Transnational CDW Valorisation for Secondary Raw Materials: Technological, Economic and Social Perspectives

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Abstract. Construction and Demolition Waste (CDW) represents a key barrier and opportunity in advancing circularity within the built environment, as countries intensify efforts to reduce waste and recover resources more effectively. Its valorisation increasingly relies on the combined influence of technological capabilities, economic feasibility and social acceptance. This study brings together national data from eight countries: Cyprus, Estonia, Greece, Latvia, Romania, Slovenia, Switzerland, and Türkiye to explore how economic, technological and social perceptions shape the potential of CDW in circular construction. The analysis examines the main economic opportunities and challenges in CDW recycling, including national market gaps and the availability of certified CDW-based products. It also highlights the growing role of digital tools, such as material-tracking systems,

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which support more reliable and transparent reuse pathways. From a social perspective, public perceptions and user preferences regarding recycled materials are analysed, along with stakeholder roles across the CDW value chain and the social implications of waste management. The study shows that an integrated approach that combines economic incentives, digital technologies, and stakeholder and community participation can effectively transform CDW into a valuable secondary raw material. It aims to guide policymakers, local governments, and industry professionals in creating diverse, practical initiatives from a comprehensive perspective, while also helping establish a strategic waste management framework.

Keywords: Construction and Demolition Waste (CDW) · Circular Construction · Secondary Raw Materials · CDW Valorisation · Digitalisation in Construction

1 Introduction

Construction and Demolition Waste (CDW) is one of the key material streams in the global transition toward a circular economy. With urbanisation, infrastructure development, and growth in the building stock, the amount of waste generated by construction activities will also increase. Therefore, this situation is transforming into a large consumption sector that uses primary raw materials [1]. In total waste statistics at the European Union, more than a third comes from CDW -over about 925 million tons per year- highly heterogeneous both in mineral and non-mineral content: concrete, bricks, metals, wood, glass, plastics [2]. Consequently, the management of CDW is of strategic importance due to its scale, material density, and environmental footprint. CDW is now increasingly conceptualised as a secondary raw material within broader systems of circular construction. The shift is associated with the transformation of linear "take–make–dispose" models into more resource-efficient modes that include waste prevention, reuse, and high-quality recycling, parallel to the gradual mainstreaming of circular economy discourse [3]. Despite increasing awareness of the problems related to CDW, fragmented policies, technological limitations, economic deterrents, and societal acceptance barriers remain a challenge for countries.

Most existing studies on CDW management evaluate single dimensions, predominantly emphasising technological and economic analyses [4, 5]. Increasing evidence in recent years shows that economic conditions - infrastructure, both digital and physical, and societal-level governance models and behavioural norms - play a key role in enabling or constraining technological readiness and cost-competitiveness pathways to successful CDW valorisation. This paper is therefore framed within an integrated, cross-country perspective, evaluating the economic, technological, and social dimensions and interactions that drive or hamper the valorisation of CDW. Eight countries (Cyprus, Estonia, Greece, Latvia, Romania, Slovenia, Switzerland, and Türkiye) from dıverse geographical contexts, with emerging to mature markets and under different governance structures, were selected. The study will evaluate national experiences to capture common and shared trends, enabling factors, and obstacles in transforming CDW from an assumed problem into a secondary raw material.

This study aims to address gaps in the literature by expanding the limited economic and technological perspectives on CDW through social and stakeholder engagement and by conducting an international synthesis. In line with this objective, the main research question guiding the evaluation is: How do economic and technological conditions, along with social acceptance and stakeholder perceptions, shape CDW valorisation within the circular construction context? By addressing this question, the paper contributes to a growing body of literature advocating multidimensional, governance-oriented approaches to implementing the circular economy in the built environment.

2 Method

The study uses a multi-country research design to analyse the economic, technological, and social aspects of CDW valorisation in circular construction systems. Eight countries - Cyprus, Estonia, Greece, Latvia, Romania, Slovenia, Switzerland, and Türkiye - were selected to represent diverse geographical regions and various levels of economic development, with different governance structures, spanning emerging to fully developed waste management and recycling markets. Such diversity allows both an analysis of how very different institutional/regulatory/market environments shape paths for CDW valorisation and the discovery of common challenges across national contexts, as well as potentially transferable practices.

Data were collected by systematically reviewing national statistics and official policy documents, strategic plans, regulatory frameworks, and publicly available reports on CDW management and circular economy implementation in construction practices. The resource selection focuses on documents that address direct CDW, recycling, digitalization, and circular construction practices. To ensure data consistency, the data collected using the same thematic coding structure were evaluated: economic conditions, technological/digital enablers, and social perceptions. The evaluation incorporated stakeholders' roles within a cross-country comparative synthesis, aiming to identify emerging common themes and structural gaps across enabling factors, while retaining sensitivity to country-specific contexts. The thematic comparative approach (inductive) allows for the discovery of both widespread regularities and context-dependent dynamics (interaction effects), thus providing a strong intellectual footing for developing fine-grained yet practically relevant (hence evidence-based) recommendations. The study is limited by the fact that CDW levels vary across countries and are based on national data sources. Therefore, the findings should be interpreted as a comparative thematic synthesis rather than a statistically definitive assessment.

3 Economic Perspectives on CDW Valorisation

The reuse of CDW as a secondary raw material brings wide economic benefits, particularly within circular construction systems. National strategies, policy assessments, and market analyses demonstrate that, in addition to reducing waste, the recovery of CDW creates jobs in the country's labour market, develops local markets, and improves resource-use efficiency in construction value chains. Enterprise support schemes further

illustrate the effects of incipient market formation: national circular economy de minimis programs have financed dozens of projects and created new jobs, thus registering growing economic activity related to CDW valorisation [6, 7].

Evidence from each country shows distinct yet parallel benefits. In relatively advanced CDW markets such as Romania, Greece, and Slovenia, government programs, circular economy plans, and green public procurement practices play a significant role in both supplying and using CDW [8–11]. These measures facilitate greater use of recycled materials in construction and expand recycling systems [12, 13]. On the other hand, in growing markets such as Türkiye, Cyprus, Estonia, and Latvia, using CDW mainly creates jobs in areas including landfill management, road construction, landscaping, infrastructure development, and local recycling businesses [14–17]. Despite differences in scale and implementation difficulty, the basic economic reasoning remains strong: using CDW reduces dependence on imported materials, supports local supply chains, and adds value by keeping resources within national and regional economies.

Data from each country shows similar gaps and shared challenges. In Romania and Greece, even though governments set rules and technical standards, the use of recycled materials remains low. This can be attributed to several factors, including lower costs of new construction materials, limited high-quality data, uncertainties about implementing such changes, and persistent concerns about the quality of recycled products [18–20]. In Türkiye, Cyprus, Slovenia, and Latvia, the main challenges are associated with certification procedures for materials, difficulties in recruiting skilled labour, the high costs of processing and transporting materials, and insufficient demand or support from businesses purchasing these materials [15, 21–23]. Unless there is a cohesive economic strategy that integrates the establishment of common standards, improvements in certification processes, financial incentives, and the enhancement of trust within the market, recycling of CDW is likely to remain economically unviable and inefficient, even with current technological capabilities.

4 Technological Perspectives on CDW Valorisation

Even though the level of development and use of digital tools (DT) varies from country to country, they are becoming essential in circular CDW management. Tools like Building Information Modelling (BIM), artificial intelligence (AI), material passports, and digital tracking systems help make better decisions, identify which parts to remove, recover materials, and recycle them properly [24, 25]. Common trends in the countries studied show a preference for DT in the processing and CDW.

In Romania, progress is reflected in increased institutional attention to digitalisation, including the development of a national BIM roadmap and initiatives to strengthen digital skills in the construction sector. Implementations at the project level include Scan-to-BIM workflows using laser scanning and photogrammetry as well as pilot initiatives exploring AI- and sensor-assisted CDW sorting, such as Robot Efficient Cdw Intelligent Classifier for Automatic Recycling Management (RECICLARM) [26, 27]. Slovenia's CINDERELA project presents a digitally integrated circular business model for a one-stop-shop platform marketplace for stakeholders in the waste-to-resource value chain. Latvia LIFE "Waste to Resources" provides easily accessible information and an

actual citizen engagement platform that supports circular economy practices through digital dissemination and the development of local repair and recycling infrastructure. Switzerland has developed digital solutions such as "Madaster" and "buildingSMART", both with a strong focus on technology [28]. Greece is a participant in the RECONMATIC project, which will develop automated, digital, and robotic solutions to support collaboration among construction industry stakeholders and improve waste traceability [29].

Digitalisation efforts in Türkiye and Cyprus are shaped more by governance structures and regulatory practices than by advanced automation. Cyprus provides a notable example of operational digital traceability through its mandatory collective systems and the Electronic Waste Recording System [30]. In Türkiye, digitalisation efforts primarily focus on electronic monitoring and reporting mechanisms, exemplified by systems such as the Electronic Concrete Monitoring System (ECMS). In parallel, the emerging consideration of AI-based tools for post-disaster damage assessment indicates a growing potential to support future evaluation and management of CDW [31, 32]. Although digital CDW technologies are not yet mature, their broad use is considered essential.

5 Social Perspective, Public Perceptions, and Stakeholder Roles on CDW Valorisation

A comparative social perspective on CDW valorisation indicates that, across countries, public acceptance and stakeholder engagement are influenced less by general environmental awareness than by tangible institutional, economic, and regulatory frameworks. Despite variations in governance structures and market maturity, the evidence consistently suggests that trust in certified quality standards, affordability, and clearly defined stakeholder responsibilities plays a decisive role in normalising reused and recycled construction materials within mainstream construction practices.

In Romania, consumer and stakeholder perceptions are strongly influenced by price- and quality-considerations; surveys indicate a cautiously positive yet conditional acceptance of reused and recycled materials, with 73% of buyers favouring certified "green" products, while demonstrating limited willingness to pay a premium [33, 34]. Evidence from the RECONMATIC Project suggests that technical familiarity and workflow reliability dominate decision-making over sustainability motivations, positioning Greece at an early stage in the social normalisation of CDW valorisation [35]. In Slovenia, while environmental awareness is increasing, scepticism about the quality and safety of recycled construction materials persists, but awareness is being raised through EU-funded projects [36].

In Cyprus, stakeholder surveys conducted under the Build CIRCULAR Up project show that 65% of construction actors actively separate CDW and derive economic benefits from selling recycled materials, despite gaps in standards, infrastructure, and cross–supply-chain collaboration [37]. In Türkiye, academic and stakeholder studies report broadly positive attitudes among users, designers, and professionals toward recycled and reusable materials, particularly regarding environmental benefits and design potential [38]. Public perception in Estonia (as well as in the Nordics) is mixed and largely characterised by a lack of awareness [39]. Similarly, in Latvia, the public lacks sufficient

knowledge of circular construction principles, identifying insufficient information and awareness as a primary societal barrier to the adoption of circularity [40]. Collectively, these cases demonstrate that while social receptivity exists across contexts, its consolidation depends on aligning awareness with enforceable regulations, credible quality assurance systems, and tangible economic benefits.

6 Conclusions and Recommendations

This study demonstrates that utilising CDW as a secondary raw material is a multidimensional process shaped not only by economic and technological capacity but also by re gulatory alignment and societal dynamics. Evidence from eight countries highlights the significant potential to increase recycling capacity through technological innovation, particularly through improved sorting, monitoring, and material recovery systems. Economic instruments (especially green public procurement, certification schemes, and incentives) play a decisive role in shaping viable markets for CDW-derived products. The finding further confirms that social acceptance is influenced not solely by environmental awareness but by pricing structures, regulatory clarity, and clearly defined stakeholder responsibilities (Table 1).

Table 1. Comparative Patterns in CDW Valorisation Across Countries

Country	Economic	Digitalisation	Social	Main Barrier	Key Enabler
Romania	◆◆◆◆◇	◆◆◆◇◇	◆◆◆◇◇	Market trust	Green procurement
Greece	◆◆◆◆◇	◆◆◆◇◇	◆◆◆◇◇	Cost competition	Policy frameworks
Slovenia	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◇◇	Quality perception	Circular platforms
Türkiye	◆◆◇◇◇	◆◆◇◇◇	◆◆◆◇◇	Digital gaps	Regulatory transition
Latvia	◆◆◇◇◇	◆◆◇◇◇	◆◆◇◇◇	Knowledge gaps	EU initiatives
Cyprus	◆◆◇◇◇	◆◆◆◇◇	◆◆◆◇◇	Infrastructure	Digital traceability
Estonia	◆◆◆◇◇	◆◆◆◇◇	◆◆◇◇◇	Public engagement	Digital governance
Switzerland	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◇◇	Public engagement	Advanced digital systems

Comparative findings indicate that a successful CDW evaluation depends on the alignment of the following three dimensions: (i) economic incentives and market stability, (ii) digital and technological traceability systems, and (iii) social trust supported by regulatory legitimacy and stakeholder coordination. Based on these findings, the study

recommends adopting a multi-faceted approach that simultaneously addresses economic, technological, and social dimensions through coordinated policy action. Finally, future research should expand this cross-country synthesis by incorporating empirical data and long-term assessments to better analyse the impacts of governance reforms and digital innovation on circular construction systems.

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