Towards Smart and Sustainable Management of Construction and Demolition Waste in Island Communities

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Abstract. Construction and Demolition Waste (C&DW) represents one of the largest waste streams in the European Union and poses specific challenges in disadvantaged regions, such as islands, where logistical constraints, inadequate infrastructure, and high transportation costs hinder the transition to circularity. The transition to sustainability in the construction industry requires integrated and efficient C&DW management strategies, based on pre-demolition audits, selective demolition, traceability, recycling, and digitalization. This paper presents the results of a survey conducted among Italian and French construction companies to assess operational practices, perceived barriers, and opportunities for improving C&DW management in both continental and island regions. The analysis compares the Italian and French contexts, reserving a specific focus on the differences between islands and coastal continental territories, identifying recurring issues such as costs, transportation, documentation complexity, treatment and recycling constraints, and emerging trends such as digitalization, selective practices, and interest in recycled materials. The results are critically analyzed and discussed, and recommendations are proposed to support smart, resilient, and circular management of C&DW, particularly in the most disadvantaged areas such as islands.

Keywords: Construction and Demolition Waste · Circular Economy · Waste Management · Cross-border Cooperation

1 Introduction

Construction and Demolition Waste (C&DW) constitutes approximately 30–40% of global waste generation and represents one of the most significant solid waste streams globally. In the European Union (EU) alone, annual production reaches hundreds of millions of tonnes, with recent estimates ranging around 800 million tonnes per year. Beyond volume, C&DW management is inherently complex due to its heterogeneity, the need for selective demolition, and stringent regulatory requirements [1, 2].

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In this context, island communities face additional structural challenges, such as limited land availability, geographic isolation, low economies of scale, dependence on external infrastructure, and high waste transportation and treatment costs. These constraints make C&DW management particularly challenging in island communities, resulting in islands being disproportionately affected by waste accumulation, scarcity of treatment facilities, and environmental vulnerabilities. However, island contexts can be at the forefront of circular innovation, if supported by appropriate governance frameworks [3–6].

Within this framework, the Interreg Italy-France Maritime Programme promotes cooperation between coastal and island regions to strengthen environmental sustainability, competitiveness and resource efficiency. The IMPACT+ project [7] specifically addresses the challenge of improving C&DW management through benchmarking and mapping of C&DW treatment facilities in the cross-border area, the development of innovative solutions, training activities and pilot actions for companies in the sector.

This paper analytically and critically illustrates the results of a cross-border survey aimed at understanding practices, challenges and opportunities at construction company level in C&DW management, with particular attention to the comparison between island and continental territories of the Italy-France maritime area, following the principles of Smart and Sustainable Island Communities (SSIC).

2 Background and Related Work

C&DW management has become a key research topic in sustainability and circular economy studies, especially in regions where material flows, logistical constraints, and infrastructure limitations converge, amplifying systemic inefficiencies. C&DW currently accounts for approximately one-third of global waste generation, posing both environmental and economic challenges for the construction sector. Despite growing political and scientific attention, the sector still lacks unified frameworks for implementing circularity, reliable traceability tools, and standardized decision-making support systems. Indeed, although recycling, selective demolition, and material reuse are recognized as key elements of circularity, their effective adoption remains uneven, hampered by regulatory fragmentation, limited technical capacity, and insufficient infrastructure in many regions [1, 8–11].

When examining island and coastal territories, these structural constraints tend to intensify, as geographic isolation, transport dependence, land scarcity, and reduced economies of scale make C&DW management an inherently fragile field [3–6, 8]. Waste flows often accumulate in contexts lacking adequate treatment infrastructure, resulting in increased environmental pressures and greater vulnerability. In such contexts, sustainable waste management strategies must integrate logistical optimization, decentralized pre-treatment solutions, and governance models adapted to small-scale and resource-constrained systems. Islands that adopt community-based or collaborative models tend to achieve more resilient outcomes, combining social engagement with operational improvements [12–15].

In the EU context, the push towards circularity is supported by a variety of cross-border and regional initiatives, many of which have produced highly relevant methodologies and tools for C&DW management. For example, the CIRCULA project focuses

on strengthening skills to support circular economy models and the exchange of good practices for companies in the Mediterranean sustainable construction supply chain [16]. The CHARM (Circular Housing Asset Renovation & Management) project aims to optimise (re)use of material and natural resources and to demonstrate innovative approaches for housing renovation and asset management that prevent downcycling [17]. The CONDEREFF (Construction & demolition waste management policies for improved resource efficiency) project aims to exchange experiences and practices on how to move forward from existing procedures on C&DW management towards the adoption and further exploitation of the best practices and measures applied in the field [18]. The MED 3R (Euro-Mediterranean Strategic Platform for Adapted Waste Management) project proposes to strengthen coordination and cooperation between territories and the different groups of actors involved in the waste cycle to develop integrated waste management systems that are effective, intelligent, virtuous and adapted to local contexts [19]. The PORT 5R (For a sustainable management of waste in Mediterranean ports) project has adopted the 5R strategy: Reduction, Reuse, Recycling, Collection, Recovery and has provided for the definition of guidelines for the development of a joint plan for the prevention, reduction and disposal of waste in port areas [20]. In Sardinia, the MEISAR project (Materials for Sustainable Building and Infrastructure - Recycled Aggregates) addresses the issue of overexploitation of land related to the extraction of building materials and intends to promote, through participatory and applied research, the use of recycled materials for the construction of structures and infrastructure [21].

Even from these research and project contexts, a recurring theme emerges: circularity in construction cannot advance without a solid understanding of current practices, obstacles, and levels of preparedness within the construction sector. This is particularly true in island and coastal areas, where the interaction between geographic constraints, infrastructure, and economic structures requires context-sensitive solutions, also guided by empirical and specific assessments tailored to the specific territory. The research presented in this article addresses precisely this still lacking framework, providing insights into how construction companies operate and manage C&DW, and the specific obstacles and opportunities that exist in both the island and continental regions of the Italy-France maritime space. Thus, the study contributes new empirical evidence to a field where robust, geographically specific data remain limited, despite strong community interest in the circular economy, sustainability, and island's smart governance.

3 Materials and Methods

The methodological approach of this study combines a survey conducted through a questionnaire administered to construction companies in the Italian-French cross-border area, the harmonization of qualitative and quantitative data derived from the responses, and a comparative analysis to capture the operational realities of C&DW management.

The research starts from the IMPACT+ (Innovation in the selective management of building waste towards the activation of circular economy processes in order to reduce energy consumption and minimize CO_2 emissions) project [7], developed within the Interreg Italy-France Maritime Programme, which aims to improve the management of C&DW in coastal and insular areas, involving the cross-border regions of Var and the

Maritime Alps, Corsica, coastal Tuscany, Liguria, and Sardinia. It addresses common territorial issues, particularly acute in Sardinia and Corsica, where geographic isolation and limited treatment capacity exacerbate C&DW-related pressures. The project adopts a participatory and practice-oriented methodology, directly involving companies and enterprises active in the construction sector in identifying operational needs, jointly developing technical tools, and testing innovative solutions on pilot construction sites. It is structured in three integrated phases: i) territorial analysis and tool development; ii) experimental activities on selected pilot sites and construction sites; iii) cross-border consolidation through shared models and guidelines. The project's cross-border partnership, combining institutional, technical, and academic expertise, ensures that the solutions are scientifically sound and operationally relevant. The goal of the research is to integrate circular economy principles into routine construction practices and strengthen the sector's capacity to manage C&DW sustainably even after the project's conclusion.

In particular, the research illustrated in the paper is the result of collaboration during the first phase of the project between the Universities of Cagliari and Genoa, the two research institutions belonging to the IMPACT+ project partnership.

The survey was designed to collect consistent information from companies operating in different regulatory, territorial, and organizational contexts. To ensure comparability while respecting national specificities, two parallel questionnaires were developed, one in Italian and one in French, using a fully aligned structure, obtaining 21 responses from Italian companies and 17 from French companies. Both instruments explore the same thematic areas.

The questionnaire is structured around seven coherent thematic areas:

1. Company Identification Data

This section, designed to contextualize the sector landscape in the cross-border area, concerns the company identification and its operational characteristics, such as geographic location, number of employees, number of active construction sites, and turnover.

2. Operational Profile

This section, designed to gather information on company characteristics that could influence the production and management of C&DW, concerns the nature of its activities, including the predominant sector (e.g., residential construction, commercial construction, industrial works, or artisanal services) and the type of customer.

3. Regulatory Compliance and Planning

This section, designed to understand companies' perceptions of the regulatory framework, explores the adoption of waste pre-sorting practices, as well as the level of internal structuring of waste management procedures, through systematic protocols, dedicated storage areas, or other organizational arrangements.

4. Operational Waste Management

This section, aimed at understanding the operational aspects associated with C&DW management, assesses the types and volumes of waste produced based on the European Waste Code List [22] for the C&D stream, allowing companies to identify the categories

most frequently generated on their construction sites and estimate the annual quantity of C&DW produced. This section also explores the economic dimension of C&DW management by estimating annual management costs, identifying the cost components with the greatest impact, and identifying any strategies implemented by companies to reduce disposal costs.

5. Human Resources and Critical Issues

This section explores the type and quantity of human resources, such as environmental managers, on-site sorting personnel, drivers, and administrative staff, employed by companies in C&DW management. The section also identifies any critical issues encountered, including problems with on-site sorting, limited availability of treatment facilities, high transportation costs, bureaucratic burdens, or uncertainty regarding regulatory updates.

6. Treatment and Disposal

This section, designed to examine companies' relationships with external stakeholders and the decision-making processes related to the selection of C&DW treatment facilities, identifies the criteria used in selecting landfills/disposal centers, including distance, cost, type of waste accepted, opening hours, and the need for specific documentation. It also identifies difficulties encountered in managing mandatory documentation, such as C&DW identification forms or traceability records.

7. Circular Economy Practices

This section identifies the use of recycled materials, the promotion of circular economy practices in construction projects, and the perceived added value of sustainable C&DW management in terms of enhancing corporate image or opening up new market opportunities.

The survey responses were harmonized through a process designed to ensure comparability across countries and thematic areas: categories were standardized, qualitative responses were coded thematically, and cross-border taxonomies, such as C&DW type and cost category, were aligned (Fig. 1). The resulting dataset was used to develop descriptive statistics and comparative analyses between Italian and French companies, and between island territories (Sardinia and Corsica) and mainland territories (Var and the Maritime Alps, coastal Tuscany, Liguria).

It is worth emphasizing that the purpose of this paper is not to draw generalizable statistical inferences, but rather to use the survey conducted on C&DW management as an exploratory and diagnostic tool useful for providing context-specific empirical evidence, given the structural heterogeneity of the analyzed territories, particularly the island ones, and the absence of consolidated datasets on the topic at the construction company level.

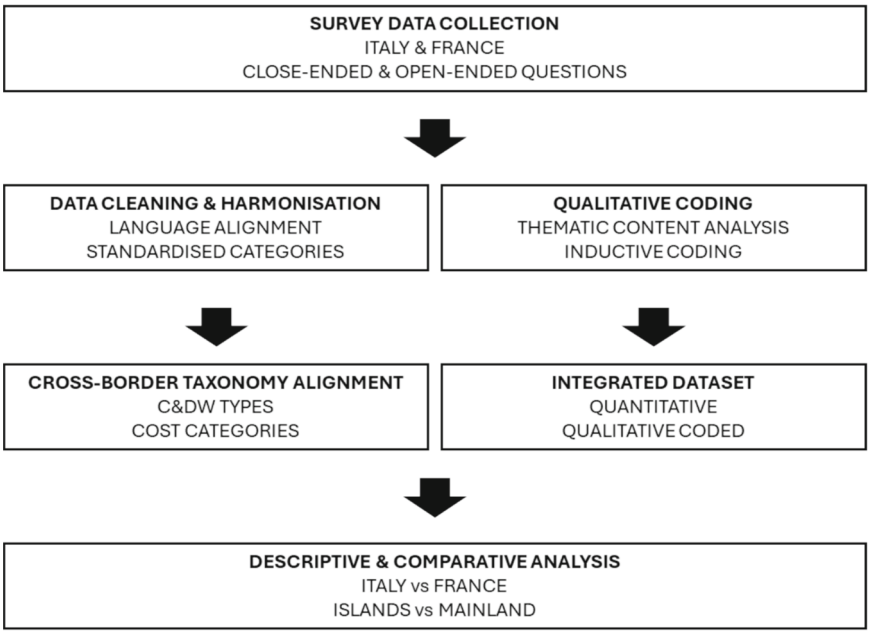

Fig. 1. Flowchart of the methodology for processing and analyzing questionnaire responses.

4 Results

Based on the methodological approach described above, the results summarize quantitative indicators, such as annual waste volume, cost typologies, adoption of pre-demolition audits, use of recycled materials, and qualitative data relating to organizational practices, operational obstacles, and regulatory constraints. The analysis aims to provide a coherent overview of current C&DW management practices in the considered area, highlighting both converging trends and territorially specific patterns, with particular attention to the different conditions observed in island versus continental contexts. Figure 2 shows the territorial distribution of the companies that participated in the survey.

The survey results first reveal a certain degree of diversification among both Italian and French companies in terms of staff, turnover, number and size of construction sites managed, and predominant operating sector, which is reflected in the varying approaches to managing C&DW. However, overall, the predominance of small firms emerges, primarily operating in the residential construction sector.

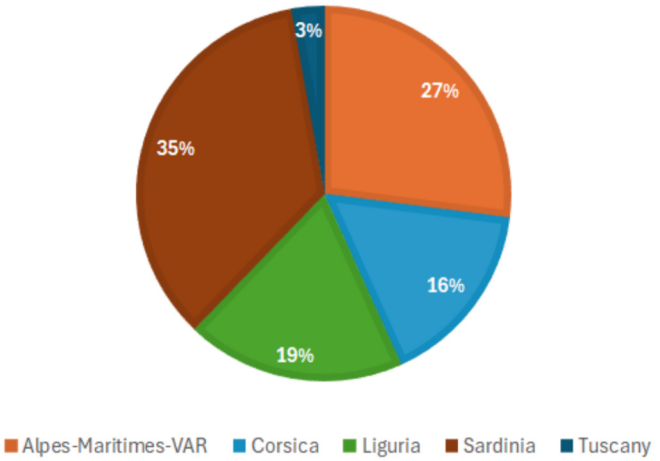

Fig. 2. Territorial distribution of the participants in the survey.

The prevalence of small/medium-sized enterprises is also confirmed by the analysis of the annual volume of C&DW generated, which stands at less than 50 tons for both Italian and French companies (Fig. 3).

It should be noted, however, that the results of this survey are influenced by the fact that almost half of the companies interviewed were unable to estimate their annual volume of C&DW produced. This result is probably due to the fact that C&DW management processes are often not structured in an organised way, so some data are not acquired in a systematic way by the companies themselves.

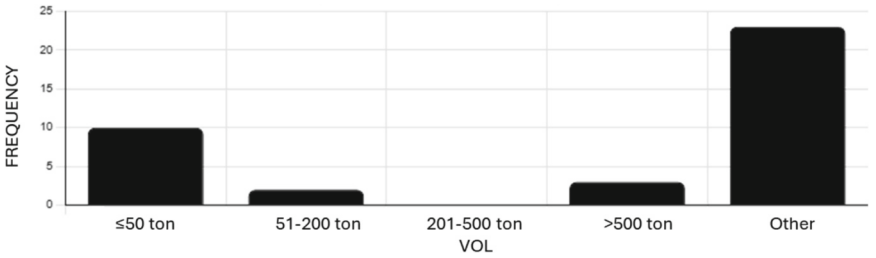

Fig. 3. Annual C&DW volume. "Other" includes non-quantifiable responses such as "unable to estimate", incomplete or invalid entries, and values that could not be classified within the predefined volume ranges.

Regarding the financial costs associated with C&DW management, the results show that the majority of Italian and French companies report costs below €15,000 per year, with the exception of a few companies managing multiple construction sites, which report significantly higher costs. The most significant cost factors are transportation, landfill disposal, and recycling operations (Fig. 4).

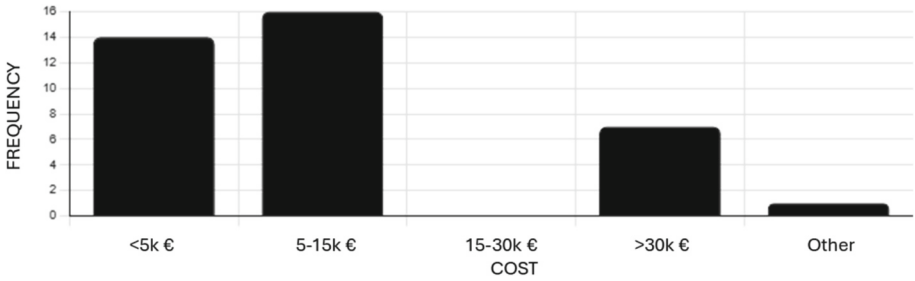

Fig. 4. Annual waste management costs

Regarding planning procedures, the adoption of pre-demolition audits, essential for selective demolition, appears to be somewhat heterogeneous (Fig. 5), consistently more widely adopted by French companies than by Italian ones, due to the aforementioned different regulatory framework.

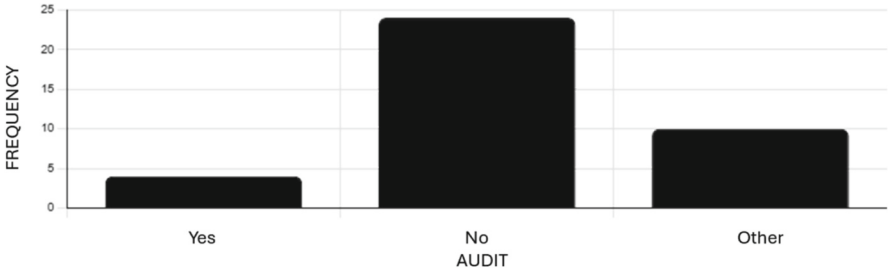

Fig. 5. Pre-demolition audits. "Other" includes responses such as "only for certain projects", partial or ambiguous answers, and entries that could not be classified unequivocally as "Yes" or "No"

Regarding the use of recycled materials, it is interesting to note that this is an emerging practice, albeit still in a heterogeneous and unstructured manner (Fig. 6).

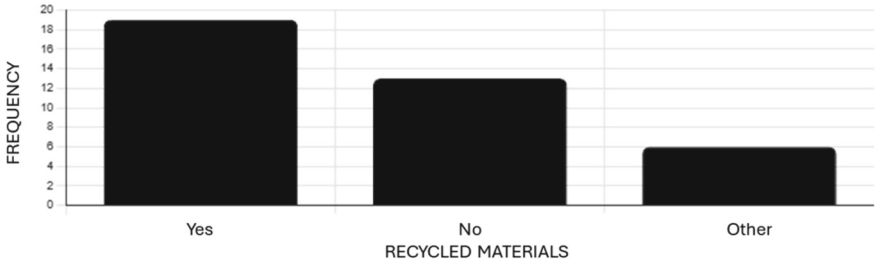

Fig. 6. Use of recycled materials. "Other" includes ambiguous, incomplete or non-standard responses that could not be classified as "Yes", "No".

Indeed, it is noted that several companies still use these materials only occasionally, influenced by the current limited availability, associated costs, and concerns about their technical performance. Distance from the construction site, the types of waste accepted and their associated costs, as well as the logistical and infrastructural constraints, particularly in the island regions of Sardinia and Corsica, influence the choice of treatment and recovery facilities.

Regarding documental aspects associated with C&DW management procedures, the survey highlights difficulties in acquiring mandatory traceability registers or waste identification forms, resulting in delays in management operations and exposing companies to the risk of non-compliance. These difficulties may be linked to the internal organization of companies, which appears to vary significantly (Fig. 7), as some companies adopt structured procedures, including dedicated storage spaces and codified internal protocols, while others rely on informal practices.

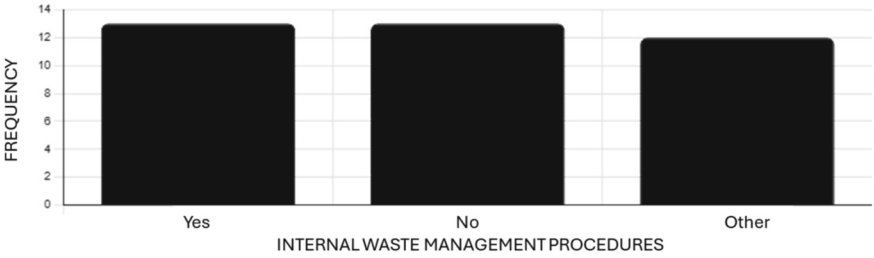

Fig. 7. Internal waste management procedures. "Other" includes responses such as "currently under development", "applied only to certain construction sites", unclear or incomplete answers, and cases where no response was provided.

Finally, the analysis of responses regarding perceived critical issues confirmed several recurring obstacles, including problems related to on-site C&DW sorting, limited availability of treatment and recovery facilities, high transportation and disposal costs, lack of adequately trained personnel, regulatory uncertainty, and concerns about the quality of recycled materials (Fig. 8). These findings highlight the structural and organizational constraints that hinder the full adoption of circular economy practices.

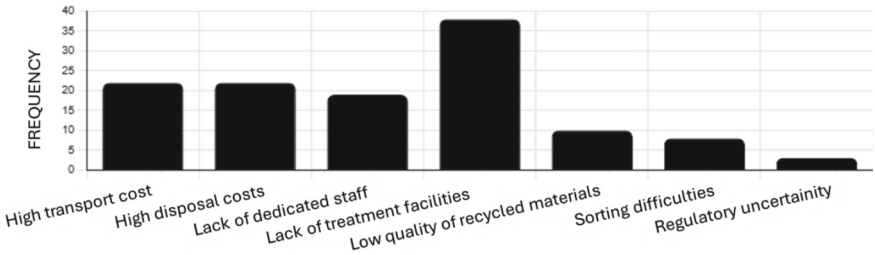

Fig. 8. Recurring themes in operational difficulties

5 Comparative Analyses

5.1 Italy vs France

The comparison between Italian and French companies highlights some distinctions, primarily arising from differences in national regulatory frameworks, but also from the level of organizational maturity and the characteristics of the local construction market.

French companies are generally characterized by a more advanced level of systematization of C&DW management procedures, primarily due to the long-standing enforcement of management practices that are not yet mandatory in Italy. These practices encourage pre-demolition audits, selective demolition, and the adoption of clear and codified internal protocols. Italian companies are a more diverse group, as some, especially those operating in large urban centers, often report adopting structured internal protocols, while many others rely on informal or experience-based approaches, often dependent on the nature of the project or the client's needs (Fig. 9).

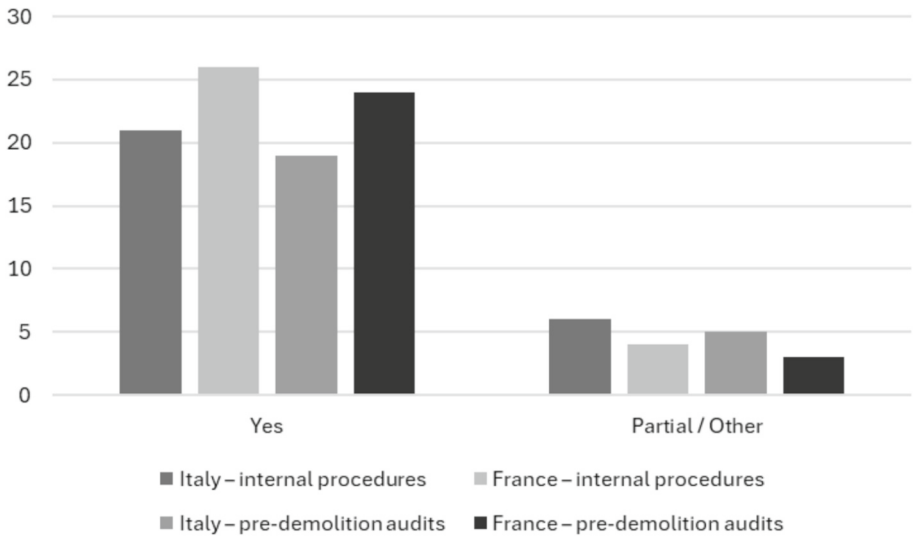

Fig. 9. Organizing of C&DW management practices. Italy vs France.

Some differences also emerge with regard to perceived critical issues. Italian companies point to economic pressures, particularly transportation and disposal costs, often amplified by territorial fragmentation and limited local treatment capacity. French companies, while reporting similar challenges, emphasize the importance of organizational and quality aspects of supply chain management, likely due to the greater integration of C&DW management into workflows (Fig. 10).

Despite these differences, both regions share a growing awareness of the principles of circular and sustainable construction and recognize the potential value generated by improved C&DW management practices.

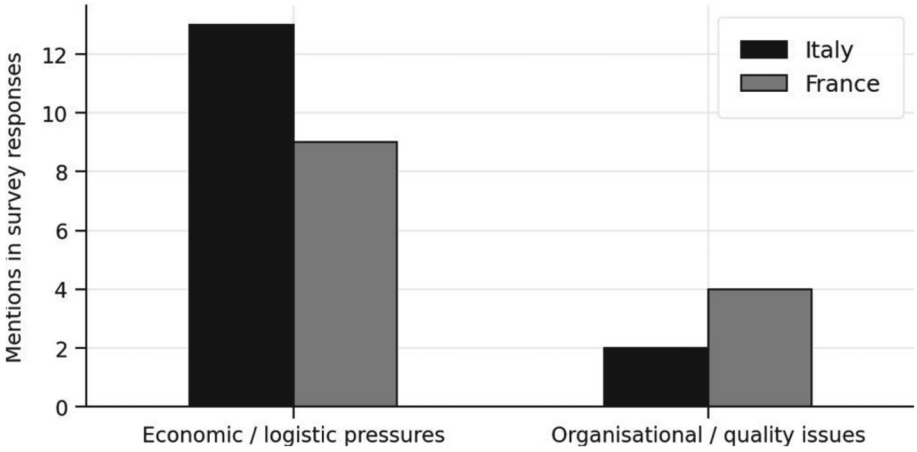

Fig. 10. Perceived critical issues in C&DW management. Italy vs France.

5.2 Islands vs Mainland

The comparison between island and mainland territories highlights the structural impact of geographic characteristics on C&DW management. Indeed, companies operating in Sardinia and Corsica face significantly more stringent and impactful constraints, limitations, and critical issues than companies operating in the mainland regions of Var and Maritime Alps, coastal Tuscany, and Liguria (Fig. 11).

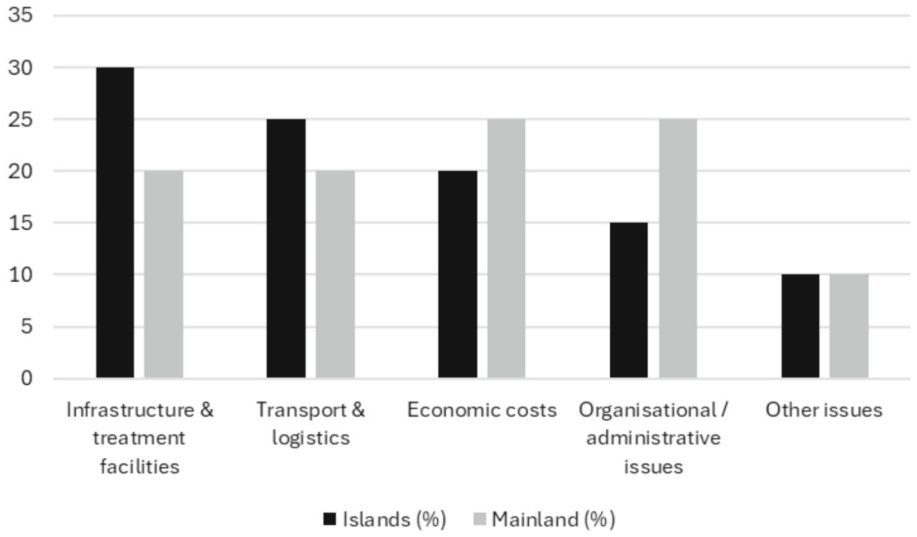

Fig. 11. Perceived critical issues in C&DW management. Islands vs Mainland.

A very significant island challenge is due to the limited availability of authorized treatment facilities and their sparse distribution across the territory, which forces companies to take longer transportation routes and rely on a smaller number of suppliers, resulting in higher costs and operational delays. This constraint also significantly impacts the management of selective demolition and temporary storage of C&DW, which also become critical phases in the management chain.

Mainland companies, while not exempt from regulatory, administrative, and logistical challenges, can benefit from denser infrastructure networks, greater accessibility and diversification of recycling treatment facilities, and more generally from a more stable operating environment less affected by transportation constraints or seasonal variability.

Overall, although companies in both territories share common obstacles, island ones face a combination of geographic isolation, limited infrastructure, and higher logistics costs, highlighting the need for specific strategies and cross-border coordination to mitigate structural disparities.

6 Discussion

The results derived from the questionnaire administered to construction companies in the Italy-France maritime cross-border area provide a comprehensive overview of C&DW management, highlighting the structural characteristics of the sector and the main critical issues perceived by respondents.

It is worth emphasizing that the constraints on more sustainable C&DW management revealed by the analysis of the questionnaire results confirm generally expected trends. In this context, this study aims to provide a structural interpretation of these constraints through a territorially differentiated perspective, rather than identifying new barriers. This helps to construct a specific framework of critical issues and opportunities in the analyzed territories and gather evidence for planning corrective actions.

To this end, a comparison was conducted between the island and mainland contexts in the two national regions of Italy and France. This comparison highlights not only the presence and typology of the issues, but also their configuration, concentration, and operational relevance, which differ depending on geography and governance characteristics. This analysis thus stimulates reflection on the strategies needed to guide the sector toward more sustainable C&DW management.

It is also important to note that the survey conducted through the questionnaire is intended to provide the basic knowledge necessary to effectively design and implement, in a targeted and geographically differentiated manner, the subsequent analytical phases envisaged in the IMPACT+ project, including on-site assessments and material flow analysis (MFA). At this stage, it was decided not to conduct MFA because the objective of the study is to preliminary identify and characterize the barriers, obstacles, and organizational, regulatory, and territorial constraints that influence the sustainable management of C&DW, rather than quantifying physical waste flows.

The key aspects emerging from the analysis of the results fall primarily into two categories: the role of the regulatory framework and the influence of the geographical context.

Regarding the regulatory framework, it emerges that the more consolidated regulatory framework in France favors the adoption of planned procedures, pre-demolition

analyses, and selective demolition by companies. In Italy, on the contrary, companies operate within a more complex and evolving regulatory framework, which includes the recent introduction of mandatory elements, such as digital traceability, that have not yet been fully assimilated by the sector.

These differences powerfully underscore the need for a stable and harmonized regulatory framework, including across borders. They suggest the opportunity for both cross-border knowledge and best practices exchange and for implementing training activities for sector operators to facilitate the transition to greater sustainability in C&DW management.

Regarding the influence of geographic context, the data highlights the disadvantages faced by the island territories of Sardinia and Corsica. In these regions, C&DW management is heavily impacted, especially by infrastructural constraints on mobility and accessibility, and by a limited supply of treatment and recycling services. This results in a general increase in management costs and a hindrance to the implementation of virtuous recycling practices. This situation highlights the need to study and plan specific C&DW management improvements, appropriately tailored to the geographical and structural characteristics of the most disadvantaged territories.

It is worth emphasizing, however, that despite the critical issues highlighted, companies still recognize the potential environmental, economic, and reputational benefits associated with more sustainable management of the C&DW supply chain. This demonstrates the presence of fertile ground for innovation, which should be embraced but also accompanied by streamlining documentation procedures and training for operators, who still have uncertain perceptions of the quality of recycled materials.

The concept of smart C&DW management fits into this framework, and is understood here as companies' organizational and procedural readiness for digitalization. This readiness, interpreted as an essential prerequisite for the smart governance of the C&DW management process, is captured by indicators such as the degree of internal structuring of companies, the adoption of traceability practices, including mandatory digital tools, and planning and compliance capabilities (e.g., pre-demolition audits).

Overall, therefore, the survey results suggest that the transition to more sustainable C&DW management in the cross-border area analyzed should be an organic and systemic process, harmoniously involving regulation, infrastructure, training and awareness-raising, and organizational capacity, positively impacting the resolution of the main structural constraints in the most disadvantaged areas.

7 Conclusions and Future Work

This paper critically illustrates the results of a questionnaire on the perception of the current state of the art regarding C&DW management, administered to 38 construction companies operating in the Var and Maritime Alps, Corsica, coastal Tuscany, Liguria, and Sardinia regions of the Italian-French cross-border area.

The questionnaire compares both the national situation in the two countries considered and the regional situation, focusing particularly on the differences between continental coastal regions and island regions (Sardinia and Corsica), placing island territories at the center of the analysis as structurally disadvantaged contexts.

The survey explores seven aspects related to how companies approach C&DW management, including:

- Regulatory Compliance and Planning
- Operational Waste Management
- Treatment and Disposal
- Circular Economy Practices
- Human Resources and Critical Issues.

The limited and heterogeneous sample size and reliance on self-reported data preclude statistical generalizations, which, however, are not the objective of this study. The study adopts an exploratory and diagnostic approach, aiming to provide a useful tool for providing context-specific empirical evidence, given the structural heterogeneity of the analyzed territories, particularly the island ones, and the lack of consolidated datasets on the topic at the construction company level.

The survey results identify several barriers to more sustainable C&DW management, including:

- high transportation costs
- limited availability of treatment facilities
- regulatory complexity
- organizational weaknesses within companies.

In this context, the main contribution of the paper is to provide a structural interpretation of these constraints through a territorially differentiated perspective. This interpretation highlights that in the island regions of Sardinia and Corsica, critical issues are concentrated and pervasive, affecting multiple stages of the C&DW management chain. In coastal continental regions, similar challenges are mitigated by denser infrastructure networks and greater operational flexibility. This confirms the importance of geographic, territorial, and morphological factors in the vulnerability of the C&DW management chain, which is particularly acute in island regions.

The survey also highlights companies' weaknesses in aspects such as the degree of internal organization, the adoption of traceability practices including mandatory digital tools, and planning and compliance capabilities. These, on the one hand, hinder smart C&DW management, understood as companies' organizational and procedural readiness for digitalization, and, on the other, highlight that technological solutions alone are insufficient without parallel investments in organizational capacity, training, and territorial coordination.

It should also be noted that the survey also reveals a growing awareness of the importance of sustainability and circularity, and the use of recycled materials, although a certain mistrust regarding the reliability of these materials persists.

A critical analysis of the questionnaire results highlights several operational priorities, particularly for island contexts:

- strengthening internal organizational structures
- promoting adherence to traceability and compliance practices
- supporting systematic pre-demolition audits that encourage selective demolition
- implementing decentralized or intermediate pre-treatment solutions to reduce long-distance transport

- promoting the use of recycled materials.

At the general policy level, the value of cross-border coordination and cooperation emerges to address regulatory fragmentation, replicate good practices already in place in different territories, and mitigating the specific infrastructural and logistical constraints of island communities.

Future research may build on the investigation conducted in this paper, focusing on the implementation of targeted and specific actions, such as:

- study of cross-border MFA models for managing C&DW flows in pilot construction sites
- development and testing of digital or semi-digital decision-support tools
- training and information activities to improve the culture of sustainable C&DW management and the use of recycled materials
- engaging additional stakeholders, particularly public administrations and regulatory bodies.

Overall, therefore, the study conducted in this paper highlights the structural specificity of island contexts and provides the basis for planning and designing targeted and site-specific solutions, framing island regions as potential laboratories for implementing resilient, circular, and smart C&DW management strategies.

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