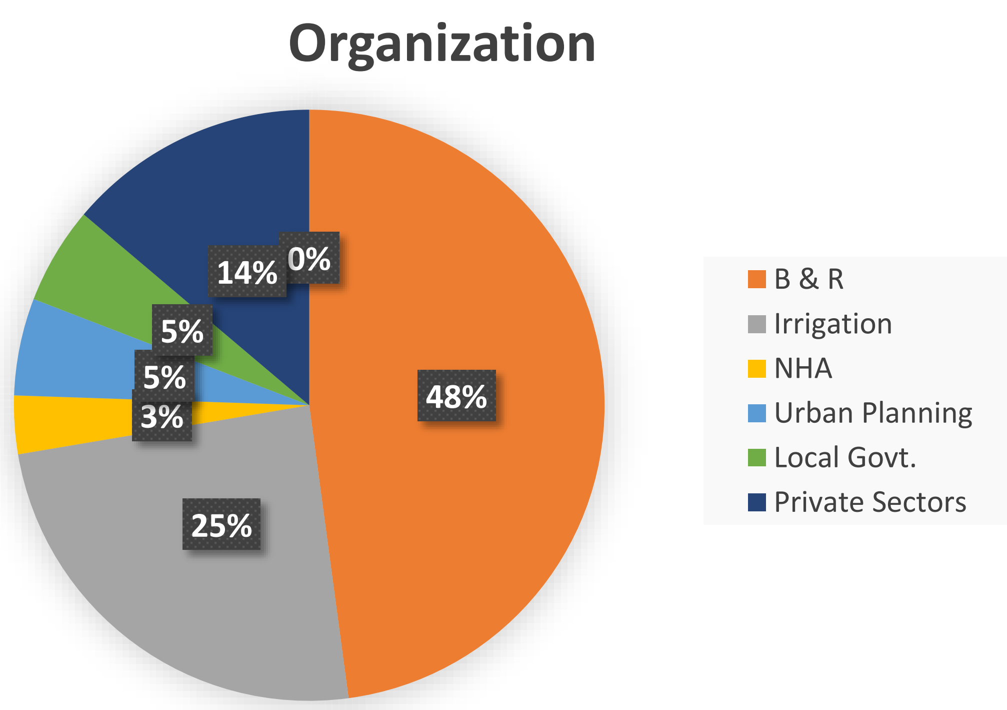


Figure 36: Organization of Respondants

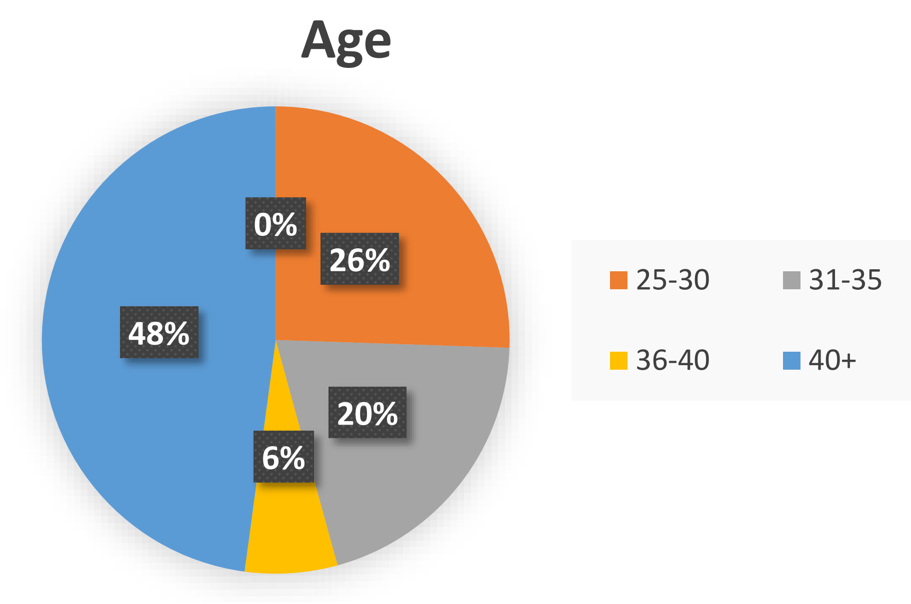


Figure 37: Age of Respondants

4.2.5 Results and Discussion:

A questionnaire consisting of 10 questions of suggestions for the implementation of CE in CI designed and distributed to know the top ranking implementation need. Questions based on the mean scale were initially analyzed using SPSS software, then these were further analyzed using MS excel. The overall results of the SPSS software, MS excel, and presented in the Tabular, Pie chart, and Bar charts form.

Table 3: Results of Questionaire Survey 2

Sr. No.	Implementation of CE in CI	Mean	Ranking
1	Using KPI to measure the success of CE.	4.05	1
2	Adoption of advanced technology and tools. (BIM)	3.95	2
3	Invest in Training & Educating about CE.	3.94	3
4	Comply with existing CE regulations.	3.85	4
5	Implements CE strategies in Construction.	3.73	5
6	Engage in sustainable procurement practices.	3.72	6
7	Implement Circular Business Models.	3.56	7
8	Collaborate with stakeholders to promote CE.	3.45	8
9	Design for construction projects to facilitate reuse.	3.28	9
10	Prioritize the reuse of construction materials to reduce waste.	3.23	10

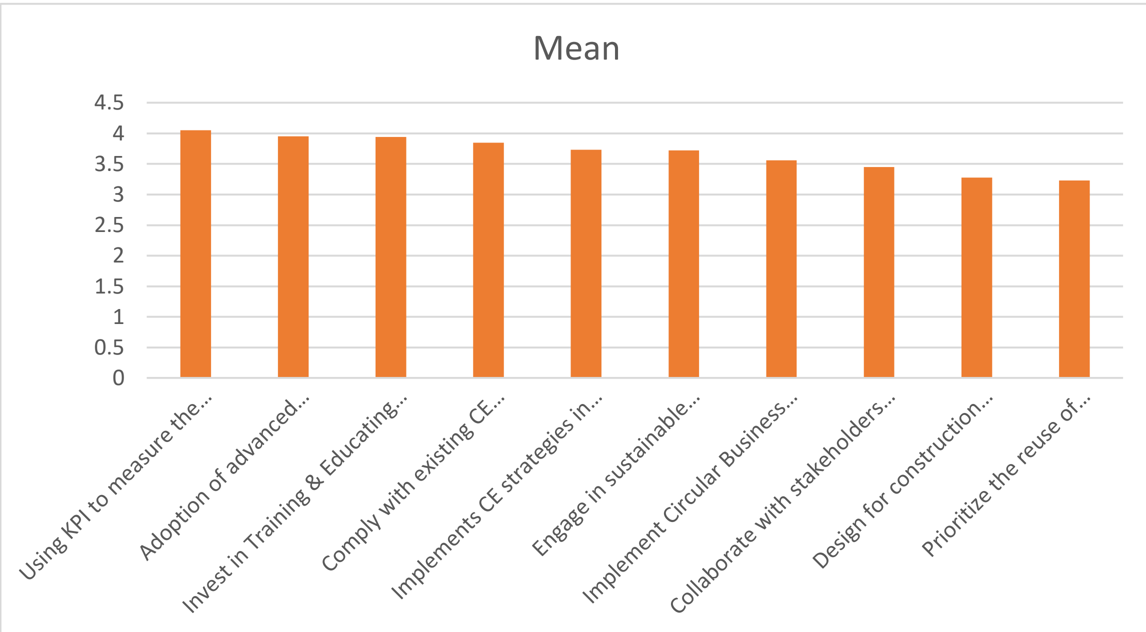


Figure 38: Mean Chart of Questionaire Survey 2

The above bar graph is the result of MS excel analysis, which shows the top 10 suggestions for the implementation of CE in CI based on the highest mean at the first.

CHAPTER-5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The research study utilized the VOS Viewer tool to analyze similar keywords across published research papers on the applications of Circular Economy (CE) in Construction Industry (CI).

The findings highlight several barriers hindering the adoption of CE in CI, including:

- Progress Regarding Recyclable Building
- Resistance in adopting new CE practices
- Lack of Collaboration between stakeholders
- Short-term focus on immediate profit
- Impact of inadequate policies
- Limited Government Support
- Slow Adoption of Technology within construction
- Incomplete Supply Chain
- Lack of information about materials
- Lack of clear rules to adopt clean energy

To address these challenges, the following suggestions are proposed for the successful implementation of CE in CI:

- Use Key Performance Indicators (KPIs) to measure the success of CE.
- Adopt advanced technology and tools, such as Building Information Modeling (BIM).
- Invest in training and education about CE.
- Comply with existing CE regulations.
- Implement CE strategies in construction practices.
- Engage in sustainable procurement practices.
- Implement Circular Business Models.
- Collaborate with stakeholders to promote CE.
- Design construction projects to facilitate reuse.
- Prioritize the reuse of construction materials to reduce waste.

By incorporating these suggestions into CI practices, it is anticipated that the industry can overcome the identified barriers and successfully embrace Circular Economy principles.

References:

[1] G. L. F. Benachio, M. do C. D. Freitas, and S. F. Tavares, "Circular economy in the construction industry: A systematic literature review," *J. Clean. Prod.*, vol. 260, p. 121046, 2020, doi: 10.1016/j.jclepro.2020.121046.

[2] B. C. Guerra and F. Leite, "Circular economy in the construction industry: An overview of United States stakeholders' awareness, major challenges, and enablers," *Resour. Conserv. Recycl.*, vol. 170, no. April, p. 105617, 2021, doi: 10.1016/j.resconrec.2021.105617.

[3] H. Corvellec, A. F. Stowell, and N. Johansson, "Critiques of the circular economy," *J. Ind. Ecol.*, vol. 26, no. 2, pp. 421–432, 2022, doi: 10.1111/jiec.13187.

[4] J. Kirchherr, D. Reike, and M. Hekkert, "Conceptualizing the circular economy: An analysis of 114 definitions," *Resour. Conserv. Recycl.*, vol. 127, no. September, pp. 221–232, 2017, doi: 10.1016/j.resconrec.2017.09.005.

[5] M. U. Hossain, S. T. Ng, P. Antwi-Afari, and B. Amor, "Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction," *Renew. Sustain. Energy Rev.*, vol. 130, no. June, p. 109948, 2020, doi: 10.1016/j.rser.2020.109948.

[6] W. R. Stahel, "The circular economy," *Nature*, vol. 531, no. 7595, pp. 435–438, 2016, doi: 10.1038/531435a.

[7] S. da C. Fernandes, D. C. A. Pigosso, T. C. McAloone, and H. Rozenfeld, "Towards product-service system oriented to circular economy: A systematic review of value proposition design approaches," *J. Clean. Prod.*, vol. 257, p. 120507, 2020, doi: 10.1016/J.JCLEPRO.2020.120507.

[8] R. AliAkbari *et al.*, "High value add bio-based low-carbon materials: Conversion processes and circular economy," *J. Clean. Prod.*, vol. 293, p. 126101, 2021, doi: 10.1016/J.JCLEPRO.2021.126101.

[9] K. A. Schumacher and A. L. Forster, "Textiles in a circular economy: An assessment of the current landscape, challenges, and opportunities in the United States," *Front. Sustain.*, vol. 3, 2022, doi: 10.3389/frsus.2022.1038323.

[10] C. Product and Q. Reference, "Cisco Product Quick Reference Guide," *Digit. Media*, no. February, 2008.

[11] M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, "The Circular Economy – A new sustainability paradigm?," *J. Clean. Prod.*, vol. 143, pp. 757–768, 2017, doi: 10.1016/j.jclepro.2016.12.048.

[12] L. A. Akanbi *et al.*, "Disassembly and deconstruction analytics system (D-DAS) for construction in a circular economy," *J. Clean. Prod.*, vol. 223, pp. 386–396, 2019, doi: https://doi.org/10.1016/j.jclepro.2019.03.172.

[13] B. Sanchez and C. Haas, "Capital project planning for a circular economy," *Constr. Manag. Econ.*, vol. 36, pp. 1–10, Feb. 2018, doi: 10.1080/01446193.2018.1435895.

[14] A. M. Manelius, S. Nielsen, and J. Schipull Kauschen, "City as Material Bank - Constructing with Reuse in Musicon, Roskilde," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 225, no. 1, 2019, doi: 10.1088/1755-1315/225/1/012020.

[15] C. J. Gelderman, J. Semeijn, and P. P. Mertschuweit, "The impact of social capital and technological uncertainty on strategic performance: The supplier perspective," *J. Purch. Supply Manag.*, vol. 22, no. 3, pp. 225–234, 2016, doi: https://doi.org/10.1016/j.pursup.2016.05.004.

[16] D. Wilber, "Book Review: Cradle to Cradle: Remaking the Way We Make Things. William McDonough and Michael Braungart. 2002. North Point Press, New York. 208 pp. $27.50 paperback (978-0-86547-587-8)," *Environ. Pract.*, vol. 12, Mar. 2010, doi: 10.1017/S1466046609990494.

[17] M. EGAN, "THE SOCIAL SIGNIFICANCE OF THE ENVIRONMENTAL CRISIS: Barry Commoner's 'The Closing Circle,'" *Organ. Environ.*, vol. 15, no. 4, pp. 443–457, Aug. 2002, [Online]. Available: http://www.jstor.org/stable/26161761

[18] W. Stahel, "The Performance Economy," *Perform. Econ. 2nd Ed.*, Feb. 2010, doi: 10.1057/9780230274907.

[19] A. Chizaryfard, P. Trucco, and C. Nuur, "The transformation to a circular economy: framing an evolutionary view," *J. Evol. Econ.*, vol. 31, no. 2, pp. 475–504, 2021, doi: 10.1007/s00191-020-00709-0.

[20] H. Frankel, "A review of: 'Industrial Ecology' T.E. Graedel and B.R. Allenby prentice Hall, Inc., 1995, 412 pp., ISBN 0-13-125238-0," *IIE Trans.*, vol. 28, no. 6, pp. 521–523, Jun. 1996, doi: 10.1080/07408179608966300.

[21] Unknown, "Innovation inspired by nature," *Ecos*, no. 129, pp. 27–29, 2006, doi: 10.1071/EC129p27.

[22] A. Uhl and O. Hanslik, "The Blue Economy: Innovations for a New Level of Competition," *360° - Bus. Transform. J.*, pp. 16–21, Jan. 2012.

[23] A. Hasan and A. Othman, "Towards a Circular Economy in The Arab Region : Development of Transformation Measurement Index Economic Studies Towards a Circular Economy in The Arab Region : Development of Transformation Measurement Index Dr . Anwar Othman," no. October, 2022.

[24] A. M. Farouk, R. A. Rahman, and N. S. Romali, "Sm ar t a Non-revenue water reduction strategies : a systematic ina e B uil t E nv iro en nm t," no. September, 2021.

[25] Z. Alwan, P. Jones, and P. Holgate, "Strategic sustainable development in the UK construction industry, through the Framework for Strategic Sustainable Development, using Building Information Modelling," *J. Clean. Prod.*, vol. 140, Jan. 2016, doi: 10.1016/j.jclepro.2015.12.085.

[26] M. U. Hossain and S. Thomas Ng, "Influence of waste materials on buildings' life cycle environmental impacts: Adopting resource recovery principle," *Resour. Conserv. Recycl.*, vol. 142, pp. 10–23, 2019, doi: https://doi.org/10.1016/j.resconrec.2018.11.010.

[27] S. Copeland and M. Bilec, "Buildings as material banks using RFID and building information modeling in a circular economy," *Procedia CIRP*, vol. 90, pp. 143–147, 2020, doi: https://doi.org/10.1016/j.procir.2020.02.122.

[28] M. Honic, I. Kovacic, P. Aschenbrenner, and A. Ragossnig, "Material Passports for the end-of-life stage of buildings: Challenges and potentials," *J. Clean. Prod.*, vol. 319, no. December 2020, p. 128702, 2021, doi: 10.1016/j.jclepro.2021.128702.

[29] S. H. Khahro, A. H. Memon, N. A. Memon, A. Arsal, and T. H. Ali, "Modeling the factors enhancing the implementation of green procurement in the pakistani construction industry," *Sustain.*, vol. 13, no. 13, pp. 1–15, 2021, doi: 10.3390/su13137248.

[30] S. Bansal and S. K. Singh, "A Sustainable Approach towards the Construction and Demolition Waste," *Int. J. Innov. Res. Sci. Eng. Technol. (An ISO*, vol. 3297, no. 2, pp. 2319–8753, 2007, [Online]. Available: www.ijirset.com

[31] M. Linder and M. Williander, "Circular Business Model Innovation: Inherent Uncertainties," *Bus. Strateg. Environ.*, vol. 26, no. 2, pp. 182–196, 2017, doi: 10.1002/BSE.1906.

[32] A. de Jesus and S. Mendonça, "Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy," *Ecol. Econ.*, vol. 145, pp. 75–89, 2018, doi: https://doi.org/10.1016/j.ecolecon.2017.08.001.

[33] M. P. P. Pieroni, T. C. McAloone, and D. C. A. Pigosso, "Circular economy business model innovation: Sectorial patterns within manufacturing companies," *J. Clean. Prod.*, vol. 286, p. 124921, 2021, doi: https://doi.org/10.1016/j.jclepro.2020.124921.

[34] V. Veleva, G. Bodkin, and S. Todorova, "The need for better measurement and employee engagement to advance a circular economy: Lessons from Biogen's 'zero waste' journey," *J. Clean. Prod.*, vol. 154, pp. 517–529, 2017, doi:

https://doi.org/10.1016/j.jclepro.2017.03.177.

[35] K. Winans, A. Kendall, and H. Deng, "The history and current applications of the circular economy concept," *Renew. Sustain. Energy Rev.*, vol. 68, pp. 825–833, Feb. 2017, doi: 10.1016/j.rser.2016.09.123.

[36] P. Schröder, M. Bengtsson, M. Cohen, P. Dewick, J. Hofstetter, and J. Sarkis, "Degrowth within – Aligning circular economy and strong sustainability narratives," *Resour. Conserv. Recycl.*, vol. 146, pp. 190–191, 2019, doi: https://doi.org/10.1016/j.resconrec.2019.03.038.

[37] K. Adams, M. Osmani, A. Thorpe, and J. Thornback, "Circular economy in construction: current awareness, challenges and enablers," *Proc. Inst. Civ. Eng. - Waste Resour. Manag.*, vol. 170, pp. 1–11, Feb. 2017, doi: 10.1680/jwarm.16.00011.

[38] L. Eberhardt, H. Birgisdottir, and M. Birkved, "Potential of Circular Economy in Sustainable Buildings," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 471, p. 92051, Feb. 2019, doi: 10.1088/1757-899X/471/9/092051.

[39] F. Pomponi and A. Moncaster, "Circular economy for the built environment: A research framework," *J. Clean. Prod.*, vol. 143, pp. 710–718, 2017, doi: 10.1016/j.jclepro.2016.12.055.

[40] Y. Zhao *et al.*, "Economics- and policy-driven organic carbon input enhancement dominates soil organic carbon accumulation in Chinese croplands," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 115, no. 16, pp. 4045–4050, 2018, doi: 10.1073/pnas.1700292114.

[41] M. R. Esa, A. Halog, and L. Rigamonti, "Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy," *J. Mater. Cycles Waste Manag.*, vol. 19, no. 3, pp. 1144–1154, 2017, doi: 10.1007/s10163-016-0516-x.

[42] B. J. A. van Bueren, U. Iyer-Raniga, K. Argus, and M. A. A. M. Leenders, "Closing the loopholes in circular economy definitions and assessments using ontological criteria, with a demonstration for Australia," *Resour. Conserv. Recycl.*, vol. 186, p. 106554, 2022, doi: https://doi.org/10.1016/j.resconrec.2022.106554.

[43] E. Leising, J. Quist, and N. Bocken, "Circular Economy in the building sector: Three cases and a collaboration tool," *J. Clean. Prod.*, vol. 176, pp. 976–989, 2018, doi: https://doi.org/10.1016/j.jclepro.2017.12.010.

[44] A. Mangialardo and E. Micelli, "Rethinking the Construction Industry Under the Circular Economy: Principles and Case Studies," in *Green Energy and Technology*, 2018, pp. 333–344. doi: 10.1007/978-3-319-75774-2_23.

[45] A. L. Maerckx, Y. D'Otreppe, and N. Scherrier, "Building circular in Brussels: An

overview through 14 inspiring projects," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 225, no. 1, 2019, doi: 10.1088/1755-1315/225/1/012059.

[46] K. T. Adams, M. Osmani, T. Thorpe, and J. Thornback, "Circular economy in construction: Current awareness, challenges and enablers," *Proc. Inst. Civ. Eng. Waste Resour. Manag.*, vol. 170, no. 1, pp. 15–24, 2017, doi: 10.1680/jwarm.16.00011.

[47] R. Volk, J. Stengel, and F. Schultmann, "Building Information Modeling (BIM) for existing buildings - Literature review and future needs," *Autom. Constr.*, vol. 38, no. October 2017, pp. 109–127, 2014, doi: 10.1016/j.autcon.2013.10.023.

[48] J. Dumay, J. Guthrie, and P. Puntillo, "IC and public sector: A structured literature review," *J. Intellect. Cap.*, vol. 16, no. 2, pp. 267–284, 2015, doi: 10.1108/JIC-02-2015-0014/FULL/XML.

[49] EMAF, "Towards the circular economy. Journal of Industrial Ecology," *Ellen MacArthur Found.*, pp. 23–44, 2013, [Online]. Available: https://www.aquafil.com/assets/uploads/ellen-macarthur-foundation.pdf

[50] A. Gallego-Schmid, H.-M. Chen, M. Sharmina, and J. M. F. Mendoza, "Links between circular economy and climate change mitigation in the built environment," *J. Clean. Prod.*, vol. 260, p. 121115, 2020, doi: https://doi.org/10.1016/j.jclepro.2020.121115.

[51] M. Sparrevik, L. de Boer, O. Michelsen, C. Skaar, H. Knudson, and A. M. Fet, "Circular economy in the construction sector: advancing environmental performance through systemic and holistic thinking," *Environ. Syst. Decis.*, vol. 41, no. 3, pp. 392–400, 2021, doi: 10.1007/s10669-021-09803-5.

[52] K. Alhola, S. O. Ryding, H. Salmenperä, and N. J. Busch, "Exploiting the Potential of Public Procurement: Opportunities for Circular Economy," *J. Ind. Ecol.*, vol. 23, no. 1, pp. 96–109, 2019, doi: 10.1111/JIEC.12770.

[53] R. Charef, J. C. Morel, and K. Rakhshan, "Barriers to implementing the circular economy in the construction industry: A critical review," *Sustain.*, vol. 13, no. 23, pp. 1–18, 2021, doi: 10.3390/su132312989.

[54] Y. Geng and B. Doberstein, "Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development,'" *Int. J. Sustain. Dev. World Ecol.*, vol. 15, no. 3, pp. 231–239, Jun. 2008, doi: 10.3843/SusDev.15.3:6.

[55] K. Webster, *The Circular Economy: A Wealth of Flows*. Ellen MacArthur Foundation Publishing, 2015. [Online]. Available: https://books.google.com.pk/books?id=c7QujgEACAAJ

[56] M. Lieder and A. Rashid, "Towards circular economy implementation: a

comprehensive review in context of manufacturing industry," *J. Clean. Prod.*, vol. 115, pp. 36–51, 2016, doi: https://doi.org/10.1016/j.jclepro.2015.12.042.

[57] M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, "The Circular Economy – A new sustainability paradigm?," *J. Clean. Prod.*, vol. 143, pp. 757–768, 2017, doi: https://doi.org/10.1016/j.jclepro.2016.12.048.

[58] S. Sauvé, S. Bernard, and P. Sloan, "Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research," *Environ. Dev.*, vol. 17, Sep. 2015, doi: 10.1016/j.envdev.2015.09.002.

[59] J. Basic, L. Jovčić, and L. Janić, "Peter Lacy, Jessica Long, Wesley Spindler: The circular economy handbook: Realizing the circular advantage, Palgrave Macmillan, UK, 2020," *Ekon. Poljopr.*, vol. 67, pp. 601–608, Jan. 2020, doi: 10.5937/ekoPolj2002601B.

[60] P. Ghisellini, C. Cialani, and S. Ulgiati, "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems," *J. Clean. Prod.*, vol. 114, pp. 11–32, 2016, doi: https://doi.org/10.1016/j.jclepro.2015.09.007.

[61] M. U. Hossain, S. T. Ng, P. Antwi-Afari, and B. Amor, "Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction," *Renew. Sustain. Energy Rev.*, vol. 130, p. 109948, 2020, doi: https://doi.org/10.1016/j.rser.2020.109948.

[62] F. Heisel and S. Rau-Oberhuber, "Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and Madaster," *J. Clean. Prod.*, vol. 243, p. 118482, 2020, doi: https://doi.org/10.1016/j.jclepro.2019.118482.

[63] H. Desing, D. Brunner, F. Takacs, S. Nahrath, K. Frankenberger, and R. Hischier, "A circular economy within the planetary boundaries: Towards a resource-based, systemic approach," *Resour. Conserv. Recycl.*, vol. 155, p. 104673, 2020, doi: https://doi.org/10.1016/j.resconrec.2019.104673.

[64] Y. Kalmykova, M. Sadagopan, and L. Rosado, "Circular economy – From review of theories and practices to development of implementation tools," *Resour. Conserv. Recycl.*, vol. 135, pp. 190–201, 2018, doi: https://doi.org/10.1016/j.resconrec.2017.10.034.

[65] C. J. Kibert *et al.*, "Advanced topics in manufactured construction," *Univ. Florida, United States*, 2016.

[66] A. Koutamanis, B. van Reijn, and E. van Bueren, "Urban mining and buildings: A review of possibilities and limitations," *Resour. Conserv. Recycl.*, vol. 138, pp. 32–39, 2018, doi: https://doi.org/10.1016/j.resconrec.2018.06.024.

[67] Y. Yu, D. M. Yazan, V. Junjan, and M. E. Iacob, “Circular economy in the construction industry: A review of decision support tools based on Information & Communication Technologies,” *J. Clean. Prod.*, vol. 349, no. July 2021, p. 131335, 2022, doi: 10.1016/j.jclepro.2022.131335.

[68] P. Ghisellini, M. Ripa, and S. Ulgiati, “Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review,” *J. Clean. Prod.*, vol. 178, pp. 618–643, 2018, doi: https://doi.org/10.1016/j.jclepro.2017.11.207.

[69] L. A. López Ruiz, X. Roca Ramón, and S. Gassó Domingo, “The circular economy in the construction and demolition waste sector – A review and an integrative model approach,” *J. Clean. Prod.*, vol. 248, p. 119238, 2020, doi: https://doi.org/10.1016/j.jclepro.2019.119238.

[70] M. Munaro, S. Tavares, and L. Bragança, “Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment,” *J. Clean. Prod.*, vol. 260, p. 121134, Mar. 2020, doi: 10.1016/j.jclepro.2020.121134.

[71] R. Asante, D. Faibil, M. Agyemang, and S. A. Khan, “Life cycle stage practices and strategies for circular economy: assessment in construction and demolition industry of an emerging economy,” *Environ. Sci. Pollut. Res.*, vol. 29, no. 54, pp. 82110–82121, 2022, doi: 10.1007/s11356-022-21470-w.

[72] I. Kovacic, M. Honic, and M. Sreckovic, “Digital platform for circular economy in aec industry,” *Eng. Proj. Organ. J.*, vol. 9, no. October, pp. 1–16, 2020, doi: 10.25219/epoj.2020.00107.

[73] R. Bagozzi, “The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift,” *J. AIS*, vol. 8, Apr. 2007, doi: 10.17705/1jais.00122.

[74] M. Osmani, J. Glass, and A. D. F. Price, “Architects’ perspectives on construction waste reduction by design,” *Waste Manag.*, vol. 28, no. 7, pp. 1147–1158, 2008, doi: https://doi.org/10.1016/j.wasman.2007.05.011.

[75] L. Jaillon, C. S. Poon, and Y. H. Chiang, “Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong,” *Waste Manag.*, vol. 29, no. 1, pp. 309–320, 2009, doi: https://doi.org/10.1016/j.wasman.2008.02.015.

[76] F. Schiavone, J. M. Maqueira Marín, P. Núñez-Cacho, J. Moyano-Fuentes, and S. Bruque Camara, “Best-practices of teaching digital entrepreurship in the fourth industrial revolution,” 2021, pp. 41–50.

[77] R. V. Molchanova, “Circular Economy in the Construction Industry,” *Ekon. I Upr. Probl. Resheniya*, vol. 4/3, no. 136, pp. 110–116, 2023, doi: 10.36871/ek.up.p.r.2023.04.03.013.

[78] X. Zeng *et al.*, "Reshaping global policies for circular economy," *Circ. Econ.*, vol. 1, no. 1, p. 100003, 2022, doi: 10.1016/j.cec.2022.100003.

[79] M. Ghufran *et al.*, "Circular Economy in the Construction Industry: A Step towards Sustainable Development," *Buildings*, vol. 12, no. 7, pp. 1–26, 2022, doi: 10.3390/buildings12071004.

[80] J. Fořt and R. Černý, "Transition to circular economy in the construction industry: Environmental aspects of waste brick recycling scenarios," *Waste Manag.*, vol. 118, pp. 510–520, 2020, doi: 10.1016/j.wasman.2020.09.004.

[81] P. Hopkinson, R. De Angelis, and M. Zils, "Systemic building blocks for creating and capturing value from circular economy," *Resour. Conserv. Recycl.*, vol. 155, no. November 2018, p. 104672, 2020, doi: 10.1016/j.resconrec.2019.104672.

[82] A. Afshari and J. Górecki, *CIRCULAR ECONOMY IN CONSTRUCTION SECTOR*. 2019.

[83] K. van Breugel, "How models can make a difference for a sustainable future of the building industry," *Mater. Struct. Constr.*, vol. 51, no. 6, pp. 1–13, 2018, doi: 10.1617/s11527-018-1287-8.

[84] M. Winning, A. Calzadilla, R. Bleischwitz, and V. Nechifor, "Towards a circular economy: insights based on the development of the global ENGAGE-materials model and evidence for the iron and steel industry," *Int. Econ. Econ. Policy*, vol. 14, no. 3, pp. 383–407, 2017, doi: 10.1007/s10368-017-0385-3.

[85] Environmental Services Association, "Planning for a Circular Economy," *Esa*, p. 20, 2017, [Online]. Available: https://thefifthestate.com.au/urbanism/planning/planning-for-a-…=IwAR1m4ODte1ZbYFfJjJe0SF6N-2-W676KdG3x0RTuI5tLMftPVUbjG9v1GQU%0Ahttp://www.esauk.org/esa_reports/20170411_Planning_for_a_Circular_Economy_FINAL.pdf

[86] M. Gharfalkar, Z. Ali, and G. Hillier, "Clarifying the disagreements on various reuse options: Repair, recondition, refurbish and remanufacture," *Waste Manag. Res.*, vol. 34, no. 10, pp. 995–1005, 2016, doi: 10.1177/0734242X16628981.

[87] X. Xu, J. Y. L. Thong, and V. Venkatesh, "Effects of ICT service innovation and complementary strategies on brand equity and customer loyalty in a consumer technology market," *Inf. Syst. Res.*, vol. 25, no. 4, pp. 710–729, 2014, doi: 10.1287/isre.2014.0540.

Appendix-A

BALOCHISTAN UNIVERSITY OF ENGINEERING AND TECHNOLOGY, KHUZDAR

Dear Sir,

We are students of **Balochistan University of Engineering and Technology, Khuzdar**, and we are conducting a comprehensive questionnaire survey as part of our academic research on the topic of "Circular Economy in the Construction Industry." Your valuable insights and participation are crucial to the success of this study.

As future engineers and stakeholders in the construction industry, we believe that embracing sustainable practices is essential to address the environmental and economic challenges associated with construction projects.

The concept of a circular economy in the construction industry entails the reduction, reuse, and recycling of materials, thus minimizing waste and promoting long-term sustainability.

Your feedback, as an experienced officer, stakeholder, or contractor in the construction industry, is invaluable. The insights you provide will help us gain a better understanding of the industry's current practices, challenges, and opportunities for implementing circular economy principles.

We kindly request you to participate in our survey. The questionnaire, containing a series of questions related to circular economy practices in the construction industry, is provided on the next page. Your responses will be kept confidential and used solely for research purposes.

Thank you for your time.

The barriers and challenges in the adoption of Circular Economy faced by the construction industries of Pakistan

Questionnaire survey

AIM:

The aim of this questionnaire survey is:

- To identify the Barriers and Challenges in the adoption of CE

CONFIDENTIALITY:

All information collected in this questionnaire survey will be kept strictly confidential, no Organizations or individuals will be identified in any research report, and all the information Provided will be solely for the academic research.

FEEDBACK OF RESULT:

All the surveys are gathered and analyzed, feedback on the research results will be given upon demand to interested respondents in this study.

CONTACT DETAILS:

If you have any queries regarding this survey, please do not hesitate to contact:

Engr. Syed Abdullah shah on +92 3331377447 or email: **engrabdullah329@gmail.com**

PERSONAL INFORMATION:

Name (optional)	
Age	
Qualification	
Designation	
Organization	

Signature: ______________________________________

S.No	Questions	Rating				
1	How do you think the lack of clear rules in the construction industry affect the adoption of clean energy?	1	2	3	4	5
2	How much progress has been done, regarding the designing of recyclable buildings?	1	2	3	4	5
3	How much does the lack of information about materials and processes make it difficult for sustainability?	1	2	3	4	5
4	In your opinion, how does the slow adoption of technology within the construction industry affect CE development?	1	2	3	4	5
5	How much does an incomplete supply chain affect CE practices in Construction?	1	2	3	4	5
6	How significant is the lack of collaboration between stakeholders in impeding CE efforts within the construction industry?	1	2	3	4	5
7	How does the short-term focus on immediate profits in the industry impact the integration of CE principles?	1	2	3	4	5
8	In your experience, how resistant is the industry to adopting new practices, including CE strategies?	1	2	3	4	5
9	To what extent does limited government support hinder the advancement of environmentally friendly construction practices?	1	2	3	4	5
10	How do you perceive the impact of inadequate policies and regulations on the integration of CE in construction?	1	2	3	4	5

Note: Please use the provided scaling order from 1 to 5 to indicate the level of your activity or involvement for each item on the questionnaire by ticking [√] the appropriate cell.(1 being the highest and 5 being the lowest)

1. Significantly 2. Fairly 3. Adequately. 4. Slightly 5. Insignificantly

Appendix-B

BALOCHISTAN UNIVERSITY OF ENGINEERING AND TECHNOLOGY, KHUZDAR

Dear Sir,

We are students of **Balochistan University of Engineering and Technology, Khuzdar**, and we are conducting a comprehensive questionnaire survey as part of our academic research on the topic of "Circular Economy in the Construction Industry." Your valuable insights and participation are crucial to the success of this study.

As future engineers and stakeholders in the construction industry, we believe that embracing sustainable practices is essential to address the environmental and economic challenges associated with construction projects.

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Your feedback, as an experienced officer, stakeholder, or contractor in the construction industry, is invaluable. The insights you provide will help us gain a better understanding of the industry's current practices, challenges, and opportunities for implementing circular economy principles.

We kindly request you to participate in our survey. The questionnaire, containing a series of questions related to circular economy practices in the construction industry, is provided on the next page. Your responses will be kept confidential and used solely for research purposes.

Thank you for your time.

The Implementation of Circular Economy in construction industries of Pakistan

Questionnaire survey

AIM:

The aim of this questionnaire survey is:

- To Provide Suggestions for the Implementation of CE

CONFIDENTIALITY:

All information collected in this questionnaire survey will be kept strictly confidential, no Organizations or individuals will be identified in any research report, and all the information Provided will be solely for the academic research.

FEEDBACK OF RESULT:

All the surveys are gathered and analyzed, feedback on the research results will be given upon demand to interested respondents in this study.

CONTACT DETAILS:

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Engr. Syed Abdullah shah on +92 3331377447 or email: **engrabdullah329@gmail.com**

PERSONAL INFORMATION:

Name (optional)	
Age	
Qualification	
Designation	
Organization	

Signature: ___________________________________

Note: Please use the provided scaling order from 1 to 5 to indicate the level of your activity or involvement for each item on the questionnaire by ticking [√] the appropriate cell.(1 being the highest and 5 being the lowest)

1. Very actively. 2. Actively. 3. Moderately. 4. Not actively. 5. Not at all.

S.No	Questions	Rating				
1	How actively does your organization implement CE strategies in construction?	1	2	3	4	5
2	To what extent does your organization actively prioritize the reuse of construction materials to reduce waste?	1	2	3	4	5
3	How actively does your organization consider design for disassembly in construction projects to facilitate future reuse and recycling?	1	2	3	4	5
4	How actively does your organization collaborate with other stakeholders in the construction industry to promote CE practices?	1	2	3	4	5
5	How actively does your organization explore or implement circular business models (e.g., product-as-a-service) in construction projects?	1	2	3	4	5
6	How actively does your organization comply with existing CE-related regulations and standards in the construction industry?	1	2	3	4	5
7	How actively does your organization invest in training and educating employees about CE principles and practices?	1	2	3	4	5
8	How actively does your organization engage in sustainable procurement practices, considering the environmental impact of construction materials and suppliers?	1	2	3	4	5
9	How actively does your organization adopt advanced technologies and tools (e.g., BIM, IoT) to enhance CE implementation in construction?	1	2	3	4	5
10	How actively does your organization use specific metrics or key performance indicators (KPIs) to measure the success of CE implementation in construction projects?	1	2	3	4	5

CIRCULAR ECONOMY IN CONSTRUCTION INDUSTRY

ORIGINALITY REPORT

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