Resources, Conservation & Recycling Advances 17 (2023) 200135

Contents lists available at ScienceDirect

Resources, Conservation & Recycling Advances

journal homepage: www.sciencedirect.com/journal/Resources-Conservation-and-Recycling-Advances

Local scale dynamics to promote the sustainable management of construction and demolition waste

Mário Ramos *, Graça Martinho, Lia Vasconcelos, Filipa Ferreira

MARE – Marine and Environmental Sciences Centre / Associate Laboratory ARNET – Aquatic Research Network, Department of Environmental Sciences and Engineering, NOVA School of Science and Technology, NOVA University Lisbon, 2829-516 Caparica, Portugal

ARTICLE INFO

Keywords:
Construction and demolition waste (CDW)
Local scale
Micro and small construction company
Municipality
Participatory process

ABSTRACT

On a local scale, municipalities often incur high costs as a result of the illegal dumping of construction and demolition waste (CDW), due to gaps in awareness and training, a lack of adequate oversight actions or infrastructure and equipment. Moreover, there is a loss of resources, failing to close the loop of the circular economy. Six participatory workshops were implemented in 2021, via videoconference due to the Covid-19 pandemic, in a rural Portuguese region, to understand the contribution of local scale dynamics in the promotion of CDW management from an operational perspective. Three of them were dedicated to municipal technicians (39 participants, on average) and the other three to representatives of micro and small construction companies (25 participants, on average). The results reveal that strategies must rely on investment in local solutions to optimise logistics and cost issues, cooperation between stakeholders, and improving the market for recycled aggregates. Also, support for information, awareness, and training is essential, focusing on good practices onsite and oversight procedures. Additionally, municipalities were involved in the prioritisation of legal framework issues, and micro and small construction companies concerning the determinants contributing for their behaviour change. These findings contribute to solving gaps in the literature, useful for researchers and decision-makers in rural or less developed areas.

1. Introduction

For a strategy to succeed, through the recognition of its vision and prioritised goals, followed by its implementation, it is important to enhance resilience and stakeholders' cooperation, boosting values for the various parties (Mahajan et al., 2022). In this perspective, a participatory approach is essential to forming strategies and policies involving interdisciplinary environmental problems, since they link to consequences at a social level (Ferkany and Whyte, 2012). Besides, conflicts of interest between actors may arise, requiring problem-solving processes that allow coordination across policy areas (Van Den Hove, 2000). This is important, as stakeholders are involved in operations that have significant implications for the realisation of circular economy principles, such as waste management (Oluleye et al., 2022; Liu et al., 2021), involving environmental, economic, and social aspects, but also contributing to the overarching vision of accomplishing the waste hierarchy principles (Zhang et al., 2022; Kabirifar et al., 2020; Liu et al., 2020).

Several participatory processes have been conducted in recent years in the waste management field, an area where various stakeholders intervene, with different responsibilities and levels of collaboration, for example: waste collection programs design, in Canada (Pérez et al., 2021); source separation in rural areas, in Thailand (Manomaivibool et al., 2018); urban waste management, in Italy (Hornsby et al., 2017); and selective household waste collection with recycling cooperatives, in Brazil (Gutberlet, 2015). But participatory approaches directly involving the interaction between stakeholders, as a collective problem-solving approach, has not been taken for construction and demolition waste (CDW) management with the research approach followed here.

In this context, the current research project aims to contribute to the study of the CDW management constraints and challenges on a local scale, as a collective problem, from an operational perspective. For this purpose, it was decided to consider a case study, involving municipalities and micro and small construction companies, because specific challenges were identified that both groups must overcome, individually or in collaboration (Ramos and Martinho, 2022, 2021; Martinho et al., 2015). In these terms, the research approach was supported by participatory workshops, to involve presentation and discussion of

* Corresponding author at: Department of Environmental Sciences and Engineering, NOVA School of Science and Technology, NOVA University Lisbon, Portugal.
E-mail address: mario.ramos@fct.unl.pt (M. Ramos).

https://doi.org/10.1016/j.rcradv.2023.200135

Available online 26 February 2023

contributions from different perspectives regarding action and responsibility (Al-Otaibi et al., 2022; Santos et al., 2019). It was intended to understand the aspects that are common concerns to these stakeholders, but also to identify the differences existing between them.

2. Background

2.1. Construction and demolition waste management challenges in different contexts

In general, there are different methodological approaches for the study of CDW management (Wu et al., 2019; Umar et al., 2017; Bovea and Powell, 2016), considering various environmental and economic aspects (Ding et al., 2018; Tatiya et al., 2018), evaluated through holistic methods (Devaki and Shanmugapriya, 2022; Marrero et al., 2017; Tam et al., 2014). Also, there are distinct realities related to the implementation or reinforcement of good practices (Menegaki and Damigos, 2018; Tam et al., 2018; Ding et al., 2016), and approaches concerned with more technical and specific attributes (Le and Bui, 2020; Wang et al., 2019; Vilches et al., 2017), as for instance recycled aggregates (Shooshtarian et al., 2022a, 2020; Silva et al., 2019).

Even considering a territorial analysis, it is important to be aware between distinct practices and strategies within different countries, even if they share the same cultural and legal background, as is the case of the European countries (European Commission, 2017). Some countries prioritise specific determining factors, according to their reality. This is the case in France, which opts to encourage a more sustainable materials market over time, intending to achieve competitiveness. In contrast, Brazil, in another reality, prioritises cost reduction for stakeholders, demonstrating a reality centred on the practical aspects of the problem of CDW management (Doussoulin and Bittencourt, 2022).

But one major concern in recent years lies in the circular economy concepts applied to the construction sector. Although confined to Australia, a literature review conducted by Shooshtarian et al. (2022c) demonstrated that in this area, the most relevant opportunities rely, in the first instance, on the design stage (substantiated in other contexts by Yao et al., 2022; Carpio et al., 2016; and Ajayi et al., 2015). Also in Australia, the lack of incentives, the absence of specific regulations, and knowledge gaps were identified as the main barriers to achieving the goals of the circular economy (Shooshtarian et al., 2022b).

In China, for instance, the constraints associated with the implementation of the circular economy are, again, related to the inadequate incentives from the government or inadequate policies to facilitate awareness-raising and education about CDW recycling; to reinforce the CDW legal framework; and to encourage the use of recycled products (Liu et al., 2021). In the same country, taxes and penalties (Wang et al., 2019; Tam et al., 2014), but also economic incentives, have been studied to determine the relative benefits to waste recycling operators. Furthermore, the recognition that several stakeholders are involved in the CDW value chain is a vital conclusion to be addressed in further studies (Liu et al., 2022), to comprehend roles and cooperation.

The varied selection of research projects mentioned above, each focusing on different research approaches and with distinct objectives, lead to the inevitable conclusion that each reality is different and needs to be tackled in association with the stakeholders involved, creating a solution where all feel motivated and part of the solutions in their specific realities. In this context, all the conclusions achieved are relevant in terms of creating a baseline for reflection and of the design of each research approach and initiative to be implemented. However, it is not possible to replicate exactly one reality from one country to another, or even from a region of the same country to another region.

2.2. The local reality

The evolution of the construction sector, dynamic over time, leads to an increase in challenges to CDW management in the context of a circular economy, particularly concerning the different scales and realities within the field (Zhang et al., 2022; Duan et al., 2019; Ghisellini et al., 2018). When considering smaller regions, instead of the national reality, other types of responsibilities and difficulties arise for CDW management (Esa et al., 2017). For example, the established literature reinforces several times the lack of technical knowledge as a barrier to CDW management (APA, 2018; Gangolells et al., 2014; Begum et al., 2009), also citing environmental awareness as another major determinant factor (Li et al., 2022). In this case, it is necessary to cooperate with local stakeholders in the context of proximity.

Even so, less attention in the field has been dedicated to social factors, where it is important to consider a system with a large number of variables and elements interacting and cooperating (Wehn et al., 2015; Yuan, 2013, 2012). Success will require an interdisciplinary approach, and Vasconcelos et al., (2020) highlights the importance of cooperation in participatory processes, facilitating an interactive and structured meeting, where the participation of stakeholders is inclusive, creative, and based on true dialogue. At the local scale, it means studying the direct intervention of municipalities (Santos et al., 2019; APA, 2018; Martinho et al., 2015) as well as micro and small construction companies (Ramos and Martinho, 2022, 2021). In both cases, there are specific responsibilities and characteristics. This is one of the main reasons for these stakeholders to be integrated into a participatory process regarding CDW management on a local scale.

In general, municipalities must frequently deal with the challenge of illegal dumping (Glanville and Chang, 2015), including CDW (Ramos and Martinho, 2023; Nagpure, 2019; Vaverková et al., 2019). For this waste stream, especially in the case of mixtures, frequently encountered in waste abandonment, there are high municipal costs associated with cleaning actions (Ramos and Martinho, 2023; Santos et al., 2019; Sobotka and Sagan, 2016). Also, D'Amato et al. (2018) emphasise that integrated waste policies and oversight actions are needed, in addition to territorial monitoring, to avoid illegal environmental practices. And the importance of specific law reinforcement is frequently raised (Duan et al., 2019; Mihai, 2019; Menegaki and Damigos, 2018).

In Portugal, the national waste authority invites the municipalities to collaborate, through questionnaires, to better understand CDW management practices. The latest results (APA, 2018) concluded that there are important constraints at a municipal level: legal framework compliance, implementation of good practices, procedural control for private and public construction works, CDW management collection, preliminary storage services, and oversight actions on construction sites.

Additionally, construction companies play an important role when planning CDW management on construction sites correctly (Penteado and Rosado, 2016), complying with legal and procedural control (Gangolells et al., 2014), as well delivering CDW to authorised final destinations (Begum et al., 2009). Medium and large construction companies participate more frequently in studies and have more organised and controlled procedures for CDW than micro and small companies (Ramos et al., 2014). In general, this relates to the fact that individual and cooperative determinants lead to such behaviour (Bakshan et al., 2017). Nevertheless, gaps in knowledge and a lack of awareness regarding CDW management seem to be barriers for all construction companies (Saez et al., 2013), although differences exist relative to company size (Gangolells et al., 2014; Begum et al., 2009).

This reality is similar in Portugal, where a study considering the construction company size concluded that micro and small construction companies, representing more than 95% of the total number of construction companies (IMPIC, 2020), face more difficulties, lacking knowledge, for instance, concerning the recycled aggregates value chain (Ramos and Martinho, 2022). Further still, there are very few specialised human resources dedicated to CDW management working on construction sites, again making this topic more penalising for micro and small entities (Ramos and Martinho, 2021).

The characteristics mentioned for municipalities and micro and small construction companies represent the main context of the CDW

management on a local scale, because these stakeholders are attributed with specific responsibilities, mainly with operational matters, in terms of practices and solutions; the reinforcement of and compliance with laws; the implementation and response of oversight actions; and the procedural control validation.

3. Method

3.1. Context of the study area

The research project was developed in Portugal, specifically in the European Nomenclature of Territorial Units for Statistics, level 3 (NUTS 3), region named *Baixo Alentejo*, in the South and interior of the country, composed of 13 municipalities. This rural region is 8,543 km^2, representing 9.3% of the country's area. It is characterized by a very low population density when compared to Portugal in general: 13.5 inhabitants per km^2 in contrast to 112.2 inhabitants per km^2 nationally (INE, 2022).

In Portugal, the legal framework regarding CDW is defined in the national law on waste, namely in the Decree-Law 102-D/2020, implemented on the 10th of December (PCM, 2020), with further amendments. Due to their relevance to this research, it is important to identify the following aspects that are currently mandatory, in articulation with the European Waste Framework Directive (Directive 2008/98/CE, of the European Parliament and of the Council, from 19th of November): (i) it is up to the CDW producer, in the first instance, to safeguard the final destination for CDW; (ii) the municipal system responsible for municipal waste management is responsible for the provision of solutions (*i.e.*, equipment, preliminary storage) to CDW arising from small repairs and minor do-it-yourself construction and demolition activities, within private households, carried out by the waste producer; (iii) waste separation is mandatory preceding waste disposal; (iv) CDW producers shall separate CDW on construction sites, into the following types: mineral fraction, metal, glass, plastic, wood, and gypsum; (v) CDW transportation shall be accompanied by an electronic waste monitoring guide; (vi) waste producers must comply with procedural control (CDW records), and this documentation shall be verified and shall condition the licensing processes for public construction works and private construction works subject to a municipal licensing process or prior notification; (vii) the use of recycled aggregates resulting from CDW must comply with technical specifications for the applications for which they are intended and validation of the procedures is the responsibility of the project manager or, alternatively, the lead construction worker; (viii) public construction works shall incorporate, at least, 10% of recycled materials; and (ix) projects and their execution shall privilege the adoption of methodologies and practices that favour selective demolition.

Despite the existence of this national legal framework, which is considered at a mature stage (European Commission, 2017), there are, amongst other problems, numerous occurrences of CDW illegal dumping (Ramos and Martinho, 2023; APA, 2018), particularly in rural areas, revealing that legislation alone is not sufficient to resolve local CDW management problems.

3.2. The research approach

3.2.1. The participatory workshops

In terms of compliance with the research objectives identified in the Introduction (chapter 1), six workshops were organised during 2021, divided into three sessions, with the following themes (Fig. 1): A – Constraints, solutions, and training needs regarding CDW management (April); B – Specific contributions to stimulate CDW management on a local scale (September); and C – Local solutions to promote circularity in the construction sector (December). These workshops were intended to

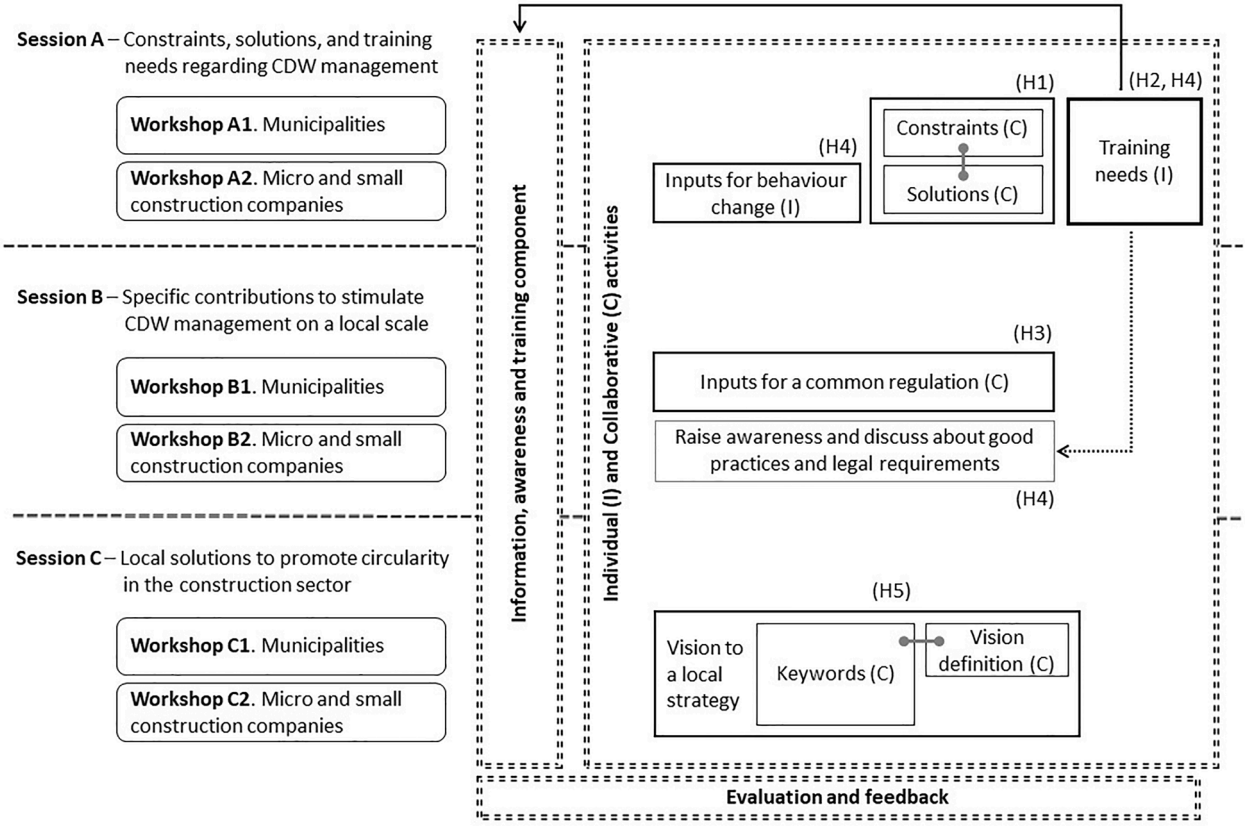

Fig. 1. Dynamic of the participatory process, within the hypotheses of the research project.
Legend: H – Hypothesis; C – Collective activity; I – Individual activity.

be delivered using a face-to-face model, but the objectives and methodology had to be adapted due to the Covid-19 pandemic. Supported by the organisation, each municipality was responsible for offering a safe environment to successfully run the workshops, adhering to national restrictions, and supplying the necessary equipment, such as audio-visual technology.

The workshops involved two interrelated elements, namely: an informative and training component; and individual or collaborative activities. To address the first element, each session's themes were explained to facilitate the subsequent activities and to introduce pre-selected topics, to essentially refresh concepts, update the regulatory framework, and demonstrate good practices.

Each workshop was designed to last three hours due to the limited availability of the participants and to maintain interest and encourage participation in the subsequent workshops. A municipal project representative was responsible for inviting the participants. For each workshop, virtual rooms were created in advance, one for each municipality. The contributions obtained and the analysis of the results were disseminated two weeks after each session.

3.2.2. The participants

Two groups of participants were involved in the workshops, as registered in Fig. 1 and Table 1. The first group was municipalities of the *Baixo Alentejo* region, with the interaction of technicians from three main intervention areas related to CDW management: environment, urbanism, and oversight actions. The second were representatives of micro and small construction companies from the *Baixo Alentejo* region. To reflect the reality and constraints, as identified in other research, faced by micro and small construction companies (Ramos and Martinho, 2021), the maximum size of the companies participating was the fourth Portuguese construction permit class (IMPIC, 2020). Construction companies' representatives were invited by each municipality.

3.3. Hypotheses

To assess the objectives of the research project, five hypotheses (H) were established to try to understand the local scale dynamics of CDW management, involving municipalities and micro and small construction companies (Fig. 1), namely the following: H1 – There are different perceptions between the two groups of participants about the constraints and solutions to promote CDW management; H2 – The two groups self-evaluate their training needs differently; H3 – Municipalities value new tools regarding the circular economy in the construction sector equally to those that have been discussed for some time; H4 – Micro and small construction companies might change their behaviour in line with the recognised constraints for this group and their self-evaluation of training needs; H5 – The two groups of participants have the same vision about the main aspects to be considered in a local strategy to promote CDW management.

3.4. Research instruments of analysis

3.4.1. Data collection and results presentation

The collaborative activities were adapted to each group, considering the intrinsic characteristics and the contributions evaluated as most relevant in each case. Whenever possible, the consensus in each municipality was aggregated instead of considering each distinct contribution from participants or combining the views of the entire group. This decision was made because of Covid-19 pandemic restrictions, and previous experience organising this type of workshop by videoconference in this context. In addition, this approach facilitated the execution of the scheduled program within the time proposed and benefited the communication and interaction between the participants in predetermined conditions.

The results presented correspond, in general, to a compilation of more specific contributions, reunited in terms of context evaluation. Specific insights are mentioned in the text, in the cases that benefit from more detail. When applicable, the contributions shared by the two groups of participants appear at the top of the figures, identifying conjoint visions, followed by the answers unique to each group, distinguishing issues affecting a specific reality.

For the group activities, the results are presented in terms of the frequency of answers gathered in each virtual room (municipality). The participants were asked to discuss the themes and to subsequently register their answers and consensus. For individual activities, as in the case of the training needs self-evaluation, and also the construction companies' behavioural changes assessment, Likert-type scales were used to evaluate and hierarchize the answers, using the median, because the data is discrete and this location statistic is robust.

3.4.2. Approach to understanding construction companies' behaviour

The development and implementation of the activity to understand behaviour change in construction companies, was evaluated using the "COM-B Model of Behaviour", developed by Michie et al. (2011), which considers behaviour change through three main components: capability, motivation, and opportunity. It is important to define the behaviours associated with each of the components, on which priority axes the actions should be based to address deficits, as well as the instruments to apply. The component "capability" is separated into the subcomponents "physical" (*i.e.,* physical capacity to execute), and "psychological" (*i.e.,* knowledge to perform it). The component "motivation" is split into the subcomponents "automatic" (*i.e.,* behaviour dependant on an instinctive/reactive decision or acquired habit), and "reflective" (*i.e.,* thoughtful attitude, for instance a reflection on the consequences of the action). The component "opportunity" is divided into the subcomponents "physical" (*i.e.,* physical resources available), and "social" (*i.e.,* for example, behaviour influenced by an external entity or authority, or even by an informal group).

In this research, this model was adapted considering the reality of the construction sector and, consequently, CDW management practices. To accomplish this assessment, 28 statements were presented to the

Table 1
Participants in the participatory actions.

Session	Municipalities' Workshops					Micro and small construction companies' workshops
	Municipalities hosting the workshop (n.°)	Municipal technicians involved (n.°)	Municipal technicians involved, by main intervention area (%)			Companies' representatives involved (n.°)
			Environment	*Urbanism*	*Oversight actions*	
A	13	40	50	25	25	41
B	13	36	42	36	22	21
C	10	42	45	29	26	14
Average	12	39	46	30	24	25

Legend: A – Constraints, solutions, and training needs regarding CDW management; B – Specific contributions to stimulate CDW management on a local scale; and C – Local solutions to promote circularity in the construction sector

participants, who then positioned them, on a Likert-type scale. The statements are presented and systematised in the Appendix A (Table 1).

3.4.3. Evaluation and feedback of the workshops

At the end of each workshop, participants were invited to submit individual and anonymous evaluations, as well as to leave suggestions for improvements. A Likert-type scale was used to assess the overall evaluation for each workshop. For the evaluation of specific components (*i.e.*, aspects that the participants liked the most, and those that they liked the least), the following pre-selected options were presented: structure and organisation, rhythm and dynamics, contents, activities, and utility. Participants were also allowed to express other opinions, through an open-answer question option. This evaluation was particularly important due to the limitations that the Covid-19 pandemic placed on the normal participatory process. In this case, the workshops were planned to use a face-to-face model and had to be adapted to function using videoconference technology.

4. Results and discussion

4.1. Constraints and solutions for construction and demolition waste management

The results for the main constraints and solutions for CDW management on a local scale were collected in session A and they were obtained from the two selected groups of participants. In the two cases, municipal technicians provided answers generally concerned with the multiple municipal responsibilities. Construction companies' representatives focused on more specific aspects, concerned with the construction activities themselves. These results, and the differences registered amongst the answers of the two groups relate to the specific natures of their actions in relation to CDW management and, as a consequence, the perceptions of the most challenging constraints differ.

Initially, participants were requested to contribute and discuss the constraints (Fig. 2). Both groups focused on aspects that are well documented in the literature, namely: the lack of municipal infrastructures or equipment for CDW preliminary storage, and the costs associated with CDW management (Menegaki and Damigos, 2018; Jung et al., 2015; Tam et al., 2014); and the lack of knowledge (Ramos and Martinho, 2022).

Specifically, municipalities recognise the lack of answers related to the following aspects: CDW collection and storage, in the region and at a municipal level; oversight action implemented by internal and external authorities with this legal responsibility; and the absence of resources to tackle these problems. The constraints presented highlighted, in most cases, specific topics that are recognised as part of the Portuguese reality (APA, 2018; Martinho et al., 2015): the lack of investment through time in infrastructure and equipment, from the municipality or inter-municipal agents; the lack of human resources; existing procedures to comply with legal orientations; and knowledge gaps that contribute to the difficulties in surpassing some of the challenges revealed.

Construction companies' representatives prioritised the constraints related to the implementation of good practice onsite for CDW management (Gangolells et al., 2014; Begum et al., 2009), in some cases related to not knowing how to act (*e.g.,* transport-orientated legal obligations), but also referring to time-consuming actions (*e.g.,* onsite obligatory CDW sorting). The lack of local solutions to reduce the transport distances to authorised final destinations was highlighted, and in this case with direct relation to the cost they support. They refer as well to the disparity between conditions imposed by municipalities to receive CDW, in line with the lack of criteria harmonisation, making actions sometimes more difficult to comply with. Specifically, the constraints related to the implementation of best practices is an important subject, and habit was identified as an important factor to improve and replicate, namely for micro and small construction companies (Ramos and Martinho, 2021).

In the second part of Session A, participants were invited to present and discuss solutions to resolve the constraints previously identified (Fig. 3). The conjoint vision was concerned with the following aspects: the creation or adaptation of decentralised controlled sites for CDW management and construction materials to be reused; the availability of adequate equipment; and the promotion of information, awareness, and training campaigns for different types of waste producers (*i.e.,* individuals, construction companies, and the municipality itself), involving municipal technicians, and political players, that have the power to make decisions on solutions and investment. In the case of the conjoint solutions proposed, they were in line with the constraints and solutions previously identified in the literature (for example by Yao et al., 2022; Saez et al., 2013; Begum et al., 2009).

Municipalities highlight other important aspects related to their responsibilities, namely: the reinforcement of legal frameworks at a municipal level, through the municipal regulation for waste

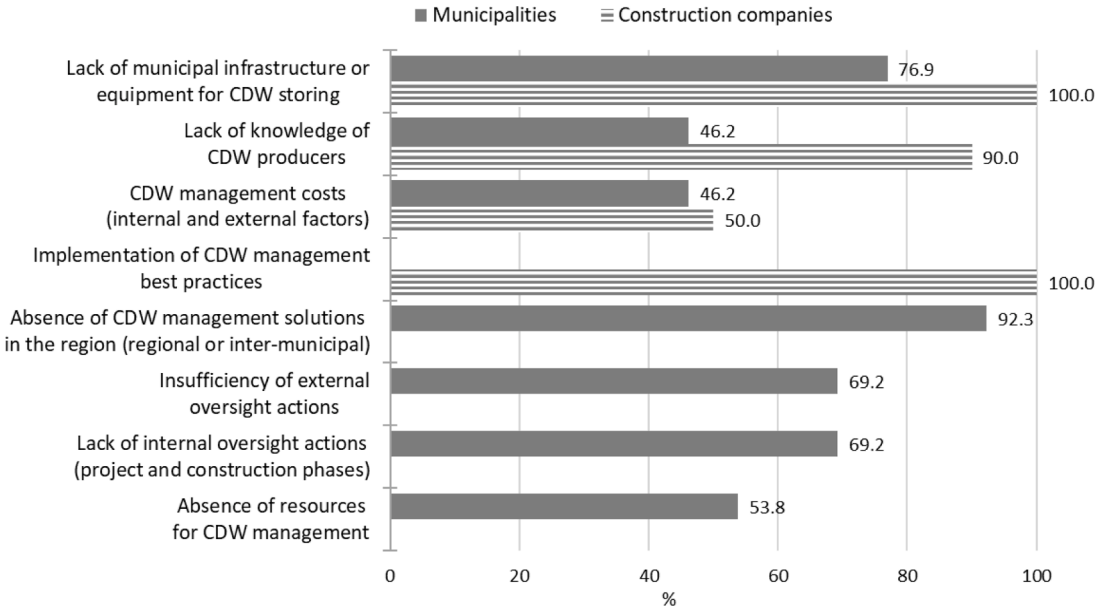

Fig. 2. Identified constraints to promote construction and demolition waste management on a local scale.

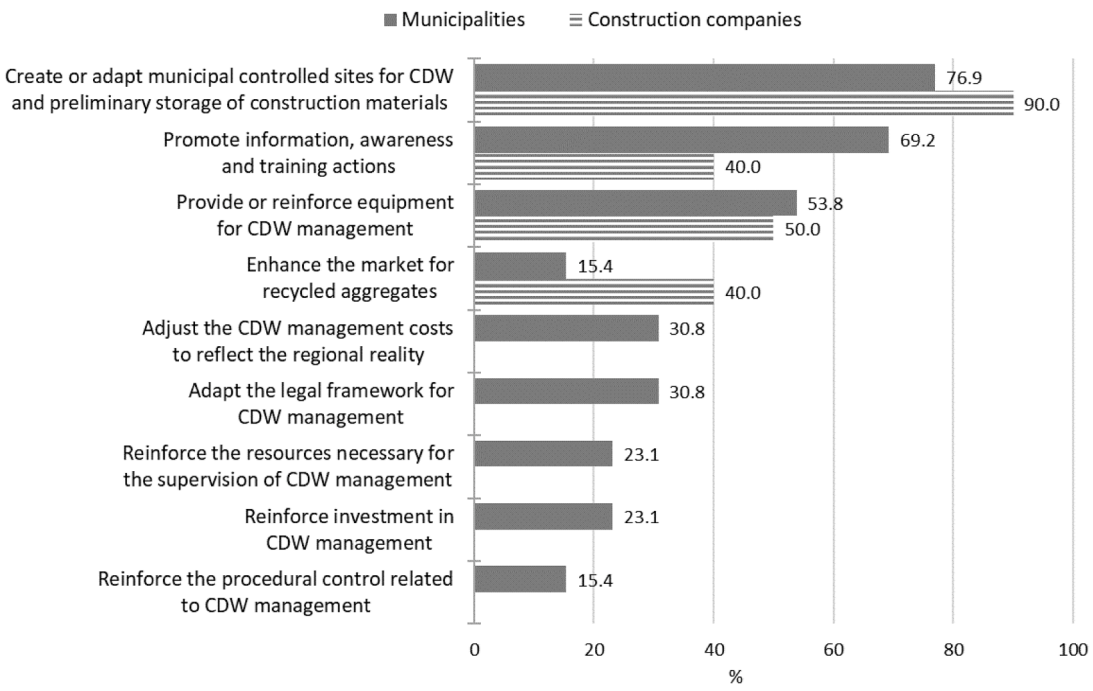

Fig. 3. Identified solutions to promote construction and demolition waste management on a local scale.

management and edification rules, which is related to the procedural control of CDW management in private and public construction works. This is due to national legal orientation, in Portugal, but is also related to the tariff defined for different cases in some municipalities, which is perceived as an important topic to be regulated. They add the need for necessary investment to tackle the lack of infrastructure, equipment, and human resources. It is recognised in the literature that these solutions improve CDW management in practice (Mihai, 2019; Menegaki and Damigos, 2018).

Construction companies' representatives highlight the proximity of CDW preliminary storage solutions, which are important in terms of operational aspects and cost, but also the investment in equipment. They think it is essential to enhance the local market for recycled aggregates (corroborated by Shooshtarian et al., 2021, 2020; European Commission, 2017), referring specifically to the distances to these facilities. This is often mentioned when relating to the constraints of the construction sector in general (context of the cost consideration, for instance, by Wang et al., 2019), but not so common when regarding construction companies' concerns, particularly when considering micro and small entities. In Portugal there are important knowledge gaps about recycled aggregates (Ramos and Martinho, 2022), nevertheless, the conjoint opinion is that this solution must be optimised. This could be because the transport distances in the *Baixo Alentejo* region penalise the acquisition of the raw materials as well, in terms of availability and transportation cost.

4.2. Training needs

A self-evaluation of training needs was performed during session A, to better understand knowledge gaps. Participants of both groups were asked to position themselves on a Likert-type scale, individually, regarding each pre-selected topic. Some of the topics related predominantly to the reality of larger construction companies and so were excluded from the pre-selected topics offered to the micro and small construction companies' representatives (Table 2).

In general, knowledge gaps were perceived in both groups concerning good practice for CDW management on construction sites (substantiated by Menegaki and Damigos, 2018; Begum et al., 2009), although this had greater relevance for municipal technicians. In particular, oversight procedures is also an essential topic to take into consideration regarding municipal technicians. This evidence is understandable as these municipal responsibilities have also been identified as

Table 2
Training needs self-evaluation.

Topic	**Statistical analysis** (using a 5-point Likert-type scale between 1 "very unnecessary" and 5 "very necessary")							
	Municipalities				**Construction companies**			
	Median	**Minimum**	**Maximum**	IQR	**Median**	**Minimum**	**Maximum**	IQR
Good practices for CDW management on construction sites	5	4	5	1	4	3	5	1
Legal framework for CDW management, in general	4	4	5	1	4	1	5	1
Legal framework, specifically for CDW containing asbestos	4	3	5	1	4	1	5	1
Reuse of construction materials	4	3	5	0	4	1	5	1
CDW composition and identification	4	2	5	1	4	1	5	0
Incorporation of recycled materials on construction sites	4	3	5	1	4	1	5	1
Technical specifications for incorporating recycled CDW onsite	4	4	5	1	4	1	5	0
CDW transport and electronic waste monitoring guides (e-GAR)	4	2	4	1	4	1	5	2
CDW final destinations	4	2	5	0	4	1	5	0
Oversight procedures for CDW management	5	4	5	1	N.A.	N.A.	N.A.	N.A.
CDW procedural control for private and public construction works	4	4	5	0	N.A.	N.A.	N.A.	N.A.
Communication approaches, for instance regarding oversight actions	4	4	5	0	N.A.	N.A.	N.A.	N.A.

Legend: IQR - InterQuartile Range; N.A. – Not Applicable.

constraints. Moreover, it can be related to the knowledge gaps about: interaction with construction companies on construction sites, raising awareness, and legal requirements about supervision. But the self-evaluation demonstrates that there is a need for training on a wide-range of topics amongst the two groups (corroborated, for instance, by Ramos and Martinho, 2021, 2022).

These results collected during session A were assessed to organise the information, awareness, and training component of the workshops from sessions B and C. For example, in session B the micro and small construction companies' representatives had more time dedicated to a presentation and discussion of good practices for CDW management on construction sites, but also about legal requirements and their consequences, for instance penalties (Fig. 1).

4.3. Specific contributions to improve construction and demolition waste management

4.3.1. Municipalities' input for a common regulation

Municipalities have responsibilities regarding the legal framework to local actors. In this sense, contributions from municipal technicians were collected during a collaborative activity developed during session B. The answers received from each municipality were agglomerated into wider groups of statements, presented in Fig. 4. It is observed that services for CDW collection and preliminary storage, as well as tariff issues, are priorities for legal enforcement on a local level.

These statements rely on specific contributions, most of the time interrelated, namely the necessity to specify criteria for: CDW origin types to receive; CDW collection and management operations to provide and regulate; typologies of equipment to make available for adequate CDW temporary storage; breakdown the tariff (corroborated by Tam et al., 2014), by type of waste; and criteria to the reuse of construction materials. These topics are generally aligned with the Portuguese municipalities' main concerns regarding CDW management law enforcement (APA, 2018).

Nonetheless, important subjects related to the implementation of principles of the circular economy in the construction sector, for example the concept and processes related to selective demolition (or deconstruction), and tools such as pre-demolition audits, or even a materials passport (European Commission, 2016, 2017), seem to arouse less interest in municipal technicians. This is maybe because they are relatively new topics being discussed in Portugal, although they have been implemented in other European countries for some years (European Commission, 2017).

4.4. Construction companies' input to behavioural change

First, during Session A, micro and small construction companies were invited to explain their frequent construction activity dynamics. In Fig. 5 the results are presented, showing that the majority of their construction activity is undertaken locally, specifically within the *Baixo Alentejo* region (90%), within the same municipality as their company headquarters, or in contiguous municipalities (87%). These results show the importance of the existence of local solutions for CDW management, identified in the constraints and solutions (subchapter 4.1).

Session A's main activity was designed to try to comprehend how to act and communicate with micro and small construction companies, solving their knowledge gaps and improving their local practices, but also recognising that the habit is necessary for behavioural changes (Ramos and Martinho, 2021). A set of statements were presented, and individual participants were invited to position themselves, relative to each statement, on a Likert-type scale. The main results express the level of agreement of these companies' representatives (Table 3, and Appendix A - Table A1).

Especially in more sensitive statements from the point of view of irregular practices analysis, companies may have responded in ways that make them appear meritable, rather than entirely accurately. Nevertheless, during this activity it was frequently emphasised that the objective was to report the experience of each company without judgement. In this context, some results obtained do not corroborate the conclusions of other studies or contributions from the same participants in other activities.

It is the case that most companies feel motivated and recognise the importance and frequency of CDW sorting onsite, although it is infrequently carried out on construction sites (stated by Tam et al., 2018). The recognition by most companies that they must comply with technical standards for the use of recycled aggregates, contradicts the results presented about knowledge gaps by Ramos & Martinho (2022). Moreover, in terms of good practices and legal requirements compliance, there are important differences between what companies declare that they execute and what they self-evaluate in their training needs (subchapter 4.2), and the findings in wider literature (Gangolells et al., 2014). In this context, more care must be taken when interpreting some

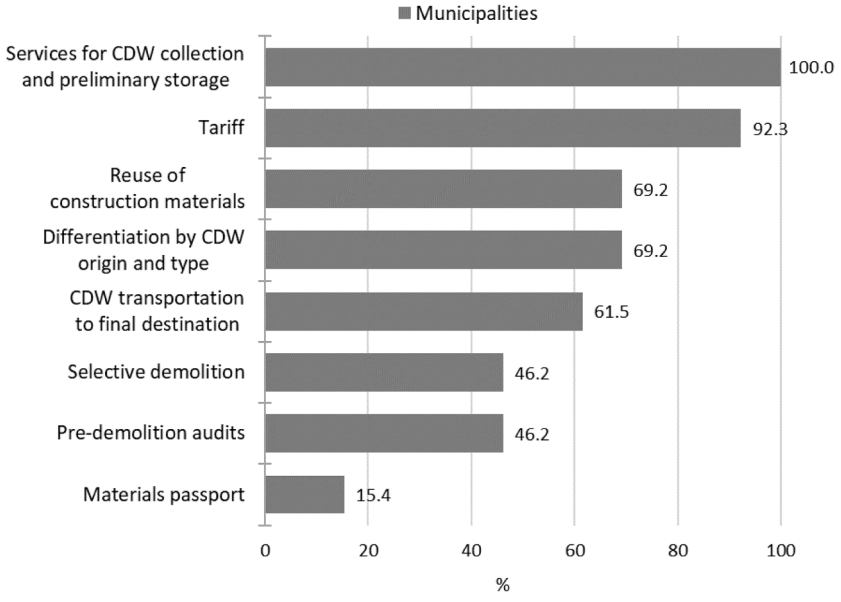

Fig. 4. Topics to consider on a common regulation for construction and demolition waste management on a local scale.

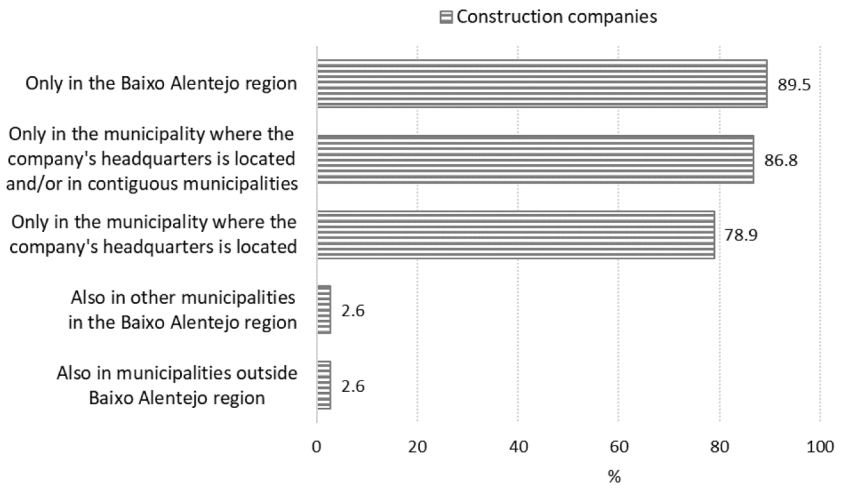

Fig. 5. Construction activity dynamic for micro and small construction companies in the *Baixo Alentejo* region.

of these results, mainly because of the incongruences noticed.

In alignment with the literature (Sobotka and Sagan, 2016), some micro and small construction companies' representatives do not associate CDW sorting onsite with the cost optimisation for CDW treatment. Also, the close relationship with oversight actions supervisors seems to be a factor influencing consequent actions on construction sites, because they can be understanding of irregular occurrences. This situation is important because oversight actions are rarely implemented, due to a lack of human resources (APA, 2018). And this evidence makes supervision of construction sites and subsequently an improvement in good practices even more challenging.

A good portion of the companies state that they feel motivated to reuse construction materials. On the other hand, the perception of recycled materials by clients seems to have more importance than the confidence that micro and small construction companies have in using them. These results are in line with the conclusions of Ramos and Martinho (2022), so it is important to more thoroughly explore the causes behind this finding, to actively improve the situation.

CDW abandonment is recognised as a problem resulting from the construction activity developed by this group of participants, but not with the impact level expected that is reflected in the literature internationally (Nagpure, 2019; Vaverková et al., 2019; Glanville and Chang, 2015), and within Portugal (Ramos and Martinho, 2023; Santos et al., 2019; Martinho et al., 2015; De Melo et al., 2011). Additionally, it is understood as connected to the lack of local solutions for CDW preliminary storage, but some of the companies also suggest that external pressures (*e.g.,* society) do not recognise the importance of this problem, a further barrier to positive change.

4.5. Vision to a local strategy

Bearing in mind local strategies to promote the circular economy in the construction sector, results were gathered in session C from both groups of participants. In the first phase, this task was performed specifically through participants nominating relevant keywords to incorporate into the vision definition. As previously noted, municipal technicians identify a broader range of topics, and the representatives of micro and small construction companies were more narrowly focused. Again, these results and the differences registered amongst some answers from the two groups are related to the specific natures of their actions in relation to CDW management.

Results demonstrate that proximity solutions and related CDW management conditions, the cost factor, but also the information, awareness, and training component are important subjects that participants from both groups agree on, although in some cases in different proportions (Fig. 6). It is essential to note that "cooperation" (*i.e.,* stakeholders and their relations) is the most important keyword for municipal technicians, which is in line with literature outcomes (Santos et al., 2019). On the other hand, the proximity context for CDW management solutions, and the adequacy of cost are the most relevant subjects for construction companies (corroborated by Mihai, 2019), in this case for micro and small entities' representatives.

In a second phase, only municipalities were invited to contribute with a definition representing their vision of a local scale strategy to tackle the problems for a circular economy approach, reuniting all the keywords previously identified in each working group. For example, one municipality defined the following vision: "*To implement a logic of sustainability, raising awareness of the construction companies and the entities involved, and the implementation of a network for CDW collection, promoting proximity between the players.*" Another municipality contributed with the following: "To *find a solution that involves articulation between entities, seeking to raise awareness to all of those involved in the process. In addition to legal requirements, it must identify the costs and benefits of the principles of the circular economy in the construction sector.*"

5. Participatory processes evaluation in the context of the Covid-19 pandemic

At the end of each workshop, participants were invited to evaluate the event, in an anonymous and confidential format. In this section, the conclusions from the six workshops (organised in three sessions) are presented as a whole, to facilitate the understanding of the participatory process dynamics, but also to avoid detailing specific aspects associated with each session.

The overall evaluation of each workshop was measured on a 7-point Likert-type scale, between 1 "very bad", and 7 "very good". For this

Table 3
Micro and small construction companies' main inputs to behavioural change.

Topics	**Construction companies' inputs, on a positive approach** (Median, on a 6-point Likert-type scale, between 1 "strongly disagree", and 6 "strongly agree")
Planning about CDW management	The companies demonstrate more knowledge gaps related to CDW management costs estimation (4) than with the quantities and types of CDW estimation that construction site will generate (5). The cost reduction through the correct CDW sorting onsite is a motivation for a large part of the companies (5), and a good proportion of them often include CDW management costs in their budgets (5). Some companies lack skilled workers, with environmental related technical knowledge (4), and part of them do not have frequent and facilitated access to the clarification of doubts, from internal or external sources (4).
CDW sorting and storage on construction sites	There is a good level of knowledge about the mandatory legal requirement for CDW sorting on construction sites (6), the proper CDW containing asbestos management (6), and the competencies of supervision entities regarding CDW management (5). There is a motivation from most of the companies to undertake CDW sorting at construction sites, as they assume it is a frequent practice in the company (5), contributing to the legal obligation to proceed in this way (6) and, to a lesser extent, the costs reduction associated (5). A considerable proportion of companies recognise that there is a close relationship with supervisors, who can be understanding about irregular situations (5). A good part of companies can easily provide equipment to properly store the CDW (4).
Reuse of construction materials and incorporation of recycled materials	A good proportion of the companies respond that they feel motivated to reuse construction materials (5). Most companies agree that they must comply with technical standards for the use of recycled aggregates (5). A large proportion of the companies feel motivated to use recycled aggregates, due to the confidence they feel in these materials (5), but some of them are reluctant to use them due to the clients' perceptions (4).
CDW transportation and final destination	A good proportion of the companies recognise knowing that, in Portugal, CDW transport has to be accompanied by an electronic monitoring waste guide (5), that they have to send CDW to final licensed destinations (5), and that the penalties are high for illegal dumping (6). It is a motivation for companies to use electronic waste monitoring guides (e-GAR), due to the perception, in most cases, that they are frequently supervised (5), to send CDW to waste management operators as a common practice (5), but also because some of them have concerns about what happens to CDW in final destinations (5). Regarding CDW illegal dumping, few companies recognise that they do it (2), but they understand that CDW dumpsites would be less widespread if more equipment and infrastructure existed (6). Certain companies acknowledge information and awareness campaigns focusing on CDW illegal dumping (4) and some of them perceive that society does not attribute great importance to these occurrences (4).

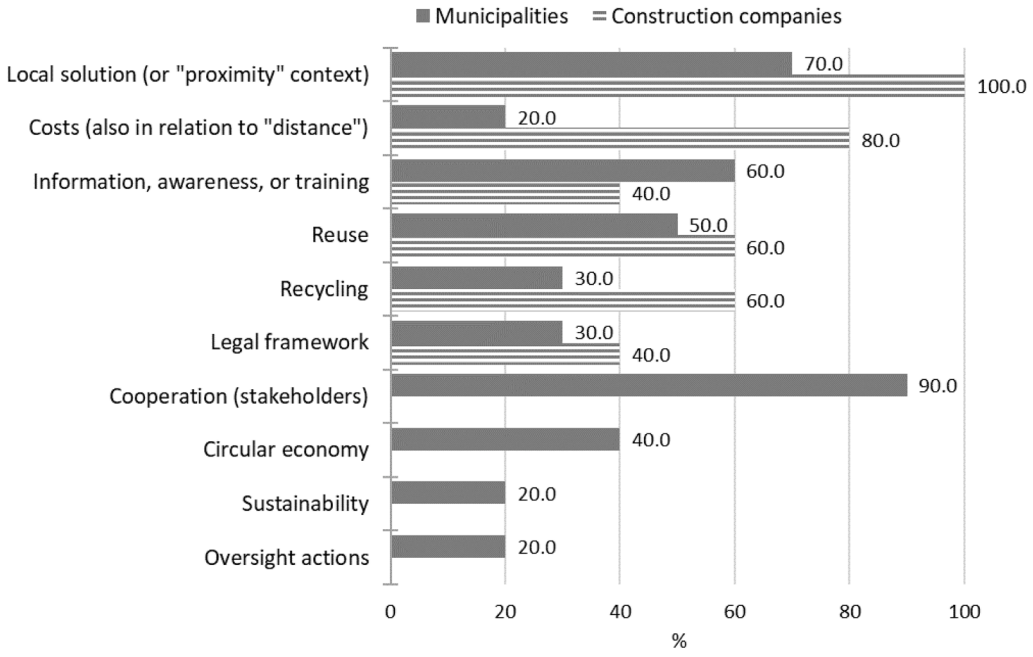

Fig. 6. Keywords to the vision definition about local solutions to promote circularity in the construction sector.

assessment, it was considered 75 responses received from municipal technicians, and 69 answers from micro and small construction companies' representatives that wanted to participate in this component. For the three workshops dedicated to municipal representatives, the median was 6 (minimum: 2; maximum: 7; interquartile range: 1). For the three workshops for micro and small construction companies, the median was also 6 (minimum: 1; maximum: 7; interquartile range: 0). The conclusions are good and demonstrate that the workshops fulfilled a significant portion of the objectives proposed.

Firstly, the aspects of the workshops that participants liked the most were evaluated. For municipal representatives, it was the structure and organisation (59%), but also the contents (51%). For micro and small construction companies' representatives, the tendency was the same, represented in this case by structure and organisation (72%), utility (62%), and contents (55%). This evidence is motivating, not only due to limitations that arose amidst the Covid-19 pandemic restrictions, but also because it demonstrates utility, interest, and motivation from the participants, where it is clear that a good number of them want to feel

engaged in the solutions that are being proposed and evaluated.

Subsequently, participants were asked about the aspects they liked the least, and for both municipal representatives and the representatives of micro and small construction companies, the consensus was rhythm and dynamics (33% and 11%, respectively). Activities were also a factor for a small number of participants (14% and 10%, respectively for municipalities and companies' representatives). In this case, it represents some constraints of logistics and sound and image conditions that were observed in some municipalities, but it is also justified by the lack of interest that is a reality in this type of processes. Nevertheless, the fact that these workshops were undertaken by videoconference is considered the major factor influencing the motivation, at least for some of the participants responding this way.

In the last workshop dedicated to municipalities, it was interesting to note that, although it is often difficult to involve municipal technicians in these participatory processes, due to their agendas, in the last session (session C), 41% of the participants responded that they had participated in at least in one previous session (A or B), which demonstrates an interest in being involved frequently in this research. This was not possible to evaluate in the last workshop dedicated to micro and small construction companies' representatives, because only a small number of participants were present due to Covid-19 restrictions and due to the extreme weather conditions that happened the day before, affecting ongoing construction projects. And in this case, unfortunately, it was not possible to reschedule the session.

6. Conclusions

In the *Baixo Alentejo* region, a rural Portuguese region, with a low population density and a lack of CDW treatment infrastructure, municipal technicians and representatives of micro and small construction companies were involved in six videoconference participatory workshops. These did not take place in person due to Covid-19 pandemic, which was a uniquely challenging period to develop this type of project. The main objectives were to better understand the common but also the unique challenges and constraints faced by stakeholders, and how to implement solutions to promote effective CDW management on a local scale.

The innovation of this research lies in the fact that it was possible to involve local stakeholders in several participatory workshops, which allowed for the identification of problems and the opportunity for the co-building of solutions adapted to the reality of rural or less developed areas. Although some of the findings might be perceived as intuitive and identified at other scales of analysis and in other contexts, they have not been studied from a research perspective, with a pre-established line of reasoning, and a consideration of the comparison of contributions from stakeholders on a local scale. This was a new approach to a participatory process, addressing this collective problem regarding an operational component of CDW management. Also, it was possible to collect data with the intention of filling in knowledge gaps on smaller scales, where the absence of this type of systematised information makes the decision making process more difficult, whether it is technical or political. Moreover, this participatory process allowed stakeholders to feel valued and motivated to participate, according to the evaluation made. And this approach contributes to long-lasting positive effects.

In terms of results, the constraints identified by the two groups were essentially associated with the lack of local infrastructure and equipment to facilitate CDW management, the distances that increment cost, as well as the knowledge gaps. Additionally, municipal technicians valued the absence of regional or inter-municipal solutions, as well as the absence of oversight actions. In turn, construction companies' representatives prioritised the difficulties of applying good practices onsite. For the vision to promote better local conditions to enhance CDW management, the key factors identified were the concept of proximity, the cooperation between stakeholders, and the adequacy of costs. Additionally, training needs were identified, there being a consensus about the necessity to promote training actions in several areas of CDW management, but with a focus on good practices on construction sites and oversight procedures. These were deemed particularly important when considering the self-evaluation of the municipal technicians.

Specifically, recent solutions and tools aiming to promote circularity in the construction sector, such as selective demolition and pre-demolition audits, are less well-regarded for planning issues by municipal technicians. On the other hand, it is understood that the representatives of micro and small construction companies have difficulty in sharing recognised intrinsic practices and constraints in more sensitive matters, such as CDW illegal dumping and, because of that, it is recommended that these parts of the results must be used carefully.

For future research projects, it is recommended that municipal technicians and the representatives of micro and small construction companies have the opportunity to debate their ideas together, trying to achieve consensus about the prioritisation of the compromises and solutions proposed to CDW management on a local scale. Moreover, because the current sessions were more focused on the operational issues, a subsequent phase should involve political actors, those who must consider technical alternatives and make decisions about planning, types of investment, and the governance models.

CRediT authorship contribution statement

Mário Ramos: Project administration, Conceptualization, Methodology, Investigation, Validation, Formal analysis, Writing – original draft, Writing – review & editing. **Graça Martinho:** Funding acquisition, Supervision, Resources, Conceptualization, Writing – review & editing. **Lia Vasconcelos:** Conceptualization. **Filipa Ferreira:** Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

The authors would like to thank the municipal technicians and the representatives of the construction companies who collaborated in this participatory process.

The authors acknowledge financial support from the "(De)construct for Circular Economy" project, financed by the EEA Grants Environment Program (08_Call#2_(Des)construir_Economia_Circular). This work was also supported by the Portuguese *Fundação para a Ciência e a Tecnologia* (FCT) under the project LA/P/0069/2020 granted to the Associate Laboratory ARNET, and the strategic project UIDB/04292/2020 granted to MARE - Marine and Environmental Sciences Centre.

Appendix A

Table A1
Questions from the activity about micro and small construction companies' inputs to behavioural change.

Topic	Statement	COM-B component	N	Statistical analysis (using a 6-point Likert-type scale, between 1 "strongly disagree" and 6 "strongly agree")			
				Median	Minimum	Maximum	IQR
Planning about CDW management	We know how to estimate the amount and type of CDW that a construction site will generate.	Capability	40	5	1	6	2
	What motivates us to plan CDW management for a construction site is the possibility of this practice enabling cost reduction for the company.	Motivation	41	5	1	6	3
	It is common practice for the company to include the costs associated with the CDW management in the budget for a construction work.	Motivation	39	5	1	6	3
	It is easy to access information and resources to clarify doubts about CDW management onsite (internal and external sources).	Opportunity	39	4	1	6	13
	We know how to estimate the costs of conditioning, transportation, and treatment of CDW.	Capability	41	4	1	6	2
	We have qualified technicians to estimate the amount and type of CDW that a construction site will generate, as well as the associated costs.	Opportunity	40	4	1	6	4
CDW sorting and storage on construction sites	We know that according to the legal framework it is mandatory to separate the CDW on construction sites.	Capability	41	6	1	6	1
	We know that CDW with asbestos must be managed with specific mandatory criteria.	Capability	39	6	1	6	1
	We always separate the various types of CDW onsite because we want to avoid penalties.	Motivation	40	6	1	6	1
	We separate the CDW onsite as it is a frequent practice in the company.	Motivation	40	5	1	6	1
	We know that authorities have the competence to supervise our procedures for CDW management.	Capability	40	5	2	6	2
	We always separate the different types of CDW onsite because it represents less costs for the company.	Motivation	40	5	1	6	2
	We have good relations with the local supervision authorities, so we feel that they have a benevolent/understanding attitude towards us in irregular situations.	Motivation	41	5	1	6	2
	We easily supply the equipment that allows us to condition the CDW onsite.	Opportunity	41	4	1	6	2
Reuse of construction materials and incorporation of recycled materials	We often reuse construction materials because we consider them to be advantageous in environmental terms.	Motivation	41	5	1	6	2
	We know that recycled aggregates resulting from CDW must comply with specific standards for their use.	Capability	41	5	1	6	1
	We often use recycled aggregates resulting from CDW because we feel confident in their use.	Motivation	41	5	1	6	1
	We are afraid to use recycled materials due to the perception that the client may have about their use and the final result.	Motivation	40	4	1	6	2
CDW transportation and final destination	We know that the transport of CDW must be accompanied by an electronic waste monitoring guide (e-GAR).	Capability	41	5	1	6	2
	There would be fewer occurrences of CDW abandonment if there was more equipment or infrastructures for preliminary storage and treatment.	Opportunity	40	6	1	6	1
	We know that the penalties applied to those who abandon CDW are very high.	Capability	40	6	1	6	1
	We know that it is mandatory to send the CDW generated to an authorised final destination	Capability	41	5	1	6	2
	The transportation of CDW to an authorised waste management operator to receive and treat it is common practice.	Motivation	41	5	1	6	12
	We are concerned about electronic waste monitoring guide (e-GAR) because it is frequently supervised by authorities.	Motivation	40	5	1	6	2
	We care about what happens to CDW after delivering it to a waste management operator, because we want to ensure it is treated correctly.	Motivation	40	5	1	6	2
	In general, society attributes great importance to CDW illegal dumping.	Opportunity	41	4	1	6	3
	Sufficient information and awareness campaigns are addressing CDW illegal dumping.	Opportunity	40	4	1	6	2
	We often abandon CDW because we are unable to manage it onsite, in terms of the necessary equipment or costs	Opportunity	40	2	1	6	3

IQR-InterQuartile Range

References

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A., Owolabi, H.A., Kadiri, K. O., 2015. Waste effectiveness of the construction industry: understanding the impediments and requisites for improvements. Resour. Conserv. Recycl. 102, 101–112. https://doi.org/10.1016/j.resconrec.2015.06.001.

Al-Otaibi, A., Bowan, P.A., Abdel daiem, M.M., Said, N., Ebohon, J.O., Alabdullatief, A., Al-Enazi, E., Watts, G., 2022. Identifying the barriers to sustainable management of construction and demolition waste in developed and developing countries. Sustainability 14, 7532. https://doi.org/10.3390/su14137532.

APA, 2018. Construction and demolition waste management - summary of survey responses to Portuguese municipalities, 2018 (in Portuguese: gestão de resíduos de construção e demolição – resumo das respostas ao inquérito aos municípios, 2018. Agência Portuguesa do Ambiente (Portuguese Environment Agency). Portugal. Available (in Portuguese) at: https://apambiente.pt/sites/default/files/_Residuos/FluxosEspecificosResiduos/RCD/Inquerito_2018_e_compilacao.pdf.

Bakshan, A., Srour, I., Chehab, G., El-Fadel, M., Karaziwan, J., 2017. Behavioral determinants towards enhancing construction waste management: a Bayesian Network analysis. Resour. Conserv. Recycl. 117, 274–284. https://doi.org/10.1016/j.resconrec.2016.10.006.

Begum, R.A., Siwar, C., Pereira, J.J., Jaafar, A.H., 2009. Attitude and behavioral factors in waste management in the construction industry of Malaysia. Resour. Conserv. Recycl. 53, 321–328. https://doi.org/10.1016/j.resconrec.2009.01.005.

Bovea, M.D., Powell, J.C., 2016. Developments in life cycle assessment applied to evaluate the environmental performance of construction and demolition wastes. Waste Manag. 50, 151–172. https://doi.org/10.1016/j.wasman.2016.01.036.

Carpio, M., Roldán-Fontana, J., Pacheco-Torres, R., Ordóñez, J., 2016. Construction waste estimation depending on urban planning options in the design stage of residential buildings. Constr. Build. Mater. 113, 561–570. https://doi.org/10.1016/j.conbuildmat.2016.03.061.

D'Amato, A., Mazzanti, M., Nicolli, F., Zoli, M., 2018. Illegal waste disposal: enforcement actions and decentralized environmental policy. Socioecon. Plann. Sci. 64, 56–65. https://doi.org/10.1016/j.seps.2017.12.006.

De Melo, A.B., Gonalves, A.F., Martins, I.M., 2011. Construction and demolition waste generation and management in Lisbon (Portugal). Resour. Conserv. Recycl. 55, 1252–1264. https://doi.org/10.1016/j.resconrec.2011.06.010.

Devaki, H., Shanmugapriya, S., 2022. LCA on construction and demolition waste management approaches: a review. Mater. Today Proc. 65, 764–770. https://doi.org/10.1016/j.matpr.2022.03.286.

Ding, Z., Yi, G., Tam, V.W.Y., Huang, T., 2016. A system dynamics-based environmental performance simulation of construction waste reduction management in China. Waste Manag. 51, 130–141. https://doi.org/10.1016/j.wasman.2016.03.001.

Ding, Z., Zhu, M., Tam, V.W.Y., Yi, G., Tran, C.N.N., 2018. A system dynamics-based environmental benefit assessment model of construction waste reduction management at the design and construction stages. J. Clean. Prod. 176, 676–692. https://doi.org/10.1016/j.jclepro.2017.12.101.

Doussoulin, J.P., Bittencourt, M., 2022. How effective is the construction sector in promoting the circular economy in Brazil and France? : A waste input-output analysis. Struct. Chang. Econ. Dyn. 60, 47–58. https://doi.org/10.1016/j.strueco.2021.10.009.

Duan, H., Miller, T.R., Liu, G., Tam, V.W.Y., 2019. Construction debris becomes growing concerns of growing cities. Waste Manag. 83, 1–5. https://doi.org/10.1016/j.wasman.2018.10.044.

Esa, M.R., Halog, A., Rigamonti, L., 2017. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. J. Mater. Cycles Waste Manag. 19, 1144–1154. https://doi.org/10.1007/s10163-016-0516-x.

European Commission, 2017. Resource-efficient use of mixed wastes. Improving management of construction and demolition waste. Developed for the European Commission (Directorate-General for Environment) by the consortium led by Deloitte, in partnership with BRE, ICEDD, RPS, VTT and FCT NOVA. Luxembourg: publications Office of the European Union. Available at: https://op.europa.eu/en/publication-detail/-/publication/78e42e6c-d8a6-11e7-a506-01aa75ed71a1/language-en.

European Commission, 2016. European Union construction and demolition waste management protocol. European Commission. Available at: https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en.

Ferkany, M., Whyte, K.P., 2012. The importance of participatory virtues in the future of environmental education. J. Agric. Environ. Ethics 25, 419–434. https://doi.org/10.1007/s10806-011-9312-8.

Gangolells, M., Casals, M., Forcada, N., Macarulla, M., 2014. Analysis of the implementation of effective waste management practices in construction projects and sites. Resour. Conserv. Recycl. 93, 99–111. https://doi.org/10.1016/j.resconrec.2014.10.006.

Ghisellini, P., Ripa, M., Ulgiati, S., 2018. Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. a literature review. J. Clean. Prod. 178, 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207.

Glanville, K., Chang, H.C., 2015. Remote sensing analysis techniques and sensor requirements to support the mapping of illegal domestic waste disposal sites in Queensland, Australia. Remote Sens. 7, 13053–13069. https://doi.org/10.3390/rs71013053.

Gutberlet, J., 2015. More inclusive and cleaner cities with waste management co-production: insights from participatory epistemologies and methods. Habitat Int. 46, 234–243. https://doi.org/10.1016/j.habitatint.2014.10.004.

Hornsby, C., Ripa, M., Vassillo, C., Ulgiati, S., 2017. A roadmap towards integrated assessment and participatory strategies in support of decision-making processes. The case of urban waste management. J. Clean. Prod. 142, 157–172. https://doi.org/10.1016/j.jclepro.2016.06.189.

IMPIC, 2020. Report for the construction sector in Portugal, 2020 (in Portuguese: relatório do Setor da Construção em Portugal, 2020). Portuguese Institute of Public Markets, Real Estate and Construction. Available at (in Portuguese): https://www.impic.pt/impic/assets/misc/relatorios_dados_estatisticos/Rel_Anual_Constr_2020.pdf.

INE, 2022. Territorial and demographic statistics. Statistics Portugal. Portugal. Available at: http://www.ine.pt.

Jung, J., Song, S., Jun, M., Park, S., 2015. A comparison of economic feasibility and emission of carbon dioxide for two recycling processes 19, 1248–1255. https://doi.org/10.1007/s12205-015-0708-2.

Kabirifar, K., Mojtahedi, M., Wang, C., Tam, V.W.Y., 2020. Construction and demolition waste management contributing factors coupled with reduce, reuse, and recycle strategies for effective waste management: a review. J. Clean. Prod. 263, 121265 https://doi.org/10.1016/j.jclepro.2020.121265.

Le, H.B., Bui, Q.B., 2020. Recycled aggregate concretes – A state-of-the-art from the microstructure to the structural performance. Constr. Build. Mater. 257, 119522 https://doi.org/10.1016/j.conbuildmat.2020.119522.

Liu, J., Gong, E., Wang, X., 2022. Economic benefits of construction waste recycling enterprises under tax incentive policies. Environ. Sci. Pollut. Res. 29, 12574–12588. https://doi.org/10.1007/s11356-021-13831-8.

Liu, J., Wu, P., Jiang, Y., Wang, X., 2021. Explore potential barriers of applying circular economy in construction and demolition waste recycling. J. Clean. Prod. 326, 129400 https://doi.org/10.1016/j.jclepro.2021.129400.

Liu, J., Yi, Y., Wang, X., 2020. Exploring factors influencing construction waste reduction: a structural equation modelling approach. J. Clean. Prod. 276, 123185 https://doi.org/10.1016/j.jclepro.2020.123185.

Li, J., Yu, S., Tang, X., Wu, W., 2022. Determinants of workers' pro-environmental behaviour towards enhancing construction waste management: contributing to China' s circular economy. J. Clean. Prod. 369, 133265 https://doi.org/10.1016/j.jclepro.2022.133265.

Mahajan, S., Hausladen, C.I., Argota Sánchez-Vaquerizo, J., Korecki, M., Helbing, D., 2022. Participatory resilience: surviving, recovering and improving together. Sustain. Cities Soc. 83, 103942 https://doi.org/10.1016/j.scs.2022.103942.

Manomaivibool, P., Srivichai, M., Unroj, P., Dokmaingam, P., 2018. Chiang Rai Zero Waste: participatory action research to promote source separation in rural areas. Resour. Conserv. Recycl. 136, 142–152. https://doi.org/10.1016/j.resconrec.2018.04.002.

Martinho, G., Ramos, M., Gomes, A., Santos, P., Pires, A., 2015. Construction and Demolition Waste management in Portugal (September 2015). In Resource Efficient Use of Mixed Wastes. Developed for the European Commission (Directorate-General for Environment) by the Consortium led by Deloitte, in partnership with BRE, ICEDD, RPS, VTT and FCT NOVA. Available at: https://ec.europa.eu/environment/pdf/waste/studies/deliverables/CDW_Portugal_Final.pdf.

Marrero, M., Puerto, M., Rivero-Camacho, C., Freire-Guerrero, A., Solís-Guzmán, J., 2017. Assessing the economic impact and ecological footprint of construction and demolition waste during the urbanization of rural land. Resour. Conserv. Recycl. 117, 160–174. https://doi.org/10.1016/j.resconrec.2016.10.020.

Menegaki, M., Damigos, D., 2018. A review on current situation and challenges of construction and demolition waste management. Curr. Opin. Green Sustain. Chem. 13, 8–15. https://doi.org/10.1016/j.cogsc.2018.02.010.

Michie, S., Stralen, M.M.Van, West, R., 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement. Sci. 6, 42. https://doi.org/10.1186/1748-5908-6-42.

Mihai, F.C., 2019. Construction and demolition waste in romania: the route from illegal dumping to building materials. Sustain 11. https://doi.org/10.3390/su11113179.

Nagpure, A.S., 2019. Assessment of quantity and composition of illegal dumped municipal solid waste (MSW) in Delhi. Resour. Conserv. Recycl. 141, 54–60. https://doi.org/10.1016/j.resconrec.2018.10.012.

Oluleye, B.I., Chan, D.W.M., Saka, A.B., Olawumi, T.O., 2022. Circular economy research on building construction and demolition waste: a review of current trends and future research directions. J. Clean. Prod. 357, 131927 https://doi.org/10.1016/j.jclepro.2022.131927.

PCM, 2020. Portuguese Law on Waste. Decree-Law 102-D/2020, of 10th December, amended by Declaration of Rectification 3/2021, of 21st January, and Law 52/2021, of 10th August. Presidency of the Council of Ministers. Portugal.

Penteado, C.S.G., Rosado, L.P., 2016. Comparison of scenarios for the integrated management of construction and demolition waste by life cycle assessment: a case study in Brazil. Waste Manag. Res. 34, 1026–1035. https://doi.org/10.1177/0734242X16657605.

Pérez, C., Arroyo, P., Richards, C., Mourgues, C., 2021. Residential curbside waste collection programs design: a multicriteria and participatory approach using choosing by advantages. Waste Manag. 119, 267–274. https://doi.org/10.1016/j.wasman.2020.08.055.

Ramos, M., Martinho, G., Pires, A., Santos, P., Gomes, A., Moura, E., 2014. Construction and demolition waste in Portugal: actual situation and future perspectives. In: International Solid Waste Association World Congress 2014, 10th September. International Solid Waste Association, São Paulo (Brazil).

Ramos, M., Martinho, G., 2023. An assessment of the illegal dumping of construction and demolition waste. Clean. Waste Syst. 4 https://doi.org/10.1016/j.clwas.2022.100073.

Ramos, M., Martinho, G., 2022. Relation between construction company size and the use of recycled materials. J. Build. Eng. 45 https://doi.org/10.1016/j.jobe.2021.103523.

Ramos, M., Martinho, G., 2021. Influence of construction company size on the determining factors for construction and demolition waste management. Waste Manag. 136, 295–302. https://doi.org/10.1016/j.wasman.2021.10.032.

Saez, P.V., Del Río Merino, M., San-Antonio González, A., Porras-Amores, C., 2013. Best practice measures assessment for construction and demolition waste management in building constructions. Resour. Conserv. Recycl. 75, 52–62. https://doi.org/10.1016/j.resconrec.2013.03.009.

Santos, A.C., Mendes, P., Ribau Teixeira, M., 2019. Social life cycle analysis as a tool for sustainable management of illegal waste dumping in municipal services. J. Clean. Prod. 210, 1141–1149. https://doi.org/10.1016/j.jclepro.2018.11.042.

Silva, R.V., de Brito, J., Dhir, R.K., 2019. Use of recycled aggregates arising from construction and demolition waste in new construction applications. J. Clean. Prod. 236, 117629 https://doi.org/10.1016/j.jclepro.2019.117629.

Shooshtarian, S., Caldera, S., Maqsood, T., Ryley, T., 2020. Using recycled construction and demolition waste products: a review of stakeholders' perceptions, decisions, and motivations. Recycling 5, 1–16. https://doi.org/10.3390/recycling5040031.

Shooshtarian, S., Caldera, S., Maqsood, T., Ryley, T., Khalfan, M., 2021. An investigation into challenges and opportunities in the Australian construction and demolition waste management system. Eng. Constr. Archit. Manag. https://doi.org/10.1108/ECAM-05-2021-0439.

Shooshtarian, S., Caldera, S., Maqsood, T., Ryley, T., Wong, P.S.P., Zaman, A., 2022a. Analysis of factors influencing the creation and stimulation of the Australian market for recycled construction and demolition waste products. Sustain. Prod. Consum. 34, 163–176. https://doi.org/10.1016/j.spc.2022.09.005.

Shooshtarian, S., Hosseini, M.R., Kocaturk, T., Arnel, T., Garofano, T., 2022b. Circular economy in the Australian AEC industry: investigation of barriers and enablers. Build. Res. Inf. https://doi.org/10.1080/09613218.2022.2099788.

Shooshtarian, S., Maqsood, T., Caldera, S., Ryley, T., 2022c. Transformation towards a circular economy in the Australian construction and demolition waste management system. Sustain. Prod. Consum. 30, 89–106. https://doi.org/10.1016/j.spc.2021.11.032.

Sobotka, A., Sagan, J., 2016. Cost-saving environmental activities on construction site - cost efficiency of waste management: case study. Procedia Eng 161, 388–393. https://doi.org/10.1016/j.proeng.2016.08.579.

Tam, V.W., Li, J., Cai, H., 2014. System dynamic modeling on construction waste management in Shenzhen, China. Waste Manag. Res. 32, 441–453. https://doi.org/10.1177/0734242X14527636.

Tam, V.W.Y., Le, K.N., Wang, J.Y., Illankoon, I.M.C.S., 2018. Practitioners recycling attitude and behaviour in the Australian construction industry. Sustain 10. https://doi.org/10.3390/su10041212.

Tatiya, A., Zhao, D., Syal, M., Berghorn, G.H., LaMore, R., 2018. Cost prediction model for building deconstruction in urban areas. J. Clean. Prod. 195, 1572–1580. https://doi.org/10.1016/j.jclepro.2017.08.084.

Umar, U.A., Shafiq, N., Malakahmad, A., Nuruddin, M.F., Khamidi, M.F., 2017. A review on adoption of novel techniques in construction waste management and policy. J. Mater. Cycles Waste Manag. 19, 1361–1373. https://doi.org/10.1007/s10163-016-0534-8.

Van Den Hove, S., 2000. Participatory approaches to environmental policy-making: the European Commission Climate Policy Process as a case study. Ecol. Econ. 33, 457–472. https://doi.org/10.1016/S0921-8009(99)00165-2.

Vasconcelos, L.T., Farrall, H., Ferreira, J.C.R., 2020. *Socio-Ecological Literacy: Collaboration as a Learning Tool for Society Transformation*. Advances in Educational Technologies and Instructional Design. https://doi.org/10.4018/978-1-7998-4402-0.ch009.

Vaverková, M.D., Maxianová, A., Winkler, J., Adamcová, D., Podlasek, A., 2019. Environmental consequences and the role of illegal waste dumps and their impact on land degradation. Land Use Policy 89. https://doi.org/10.1016/j.landusepol.2019.104234.

Vilches, A., Garcia-Martinez, A., Sanchez-Montañes, B., 2017. Life cycle assessment (LCA) of building refurbishment: a literature review. Energy Build. 135, 286–301. https://doi.org/10.1016/j.enbuild.2016.11.042.

Wang, J., Wu, H., Tam, V.W.Y., Zuo, J., 2019. Considering life-cycle environmental impacts and society's willingness for optimizing construction and demolition waste management fee: an empirical study of China. J. Clean. Prod. 206, 1004–1014. https://doi.org/10.1016/j.jclepro.2018.09.170.

Wehn, U., Rusca, M., Evers, J., Lanfranchi, V., 2015. Participation in flood risk management and the potential of citizen observatories: a governance analysis. Environ. Sci. Policy 48, 225–236. https://doi.org/10.1016/j.envsci.2014.12.017.

Wu, H., Zuo, J., Yuan, H., Zillante, G., Wang, J., 2019. A review of performance assessment methods for construction and demolition waste management. Resour. Conserv. Recycl. 150, 104407 https://doi.org/10.1016/j.resconrec.2019.104407.

Yao, L., Liang, Y., Li, X., Wang, Z., Jiang, S., Yan, C., 2022. The influence of message framing on project managers' behavioral intentions regarding construction waste reduction. buildings 1-18. https://doi.org/10.3390/buildings12081266.

Yuan, H., 2013. Key indicators for assessing the effectiveness of waste management in construction projects. Ecol. Indic. 24, 476–484. https://doi.org/10.1016/j.ecolind.2012.07.022.

Yuan, H., 2012. A model for evaluating the social performance of construction waste management. Waste Manag. 32, 1218–1228. https://doi.org/10.1016/j.wasman.2012.01.028.

Zhang, C., Hu, M., Di Maio, F., Sprecher, B., Yang, X., Tukker, A., 2022. An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe. Sci. Total Environ. 803, 149892 https://doi.org/10.1016/j.scitotenv.2021.149892.