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Posted Date: 24 June 2024

doi: 10.20944/preprints202406.1646.v1

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Article

Policy Instruments Fostering Site Level Application of Circular Practices in Construction

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Abstract: One of the most pursued predicaments in the recent past is the slowness in transmuting circular practices. In the hope for many apparent advantages, construction firms have been attempting to embrace circularity oriented functions, thus controlling its negativities, to the extent where possible. However, many of these are futile attempts that have been made ad-hoc without having validated policy instruments intact. Only a few studies have taken an overarching approach to address this matter and effectively inculcate circularity at construction sites. This article is aimed to fill this knowledge gap by introducing a structured outline resulting in 9 policy categories and over 100 policy instruments. Developed from a review of 90 studies selected from Google scholar platform and 16 policy documents essentially contributed by eminent research groups, these policy instruments were subsequently validated in a series of 18 semi-structured interviews with experts and industry personnel having international exposure in large scale construction projects. This study provides over 150 practical examples scaffolding circularity as a noble cause. Of a practical insight, a fundamental reconfiguration of site operations deem indispensable.

Keywords: construction projects; circular practices; policy instruments; site level application

1. Introduction

Circular economy (CE) essentially warrants policy instruments to achieve its policy targets. For example, the United Nations Sustainable Development Goals (SDGs) [1] introduced a centrally coordinated macro level framework with several policy targets inspiring a societal transition towards circularity. There are many other policy frameworks that have come into global attention [2–4]. Few developed countries have worked out their own policies specifically related to circularity in construction [5]. Non-governmental agencies have also worked out strategies for circularity initiatives for a long time [6]. Many recent studies have addressed in-depth the conceptual and theoretical dimensions of CE transition, while identifying critical factors inhibiting the smooth transition [7–10]. Quite often, these studies used product and project life-cycle as the basis for streamlining and rationalizing CE transition policies, targets and tools [7,11]. Indeed, there is a broader scholarly consensus that governments are the top most influencing agencies which can aptly offer a sizeable patronage at all levels of product and project life cycles [12]. For example, Kirchherr et al. (2018) [10] stress the importance of having state intervention for the CE apparently because of its capacity to intervene in policy matters. Despite these initiatives to further the CE transition, CE policy related literature has only handful of studies on micro level applications such as construction projects [13]. A systemic approach therefore calls for a ground level experience about the extent of policy influence in CE transition which eventually prompted the following research question: Are there any further construction industry related circularity aspects that can be holistically integrated in the academic research? This question is answered by introducing over 100 policy instruments based on insights derived from the literature, policy contents and scholarly opinion cited by academia and industry personnel. It is intended that this paper will help widen the scope of policy dialogue in regards to circular applications, at meta and object level.

2. Materials and Methods

The study involved a three-step process; literature review, policy review and expert interview, an approach analogous to that castoff in a couple of review of CE policies in the recent past [14]. A working version of policy instruments was initially evolved using an interdisciplinary approach based on the premise that industries sustain on backward and forward linkages. In essence, an interdisciplinary approach, combining a wide variety of expertise, will co-produce a significant body of knowledge from a wider perspective [15,16]. This is, to a certain degree, similar to life-cycle perspective adopted by previous studies such as Milios (2018) [11]. Second, a desk review was conducted using 16 selected policy documents widely used in the EU. To-date, the EU has unreservedly occupied the headship in publishing CE policy frameworks [17]. It must be mentioned that the Circular Economy Action Plan (European Union, 2020) offers a catalyst for many subsequently published documents [18]. Grey literature was also referred to in the desk review in pursuing further policy initiatives for valuable insights of practical importance relevant to the field of construction [19–39]. A couple of policy documents outside the EU were also referred to in the desk review with a view to obtain a global perspective [40–42]. An iterative process of clustering policies was thereafter undertaken using the approach suggested by Milios (2018) [11]. The papers have been selected from Google scholar platform. No citations were taken into consideration at this stage since the secondary data specific to construction industry are relatively scattered. Third, semi-structured interview was conducted with scholars having expertise in the construction industry in order to validate and refine the contents (Hartley et al. (2020) [7]. It is hoped that interview helps establish connectivity between theory with practice, demystify grey areas, reconfirm pertinence, synthesize findings into themes and test them against individual experiences. Next, 18 scholars were consulted to improve and validate policy instruments. Judgment sampling method was used to identify experts [43]. The objective was to gauge the opinion of experts belonging to a diversity of disciplines (i.e., governance, business, consultancy and academia). It is hoped that this approach would dilute the researcher bias inherent in judgmental sampling, to a reasonable extent, and will enhance the generalizability of research outcomes.

3. Results and Discussion

This section is divided into three subheadings, namely literature review, desk review and interview, offering a concise description of the key literature findings, desk review outcomes and experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

3.1. Literature Survey

Research on circularity in construction has significantly contributed to sustainability theory by providing frameworks that endorse reuse, recycling, and reduction of materials. Pravin K et al, 2023 [45] introduced a conceptual framework showing the correlation between drivers and barriers. Circularity research has also impacts on organizational theory, particularly in how construction firms and supply chains organize themselves to implement circular practices. These researches explore new organizational structures, cultures, and leadership styles that facilitate circular economy principles. Lundberg, K et al, 2009 [46], have come up with a causal-chain framework concerning strategic and operational objectives. Meantime, Bigliardi, et al. [47] introduced an integrative theoretical framework while Tura, N et al, 2019 [48], generated a framework interacting drivers and barriers. Research on circularity informs environmental management theories by highlighting methods to reduce environmental impacts. This includes theories on waste reduction, resource conservation, and minimizing carbon footprints. For example, Zhang et al, 2022 [49], introduced a waste hierarchy while Govindan, K Hasanagic, M., 2018 [9] offered sound practices towards circular economy. De Jesus, A.; Mendonça, S.2018 [8] also discussed drivers and barriers in the context of eco-innovation. Zhang, A et al, 2019 [49] discussed in length how smart waste management would work as a catalyst for circular economy. Heurkens, E., & Dąbrowski, M. (2020) [50] identified barriers for circular transition at a regional scale and how to overcome them.

Having applied the systems theory, Ritala, P., 2019 [51] examined the issue of circularity from three perspectives: skeptical, pragmatic, and ideal. Meantime, Rios, F et al 2022 [52] focused on

business modeling geared for circularity. In fact, business modeling seems topical in the research arena that has a tail-end stake in those who implement circular practices at ground level such as construction companies. Green purchase decisions are also found to have been incentivizing the buyers via effective tax reforms. Encouraging these decisions requires a concerted effort from businesses and governments to create an environment where sustainable choices are made easy and rewarding. Lopes, J.M.M et al, 2024 [53] has also investigated consumers' green orientation in decision making. However, Helbling, T., 2020 [54], posited that the lapses in pricing decisions are evident in that no consideration is given to indirect costs of pollution.

Kwasifo, Oscar et al, 2024 [55], provided insights into practices involved in green procurement. Amilton Bet al, 2023 [56] studied on urban mining whereas Akomea-Frimpong, et al, 2023 [57] recognized success factors related to circular implementation in PPP projects. Shahi S, et al, 2020 [58] suggested that building adaptation is crucially relevant in the pursuit of circularity. Lestari, E.R., 2022 [59], inquired about tax policy while Ljumović, I., Hanić, A. (2023) [60] investigated the role of crowd funding in promoting circular practices. Mervyn Jones, et al 2018 [61] focused on different ways of integrating circular thinking in the discourse of procurement. Matthias Multani, Kris Bachus, 2024 [62] explored the relationship between circular economy and employment, crucial for circular transition. Salinas-Navarro, D.E.; et al, 2024 [63] studied how to navigate challenges in commercially capitalizing solid waste. Mohd Zairul, 2021 [64], emphasized the significance of prefabrication as a short-cut for circularity in construction projects for many obvious reasons. Hence, the economic implications of circular construction are significant, contributing to theories related to resource efficiency, cost savings, and new business models accruable at site level. It is also seen that the circularity in construction promotes advancement in LCA theory from production to end-of-life disposal or recycling. Incorporating circular principles into construction also influences design theory, encouraging architects and engineers to rethink design approaches that facilitate disassembly, material recovery, and adaptability. For example, modular construction occupied a considerable space on morphological theories. Material Recovery and Reuse is quite frequent in the circularity research including strategies for recovering and reusing materials from demolition sites. Further, circular construction research has advanced systems theory by emphasizing the interconnectedness of different components within the construction lifecycle. It underscores the importance of viewing buildings and infrastructure as part of a broader system where materials and resources are continuously cycled. Conducting life cycle cost assessments has therefore added a significant theoretical relevance. Rabta, Boualem. (2020) [65], presented a modified Economic Order Quantity inventory model incorporating circularity aspects measurable by an index. It is intended that this kind of an approach if exploited properly with a sense would in no doubt avoid excess of materials that are brought to the site for incorporation into permanent works. Stahel, W.R. 2016, [66] empirically derived a sustainability agenda for those affected by circular practices. Nascimento, D.L.M, et al, 2018 [67] engaged in modeling symbiotic industrial ecosystems. S. Pantini, L. Rigamonti [68] and Mário Ramos et al, 2024 [69] find strategies that encourage selective demolition, using a behavioral approach.

Waris, M., et al, 2014 [70] largely researched on onsite mechanization. Timm, J.F.G et al, 2023 [71] adopted a framework to support trade-offs in collaborative decision-making. By studying the implementation of circular principles, researchers contribute to innovation theory, particularly in how new technologies and processes are adopted within the construction sector. Fagone, C. et al, 2023 [72] created a flow of site operations on circularity based approaches. Santos, P. et al, 2024 [73] identified patterns, relationships, etc by giving further valuable insights. Tsui, Tanya, 2022[74] discussed municipal-led circular land mass coordination whereas Paulo de Sa & Jane Korinek, 2021 [75] contributed in offering savings to offset green premium for mass consumers. In this manner, theoretical contributions have considerably extended to policy and governance by providing evidence-based recommendations which involves demarcating the role of government, industry standards, and incentives in fostering circularity.

Relatively few studies were come across in the quest for circular principles at site level. Given that most of these articles (i) examine CE policies in explicit territories, (ii) emphasis on specific

aspects, or (iii) aligning product life-cycle, there is a dearth of studies on policy instruments germane firm and site operations.

3.2. Desk Review

Desk review forms a significant component of this study due to its comprehensive inquiry on existing policies widely acclaimed in the circular policy debate. Twenty three (23) policy documents, guidelines and protocols issued in the Europe have been referred to in this study. Ireland's National Waste Policy 2020-2025 [76] sets out measures across different forms of wastes, including wastes arising out of construction and demolition. The NSW Circular Economy Policy Statement (NSW, 2019) [41] concentrates on the product life cycle, stimulating mostly on long-lasting design, maintenance, repair, re-use, sharing, remanufacturing, and recycling. Product stewardship has been identified as a key enabler of circularity while promoting re-use and recycling options [41]. In addition, value organics and responsible packaging are identified unique to this policy framework. IWP, 2025 [75], proposed a waste recovery levy with a view to encourage recycling and by-products. Among the measures supporting the circular economy in Ireland, Green Public Procurement (GPP) has inspired offsite design and manufacture, modular building design, refurbishment and retrofitting of existing stock, and increased use of demolition waste as secondary construction material. European Investment Bank (2023) [77] prioritize green and renewable energy as a catalyst for circularity. In particular, it aims to reduce materials required for energizing equipment and infrastructure.

Libby Peake et al (2023) [77] foresee a sizable reduction in the carbon footprint, relieving land use, biodiversity, water and waste by 2030. To set this change in motion, the model of Netherlands is highly recommended for urgent action such as financial incentives, zero-rated for VAT, and retrofitting. Holcim (2022) [79] focus their efforts in eight main areas namely, manufacturing using recycled industrial byproducts as raw materials, creating new building products from recycling waste, including reclaimed waste from landfills, fueling sites with energy derived from materials, design with minimal material use, innovative repair and retrofitting systems to make buildings more energy efficient and last longer, testing and commercializing the utilization of CO₂ in new products and working with stakeholders to evolve regulatory building norms and circular procurement standards. Interreg Europe, 2024 [80] in Sweden defines actions on the ground for enhancing circularity such as maximizing the use of existing buildings, setting up reuse centers and online platforms to boost reuse of construction materials.

The policy recommendations are proposed to further promote and increase circularity in the built environment. For example, the UKGBC policy asks – the current UK context, evidence for why action is needed, and examples of where policy has been successfully implemented (UKGBC, 2023) [81]. Linda Høiby and Henrik Sand, 2023 [82] advocate a specific waste hierarchy; from prevention and waste reduction to reuse and recycling, recovery and disposal. Circular Transition Agenda, 2018 [83] recommend high-grade recycling in all construction submarkets. End-of-waste criteria are important for Dutch circular policies, facilitating the use of secondary raw materials. The gist of this proposal implies setting up feedback loops, where materials are re-entering the supply chains as valuable inputs [6]. European Commission, 2024 [84] emphasizes the importance of standardisation and report pre-normative research in metrology, performance characterisation, compatibility and operability assessments. The report identifies several opportunities for synergies, such as collaboration and gap analysis in the construction sector, refuting cradle-to-grave construction frameworks. In here, a couple of instruments have been endorsed: a) indicators to measure circularity, b) quality measures for reused and recycled materials, c) end-of-waste criteria, d) design for adaptability and disassembly, and e) building information. Meanwhile, the World Green Building Council (2024) [85] emphasizes the significance of creating a circular value chain. Green Alliance Trust (2023), [78] focus on reduction of using virgin materials through changes to design as long as possible. Priorities supporting these aims include developing uniform measurement of circularity, for which PBL (the Netherlands' environment assessment agency) [35] has also acceded through establishing the baseline for metrics and monitoring. As per Cityloop (2024) [86] the key to transition is knowledge diffusion and recommends local authorities to recognize this potential as a driving

force. Cityloop (2024) [86] emphasizes construction choices that favour bio-based materials and projects that incorporate secondary materials. According to Deloid (2019) [87] the policy tools in Finland include green construction procurement, industrial symbiosis, waste management investment, green mobility investment and business support schemes.

Of the foregoing measures, the majority of the policy instruments have been geared towards facilitating reuse and recycling for example, NYCEDC, 2024 [40]. Hanemaaijer, A. et al. (2023), [88] report that their findings in Netherlands confirm an integrated approach to maximize benefits out of demolition waste generated in the infrastructure development.

3.3. Scholarly Opinion

Interviews with the scholars and industry personnel were conducted via zoom platform. Table 1 shows interviewee profile.

Table 1. Interviewee profile.

No	Designation	Type of Organization	Geography
1	Consultant	Construction Consultancy firm	UK
2	Researcher	Government	UK
3	Advisory	Bank	Azerbaijan
4	Professor	Public University	Sri Lanka
5	Senior Lecturer	Public University	Sri Lanka
6	Chartered Architect	Private practice	India
7	Chartered Engineer	Private practice	Malaysia
8	CEO	Contracting firm	UAE
9	Project Lead	NGO	Finland
10	Senior Executive	Bank	Oman
11	Chartered Engineer	Ministry	Qatar
12	Senior Lecturer	Private University	Sri Lanka
13	Research Assistant	University	Denmark
14	Economist	Bank	Poland
15	COO	Construction firm	Oman
16	Chartered Quantity Surveyor	Private consultancy firm	Bahrain
17	Managing Director	Contracting firm	India
18	Expert	NGO	Norway

On a methodological note, this might demonstrate a potential geographical bias; however, the scholars are all having international exposure in the construction industry. The best practices showcased during review are lumped together to capture and reflect innovations from eight (8) different dimensions namely, regulatory, design, economic, financial, informative, voluntary, technical and digital. It is hoped that this approach would help operationalize policy instruments scaffolding the overarching circularity in construction. These guidelines require further breakdown into sector specific activities that must indeed be capable of being easily implemented at ground level. Hence, this paper provided a structural outline for implementing circular practices at site level structurally aligned with eight (8) dimensions encountered in the detailed literature survey reflecting specificity.

Regulatory instruments have been largely scattered across legislations, standards, building codes, site protocols, warranties and certifications. More often than not, waste management laws mandate the reduction, segregation, and recycling. The EU Waste Framework is one classic example. These regulations make site personnel responsible for the entire process, including take-back, recycling, and final disposal. In addition, there are Building Codes and Zoning Laws intending the site personnel to use of recycled materials. Cradle to Cradle certification encourages the use of safe,

circular, and responsible materials and products in construction projects. Shankland, A. (2011) [89] confirms accrediting material sources will boost up waste reduction practices, to a reasonable extent. RICS 2016 [90] sets out the targets generally focused on longer term objectives than in short run to reduce the amount of resources used rather than immediate change in efficiency and waste reduction. Looking at the most effective use of natural resources, resource efficiency is highly desired through strong business models in this context. The EU Circular Economy Action Plan [32] includes measures specifically targeted at construction, such as promoting the use of recycled materials and improving waste management. Likewise, policy instruments related to the function of design for circular practices in construction projects focus on creating systems and processes that promote reduced waste. These policy guidelines promote adaptive reuse, user centered design, flexible design, and use of modular components in fostering circularity. Experts are of the view that design and build projects can easily implement these initiatives whenever the client has the single point of expertise for both design and construction. In the meantime, economic policy instruments are essential tools for promoting circularity in construction at site level. These instruments provide financial incentives or disincentives to encourage construction practices that minimize waste, optimize resource use, and enhance sustainability. The interviewees held that the ability of the contractor to make value engineering proposals crops up this ideal opportunity during construction. Value engineering enables the contractor to look for alternative measures that improve efficiency of the building function without relaxing the initial design parameters. On the other hand, tax incentives, rebates and tax disincentives, subsidies to purchase more circular products and discourage purchase of non-circular materials are several key economic policy instruments highlighted in many of the policy documents. Table 2 depicts policy instruments validated in this dialogue with experts together with practical examples highlighted during the interview.

Table 2. Policy instruments.

Policy category	Policy group	Policy Instruments	Examples of Circular Practice
Regulatory	Building Codes and Standards	Recycling quota	A percentage of non-hazardous construction waste diverted from landfills
		Production standards for re-looping waste	Ways to reuse residues in production such as metal, sand etc
		Waste Separation Requirements	Mandating the separation of different types of construction waste (e.g., wood, metal, concrete) on-site to facilitate recycling and reuse.
	Landfill Bans and Restrictions	Waste Management Plans	Detailed waste management plan submitted by developer outlining how waste will be minimized, sorted, and disposed off-site
		Landfill Prohibitions	Prohibiting certain types of construction waste from being sent to landfills, such as banning the disposal of recyclable materials
		Landfill Taxes	Taxes on landfill disposal to make recycling and reuse more economically attractive
		Surcharge and royalty fee	imposition of royalty fee/surcharge on borrow excavation
	Zoning and Land Use Regulations	Bonus Incentives	Offering additional floor area ratio (FAR) or other zoning bonuses for projects that incorporate circular practices.

	Green Building Zones:	Designating specific zones where circular construction practices are required or highly encouraged.
Redevelopment Policies	Adaptive Reuse Requirements	Encouraging or mandating the adaptive reuse of existing buildings, preserving existing materials and reducing waste.
	Brownfield Redevelopment	Promoting redevelopment of brownfield sites using circular construction principles to revitalize contaminated or underused land.
Product and Material Regulations	Extended Producer Responsibility (EPR)	Taking back products at the end of life cycle for recycling or reuse, (eg, insulation, roofing, and flooring)
	Treatment bans	Incineration of recyclable materials not allowed
	Material Labeling	Labeling construction materials to indicate recyclability and potential for reuse
	Haulage	Disposing hazardous waste material off-site by a haulier with a valid waste collection permit, dumping to an authorized waste facility
Liability by law	Producers' liability	Guarantee for durability of products
	Decennial liability	Strict liability insurance that provides cover for a longer period for serious building defects and indemnity against unsound construction and collapse.
	Insurance	Insurance for design deficiencies, errors and omissions
	Warranty	A covenant that the warrantor has and is continuing to fulfill their obligations under the underlying contract
	Safety and health protocols	Covid 19 protocol to implement at sites that avoid site congestion
Design	Design for Disassembly and Deconstruction	Design for the easy dismantling of building components
	Design for Deconstruction	Designs that avoid adhesives and composite materials that are hard to separate
	User centered design	Design focused on the end user aspirations
	Flexible Building Design	Designing buildings with adaptable floor plans and services to extend their useful life and accommodate changing needs without major renovations
	Reused Materials Mandate	Certain percentage of materials used in new construction or renovation projects is sourced from recycled or reclaimed materials such as paper, cardboard, metal and plastics
	Deconstruction Plans	Deconstruction plan outlining how the building will be dismantled and materials recovered at the end of its life

		Longevity	Design for maximum potential life span
	Modular design	Modular Coordinated Standards	Encouraging the use of modular components and techniques such as pre-cast structural concrete panels, prefabricated composite panels, pre-cast hollow-core flooring etc that enhance buildability and reduce waste
	Eco-design Standards	Material Efficiency Standards	Setting standards for the material efficiency of building products, encouraging the use of materials that are durable, recyclable with a low environmental impact
		Product stewardship	Incentive to design with bio-based products such as bio-composites, natural insulation materials, bio-plastics and natural fibers to facilitate re-use, recycling, low emissions, carbon sequestration and biodegradability
		Circular Product Certification	Developing certification schemes for building materials that meet circular economy criteria, providing a market advantage for certified products
	Permitting and Approval Processes	Sustainable Construction Permits	Specific criteria related to circular economy practices, such as using eco-friendly materials, reducing waste, and planning for material recovery
		Conditional Permits	Issuing construction permits conditionally, based on the developer's adherence to waste management and recycling plans
		Environmental Impact Assessments (EIA)	EIA process, requiring developers to demonstrate how they will minimize waste, maximize material reuse, and reduce the environmental impact of their projects
	Design parameters	Optimum design	Avoid over-engineered structures minimizing inefficient use of virgin materials
		Incentive-based Zoning	Offering zoning bonuses, such as increased floor area ratios, for projects that meet certain circular construction criteria
		Setting out	Use the existing topography in a way that the need for excavation is minimal
		Procure products as a service	Procure products on the rationale of customer pays for the performance, not for ownership
Economic	Tax Incentives and Subsidies	Tax Credits	Tax breaks or credits for recycled or reused materials
		Energy Efficiency Tax Incentives	Tax deductions or credits for buildings that achieve high standards of energy efficiency, often correlated with sustainable and circular construction practices
		Subsidies and grants	Financial incentives for companies that implement circular economy practices, such as subsidies for setting up material recovery facilities on-site

	Green Building Grants	Offering grants for projects that combine circular principles, such as using sustainable materials, designing for disassembly, and implementing waste reduction strategies
Pay-as-you-throw Schemes	Differential Waste Disposal Fees	Charging higher fees for sending waste to landfill compared to recycling facilities to incentivize waste separation and recycling at construction sites
	Discounted Recycling Fees	Reduced fees for the disposal of sorted recyclable materials to encourage proper waste management practices
	Premature obsolescence	Tax levied on early technical obsolescence
	Tax incentives and rebates	Encourage specific circular activities (e.g., tax credits for remanufacturing)
	Tax disincentives	penalizing practices that contribute to environmental degradation, resource depletion, and waste generation such as carbon tax, landfill tax, plastic tax etc
Green Public Procurement (GPP)		
	Gateway reviews	Monitoring compliance with designing out waste principles
	Just in time delivery	Options for reduced packaging with subcontractors and suppliers
	Take back scheme	Sale of material surplus and offcuts
	Waste limit	Set out contractually agreed waste limit to avoid excess waste
Market access regulation	Banning non-circular products	Ban the use of construction materials that cannot be reused or recycled, such as certain types of concrete or insulation materials
	Allowing market access for circular products/services	Promote sustainable building materials, such as reclaimed wood, recycled metal, and environmentally friendly insulation
Economies of scale	Standardization	Simplify the process of deconstructing and reusing materials
	Prefabrication	Components are manufactured off-site in a controlled environment. This reduces waste, improves efficiency, and allows for better quality control
	Material Exchange Platforms	platforms where surplus materials from one site can be sold or traded for use at another site
	Bulk Buying	Purchase sustainable in bulk to reduce costs enjoying discounts for large quantities, making it economically viable to choose eco-friendly options.
Economies of scope	Uniform Practices	Implementing uniform construction practices and materials simplifies training, reduces errors, and enhances reusability

Scope creep control	Regular Reviews	Conduct regular risk reviews to identify new risks and reassess risk profile of the site operations
Descoping	Potential change notices	Redesign to reflect the reduced scope while maintaining functionality and quality; redefining project scope to align with circular principles
Value engineering	Functionality Analysis	Evaluate the essential functions of materials and components in the construction process; Determine if there are more sustainable alternatives to reach same function
	Material Optimization	Identify materials that can be recycled, reused, or are biodegradable
	Design Innovation	Implement flexible design strategies that facilitate disassembly and material recovery
	Lifecycle Cost Assessment	Analyze the costs associated with the entire lifecycle of materials, including disposal. Focus on long-term savings through durable and sustainable materials
	Process Efficiency	Streamline construction processes to minimize waste and energy consumption. Incorporate on-site recycling and waste management practices
Remanufacture	Resource efficiency	Structural components, façade elements, interior fixtures can be re-manufactured and reused after thorough inspection; Concrete can be crushed and re-manufactured into aggregate for new concrete production, reducing the need for virgin aggregate materials.
JIT Purchasing	Economic order quantity indicator	Using optimal parameters in the materials purchase decisions
Financial Green Bonds	Sustainable Construction Bonds	Issuing green bonds for financing circular construction projects that prioritize recycling, reuse, and waste reduction
	Green Financing Programs	Providing low-interest loans or favorable financing terms for developers and construction companies that implement circular construction practices
	Revolving Loan Funds	Establishing revolving loan funds that provide ongoing financial support for circular construction projects. As loans are repaid, the funds are reinvested in new projects
Pricing Mechanisms	Emissions Trading Systems (ETS)	Emissions trading schemes, where companies can trade emissions allowances; and sale of excess allowances
	Raw Material Levies	Imposing levies on extraction and use of virgin raw materials to make recycled materials more economically attractive
	Water and Energy Charges	Implementing higher charges for water and energy usage in construction projects,

Informati ve	Education and Training Programs	Workshops and Certification Programs	encouraging efficient use of resources and sustainable practices
			Offering training sessions and certifications for construction professionals on circular construction techniques and best practices
		Awareness Campaigns	Running campaigns to inform developers and contractors about the benefits and methods of circular construction
	Reporting Requirement s	Material Passports	Requiring detailed documentation of all materials used in construction, their origins, and their recyclability, promoting accountability and ease of future material recovery.
Voluntari y	Green Building Certifications	Annual Reporting	Mandating annual reporting of waste management practices and outcomes for large construction projects
		LEED and BREEAM Credits	Encouraging adoption of green building certification systems that include credits for circular practices, such as use of recycled content and waste management strategies
	Voluntary Agreements	Partnerships and Pacts	Agreements between regulatory bodies, construction firms, and waste management entities to collectively work for higher recycling rates and reduced waste generation
Market- based	Material Exchange Platforms	Materials Banks	Supporting online platforms where surplus building materials and components can be bought, sold, or traded, thus promoting reuse and reducing waste
		Deposit-refund Systems	Establishing systems where a deposit is paid on construction materials that can be refunded when the materials are returned for recycling
Technical Labour		Multidisciplinary Teams	Form teams with diverse skills (e.g., architects, engineers, craftsmen) to address different aspects of circular construction
		Training Programs	Provide training on sustainable building practices, modular construction techniques, and use of recycled materials
		Certification Programs	Encouraging site personnel to obtain certifications in sustainable construction and waste management
		Lean Construction	Apply lean principles to minimize waste and optimize workflow, improving labor productivity
		Green Building Practices	Educate laborers on health hazards associated with traditional construction materials and promote the use of eco-friendly alternatives
		Safety Protocols	Implement safety protocols specific to circular construction practices, such as handling recycled materials and managing waste.
	Site preparation	Pre-demolition	Conducting pre-demolition audit for the best option of resource recovery

	Selective demolition	Dismantling components in the building for reuse
	Temporary works	Discourage excessive temporary works, e.g. site roads, site offices/foundations
	Protective measures	Protection of the local environment from impacts associated with the sorting, segregation, storage and transport of waste
Plant	Energy Efficiency	Utilize plants with efficient energy management systems and renewable energy sources (eg,, solar panels to power plant operations and reduce reliance on grid electricity).
	Resource Efficiency	Partnered with a plant that uses recycled steel and sustainably sourced timber for modular components. Installed energy-efficient equipment and solar panels to power plant operations
Waste Segregation and Sorting	Designated Waste Bins	Labeled bins for different types of waste (e.g., wood, metal, concrete, plastics) for on-site segregation
	On-site Sorting Facilities	Setting up small-scale sorting facilities on the construction site to separate and process materials for recycling and reuse
Waste Management Plans	Mandatory Waste Audits	Regular waste audits to monitor and report effectiveness of waste management practices
	Waste Minimization Strategies	Implementing strategies to minimize waste, such as prefabrication, modular construction, and just-in-time delivery to reduce excess materials
	Sale at disposal	Auction/donate reusable products and appliances at site de-mobilization
Material Efficiency Practices	Material Passports	Maintaining a database of materials used in construction, including their properties, origins, and recyclability, facilitating future reuse and recycling
	Digital Twins	Using digital twin technology to create virtual replicas of buildings, tracking materials for easier maintenance and eventual deconstruction
On-site Material Reuse	Salvage and Reuse Stations	Establishing areas on-site where reusable materials can be stored and accessed for future use in the project.
	Non-Permanent Joints	Using mechanical fasteners instead of adhesives and welds to allow materials to be easily separated and reused.
	Multiple use	Use temporary works multiple times such as formwork, scaffolding etc
	Equal use	Equalizing cut and fill volumes at site to avoid disposal off site
	Reuse	Excavated materials on site to make up levels

On-site Energy	By product	Excavated material to infill abandoned quarries
	Renewable Energy Integration	Utilize solar panels, bioenergy or wind turbines to energize construction activities
	Energy storage	Implement battery systems to store excess energy and use thermal energy storage systems to retain heat or cold for later use.
	Energy efficiency	Energy-efficient construction machinery and equipment and LED lighting for site illumination
	Rainwater harvesting	Installing systems to collect and use rainwater for construction activities, reducing the demand for potable water
	Grey water recycling	Recycle grey water for non-potable uses like dust suppression and equipment cleaning
	Optimized logistics	Electric vehicles for on-site transportation
Digital BIM	Knowledge Sharing Platforms	Using Intranet or mobile apps to share best practices, guidelines, and updates on circular construction among site workers and site managers
	Peer Learning	Facilitating peer learning sessions where workers can share their experiences and solutions related to circular construction
	Incorporating Reused Materials	Actively integrating salvaged materials from the site or other projects into the construction process, reducing the need for new resources
	Lifecycle Assessment	Building Information Modeling (BIM) allows for detailed modeling of buildings, capturing every phase from design to demolition
		Facilitates lifecycle assessment of materials, enabling designers to choose sustainable and recyclable options
	Resource Optimization	Use of materials, reducing waste by precise planning and virtual simulation
		Allow for clash detection to avoid errors and rework during construction
	Material Tracking:	Supports tracking the lifecycle of materials, ensuring that reusable components are recovered
	Internet of Things (IoT)	IoT sensors can monitor real-time data on energy use, material consumption, and waste generation.
	Smart Construction Sites	Predictive maintenance of equipment, reducing downtime and extending the lifecycle of machinery.
Block chain Technology	Resource Monitoring	Sensors track the movement and usage of materials, ensuring efficient resource management and reducing waste
	Supply Chain Transparency	Immutable ledger for tracking the provenance of materials

		Ensures ability to trace out in the supply chain the use of sustainable and recycled materials
Material Passports		Digital passports for materials record their properties, usage history, and recycling potential
		Facilitate reuse and recycling by providing detailed information on their composition and condition
Digital Marketplaces	Material Exchange Platforms:	Online platforms where surplus materials from construction projects can be bought and sold
	Second-Life Materials	Platforms dedicated to the sale and purchase of reclaimed and recycled construction materials.
		Encourages the circular use of materials, extending their lifecycle
AI and ML	Predictive Analytics	Artificial intelligence and machine learning algorithms to predict material needs, optimize procurement and minimize waste
		Project planning and execution by forecasting potential issues and optimizing resource allocation
Design Optimization:		AI tools assist in designing buildings for disassembly and recycling
		Multiple design options that prioritize sustainability and resource efficiency
Digital Twins	Virtual Models	Digital twins create real-time, dynamic replicas of physical buildings and infrastructure
		Allows for continuous monitoring and optimization of building performance throughout its lifecycle
Simulation and Testing		Enables virtual testing of materials and designs to ensure they meet sustainability criteria
		Reduces the need for physical prototypes, saving resources and time.
Collaborative Platforms	Project Management Tools:	Platforms like Procore, Autodesk BIM 360, and others facilitate collaboration among stakeholders.
		Centralizes project information, enhancing communication, reducing errors, and improving efficiency.
Knowledge Sharing		Online forums and databases where best practices, case studies, and innovations in circular construction can be shared.
		Promotes continuous learning and adoption of circular principles across the industry
AR and VR Training and Education		Augmented reality and Virtual reality for immersive training experiences for workers on circular construction techniques and safety protocols

		Adoption of sustainable practices through interactive learning
	Design Visualization	Visualize and interact with building designs in a virtual environment
		Identifying potential design issues and opportunities for material reuse early in the project lifecycle
Implement ation	Integration and Standardization	Establishing standards for the use of digital tools across the industry ensures consistency and compatibility
		Encouraging the integration of various digital tools for seamless data exchange and workflow optimization
	Training and Capacity Building	Investing in training programs to upskill the workforce in the use of digital tools and platforms
Real-time Monitoring	Collaboration and Partnerships	Collaborative efforts to ensure the development of tools that meet industry needs and regulatory requirements
	Sensors and IoT	Monitoring waste generation, material usage, and energy consumption in real-time
	Data Analytics:	Using data analytics to identify trends and areas for improvement in waste management and resource efficiency
Reporting and Feedback	Regular Reporting	Requiring regular reports on circular construction metrics, such as waste diversion rates, material reuse, and energy consumption
	Feedback Loops	Establishing feedback mechanisms where workers and managers can provide suggestions for improving circular practices on-site.

Financial instruments also play a crucial role in promoting circular practices at sites through various monetary schemes. These instruments include sustainable construction bonds, green financing programs, emissions trading systems (ETS), raw material levies etc. These instruments eventually help lower the project costs, reduce risks, and enhance the economic viability of sustainable construction. In the meantime, informative policy instruments aim to educate, guide and encourage circular practices in construction projects. These instruments rely on disseminating information, raising awareness, and providing the technical knowhow on sustainable practices. For example, material passports are a commonly recommended digital tool to foster circularity that almost every policy document has lavishly endorsed. Technical policy instruments are another category of policy instrument critical for fostering circularity in construction by establishing standards, providing tools, and enforcing regulations and best practices. Pre-demolition audit, selective demolition, protective measures, energy efficiency, resource efficiency, waste audits are a couple of policy instruments having a direct technical relevance. The experts held the view that there can be site specific actions that can be taken at site level such as non-permanent joints in erections, maximum use of existing materials, avoiding all forms of wastes, multiple use of temporary works, equalizing cut and fill volumes so that there is no transit involved, reclaim materials as product, altogether representing the most site level approach of the framework. Further, digital policy instruments can significantly enhance the promotion of circular construction by leveraging technology to streamline processes, improve data management and foster collaboration. Some key digital policy instruments are digital twins, salvage and reuse stations (materials exchange

platforms), predictive analytics, design optimization, virtual models and simulation and testing. These tools not only enhance the implementation of circular principles but also provide valuable data and insights to drive continuous improvement in the construction sector.

The experts largely agreed that the circular practices referred to in the body of literature aim to minimize waste, optimize resource use, and extend the lifecycle of materials and products. Aligning with the principles of the circular economy, such practices engender a closed-loop system where the resources are continually reused, refurbished, and recycled rather than discarded. Waste minimization, recycling and resource recovery, sustainable procurement, and energy efficiency becomes integral to any typical pursuit of circularity at site level. The policy debate in this regard entirely drives on the caveat of life cycle thinking. The discussion ended with the emphasis on key performance indicators (KPIs) to measure the efficacy of circular practices, such as waste diversion rates, resource efficiency, and carbon footprint. These are considered to be policy instruments derived out of the interview. Many industry representatives suggested that policy is the most potent tool to drive circularity. It should, therefore, be introduced alongside circularity metrics, to deal with all the policy categories on a level playing field. This would mean a given policy category will never sustain in isolation without other policies intact. For example, the designs are inferred to be within the tolerance that does not exceed the quality parameters set out in the specification, amounting to over-design and over-engineering that would otherwise unnecessarily spent for almost no particular gain. In here, the designers will adhere to building codes and substantive judgment will be made to inculcate circularity in the design itself.

As long as data is readily available and usable, material passports may facilitate reuse. Regulations, such as those pertaining to low-carbon cement or modular building, may enable the expansion and greater influence of current technology. Reporting on recycling and reuse separately would encourage innovation. This is particularly important for high impact materials that have a large potential for reuse, such as concrete and steel. Including more categories in recycling reports would motivate people to move away from low-value down cycling. According to some experts, certain pre-manufactured modular homes may be challenging to recycle after they are done because their components may require a lot of glue and other sealants to keep them from breaking during transportation, making it challenging to separate the elements. In order to become ready for selective demolition, a pre-demolition audit must be conducted. This involves a thorough evaluation of the building material fractions in terms of quantity, quality, purity, and appropriateness for circularity (reuse, recovery, recycling). It should be used when organizing demolition projects, allowing enough time and facilitating actor cooperation, to make pre-demolition screening and selected demolition necessary when hiring a demolition contractor.

4. Conclusion

It is clear that, the majority of studies provides theoretical framework to support the arguments cited in the papers. In complementarity, researchers have provided conceptual frameworks to guide research by providing a clear, visual or descriptive representation of the key concepts, variables, and their relationships. These frameworks provide a roadmap for how the study will proceed. As a prologue, this transition will generate jobs, increase the robustness of the economy, increase the accessibility of goods, maximise the value of resources, and reduce waste. These guidelines identify potential challenges that could arise in the pursuit of circular practices, such as concerns about compliance with building codes and regulations, and suggests solutions to overcome these challenges while helping designers to reduce their embodied carbon footprint, incorporating circular economy design principles through early considerations, retaining building layers at their highest value.

While there is growing interest and progress in this area, experts contend that several research gaps still need to be addressed to effectively foster circularity at the site level. Developing more detailed and localized LCA methods is crucial. These methods should account for the unique characteristics of each site, including local environmental conditions, resource availability, and waste management infrastructure. Improved LCA tools will enable more precise measurement and optimization of circularity initiatives. As Rabta, Boualem 2020 [65] contended, economic order

quantity formula has to be revisited to absorb new considerations arising out of circular context. The experts are also of a similar viewpoint and affirm that revisiting the EOQ formula in the context of circular projects is essential to align inventory management practices. By integrating considerations such as extended product lifecycles, reverse logistics, sustainability metrics, dynamic demand, and the use of recovered materials, the updated EOQ model can better support the goals of resource efficiency, waste reduction, and environmental sustainability. Economic incentives and viable business models are essential for the widespread adoption of circular practices. Research should explore innovative business models, such as product-as-a-service, sharing economy frameworks, and extended producer responsibility schemes that can make circular initiatives profitable. Digital technologies have the potential to revolutionize circular practices by enhancing tracking, transparency, and efficiency. Research should focus on developing practical applications of these technologies to monitor resource flows, predict maintenance needs, and optimize recycling processes in real-time. Fostering a circular culture requires more than just technological solutions; it necessitates a shift in mindset among all stakeholders. Research should investigate strategies for training, motivation, and change management that can encourage individuals and organizations to embrace circular principles.

In practice, construction sites are temporary endeavors, unique in character, measurable on its own merit for circular adoption. However, CE often seen ad-hocly adopted as a part of a system, not process. In contrast with this view, the policy categories showcase that CE is achievable only with a more transformational perspective that informs all aspects of business, policy and practice. In bringing practicalities, it is crucial that all stakeholders of the construction industry and all partnering the construction supply chain work together in unison. In a nutshell, existing policies appear, in general, to be less site-oriented. To accelerate CE transition, further research is needed on policy intervention. The framework is novel because it does not necessarily integrate lifecycle of the project. While the paper offers a fresh tier on CE transition policy landscape, a grave limitation is that the policy landscape is dynamic so that these findings may get potentially outdated.

Funding: This research received no external funding.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflicts of interest.

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