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Designing for a Circular Economy in the Architecture, Engineering, and Construction Industry: Insights from Italy

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Abstract: Resource consumption in the construction industry is expected to increase globally in the coming years. Additionally, construction and demolition waste (CDW) remains a significant priority within numerous global policies due to its vast volume and the inefficiencies in its management. This situation results in substantial environmental repercussions, primarily due to the low rates of material recovery in the manufacturing processes for new building materials. In response, the concept of the circular economy (CE) emerges as a promising solution across various sectors. CE promotes more resource- and energy-efficient practices, reducing waste generation and mitigating the environmental impacts associated with product life cycles while also unlocking potential economic opportunities. The primary aim of this study is to identify and assess the design practices influencing the adoption of CE principles within the Italian architectural, engineering, and construction (AEC) sector. The study's main contribution lies in a survey of 77 Italian designers to explore the core strategies driving the development of comprehensive circular approaches. This investigation seeks to understand the constraints and opportunities for CE implementation. The findings will assist in decision-making, inform policy, promote literacy around the CE topic, enable new quality standards, and serve as a baseline reference for businesses regarding sustainability investment indexes and markets.

Keywords: circular economy; construction and demolition waste; design for circular economy; practices; Italy

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1. Introduction

As an economic paradigm and approach for resource management, a circular economy (CE) is designed to minimise waste, promote sustainability, and maximise the use of resources whereby products, materials, and resources are reused, refurbished, remanufactured, and recycled to extend their lifespan [1]. By transitioning to a CE, societies aim to create a more sustainable and regenerative economic system that benefits both the environment and the economy. Despite its evident advantages, achieving this transition has proven to be challenging despite global initiatives.

The Circularity Gap Report, an annual publication since 2018, provides a comprehensive assessment of the CE's status. It illustrates global material flows and identifies key circular solutions capable of reversing the overshoot of numerous planetary boundaries. However, the report released in February 2023 reveals a concerning trend, which is a decline in the proportion of secondary materials reintegrated into the global economy. This figure has dropped from 9.1% of total material inputs in 2018 to 8.6% in 2020, further declining to 7.2% in 2023 [2]. This reduction is attributed not only to a failure to increase recycling rates but also to a rise in virgin material extraction and the growing tendency to stockpile materials in infrastructure such as roads, buildings, and durable goods. For example, like many developed nations, Italy is striving to transition from a linear economic model to a circular one. However, material consumption in the construction sector is projected to increase in the coming years. Currently, approximately 50 million m^3 of inert resource extraction occurs annually. The raw materials are not costly enough to stimulate demand for secondary aggregates. Natural sand and gravel, for instance, cost between 10–15 €/m^3, with transportation costs being quite affordable [3]. Similarly, the UK has pledged to achieve net-zero greenhouse gas emissions by 2050. Nevertheless, over 90% of the country's material use is sourced from virgin materials, 80% of which are extracted abroad [3], which indicates high consumption of virgin materials and low material self-sufficiency.

Conversely, the substantial generation of construction and demolition waste (CDW) poses a significant challenge to the sustainability of the architecture, engineering, and construction (AEC) industry, the broader national economy, and global environmental sustainability. In 2015, the industry alone accounted for 36% of total waste production, amounting to an annual range of 2.5–3.5 billion tonnes [4]. To provide perspective, the UK generates around 138 million tonnes of CDW annually, constituting approximately 66% of overall landfill waste [5]. In Italy in 2020, 65.8 million tons of CDW were generated, representing 48% of total Italian special waste [6], and in the USA, it was 569 million tonnes in 2017 [7]. Beyond the challenges of depleting landfill space and financial losses linked to CDW, the environmental consequences are immense.

To tackle these escalating challenges, various solutions have been developed to achieve a closed-loop CE and minimise waste at every phase of the construction project. The Circular Economy Action Plan by the European Commission [8] aims to advance this goal, with many EU member states adopting varied implementation strategies. An expanding body of literature, notably contributions from Dokter et al. [9], Charef et al. [10], and Eberhardt et al. [11], underscores the crucial role of designers in CE implementation in CDW management. This encompasses key responsibilities for designers, including advising clients and enhancing design practices by embracing sustainable, green, and smart design strategies. Designers thus wield significant influence in realistically and effectively accelerating the transition to a CE in the AEC industry. A core challenge for design teams is the limited research on implementing the CE model within CDW management. Recent studies have mainly focused on optimal CDW management [12,13] and case studies exploring the application of CE based on the reduce, recycle, reuse (3R) principle, mostly during the construction stage [14]. This is particularly relevant given the findings from comprehensive literature reviews by Çimen [15] and Charef et al. [10], which highlight that "Design" remains one of the least studied stages in the construction process concerning the CE subject.

Questions remain about whether designers are culturally, strategically, and logistically prepared for proactive supply chain partnerships to significantly improve CDW management performance within the CE framework. Additionally, designers face the challenge of embedding such improvements within conventional design processes, which requires a clear understanding of CE principles. What designers need, and what the literature has not identified, is a clear and comprehensive tool to assist them in incorporating waste management practices throughout all stages of the design process. Therefore, this paper aims to assess current design practices employed in the Italian AEC industry, identifying weaknesses, trends, and opportunities and proposing enhancements to inherently contribute to a CE. Consequently, two distinct sets of research activities were undertaken, which are described in the next section.

2. Designing for Circular Economy Assessment Criteria

The CE is a regenerative innovative framework designed to optimise material use and maximise its value throughout lifecycle stages while minimising waste generation. An expanding body of literature, including works by Dokter et al. [9], Charef et al. [10]), and Eberhardt et al. [11], highlights the essential role of designers in implementing CE principles in CDW management. According to the Royal Institute of British Architects Plan of Work Stages [16], designers are crucial in promoting the transition to a CE by initiating waste reduction at the project level and enhancing design practices. As a result, designers are increasingly incorporating CE principles into their work to address sustainability challenges. The existing literature identifies various design practices and strategies that support the shift towards a CE. These practices are categorised into four main groups using the PEST analysis framework (Political, Economic, Social, Technological), serving as reference baselines for CE assessment criteria related to solution implementation, as discussed in Table 1. The classification and selection of the assessment criteria in Table 1 are based on a literature review [17–19] and the identification of international and national policies, guidance, and projects [20–24].

Table 1. Assessment criteria for construction designers in CE categorised by PEST framework.

PEST Category	CE Assessment Criteria
Political	Corporate environmental responsibility: Corporate environmental responsibility to embrace CE adoption in construction, encompassing regulatory promotion and establishing plans, schemes, and targets to enhance CE practices
	Assessment and Certification Processes: Establish conformity standards, certification procedures, and assessment methods that promote CE principles for construction products and materials
Economic	Circular Business: Assessing businesses' engagement in construction's CE, including service creation around products, fostering additional business opportunities without extra resource consumption (e.g., maintenance, repairs).
	Circular Design: Exploring sustainable and eco-friendly design solutions that remain cost-effective or may even lower costs, promoting the CE in construction. This encompasses disassembly, building adaptation, maintenance, repair, and the use of durable secondary materials.
Social	Knowledge, Skills, and Awareness: Assessing knowledge about products and materials used in construction, including hazardous materials content, recycled material content, embodied carbon, and energy, as well as recovery information regarding product reusability and recyclability, to support CE implementation.
Technological	IT and Digital Systems: Digital transformation and innovative technologies aimed at enhancing the CE in construction. Evaluating BIM adoption levels and CDW management integration, alongside other digital tools.
	Infrastructure: Examining physical and virtual facilities/services for CDW management.

The next section discusses in detail the design for CE key practices pertaining to the assessment criteria, each of which reflects a key method for attaining a successful transition towards a CE. These can serve as a baseline for evaluating the current uptake of CE principles amongst designers in Italy.

3. Designing for Circular Economy Practices

In Table 2, a synthesis of the design for CE key practices is listed against each of the CE assessment criteria. Corporate environmental responsibility involves policies and regulations promoting CE in the AEC. The EU's Waste Framework Directive targets aim to ensure that CDW is managed in an environmentally sound way. By 2020, at least 70% (by weight) of non-hazardous CDW should be reused, recycled, or recovered [25]. Despite its potential, the recycling and material recovery rates of CDW vary significantly across the EU, ranging from less than 10% to over 90%. In 2022, Italy exceeded this target, recovering or reusing 77.9% of CDW [6]. Supporting this, several schemes have been established. The Extended Producer Responsibility (EPR) scheme requires producers to bear financial or organisational responsibility for the waste stage of a product's life cycle, including prevention, separate collection, sorting, and treatment operations. This can also involve contributing to enhancing product reusability and recyclability [26]. Similarly, the EU Taxonomy regulation, which came into force on 12 July 2020, provides a classification system for environmentally sustainable economic activities. This regulation helps scale up sustainable investment and implement the European Green Deal by providing clear definitions for companies, investors, and policymakers about which economic activities are environmentally sustainable [27]. Another example is Green Public Procurement (GPP), which integrates environmental criteria into public procurement procedures for goods, services, or works. In 2016, common GPP criteria for 'office building design, Construction, and Management' were established to facilitate the inclusion of green requirements in public tender documents [28].

While the aforementioned practices are established on a mandatory basis, there are also voluntary instruments supporting the CE. In the context of assessment and certification processes, Life Cycle Assessment (LCA), based on the International organisation for Standardisation (ISO) 14040 [29], is an internationally standardised methodology for measuring the environmental impacts of products and processes. This standard supports companies in improving product competitiveness and requesting environmental certifications. Additionally, the use of CE assessment tools and certifications accelerates the shift towards a CE, balancing social, economic, and environmental sustainability. Furthermore, LEED and BREEAM are well-known sustainable-building schemes. Though adopted on a voluntary basis, they impose more binding requirements compared to legal standards. These schemes include provisions for the storage and collection of recyclables, CDW management plans, durability of materials and design, sourcing of raw materials, and material ingredients [30].

Circular design involves sustainable design solutions that remain cost-effective. The use of environmentally friendly materials can effectively promote CE in construction. This involves using low-carbon and non-hazardous materials during the design stage. Further, a durable product demands less maintenance, generates less waste, and promotes eco-efficiency, leading to more sustainable design of construction projects [31]. Similarly, the use of secondary materials in the AEC industry for constructing buildings and roadworks and for environmental restoration reduces the volume to be disposed of and activates new local production processes and supply chains through the reuse and recycling of construction and demolition materials [12]. Furthermore, design standardisation establishes consistent procedures, specifications, dimensions, processes, and materials, offering clear and detailed guidelines for design work processes [32,33]. This includes practices like offsite construction, adaptable building design, and design for disassembly, which are crucial for improving quality control by reducing errors and defects, preventing waste, and enhancing the recyclability and reuse of materials at the end of a construction project's life. Regarding circular business, evaluating businesses' engagement in the CE involves developing services around products and fostering additional business opportunities without consuming extra resources. This includes adopting designs that ensure the maintenance and repair of construction products to prolong their lifecycle and implementing renovation instead of demolition [34].

Table 2. Key design practices in construction CE (compiled from the main sources within the literature).

PEST Category	CE Assessment Criteria	Design Practice
Political	Corporate Environmental Responsibility	Defining/implementing measurable waste recovery targets (% of targeted recovery)
		Implementation of Extended Producer Responsibility (EPR) schemes in construction
		Implementation of green finance businesses (EU Taxonomy) to support CE initiatives
		Implementation of Green Public Procurement (GPP) in construction
		Implementation of Life Cycle Assessment (LCA) of construction products
	Assessment and Certification Processes	Use of CE assessment tools/certification schemes
		Use of sustainable/green construction schemes (e.g., LEED, BREEAM) that include CE aspects

Table 2. *Cont.*

PEST Category	CE Assessment Criteria	Design Practice
Economic	Circular Business	Implementation of reverse logistics (e.g., maintain, repair, re-manufacture)
		Implementation of renovation instead of demolition
	Circular Design	Consideration of disassembly in design
		Consideration of adaptable building design
		Consideration of maintenance and repair in design
		Consideration of the use of durable materials in design
		Consideration of the use of low carbon/non-pollutant materials in design
		Consideration of non-hazardous materials in design
		Consideration of the use of secondary materials in design
		Consideration of modular (off-site) construction in design
Social	Knowledge, Skills, and Awareness	Knowledge of embodied energy information concerning construction products and materials
		Knowledge of embodied carbon information concerning construction products and materials
		Knowledge of recyclability information concerning construction products and materials
		Knowledge of recycled content information concerning construction products and materials
		Knowledge of hazardous materials' content concerning construction products and materials
Technological	IT and Digital Systems	Level of BIM implementation
		Use of Artificial Intelligence (AI) technology in the design stage
		Use of Blockchain technology in the design stage
		Use of Internet of Things (IoT) technology in the design stage
		Use of Geographical Information System (GIS) technology in the design stage
		Use of geospatial data analysis in the design stage
		Use of Virtual Reality (VR) technology in the design stage
		Use of Augmented Reality (AR) technology in the design stage
		Use of material passport technology in the design stage
	Infrastructure	Use platforms/hubs for communication and collaboration in a CE

The social category encompasses human factors, including cultural aspects and industry attitudes [35]. The most crucial practice within this category is acquiring knowledge and awareness about the characteristics of construction materials, which is a key enabler of the CE. This involves understanding the hazardous content, recycled material content, embodied carbon and energy, and recovery information related to product reusability and recyclability. Gaining knowledge in these areas helps promote the use of recycled and reused materials in design specifications, advocating for materials recycling at the end-of-life stage and prioritising environmentally friendly, non-pollutant materials [36].

IT and digital systems encompass a variety of digital solutions available for waste management and CE practices in construction design through software applications. A leading-edge technology in this field is Building Information Modelling (BIM), which offers key capabilities for achieving CE goals in the AEC industry. These capabilities include design error reduction, visualisation, automatic clash detection, waste performance simulation, waste management reporting, and early stakeholder collaboration [37]. Central to digital systems, like Artificial Intelligence (AI), the Internet of Things (IoT), Blockchain, Virtual Reality (VR), and Augmented Reality (AR), is the CE concept, which supports the adoption of construction practices that are both efficient and sustainable, meeting the demands of society and the environment [38]. The introduction of material passports can further enhance knowledge about the materials within a building, increasing the chances of reusing, recycling, or repurposing materials to reduce the demand for new resources and minimise CDW generation. Material passports maintain long-term knowledge of all building materials, preserving their economic value. In fact, these systems and databases can interact with BIM application and be accessible to all users involved [39]. Regarding technological infrastructure, digital platforms are designed to provide companies with tools to integrate environmental sustainability into their operations. Collaboration platforms enable interdisciplinary and cross-disciplinary professionals, such as architects, engineers, and construction specialists, to work together on a unified platform, enhancing communication and coordination among stakeholders [38]. Additionally, waste-sharing platforms offer opportunities to swap, sell, and share unused construction equipment, materials, resources, and second-hand products, thereby boosting waste reduction.

To maximise the impact of designers, it is imperative for them to comprehend the constraints and opportunities related to the practical approaches for achieving improvements in construction across all levels by emphasising the design for CE principle. Consequently, this paper aims to assess current design practices employed in the Italian AEC industry, identifying trends and weaknesses and proposing enhancements to inherently contribute to a CE.

4. Methods

This study employed a two-fold quantitative research approach, as shown in Figure 1. First, a comprehensive literature review (Sections 2 and 3) was conducted to achieve three objectives: evaluate the role of designers in CE implementation in CDW management; gain insights into circularity assessment criteria for designers in construction; and identify prevailing design practices reflecting the assessment criteria. Second, a questionnaire was distributed to Italian designers. Potential participants were identified through industry hubs and governmental/non-governmental institutions in Italy, including the National Council of Engineers (CNI), Board of Engineers of Como Province, Sustainable Infrastructure Association (AIS), Ferrovie dello Stato Italiano (FS Group: Rome, Italy), Geotechnical and Environmental Engineering Group (GEEG Group: Rome, Italy), and Rete Sand (Sand Network: Milan, Italy). These institutions and hubs were initially contacted to explain the project's scope and aim and to request their assistance in distributing the surveys within their networks. The survey questions were developed based on the investigation of circularity assessment criteria and their related practices. The survey was carried out online using JISC surveys and consisted of 5 sections with 36 questions covering participant information and political, economic, social, and technological-related practices. A combination of Likert scale (with an option for "unsure" or "non-applicable" scale) and multiple-choice questions was administered, with additional space to expand on responses and share views on other design issues not covered in the survey. Responses were requested based on current or recently completed building design projects.

An important aspect of conducting a questionnaire survey is to ensure a high response rate for meaningful data analysis [40]. To achieve this, several efforts were made to maximise respondent participation. Initially, a pilot questionnaire was distributed within the RECONMATIC project consortium, which included academics, researchers, and industry partners. The pilot aimed to check the survey's structure, clarity, flow of information, and length. Feedback from the pilot led to minor corrections. The questionnaires were then translated into Italian and further reviewed for clarity and validity. The survey package in JISC included a study information sheet, a consent form, and a confidentiality statement to assure respondents that their data would be kept confidential. Contact details for the corresponding researcher were also provided. The survey was open for two months, from 30 May to 31 July 2023, resulting in a total of 77 usable responses.

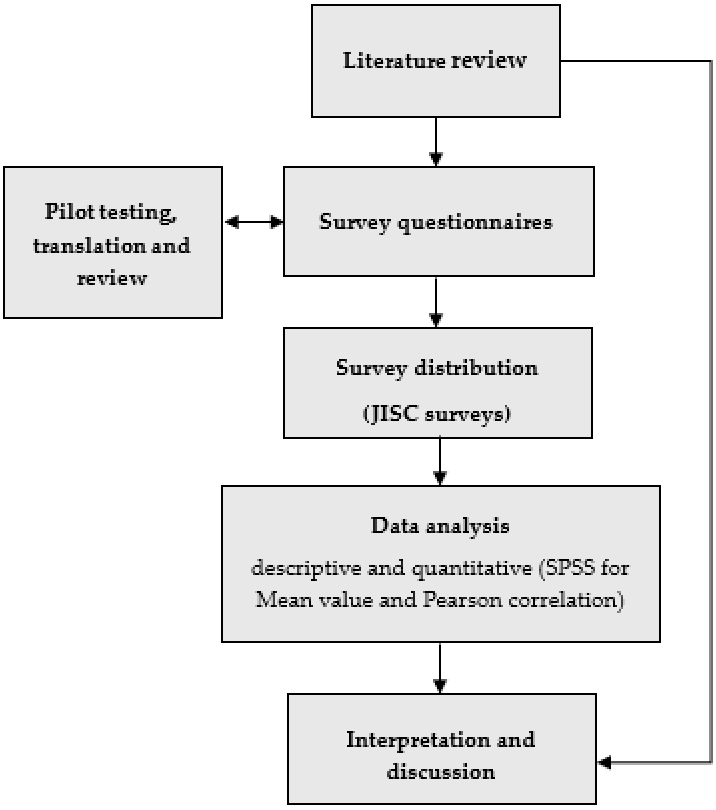

Figure 1. A flowchart of the research methodology.

The quantitative responses were analysed using SPSS software, version 26. Prior to data entry, the questions and variables were coded. After entering the questionnaire responses, a data 'cleaning' process was conducted to ensure accuracy. This included removing double entries where the data was entered twice, and discrepancies were checked against the original questionnaires. SPSS frequency distribution was also used to scan for value errors based on the original questionnaires. To validate the findings, Cronbach's alpha value was calculated. The analysis of the five-point Likert scale questions involved comparing the means of each data set to determine the order of practices by their adoption frequency. Additionally, correlation analysis was conducted using Pearson correlation coefficients to identify potential correlations between significant variables. Finally, any qualitative responses were manually tabulated.

Reliability of Results

Ensuring reliability is essential as it verifies the consistency of a measuring instrument. The Cronbach's alpha coefficient is widely employed to assess internal consistency, and Likert scales are especially effective for this purpose [41]. In this study, reliability analysis was carried out using SPSS version 26, with the standardised Cronbach's alpha calculated as shown in Equation (1),

$$\alpha = \frac{N}{(N-1)} \times \left[\frac{\sigma_x^2 - \sum_{i=1}^{N} \sigma_{yi}^2}{\sigma_x^2} \right] \quad (1)$$

where N is the number of items in the test, σ_{yi}^2 represents the sum of the variances for each item, and σ_x^2 denotes the variance of the total observed scores. Cronbach's alpha values range from 0 to 1, with values above 0.5 considered acceptable. Values closer to 1 indicate higher internal consistency, while lower values suggest less consistency [42]. In this study, the Cronbach's alpha value for the political, economic, social, and technological categories was calculated to be 0.929, indicating excellent internal consistency. Therefore, the variables are deemed reliable for further analysis.

5. Survey Findings and Discussion

5.1. Questionnaire Participants

The results of the statistical analysis regarding the characteristics of questionnaire participants are presented. The figures below describe aspects such as organisation size, the organisation's primary activities, and participants' roles within their companies. As observed in Figure 2, the majority of participants work in micro-businesses (50%), followed by small (12%) and medium-sized organisations (21%). Lastly, participants from large organisations contribute to 17% of the total. In 2021, the vast majority of construction enterprises in Italy were micro-sized companies (95%) with zero to nine employees [43].

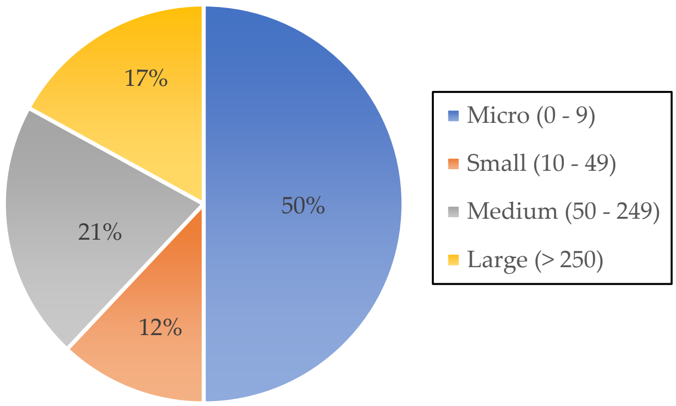

Figure 2. Distribution of participants per organisation size.

Figure 3 illustrates the primary construction activities identified by the participants. Renovation and refurbishment are the most common activities, with 47% of participants involved. New building construction is also significant, with 32% of participants engaged in this activity. Approximately 14% of participants are linked to infrastructure projects. Finally, around 22% of participants are not associated with a specific construction activity. These participants may be involved with public or private developers whose main activities differ from construction, or they may be engaged in consultancy work.

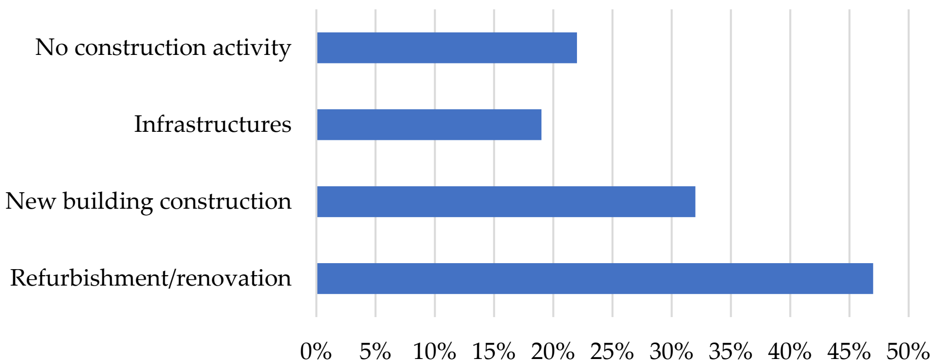

Figure 3. Distribution of primary construction activities of participants' organisations.

Figure 4 illustrates the roles participants hold within their organisations, providing insight into their decision-making and capacity for change. A significant portion, 49%, are involved specifically in architectural design. Following this, 27% of participants hold managerial roles, and 11% are directors. A small portion, 4%, are in administrative roles. Additionally, 11% of participants fall under the 'others' category, which includes consultancy and other unique positions. Notably, there is a substantial representation of participants with high-level decision-making capacity, including directors and managers (36%). This diversity of roles among the participants offers valuable insights into the dynamics of their organisations and potential opportunities for change and improvement.

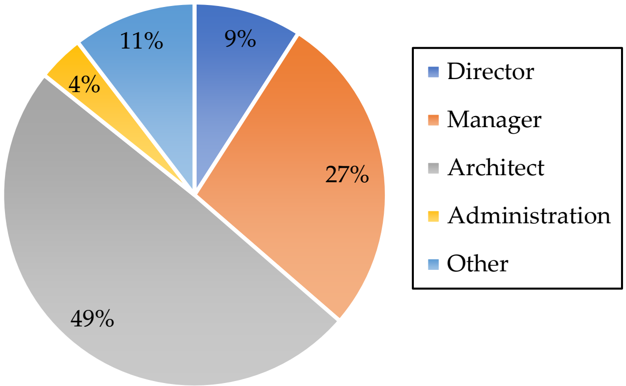

Figure 4. Distribution of professional role of participants.

5.2. Evaluation of the Design for Circular Economy Practices

This section of the survey findings ranks the design practices influencing the adoption of CE principles under the four categories: political, economic, social, and technological. SPSS (version 26) was used to analyse the mean values of the responses, allowing for a comparison of these values to identify the most and least adopted practices and the emphasis placed on them. The mean value is calculated using Equation (2) [44],

$$MS = \frac{\sum(f \times s)}{N'}(1 \leq MS \leq 5), \tag{2}$$

where S is the score given to each factor by participants (ranging from 1 to 5, with 1 being "never" and 5 being "always"), f is the frequency of participants' ratings for each factor, and N' is the total number of participants for that factor. The results of the mean values for each section are shown below.

5.2.1. Political

Table 3 illustrates that the GPP scheme was accorded the highest adopted practice within the Italian AEC industry, with a mean score of 3.63. GPP has been mandatory in Italy since 2016, regulated by the New Procurement Code under legislative decree 50/2016, where all public investments are required by law to implement GPP [45], possibly explaining its high adoption rate. The respondents rated EPR as the second most adopted practice, with a mean rating of 2.95. EPR is governed by Italy's Environmental Consolidated Act under legislative decree 116/2020. Currently, this scheme primarily targets packaging waste and waste from both electrical and electronic equipment, as reported by the Ministry of the Environment and Protection of Land and Sea, Italy [46]. Notably, there is a lack of specification regarding construction product categories covered by the EPR scheme in Italy, and there are ongoing considerations to expand its scope to include additional categories. The third practice within this category was the LCA scheme, with a mean value of 2.56. Close to this scheme in terms of adoption, EU Taxonomy was ranked as the fourth most adopted practice. Italy has adopted the EU Taxonomy following EU Regulation (EU) 2020/852, applicable to large firms with over 500 employees [27]. The adoption of such regulations in Italy serves as an important performance indicator for the Italian industry, directing investments towards economic activities crucial for transitioning towards a CE. However, given that approximately 95% of AEC enterprises in Italy are classified as micro-sized companies, more emphasis on the adoption of EU Taxonomy among these companies is crucial.

Table 3. Mean value of design for CE practices in political context.

Participant Responses	**Participant Responses**					**Mean Ranking**	**Ranking**
	Percentage						
	1	**2**	**3**	**4**	**5**		
GPP	14.0	6.50	13.0	35.5	31.0	3.63	1
EPR	10.5	23.5	35.5	21.5	9.00	2.95	2
LCA	7.50	45.5	31.5	14.0	1.50	2.56	3
EU Taxonomy	9.50	45.5	33.0	9.00	3.00	2.52	4
CE certification	62.0	13.0	11.0	11.0	3.00	1.81	5

Conversely, practices with lower mean values typically indicate lower perceived importance. Respondents were asked about their use or request for CE certification schemes (e.g., ISO/TC 323 standards [29], XP X30-901, BS 8001, etc.) for organisational management or products. Such practice ranked lowest, with a mean of 2.74. Design companies aiming to lead in the CE field can more easily and readily adopt these standards and guidelines to accelerate the shift towards responsible and sustainable consumption and production. CE certification, particularly according to the XP X30-901 standard, offers numerous benefits to construction design companies, certifying the systemic approach to CE management and ensuring the circularity of any adopted projects. However, the low response rate may be attributed to two factors: a lack of interest from decision-makers in Italian design companies towards implementing such standards, given their voluntary nature, and a lack of awareness about the existence or importance of such certification, as almost 23% of respondents were unsure. Nonetheless, these results provide valuable insights for further investigation.

5.2.2. Economic

The results in Table 4 indicate that the use of non-hazardous materials is the highest adopted practice, with a mean value of 2.91. Italy, like many other EU countries, has stringent regulations and policies aimed at minimising the use and impact of hazardous substances in the AEC industry to protect public health and the environment. For instance, the EU REACH regulation plays a key role in regulating the utilisation of materials and chemicals that may contain hazardous substances in construction materials [47]. Following closely is the use of durable materials and products, with a mean value of 2.88, making it the second-highest adopted practice, according to survey respondents. It is noteworthy that a primary criterion of GPP is the reduction of hazardous material usage and the promotion of durable and easily reparable materials and products. Considering the previous section, where GPP was identified as the most widely adopted practice, it can be inferred that this emphasis on these two types of materials may explain its top ranking. The use of secondary and low-carbon materials was ranked fifth and sixth, respectively, with very close mean values (2.09 and 2.08). There is a growing trend towards the circular use of materials, with the secondary material use rate in Italy increasing from 5.8% to 19.3% between 2004 and 2019 [48]. However, the recycling rate of CDW is still hindered by the low cost and perceived regulatory/safety of using virgin quarry materials [3].

Table 4. Mean value of design for CE practices in economic context.

Practice	Participant Responses Percentage					Mean Ranking	Ranking
	1	2	3	4	5		
Use of non-hazardous materials	2.50	6.50	17.0	43.0	31.0	2.91	1
Use of durable materials/products	4.00	2.50	15.5	51.5	26.5	2.88	2
Maintenance and repair during design	1.50	14.0	33.0	34.0	17.5	2.50	3
Renovation instead of demolition	5.50	10.5	24.0	45.5	14.5	2.40	4
Use of secondary materials	7.00	16.5	38.5	34.0	4.00	2.09	5
Use of low-carbon materials/products	8.00	21.0	33.5	31.0	6.5	2.08	6
Flexible design	13.5	23.0	27.0	29.5	7.00	1.89	7
Offsite construction	15.5	25.5	33.5	15.5	10.0	1.76	8
Reverse logistics	21.5	23.0	27.5	21.0	7.00	1.70	9
Design for disassembly	33.5	25.0	17.5	16.0	8.00	1.42	10

Interestingly, offsite construction was ranked eighth with a mean value of 1.70, despite its increasing prevalence in the AEC industry, particularly with the growing interest in automated production and assembly. This was confirmed by Jayawardana et al. [49], who noted that the offsite construction production system has not reached its full capacity due to a significant drop in construction investment over the past decade and a lack of knowledge about the quality of prefabricated products. Offsite construction has significant potential to improve the performance of the construction industry, offering many key advantages, including contributing to a greener built environment [32]. Design for disassembly was the least adopted practice, with a mean value of 1.42, according to respondents. In Italy, there is no binding law requiring the design of buildings for disassembly, except for large companies with more than 500 employees under the EU Taxonomy's transition to a circular economy regulation, as provided by ISO 20887 [50]. This lack of regulation likely contributes to the low emphasis on this practice, especially since the majority of construction-related companies in Italy are micro- to small-sized. Other factors may also play a role; however, it is worth highlighting this issue for future consideration.

5.2.3. Social

The data in Table 5 reveal that Italian design companies prioritise obtaining information about the hazardous content in construction materials, with a mean value of 3.19. This supports previous findings that respondents are highly interested in using non-hazardous materials in construction projects. Such an interest naturally leads designers to seek information about the hazardous content of these products. Following closely as the second most adopted practice is acquiring information on whether a product is recyclable, with a mean value of 3.17. According to Guerra & Leite [36], this practice is a crucial design strategy for achieving a closed-loop CE by understanding the recyclability of materials and prioritising those that can be recycled at the end of the project's life. The use of recycled materials is similarly important, as it significantly boosts the secondary materials market. It is evident that this practice has contributed to the circular use of materials in Italy, where the rate has increased from 5.8% to 19.3% over the last two decades [48]. Lastly, gathering information about both embodied energy and carbon content has shown lower emphasis among respondents, with mean values of 2.26 and 2.25, respectively.

Table 5. Mean value of design for CE practices in social context.

Practice	Participant Responses Percentage					Mean Ranking	Ranking
	1	2	3	4	5		
Knowledge about hazardous materials content	10.5	21.5	21.5	32.0	14.5	3.19	1
Knowledge about recyclability	8.00	16.0	30.5	41.5	4.00	3.17	2
Knowledge about recycled content	6.50	18.5	35.5	33.0	6.50	3.14	3
Knowledge about embodied energy	33.5	25.0	26.5	12.5	2.50	2.26	4
Knowledge about embodied carbon	34.5	28.0	18.0	16.5	3.00	2.25	5

5.2.4. Technological

The results in Table 6 indicate that material passports are the most widely adopted amongst the below technologies according to the respondents, with a mean value of 2.87, reflecting significant emphasis on this practice. In Italy, the application of material passports is still emerging as a means to enable circularity in materials management. Interestingly, respondents emphasised this practice even though mandatory legislation for material passports has not yet been introduced in Italy, and there is no common definition or harmonised tools and systems [39]. Networking and sharing platforms were the second most emphasised technology among Italian designers. Several platforms exist in Italy for reuse and repair at both the national and local levels, such as ICESP (Italian Circular Economy Stakeholder Platform), Circularity, Re-sign, and Taranto Circolare.

Table 6. Mean value of design for CE practices in technological context.

Practice	Participant Responses Percentage					Mean Ranking	Ranking
	1	2	3	4	5		
Material passports	15.0	39.0	30.0	13.0	3.00	2.87	1
Platforms/hubs	36.0	24.0	28.0	9.00	3.00	2.51	2
GIS	37.5	30.0	28.5	2.50	1.50	1.94	3
Geospatial data analysis	47.5	22.5	23.5	4.00	2.50	1.86	4
IOT	59.5	20.5	17.5	2.50	0.00	1.43	5
VR	79.0	4.00	10.5	4.00	2.50	1.33	6
Blockchain	74.0	9.50	13.5	1.50	1.50	1.20	7
AR	81.5	6.50	10.5	1.50	0.00	1.17	8
AI	84.5	4.00	8.00	1.50	2.00	1.14	9

Conversely, VR and AR technologies showed low emphasis, with mean values of 1.33 and 1.17, respectively. Despite Italy's national Digital Transformation agenda, driven by Ministerial Decree 560/2017, which mandates the progressive introduction of electronic modelling methods and tools for construction and infrastructure [51], integrating more digital elements like AR and VR is crucial. These cutting-edge technologies can significantly enhance sustainable and eco-friendly design practices. Similarly, AI was the least adopted technology in this category by Italian designers. It is noteworthy that the integration of AI technologies in various fields, including construction design, is still in its infancy due to various challenges, such as technical, ethical, and practical issues [38].

5.3. Correlation Analysis

To assess statistically significant differences among the multiple-choice questions, correlation analysis was performed using Pearson correlation coefficients. This method identifies potential correlations between key variables by measuring the linear relationship between two continuous variables, assuming the data are both continuous and normally distributed [52]. The Pearson correlation coefficient quantifies the strength and direction of this relationship. While multiple-choice questions typically produce categorical data, in this study, they are treated as continuous metric data, including organisation size (from micro to large), participant roles (from regular staff to top management positions), levels of BIM adoption (from level 0 to level 3), and the percentage of sustainable scheme adoption and waste recovery targets (from 0% to 100%). Consequently, this approach is considered suitable and reliable for statistical analysis. For these statistical tests, a value of $\rho \leq 0.01$ was considered the minimum acceptable significance level [52]. Participants' information, including organisation size and their roles, was analysed to identify correlations with survey questions regarding waste recovery targets, sustainable construction schemes, and the level of BIM adoption. These three subjects were chosen for their significant impact on CE implementation [21,22,26]. The investigation aimed to identify potential correlations that could drive the development of comprehensive circular approaches. The results of the correlation statistical analysis for each subject are shown below.

5.3.1. Waste Recovery Target

The survey questionnaire inquired whether Italian designer companies had defined waste recovery targets during the design stage for construction projects conducted at the time of the survey or for future projects. The correlation analysis in Table 7 reveals a statistically significant positive correlation between the organisation's number of employees and the targeted recovery percentage for the year. The Pearson correlation coefficient is 0.426, with a p-value of less than 0.001. This significant positive correlation indicates that as the number of employees increases, so does the targeted recovery percentage for the year, and vice versa. Thus, there exists a relationship between workforce size and recovery goals set by the organisation. With more employees, there is a potential for pursuing ambitious recovery targets, while a smaller workforce may result in more conservative goals. According to ISPRA [6], the waste recovery percentage from demolition and construction operations stands at 77.9%, surpassing the 70% objective set by the European Commission. However, considering the observed positive correlation between company size and waste recovery target determination, it is pertinent to underscore the role of micro-sized companies in boosting the overall percentage of the country's waste recovery target. This is particularly significant given that, according to the European Commission [43], approximately 95% of construction enterprises in Italy are classified as micro-sized companies.

Table 7. Correlation between organisation size and role category with waste recovery target implementation percentage.

	Waste Recovery Percentage Your Organisation Is Targeting?		**Decision**
	Statistic Test		
Number of employees in your organisation?	Pearson Correlation Sig. (2-tailed) N	0.426 <0.001 77	Correlation is significant at the 0.01 level (2-tailed)
What is your position in your organisation?	Pearson Correlation Sig. (2-tailed) N	0.41 0.717 77	Correlation is not significant

On the other hand, the analysis revealed a lack of statistically significant correlation between the waste recovery target and the organisational role category, as evidenced by the Pearson correlation coefficient of 0.041 and a p-value of 0.717, exceeding the conventional significance level of 0.05. This suggests that factors beyond organisational role may exert a more pronounced influence on individuals' decisions regarding recovery targets, such as the company size. While roles within the organisation may differ in terms of responsibilities and decision-making authority, they do not seem to directly affect ambitions or strategies concerning waste recovery. It is important to acknowledge that the absence of correlation does not necessarily imply the absence of influence; other unmeasured variables may still be at play. Therefore, further research may be necessary to explore additional factors that could impact recovery goal setting within the organisation.

5.3.2. Sustainable Construction Schemes

The questionnaire asked about the proportion of certified construction projects within Italian designer companies under sustainable green schemes like BREEAM, LEED, etc., either at the time of the survey or in progress for future projects. The correlation analysis in Table 8 unveiled a statistically significant relationship between the organisation size and role categories with the application of sustainable construction schemes. However, each relationship functions in the opposite direction. Specifically, there is a positive correlation between the percentage of construction projects certified under sustainable construction schemes and the number of employees in the organisation. The Pearson correlation coefficient was 0.308, with a p-value of 0.005. This correlation suggests that as the number of employees increases, the percentage of certified projects tends to rise as well. This implies that with an expanding workforce, there may be more resources and capacity available to pursue certifications under sustainable construction schemes. Typically, when a company experiences greater capacity in terms of size and finances, it is more inclined to set higher recovery goals for the year ahead. In Italy, LEED and BREEAM certifications are widely used for office and commercial buildings, while CasaClima and SBTool protocols are common in residential developments. For social housing projects, ITACA is the main standard. Although energy certificates are mandatory for property sales, these certification standards remain voluntary [53]. Therefore, there is value in considering additional mandatory requirements or incentivisation measures concerning key CE aspects such as recyclables, CDW management plans, material durability, sourcing, and raw materials composition.

Table 8. Correlation between organisation size and role category with sustainable construction scheme implementation percentage.

	What Is the Percentage of Certified Projects in Your Organisation under Any Sustainable Schemes (e.g., LEED, BREEAM)?		**Decision**
	Statistic Test		
Number of employees in your organisation?	Pearson Correlation Sig. (2-tailed) N	0.308 0.005 77	Correlation is significant at the 0.01 level (2-tailed)
What is your position in your organisation?	Pearson Correlation Sig. (2-tailed) N	−0.250 0.024 77	Correlation is not significant

Conversely, there is a negative correlation between the employees' job roles within designers' companies and the percentage of construction projects certified under national or international sustainable construction schemes, with a correlation coefficient of −0.250 and a p-value of 0.024. These findings suggest that as the organisational role category changes (presumably indicating higher-level positions or managerial roles), the percentage of construction projects certified under sustainable construction schemes tends to decrease. This implies that individuals in higher-level roles may prioritise different aspects of construction projects and encounter constraints that make pursuing sustainable certifications less feasible, or they experience a lack of clients' interest. Conversely, those in lower-level roles may be more inclined to pursue sustainable certifications, typically with fewer concerns or responsibilities related to managerial or administrative commitments, if such schemes are to be applied. While it is vital to acknowledge that correlation may not imply causation, other factors may influence both the organisational hierarchy and sustainable construction practices. Still, the observed correlation offers valuable insight into the relationship between the two variables.

5.3.3. Level of BIM Implementation

The questionnaire asked about the adoption of BIM by Italian designer companies. A correlation analysis was conducted to examine the relationship between the size of the organisation and the role category with the adoption of BIM practices, according to ISO 19650 [54]. In Table 9, the correlation analysis revealed a statistically significant positive correlation between the number of employees and the level of BIM adoption. The Pearson correlation coefficient was found to be 0.270 with a *p*-value of 0.015, which suggests that the level of BIM adopted tends to advance as the number of employees in the organisation increases. Companies with higher turnovers may have more resources and capabilities to invest in BIM technology and processes, leading to advancements in BIM implementation. The National BIM Survey Report 2020 highlighted distinctions between larger and smaller organisations, revealing higher BIM adoption rates among the former. According to the report, 80% of organisations with more than 50 employees have adopted BIM, in contrast to 62% of those with 15 employees or fewer [55]. While correlation between these variables may not signify causation, various factors could impact the stage of BIM adoption. Nevertheless, the report offers valuable insights into their interdependencies.

Table 9. Correlation between organisation size and role category with level of BIM adoption.

	What Stage of BIM Maturity Does Your Organisation Implement? (According to ISO 19650 Categorisation)		Decision
	Statistic Test		
Number of employees in your organisation?	Pearson Correlation Sig. (2-tailed) N	0.270 0.015 77	Correlation is significant at the 0.05 level (2-tailed)
What is your position in your organisation?	Pearson Correlation Sig. (2-tailed) N	−0.075 0.505 77	Correlation is not significant at the 0.05 level (2-tailed)

However, the analysis did not reveal a statistically significant relationship between the stage of BIM development used in the company and the job roles of respondents. The Pearson correlation coefficient was −0.075 for both variables, with a *p*-value of 0.505. Nonetheless, it is important to consider that other factors or variables not included in this study may influence the adoption of BIM development stages within the organisation. Therefore, further research or investigation may be warranted.

6. Conclusions

The aim of this study was to identify and assess design practices influencing the adoption of CE principles within the Italian AEC sector. The research employed a two-fold quantitative approach. First, a comprehensive literature review was conducted to evaluate the role of designers in CE implementation, gain insights into circularity assessment criteria for designers, and identify prevailing design practices reflecting these criteria. Following this, a questionnaire was distributed to 77 Italian designers to explore the core strategies driving the development of comprehensive circular approaches. Initial findings revealed that most participants work in micro-businesses (50%), with renovation and refurbishment being the most common construction activities (47%). Notably, a significant portion of participants (36%) hold high-level decision-making positions, including directors and managers.

Statistical analysis of the survey results identified GPP, the use of non-hazardous materials, awareness about hazardous materials content, and the use of material passports as the most adopted practices in the political, economic, social, and technological categories, respectively. This indicates a strong emphasis on these methods being used in the Italian AEC sector. Notably, the use of regulations and policies have been successful in driving the implementation of these methods; for example, the EU REACH regulation has undoubtedly ensured limited use of non-hazardous materials (Table 4), which has perpetuated increased priority for design companies to seek information on any hazardous content in construction materials (Table 5). The use of material passports (Table 6), whilst still an emerging technique, has been increasingly adopted despite any mandatory legislation, which somewhat demonstrates widespread industry recognition of the value of such a tool. Conversely, CE certification implementation, designing for disassembly, knowledge about embodied carbon, and AI use were the least adopted practices in each category, suggesting these areas are not as predominantly employed or prioritised amongst the participants. For designing for disassembly, this is not surprising given that offsite has yet to reach its full capacity due to lack of construction investment and drive, nor is there a lack of regulation requiring such practices, with the exception of the design of developments to cater for 500+ employees. In addition, the low adoption of AI is somewhat surprising (Table 5) given its rapid emergence as a revolutionary tool that is quickly penetrating all parts of society, with a remarkable acceleration in the last two years.

To evaluate statistically significant differences among key variables, correlation analysis using Pearson correlation coefficients was conducted. Participants' information, including organisation size and their roles, was analysed to identify correlations with survey questions regarding waste recovery targets, sustainable construction schemes, and the level of BIM adoption. A positive correlation was found between organisation size and the three aforementioned subjects, highlighting the significance of support to enhance the capability of smaller-sized design companies in advancing CE. In particular, as expected, it was noted that the greater the number of employees, the greater the potential to pursue and reap more ambitious recovery targets; equally, smaller workforces will naturally adopt more conservative goals given their limited resources and limited projects. Regarding participants' roles, only one negative correlation was identified between the role category and sustainable construction schemes, indicating a higher level of interest among lower management compared to higher management positions.

A limitation of this study was the difficulty in gaining a reflective sample of participants to best reflect the Italian AEC sector. Notably, Figure 2 shows that 50% of the participants worked in micro-businesses, whereas in 2021, 95% of such enterprises employing zero to nine employees was a staggering 95%. Indeed, access to the contact details of micro-organisations is difficult due to the lack of access to national stakeholders' databases, which often do not exist. While the use of hubs and institutions for questionnaire distribution helped in targeting the population, it remains challenging to ensure national representation. Equally, it must be recognised that gaining a large micro-participant sample may heavily bias the results, as usually, such organisations' remit of operation in CE is often narrow in focus compared to larger organisations with national reach. Future research could extend to conducting surveys that involve a larger number of participants by examining further practices impacting the adoption of CE principles among design companies and conducting additional statistical tests to identify correlations with other survey variables.

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