Frameworks for Circular Economy in Construction Sector: A Review

Pradeep Kumar[1], Richa Bhalla[2]

[1]*Research Scholar, Fellow Program in Management, ISBR Business School, India*
[2]*Associate Professor, ISBR Business School, India*
Email: pradeep.fpm2021@isbr.in

The construction sector is considered the world's largest consumer of raw materials in the world. Further, most of the construction is done on the principles of linear economy, where resources are designed, produced, used, and finally become waste after the service life. In the circular economy model, the materials and products are shared, leased, reused, repaired, refurbished, and recycled. Thus, a circular economy addresses global challenges such as climate change, loss of biodiversity, waste, and pollution. Researchers have suggested various Frameworks for using Circular Economy in Construction Projects. This paper is an attempt to review the various frameworks systematically, analyze them, find the research gaps, and suggest the further scope of research.

1. Introduction

The buildings and construction sector contributes significantly to global climate change, accounting for about 21 percent of global greenhouse gas emissions. In 2022, buildings were responsible for 34 percent of global energy demand and 37 percent of energy and process-related carbon dioxide (CO2) emissions [1].

The total global area of constructed buildings has grown by over 31 percent since 2010. Most of the countries have shown upward growth in construction [2].

The construction industry is still predominantly based on a linear economic model of high natural resource consumption and low resource recovery, popularly known as "take-make-dispose" [3]. In a linear economy, natural resources are turned into products that are ultimately destined to become waste after use because of the way they have been designed and manufactured. This process is often summarized by "take, make, waste" [4].

Fig-1- Concept of Linear Economy

A circular economy (also referred to as circularity and CE) is a model of production and consumption that involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products for as long as possible [5]

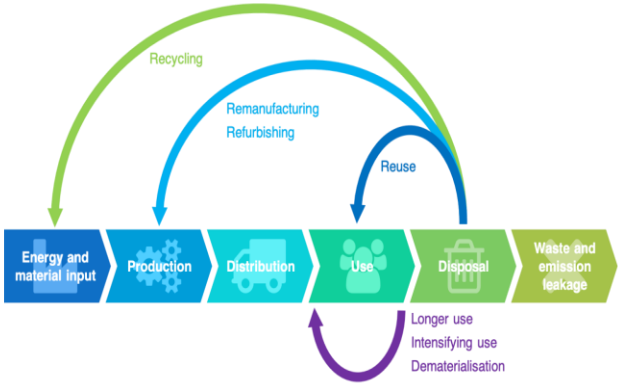


Fig-2- Concept of Circular Economy

CE aims to tackle global challenges such as climate change, loss of biodiversity, waste, and pollution by emphasizing the design-based implementation of the three base principles of the model. The three principles required for the transformation to a circular economy are,

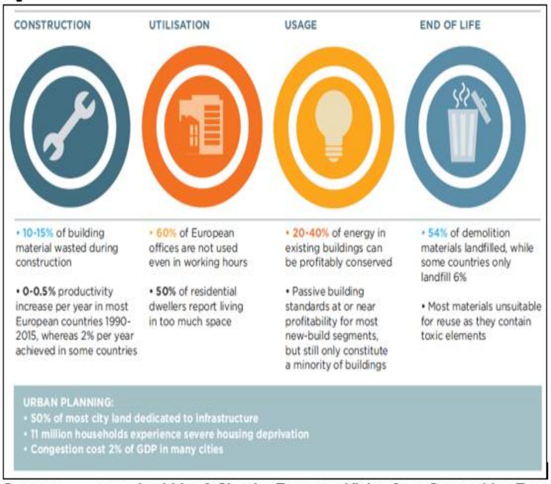
Eliminating waste and pollution,

Circulating products and materials,

Regeneration of nature.

The circular economy aims to keep products, materials, equipment, and infrastructure in use for longer, thus improving the productivity of these resources. Waste materials and energy should become input for other processes either as a component for another industrial process or as regenerative resources for nature [6]. The Ellen MacArthur Foundation (EMF) defines the circular economy as an industrial economy that is restorative or regenerative by value and design [7].

A circular approach can help minimize the environmental footprint of the built environment sector, potentially reduce the life cycle costs, and avoid construction delays due to the volatility of commodity markets in procuring virgin materials [8]. The typical utilization and waste in the built environment are shown in the figure below.



Source: growth within: A Circular Economy Vision for a Competitive Europe

Fig-3- Waste in Building Construction

2. FRAMEWORKS FOR CIRCULAR ECONOMY IN CONSTRUCTION PROJECTS

Though the subject of circular economy has been explored to a certain extent, still in the context of construction projects the subject is yet to receive the required attention. Many organizations and researchers have developed the frameworks for circular economy in construction projects. The important frameworks are discussed as follows.

➢ Bilal M. at. al. (2020) [9] have done the assessment of the current state and barriers to the circular economy in the building sector of developing countries. This study was developed and used a circular economy assessment scale for the building sector of developing countries. It was found that the current state of circular economy implementation in the building sector is unsatisfactory. Out of the seven circular economy dimensions used for analysis, the energy dimension showed the best performance and the waste dimension showed the worst performance. Further, it is suggested that serious steps are required by all the stakeholders of the building sector to improve the adoption of the circular economy. Furthermore, interpretive structural modeling (ISM) and matrice d'Impacts croises-multipication applique an classment (MICMAC) techniques are used to identify and classify the key barriers to the circular economy. It is found that a lack of environmental regulations and laws is driving the rest of the barriers to the circular economy. Equally critical is the lack of public awareness and support from public institutions.

A mitigation framework for the building sector of developing countries has been proposed, which is an addition to the circular economy existing body of knowledge. The proposed framework is as under.

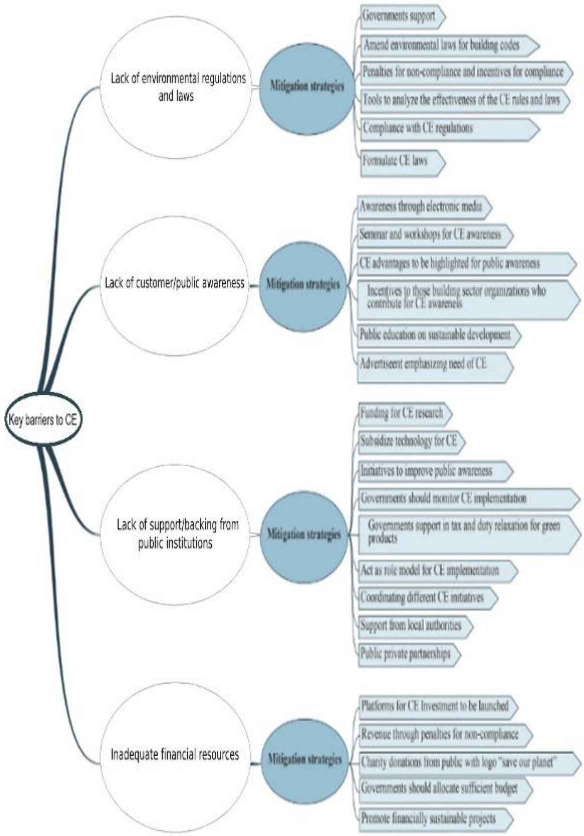


Fig-4- Enabling Parameters of CE in Construction

With the above-mentioned framework and given parameters, an assessment of the scale of the circular economy can be done. However, this study has limitations such as the indicators used for CE assessment were shortlisted based on a single round of expert opinion. Preferably, several rounds for shortlisting should have been conducted, which was not done in this study. Secondly, the inclusion of indicators into respective dimensions was based upon the expert opinion only. This could have been tested in the field. Thirdly, the assessment of CE for the construction sector is based on the qualitative data collected from the construction sector experts of different developing countries. Which has varying states of CE with different indicators and dimensions. Hence, results may include outliers. Fourthly, the screening and mapping of the CE barriers for this study were based on expert opinions, which were prone to subjectivity. Finally, the proposed framework is based upon the suggestions and recommendations from the experts of the local building sector and not from national or international experts. Also, the proposed mitigation strategies were based on the consensus of 5 experts only. Ideally, the number should have been more.

Considering the above-mentioned limitations, this study has further scope for exploration, such as developing a CE assessment scale using multiple rounds of expert opinion and collecting data using more robust methods. For a better assessment, purely quantitative data can be collected and used for analysis. Further, this study can be done in a specific developing country for region-specific results as this study is generic for all developing countries. Finally, studies can be undertaken to overcome the other limitations mentioned above.

➢ Jim Hart et, al. (2019) [10] have identified the barriers to and enablers for the circular economy within the built environment. They have suggested that technological and regulatory developments alone will not suffice, and a shift is required in business models and stakeholders' behaviors and attitudes. They have categorized the barriers and enablers into four categories - Cultural, Regulatory, Financial, and Sectoral. The identified barriers are as under,

	Code	Barrier	Enabler
Cultural	C1	Lack of interest, knowledge/skills and engagement throughout the value chain	Leadership
	C2	Operating in linear economy	Sustainability/environmental drivers
	C3	Lack of vertical and horizontal collaboration	Stimulate demand
	C4	Lack of collaboration between business functions – silo mentality	Value chain engagement
			Longer term relationships and partnerships
			Systems thinking
Regulat.	R1	Lack of consistent regulatory framework	Policy support & public procurement
	R2	Obstructing laws and regulations	Regulatory reform
	R3	Lack of incentives for CE	Fiscal support
			Producer responsibility
Financial	F1	Short-term blinkers – CAPEX prioritised over OPEX	Whole life costing
	F2	High upfront investment costs.	Easy wins
	F3	Low virgin material prices	CBMs
	F4	Poor business case / unconvincing case studies	Scale
	F5	Limited funding	
Sectoral	S1	Lack of bandwidth compounded by no coherent vision	Clearer vision for CE in the built environment
	S2	Complexity / confused incentives	Better evidence base
	S3	Long product lifecycles (buildings and materials)	Collaboration and design tools and strategies
	S4	Technical challenges re material recovery	R&D, innovation
	S5	Lacking standardization	Develop standards and assurance schemes
	S6	Insufficient use or development of CE-focused design and collaboration tools, information and metrics	Develop reverse logistics infrastructure
	S7	The industry itself – conservative, uncollaborative, risk-averse	

Similarly, they have also identified the enablers under the four categories, which are as under, It has been noted that technical and regulatory challenges are there but the real obstacles to a more circular built environment are the cultural and financial / market issues, such as the approach businesses take to collaboration with the supply chain (or not), and the difficulties of demonstrating a strong business case for circular models.

This study has limitations as study is generic in nature and gives insight into the overall framework of CE in construction projects. Further, this study has not been tested and analyzed.

Future work may test this analysis and define what is required to put the enablers into practice and accelerate the uptake of CE in the built environment.

Considering the above-mentioned limitations, this study has further scope of exploration, such as to test the framework in a specific environment or country.

Eline Leising et al. [11] have developed a framework for developing and operating circular buildings and their supply chain collaborations. First, a conceptual framework is developed to study supply chain collaboration in circular buildings, which uses theoretical building blocks for visions, actor learning, network dynamics, and business model innovation.

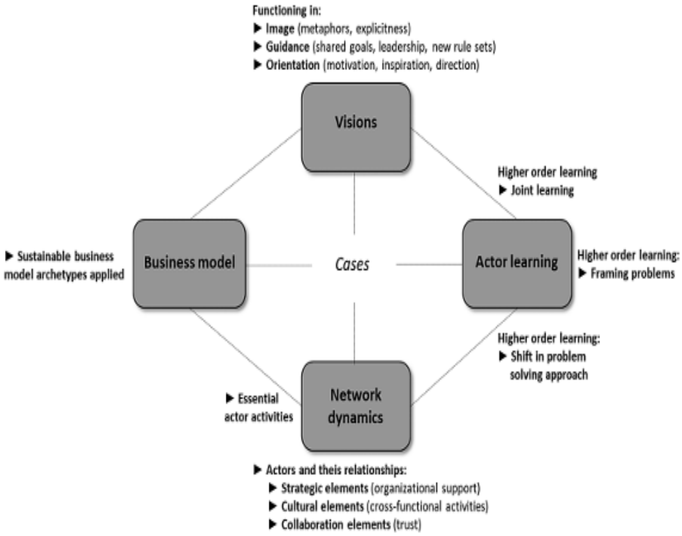


Fig-5- Conceptual framework for CE in Supply Chain

This framework has been applied to three cases using semi-structured interviews and document analysis. It was found that developing circular buildings requires (i) a new process design where a variety of disciplines in the supply chain is integrated upfront, (ii) the co-creation of an ambitious vision, (iii) extension of responsibilities to actors along the entire building supply chain, and (iv) new business and ownership models. The suggested framework for CE in the building sector from the supply chain point is as below.

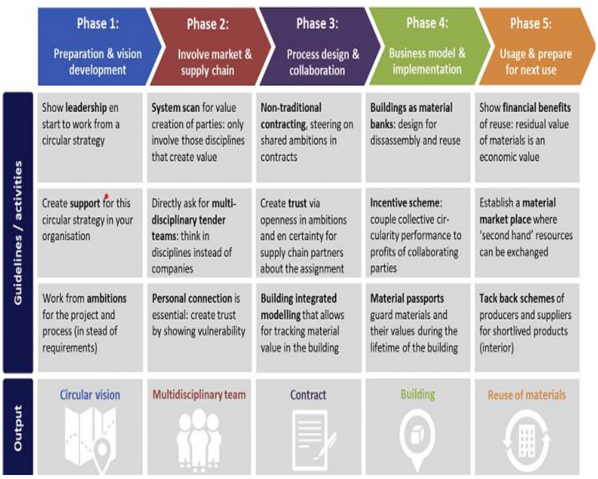


Fig-6- Framework for CE in Supply Chain in Construction

This study is only limited to the supply chain framework of CE in construction. However, this would give detailed insight into the supply chain in framing the overall policy or framework for CE in construction.

➢ Katherine T.A. et al. (2024) [12] have analyzed the industrywide perspective of circular economy awareness, challenges, and enablers in the context of the UK construction Industry. To encourage greater implementation of circular economy principles throughout the supply chain, a clear economic case is paramount, supported by metrics, tools, and guidance. The framework parameters were developed based on previous studies and the same are as under,

Life cycle stage	Circular economy aspect
Design	DfD Design for adaptability and flexibility Design for standardisation Design out waste Design in modularity Specify reclaimed materials Specify recycled materials
Manufacture and supply	Eco-design principles Use less materials/optimise material use Use less hazardous materials Increase the lifespan Design for product disassembly Design for product standardisation Use secondary materials Take-back schemes Reverse logistics
Construction	Minimise waste Procure reused materials Procure recycled materials Off-site construction
In use and refurbishment	Minimise waste Minimal maintenance Easy repair and upgrade Adaptability Flexibility
End of life	Deconstruction Selective demolition Reuse of products and components Closed-loop recycling Open-loop recycling
All stages: management of information including metrics and datasets	

Table-1- Parameters of CE in Construction Industry

This study was done by involving most of the stakeholders including clients, Designers, manufacturers, contractors, and sub-contractors. The study indicates that at an individual level, the majority of the survey respondents were aware of the circular economy concept. However, at an industrywide level, there was a lack of awareness. The absence of a broad consensus on what the circular economy looks like in the built environment could be a contributing factor to this. Clients and designers have little knowledge of how to adopt circular economy principles is likely to impede the uptake of circularity in the short term. The most significant challenges identified are the lack of incentive to design for end-of-life issues, followed by the lack of market mechanisms to aid greater recovery and an unclear financial case. These challenges, combined with the fragmented nature of the construction industry), suggest that further incentives are required to enable a transition to a circular economy.

The study has been conducted for the UK construction industry, which is quite advanced in CE as compared to developing countries. This framework can be analyzed for developing countries such as India but it might require tuning as per social, political, and economic environments.

➢ Seyed Hamidreza et al. (2020) [13] have investigated the current practices of C&DW management and circular construction (reuse, recycle, and recovery of materials) concept awareness in the UK. Relevant stakeholders from the construction industry (contracting, demolition, and C&DW organizations) were selected for study. The framework used in the study is as under,

Fig-7- Circular construction concept

The study revealed that legislation by the government on the reuse and recycling threshold for every new project can substantially improve circularity within the built environment. More specifically, the focus should be on the smart dismantling of buildings and ways of optimizing cost-effective processes. This will enable fair competition between stakeholders and eventually lead to investments in innovative approaches for resource recovery from C&DW. Further incentives and appreciation from the government should also be given to stakeholders who are innovating and setting benchmarks in circular construction. This can lead to harmonized technological and non-technological solutions, closed-loop material processes, and a circular economy.

The study has also suggested a more targeted dissemination of knowledge to increase public and industry awareness.

The study was conducted for the UK construction industry. The framework of the study is quite broad and mostly focused on construction & demolition waste (C&DW). This study can be further extended for the complete framework of CE in the construction industry.

Olugbenga O. Akinade et al. (2019) [15] developed a BIM-based computational tool for building waste analytics and reporting in the construction supply chains. A Construction Waste (CW) prediction model using an Adaptive Neuro-Fuzzy Inference System (ANFIS) was developed and integrated into the Autodesk Revit BIM platform. The process flow of the model is as under,

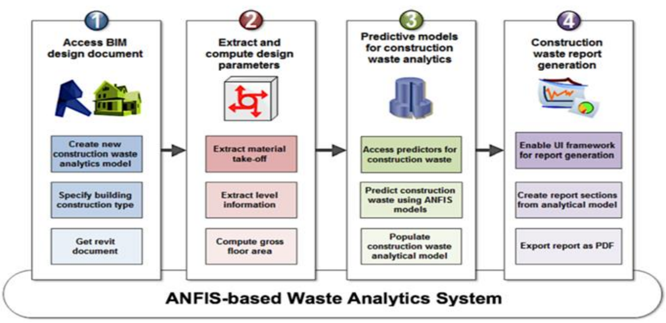


Fig-8-Process flow for the ANFIS-based Waste Analytics System(A-WAS)

This study reveals that "Gross Floor Area" and "Construction type" are the two key predictors for CW. The results of the study show that the tool offers useful insights into CW minimization opportunities. This study has developed a computational approach to CW measurement.

This study has many limitations and the first is that the study is only about the supply chain aspect of the overall policy framework of CE in construction. Further, the study was carried out in the UK construction industry context, so the findings have a UK bias.

Beibut Torgautov et al. (2021) [16] have identified the construction trends and performed a barrier and opportunity analysis to develop circular economy principles in construction in Kazakhstan. This study has used the ReSOLVE framework (regenerate, share, optimize, loop, virtualize, and exchange) to identify the barriers and opportunities for circular economy in the construction sector. The frameworks of study is as under,

	Client	Contractor	Manufacturer	Designer	
Regenerate	Use of second-hand materials are not desired	Non-organic materials have better characteristics and quality than biodegradable ones (high-quality organics are not available)		No reuse principles are exploited	**Barriers**
	The price advantage of the non-organic, less eco-friendly materials				
	Legal regulations could push to use more eco-materials	Actively use Eco materials as instruments	Use more structures that employ high recovery materials (e.g., steel and wood)	Plan renovation at the design stage	**Opportunities**
	Explore the local suppliers and manufacturers of recycled / organic / bio-based materials Explore organic-based materials available in the vicinity				
Share	Multipurpose areas are not financially beneficial	No orders from the client	Project uniqueness does not allow to share materials	No orders from the client	**Barriers**
	Search for the possibility to perform renovations with the least amount of new materials	Instruments are shared through the projects		Provide recommendations for the client in terms of multifunctionality	**Opportunities**
Optimize				Not available database of materials to optimize design solution	**Barriers**
	Use of modular technologies Provide service management after project execution	Avoid wet methods by using mechanical connections	Production optimization in the future by automation	Avoid complex design solutions	**Opportunities**
Loop	No recyclable infrastructure	Non-controllable waste management	No recyclable infrastructure	Not available database of materials to use in a loop design solution	**Barriers**
	Ask for materials passports	Perform waste audits	Provide a guarantee for produced materials Recycle materials with high recyclability potential	Try to apply standard shapes so some materials could be repeatedly used	**Opportunities**
	Reuse C–DW for backfilling works				
Virtualize		Visual technologies are not always required			**Barriers**
	High pace BIM development	Young professionals actively develop BIM usage	Active BIM usage		**Opportunities**
Exchange	Cost of implementation Time and resources to check new technology to implement in projects				**Barriers**
	Use advanced technologies (e.g., building blocks, drones)	Search for newly developed technologies on the market	Use advanced technologies (e.g., building blocks, drones)	Use design for deconstruction method	**Opportunities**
	Include industrial waste for primary materials production, e.g., fly ash				

Table- 2- Barriers and opportunities analysis in the ReSOLVE framework.

This analysis has shown that for most stakeholders of the Kazakhstani construction sector, virtualization is of the highest priority; therefore, opportunities for its development are recommended.

Future research could focus on the development of economically feasible solutions for the circular economy in construction with the inclusion of virtualization technologies

3. Conclusion

This paper attempted to answer the compelling research question regarding frameworks for circular economy in construction projects. The construction sector is among the major contributors to climate change and the circular economy is considered a powerful accelerator towards more sustainable practices. However, its adoption in the construction sector remains slow. This paper undertook a systematic literature review to 1) map and synthesize existing Frameworks and 2) identify future research pathways and propose a novel framework that could support the transition towards circular construction practices in the Indian context.

This paper has scaffolded upon the previous knowledge of seven circular economy frameworks, used for the gap mapping.

The analysis highlighted several areas of focus for the development and support of CE in construction,

Based on this literature review findings, a novel framework for CE implementation in construction in India can be proposed duly tuning the parameters for the Indian context.

4. Research Limitations

This literature search was limited to the scope of the study. As such, it was not fully comprehensive, and relevant publications may have been missed. Only studies published in English were included.

In this review paper, only seven frameworks are discussed, which were found suitable for this study but in actuality lot more frameworks and knowledge are available.

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