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Review

Examining the Challenges for Circular Economy Implementation in Construction and Demolition Waste Management: A Comprehensive Review Using Systematic Methods

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Abstract: The construction industry accounts for approximately one-third of the total waste generation globally. With the United Nations projecting a population increase of 2 billion within the next three decades, there is a heightened demand for building stock, generating unprecedented volumes of construction and demolition waste (CDW). To combat this, circular economy strategies are purported to help alleviate the prevailing situation. But a number of challenges are jeopardizing their implementation in the construction industry and preventing from achieving the UN Sustainable Development Goals, net zero carbon and zero avoidable waste targets. This paper systematically analyzes 54 research articles, published in the past decade within major peer-reviewed English-language scholarly publications in the form of a systematic research review. In doing so, it aims to identify and classify the challenges that prevent improved CDW management by assimilating previous research results in support of a circular economy. The classification and analysis using a PESTLE model offers insights into gaps and differences between categories, as well as regions and countries. This initial step could contribute to a better understanding of these barriers, along with associated solutions, which could result in a significant reduction on the impact of construction activities, therefore facilitating the development of an effective circular economy in the sector.

Keywords: construction waste (CW); construction and demolition waste (CDW); challenge; construction industry; circular economy; sustainability

1. Introduction

The enormous generation of construction and demolition waste (CDW) presents a colossal challenge to the sustainability of the construction industry, the country's economy at large, and environmental sustainability worldwide. CDW arises from a range of activities in building and infrastructure developments in their whole life cycle, encompassing: new construction, where excess materials may go unused due to overordering, workmanship errors, or material damage in storage or transit; renovation, which involves the removal of existing building materials; demolition, the complete or partial dismantling of buildings and infrastructure; land clearance, covering site preparation activities like excavation, grading, and site preparation; and packaging, whereby construction products and components are frequently packaged in containers, crates, or pallets, along with associated packaging materials like foam, cardboard, and

plastic. In the UK, the proportion of CDW was a staggering 67% of the overall waste in 2023, of which 32% was sent to landfill [1]; across the EU, 37.5% of the total generated CDW was sent to landfill in 2020 [2]; in China alone, this was 30-billion tons, according to statistics in 2020 [3], and in the USA, the volume was over 600-million tons in 2018 [4].

The growth of CDW presents a significant challenge to the sustainability of the construction industry. At the project level, CDW impacts the profitability and productivity of the project considerably. From a national perspective, CDW has the potential to cause environmental problems nationally and even globally, in addition to the financial burden imposed on governments resulting from the need to address CDW and its associated problems.

Setting aside the diminishing landfill and financial losses associated with CDW, the environmental impacts are monumental. CDW not only contributes heavily to land use due to large volumes of waste, but it can also contaminate both soil and groundwater: runoff impacts water pollution (particularly leachate, a liquid containing pollutants such as heavy metals, organic compounds, and hazardous substances), and even air pollution in terms of VOCs (volatile organic compounds); local ecosystems and habitats are disrupted affecting biodiversity, leading to changes in the behaviour and distribution of wildlife that can adversely impact natural ecological balances of fauna, all of which can lead to a diverse range of human health concerns [5].

As an economic model and approach to resource management, the circular economy concept is designed to minimize waste, promote sustainability, and maximize the use of resources. Products, materials, and resources are reused, refurbished, remanufactured, and recycled to extend their lifespan [6]. By transitioning to a circular economy, societies aim to create a more sustainable and regenerative economic system that benefits both the environment and the economy.

To address this growing concern in the construction industry and adhere to the paradigms of circular economy, various solutions have been developed to address waste minimization that span all stages of the project's whole life cycle. For instance, on-site waste collection, reusing, and recycling are commonly practiced in many developed countries [7,8]; low-waste technologies (LWT) have been introduced to optimize resource consumption [9,10]; the use of legislation (such as landfill disposal charges, illegal dumping penalties, etc.) has been deployed in varying degrees; and waste management strategies and associated reward schemes have been implemented. But despite the various CDW management approaches, the aforementioned statistics of CDW disposal show that the industry is far from reaching a closed-loop circular economy. The analysis of existing barriers is, therefore, paramount if we want to overcome these challenges and achieve zero waste targets in the sector.

Numerous publications identifying barriers have been made around the world, showing very common patterns and challenges but, at the same time, evidencing important differences in the appreciation of barriers for the circular economy in the construction industry. These differences depend on a number of factors and variables that are changing subject to the case study analyzed and geographic location. Analysis made in the different research developed can, therefore, only be considered from a local perspective. As challenges are not the same for every country, neither are the solutions. This systematic review paper aims to delineate the barriers that prevent the implementation of a circular economy in the construction industry and identify research trends and gaps for future development, also in different parts of the world. Understanding these challenges can help to determine appropriate solutions for the implementation of circular economy in the construction project's life cycle and, specifically, in CDW management. This review analysis categorizes these challenges according to the PESTLE model (political, economic, social, technological, legal, and environmental), analyzing them more in depth to understand current trends and ultimate consequences on different factors such as country development, traditional methods of construction, culture, access to technology, etc., so that adequate solutions can be initially

drawn. As a starting point, this review paper can help define strategies at the regional or country level for circular economy implementation in the construction industry.

2. Methodology

A systematic literature review method is considered an objective and replicable methodological tool for examining existing studies on a subject to identify areas that require further research [11]. It is a rigorous and well-defined process used in academic, scientific, and professional settings to provide a thorough overview of the existing literature and to draw meaningful conclusions based on the available evidence. It requires equivalent standards of rigour as primary research by using explicit and transparent methods for research. The PRISMA 2020 statement [12] was followed in this study with this purpose. A simplified diagram of steps followed by this method is shown in Figure 1.
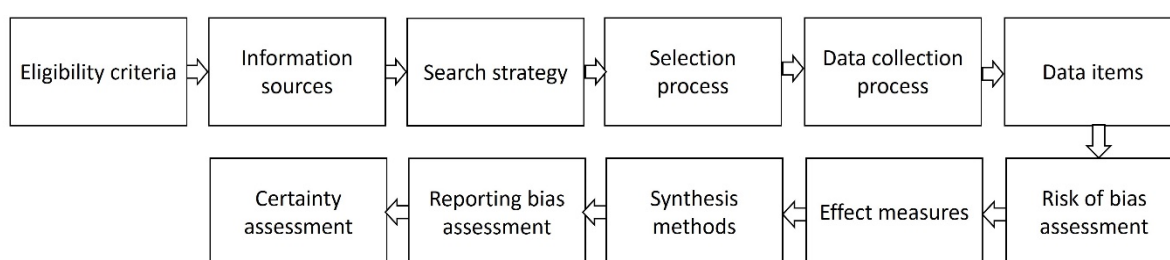

Figure 1. Methodological steps followed for a systematic review according to PRISMA 2020 checklist [12].

Focusing on the aim of this research, the studies included should focus on primary research developed about the identification and analysis of circular economy implementation barriers in the sector and in different parts of the world. The findings of the present study will be obtained through the synthesis and iterative analysis of the selected studies to develop overarching theories and strategies.

A transparent and objective research-synthesis approach was employed to minimize bias, which encompassed both quantitative and qualitative studies. Two prominent citation-index databases were utilized as the information sources, namely ScienceDirect and Scopus. According to the eligible criteria previously agreed to by the authors, searches were conducted using the terms "construction waste management" and "construction demolition waste management" (CDW), combined with "challenges", "barriers", "constraints", "limitations", and "problems", specifically targeting papers where these terms appeared in the title, abstract, and/or keywords. There was no geographical restriction on the studies, but the selection was limited to articles written in the English language. This generated a total of 710 papers up to January 2023.

To refine the scope and concentrate closely on the barriers related to CDW, the search criteria were revised to include papers with keywords published within the past decade from January 2013 to December 2022. As a result, the number of papers was reduced to 174. Subsequently, the titles and abstracts were screened manually to exclude review papers, ensuring alignment with the specified timeframe and geographic relevance for our meta-data analysis. This process yielded 54 papers that were considered suitable for inclusion in this systematic review. The methodological framework is detailed in Figure 2. It shows the study selection process to ensure reproducibility and transparency of this study.

The review of papers was completed by the three authors in different steps: independent searches in databases and with different keywords, as indicated before; discussion of inclusion and exclusion criteria; selection of included papers; and a check of study comparability by reviewing a random sample of the included and excluded papers.

Finally, the full text of the remaining studies was assessed against the inclusion criteria, and any differences were discussed and a consensus was reached.
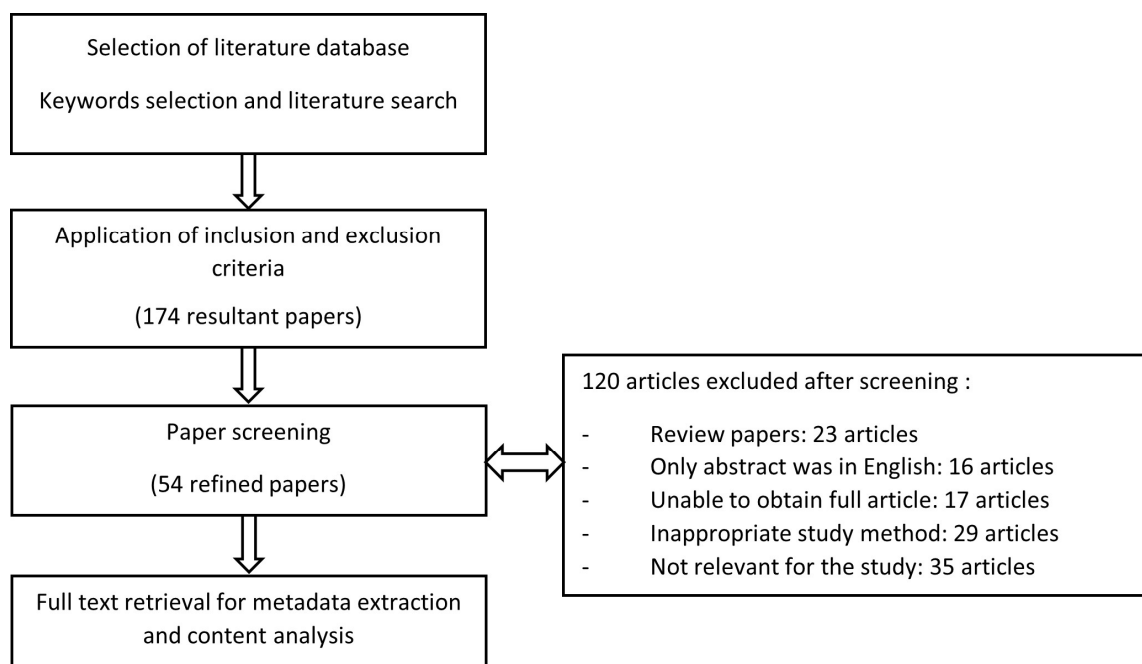

Figure 2. Methodological framework of the study, assembling PRISMA 2020 flow diagram for systematic reviews.

The data collection process from the selected papers included the creation of lists of challenges for comparison between the different studies, identifying similarities and differences and compiling this information in a spreadsheet with links to original studies and references. The synthesis process allowed for the grouping of this information and identification of 59 challenges, which were displayed in a list for later classification and analysis. This analysis comprised three different stages: analysis of publications per year and continent; classification and analysis of challenges according to the PESTLE model; and analysis of challenges per continent and specific countries.

To avoid any bias, this process was followed by the three authors independently and later discussed and agreed so that a consensus of results could be achieved, as well as to get a good level of confidence in the analysis made. Additionally, different checks and reviews were conducted by the authors to avoid any misleading action or decision during the process of this systematic review.

3. Findings

The regression analysis in **Error! Reference source not found.** shows a low-to-moderate positive correlation with an increasing trend in the number of publications available on this topic over the review period 2013–2022. Although the significance is low, the dependence between the number of published papers and time (in years) illustrates a growing research interest in the application of circular economy to construction. It is observed that the period 2020–2022 achieves the highest scores in the number of published papers. There is a substantial increase during 2021, which comprises 26% of total reviewed articles. As well, another peak is identified in 2016. A potential impact could be due to new waste targets set in previous years for carbon and waste reduction, such as the Paris Agreement in 2015 [13] and the European Waste Framework Directive targets for CDW in 2020, together with this Framework amendment in 2018 [14]. Notwithstanding, other factors, like COVID-19 pandemic confinement, could have impacted the increase in the production and publication of research papers during that specific period as well.
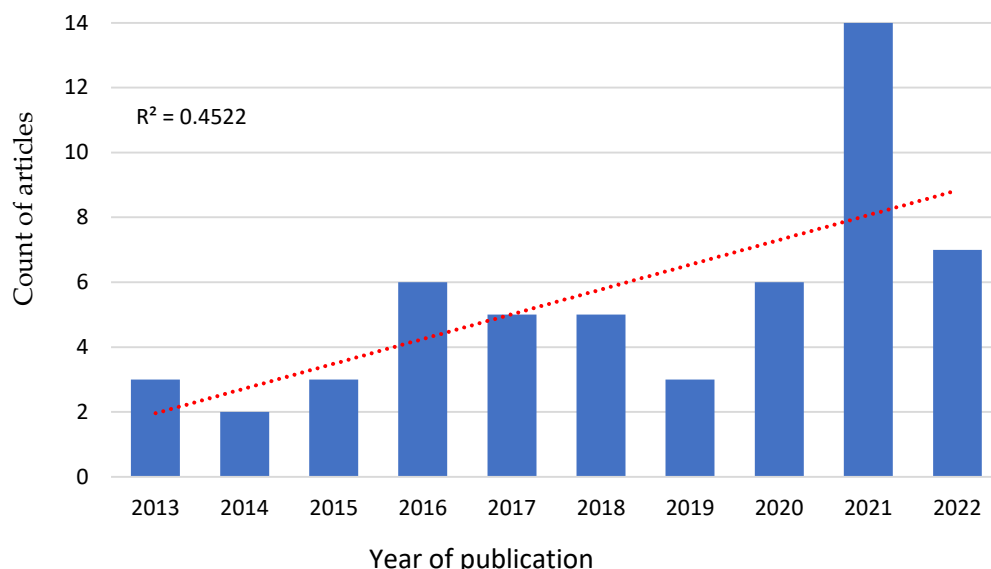
Figure 3. Distribution of reviewed articles per year of publication, from 2013 to 2022.

Nevertheless, this does not necessarily mean an overall growing concern and implementation in the construction industry globally in improved CDW management. Figure 4 shows the distribution of reviewed articles per continent. It is notably shown that Europe (44%) and Asia (36%) are the origin continents of the vast majority of the reviewed publications. In the case of Europe, significant developments have happened during this period in the regulatory framework and targets, such as the minimum 70% CDW recovery target by 2020, the updating of the Waste Framework Directive [14], and other recent regulations and standards on waste implemented in the past few years. This is to highlight the new European Circular Economy Action Plan in 2020 [15] and other zero waste strategies and targets arising in different countries (e.g., Netherlands 2016 [16]; UK 2020 [17]). The UK has the biggest number of articles reviewed in this group (8).
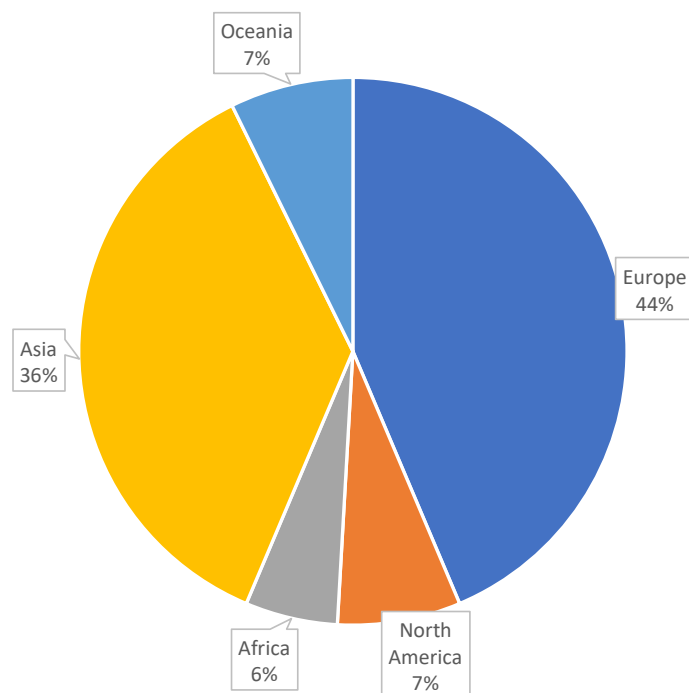

Figure 4. Distribution of reviewed articles per continent.

Regarding Asia, China is the country with the biggest number of reviewed articles in this paper (10), reaching 50% of the total number in Asia. Specifically, China's latest 14th Five-Year Plan (2021–2025) for its construction industry aims to drive a greener, smarter, and safer approach. Hence, this could account for the growing number of research in this area. The plan mandates that the construction industry in the country needs to greatly modernize its industrial chain; form the preliminary stages of green and low-carbon production modes; see more widespread application of information technologies; and steadily improve its quality of buildings. Notably, it sets targets of at least 30% of new buildings that should be constructed using off-site construction techniques by 2025, and this needs to reach 100% by 2035. The plan also intends to reduce new construction waste generation to 300 tons per 10,000 built m² [18]. On the other hand, no paper was classified in this study from relevant countries like India and Japan. Despite that, these countries have an important impact in the Asian economy and very different realities. Therefore, it would be worth considering them for further research in other later studies.

Surprisingly, North America does not show big research contributions to this field despite initiatives such as the "sustainable management of construction and demolition materials" by the United States' Environmental Protection Agency [19]. In contrast, Oceania contributes a substantial number of publications considering the size of the continent. On the other hand, Africa (6%) and South America (0%) have the lowest number of reviewed articles. Further research should be considered to be conducted for these underrepresented continents and countries.

3.1. PESTLE Analysis Classification

A total of 339 references to challenges were identified in the 54 papers reviewed. They were grouped in 59 challenges and classified using the PESTLE framework (Political, Economic, Social, Technological, Legal and Environmental) as a means to structure the discussion. To note, political and legal challenges were combined together for clarity and ease of analysis (see Table 1). The challenges were ranked based on the number of articles where they were identified, both within each PESTLE category and overall, and a frequency was calculated.

Table 1. Classification of challenges according to PESTLE analysis.

Political/Legal					
Code	Challenge	Articles	Frequency	Category Ranking	Overall Ranking
PL1	Regulation is non-existent/insufficient/inadequate/ambiguous	[7,20–36]	18	1	1
PL2	Inappropriate planning/strategies for CE	[7,21,25,29,30,33,34,37–39]	10	2	9
PL3	Lack of institutional support, coordination, and collaboration	[21,28,35,40,41]	5	3	26
PL4	Reused materials need to meet performance requirements	[41–45]	5	3	26
PL5	Administrative procedures are long and slow	[46,47]	2	5	41
PL6	Landfills are unregulated/not sustainably managed	[21,28]	2	5	42
PL7	Complicated contracting system and responsibilities	[25,48]	2	5	42
PL8	Longevity of property service life and multiple ownership	[49]	1	8	54
PL9	Illegal activities and lack of enforcement	[41]	1	8	54
	Total		47		
Economic					
Code	Challenge	Articles	Frequency	Category Ranking	Overall Ranking
EC1	Extra/high costs of waste management	[22,23,25–30,38,41,45–47,50–52]	16	1	2
EC2	Difficulties to make a business case with waste	[20,27,31–33,35,37,43,48,50,51,53,54]	13	2	4
EC3	Time constraints, extra time, and delays due to CDWM	[22,26,27,29,30,41,43–45,51,52,54,55]	13	2	4
EC4	Inadequate/lack of incentives	[21,26,28,29,31,32,34,42,54,56,57]	11	4	7
EC5	Lack of markets for reused/recycled products	[7,25,32,33,41,43,50,57,58]	10	5	9
EC6	Low cost of landfilling/low penalties	[7,23,29,30,41,42,47,54,57]	9	5	13

EC7	Very low/lack of investment for recycling	[25,29,31,35,50]	6	7	21
EC8	Low cost of raw materials/high cost of recycled materials	[20,23,30,31,41]	5	8	26
EC9	Budget constraints	[29,47,50,54]	5	8	26
EC10	Low value of reused/recycled materials	[32,41]	2	10	42
EC11	Building lifespan not the same as the developer's business plan	[27]	1	11	54
	Total		88		

Social					
Code	**Challenge**	**Articles**	**Frequency**	**Category Ranking**	**Overall Ranking**
SO1	Limited/lack of awareness and education within industry	[21,23,25–27,29,32,42,46,47,54,56,59]	13	1	4
SO2	Limited/lack of training and knowledge	[7,25–27,29,32,47,48,54,56,59]	11	2	7
SO3	Limited public awareness and attitudes	[24,25,29,32,34,41,54,57,60,61]	10	3	9
SO4	Conservatism/change resistance from traditional practice	[25,27,29,37,40,48,54,60,61]	9	4	13
SO5	Lack of interest from clients	[23,32,47,50,51,54,62]	8	5	17
SO6	Non-collaboration between stakeholders	[21,26,39,60,61,63]	6	6	21
SO7	Low acceptability of secondary materials	[20,38,41,42,51]	5	7	26
SO8	Insufficient attention to CDWM/other priorities	[35,47,49,52,59]	5	7	26
SO9	Poor/lack of supervision/management of waste	[22,47,54,59,64]	5	7	26
SO10	Lack of consideration during design	[25,26,28,62]	4	10	34
SO11	Blame culture. Shifting waste prevention responsibilities	[60,61]	2	11	42
SO12	Temporary relationship among parties	[60,61]	2	11	42
SO13	Personnel recruitment and retention	[22,43]	2	11	42
SO14	Excess of material wastage	[22,59]	2	11	42
SO15	Health and safety issues	[54,56]	2	11	42
SO16	Theft and damage	[43,59]	2	11	42
	Total		87		

Technological					
Code	**Challenge**	**Articles**	**Frequency**	**Category Ranking**	**Overall Ranking**
TE1	Lack of strong CDWM practice	[7,20,22,23,25,36,43,44,47,51,59,64,65]	14	1	3
TE2	Difficulties with waste segregation on site	[25,39,41–43,47,52,55,58,59]	10	2	9
TE3	Limited/no access to waste recovery facilities	[7,21,25,31,39,41,43,51,59]	9	3	13
TE4	Lack of uniformity/ inconsistent quality of CDW	[28,30,31,37,51,52,57,58,66]	9	3	13
TE5	Complexity of building design	[26,32,37,42,43,51,52,54,59]	8	3	17
TE6	Current waste prediction and analysis models are limited	[22,28,52,66–70]	8	5	17
TE7	CDW data management not properly developed	[35,36,44,51,52,65,69,71]	8	7	17
TE8	Material and waste traceability is not correctly performed	[21,28,37,47,57,65]	6	8	21
TE9	Design errors and changes	[25,43,59–61,63]	6	8	21
TE10	Limited/lack of investigation and demonstration cases	[24,26,27,42,53,66]	6	8	21
TE11	Limited site space	[25,46,52,56,59]	5	11	26
TE12	Incomplete designs	[43,54,60,61]	4	12	34
TE13	BIM/digital technologies do not currently support CDWM	[33,52,67,72]	4	12	34
TE14	Inappropriate specification and standardization	[43,49,59]	3	14	37
TE15	Technical challenges with waste transport, treatment, and recovery	[22,43,55]	3	14	37
TE16	Uncertain material availability and security of supply	[30,37,41]	3	14	37
TE17	Fragmented supply chains	[32,49]	2	17	42
TE18	Packaging waste increase	[43,59]	2	17	42
TE19	Lack of space for recyclables storage/recycling operations	[41,43]	2	17	42
TE20	Lack of technical support from suppliers	[54]	1	20	54
	Total		112		

Environmental					
Code	**Challenge**	**Articles**	**Frequency**	**Category Ranking**	**Overall Ranking**
EN1	Contamination issues and safety	[40,41,43]	3	1	37
EN2	Energy consumption for recycling treatments	[52]	1	2	54
EN3	End-of-pipe treatment rather than waste preventive measures	[52]	1	2	54
	Total		5		

The partial summation of frequencies per category indicates that technological challenges are the most frequently mentioned ones, comprising almost one-third (32.94%) of all references, while environmental challenges represent only 1.47%. This suggests a significant focus on technological aspects, but a very reduced consideration of environment aspects despite the main goal of the circular economy being environmental impact reduction. This could be due to a focus within the construction sector on the business impact of the circular economy rather than its environmental aspects. There may also be a bias in the research conducted by the scientific authors considering this interest from industry. The barriers in each category will be discussed in the following sections.

The overall ranking shows that the lack of regulation (or poor regulation development and implementation) (PL1) is the most significant challenge identified with 33.3% of reviewed papers, indicating this as a key barrier. The high costs of CDW management (EC1), which are often seen as additional costs to the project, is the second-most critical barrier with 29.6% of the papers. This increased cost is closely aligned to the third-ranked barrier: lack of strong CDW management practices (TE1). In Position 4, three other challenges can be identified: difficulties to make a business case with waste (EC2); time constraints due to CDW management (EC3); and limited/lack of awareness and education of CDW within the industry (SO1). In general, it is observed that economic challenges are better positioned in this ranking, with five challenges included in the top 10.

3.1.1. Political and Legal Challenges

An initial consideration for this category is that these challenges refer to the government regulations and administration involvement, i.e., a higher level or top-down approach. Political action has a big impact in the development of a framework for waste generation and management, setting targets and implementation of policies at macro-level. These solutions can have a big impact in industry, positive or negative, depending on the capacity of industry (the receiver and implementer of such solutions) to assume it and the resources provided from the government/administration for that purpose.

The most frequent challenge in this group, and in the whole analysis, was interrelated and centered around a lack of—or inappropriate—regulations for effective CDW management (PL1). The arguments around this challenge are at different levels of the administration involvement, highlighting the following: the lack of policy implication [21], more specifically about CDW management [24,25,29]; green public procurement [30]; waste sorting on site [28]; use of wastes in new materials [22,23]; and design out waste [7].

PL2 gathers issues about the implementation of strategies for CDW management. In many cases, they refer to immature policies for CDW management [21] with a diverse range of reasons, such as: lack of circularity framework for assessment (indicators) [30]; organizational aspects at a city/regional level [37]; inappropriate urban planning [7]; lack of framework or guidance for improvement [29,33,34]; and lack of promotion from the administration [21,25]. Linked to that, it is the lack of institutional support and collaboration, which is identified as Challenge PL3. Coordination between administrations and departments is missing in some cases [28,35], as well as among stakeholders (academic, governmental, and private sector) [21]. Administration is, therefore, identified as a catalyst for the implementation of circular economy policies, but it is not working.

There is an important reference to how regulations affect materials reuse (PL4), identifying the lack of specific standards for the reuse of materials. As a result, they must compete in the market with primary materials, which normally comply with known characteristics and quality standards. In the case of reused materials, these characteristics are uncertain, therefore making them unregulated and hindering access to markets [43], which prevents from any potential higher value use and relegates them to downgrading or landfill [32,41,42].

3.1.2. Economic Challenges

Economic challenges are related to business profitability, showing the difficulties in adapting CDW management to the traditional way of construction and the application of cost-effective solutions. It is evident that current construction methods and management theories are not bringing the expected monetary outputs due to a lack of accuracy and the increasing associated risks, the lack of effective resource management, and the inefficient, uncertain supply chain. These models do not work anymore and there is the need to transform the construction industry economy towards new circular business models, considering reuse, recycling, and remanufacturing as the core of the system.

It can be observed that the most repeated challenge in this group is regarding the high cost of CDW management (EC1). In general, it is perceived that CDW management increases costs and reduces production [23,47]. Specific operations are required for CDW management such as monitoring and supervision [46], waste segregation [50,52], transport [25,41], processing/treatment [45,50], and dumping [25]. Therefore, labour costs are increased [41,52], as well as the costs for the equipment and facilities needed [28,38] and dumping taxes/fees [25,41]. These are identified as upfront costs, posing a challenge for contractors [26,27,29,51]. Additionally, CDW management is seen as interfering with other site operations and introducing higher levels of risk and potential failure [52]. The process also extends construction time frames, identified as Challenge EC3, causing delays in projects [22,29,43,45]. In some cases, landfill taxes are considered as low (as well as penalties) (EC6). Consequently, landfilling results more cost-effective than recycling [30], and CDW is not considered as a potential resource anymore [42].

There are serious difficulties to make a business case around waste recovery (Challenge EC2). The main drawback considered is there are high investment requirements and uncertainty about profits [33]. Contractors, influenced by financial benefits [20,27,37,50,51], find the long payback periods and reduced profits unattractive for investment (Challenge EC7) [29,31]. On the other hand, small- and medium-sized enterprises (SMEs) struggle with high levels of investment [48], the lack of regulations for reused and recycled materials (as mentioned before), and the limited demand of these products [41,50,57,58].

The lack of markets for recovery is identified as another relevant challenge (EC5) and, linked to that, the easy access to low-cost raw materials (Challenge EC8). European countries show higher concerns than any other continent (80% of articles reviewed). In addition, scaling up innovative solutions in the construction industry is identified as difficult [35,43].

The lack of financial incentives from the government (challenge EC4) hampers CDW cost-reduction efforts [29,54], recycling rates are even slower [31], and it leads to increased precarity in recovery initiatives, pushing them to the marginality of a very reduced number of case studies [42]. Adams et al. [32] remarks about the need for incentives for the consideration of end of life at the design stage. The high cost of land use is another adverse factor that prevents larger improvements in CDW treatment facilities [28].

One highlight to make is that the built asset is often considered as an artificial investment rather than a resource, leading to buildings being renovated or demolished without completing their service life [37].

3.1.3. Social Challenges

Social challenges encompass cultural aspects, behaviours, and attitudes from industry and society in general. Probably, one of the main barriers is the lack of awareness and skills in the construction industry. Added to that, it is recognized as a traditional sector, which is clearly reluctant to change. Other aspects identified associated with social challenges are, for example, a lack of collaboration between stakeholders, non-reliance on secondary products, and poor management practice with CDW.

Limited awareness and education are considered the major challenges in the sector (SO1). Adams et al. [32] points out designers, clients, and subcontractors as the stakeholders with lower circular economy awareness. Linked to that, limited public

awareness and attitudes challenge (SO3) determine cultural aspects towards waste, such as the perception of waste as inevitable [25,32,54,57,60,61] and the lack of adequate education on waste recovery [34]. The low acceptability of secondary materials, associated with Challenge SO7, is influenced by the perceived low quality of recycled products [20,38,51] and the preference for virgin materials to secondary ones [24,41,50]. Oke et al. [29] specify the need to change citizen behaviours and consumption patterns.

A lack of training is identified as Challenge SO2. The lack of workforce skills [23,42,59] and limited knowledge about reuse and recycling options among technicians [47] are some of the factors involved. Difficulties for recruitment and retention (Challenge SO13), especially for micro and small companies [48], impact capabilities of performance in the field [22,43]. Some indirect consequences are wastage excess [22,59] and health and safety issues [54,56], identified as Challenges SO14 and SO15, respectively.

Conservatism and change resistance are recognized as significant challenges in the construction industry (SO4). Galvez–Martos et al. [40] indicate that CDW management can be improved with existing technology, but the industry is reluctant to change. Tirado et al. [37] perceive the construction industry as inflexible and not adaptable to changes. On the other hand, temporary relationships in the construction industry (Challenge SO12) pose difficulties for collaboration and innovation in future projects [60,61]. In other cases, it is again linked to high risk and low-profit margins, which prevent further investment [27].

Challenge SO6 is regarded as non-collaboration between stakeholders. Competitivity hinders information sharing [21] and forces the adoption of individual solutions, which do not solve the big problems. Challenge SO5 identifies a lack of interest, particularly from clients [51,62], which can impact dramatically circular considerations of the project. In some cases, CDW management is not considered as a priority (SO8). On the other hand, the role of designers is often overlooked regarding CDW management (SO10) [25,26,28,62]. There is the need for an effective and comprehensive collaboration between policymakers, government ministers, and companies [39].

Finally, poor supervision and control of CDW management is another relevant challenge (SO9). Lack of expertise [22], supervision breaches [64], or unprofessional behaviour [59] are some of the reasons identified. Gangolells et al. [47] recognize shortfalls in the management activity, which could include basic aspects such as not issuing waste management certificates, mixing segregated waste, or illegal dumping.

3.1.4. Technological Challenges

Technological challenges make reference to the availability of infrastructures, equipment, tools, and procedures for CDW management, as well as aspects regarding the implementation of advanced technology solutions in the design and standardization.

The largest identified technical challenge corresponds to the lack of application of strong CDW management practices (TE1). Shojael et al. [65] criticize the fact that current approaches address individual actions rather than continuous improvement in companies. Ayaji and Oyedele [20] indicate that the actions taken are mostly focused on intervention rather than waste prevention. Tafesse et al. [22] indicate the lack of waste measurement. Another handicap highlighted is the lack of site waste management plans [43,47,59,64].

Difficulties with waste sorting is the second relevant challenge identified (TE2). The majority of problems come from traditional construction methods, which hinder deconstruction and the proper segregation of materials [42], making waste processing on site challenging and costly [48] due to the large range of materials types and methods used [47], equipment and control required [41], and the impossibility of implementation to all waste streams as treatment is not always feasible [52], or it just being a very small fraction [58]. In some cases, waste sorting is just not practiced [25]. Packaging is identified as another specific technological challenge (TE18), demanding further sorting facilities and

space. As a result, space for waste treatment becomes an obstacle to proper waste sorting on site (challenge TE11).

The characteristics of waste and difficulties with segregation also bring another challenge: the lack of uniformity and quality (TE4). This raises concerns about quality assurance with reused/recycled materials [30,52,58]. There are also concerns about the uncertainty on material availability (TE16), not having a guaranteed supply, and the need to synchronize the offer and demand so that additional costs, such as storage, can be avoided [28,30,37,41,43].

Another important challenge is the limited access to waste treatment facilities (TE3), especially in remote places. That is the case, for example, in Australia, according to Crawford et al. [43], with a very low population density in rural areas. Blaisi [21] complains about improper infrastructure for the disposal of landfills and the absence of treatment facilities. The cost of land for treatment facilities grows due to the substantial number of environmental restrictions imposed and prevents any business development on recycling [41]. Other technical challenges are identified with transportation, processing, and recovery (TE15). For example, Crawford et al. [43] highlight added problems such as bad road conditions and very few transportation options for waste.

The complexity of building designs is another challenge identified (TE5), with multiple materials and combinations, some of which are difficult to segregate [32], making projects unique and impossible to share materials from other constructions [51]. Some authors describe designers as not considering other stages of the building life cycle [26,59]. Ajayi et al. [52] state that the design becomes unrealistic when designers develop complex and irregular shapes outside standardization. Design errors and changes is another source of waste generation (TE9). This can be as a consequence of incomplete design and poor contractor understanding [60,61], discrepancies between drawings (not applying BIM-based design validation) [63], design changes during the construction stage [43], and reworking due to wrong execution [59].

Limited existing models for waste prediction and analysis is Challenge TE6. Inaccurate waste quantities are estimated for construction projects, and they only rely on national statistics [28,67–69]. Even further, some authors complain that waste generation is not measured/recorded [22,70]. Linked to that challenge is TE7, which identifies that data management is not properly developed. There are extensive sources of data in CDW management that make it a complex task and are disregarded by industry [69]. This causes a lack of fundamental data, especially on waste generation and disposal [21,35,44]. Torgautov et al. [51] identify the lack of materials databases for design optimization. Shojaei et al. [65] state that current methods used for data capture and maintenance are not effective. In this regard, Ajayi et al. [52] complain about data having to be inputted manually. Also, Lu et al. [71] affirm to have issues with the application and acceptance of big data and data mining in construction [71]. As a result, material and waste traceability are not correctly performed (Challenge TE8). In fact, Shojaei et al. [65] state that the construction industry is far from achieving the required level needed for the implementation of circular economy principles. Regarding digital technologies, it is also identified that BIM/digital technologies do not support CDW management (Challenge TE13) due to the incompatibility of tools with BIM [67], and that life-cycle data are not yet integrated in the different BIM maturity levels [33,72], among other reasons.

3.1.5. Environmental Challenges

Finally, environmental challenges comprise a short number of them in the articles reviewed. Contamination and safety issues are identified as Challenge EN1. Aspects included are, for example, the risk of increasing the volume of hazardous waste with recycling [40], poor management of landfill sites [43], the need for storage and sheltering of recyclables [43], and the lack of suitable space for recycling [41]. Other challenges correspond to energy consumption for recycling treatments and the selection of end-of-pipe treatments rather than waste prevention measures [52], which are Challenges EN2 and EN3, respectively.

3.2. Analysis of Challenges per Continent and Specific Countries

Figure 5 illustrates the political and legal challenges per continent. European countries are mostly represented in PL1. Looking deeper into this group, a lack of regulation is more highly identified in Asian countries [21,22,24,25,34]. A lack of landfill regulation (PL6) is also identified in publications from Saudi Arabia and China [21,28]. On the other hand, European countries experience more the issues with insufficient regulations and guidelines, ambiguity, and incomplete application [23,30,32,33,38]. The waste regulatory framework in the EU seems not to be equally applied in all member countries and regions, which makes a despair achievement of results due to the technology used and barriers to overcome in each country/region [40]. A similar situation happens in PL2 (inappropriate planning/strategies for circular economy). Asian countries face immature strategic policies for basic CDW management, including aspects such as waste collection and sorting [7,21,25,29,34]. On the other hand, European countries challengesmake reference to the development of aspects such as closed-loop construction solutions, census and data management, secondary materials markets, or Green Public Procurement [30,33,37,39].

Added to the previous analysis, Asian countries are more related to PL3 (lack of institutional support) and PL6 (unregulated landfills). On the other hand, European countries are more related to PL5 (long and slow administrative procedures) and PL8 (longevity of property and multiple ownership). Oceania is very well represented in PL4 (reuse materials to meet performance requirements) and PL9 (illegal activities and lack of enforcement).
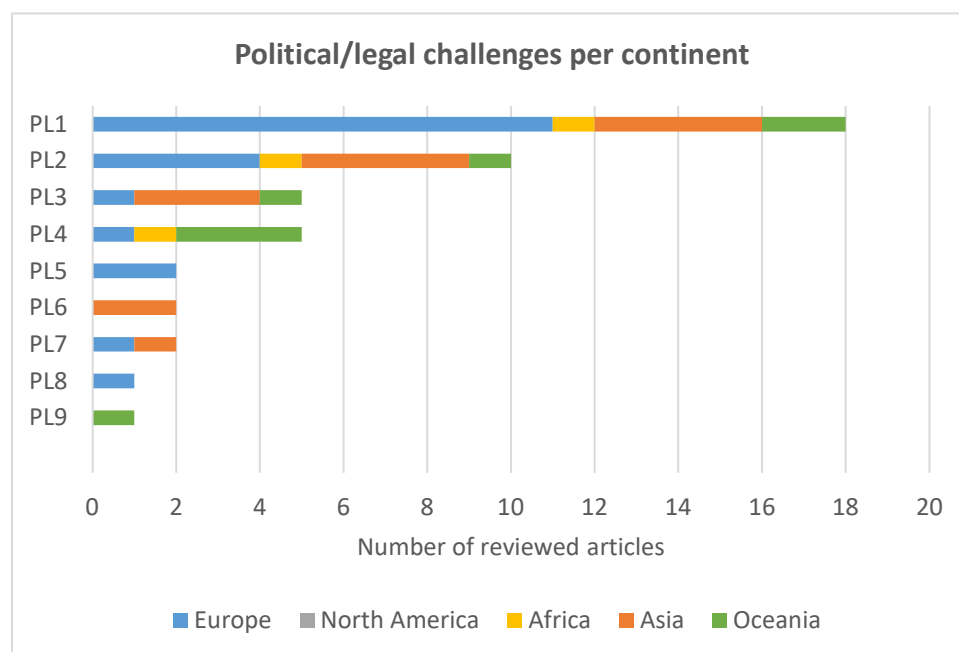

Figure 5. Political and legal-challenge representation per continent.

Figure 6 shows the distribution of frequencies of economic challenges per continent. In general, it can be observed that there is a predominant number of articles from European countries in most of the challenges identified, with the highest percentages in EC8 (low cost of raw materials/high cost of recycled materials), EC5 (lack of markets for reused/recycled products), and EC10 (low value of reused/recycled products). The competition between primary and secondary materials, with a focus on quality assurance and standardization, is evident. On the other hand, Asian countries are only predominant in challenge EC7 (lack of/very low investment in recycling). Relevant presence is also identified in Challenges EC1 to EC6, as well as EC9. Oceania has an important representation as well, showing a relevant presence in challenges from EC1 to EC6.
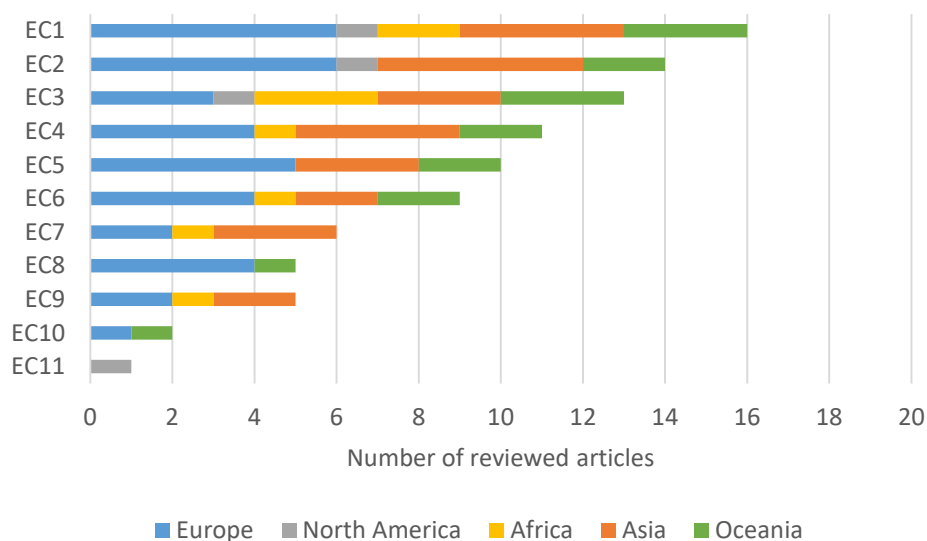
Figure 6. Economic challenges representation per continent.

Figure 7 shows the representation of social challenges per continent. It can be observed that there is a relevant weight of European and Asian countries, which comprise most of the articles identified. Equal representation is achieved in SO1 (limited awareness and education within industry), showing a common problem with both markets. On the other hand, Europe is predominant in SO4 (conservatism and change resistance), SO6 (non-collaboration between stakeholders), SO8 (insufficient attention to CDW management), SO11 (blame culture), and SO12 (temporary relationships). On the other hand, Asia is predominant in SO2 (lack of training and knowledge), SO3 (limited public awareness), SO5 (lack of interest from clients), SO7 (low acceptability of secondary materials), SO8 (insufficient attention to CDW), SO9 (poor supervision), and SO10 (lack of consideration during design). Asia does not have a high representation, or is not represented, in SO6, SO11, and SO12. Further analysis would be needed of the Asian market to understand the relationships between stakeholders and what considerations are taken about collaboration. It is to highlight a substantial presence of Oceania in SO1, SO2, and SO7.

According to Figure 8, there is a significant representation of European countries in the technological challenges identified. The largest number of articles from Europe are identified in challenges TE1 to TE9 and TE13. European countries are predominant in TE4 (lack of uniformity and inconsistent quality of CDW), TE5 (complexity of building design), TE7 (CDW data management not properly developed), TE8 (material waste traceability not correctly performed), TE9 (design errors and changes), TE12 (incomplete designs), TE13 (BIM/digital technologies do not currently support CDW management), TE16 (material availability and security of supply), and TE17 (fragmented supply chains). It is evident a higher concern about the use of digital technologies and data management to enhance CDW management, making reference to other stages of the project life cycle (like design and end of life) and CDW's low quality, hampering its competition with primary materials. Asian countries, on the other side, are predominant in TE2 (difficulties with waste segregation), TE3 (limited access to waste recovery facilities), TE10 (lack of investigation and case studies), TE15 (challenges with transportation, transformation, and recovery), TE18 (packaging), and TE20 (lack of information from vendors). Equal representation is in TE1 (lack of strong CDW management practices), TE6 (existing models for waste prediction are not accurate), TE11 (limited site space), and TE14 (inappropriate standardization). Oceania achieves a relevant frequency in TE5, whereas North America is well represented in TE7 and TE10.
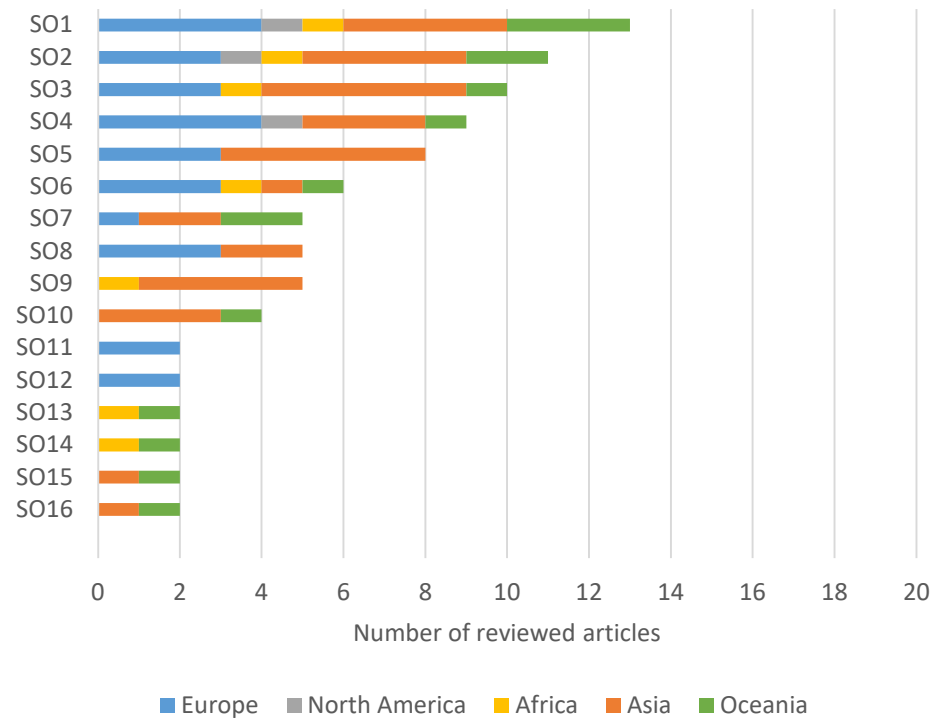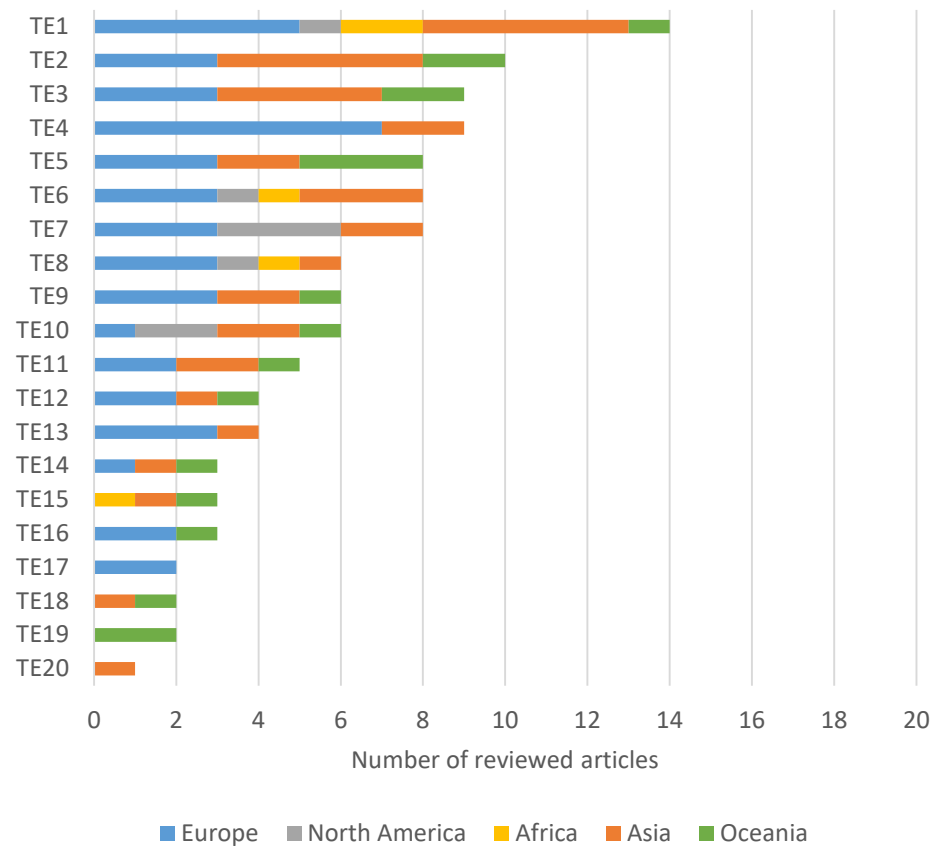
Figure 7. Social challenges representation per continent.

Figure 8. Technological challenges representation per continent.

4. Conclusions

The need for circular economy practices in construction activity is crucial for several reasons, encompassing political, environmental, social, economic, technological, and environmental challenges. This paper reviewed 54 research articles with the aim of identifying and classifying challenges for circular economy implementation in the sector, which is essential for finding solutions to overcome these barriers. A total of 59 challenges were identified and listed according to the number of papers that included them, the top ones of which are the following:

1. Regulation is non-existent/insufficient/inadequate/ambiguous (in 18 papers)
2. Extra/high costs of waste management (in 16 papers)
3. Lack of strong CDWM practice (in 14 papers)
4. Difficulties to make a business case with waste (in 13 papers)
4. Constraints, extra time and delays due to CDW management (in 13 papers)
4. Limited/lack of awareness and education within industry (in 13 papers)

The 59 challenges were classified according to the PESTLE analysis model, and a summary of the key findings is as follows:

Overall, the political and legal challenges span regulatory, implementation, collaboration, and material reuse aspects. They highlight the need for comprehensive and coordinated efforts in CDW management and the development of an appropriate regulatory framework, policies, and collaborations at project and administration levels. At an administration level, these challenges require top-down solutions where political action should be taken. This can comprise, for example, influence in regulation proposition and development, industry expertise participation and contribution, and coordinated lobby actions from industry. On the other hand, at a project level, there is a need for awareness and willingness from the company direction to establish their internal policies and waste targets and bringing adequate resources for implementation and monitoring. Therefore, a wider outlook is demanded by those internal to the industry and those external (governments, occupants/users, and all citizens, as we are impacted by the built environment). This can be developed by, for example, stimulating the growth of industries related to recycling, remanufacturing, and waste management, creating new employment opportunities that foster innovation and entrepreneurship in sectors focused on sustainable practices.

The identified economic challenges underscore the need for comprehensive strategies to promote feasible business models within CDW management, i.e., sustainable CDW management practices and reused/recycled materials and products markets. More efficient and accurate CDW management solutions must be developed, reducing risks and uncertainty in the sector. It needs to be made more apparent that circular economy practices, such as reuse and recycling, can lead to cost savings by reducing the need for raw materials, lowering energy consumption with limited processing of construction components, and the support of localized/regional practices. This should include the diversification of supply chains, which can enhance resilience to external shocks and supply chain disruptions. Current procurement routes should be adapted to new markets for reused and recycled products, which will improve profitability for new business models in a more circular system. On the other hand, the perception of built assets should shift towards resource efficiency and keeping the asset value up along the life cycle. These considerations should be embraced from the early stages of the design, and with the collaboration of all stakeholders participating in the project.

The identified social challenges are dependent on many cultural aspects that involve behaviours and attitudes that resist the transformation proposed by the circular economy principles in the construction sector. Addressing these challenges requires a holistic approach that involves education, training, and collaboration at different levels, including changes in industry attitudes, as well as society awareness and practices. It is imperative to promote quality assurance procedures for reused/recycled components so that adequate information can be provided to users/customers. Additionally, technical skills

should be improved for professionals, technicians, and labourers involved in the construction process regarding the performance, installation, and use of these products, as well as health and safety issues. On the other hand, companies need to overcome competition and embrace the idea of collaboration as an opportunity to increase benefits (and profit) for all parties by the creation of more stable partnerships, associations, or any other kind of more permanent collaborative structures. This is particularly important in the face of a globalized industry, considering climate-related events, geopolitical tensions, and global health crises, which all directly impact the construction industry.

The technological challenges identified are very much dependent on country development. They remark on the need for innovation in different fields of application and at different levels.

1. Waste segregation. This is a basic step towards waste recovery. The purity of the different fractions sorted will determine the quality of the material and, therefore, its final recovery at a higher or lower value use. Construction methods and waste handling will determine solutions to implement.

2. Improved CDW management practices. This comprises waste generation and management at the construction site, but also waste traceability and value chain until the final destiny. This includes the implementation of site waste management plans, including transport, handling, and treatment off-site. At this point, CDW management on site is substantially improved, as well as waste transfer facilities, treatment infrastructures, and the development of the waste-processing industry.

3. Design out waste. At this level, the design stage is integrated, having a substantial impact on waste minimization. Standardization and modular construction are essential parts at this level.

4. Whole life-cycle and value-chain strategies. Finally, the integration of all life-cycle stages in the project brings the optimization of resources and solutions for a complete circular economy in the construction industry. Data management (big data) and automated solutions bring the possibility of optimizing cost and resources, making more efficient processes and facilitating stakeholder collaboration. This involves the use of digital technologies such as IoT, visual recognition, machine learning, blockchain, etc., as well as the introduction of robotics at different levels.

Finally, environmental challenges are not sufficiently identified in the papers analyzed, comprising only 1.5% of the total number of challenges. This causes a shortfall in data in this regard and avoids a reliable analysis of this group.

Regarding the relevance of these challenges per continent, it is observed the following:

-   Asian countries are more focused on the lack of regulations and strategies, whereas European countries target further developments around existing regulations and policies to achieve improved closed loops in construction.

-   There is a predominant representation of European countries in identifying economic challenges. Challenges identified mainly refer to the difficulties of making a business case, limited investment, high risk and uncertain profit margins, and the reused/recycled products market.

-   The representation of both European and Asian countries in the number of papers reviewed is substantial. Comparing them, it can be highlighted that the focus of the challenges identified is different. While Asian countries seek further awareness, education, and skills development, European countries demand further stakeholder collaboration and avoid change resistance.

-   In this regard, Asian papers make more references to challenges in waste management and processing (sorting, transport, treatment, and recovery), whereas European countries identify other challenges more related to CDW data management and the use of digital technologies, waste traceability, design standardization, and quality assurance processes for reused/recycled products.

The construction industry must make the transition to a circular economy for a sustainable future. Understanding existing challenges will help to eliminate or reduce them, contributing to a more balanced and regenerative relationship between the built environment and the natural world. This study analyzed 54 studies and classified challenges from different continents and countries. This analysis provided general strategies that allow for the ability to work towards reducing and eliminating them in different contexts and realities. The definition of these strategies is limited and cannot be applied in any case. There are social/cultural, economic, technological, legal, and environmental factors to consider, and the development of that country in each of those factors will determine the selection of such solutions. The development and implementation of specific strategies depend on involved stakeholders in the construction asset life cycle, including investors and banks, regulators that govern technical standards, material and product suppliers, designers, contractors, waste managers, governments, and all citizens at large are deemed to be responsible agents for this change in the sector.

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