NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTMENT OF ENVIRONMENTAL SCIENCES AND ENGINEERING

DETERMINING FACTORS AND STRATEGIES TO PROMOTE CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT ON A LOCAL SCALE

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Master in Environmental Engineering

DOCTORATE IN ENVIRONMENT AND SUSTAINABILITY

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February 2023

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NOVA University Lisbon
February 2023

Determining factors and strategies to promote construction and demolition waste management on a local scale

Acknowledgments

First of all, I would like to express my heartfelt gratitude to Graça Martinho for the privilege of having benefited from her guidance throughout this research project. But above all, for the many years of dedication, during which she allowed me to work alongside her. She instilled in me the need to question, to always try to do better, to think innovatively. I would also like to express my gratitude for the support at the times I was afraid of making mistakes or venturing out. Also, a big thank you for teaching me the pleasure of working with others, so that I could address their interests and sensitivities, thus achieving a more useful and lasting contribution. I tried to apply as much as possible of what I have learned and, in this sense, I feel happy with the evolution I have gone through.

I would like to thank the members of my Thesis Advisory Committee, namely Ana Sofia Vaz, Isabel Martins and Paula Urze, for having agreed to take part in the development of my research project that has led to the completion of my thesis. I offer special thanks for the scientific questions they raised, which helped me to reflect and improve on the methodological approach, for their words of motivation and for the sharing of their own experiences.

Furthermore, I thank Lia Vasconcelos and Filipa Ferreira, for supervising the participatory processes, as without their experience it would not have been possible to carry out the tasks with the same degree of success. I would like to thank Joaquim Pina for his availability and for monitoring and validating the statistical processing of the data, which helped to change moments of doubt into moments of fulfilment. Also to Nuno Lapa, for all the support and motivation he gave me. And to Teresa Calvão, for always being there for me with a smile and encouragement.

I must also thank each member of the team of *Comunidade Intermunicipal do Baixo Alentejo* (CIMBAL), especially Fernando Romba, Ana Catarina Lopes, and Rui Silva, for interacting and collaborating on the project "(De)construct for Circular Economy", without which this research project would have been far more difficult to realise. And to Jorge Pulido Valente for being the driving force and for involving me in this challenge. I tried to give my best to the region of *Baixo Alentejo*, truly hoping to have made a lasting impact. A special thank you to all the technicians from the municipalities, as well as to the numerous representatives of construction companies from the region who actively collaborated. Additionally, to all the Portuguese construction companies that answered the questionnaire submitted on a national level, as their participation made it possible to decide on the direction I was to pursue.

This research project would not have been viable without the project "(De)construct for Circular Economy", financed by the EEA Grants Environment Program (08_Call#2_(Des)construir_ Economia_Circular). I also acknowledge the Portuguese Foundation for Science and Technology under the project LA/P/0069/2020, granted to the Associate Laboratory ARNET - Aquatic Research Network, and the strategic project UIDB/04292/2020, granted to MARE - Marine and Environmental Sciences Centre.

A big thank you to my friends and co-workers, Ana Margarida Gomes and Pedro Santos, for sharing many unique moments over the years, which we will certainly never forget. Also to my friends and colleagues who helped me to discuss the doubts related to the know-how of those who, on a daily basis, deal with the constraints that I seek to mitigate. A special thank you to Alda Cristino, for always being there, and to Paulo Biscaia, for the challenging conversations. And to Robert Kuzka, for all the help and patience with the "English poetry" adjustments.

And to my mother, I offer my sincere thanks and gratitude for having been stronger than she thinks she is, for being more present than she believes herself to have been, for having taught me more than she will ever admit, and for understanding me at times when I might have been unfair. A very special thank you for the countless sacrifices she made so that I could study without feeling different from others, for the support she offered me, even if sometimes silent, in the difficult moments that have made us grow together. And for the desire to continue sharing a happier and more peaceful present and future.

Finally, my deepest thanks to those who are no longer with us. Thank you to my grandmother Gilberta, my grandfather Eugénio, and my great-grandmother Conceição. During this research project I spoke to myself a lot, but also to you, and now I would like you to see what I have been capable of. Because I am very much of what you were and taught me to be. And also to my sister Graça, with whom I would have loved to have grown up alongside and played with, but destiny wanted otherwise. I cannot say that I did not have you because you have always been with me.

"We shrink back from the truth if we believe that the destructive forces of the modern world can be 'brought under control' simply by mobilising more resources – of wealth, education, and research – to fight pollution, to preserve wildlife, to discover new sources of energy, and to arrive at more effective agreements on peaceful coexistence. Needless to say, wealth, education, research, and many other things are needed for any civilisation, but what is most needed today is a revision of the ends which these means are meant to serve."

E.F. Schumacher, in *Small is Beautiful* (1973)

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ABSTRACT

Construction and demolition waste (CDW) management has attracted growing interest amongst the research community, especially in terms of the implementation of circular economy principles in the construction sector, mainly due to the large amount of waste generated. The problem has been explored through different approaches and in various contexts, but knowledge gaps persist within the study of proximity dynamics.

Therefore, this research project focuses its analysis on the study of behaviour change in CDW management on a local scale, converging on the role of municipalities and micro and small construction companies, from an operational perspective. For this, research questions were formulated related to the study of the determining factors for CDW management on the local scale; with the deepening of knowledge regarding the reality of illegal dumping of CDW, which is a problem involving the identified stakeholders; and with the implementation of intervention strategies to promote the improvement of the management of this waste stream.

The research project approached the topic in a transdisciplinary way, selecting different research methods, including a literature review, a survey by questionnaire, workshops, and fieldwork, as a way to integrate different realities, with different approaches, contributing to the adaptation of research tasks, but also leaving a more solid research contribution for researchers, technicians, policy-makers and authorities.

In terms of results, there are determining factors for CDW management that are common to municipalities and to micro and small construction companies, such as the lack of proximity facilities and equipment for the waste management generated, or the need to address knowledge gaps. On the other hand, the size of construction companies is a determining factor, with micro and small construction companies presenting specific constraints, and municipalities above all identifying the need for cooperation between entities as a key factor. Illegal dumping is still a problem that results from the constraints identified, and one which is of particular importance from both the point of view of the behaviour of abandonment, and the loss of resources, but also because of the cost of cleaning actions for municipalities.

At the level of the intervention strategies tested, local CDW management facilities and a proximity approach involving the municipal technicians and representatives of construction companies, or applicants for processes, can lead to very favourable results, with direct implications for behaviours acquired over time, and also in cost reduction. However, all these strategies must be accompanied by robust and frequent capacitation, training and supervision actions.

Keywords: Construction and demolition waste (CDW), Local scale, Micro and small construction company, Municipality, Strategies to change behaviour

RESUMO

A gestão dos resíduos de construção e demolição (RCD) tem assumido um crescente interesse na comunidade científica, sobretudo pela implementação dos princípios da economia circular no setor da construção, em grande parte devido à grande quantidade de resíduos gerada. O problema tem sido explorado com abordagens e em contextos distintos, mas as lacunas de conhecimento persistem no que se refere ao estudo das dinâmicas de proximidade.

Assim sendo, o presente projeto de investigação foca a sua análise no estudo da mudança do comportamento na gestão dos RCD à escala local, com ênfase no papel dos municípios e das micro e pequenas empresas de construção, numa perspetiva operacional. Para isso, foram formuladas questões de investigação relacionadas com o estudo dos fatores determinantes para a gestão dos RCD à escala local; com o aprofundar do conhecimento da realidade das deposições ilegais de RCD, que é um problema que relaciona os *stakeholders* identificados; e com a implementação de estratégias de intervenção para promover a melhoria da gestão destes resíduos.

O projeto de investigação abordou o tema de forma transdisciplinar, selecionando diferentes métodos, como a revisão de literatura, um inquérito por questionário, *workshops* e trabalho de campo, como forma de se integrar em diferentes realidades, com diferentes abordagens, contribuindo para a adaptação das tarefas da investigação, mas deixando também um contributo mais sólido para investigadores, técnicos, decisores e autoridades.

Em termos de resultados, existem fatores determinantes para a gestão dos RCD que são comuns aos municípios e às micro e pequenas empresas de construção, como é o caso da ausência de infraestruturas e equipamentos de proximidade para a gestão dos resíduos produzidos, ou a necessidade de proceder à atualização do conhecimento. Por outro lado, a dimensão das empresas de construção é um fator determinante, com as micro e pequenas empresas de construção a apresentarem constrangimentos específicos, e os municípios a identificarem sobretudo a necessidade da cooperação entre entidades como um fator chave. As deposições ilegais são ainda um problema que resulta dos constrangimentos identificados, e que assume especial relevo, quer do ponto de vista do comportamento do abandono, e da perda de recursos, mas também pelo custo das ações de limpeza para os municípios.

Ao nível das estratégias de intervenção testadas, constata-se que soluções locais de gestão de RCD e uma abordagem de proximidade entre os técnicos dos municípios e os representantes das empresas de construção, ou requerentes de processos, pode conduzir a resultados bastante favoráveis, com implicações diretas em comportamentos adquiridos ao longo do tempo, e também na redução dos custos. Contudo, todas estas estratégias devem ser acompanhadas de ações robustas e frequentes de capacitação, formação e supervisão.

Palavras chave: Resíduo de construção e demolição (RCD), Escala local, Micro e pequena empresa de construção, Município, Estratégias para alteração de comportamentos

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Introduction

1.1 Motivation

The construction sector is an economic activity with a great potential to achieve the principles of the circular economy, considering a holistic approach composed of environmental, economic, and social components. Specifically concerning the construction and demolition waste (CDW) generated in large quantities by construction activity, it is essential to focus on the efforts to mitigate the associated environmental impacts. In this context, to start this Ph.D. project, it was essential to attempt to meet certain conditions, to try to leave a contribution that would be useful, providing a better understanding of and trying to solve specific constraints associated with CDW management on a local scale dynamic. The motivation for this came from the knowledge previously acquired in the exercise of professional activities within the construction sector, research gaps often discussed informally with peers and, above all, from the willingness to work to address the many challenges that still need to be faced, welcoming the participation of stakeholders who were motivated to involve themselves.

However, during the research project, it was necessary to adapt and know how to evolve, considering the dynamics of the construction sector, the initiatives associated with national, regional, and local agendas, as well as the specific interests of each contact, through which viable alternative solutions were explored. It was important to establish a balance between accomplishing work of scientific interest and adapting to the political interests and agenda of decision-makers in the local reality, these latter interests often not being directly compatible with the temporal agendas of science. In this context, forming, over time, a very close relationship with the municipalities and with representatives of the smaller companies within the construction sector, facing very specific constraints, was essential.

Personally, a turning point came when it became easier to abandon the idea of being able to do absolutely everything or the best of what had been planned, choosing to do the best that

was possible within the context. And this does not mean less dedication in quantity or quality, but it just means being more willing to adapt, making the most of the opportunities that arise at the right moment. Or relying on the people who gradually believe in the ideas, although sometimes we were seeing through different prisms. My motivation developed further upon realising that this contribution to the field could be essential in helping others to evolve, whether people or organisations, without forgetting that our motivation grows in the same measure when we are also taught by others.

But this research project would not have been possible without funding, which originated from the project "(De)construct for the Circular Economy", within the scope of the European Economic Area (EEA) Agreement Grants, Environment Program, beginning at the end of 2020, with a duration of two years. Everything mentioned above is closely related to the connections fostered with the *Baixo Alentejo* region, without which all operational issues, but also motivational ones, closely linked to the contribution of each individual, would not have been possible to achieve.

1.2 Contributions from different scales for circular economy in the construction sector

1.2.1 The perspective of larger scale dynamics

Larger territories or organisations, even in a context of globalization (Kylili & Fokaides, 2017), refer frequently to the implementation of sustainable practices in the construction sector, where support from the government or the company board is vital. Nevertheless, most of the time the client demand is crucial in terms of the decision because of the requirements of the contracts, the perceived or unexpected costs for CDW management, the cost-effective conditions at each period (Ajayi *et al.*, 2015), or even the necessity to adapt to routines or the skills of employees (Duan *et al.*, 2015; Opoku & Ahmed, 2014).

From the perspective of trying to mitigate the CDW intensity of this economic activity, the will to achieve circular economy principles within the construction sector has gained interest (Oluleye *et al.*, 2022). In this context, Ghaffar *et al*. (2020) highlight the importance of collaboration between various stakeholders, namely scientists, governments, and policy-

makers. Specifically, universities are considered important for improving efficiency in CDW management (Shooshtarian et al., 2022b), but also providing alternative solutions, thanks to highly qualified staff (Calvo *et al.*, 2014).

Also, it is necessary to consider different realities and the adaptation of solutions to better solve existing problems. It is the case that every European Union country complies, in general, with the theoretical guidelines for the incorporation of circular economy principles in the construction sector, although each at different rhythms (European Commission, 2017). But it is also the case that environmental awareness can make the biggest difference in deciding between options. For example, France opts to be part of a more sustainable materials market, as a form of competitiveness, while in Brazil, the focus remains above all on cost reduction for stakeholders (Doussoulin & Bittencourt, 2022).

It is also worth referring to the abilities of the new technologies (Li *et al.*, 2020), such as the case of building information modelling (Shi & Xu, 2021; Bakchan *et al.*, 2019) and big data approaches (Hu *et al.*, 2022). New solutions must be considered for improving profit and diminishing waste, developing analysis to consider the specificities of national or regional development (Luciano *et al.*, 2022; Aslam *et al.*, 2020; Chen & Lu, 2017; Kylili & Fokaides, 2017).

Life cycle assessment has been playing an important role in helping the process of planning and decision-making. For CDW management approaches, this tool is important because it focuses on processes and it considers adaptability (Devaki & Shanmugapriya, 2022). Moreover, concerning the process, from the project phase to the construction site (Yao *et al.*, 2022; Carpio *et al.*, 2016; Ajayi *et al.*, 2015), policies have been encouraging consideration of waste prevention methods, followed by the reuse of components or construction materials, and then waste recovery. It is important to mention the deconstruction processes of buildings, with the necessity to evaluate in which cases these processes are more sustainable (Tatiya *et al.*, 2018), balancing labour costs, tipping fees, and market prices (Coelho & De Brito, 2011a).

In this context, defining whether recycled materials are environmentally competitive (Yazdanbakhsh, 2018) is also essential, for example in the frequent options for downcycling processes (Di Maria *et al.*, 2018), with the use of recycled aggregates as filling materials instead

of more valuable options, promoting circularity, or when implementing reverse logistics, trying to make companies or processes more efficient (Tazi *et al*., 2020; Chileshe *et al*., 2018).

But does it make sense to tackle the problem of large scales dynamics if other scales of analysis are not considered, solving the problems of circularity in the construction sector as a whole? Could it be that solutions effective at larger scales may prove inadequate in identifying and solving the problems of smaller scale dynamics?

1.2.2 The perspective of smaller scale dynamics

Even considering the smaller scale dynamics, it is necessary to distinguish between realities, such as the practices within different countries despite sharing the same cultural and legal background (European Commission, 2017), or the reality concerning emerging economies (Torgautov *et al*., 2022), cross-regional strategies to improve CDW management (He *et al*., 2022), or regional specificities (Christensen *et al*., 2022; Santos *et al*., 2019). But, in general, smaller scales share the objective to tackle problems in a context of proximity, instead of addressing the problems from simply a global or national perspective.

One major problem in some countries is illegal dumping of CDW (Liu *et al*., 2021a; Lu, 2019; Seror & Portnov, 2018; Tasaki *et al*., 2007), which has been identified as a particularly challenging problem to solve. It is recognised as a problem that requires more research (Yang *et al*., 2019), first of all because it limits the potential of the accomplishment of the circular economy principles, for the reason that there is a loss of material that is not returning to the sector. This is particularly significant as the illegal CDW dumped is mainly composed of the mineral fraction (Sormunen & Kärki, 2019; Coelho & De Brito, 2011b). Secondly, this problem is often managed by local authorities, as in the case of municipalities (Nagpure, 2019; Vaverková *et al*., 2019), left to deal with high costs related to cleaning actions in their territories Santos *et al*., 2019). Nevertheless, information about these occurrences is often difficult to retrieve (De Melo *et al*., 2011). And there are not enough human resources available to execute oversight actions, both in terms of the workforce, but also concerning expertise, which is recognised as a determinant (D'Amato *et al*., 2018). But approaches supported by effective

fiscal policies, sustained by governments are an important strategy to encourage compliance (Chen & Lu, 2017; Ajayi *et al*., 2015).

One solution might be by reincorporating the CDW generated onsite, complying with technical norms and trying to improve the implementation of circular economy principles (Bao *et al*., 2020). But waste producers have gaps in their knowledge of CDW regarding a wider range of issues, including legal procedures, illustrating further major constraints that need to be tackled. On the other hand, the lack of the proximity of recycling facilities is a major problem often recognised by stakeholders as an obstacle on smaller scales (Martinho *et al*., 2015; Ichinose & Yamamoto, 2011). However, recycling facilities also face issues surrounding irregular sources of CDW, as the levels of waste generated can be unpredictable, but also the inconsistent behaviour of producers, for instance regarding accomplishment of legal requirements, such as sending CDW to authorised final destinations, or monitoring its transportation through traceability tools (Ma *et al*., 2020).

But it is vital to consider the contribution of good practices on construction sites, where knowledge gaps are again a recurrent constraint (Li *et al*., 2018; Bakshan *et al*., 2017; Gangolells *et al*., 2014; Begum *et al*., 2009). The implementation of good practices, such as separating CDW onsite, leads to more efficient processes in terms of circularity and cost-efficiency (Menegaki & Damigos, 2018; Saez *et al*., 2013). But to accomplish that it is necessary to consider the role of human factors (Jin *et al*., 2019), especially understanding behaviour change (Li *et al*., 2018; Li *et al*., 2015; Teo & Loosemore, 2001), individually or in collaboration with other stakeholders and authorities (Ajayi *et al*.; 2016; Chen *et al*., 2019; Mak *et al*., 2019). In some contexts, it is very important to improve the access of workers to innovation, because employees will acquire knowledge that is important to boosting circular economy principles (Torgautov *et al*., 2022).

When considering smaller scales of activity, instead of the national reality, other types of responsibility and difficulties arise (Esa et al., 2017), such as the lack of technical knowledge to intervene, as is commonly referred to in the literature (APA, 2018a; Gangolells *et al*., 2014; Begum *et al*., 2009). In this case, it is necessary to cooperate with local stakeholders in a context of proximity for CDW management. Mainly, this means studying the direct intervention of

municipalities, and local construction companies, in both cases because they have specific responsibilities and characteristics (Santos *et al.*, 2019; APA, 2018a; Martinho *et al.*, 2015).

But to accomplish unified solutions, designed with the involvement of all, and accepted by all, participatory processes involving all stakeholders are needed, especially to address problems concerning interdisciplinary environmental issues, as is the case with CDW management, not to mention the limited attention offered to the social component when planning solutions (Wehn *et al.*, 2015; Yuan, 2012, 2013).

1.2.3 A brief perspective of the Portuguese reality

This research project has been developed within the Portuguese reality, in which the legal framework for CDW management was established in 2008, through the Decree-Law 46/2008, of the 12th of March. This legislation was revoked by Decree-Law 102-D/2020, from the 10th of December (PCM, 2020), with subsequent amendments, now including CDW management legal requirements. In this context, Portugal is considered as having well-established legislation encompassing CDW management (European Commission, 2017), although several operational constraints remain unsolved.

The construction sector was considered, among all the Portuguese economic activities, the one with the greatest potential to improve the realisation of circular economy principles in the country (EY-AM&A, 2018). And supporting this line of reasoning, the Portuguese action plan for the circular economy states that regional and local agendas have to consider the construction sector as a strategic economic activity for the promotion of the circular economy (PCM, 2017).

Several projects have been conducted in Portugal regarding CDW management or closely related subjects in recent years, both from a national perspective and integrated into a more extensive analysis of the territory. For example, in the last decade, the following were developed within the identified main subjects: the national characterisation in terms of CDW management (Martinho *et al.*, 2015), integrated with the context of assessment for the 28 European member states (European Commission, 2017); projects regarding the specificities and planning of regional agendas (*e.g.*, 3drivers & FCT NOVA, 2020; ASWP & 3drivers, 2019;

Martinho *et al*., 2013); and most recently the project "(De)construct for Circular Economy", regarding a regional strategy in the *Baixo Alentejo* region to promote circularity in the construction sector, and the project CLOSER, regarding pre-demolition audits, the last two under the financing mechanism of the EEA Grants.

In 2015, the characterisation of Portugal was made regarding CDW management procedures (Martinho *et al*., 2015), where stakeholders, consulted from different areas, were invited to collaborate with their experiences and perceptions of different subjects. Regarding legal procedures, the following aspects were mentioned: too much bureaucracy associated with CDW management; the absence of a legal figure responsible for the environmental management at construction sites; and insufficient oversight and inspection actions. Concerning the recycling component, these topics referred to: the heterogeneity of geographical distribution for recycling solutions, mainly in the regions with a low demographic density, leading to the illegal dumping of CDW; and significant amounts of mixed CDW, that influence both the costs for waste producers, and the quality of the recycled materials. For the availability of the materials, market prices are not competitive for recycled aggregates, in contrast to the low price of natural raw materials, leading to the absence of an effective market for the former. Moreover, a lack of synergy between stakeholders was recognised by Santos *et al*. (2019), as well as the absence of proactive initiatives.

Additionally, *Agência Portuguesa do Ambiente* (Portuguese Environment Agency), who is the national waste authority, frequently invites municipalities to answer a survey about CDW management practices, where the main constraints of the local scale dynamic are made evident, characterised in the responses of the last survey from 2018 (APA, 2018a): few municipalities provide CDW solutions with sufficient proximity, for instance for CDW preliminary storage; municipalities are unaware of the costs associated with the removal of illegally dumped CDW carried out by their services; few municipalities carry out oversight actions for legal procedures or good practices onsite, exacerbated by the lack of workforce, resources, and technical expertise; and there is a general absence of supervision regarding the legal requirements articulated between municipal regulations for waste management and construction, conditioning the respective administrative acts that stimulate effective CDW

management. Additionally, in Portugal, more than 95% of construction companies are micro and small companies (IMPIC, 2020), with limitations such as knowledge gaps, and obstacles to the implementation of CDW management good practices (APA, 2018a).

1.3 Research gaps

Especially since 2008, there has been a growing interest in CDW in different disciplines, with an increasing number of scientific articles published on this topic. Alongside this evolution, several review articles have been published, which are a starting point for exploring the various elements studied from different perspectives, including: a general overview of CDW research tendencies (Li *et al*., 2022; Wu *et al*., 2019a; Menegaki & Damigos, 2018; Umar *et al*., 2017); a circular economy approach (López Ruiz *et al*., 2020); an assessment considering the reality of different countries or zones, such as China *versus* the United States of America (Aslam *et al*., 2020), Southeast Asia (Hoang *et al*., 2020), and the European countries (Kylili & Fokaides, 2017); life cycle assessment (Devaki & Shanmugapriya, 2022; Vilches *et al*., 2017); the use of recycled materials, specifically recycled aggregates (Tam *et al*., 2018b); and even particular materials, such gypsum (del Río-Merino *et al*., 2022).

These reviews demonstrate the focus in certain countries or specific zones but do not refer to the context of proximity, of smaller scales, and specifically omit rural areas. Even in the remaining literature, the reference to the regional or local scales (*e.g.,* municipalities), or specific contexts, such as smaller construction companies, is very scarce or even non-existent in terms of presenting substantial detail.

The existing references for local scales are generalist, recognising the problem, but without presenting data allowing its in-depth study, neither or supporting nor opposing results. Moreover, the recognition relies on generalist aspects such as government support or cooperation (Santos *et al*., 2019); CDW management improvement in terms of the availability of facilities at intermediary scales (Ichinose & Yamamoto, 2011); promoting law enforcement or encouraging good practices onsite, considering the reality of different actors within the construction sector (Gangolells *et al*., 2014; Begum *et al*., 2009); and CDW generation indicators and final destinations for this type of waste (De Melo *et al*., 2011).

From this perspective, the literature lacks an assessment of the relevant factors and strategies for the promotion of CDW management on a local scale, involving municipalities and micro and small construction companies, specifically in a rural context, where there are obstacles to exploring the constraints and solutions, and for which several challenges have been identified over time but never studied in-depth through a research project.

1.4 Main objective and research questions

An important step of a research project is to formulate the main objective and initial questions, since they guide the research design, the data collection approaches, and the analysis of results (Saunders *et al*., 2013; Bryman & Bell, 2011). These questions also contextualise data within the main pre-defined objectives, facilitating an interconnecting approach.

In this perspective, this research project aims to understand how to improve CDW management on a local scale dynamic, in a rural area, considering the problem from an operational perspective, to fill in gaps in the scientific literature, but also pragmatically in the field, because without this information it is more difficult for stakeholders to plan and to act.

To accomplish this main objective, this research project seeks to address the following interconnected Research Questions (RQ), which in turn try to respond to Specific Objectives (SO):

RQ 1. Which determining factors[1] are relevant for CDW management on a local scale?

SO 1.1. Which determinants have a closer connection with micro and small construction companies, and which ones have a more direct relationship with municipalities?

SO 1.2. Which are the common determinants that play a relevant role in the context of local dynamics?

[1] In this thesis, a "determining factor" is to be understood as a characteristic or circumstance that leads to or influences a result, more specifically the nature of a behaviour or an initiative.

RQ 2. How can the reality of the illegal dumping of CDW in the context of local scale dynamics be assessed?

SO 2.1. What are the characteristics?

SO 2.2. Which factors determine this reality?

SO 2.3. How to raise awareness of the problem?

RQ 3. Which local strategies might be the most appropriate to promote and result in successful CDW management in the context of local dynamics?

SO 3.1. How effective is the creation of local solutions for the preliminary storage of CDW, under municipal responsibility, with defined rules and control regarding delivery conditions?

SO 3.2. How effective is the regular supervision of smaller-scale construction interventions, with awareness and training components, carried out by municipal technicians?

SO 3.3. How effective is the regular control of legal procedures by municipal technicians, whether referring to public or private construction works subjected to prior control?

SO 3.4. How effective is a capacitation, training, and supervision component, strictly adhering to the objectives defined in the local strategies?

2

Research design

2.1 The concept behind the research project

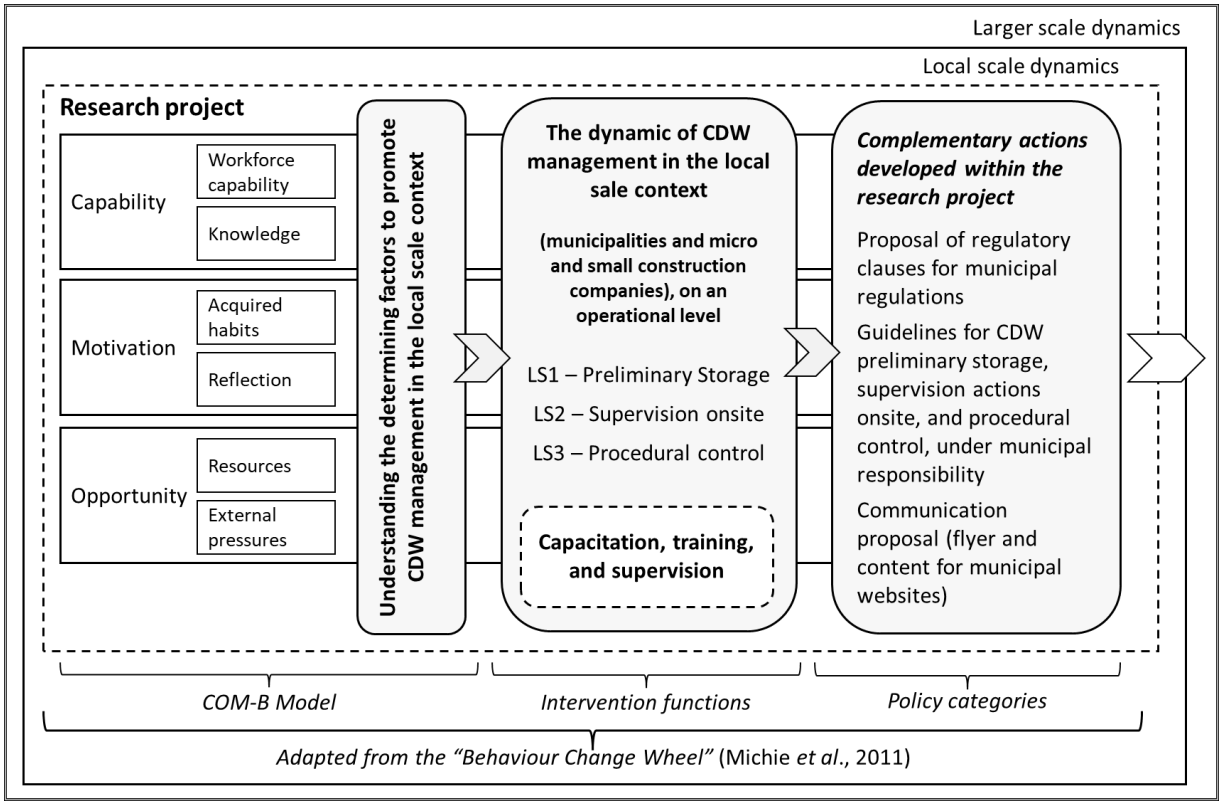
After identifying specific research gaps in the literature about the implementation of circularity principles in the construction sector, understood as the group of activities developed within the Statistical Classification of Economic Activities in the European Community (NACE), namely section F ("Construction"), the decision was made to engage in a research project focused on local scale dynamics. The objective was defined to identify the means to improve and achieve more effective construction and demolition waste (CDW) management in a context of proximity, namely in rural areas, interpreted within the classification of "predominantly rural regions", corresponding to the European Nomenclature of Territorial Units for Statistics, level 3 (NUTS 3) (Eurostat, 2019).

The research was dedicated to the operational level, since it is more difficult to involve the political level, characterised by political objectives and agendas that may differ from the precise motivation of a scientific program. Nevertheless, the contribution of an operational vision or strategy is always necessary to inform the political level when deciding about the optimal strategies to adopt, the financing to gather, or the governance model to involve.

In the context of an operational level, two key groups of stakeholders were identified, experiencing constraints, as identified through the gaps noted in the literature review, but also the professional experience acquired before the research project begun. These two groups are: the municipalities, because they have specific legal responsibilities regarding CDW management; and micro and small construction companies, because they are a group within the construction sector that experience difficulty engaging with legal procedures and good practices. The constraints faced by each of these two groups, but also the dynamics between them were identified as the focus of assessment in this research project.

In these terms, behaviour change was selected as the main priority. So, the "Behaviour Change Wheel" (BCW) developed by Michie *et al*. (2011) was inspiration for the design of the conceptual model for this research project. The BCW is a tool for designing and evaluating interventions designed to induce behavioural change. This model integrates the "COM-B Model (Capability, Opportunity, Motivation – Behaviour)", used to make a diagnosis of the three dimensions of behaviour identified. After the diagnosis, necessary strategies and policies are identified for implementation.

In the present research project, the "COM-B Model" was an inspiration to study the determinants and strategies leading to behaviour change in municipalities and micro and small construction companies, trying to achieve better results in terms of CDW management in the context of a local dynamic, in a rural area (Figure 2.1).



Legend: LS – Local Strategy; COM-B Model (Capability, Opportunity, Motivation – Behaviour).

Figure 2.1 - The conceptual model for the research project.

Although beyond the scope of the research project, whenever possible, municipalities were provided with support detailing actions/interventions designed for the external sphere of

behaviour change, for example: a guide to help municipalities to implement local strategies regarding CDW management that indicated which technical characteristics should be considered when planning controlled spaces, under municipal responsibility, for CDW preliminary storage (Ramos *et al*., 2020); a proposal of regulatory clauses about CDW management, to be applied at a municipal level (Annex I); a document with procedures to help municipalities to be self-sufficient when implementing supervision actions on construction sites, or to execute procedural control, and indicating how to communicate and what communication channels to prioritise (Annex II); or guidelines to help municipalities to communicate with waste producers, through a proposed flyer and content to include on the websites of municipalities, all designed to harmonise criteria among the municipalities and avoid destabilisation (Annex III).

2.2 The case study

The *Baixo Alentejo* region, in Portugal, classified as a European Nomenclature of Territorial Units for Statistics, level 3 (NUTS 3), was selected as a case study for this research project. It is situated within the South and interior of the country and is composed of 13 municipalities (Figure 2.2).

Figure 2.2 - The *Baixo Alentejo* region, in Portugal.

As presented in Table 2.1, it is a territory of 8,543 km² with 115,356 inhabitants and a low population density of 13.5 inhabitants per km² (INE, 2020). Considering this data, it is classified, according to Eurostat criteria as a "predominantly rural area" (Eurostat, 2019).

Table 2.1 - Territorial and populational data for the *Baixo Alentejo* region.

Municipality	**Area** (km²)	**Inhabitants** (n.º)	**Population density** (inhab/km²)
Aljustrel	459	8,140	17.7
Almodôvar	778	6,660	8.6
Alvito	265	2,468	9.3
Barrancos	168	1,623	9.7
Beja	1,147	33,340	29.1
Castro Verde	569	6,890	12.1
Cuba	172	4,547	26.4
Ferreira do Alentejo	648	7,807	12.0
Mértola	1,293	6,049	4.7
Moura	958	13,606	14.2
Ourique	663	4,545	6.9
Serpa	1,106	14,177	12.8
Vidigueira	317	5,474	17.3
Baixo Alentejo region	8,543	115,326	13.5

Source: INE (2020)

In general, it is a region with scarce final and intermediate facilities for CDW management, leading to large distances and therefore high costs for the transportation of materials and waste. There are gaps in technical knowledge regarding compliance with legal procedures and the implementation of good practices for CDW management, and several information gaps within local records for this waste stream.

The aforementioned municipalities are aggregated in a Portuguese Intermunicipal Community, in this case CIMBAL – *Comunidade Intermunicipal do Baixo Alentejo* (Intermunicipal Community of *Baixo Alentejo*). The mission of this entity is to promote the following main objectives in the region: to undertake the management of economic, social, and environmental development; to articulate the intermunicipal investment and programs to

encourage regional development; and to endorse the actions of public entities. From this perspective, the support from CIMBAL was essential to allow the implementation of the experimental component of the research project in the *Baixo Alentejo* region.

2.3 Research approach

A research design is often the result of research gaps identified through or inconsistencies detected in the literature review (Bryman & Bell, 2011). In the specific case of the design of this research project, it was indeed based essentially on the research gaps that have been identified and explored through time. An applied research methodology was considered rather than a basic research approach (Saunders *et al*., 2013), since the objective was to understand particular problems and to try to find solutions to them, adding value to the stakeholders involved, revisiting the problems identified several times, instead of a linear assessment (Vasconcelos *et al*., 2020).

In any case, it was necessary to ponder the specific research methods to be employed in the present research project, to collect data and analyse results, trying to express connections between variables, understanding behaviour, contextualising, but also trying to generalise for other contexts (Fritz *et al*., 2019). In the present case, the research design approach included different interconnected components, considered by Bryman & Bell (2011), that are somehow implicit in the research methods selected, for example: a survey by questionnaire; a selection of a case study, since it was necessary to circumscribe the research project, specifying a boundary so the effects could be measured and precise, with the implementation of a participatory process; and, in the same context, experimental field work.

To accomplish the formulated purposes, two main types of research strategy were adopted, predominantly a quantitative approach, but also a qualitative approach, with the latter to be considered as complementary to the quantitative data, to better understand the results obtained and how to proceed with future initiatives or methods design. This was decided because, with some approaches, it was necessary to adopt a deductive/empirical assessment, and in others it was important to consider an inductive approach, through the observation and understanding of patterns (Saunders *et al*., 2013). In this case, it was also vital to consider the

importance of achieving robust data and its respective validity, to increase the likelihood of the work being accepted in the indexed journals where the research articles were submitted for publication, accomplishing reliability, replication, and validity (Saunders *et al*., 2013; Bryman & Bell, 2011).

This research project considers a transdisciplinary methodology (Krohn, 2017), in this case because this research involved the consideration of different types of stakeholders, and different types of methods to achieve results (Fritz *et al*., 2019), including initially an academic vision, but also the contributions of practitioners and policy-makers. In this context, the boundaries of single disciplines were surpassed and the contribution from different methods, and the interaction between these different approaches, was necessary.

Following the considerations explained above, the research methods described below were integrated into the research design. They are presented in this subchapter in general terms, to achieve a broad comprehension of their contribution, but explained in greater detail in the specific chapters where they are directly involved.

2.4 Methods

2.4.1 Literature review

The literature review is an important step of any research project because it is essential in the formulation and adaptation of the research questions, as well as the creation and adaptation of the research design and respective methods (Saunders *et al*., 2013). This is in addition to the value of engaging in a systematic review or a narrative review of the most up-to-date research in the field (Torraco, 2005). Although the systematic literature review was a process developed with greater depth in the initial phase of the research project, a narrative review was the most appropriate method for trying to inform particular elements of the research project, namely those related to inductive approaches involved in specific research methods. In any case, primary sources of information were the first choice for this research project when useful data was available, always evaluating the information assessed to begin with, and subsequently incorporating secondary sources, such as organisational databases or government publications (Saunders *et al*., 2013).

Each specific chapter contains a literature analysis on the main subtheme that is being assessed, contributing through the distinct sections towards a more general perspective about the problem of CDW management, whenever possible, prioritising the integration of local scale dynamics related issues, although literature with this specific focus is scarce.

Different main areas of focus were considered, namely: the construction sector within the objectives of circular economy; the illegal dumping of CDW; the challenges of CDW management; the constraints and solutions for this waste stream in different contexts, for instance the scale of analysis (*e.g.* global *versus* national or regional); waste treatment facilities or local solutions to implement good practices on construction sites; behaviour change in large organisations or in smaller construction companies (or even individual approaches); the reality of using recycled materials as a contribution to circularity; and participatory processes, from the perspective of integrating people and organisations into solutions.

2.4.2 Questionnaire and data treatment

A survey by questionnaire, specifically a self-administered questionnaire, was distributed to Portuguese construction companies in 2017 to try to understand if differences exist in CDW management procedures based on the size of companies, in terms of compliance with good practices and knowledge gaps, amongst other aspects (chapters 3 and 4).

The results were split into two groups, trying to orientate the sampling and considering pre-selected closed questions to enable a quantitative approach. This allowed comparisons between normalised data, with the objective of achieving descriptive or explanatory research data (Saunders *et al*., 2013). The first group of data obtained is more dedicated to general subjects relating to CDW management by construction companies. The second group concerns the use of recycled materials, with a focus on recycled aggregates resulting from CDW.

The results were statistically analysed. The existence of statistically significant differences between the distinct groups of construction companies was considered as a hypothesis to be tested in light of the variables selected. The conclusions of this questionnaire were instructive in the formation of the main objectives of the research project and the decision to narrow the focus of study to micro and small construction companies.

2.4.3 Workshops and content analysis

A participatory process was conducted in the *Baixo Alentejo* region in 2021, consisting of six workshops. They were organised in three sessions, divided into two workshops on each occasion: one dedicated to consulting municipal technicians, and the other involving the representatives of micro and small construction companies (Figure 2.3; chapter 5). The latter group was chosen after consideration of the results obtained through the survey by questionnaire mentioned above.

The workshops were organised in April, September, and December, and tried, from an operational perspective, to establish the constraints and solutions to CDW management at a local dynamic; to encompass the specific contributions of the participants concerning their responsibilities (municipality responsibilities or those of waste producers); and to accomplish both a vision for a regional strategy and local solutions to tackle the localised problems related to CDW management, following directions from literature on this topic (Vasconcelos *et al.*, 2020; Hassan, 2014; Joseph, 2006).

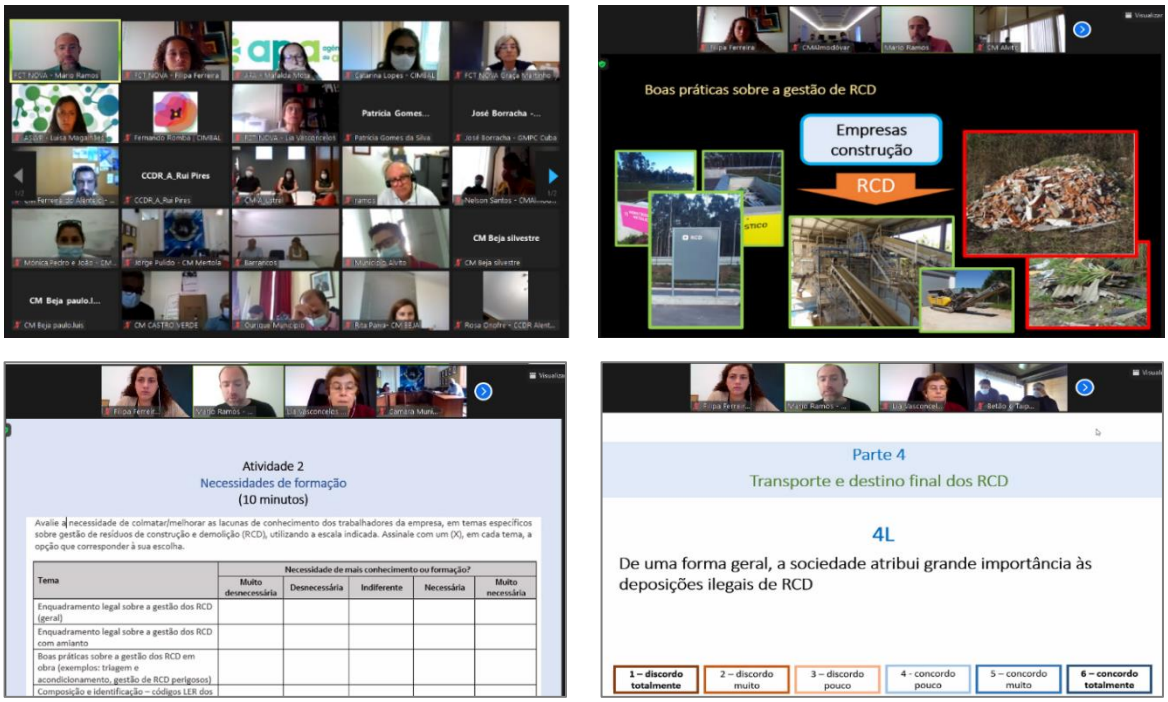


Figure 2.3 - Photographic register, as an example of the workshops developed.

In some cases, the data collected was processed using content analysis, since the specific subject of the contributions was not always solely concerned with the specific theme that participants were invited to present ideas on. The content analysis attempted to quantify the mentioned topics into categories in a systematic and replicable manner, also taking into consideration that this approach is regarded as an important method for studying the culture of organisations (Bryman & Bell, 2011). In this case, the opinions expressed in the discussions that happened in the workshops were also considered.

2.4.4 Field work and data treatment

Pursuing, in first instance, the objective to move towards a quantitative approach, monitoring work was developed in this research project, through data treatment and indicators (Bryman & Bell, 2011), that aimed to measure the findings and tried to validate and replicate them through the results obtained in the case study. This was in addition to completing the data and improving the next steps and methods, with a view to subsequent enhancements through adaptation (Saunders *et al*., 2013).

Monitoring work was conducted within twelve of the thirteen municipalities of the *Baixo Alentejo* region, between 2021 and 2022, to collect data and try to understand the reality of illegal dumping of CDW (Figure 2.4; chapter 6). These results allowed an understanding of the characteristics of these occurrences in the region, namely through performance and cost indicators, but also how they relate to their specific determining factors.

Later, six municipalities engaged in three specific local strategies to try to understand how to improve CDW management on a local scale (chapter 7). These strategies were designed considering the necessity to maintain controlled spaces under municipal supervision for CDW preliminary storage (Figure 2.5); the need to create agendas for supervision actions, under municipal responsibility, of smaller scale construction companies, from a perspective of creating awareness and capacitation (Figure 2.6); and to understand the constraints related to procedural control about legal requirements for CDW management in the context of public construction works or private construction works subjected to a municipal license or prior notification (Figure 2.7).

The results were statistically analysed, comparing the progress at distinct phases, depending on the cases evaluated, to assess the evolution achieved overtime through improving awareness, training, and supervision.

Figure 2.4 - Photographic register, as an example of the work monitoring the illegal dumping of construction and demolition waste.

Figure 2.5 - Photographic register, as an example of the local strategy for preliminary storage.

Figure 2.6 - Photographic register, as an example of the local strategy for supervision onsite.

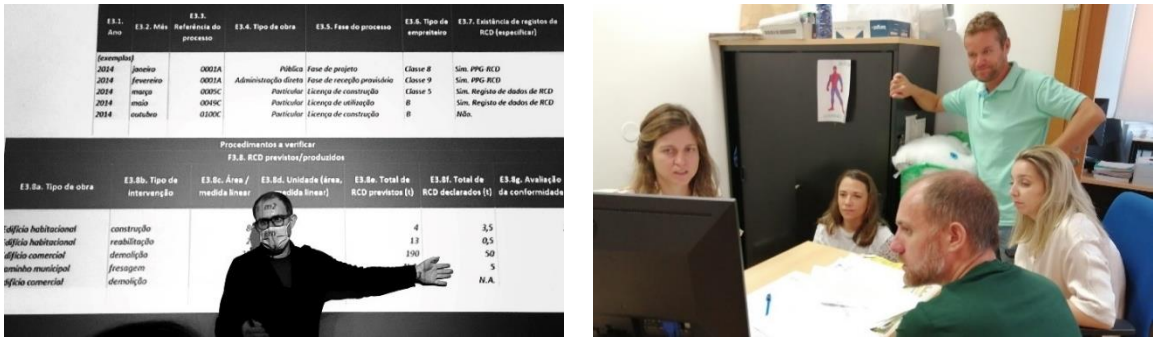


Figure 2.7 - Photographic register, as an example of the local strategy for procedural control.

2.4.5 Capacitation, training, and supervision

Monitoring work was executed by the municipal technicians, in collaboration with the construction companies, focusing on the micro and small scale. This monitoring work always had supervision, throughout the planning; the establishment of monitoring criteria; the validation of data; and accompanying the monitoring work onsite by improving procedures, resolving knowledge gaps and the problems of harmonising criteria between municipalities and even between different participants. The supervision began by videoconference, because

of the Covid-19 pandemic restrictions, between January and April 2021, but after May 2021 it was possible to supervise the procedures in person in the *Baixo Alentejo* region. Supervision actions in person were executed in each municipality involved, individually. The visits took place in 2021 (May and December) and 2022 (January, February, April, June, July, October, and November).

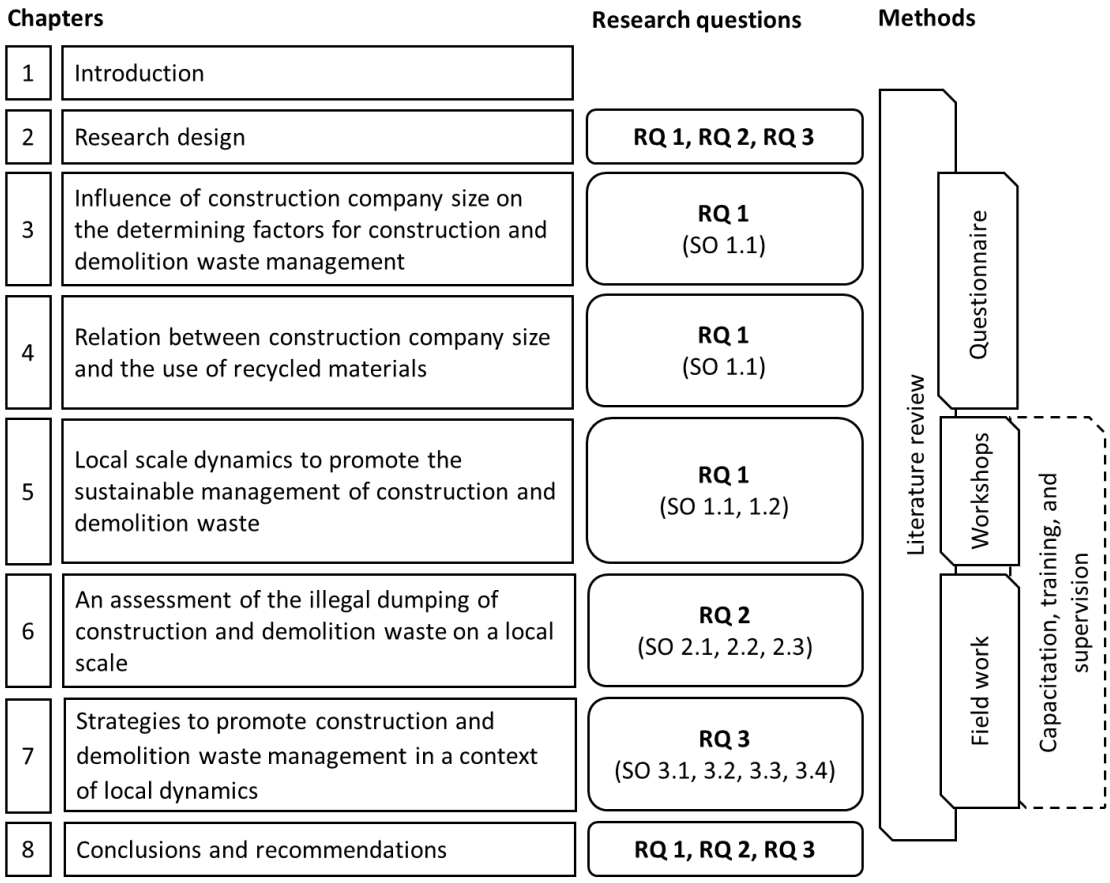
But to be possible to implement the monitoring work, considering the knowledge gaps existing in the main two groups involved, namely the technicians from municipalities and the representatives of micro and small construction companies, it was necessary to plan, and also to embrace spontaneous training actions to tackle the constraints identified in each case. The training actions considered the needs highlighted in the workshops described above, but also the perception of difficulties observed during the supervision actions.

The training themes focused on the realities of the construction sector within CDW management challenges, always involving local legal responsibilities. It also included a component sharing technical knowledge about responsibilities and good practices, whether related to legal procedures or not.

2.5 Structure of the thesis

This thesis is structured in eight chapters, where chapters 1 and 2 introduce the theme and the research project and its design, chapters 3 to 7 present the research developed through articles published in peer-reviewed journals, and chapter 8 presents the conclusions and recommendations.

Although chapters 3 and 7 are sequential, they can be read individually, because they concern specific topics contributing to the assessment of the CDW management challenges as a whole in a local scale dynamic context. Figure 2.8 presents the structure of the thesis, and the relation of each element to the Research Questions (RQ), the Specific Objectives (SO), and methods used in each case. A brief description of the objectives and content of each chapter is presented below.



Legend: RQ – Research Question; SO – Specific Objective

Figure 2.8 - The structure of the thesis, and the relation to the research questions and methods.

Chapter 1 consists of the Introduction, where the motivation for this research project is presented, followed by a brief framework of the contributions from different scales to promote the circular economy in the construction sector, beginning at larger scales, analysing smaller scales, describing the Portuguese context, and finishing with the research gaps. After that, the main objective and the RQ to be addressed are presented, and the respective specific objectives.

Chapter 2 outlines the research design, presenting the concept behind the research project, a brief description of the methods used to develop the investigation, the structure of the thesis (this chapter), and then features a contribution from the authors of the peer-reviewed articles.

Chapters 3 and 4 study the relation between construction company size and the determinants leading to more efficiency in CDW management, specifically because in this subject there was

not enough data to justify differences within the reality of the construction sector. Chapter 3 focuses more on general aspects, and Chapter 4 is dedicated to the analysis of the use of recycled materials by construction companies, focusing on recycled aggregates resulting from CDW. In both chapters, the assessment was based on a survey by questionnaire conducted on Portuguese construction companies. These results address RQ 1, about the determining factors for CDW management on a local scale, with a focus on the reality for construction companies.

Chapter 5 is also dedicated to the determining factors promoting CDW management, but at this time integrating the vision of municipalities and micro and small construction companies, because these two groups have specific responsibilities and face constraints regarding CDW management. The assessment presents the conjoint vision of these players but also identifies matters where visions differ and, in this case, addresses the concerns of RQ 1, not only for each of the groups but also their dynamics on an operational level. The results were obtained through workshops developed in the *Baixo Alentejo* region, aiming to involve the identified groups in the process of discussing challenges, solutions, and specific contributions, and offering their own visions for mitigating problems.

Chapter 6 assesses the reality of illegal dumping of CDW because it is the main concern from the perspective of circularity in the construction sector since it has environmental impacts, and also leads to a loss of material that otherwise could be returned to the construction sector under controlled conditions. This analysis was conducted on a local scale, specifically in the *Baixo Alentejo* region, through monitoring work. It answers RQ 2, how to assess the reality of these occurrences in the context of a local scale, considering the characteristics, and the factors that lead them to occur, as well as presenting results to raise awareness about the problem.

Chapter 7 explores which local strategies are most suitable to promote CDW on a local scale, considering the experience of the study of the determining factors mentioned previously and their integration within a local scale dynamic context, as well as the reality of the illegal dumping of CDW. For this, specific strategies were chosen, involving actions under municipal responsibility and, in most cases, micro and small construction companies. Three local solutions were chosen, relating to the preliminary storage of CDW in a context of proximity, oversight actions at construction sites, and procedural control regarding legal requirements

for public or private construction works. Approaches to communication were interconnected with the previously mentioned strategies. These local solutions were implemented by six municipalities of the *Baixo Alentejo region*, where it was possible to address the objectives of RQ 3.

Chapter 8 presents the key findings of the research project, detailing the main conclusions resulting from the discussion of results reached in the previous chapters from the perspective of identifying the determining factors and strategies for CDW management on a local scale. Moreover, recommendations are made for future research projects or interventions, based on the results of this research project.

2.6 Contribution of other authors

The main author for the design and implementation of this research project is Mário Ramos, under the supervision of Graça Martinho. The leading author of all the chapters of this thesis is Mário Ramos, who was responsible for the conceptualisation, project administration, methodology, formal analysis, investigation, validation, and writing (original draft, review, and editing). Graça Martinho was responsible for funding acquisition, supervision, resources, conceptualisation, and writing (review).

Lia Vasconcelos and Filipa Ferreira collaborated in the participatory process with the municipal technicians and the representatives of micro and small construction companies of the *Baixo Alentejo* region and, specifically in Chapter 5, in conceptualisation. Joaquim Pina collaborated in the statistical assessment in Chapter 7, in formal analysis.

3

Influence of construction company size on the determining factors for construction and demolition waste management [2]

Abstract

Due to the relevance of construction and demolition waste (CDW) generation for circular economy and reduction of environmental impacts, it is important to evaluate the factors leading to constraints. Previous researchers have assessed construction company attitudes and behaviours toward CDW management, but factors such as the presence of environmental technicians, registration of the CDW generated, commitment to the legal framework, the subcontracting regime, and construction works' oversight were rarely addressed in terms of the differences existing within the construction sector. Thus, the objective of this research is to evaluate the relationship of these factors with construction company size. A questionnaire was sent to Portuguese construction companies, and 652 responded. The sample was divided into three groups: micro, small, and medium/large companies. Statistical data treatment was carried out to assess whether there were statistically significant differences in the mentioned factors between groups. The main conclusions highlight: the prevalence of environmental technicians working in larger companies; the registration of waste platforms being only performed consistently by medium/large companies; a considerable proportion of micro and small companies having knowledge gaps about the practices adopted; the responsibility for CDW management within the subcontracting regime being mainly from subcontractors; and the presence of a gap regarding onsite construction works oversight. These differences lead to the need to re-evaluate the strategies for CDW management and adapt the strategies to the specific conditions of the construction sector, including the size of construction companies.

Keywords

Behaviour; Construction and demolition waste (CDW); Construction company; Construction sector; Waste management.

[2] Published as a peer-reviewed article:

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

3.1 Introduction

Besides the important economic and social contribution of the construction sector in promoting wealth and job creation (European Commission, 2012), it is also relevant to consider the environmental impacts, such as the extraction of raw materials; CO_2 emissions (Huang *et al.*, 2018; European Commission, 2011); as well as construction and demolition waste (CDW) generation, which accounts for around a third of the total waste in the European Union per year (Eurostat, 2018; European Commission, 2016). To reduce environmental impacts, specifically about waste, it is important to analyse the determining factors influencing CDW management. In general, construction companies have a major role concerning their attitudes and behaviours (Li *et al.*; 2018; Li *et al.*, 2015; Teo & Loosemore; 2001), and in more specific terms, their knowledge (Li *et al.*; 2018, 2015), their individual or collaborative approaches with other stakeholders and authorities (Chen *et al.*, 2019; Mak *et al.*, 2019; Ajayi *et al.*; 2016), and their onsite construction practices (Tam *et al.*, 2018a; Ding *et al.*, 2016; Ramos *et al.*, 2014; Begum *et al.*; 2009, 2006).

Although CDW management practices and the results achieved diverge across the European Member States (Zhang *et al.*, 2021; Gálvez-Martos *et al.*, 2018), the construction sector has been considered as a main driver in the European Circular Economy Action Plan (European Commission, 2020; European Commission, 2015). The Portuguese Plan of the same subject (PCM, 2017) defines that regional and local agendas also have to consider the construction sector as a strategic economic activity, so it can be possible to tackle the constraints to the implementation of circularity principles. Also, a study on waste management conducted by EY-AM&A (2018) identified that the construction sector is, among all Portuguese economic activities, the one that has the most relevant potential contribution to circular economy principles implementation.

But for this strategy to be effective, it is necessary to fill in information gaps in Portugal, as in other countries, about the different realities within the construction sector. In this context, research was focused on the analysis of possible relationships between the practices and the perceptions about CDW management on the part of Portuguese construction companies according to their size.

3.2 A brief review of construction and demolition waste management by construction companies

3.2.1 Attitudes and behaviour determinants for better construction and demolition waste management

In terms of behavioural evaluation, construction company attitudes differ between organizations (Ding *et al.*, 2016; Teo & Loosemore, 2001) depending on the culture of the construction companies as well as on their existing waste management policies. The research from Teo & Loosemore (2001) also indicated that there are factors that are important to leading to best practices: a commitment to waste management issues, but also to the existence of waste facilities with a positive cost-benefit balance; a communication and awareness component about CDW management strategies that must be encouraged through training and awareness campaigns; and CDW management policies properly communicated on an equal basis between hierarchical levels.

Some specific studies were carried out with this line of reasoning. For instance, to reduce the CDW intensive generation in the United Kingdom, it was concluded that a set of issues needed to be addressed by construction companies (Ajayi *et al.*, 2016): the knowledge gaps on how to operate in the absence of a collaborative agenda; the issue of not assuming responsibilities and passing them between entities; the belief in the inevitability of CDW generation; and the conservatism that prevents the introduction of innovation. Nevertheless, it seems that the commitment of construction companies that are already practicing CDW management helps these companies to have a better performance at the environmental level (Yusof *et al.*, 2016).

Evaluating the factors influencing CDW management in the construction sector, Bakshan *et al.* (2017) classified them into two categories: personal (attitudes toward CDW management, raising awareness of consequences, experiences in the past, and social pressure) and corporate (training, inspection and oversight actions and financial incentives). The authors concluded that boosting both personal and corporate factors influence CDW management, through the effect on worker attitudes and behaviour; and for this reason, it is necessary to create conditions to improve worker awareness of the environmental and economic consequences to the construction companies where they are employed. The research also highlights the

relevance of involving contractors and investors, designers, consultants, and regulatory and oversight authorities in future approaches.

Li *et al.* (2018) created a conceptual model based on the classic Ajzen's theory of planned behaviour (Ajzen, 1991), to which they added some more variables, namely: knowledge, and personal norms. The results obtained revealed that worker knowledge was the most relevant factor in influencing behaviour related to CDW management, compared to subjective norms, attitudes, personal norms and perceived behavioural control. In turn, Waziri *et al.* (2014) had already identified the roles of individual commitment and attitudes as essential to creating commitment to the application of sustainable practices in construction companies.

The intent to recycle CDW is determined by the perception of benefit and cost, social values, and personal beliefs, for both public and private organizations (Mak *et al.*, 2019). At the individual level, the factor that most influences this action is compliance with legislation, but at the level of organizations, economic incentives are more valued as a driving force for recycling. In turn, Wu *et al.* (2017) have already stated that this behaviour is not related to the good intentions of the companies, but to the economic viability of the solutions, and once again, it is related to government commitment to the oversight of construction works.

In a complementary perspective, researchers (*e.g.*, Ding *et al.*, 2018; Tam *et al.*, 2018a; Udawatta *et al.*, 2015; Wang *et al.*, 2014) also identified that for better CDW management, the design phase must be considered in project specification as a tool to plan and control CDW prevention (Ajayi & Oyedele, 2018). In this context, the conclusions of Li *et al.* (2015) are relevant, because they warn about the importance of visual demonstration, as CDW accumulation resulting from construction works, and how the adoption of practices for minimizing waste generation through designer actions can be encouraged. They also state that education strategies and an appropriate legal framework should be adopted to demonstrate the importance of minimizing CDW generation.

3.2.2 Construction company size factor

In 2009, research was undertaken in Malaysia (Begum *et al.*, 2009) in which a survey was submitted to 130 construction contractors, divided into three groups related to their

characteristics in terms of size. The contractors were questioned about: the general characteristics of the entities; collection and packaging systems; sorting, reduction, reuse, and recycling practices; worker knowledge about the CDW management; as well as about their behaviour.

Begum *et al.* (2009) concluded that construction contractor attitudes and behaviours regarding CDW management cannot be compared with the results obtained in studies carried out for municipal solid waste management. In addition, the authors found that most contractors do not carry out CDW management practices, including reuse and recovery at the intervention site; nor do they send waste to licensed facilities, which may be due to the costs associated with the operations; and that construction companies lack knowledge in this area. The authors also identified the factors related to contractors' attitudes about CDW management, concluding that the size of the construction company is an important determinant for CDW management behaviour (supported by Gangolells *et al.*, 2014 in respect to legal framework compliance to construction company size). Other factors identified by these authors were the reduction, reuse, and recycling measures adopted in construction interventions; the frequency of CDW collection; the participation of employees in training programs; and the experience of contractors carrying out construction works. The last two factors were corroborated by Ikau *et al.*, (2016), who also added the purchase of material that does not meet defined technical specifications or appropriate storage conditions.

3.2.3 Knowledge gap identification

Within the analysed context, there are factors in need of being studied deeply for complementing information about constraints assisting construction companies regarding CDW management. These constraints may be related to intrinsic factors, such as: characteristics of employees in terms of environmental knowledge about CDW management; or on the other hand, adoption of practices that interfere with CDW generation data records, in this case in terms of assessing the disturbance that may be caused in the official datasets. Additionally, it is necessary to consider factors extrinsic to construction companies that may result, for instance, from authority decisions or actions, as in the cases of legal frameworks, implementation of new tools for CDW management, or the pressure felt at the level of

frequency of inspection and oversight actions. It is also important to understand how the cooperative factor, namely in terms of established responsibilities between construction companies, can affect CDW management.

It is the understanding of the authors of this research that these knowledge gaps are important to be analysed from the point of view of construction company size. This is essential because the guidelines for the construction sector are almost always issued without considering the reality of different levels of knowledge or execution capability. For this reason, it is the objective of this research to evaluate how the different factors are perceived and executed by construction companies of different sizes and how these realities can impact CDW management.

The present research will also consider the experience acquired by the authors of this research since 2012 through the study of CDW management in Portugal and projects for European and national public entities, and experience gained through the supervision of master's thesis on environmental engineering in the NOVA School of Science and Technology of NOVA University Lisbon. In specific, performed research addresses the Portuguese framework of CDW management, within a European characterization of CDW (Martinho et al, 2015; European Commission, 2017); the study of regional strategies or demonstration projects for CDW management (Ramos *et al.*, 2020; Ramos *et al.*, 2014; Martinho *et al.*, 2013); the analysis of Portuguese CDW official data analysing constraints (Martinho & Ramos, 2015); the factors influencing sustainable CDW management (Costa, 2014); the perception of Portuguese stakeholders about selective demolition processes (Paiva, 2019); and the assessment of the introduction of a new digital tool related to Portuguese waste traceability, including CDW (Galharda, 2018).

3.3 Method

3.3.1 The questionnaire

To achieve the proposed objectives, an online structured questionnaire was prepared for Portuguese construction companies with a set of questions formulated to explore the following variables related to CDW management: i) number of workers assigned to the

company's environmental component (*e.g.*, management and monitoring of CDW, wastewater quality, air emissions quality, soil pollution, as well as environmental awareness and training actions); ii) registration of the quantities of CDW generated and its destination on the *Agência Portuguesa do Ambiente* (Portuguese Environment Agency) online platform on waste, but also including the evaluation of the period when a new waste digital traceability tool was created to substitute for waste monitoring guides printed on paper; iii) commitment to meeting the goal of incorporating at least 5% recycled materials in public construction works (when technically feasible), as determined by the Portuguese Law on Waste; iv) procedures of CDW management in subcontracting regimes; and v) construction works inspection and oversight actions carried out by external authorities.

The questionnaire was sent to Portuguese construction companies in September 2017 and the answers were received until the end of November of the same year. Since then, the reality remains similar in Portugal to CDW management practices and the regulatory framework.

The questionnaire was submitted to the construction companies using the online platform *LimeSurvey*, existing in the NOVA School of Science and Technology NOVA University Lisbon), and the answers were statistically treated using the *software IBM SPSS Statistics*.

3.3.2 Definition of construction company groups

In Portugal, the official criteria for the classification of companies by size are based on the number of employees and their turnover. Accordingly, companies are subdivided into the following categories: micro company (fewer than 10 workers and equal to or less than €2 million); small company (fewer than 50 workers and equal to or less than €10 million); medium company (fewer than 250 workers and equal to or less than €50 million); and large company (equal to or more than 250 workers and more than €50 million).

For this research, the size of the construction companies was selected as a group variable, using the Portuguese official classification in nine construction permit classes, defining in general terms the maximum allowed value determined for construction works. In 2017, 22,445 construction companies were registered by a Portuguese public organization related to the construction sector, the *Instituto dos Mercados Públicos, do Imobiliário e da Construção* (IMPIC)

(Institute of Public Markets, Real Estate, and Construction), with the distribution by construction permit classes indicated in Table 3.1.

For this research, an economic and financial report from 2017 for the construction sector in Portugal was evaluated (IMPIC, 2017a), considering data referring to the average number of workers for each construction permit class, but also the representativeness of the permit titles attributed to that year. In this context, three groups were defined for the present research: group A - micro construction companies (construction permits from classes 1 to 3); group B - small construction companies (construction permits from classes 4 to 6); and group C - medium/large construction companies (construction permits from classes 7 to 9).

Table 3.1 - Criteria for defining Portuguese construction company groups.

Construction permit classes, according to the maximum allowed value (€)		**Construction companies registered in Portugal**		**The average number of workers** [A]	**Predominant criteria for classifying construction company size**					
					Representativeness of the construction permit titles attributed (by predominant construction titles, %) [B]					Group definition criteria, considering [A] and [B]
		N.º	%	N.º	*Micro*	*Small*	*Medium*	*Large*	*Total*	
1	Up to 166,000	10,349	46.1	8	**77.9**	20.3	1.6	0.2	100.0	Micro
2	Up to 332,000	7,411	33.0	9	**72.4**	25.8	1.8	0.1	100.0	Micro
3	Up to 664,000	1,807	8.1	10	46.6	**48.8**	4.3	0.3	100.0	Micro/small
4	Up to 1,328,000	1,355	6.0	17	34.0	**57.0**	8.5	0.5	100.0	Small
5	Up to 2,656,000	1,004	4.5	27	21.8	**60.9**	15.3	2.0	100.0	Small
6	Up to 5,312,000	268	1.2	54	6.7	**51.7**	37.8	3.8	100.0	Small/medium
7	Up to 10,624,000	130	0.6	74	0.9	28.8	**60.4**	9.9	100.0	Medium
8	Up to 16,600,000	51	0.2	105	0.0	2.3	**74.4**	23.3	100.0	Medium
9	> 16,600,000	70	0.3	182	1.7	1.7	43.1	**53.4**	100.0	Medium/large
Total		22,445	100.0	-	-	-	-	-	-	-

Source: adapted from IMPIC (2017a)

3.3.3 Population and sample size

From 22,445 Portuguese construction companies with a construction permit title registered in 2017 in Portugal, the questionnaire was sent, by *e-mail*, to a population of 12,857 companies, using the contacts existing in an online database available through IMPIC (2017b). The database was assessed and completed in some cases, for medium/larger construction companies, where missing contacts were easier to find online. During the questionnaire submission process, some *e-mails* were returned undelivered. In cases where it was possible to detect the error, the *e-mail* addresses were corrected and resent. Ultimately, the questionnaire was effectively sent to 11,626 Portuguese construction companies.

The questionnaire was answered by 652 companies, with the distribution by construction permit classes rearranged in the three groups defined for this study presented in Table 3.2. For a 95% confidence interval, the margin of error was 4% for group A, 8% for group B, and 14% for group C. In terms of the Portuguese construction company distribution for the seven regions in Portugal, the results show that *Norte*, *Centro*, and *Área Metropolitana de Lisboa* represents 82.7% of the sample, in line with the existing construction company distribution in 2017 for the same regions (83.6%) (IMPIC, 2017a).

3.3.4 Statistical treatment of hypotheses and results

The existence of statistically significant differences between the groups was considered as a hypothesis to be tested concerning the variables identified in subchapter 3.3.1. To assess whether the differences between the three groups are statistically significant, the one-way ANOVA was used for sample means, and the Pearson's chi-square test (χ^2) was used for sample frequencies. In samples in which it is not possible to use the chi-square test, due to having counts below five corresponding to more than 20% of the total, the likelihood ratio (G2) was used for sampling frequencies. For both tests, a value of $\rho \leq 0.05$ was considered as the minimum acceptable significance level, corresponding to a 95% confidence level.

Table 3.2 - The number of Portuguese construction companies contacted and number that answered the questionnaire.

Groups	Construction permit classes	Construction companies contacted				Answers to the questionnaire				
		Total		Valid contacts						
		N.º	*%, in relation to the existing construction companies*	*N.º*	*%, in relation to construction companies contacted*	*N.º*		*%, in relation to valid contacts*		*The margin of error **
A (Micro companies)	1	5,186	52.3	4,630	89.3	189	466	4.1	4.7	4
	2	4,676	74.9	4,314	92.3	198		4.6		
	3	1,046	60.6	926	88.5	79		8.5		
B (Small companies)	4	815	64.9	717	88.0	58	144	8.1	9.4	8
	5	637	68.1	579	90.9	53		9.2		
	6	255	100.0	236	92.5	33		14.0		
C (Medium/ large companies)	7	127	98.4	114	89.8	12	42	10.5	18.8	14
	8	45	100.0	43	95.6	12		27.9		
	9	70	100.0	67	95.7	18		26.9		

Legend: * for 95% confidence interval level; % in relation to valid contacts

3.4 Results and discussion

3.4.1 Construction sector characteristics about environmental knowledge

To evaluate if environmental knowledge can somehow play a role in worker behaviour of Portuguese construction companies, the number of workers dedicated to the environmental component was identified, even including those associated with a health and safety oversight professional function. Table 3.3 shows that the average number of workers dedicated to the environmental component has a relation with Portuguese construction company size, with the number of this type of worker increasing in terms of average number from micro (group A) to medium/large companies (group c), with statistically significant differences between groups ($F(2, 609) = 128.682$; $\rho \leq 0.000$).

Table 3.3 - Construction company workers that are dedicated to the environmental component.

Construction company workers by type of function	**The average number of workers, by construction company group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 437	*N = 134*	*N = 41*	*N = 612*	
All categories	9.5	44.3	219.4	31.2	F (2, 609) = 160.395; $\rho \leq 0.000$
Environmental component [A]	0.5	1.3	3.8	0.9	F (2, 609) = 128.682; $\rho \leq 0.000$
Environmental component but together with the hygiene and safety at work [B, part of A]	0.4	0.9	2.8	0.7	F (2, 609) = 100.548; $\rho \leq 0.000$

This might be justified by construction company size itself (Begum *et al.*, 2009), executing smaller construction works, and with micro and small companies not being able to hire specialized environmental technicians; but it also might demonstrate the facility to implement environmental practices in a much more consistent way by companies having this workforce. For micro companies, not all the construction companies answering the questionnaire had a worker dedicated to the environmental component.

Moreover, the number of technicians that are strictly dedicated to environmental management and monitoring operations also increased from small to larger construction companies, showing a level of commitment to environmental issues, including CDW management. Knowledge gaps were identified through literature review, as having a major role in the behaviour of CDW management by construction companies (Li *et al.*; 2018; Bakshan *et al.*; 2017; Ajayi *et al.*, 2016), and these results for Portuguese construction companies complement the existing data.

3.4.2 Registration of the quantity of construction and demolition waste generated in the Portuguese platform on waste

Portuguese construction companies, along with CDW management operators, are obligated to report data about the amount of CDW managed, yearly, to the *Agência Portuguesa do Ambiente* (Portuguese Environment Agency), according to defined criteria. In this study

respondents representing Portuguese construction companies were asked about the company registration on the online Portuguese platform on waste, to analyse how reliable CDW statistic data are. The results reveal that the majority of the medium/large Portuguese construction companies (group C) are registered (92.9%), along with 56.2% of small companies (group B), but only a minority of the micro companies (group A) are registered (20.6%), with the difference among groups being statistically significant (χ^2 (4) = 137.083; $\rho \leq 0.000$) (Table 3.4). This aspect is important to the understanding of a common debate topic about the consistency of CDW data in Portugal (Martinho & Ramos, 2015; European Commission, 2017).

Table 3.4 - Registration in the Portuguese online platform on waste.

Is the company registered in the online platform on waste?	**Number of answers (%), by construction company group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 466	*N = 144*	*N = 42*	*N = 652*	
Yes	20.6	56.2	92.9	33.1	χ^2 (4) = 137.083; $\rho \leq 0.000$
No	58.8	28.5	7.1	48.8	
Do not know	20.6	15.3	0.0	18.1	

Even considering data registered by waste management operators, executing it more consistently, there is an issue regarding the full understanding of the cross-analysis of reported data (CDW producers *versus* waste management operators). This is important, for instance, when analysing the reality in Portugal that substantial amounts of illegally dumped CDW (Ramos *at al.*, 2020; Martinho *et al.*, 2013) do not appear in the official data unless reported as cleaning actions executed by municipalities or contracted waste management operators. This reality of CDW illegal dumping, although referred few times, is becoming a relevant concern for other studies (Liu *et al.*, 2021a; Islam *et al.*, 2019; Chen *et al.*, 2019).

Additionally, the Portuguese waste traceability tool used to record waste movements changed in 2017, from paper monitoring guides to electronic monitoring guides (e-GAR). As the questionnaire caught this transition period, also studied by Galharda (2018), respondents from Portuguese construction companies were asked about the use of e-GAR in the trial period (six months) and their respective degree of satisfaction, to evaluate how adaptable construction companies can be to new electronic waste tools.

In general terms, Portuguese construction companies were not interested in testing the new electronic tool (57.7%), although the Portuguese Environment Agency organized several meetings to explain the tool and engage the stakeholders, including, in the construction sector, construction companies and CDW management operators. This question also aimed to understand whether construction company size affects the predisposition for use of new tools assisting authorities with waste reporting, and showed that differences between groups are statistically significant (χ^2 (4) = 16.946; $\rho \leq 0.002$): micro and small construction companies, from groups A and B, respectively, showed a high level of unfamiliarity with the tool within the trial period (38.2% and 28.5%, respectively), compared to only 4% of medium/large companies, from group C. This may be evidence for a lack of follow-up about the changes in the waste sector or a lack of interest in new practices on waste. These results may also show the importance of knowledge gaps demonstrated in the previous subchapter (subchapter 3.4.1).

The few Portuguese construction companies that were using the new tool during the trial period (53 construction companies; 8.1% of the total) were asked to evaluate their satisfaction, in a Likert scale (from 1 – very unsatisfied, to 7 – very satisfied). The average result of 5.04 for all construction companies reflected no statistically significant differences among the three groups (F (2, 45) = 0.069; $\rho \leq 0.933$).

On the other hand, the construction companies that were not using e-GAR (376 construction companies; 57.7% of the total) were asked to mention the main reason they were not, showing the result differences to be statistically significant between the groups (G^2 (6) = 69.599; $\rho \leq 0.000$). Micro companies indicated no knowledge of the new tool (68.3%); small companies identified that their companies intend to use it but only when it becomes mandatory, or mentioned that they did not know the new tool (42.2% and 37.8%, respectively); and medium/large companies reported that they will use it when it becomes mandatory (76.5%). These results show the resistance to the use of new tools in the waste sector, namely electronic tools used on waste traceability, even including the medium/large companies. These results complement the research of Ajayi *et al.* (2016), when identifying the knowledge gaps, the issue

of not assuming responsibilities and passing them between entities, and the introduction of innovation were identified as main factors to be considered for construction companies.

3.4.3 Legal framework compliance

For effective CDW management practice implementation, a commitment to the regulatory framework is important and, for that reason, it is relevant to understand the reality among the defined construction company groups. In Portugal, a specific regulatory framework for CDW was created in 2008 in line with the European guidelines on this matter and the Portuguese national Law on Waste. But complementary criteria about circularity in the construction sector transposed to Portugal, amending the Waste Framework Directive, came into force on July 1st of 2021. In this context, CDW specific regulations became available directly in the national Law on Waste, namely regarding selective demolition and the obligation for a separate collection system, including for CDW, from 2025 onward.

To evaluate legal framework compliance, a specific Portuguese target regarding the construction sector was evaluated in the questionnaire, as an example to assess the commitment of Portuguese construction companies to new CDW regulations. Since 2011, a specific national target was created to incorporate (only for public construction works and when technically feasible) 5%[3] of recycled materials or materials incorporating recycled components in relation to the total materials used in the respective construction work. In this context, respondents from Portuguese construction companies were asked if the company participates in the execution of public construction works. The results were statistically significant among groups (G^2 (4) = 53.132; $\rho \leq 0.000$) and showed, in general, that almost half of the construction companies execute this type of work. This tendency was encountered in small and medium/large construction companies, from groups B and C (67.4% and 85.7%, respectively). In micro companies (group A), the majority answered that they do not execute this type of work (55.8%), although a relevant percentage (42.7%) answered that they do.

[3] Meanwhile (after the questionnaire submission), this Portuguese target increased to 10%, with the Decree-Law n.º 102-D/2020, from the 10th of December, with subsequent amendments.

For the companies enrolled in public construction works (332 construction companies; 50.9% of the total), it was asked if they incorporate recycled materials. The answers demonstrated statistically significant differences between groups (χ^2 (4) = 16.071; $\rho \leq 0.003$). The majority of small and medium/large Portuguese construction companies, from groups B and C (47.4% and 61.1%, respectively) answered that they incorporate this type of material. Moreover, it is important to note that mainly for micro companies (group A), but also for small companies (group B), there is a lack of knowledge about this subject, in terms of whether the construction companies execute it or not (41.2% and 29.9%, respectively) (Table 3.5). This is important evidence, since it may demonstrate that this is not a subject considered relevant by those construction companies, or that they are not familiar with that specific mandatory Portuguese target. The results also corroborate the importance of the lack of knowledge referred by different authors mentioned before, but in the perspective of not having existing knowledge regarding the execution of construction works themselves, or the conditions on how they are executed.

Table 3.5 - Incorporation of recycled materials in public construction works.

Does the company incorporate at least 5% of recycled materials in public construction works?	**Number of answers (%), by construction company group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 199	*N = 97*	*N = 36*	*N = 332*	
Yes	37.7	47.4	61.1	43.1	χ^2 (4) = 16.071; $\rho \leq 0.003$
No	21.1	22.7	30.6	22.6	
Do not know	41.2	29.9	8.3	34.3	

The Portuguese construction companies answering that they comply with the target (143 construction companies; 21.9% of the total) were asked about the main reasons; and the results were, once again, statistically significant between groups (χ^2 (4) = 11.890; $\rho \leq 0.018$). Although the majority of answers in all groups indicates that it may be easy to comply with the target, a considerable number of respondents (49.0%) stated that the target should even be higher. Micro and small construction companies, from groups A and B, answered that a higher value for the target will not be feasible (44.0% and 39.1%, respectively), and small and medium/large construction companies, from groups B and C, reported that it depends on the type of

construction work (21.7% and 18.2%, respectively). These results comply, in general, with the conclusion achieved by Gangolells *et al.*, 2014 that the existing legal framework is not sufficiently adapted to companies of all sizes. But answers also might indicate that Portuguese construction companies may comply with more demanding targets, although the feasibility may depend on the construction work type, and if they have more knowledge (Li *et al.*, 2018).

In a complementary way, Portuguese construction companies answering that they do not comply with the target (75 construction companies; 11.5% of the total) were asked about the main reasons they do not comply. They answered, in general, with no statistically significant differences among groups (G^2 (8) = 3.521; $\rho \leq 0.898$), that: it is not usually stated in the construction work contract specification, or it is neither required or verified by the oversight construction work team or by the owner (48.0% and 29.3%, respectively); or it is not authorized by the contractor and oversight team (5.3%), among other combined reasons. These results may be related to the reasons stated by Mak *et al.* (2019), who mentioned that although at the individual level the factor that most influences the action is compliance with legislation, the economic incentives are more valued as a driving force for recycling for public organizations.

3.4.4 Construction waste management in the subcontracting regime

To understand how the relationships between construction companies can determine CDW management success, the respondents were asked about the subcontracting regime. From the answers, it was verified that most of the Portuguese construction companies answering the questionnaire work in this system (439 construction companies; 67.3% of the total), with no statistically significant differences between groups (χ^2 (4) = 5.322; $\rho \leq 0.256$).

For the construction companies participating in the subcontracting regime, it is important to understand who usually bears the responsibility for CDW management. The results show, with no statistically significant differences between groups, that the responsibility lies, in most cases, with the subcontracting entity (62.4%), although in the remaining cases it lies with the subcontracted company or with both entities (23.5% and 4.6%, respectively). These results support the importance of a collaborative agenda among entities, as referred by Ajayi *et al.* (2016), and these results show a generalized responsibility transference of CDW management.

That can be good in cases where there is compliance with the regulatory framework and good practices, but it may represent worse results when that compliance does not exist.

3.4.5 Construction works oversight

Respondents from Portuguese construction companies have been asked about the knowledge they have about annual visits from environmental inspection and oversight external authorities (national or regional authorities on waste or policy entities with delegated waste control functions), showing the results to have statistically significant differences between groups (χ^2 (4) = 25.451; $\rho \leq 0.000$). The absence of oversight visits was the most common answer (73.6% of the total, but with micro and small construction companies from groups A and B, presenting worse results – 75.3% and 72.2%, respectively – compared to 59.5% for medium/large construction companies from group C) (Table 3.6).

Table 3.6 - Visits to construction works, by external inspection and oversight authorities, for one year.

Have the construction works executed during the last year been visited by external inspection and oversight authorities?	**Number of answers (%), by construction company group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 466	*N = 144*	*N = 42*	*N = 652*	
Yes	6.2	9.7	28.6	8.4	χ^2 (4) = 25.451; $\rho \leq 0.000$
No	75.3	72.2	59.5	73.6	
Do not know	18.5	18.1	11.9	18.0	

For the Portuguese construction companies answering that they acknowledge the visits (55 construction companies; 8.4% of the total), only 31 construction companies (4.8% of the total) were able to indicate an approximate number of annual visits performed by environmental inspection and oversight authorities. The results were not statistically significant between groups (χ^2 (2) = 0.630; $\rho \leq 0.730$). From those 31 companies, an average of 1.5 environmental oversight visits were made to construction works per year, again without statistically significant results between groups (F (2, 28) = 3.071; $\rho \leq 0.062$); but with micro and small entities, respectively, presenting a lower value (1.3 visits on average), compared to a higher value from medium/large construction companies (2.1 visits, on average).

These results reveal a lack of capability of the Portuguese environmental inspection and oversight authorities to verify the regulatory compliance and the implementation of good practices on construction sites. This may lead to a perception of impunity and conduct of bad environmental behaviours, namely regarding CDW management in line with findings of Bakshan *et al.* (2017), who suggest that both personal (corroborated by Lu, 2019) and corporate factors influence CDW management, through effects on worker attitudes and behaviour; and by Chen *et al.* (2019) who stated that regarding CDW illegal dumping, monitoring actions are essential, justifying that penalties are not enough if applied in isolation from oversight actions.

3.5 Conclusions

Since other previous studies were dedicated mainly to construction company attitudes and behaviour, as well as onsite construction practices, the authors focused this research on complementary determining factors for better understanding CDW management constraints. A transversal driver seems to be the finding that environmental knowledge is a major and relevant determining factor for CDW management, as stated by other authors, although in complementary issues regarding mainly attitude and behavioural components.

In this research, micro and small construction companies are those that have fewer workers employed in the environmental component; less information about procedures developed for the company, namely regarding control of legal requirements (procedural control or legal framework compliance); and identify that they are visited fewer times on their construction sites by external inspection and oversight authorities. All these factors were found to have statistically significant differences between the identified groups.

The differences mentioned are important evidence to consider in re-evaluating the vision and strategies for CDW management within the construction sector by policymakers, above all for micro and small construction companies. This recommendation relies on the fact that Portuguese CDW management policies to the construction sector are, in most cases, general, without considering diverse realities inside the sector, and it is necessary to considerer different scales of action for strategies to be effective. In this perspective, it is important to highlight the role of the authorities in the control of established procedures, and with the

provision of human resources able to carry out environmental oversight of the construction activity. This oversight has to go through the planning phase, the procedural level, as well as monitoring on construction sites. Without these actions, there is a risk that construction companies feel they can act with impunity to violate the law or the good practices of CDW management, as about CDW illegal dumping. The results reveal that the absence of a yearly external oversight on construction sites is the most common reality.

Regarding statistical data records, the majority of Portuguese construction companies are not registered on the Portuguese registration platform on waste, which is particularly relevant in the case of micro construction companies, compared to medium/large ones, in that the latter were almost all registered (with statistically significant differences between groups). This fact can be related to the platform characteristics itself, but also with knowledge gaps that can influence compliance with the established procedures. Such situations can distort the statistical data, namely through illegally dumped CDW not being recorded, justifying the cross-evaluation of evidence with procedural control and onsite oversight by the authorities.

During the research, a new waste traceability tool was implemented in Portugal, substituting paper waste monitoring guides with electronic waste monitoring guides. In general (but without statistically significant differences between groups), construction companies were not interested in testing the new tool, and micro and small construction companies registered a high level of unfamiliarity with it. This reinforces the importance of knowledge gaps and the necessity to adjust policies and guidelines for future application.

In the context described, further studies must be conducted to better understand what type of knowledge is necessary to transmit to construction companies, especially to micro and small companies; and to understand how to communicate with them more effectively. Moreover, it is necessary to understand the behaviour regarding the often-identified CDW illegal dumping reality in Portugal, because it influences the statistics, but above all, it limits the otherwise high potential for CDW recovery resulting from construction sector activity. Finally, it is necessary to modify strategies for construction and demolition waste at local scales, namely for municipalities and small construction companies.

4

Relation between construction company size and the use of recycled materials [4]

Abstract

For a circular economy approach in the construction sector, it is important to understand the value of using recycled materials in buildings and other constructions, reducing the extraction of natural resources, as well as the generation of construction and demolition waste. The role of construction companies is relevant in the sense that they are one of the main actors for this change. However, the differences within the sector, namely the size of the construction companies, can make it hard to implement, so it is essential to understand the factors influencing it. To this end, a structured questionnaire survey was submitted to Portuguese construction companies, dividing the sample of 652 answers into three groups (micro, small, and medium/large companies). Data treatment was carried out to determine whether there are significant statistical differences between groups regarding the use of recycled materials. Their use is carried out by most of the companies, in all groups, with the factors in favour related to the internal practices of the companies, and the against factors associated with market availability. For recycled aggregates, in particular, there is a weak self-evaluation of knowledge about these materials. Furthermore, there is a risk perception in terms of confidence in its use. These conclusions are important for the definition of differentiating strategies to promote and improve the use of recycled materials by construction companies.

Keywords

Construction and demolition waste (CDW); Construction company; Construction sector; Recycled aggregates; Recycled materials.

[4] Published as a peer-reviewed article:

Ramos, M., Martinho, G., 2022. Relation between construction company size and the use of recycled materials. *Journal of Building Engineering*. 45, 103523. https://doi.org/10.1016/j.jobe.2021.103523

4.1 Introduction

Using more sustainable materials is an important contribution of the construction sector to implement the circular economy principles (Le & Bui, 2020; López Ruiz *et al.*, 2020; Tam *et al.*, 2018b). This is relevant in terms of political and technical strategies leading to the minimization of environmental impacts regarding natural resources extraction (European Commission, 2012; European Commission, 2011), the mitigation of CO_2 emissions (Huang *et al.*, 2018), as well as the reduction of construction and demolition waste (CDW) generation, in this case through the reuse of materials, but also promoting recycling (European Commission, 2020, 2016, 2015). However, the use of recycled materials, understood as materials that fully or partially incorporate recycled waste (*e.g.,* recycled aggregates resulting from CDW, urban furniture made from plastic waste, plasterboard incorporating cardboard from paper and cardboard waste) involves specific legal and procedural obligations. Knowledge in this subject has been produced in recent years and has the potential to be even more explored. The results have shown that the use of recycled materials in the construction sector, with a great focus on recycled aggregates, can be carried out without raising great constraints, as long as meeting the final products technical requirements (Le & Bui, 2020; Silva *et al.*, 2019; Tam *et al.*, 2018b; Pacheco *et al.*, 2017; Contreras *et al.*, 2016; Duran *et al.*, 2006).

In Portugal, although lagging behind other European countries (European Commission, 2017), there have been initiatives to integrate the concerns about CDW management and the use of recycled materials in legal and procedural guiding documents. However, the construction sector stakeholders recognize constraints to overcome, and there is a widespread consensus that the role of regions, municipalities, and construction companies, especially the practices of micro and small companies, must assume a primary worry in the construction sector vision and strategies (Ramos *et al.*, 2020; Ramos *et al.*, 2014). These observations have been corroborated by other authors concerning construction companies, in general, namely about: the importance of the technical knowledge covering (Chen *et al.*, 2019; Li *et al.*, 2018; Bakshan *et al.*, 2017; Li *et al.*, 2015), the companies' size and the practices' application in construction sites (Begum *et al.*, 2009), the relevance of cooperative relationships among stakeholders (Mak *et al.*, 2019; Tam *et al.*, 2018a; Ajayi *et al.*; 2016), as well as CDW illegal dumping reality (Chen

et al., 2019; Lu, 2019; Solís-Guzmán *et al.*, 2009). The last case is a problem in terms of potential loss of materials capable of being transformed into recycled components to be used in buildings and other constructions.

These constraints are essential to understand, in this case through the Portuguese reality, the factors influencing the incorporation of recycled materials, with a more detailed focus on the use of recycled aggregates. This is crucial to the extent of perceiving whether the strategies in progress should continue or be redirected towards different realities. Since this assessment is missing, this article aims to contribute to this subject, focusing the research on the size of construction companies.

4.2 Literature review

4.2.1 Construction and demolition waste generation and its physical composition

Considering all the waste generated in one year in the European Union, CDW represents around a third, in weight (Eurostat, 2018). The usual is that in datasets from countries with more complete and robust data registration systems on waste, and due to the CDW characteristics, the mineral fraction (*i.e.*, concrete, bricks, and masonry) appears in a greater proportion. Metals, on the other hand, usually appear in disproportionate quantities in less developed registration systems, where metals from other sectors of economic activity (*e.g.*, dismantling of vehicles at the end of their life) are wrongly coded in chapter 17 of the European List of Waste (Commission Decision 2014/955/EU, of December 18th, amending Decision 2000/532/EC on the list of waste), corresponding only to CDW (European Commission, 2017).

CDW generation indicators are presented in two ways, either by intervention area or *per* capita. The use of these indicators generates discussion, in Portugal, among the actors intervening in the CDW value chain, as they are not homogeneous. On the one hand, this is because they are based on a few case studies, but also since they rely on statistics where the absence of consistent data is notorious. For instance, datasets are based on declared CDW, ignoring CDW illegal dumping occurrences (De Melo *et al.*, 2011). Some indicators were disaggregated, with work based on monitoring construction interventions, with a focus on

buildings, resulting in indicators for the urban reality of Portugal (Lisbon), by type of intervention (demolition, rehabilitation, and new construction) and for two types of use (housing and commercial) (Coelho & De Brito, 2011b).

On the other side, CDW physical composition differs depending on the construction materials that are used (Coelho & De Brito, 2011b), as well as on the type of construction activity intervention. The authors calculated the CDW average physical composition for Portugal, obtaining the following values: concrete, bricks, and masonry (73.6%); bituminous mixtures (13.5%); other CDW (7.4%); wood (3.2%); metals (2.2%); and plastic (0.1%). Other studies about the Portuguese CDW declared show the prevalence of concrete, bricks, and masonry along with the CDW physical composition (Martinho & Ramos, 2015), corroborating the prevalence of the mineral component. *Agência Portuguesa do Ambiente* (Portuguese Environment Agency) also presented the declared values obtained through the registration system on waste for 2018, where concrete, bricks, and masonry mixtures represent around 76% of the CDW available for recovery (APA, 2018b). These results show the great potential that CDW has for recovery, essentially through recycling.

Within this reality, the European Union, through the Waste Framework Directive (2008/98/EC on waste, amended by Directive EU 2018/851) stated the preparing for reuse, recycling, and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous CDW, excluding naturally occurring material, shall be increased to a minimum of 70% by weight, until 2020. And to help to achieve that goal, currently Portugal also has a specific aim of incorporating in public construction works 10% of recycled materials or materials incorporating recycled components. Since the target is very low, the operational viability is easily proven. This is the case of a theoretical exercise, made regarding pre-selected subway construction works developed within *Área Metropolitana de Lisboa* (Lisbon Metropolitan Area, Portugal), above all reflecting the possible use of recycled aggregates (Carneiro *et al*., 2017).

The potential of recyclability resulting from the physical composition of CDW is a major factor where lies the importance of the construction sector for the circularity principles (EY-AM&A,

2018) and, for that reason, the analysis will continue with a greater focus on the recycled aggregates component.

4.2.2 From construction and demolition waste to recycled materials constraints

Through studies that have been conducted within Portuguese municipalities (Ramos *et al.*, 2020; Ramos *et al.*, 2014; De Melo *et al.*; 2011), CDW illegal dumping is often identified. This reality reveals a problem in terms of losing waste with potential for recovery, namely through its transformation into recycled aggregates to be used in buildings and other constructions. The majority of Portuguese municipalities are aware of CDW illegal dumping reality but, in many cases, they assume they are unable to act due to lack of human resources to carry out oversight actions (Martinho *et al.*, 2013). Portuguese waste management operators also identify CDW illegal dumping as one of the main causes for CDW not reaching their waste management facilities (European Commission, 2017).

Although scarce, other studies identify CDW illegal dumping as a difficult problem to combat (Solís-Guzmán *et al.*, 2009) or analyse the causes for its occurrence. For example, Chen *et al.* (2019) conclude that merely increasing the value of penalties does not greatly influence the disappearance of CDW illegal dumpsites, with oversight actions taking on a fundamental role. In Hong Kong, Lu (2019) used a methodology based on big data analysis, referring to CDW transport data, to assess through behavioural indicators the driving forces for CDW illegal dumping. It is stated that those who practice illegal dumping are mainly freelancers, who are usually less patient to wait in the lines of entry into the CDW treatment facilities, relating these occurrences to the behavioural issue, specifically at the individual level.

On the other hand, it is necessary to assess the CDW recovery facilities' territorial coverage. In Portugal, specifically for *Área Metropolitana de Lisboa* (Metropolitan Area of Lisbon), De Melo *et al.* (2011) indicates that the infrastructures for the CDW treatment are located at a distance of approximately 23 km from the geocentre of Lisbon. There are also records about CDW illegal dumpsites, as mentioned above. Thus, it is necessary to understand whether the distances are adjusted, or if other factors are influencing, such as communication and information and awareness, oversight, and control of procedures.

Regarding economic instruments, fixing CDW landfilling costs, as well as the associated environmental fees, is not an easy task, and it can even make CDW diverge towards illegal dumping. In this context, Wang *et al.* (2019) propose to consider life cycle analysis to optimize the environmental fee to be paid, mainly because there is wide variation in prices in China, where different zones charge prices without direct government oversight actions. These results show the need to harmonize criteria among regions, so it can be possible to tackle the problems in the same context.

Also for Portugal, the economic feasibility of using recycled aggregates, in specific, has been studied, as well as the CDW treatment infrastructures (Coelho & De Brito, 2013), including the influence that economic instruments may have in the delivery of CDW to licensed waste management facilities, since a large part of this waste continues to diverge to illegal dumpsites. The environmental cost is also not internalized into landfilling operations, nor into natural materials costs, penalizing the use of recycled aggregates.

4.2.3 The incorporation of recycled aggregates resulting from construction and demolition waste

Although the use of aggregates is high in the construction sector worldwide, as pointed out by Tam *et al.* (2018b), the use of recycled aggregates may differ from country to country, due to the construction traditions, the legislation requirements, and the perception and acceptance level of the construction sector stakeholders, but also including the clients' perception. Since CDW is generated by the construction sector activity in large amounts, the use of recycled aggregates is a great solution in terms of a circular approach to the sector's activity.

In Europe, the average for recycled aggregates incorporation on construction sites, compared to the use of total aggregates, is low (around 9.4%), with the countries above the average being those that have mature legislation and a long history about CDW management (European Commission, 2017). For instance, in Switzerland, Knoeri *et al.* (2011) demonstrated the importance that the interaction between stakeholders has in the choice of incorporating recycled aggregates, even though they continue to prefer conventional construction materials. The authors also determined that the decisions that prevail are not the ones that appear in the

initial project specification, but the legal specifications and the experience in similar works, with the recommendations of other stakeholders also playing an important role.

Although depending on their characteristics, Tam *et al.* (2018b) concluded that recycled aggregates resulting from CDW can be applied in a wide range of civil engineering works, but most is being used in lower end applications, even if it is also being incorporated in structural concrete. Through a literature review conducted in 24 countries of Oceania, Asia, Europe, Africa, and America continents, the authors concluded there is a commitment to the use of recycled aggregate, if considering for instance legislation requirements (standards and normative documents) and the reduction of natural resources depletion. In this context, recycled materials have been used in concrete, concrete pavements, roadway construction, and other civil engineering projects. Complementing this analysis, Le & Bui (2020) accomplished a state-of-the-art about the application of recycled aggregate concrete, considering the recycling techniques of old-concrete-aggregates, the mix proportioning, the mechanical properties, the durability, the structural behaviour, and the fire resistance, concluding about its viability: the possible substitution ratio for coarse aggregates can reach 100% in many cases, while for fine aggregates, it is more reasonable to limit the substitution ratio at 30% to 50%. In Switzerland, recycled aggregates have been used in civil engineering work in a percentage of around 30%, although in structural engineering this amount does not reach 10% (Knoeri *et al.*, 2011).

Silva *et al.* (2019) concluded about the technical viability for the use of recycled aggregates, through the analysis of several case studies, including the use in unbound, hydraulically-bound, and bitumen-bound applications, as well as in (non-)structural concrete in road and building construction. However, the authors highlighted the lack of confidence in the use among designers and construction companies. The authors also mentioned the use of recycled aggregates in countries like Denmark, Netherlands, and Germany, where, apart from the scarce existence of natural aggregates, the existing environmental policies promoting the use of recycled materials are important to encourage confidence in its use. On the other hand, countries not committed to CDW separation and inadequate recycling procedures have led to a general lack of confidence amongst stakeholders.

The certification process has a high impact in terms of the acceptance for the use of recycled aggregates, although most of the recycling plants are producing non-certificate products (Tam *et al.*, 2018b). Also, the authors considered necessary the commitment of government authorities supporting policies related to the use of recycled aggregates, taking into consideration: the cost of recycled versus natural aggregates, the lack of a well-developed collection and processing facilities, the scale of the market, and the proper use considering the final product in terms of a cost-efficiency analysis.

Research opportunities are still missing in what regards CDW recyclability and criteria for wasted materials and recycled products, in terms of material science and engineering perspective, but also regarding reducing CDW considering the project phase, in terms of architecture, engineering, construction, and operation of buildings (Wu *et al.*, 2019a). Cruz *et al.*, (2019) propose the application to the construction sector of the concept of "sustainable sustainability", including the design phase, trying to extend overtime the designs of the environmental, social, and economic pillars. And there is a lot of potential for innovation, as the case studied by González *et al.* (2021), using bioproducts and applying them to the surface of concrete with recycled aggregates. The purpose is to create a protective layer, being this solution a promising treatment to protect the surfaces and increase durability.

CDW recovery in waste recycling facilities is a process being conducted essentially since World War II (Silva *et al.*, 2019; Tam *et al.*, 2018b). But in the latest years, this subject gained importance through the implementation of circular economy principles. Nevertheless, recycled aggregates resulting from CDW are not being applied in developing economies, mainly because of regulatory frameworks and lack of knowledge and confidence. Their incorporation in buildings and other constructions still offers some resistance, although the studies by Le & Bui (2020), Silva *et al.* (2019), Tam *et al.* (2018b), Pacheco *et al.* (2017), and Contreras *et al.* (2016) are an important contribution to raising knowledge and awareness to the confidence levels in the use of recycled aggregates in pre-determined conditions.

But it is essential to better understand the main factors that might contribute to the use in the construction sector of recycled materials, in general, and recycled aggregates, in particular. It is necessary to undertake deep knowledge about the factors influencing the perception of

construction companies on the use of these materials. In this context, this research aims to present an evaluation of the main determining factors influencing it, trying to understand the criteria to adapt or change the policies applicable to the construction sector activity. This assessment will be made considering the reality of the construction company size.

4.3 Method

4.3.1 The questionnaire

An online structured questionnaire was planned and submitted to Portuguese construction companies with two specific groups of questions. The first group was related to recycled materials, in general (with the questions and results presented in subchapter 4.4.1). The second group was related to recycled aggregates resulting from CDW, as a specific example of recycled materials (with questions and results stated in subchapter 4.4.2). The questions tried to answer the following variables:

- About the recycled materials, in general: the perception of the importance attributed to the advantages of using recycled materials, to assess the degree of consensus about the use of this type of materials in the construction sector; the use of recycled materials in construction works, to evaluate the factors that may interfere with it; the acquisition origin of the materials; as well as the predominant types, in terms of the proportion related to the use of recycled aggregates in the total of recycled materials;

- In terms of recycled aggregates resulting from CDW: to assess the degree of knowledge that Portuguese construction companies have regarding the value chain of this type of recycled materials; and the main determining factors contributing for using recycled aggregates, namely environmental, risk perception, execution, planning, but also information and awareness.

The platform *LimeSurvey* was used to submit the questionnaire in September of 2017, allowing to receive answers until November of the same year. It is important to note that the current regulatory framework and practices referring to CDW management remain similar to that of 2017. The results obtained were statistically treated using *IBM SPSS Statistics.*

4.3.2 Population, sample size, and statistical treatment of hypotheses

To meet the main goal of this research, the size of the construction companies was selected as a group variable, using the Portuguese official classification in nine construction permit classes defined for construction companies, considering the number of employees and their turnover.

In 2017, 22,445 Portuguese construction companies were registered by a Portuguese public organization related to the construction sector, the *Instituto dos Mercados Públicos, do Imobiliário e da Construção* (IMPIC) (Institute of Public Markets, Real Estate, and Construction). Nevertheless, it was only possible to contact 11,626 companies using an online database available through IMPIC (2017b).

The questionnaire was answered by 652 companies, with the distribution by construction permit classes rearranged in the three groups defined for this study (Table 4.1) (Ramos & Martinho, 2021): group A - micro construction companies (construction permits from classes 1 to 3); group B - small construction companies (construction permits from classes 4 to 6); and group C - medium/large construction companies (construction permits from classes 7 to 9).

Table 4.1 - Number of Portuguese construction companies contacted and number that answered the questionnaire.

Groups	**Construction permit classes**	**Construction companies contacted**				**Answers to the questionnaire**	
		Total		Valid contacts			
		N.º	*%, in relation to the existing construction companies*	*N.º*	*%, in relation to construction companies contacted*	*N.º*	*%, in relation to valid contacts*
A (Micro companies)	1, 2 and 3	10,908	84.8	9,870	84.9	466	4.7
B (Small companies)	4, 5 and 6	1,707	13.3	1,532	13.2	144	9.4
C (Medium/large companies)	7, 8 and 9	242	1.9	244	1.9	42	18.8

Statistically significant differences between the groups were established as the hypothesis to be tested regarding the following variables: i) perception about the importance of the use of recycled materials, ii) use of recycled materials, iii) acquisition origin of recycled materials, iv) predominant types of recycled materials used, v) knowledge about recycled aggregates, and vi) factors contributing for using recycled aggregates.

To evaluate statistically significant differences between the groups, the one-way ANOVA was used for sample means, and the Pearson's chi-square test (χ^2) for sample frequencies. For samples in which it is not possible to use the chi-square test, due to having counts below five corresponding to more than 20% of the total, the likelihood ratio (G2) was used for sampling frequencies. For these statistical tests, a value of $\rho \leq 0.05$ was considered as the minimum acceptable significance level, corresponding to a 95% confidence level.

4.4 Results and discussion

4.4.1 Recycled materials in general

Perception about the advantages of using recycled materials

The respondents representing Portuguese construction companies answering the questionnaire were asked about the importance attributed to the advantages of using recycled materials, or materials incorporating recycled components, on construction works. For this assessment, a Likert scale was used, from 1 (totally unimportant) to 7 (extremely important). The average value increases from micro construction companies, from group A (5.34 average value), to small companies, from group B (5.49 average value), and again to medium/large companies, from group C (5.50 average value), although without statistically significant differences between the groups defined ($F(2, 608) = 1.748$; $\rho \leq 0.175$). The average value for all the construction companies (5.40) might be considered a good result concerning the importance attributed to the use of recycled materials in the construction sector. Answers corresponding to "not having an opinion about the subject" represent 6.3% of the total.

Use of recycled materials on construction works

The questionnaire asked whether Portuguese construction companies usually incorporate recycled materials, or materials containing recycled components, in the construction works, being the results described in Table 4.2. Although without statistically significant differences among groups (χ^2 (4) = 9.436; $\rho \leq 0.051$), 46.5% of the Portuguese construction companies incorporate these materials, with the medium/large companies (group C) executing it in a more consistent way (61.9%). Considering the technicians who answered the questionnaire, the lack of knowledge about the company procedures decreases from micro to medium/large construction companies (group A to C, respectively), with medium/large companies representing only 4.8%. These results also show the lack of knowledge among micro and small construction companies, that has been referred, in general, by other studies about CDW practices among constructions companies (Li *et al.*, 2018; Bakshan *et al.*, 2017; Ajayi *et al.*, 2016).

Table 4.2 - Use of recycled materials, or materials containing recycled components, on construction works.

Does the company incorporate recycled materials, or materials containing recycled components, on construction works?	**Number of answers (%), by construction companies' group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 466	*N = 144*	*N = 42*	*N = 652*	
Yes	44.4	48.6	61.9	46.5	χ^2 (4) = 9.436; $\rho \leq 0.051$
No	34.5	36.1	33.3	34.8	
Do not know	21.0	15.3	4.8	18.7	

For the 303 Portuguese construction companies (46.5% of the total) incorporating recycled materials in construction works, respondents were questioned about the reasons for companies acting this way, in this case allowing more than one answer for pre-selected options. The results are organized in Table 4.3 in descending order of the total number of answers. In general, it was observed that the most common answer is that it is a usual practice for the company to incorporate this type of material, and the less common in what regards the competitive prices in relation to other materials (60.7% versus 25.4%, respectively). It demonstrates the compromise to perform along with the current and past practices

(corroborated by Knoeri *et al.*, 2011), as well as the question is the relation to costs, that has been highlighted by other authors when there are waste facilities and a positive cost-benefit balance (corroborated by Tam *et al.*, 2018b; and Coelho & De Brito, 2013). There are no statistically significant differences between the groups in these two cases (χ^2 (2) = 4.843; $\rho \leq 0.089$; and χ^2 (2) = 0.450; $\rho \leq 0.799$; respectively).

Table 4.3 - Reasons to use recycled materials, or materials containing recycled components, on construction works.

What are the main reasons to incorporate recycled materials, or materials containing recycled components, in construction works?	**Number of answers (%), by construction companies' group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 207	*N = 70*	*N = 26*	*N = 303*	
Usual practice of the construction company	58.5	60.0	80.8	60.7	χ^2 (2) = 4.843; $\rho \leq 0.089$
Comply with the contract specification	34.8	38.6	69.2	38.6	χ^2 (2) = 11.564; $\rho \leq 0.003$
Recycled materials guarantee at least the same quality as non-recycled materials	24.2	37.1	46.2	29.0	χ^2 (2) = 8.323; $\rho \leq 0.016$
Competitive prices compared to other materials	25.1	24.3	30.8	25.4	χ^2 (2) = 0.450; $\rho \leq 0.799$

Two options achieved statistically significant difference among groups, one referring to the compliance with the contract specification (χ^2 (2) = 11.564; $\rho \leq 0.003$), and the other relative to the quality of recycled materials when compared to other materials (χ^2 (2) = 8.323; $\rho \leq 0.016$). Contract specifications are more relevant to medium/large construction companies, in line with what has been concluded by Silva *et al.* (2019), regarding the existence of environmental policies as a driving force to ensure the use of recycled aggregates. But maybe also because they assumed that is a usual practice for the company. In the case of the recycled materials quality guarantee, micro construction companies appear to be less convinced, not being clear if it is a matter of knowledge or a lack of practice regarding the use of recycled materials. For this reason, this ambiguity should be explored in further studies.

In a complementary way, the 227 companies (34.8% of the total) not incorporating recycled materials in construction works, were questioned about the reasons for this, also allowing more than one answer (Table 4.4). In this case, the lack of supply in the market for recycled materials is the more relevant topic for the construction companies (51.5% of the total), as also identified by Tam *et al.* (2018b). Nevertheless, it is a more relevant issue for micro construction companies, although it also appears to be important for medium/large construction companies. The differences are statistically significant between groups (χ^2 (2) = 8.001; $\rho \leq 0.018$). This conclusion also corroborates the lack of this type of material in the European market (European Commission, 2017). On the other extreme, the reference that the topic is not specified in the contract specification seems to be more relevant to medium/large construction companies, than it is for micro and small companies, respectively, again with statistically significant differences between groups (G^2 (2) = 7.513; $\rho \leq 0.023$). In this case, it may also indicate that micro construction companies lack environmental issues detailed in the contract specification.

Although without statistically significant differences between the groups, and far less expressive than the first option mentioned, related to market supply, the following options are important for the construction companies: the legal framework conditions (18.9% of the total), which can express a feeling that there is not enough legal support on this matter, or that the compliance with the legal background can be difficult to achieve (supported by Silva *et al.*, 2019; and Tam *et al.*, 2018b), having this topic to be more explored in other opportunities; and the uncompetitive prices of recycled materials (17.2% of the total), which can be justified by the fact that in Portugal raw materials are abundant, so recycled materials prices are not competitive (corroborated by Tam *et al.*, 2018b; and Coelho & De Brito, 2013).

But two more subjects need reflection: one concerning the lack of interest of the company regarding this matter (10.1% of the total); and a lack of confidence about using recycled materials (8.4% of the total) (also pointed out by Silva *et al.*, 2019; Tam *et al.*, 2018b; and Knoeri *et al.*, 2011). These two last results denote constraints that have to be resolved when trying to accomplish the circular economy principles in the construction sector.

Table 4.4 - Reasons not to use recycled materials, or materials containing recycled components, in construction works.

What are the main reasons for not incorporating recycled materials, or materials containing recycled components, in construction works?	**Number of answers (%), by construction companies' group**			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 161	*N = 52*	*N = 14*	*N = 227*	
Lack of supply in the market for recycled materials	57.1	34.6	50.0	51.5	χ^2 (2) = 8.001; $\rho \leq 0.018$
Legal framework conditions	16.1	28.8	14.3	18.9	χ^2 (2) = 4.338 $\rho \leq 0.114$
Uncompetitive price of recycled materials	14.3	21.2	35.7	17.2	χ^2 (2) = 4.905; $\rho \leq 0.086$
Not applicable to the company's activity	11.8	9.6	21.4	11.9	χ^2 (2) = 1.473; $\rho \leq 0.479$
Lack of interest by the company in this matter	12.4	5.8	0.0	10.1	χ^2 (2) = 3.593; $\rho \leq 0.166$
Lack of confidence using recycled materials	6.8	13.5	7.1	8.4	G^2 (2) = 2.063; $\rho \leq 0.356$
Not specified in the contract specification	5.0	9.6	28.6	7.5	G^2 (2) = 7.513; $\rho \leq 0.023$

Acquisition origin of recycled materials used

For the acquisition origin of the recycled materials used in Portuguese construction works, the questionnaire asked about the more frequent type of suppliers, between two types: national (Portuguese) or foreign. National suppliers represent 85.1% of the total answers, and only 2.0% are foreign suppliers, without statistically significant differences between the groups (G^2 (4) = 4.697; $\rho \leq 0.320$). Nevertheless, there is a considerable number of respondents from the construction companies (12.9%) recognizing that they do not know the answer, being this consistent with the lack of knowledge reported by other authors about the practices adopted along the CDW value chain (*e.g.*, Ding *et al.*, 2016; Begum *et al.*, 2009).

Predominant types of recycled materials used

About recycled materials, respondents from Portuguese construction companies were asked about the perception of the predominant types used in construction works. Although with no

statistically significant differences between the groups (G^2 (4) = 2.665; $\rho \leq 0.615$), 48.5% of the respondents recognized, in specific, the use of recycled aggregates resulting from CDW, and 48.2% the use of other recycled materials. In the last case, the questionnaire did not allow to specify which they are. These answers denote the perception about the use of a predominant type of recycled materials in the Portuguese construction sector, which are the recycled aggregates. It is also important to note that, in this case, only 3.3% of the total responded that they do not know the answer.

4.4.2 Recycled aggregates resulting from construction and demolition waste

Knowledge about recycled aggregates

There is the perception that the predominant type of recycled materials used by Portuguese construction companies is the recycled aggregates resulting from CDW (subchapter 4.4.1). In this context, the respondents were asked to self-evaluate, in general, their knowledge in what regards different aspects of the value chain of this type of materials: the production, the different types existing and different uses, the certification process and oversight authorities, the costs, and the supplier chain. With this intention, a Likert scale was used, between 1 (does not know anything) and 7 (knows everything).

The results obtained (Table 4.5) are organized in descending order of results about the perception of knowledge, showing statistically significant differences between the groups for all the topics. The results are never superior to an average value of 3.48 (possible uses), below the midpoint of the scale. For all the answers, the Portuguese micro construction companies (group A) know less than the small companies (group B), and even less than the medium/large companies (group C).

Although these results apply specifically to recycled aggregates, they demonstrate that the lack of knowledge is related to the construction company size. This conclusion is supported by Begum *et al.* (2009), although referring, in general, to CDW management practices in construction sites. These differences, depending on the construction company size, should be considered when defining awareness and training programs on this subject, whether for buildings or other construction types in general.

Regarding the knowledge about recycled aggregates, the bottom topic refers to the responsibility about technical standards, preceded by oversight authorities (average values of 2.89 and 2.92, respectively). These results show a lack of interrelation to the authorities in the matter of regulatory framework and procedures, having to be taken into account when deciding strategies in relation to the involvement of the stakeholders, as pointed out by Silva *et al.* (2019); Tam *et al.* (2018b); and Bakshan *et al.* (2017).

Table 4.5 - Knowledge self-evaluation about recycled aggregates.

Topic	**Knowledge self-evaluation about recycled aggregates,** in a Likert scale, from 1 (does not know anything) to 7 (knows everything), by construction companies' group			**Total**	**Statistic test**
	Group A	Group B	Group C		
	N = 466	*N = 144*	*N = 42*	*N = 652*	
Possible uses	3.35	3.70	4.24	3.48	F (2, 649) = 7.974; ρ ≤ 0.000
Quality for its intended purpose	3.32	3.66	4.31	3.46	F (2, 649) = 8.677; ρ ≤ 0.000
Cost	3.23	3.53	3.98	3.34	F (2, 649) = 4.876; ρ ≤ 0.008
Different types existing	3.03	3.43	4.17	3.19	F (2, 649) = 12.298; ρ ≤ 0.000
Certification for its intended purpose	3.00	3.49	4.17	3.18	F (2, 649) = 12.824; ρ ≤ 0.000
Companies providing them	3.03	3.48	3.71	3.17	F (2, 649) = 6.634; ρ ≤ 0.001
Production process	2.97	3.48	4.21	3.16	F (2, 649) = 15.605; ρ ≤ 0.000
Oversight authorities	2.75	3.09	4.12	2.92	F (2, 649) = 13.905; ρ ≤ 0.000
The entity responsible for technical standards	2.70	3.15	4.05	2.89	F (2, 649) = 14.795; ρ ≤ 0.000

Main factors contributing to the use of recycled aggregates

Aiming to better understand the behaviour of Portuguese construction companies, the respondents were asked to assess their perception about the use of recycled aggregates compared to natural aggregates. With this objective, they were invited to evaluate statements,

concerning the following factors: environment, risk perception, planning, execution, and information/awareness. For this purpose, a Likert scale was applied, from 1 (totally disagree) to 7 (completely agree). The results are presented in Table 4.6.

In general terms, the environmental factor was better evaluated, considering the perception that the use of recycled aggregates can both contribute to avoiding the extraction of natural resources (average value of 6.25) but also for minimizing CDW generation (average value of 6.14). In the last case, there are statistically significant differences between the groups ($F(2,608) = 3.543$; $\rho \leq 0.030$), where the micro companies (group A) recognize this subject less than the small companies (group B), and even less than the medium/large companies (group C). The environmental component related to the use of recycled aggregates, in specific, seems to be in line with the importance given to the use of recycled materials, in general (subchapter 4.4.1).

There is a risk perception, related to the guarantee of the safety issues of the products (average value of 4.99), but also to the client perception (average value of 4.11), with statistically significant differences among the groups in both cases ($F(2, 573) = 6.874$; $\rho \leq 0.001$; and $F(2,594) = 5.267$; $\rho \leq 0.005$; respectively). In general, these conclusions are substantiated by Silva *et al.* (2019), Tam *et al.* (2018b); and Knoeri *et al.* (2011). Regarding these results, medium/large construction companies perceive the risks in a more solid way than micro companies. These two aspects should be reinforced in information and training campaigns, but also in the communications from authorities.

In terms of the execution of the construction work, the results show that the companies may comply with the use of recycled aggregates but is necessary to guarantee an economic advantage (average value of 4.59), so the scale of use of recycled materials is an import aspect to balance the costs, as supported by Tam *et al.* (2018b) and Coelho & De Brito (2013). Nevertheless, regarding the possibility of using the materials only in less demanding technical execution (average value of 3.56), medium/larger companies recognize it less, although without statistically significant differences between groups.

Table 4.6 - Perception about the factors influencing the use of recycled aggregates on construction works.

Main factors		**Completing the sentence:** Using recycled aggregates instead of natural aggregates ...	**Perception about the factors influencing the use of recycled aggregates,** in a Likert scale, from 1 (totally disagree) to 7 (completely agree), by construction companies' group			**Total**	**Statistic test**
			Group A	*Group B*	*Group C*		
Environment	Resources	… is a way to avoid the extraction of natural resources.	6.21	6.25	6.65	6.25	F (2, 613) = 2.478; ρ ≤ 0.085
			N = 437	N = 139	N = 40	N = 616	
	Waste	… is a way to minimize the CDW generation.	6.09	6.17	6.63	6.14	F (2, 608) = 3.543; ρ ≤ 0.030
			N = 433	N = 138	N = 40	N = 611	
Risk perception	Result	… guarantees safety issues and the quality of the final products.	4.98	4.73	6.00	4.99	F (2, 573) = 6.874; ρ ≤ 0.001
			N = 403	N = 135	N = 38	N = 576	
	Client	… may be difficult to implement because of the clients' misleading risk perception.	3.99	4.25	4.95	4.11	F (2, 594) = 5.267; ρ ≤ 0.005
			N = 421	N = 136	N = 40	N = 597	
Execution	Costs	… is possible but only if the costs compensate it.	4.60	4.55	4.72	4.59	F (2, 594) = 0.118; ρ ≤ 0.390
			N = 421	N = 137	N = 39	N = 597	
	Technical component	… is possible for construction works if less demanding in terms of technical execution.	3.60	3.66	2.82	3.56	F (2, 569) = 3.005; ρ ≤ 0.050
			N = 399	N = 134	N = 39	N = 572	
Planning	Legal framework compliance	... is possible because there is an appropriate legal framework.	3.54	3.50	4.03	3.56	F (2, 526) = 1.213; ρ ≤ 0.298
			N = 371	N = 125	N = 33	N = 529	
	Execution	… is possible because there is planning for the construction works in the design phase.	3.10	3.26	2.55	3.10	F (2, 562) = 2.178; ρ ≤ 0.114
			N = 395	N = 130	N = 40	N = 565	
Information and awareness		… is possible because there is enough technical knowledge about the subject.	3.19	3.30	3.50	3.24	F (2, 568) = 0.578; ρ ≤ 0.562
			N = 399	N = 132	N = 40	N = 571	

About construction works planning, there might be a perception that the regulatory framework is not appropriate or is difficult to comply with, and that the planning for construction works is missing (average values of 3.56 and 3.10, respectively) (supported by Li *et al.*, 2015). Finally, about the information and awareness factor, there is a recognition, in general terms, referring to the lack of knowledge (average value of 3.24), also previously validated by Begum *et al.* (2009).

4.5 Conclusions

In terms of circularity in the construction sector, including buildings and other constructions, it is important to understand the main determinant factors influencing the use of recycled materials, in general, and recycled aggregates, in specific. The main results, obtained through a questionnaire submitted to Portuguese construction companies show the following, through the answers given by the respondents:

- The major reasons contributing for the practice of incorporating recycled materials include the compliance with internal procedures, as well as with the contract specification, although in this last case it is more relevant for medium/large companies than for micro and small ones;
- The lack of supply in the market for recycled materials is the main reason pointed out by the Portuguese companies for not executing it, being this subject more relevant for micro companies, but also for medium/large companies, denoting, in this case, a reality for the Portuguese construction sector itself;
- In specific to recycled aggregates, there is a weak self-evaluation of knowledge about the different aspects related, from the production, the different types existing and different uses and certification processes, the costs, the supplier chain, and the oversight authorities, showing the tendency, in all cases, that micro construction companies know less than other companies;

- The most important factor that justifies the use of recycled aggregates is the environmental factor (*i.e.*, saving resources and reducing CDW generation), which is in line with the importance attributed to the use of recycled materials, in general;
- The perceived risk of using recycled aggregates is a factor in which there are differences between the perception along with the size of construction companies, related to the guarantee of the safety issues, but also the client perception, being the medium/large construction companies more worried about those aspects then micro companies;
- For the information and awareness factor referring to recycled aggregates, there is the acknowledgment about the lack of technical knowledge.

In general, the results state the importance of using recycled materials in the construction sector. In specific, about recycled aggregates resulting from CDW, variables such as the degree of knowledge for different aspects of the value chain, but also the risk perception for its use, have to be considered in information and training campaigns. The results should also be reflected in the circularity strategies to apply in the construction sector, namely those concerning the constraints identified related to the size of construction companies.

5

Local scale dynamics to promote the sustainable management of construction and demolition waste [5]

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.

Keywords

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

[5] Published as a peer-reviewed article:

Ramos, M., Martinho, G., Vasconcelos, L., Ferreira, F. (2023). Local scale dynamics to promote the sustainable management of construction and demolition waste. *Resources, Conservation & Recycling Advances.* 17, 200135. https://doi.org/10.1016/j.rcradv.2023.200135

5.1 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 & 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.*, 2021b), 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.*, 2020a; Liu *et al.*, 2020a).

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 & Martinho, 2021; Martinho *et al.*, 2015). In these terms, the research approach was supported by participatory workshops, to involve the presentation and discussion of 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.

5.2 Background

5.2.1 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 & Powell, 2016), various environmental and economic aspects to consider (Ding *et al.*, 2018; Tatiya *et al.*, 2018), evaluated through holistic methods (Devaki & 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 & Damigos, 2018; Tam *et al.*, 2018; Ding *et al.*, 2016), and approaches concerned with more technical and specific attributes (Le & 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 & 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.*, 2021b). 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.*, 2022b), 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.

5.2.2 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, 2018a; 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 (2000) 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, 2018a; Martinho *et al.*, 2015) as well as micro and small construction companies (Ramos & 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 & Chang, 2015), including CDW (Ramos & 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 & Martinho, 2023; Santos *et al.*, 2019; Sobotka & 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 & 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, 2018a) 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 & 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 & 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 & 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.

5.3 Method

5.3.1 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).

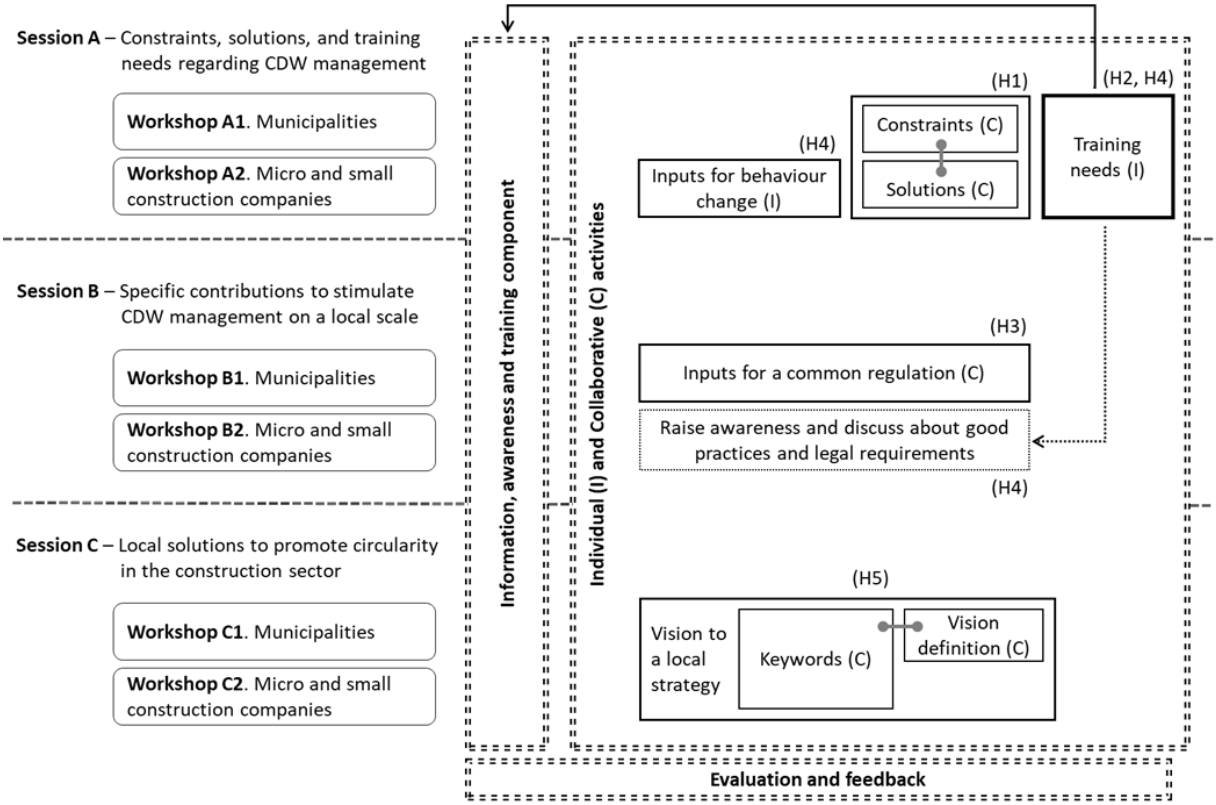
In Portugal, the legal framework regarding CDW is defined in the national law on waste, namely in the Decree-Law 102-D/2020, implemented on the 10th of December (PCM, 2020), with further amendments. Due to their relevance to this research, it is important to identify the following aspects that are currently 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 & Martinho, 2023; APA, 2018a), particularly in rural areas, revealing that legislation alone is not sufficient to resolve local CDW management problems.

5.3.2 The research approach

The participatory workshops

In terms of compliance with the research objectives identified in the Introduction (chapter 5.1), six videoconference participatory workshops were organised during 2021, divided into three sessions, with the following themes (Figure 5.1): 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).



Legend: H – Hypothesis; C – Collective activity; I – Individual activity.

Figure 5.1 - Dynamic of the participatory process, within the hypotheses of the research project.

These workshops were intended to 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.

The participants

Two groups of participants were involved in the workshops, as registered in Figure 5.1 and Table 5.1.

Table 5.1 - Participants in the participatory actions.

Session	**Municipalities' Workshops**					**Construction companies' workshops**
	Municipalities hosting the workshop (n.º)	Municipal technicians involved (n.º)	Municipal technicians involved, by main intervention area (%)			Companies' representatives involved (n.º)
			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.

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 & Martinho, 2021), the maximum size of the companies participating was the fifth Portuguese construction permit class (IMPIC, 2020). Construction companies' representatives were invited by each municipality.

5.3.3 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 (Figure 5.1), 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.

5.3.4 Research instruments of analysis

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 pre-determined 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 data is discrete and this location statistic is robust.

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 dependent 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 participants, who then positioned them, on a Likert-type scale. The statements are presented and systematised in the Appendix - Table 5.4 (at the end of this chapter).

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 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.

5.4 Results and discussion

5.4.1 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 (Figure 5.2). 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 & Damigos, 2018; Jung *et al.*, 2015; Tam *et al.*, 2014); and the lack of knowledge (Ramos & Martinho, 2022).

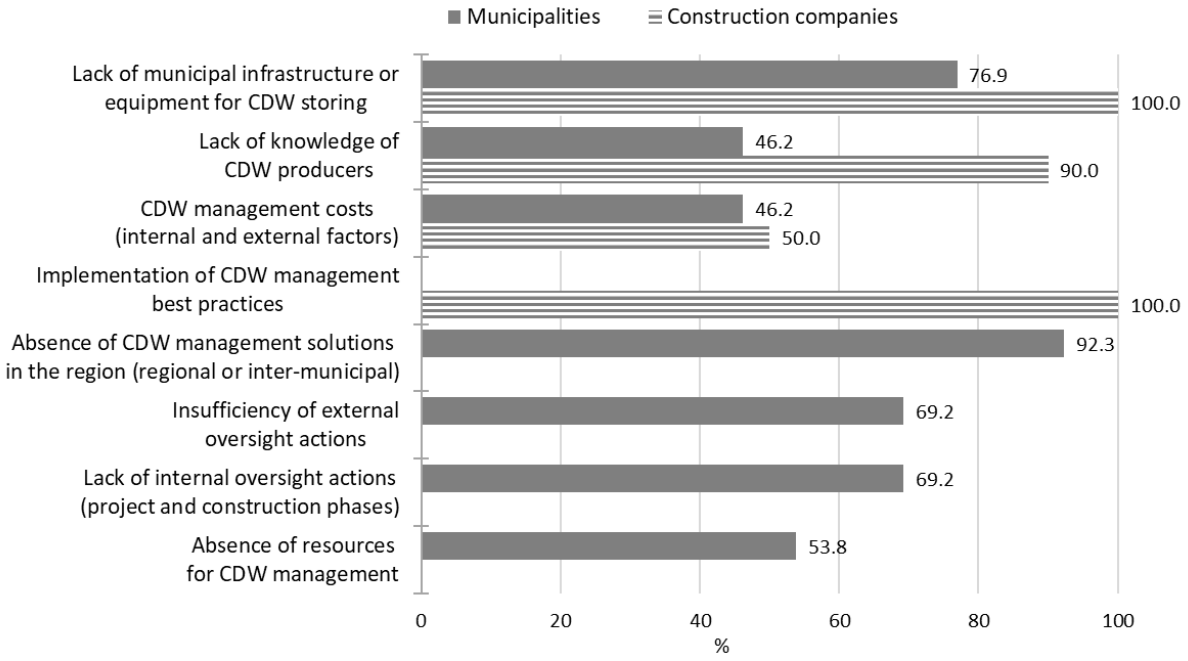


Figure 5.2 - Identified constraints to promote construction and demolition waste management on a local scale.

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, 2018a; 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 & Martinho, 2021).

In the second part of Session A, participants were invited to present and discuss solutions to resolve the constraints previously identified (Figure 5.3). 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 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 & Damigos, 2018).

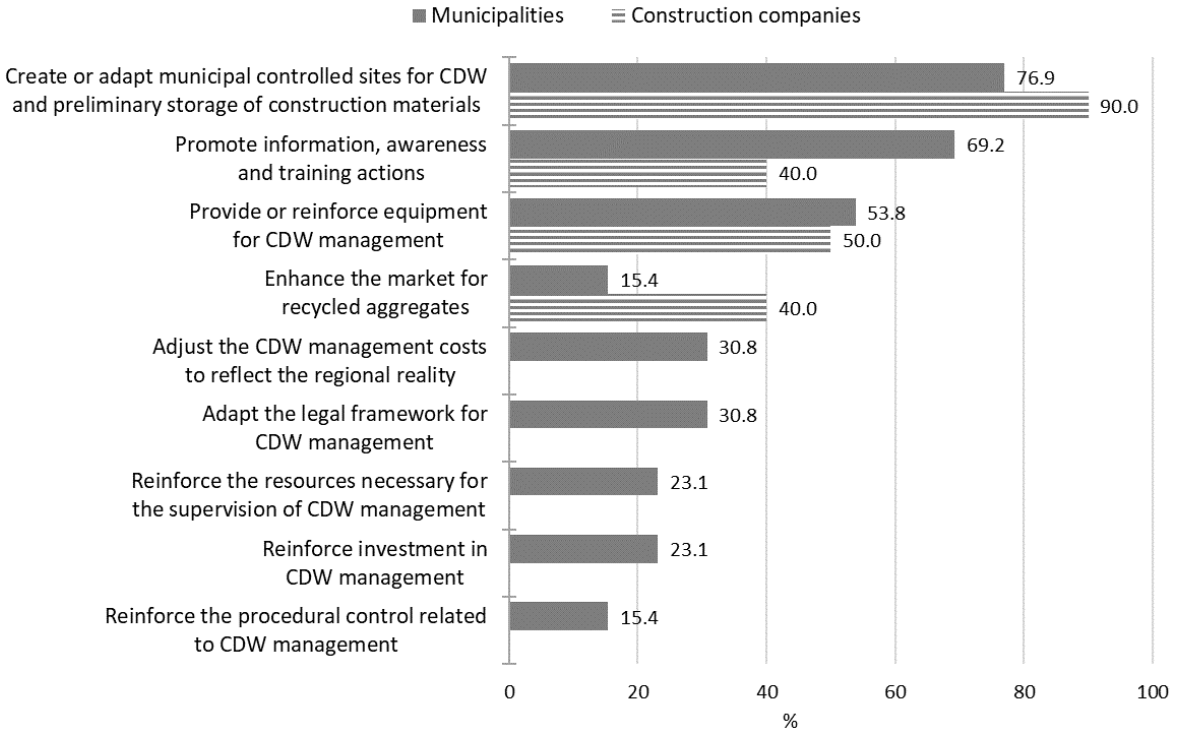


Figure 5.3 - Identified solutions to promote construction and demolition waste management on a local scale.

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 micro and small entities. In Portugal there are important knowledge gaps about recycled aggregates (Ramos & 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.

5.4.2 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 5.2).

Table 5.2 - 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

In general, knowledge gaps were perceived in both groups concerning good practice for CDW management on construction sites (substantiated by Menegaki & Damigos, 2018; Begum *et al.*, 2009), although with more relevance for municipal technicians. Regarding only municipal

technicians, oversight procedures is an essential topic to take into consideration. This evidence is understandable as these municipal responsibilities have also been identified as 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. Additionally, all the remaining topics demonstrate that there is a need for training on wide-ranging topics among the two groups, because they were all self-evaluated as necessary (corroborated, for instance, by Ramos & 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 (Figure 5.1).

5.4.3 Specific contributions to improve construction and demolition waste management

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 Figure 5.4. 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, 2018a).

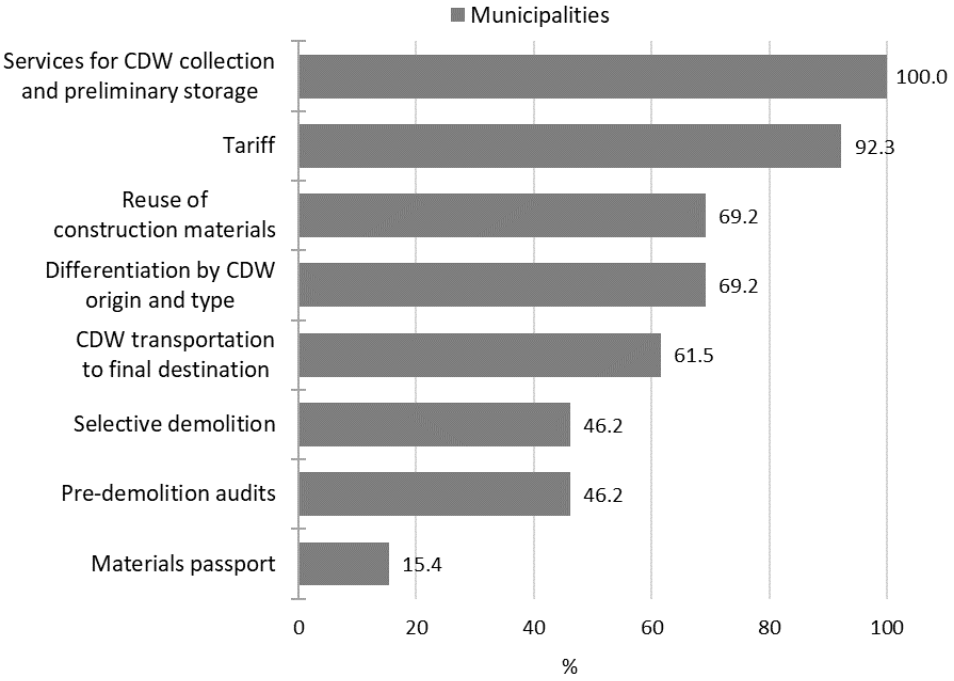


Figure 5.4 - Topics to consider on a common regulation for construction and demolition waste management on a local scale.

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, 2018, 2016), 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).

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 Figure 5.5 the results are presented, showing that the majority of their construction activity is undertaken locally, specifically within the *Baixo Alentejo* region (90%), or 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 5.4.1).

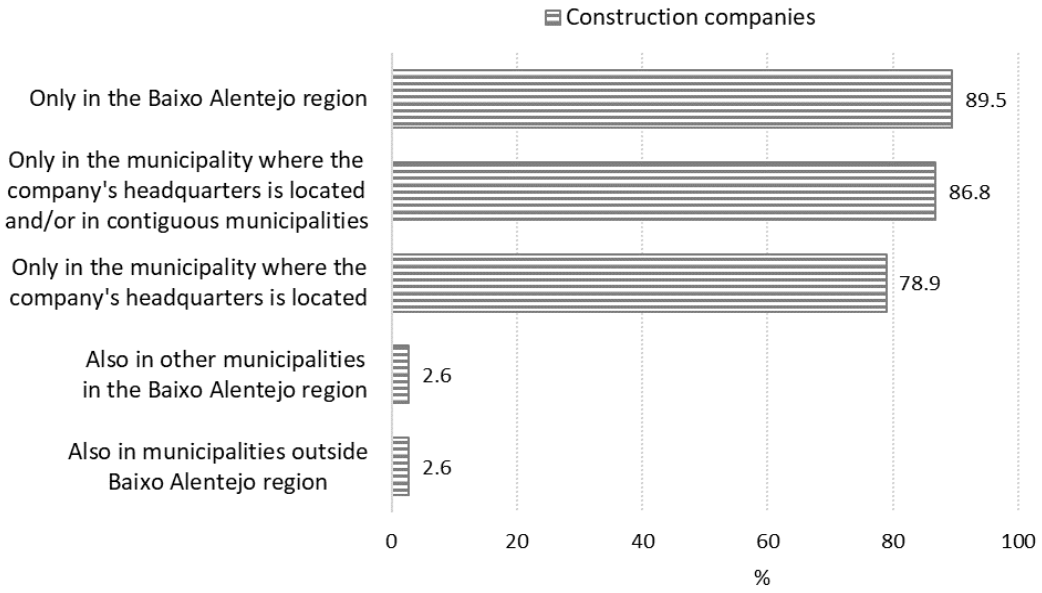


Figure 5.5 - Construction activity dynamic for micro and small construction companies in the *Baixo Alentejo* region.

Session A's main activity was designed 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. 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 5.3, and Appendix - Table 5.4, at the end of this chapter). 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 judgment. In this context, some results obtained do not corroborate the conclusions of other studies or contributions from the same participants in other activities.

Table 5.3 - Micro and small construction companies' main inputs to behavioural change.

Topics	Construction companies' inputs (statements 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 still do not 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 exist (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).

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 5.4.2), and the findings in wider literature (*e.g.,* Gangolells *et al.*, 2014). In this context, more care must be taken when interpreting some of these results, mainly because of the incongruences noticed.

5.4.4 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 (Figure 5.6). 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.

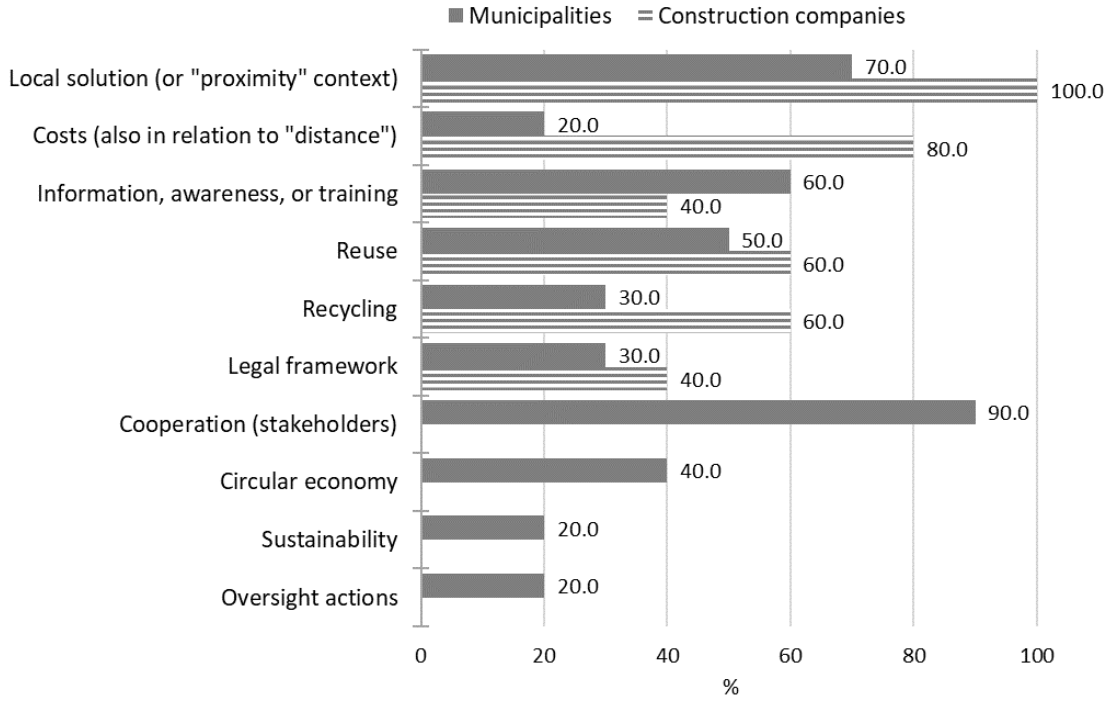


Figure 5.6 - Keywords to the vision definition about local solutions to promote circularity in the construction sector.

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."

5.5 Participatory processes evaluation in the context of 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 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 amid 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.

5.6 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 distinct period to develop this type of actions. This was an innovative approach to a participatory process addressing this collective problem regarding an operational component of CDW management on a local scale. 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 perspective to fill in knowledge

gaps on smaller scales, where the absence of this type of information systematized makes it more difficult the decision-making process, 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 identified a consensus about the necessity to promote training actions in several topics about CDW management, but with a focus on good practices on construction sites and oversight procedures, in these cases if 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 suggested 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.

Appendix

Table 5.4 - Statements 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	3
	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

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
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	2
	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

Legend: IQR - Interquartile range

6

An assessment of the illegal dumping of construction and demolition waste [6]

Abstract

Addressing the illegal dumping of construction and demolition waste (CDW) is challenging because there are significant costs associated with clean-up actions but, for many local authorities, no data is available to describe this reality and to support the decision-making process. This research is focused on how to study the dynamic of CDW dumpsites, characterising these occurrences in order to understand the factors that influence them and to raise awareness to the problem with the results obtained. It involved the municipalities of a rural region, with scant infrastructure for CDW treatment, in monthly observations of the aforementioned sites. In total, 136 dumpsites were observed, with 65% of them located on public-owned land. For these dumpsites, 18 thousand tonnes of CDW were estimated, of which 59% correspond to the mineral fraction. The cost of removing the abandoned CDW was estimated at between €84 and €99 per tonne, with the component directly associated with municipal resources estimated at around 28% of the total. During the one-year monitoring period, 26 new dumpsites were observed, and 156 tonnes per month of CDW were recorded. Performance indicators demonstrated that the municipalities with some type of local solution for CDW management report less illegal dumping. These findings are relevant for filling the gaps in data about the illegal dumping of CDW on local scales and in less developed countries, supporting decision-making processes. In terms of research, the results address gaps in the literature since there is scarce data about these occurrences.

Keywords

Construction and demolition waste (CDW); Dumpsite; Illegal dumping; Municipality.

[6] Published as a peer-reviewed article:

Ramos, M., Martinho, G. (2023). An assessment of the illegal dumping of construction and demolition waste. *Cleaner Waste Systems*. 4, 100073. https://doi.org/10.1016/j.clwas.2022.100073

6.1 Introduction

Illegal dumping, or the intentional abandonment of waste in unauthorized areas (Liu *et al.*, 2021b; Lu, 2019), has been extensively studied from the point of view of its various effects. Indeed, the interaction between these effects may be key to fully understanding the problem (Du *et al.*, 2021). For instance, research has been conducted pondering essentially the following factors: territorial and environmental conditions (Limoli *et al.*, 2019; Vaverková *et al.*, 2019; Seror & Portnov, 2018; Sharma *et al.*, 2018); law enforcement and supervision (Seror & Portnov, 2020); the need for cooperation among stakeholders (Santos *et al.*, 2019; Sahramäki & Kankaanranta, 2017); social circumstances (Wright *et al.*, 2018); and individual characteristics (Lu, 2019; Comerford *et al.*, 2018). However, most studies have focused on analysing illegal dumping as a whole, rarely presenting a detailed analysis by type of waste. In the context of those studies, the focus was on municipal waste (Jiang *et al.*, 2020; Nagpure, 2019; Yang *et al.*, 2019; Sharma *et al.*, 2018), but where different fractions are presented as mixtures.

The construction sector is an important economic activity in terms of circular economy (Zhang *et al.*, 2022; European Commission, 2020), and because illegal dumping is a problem frequently associated with this sector, the abandonment of construction and demolition waste (CDW) could be more researched (Yang *et al.*, 2019). While illegal CDW dumping is frequently mentioned (Chen *et al.*, 2019; Hao *et al.*, 2019; Islam *et al.*, 2019; Ding *et al.*, 2018; Yuan *et al.*, 2011; Webb *et al.*, 2006), the reality and reasons for it are not sufficiently explored. Several studies mention the occurrence of illegal CDW dumping, but only as part of the whole illegal dumping problem (Otwong *et al.*, 2021; Hidalgo *et al.*, 2019; Nagpure, 2019, Ichinose & Yamamoto, 2011).

This is also the case in Portugal, where there is no data available that is collected through a systematic and supervised process, with pre-established research criteria, namely considering municipal records, about the illegal dumping of CDW (APA, 2018a). This lack of data makes it difficult for municipalities to be aware of the costs of clean-up actions of abandoned CDW and how to intervene, to create solutions to the problem.

From this perspective, it is relevant to study occurrences of the illegal dumping of CDW on a local scale dynamic, comprehending causes and consequences. This research project aims to respond to the lack of data about this subject on a local scale. Furthermore, it intends to raise awareness of the constraints and, simultaneously, to encourage the implementation of solutions, in terms of political and operational decisions, but also in addressing gaps in the literature about these occurrences in rural areas or less developed countries with similar characteristics.

6.2 Literature review

6.2.1 Determinants of illegal dumping

According to Du *et al.* (2021), illegal waste dumping has generally been studied from four perspectives: environmental science and ecotoxicology; decision-making of stakeholders regarding the economic perspective; evaluation of factors from a management standpoint; and the use of emerging technologies to retrieve and manage occurrences.

In this context, contributions have been added to specific subjects. For example, geographical attributes are a common factor observed in research (Jordá-Borrell *et al.*, 2014). In most cases, illegal dumping is related to low population density, peripheral inhabited areas (Vaverková *et al.*, 2019), the percentage of forest cover, the distance to the edge of forest areas (Seror & Portnov, 2018), topographical features, and the characteristics of road networks (Matos *et al.*, 2012).

Specifically for municipal waste, households with easier access to waste collection services are less likely to act illegally (Sotamenou *et al.*, 2019). This conclusion is corroborated by Yang *et al.* (2019), pointing out that low accessibility to waste treatment is associated with illegal dumping, and that the mismanagement of spatial characteristics leads to illegal behaviour. Moreover, as a way to avoid abandonment, He *et al.* (2022) affirm the necessity of evaluating cross-regional alternatives for waste management. Other circumstances have, however, also been examined, for instance in Thailand, where Otwong *et al.* (2021) indicated the possible causes for recyclable industrial waste dumping: lack of a market, the absence of efficient

monitoring processes, poor regulations, inadequate penalties, and non-engagement of the private sector.

One peculiar remark is that it is common for pre-existing dumpsites to reappear, even after clean-up actions (Niyobuhungiro & Schenck, 2021). This may be because the geography of these sites favours illegal behaviour, or because the generation of waste is greater than the authority's ability to handle it legally (Šedová, 2016). When illegal dumpsites are an unresolved problem for several years, a decision whether to restore such sites must be made. In most cases, however, this involves high investment (Hidalgo *et al.*, 2019).

Yang *et al.* (2019) observed that higher levels of territorial monitoring and supervision are necessary. This is more relevant in cases where waste management policies and law enforcement are declared ineffective (D'Amato *et al.*, 2018). Engagement at the corporation level is a necessity, and the relationship between illegal behaviour and public awareness and participation must be explored (Sahramäki & Kankaanranta; 2017).

Analysing the reality of illegal dumping is challenging and hindered further by the lack of consistent data. From this perspective, there are limitations to the characteristics and the spatial distribution of illegal occurrences (Jordá-Borrell *et al.*, 2014). This being so, some recommendations made by Webb *et al.* (2006) deserve reflection, for instance increasing the difficulty and risk, reducing rewards and incentives, but excluding the possibility of excusing offenders.

6.2.2 Construction and demolition waste illegal dumping

Research on illegal dumping has mainly concerned solid waste (Du *et al.*, 2021). Although several studies have considered the CDW value chain, illegal dumping has not been one of the primary subjects (Yang *et al.* 2019). Though scarce, some studies have presented certain results for the illegal dumping problem, where CDW is considered in terms of its general characterization (Nagpure, 2019; Rahim *et al.*, 2017; De Melo *et al.*, 2011; Ichinose & Yamamoto, 2011). Although each of these cases has its own context, the mineral fraction is predominant.

For CDW, geographical factors, such as the distance to the nearest main road, the depth of a ravine, and the proximity of a forest are good predictors for CDW illegal dumping, as well as

for illegal dumping in general. However, the large size of some of these areas in the territory make them more difficult to monitor (Seror & Portnov, 2018). All these problems can result from inadequate planning and construction site management and supervision, as well as from the prevalence of micro and small construction companies with a lack of workforce expertise (Ramos & Martinho, 2022, 2021).

Blaisi (2019) observes that CDW illegal dumping occurs mainly because of transportation costs. This is in line with data presented by Mihai (2019), where CDW abandonment is encouraged in middle-sized and smaller cities because there are not enough waste recovery facilities. Ichinose & Yamamoto (2011) add that the number of illegal dumpsites declines if the number of intermediate waste management facilities rises. However, De Melo *et al.* (2011) studied CDW management in *Área Metropolitana de Lisboa* (Lisbon Metropolitan Area), where the facility identified is about 23 km from Lisbon, and even in this context, CDW dumpsites still occur.

Regarding CDW management, law enforcement is a topic that is frequently raised in the field (Duan *et al.*, 2019; Mihai, 2019; Menegaki & Damigos, 2018). Additionally, researchers have analysed the effect of penalties on illegal dumping, demonstrating that they can effectively control it (Chen & Lu, 2017; Tam *et al.*, 2014). However, while penalties and incentives might bear positive results, excessive values may not create the expected effects (Liu & Teng, 2022; Du *et al.*, 2020). Along the same lines, Chen *et al.* (2019) concluded that raising a penalty without maintaining the probability of supervision could be unproductive. Liu *et al.* (2021b) report that law enforcement policies might have low efficiency depending on the fines inflicted, or even on the low probability of being caught (Seror & Portnov, 2020). It is also relevant to consider that a waste producer can always try to find ways to avoid being caught acting illegally, reducing the efficacy of policies (Liu *et al.*, 2022a). Or even that although supervision could reduce illegal dumping, the subsequent effect on landfill disposal and recycling might be unclear (Liu *et al.*, 2020b).

However, You *et al.* (2020), through a case study focused on a waste transportation supervision system, also state that unauthorized vehicles continue to abandon CDW. This adds to the

complex reality of CDW management challenges, where the absence of environmental awareness is often a major problem to overcome (Hao *et al.*, 2022; Liu *et al.*, 2022a)

In Portugal, Santos *et al.* (2019) observed that CDW is illegally disposed of in public and private areas, with cleaning actions often supported by municipalities at a high cost. Despite this being a frequent problem, there is an evident lack of cooperation to resolve it. De Melo *et al.* (2011) state that data regarding illegal CDW dumping are not consistent at a municipal level, which is a constant problem in Portugal (APA, 2018a; Martinho *et al.*, 2015). In turn, Seror & Portnov (2020) observed that although local legislation exists, limited budgets and the scant human resources of local authorities make it largely ineffective at tackling CDW illegal dumping behaviour (validated by APA, 2018a). These conclusions are supported by Rahim *et al.* (2017), who also indicated the need for more cooperation between construction companies and government.

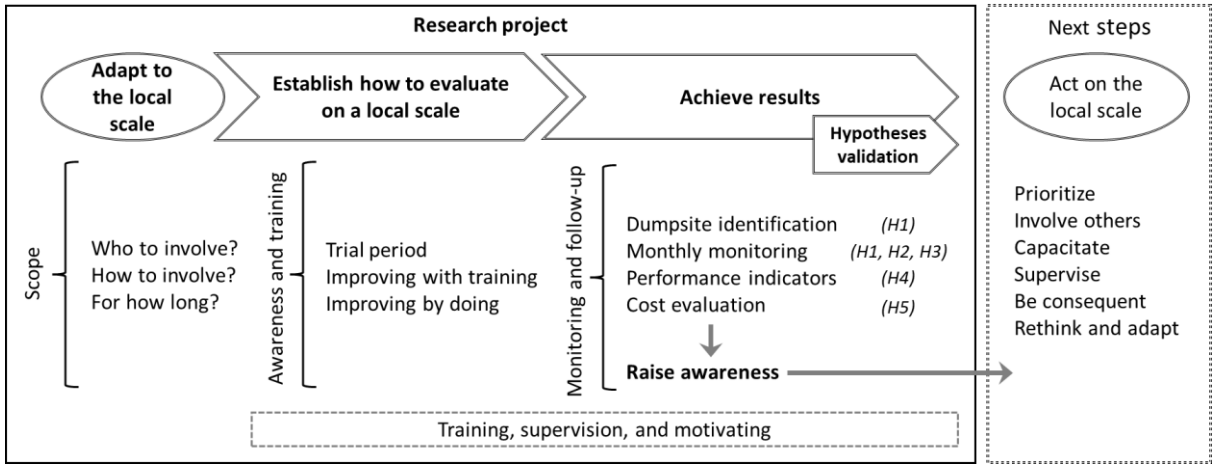
Gálvez-Martos *et al.* (2018) identified best practices for the local scale, which involved clear guidance for small waste producers, minimum waste sorting conditions, reinforcement of municipal collection service, and communication mechanisms. In fact, public involvement and government action can impact the behaviour of waste producers, as they might feel obliged to comply with norms (Du *et al.*, 2020; Chen *et al.*, 2019), or even want to feel integrated within the solutions (Al-Otaibi *et al.*, 2022; Mahajan *et al.*, 2022; Vasconcelos *et al.*, 2020). However, important gaps in knowledge have been identified over time that are transversal to the construction sector (Ramos & Martinho, 2021; Gangolells *et al.*, 2014; Saez *et al.*, 2013; Begum *et al.*, 2009).

As Yuan *et al.* (2011) state, the cost of CDW must include a component related to construction site waste management, and the environmental cost of illegal dumping. The second component, regarding the cost of clean-up actions is often overlooked, as is the indirect income loss from this material not being reincorporated into the construction sector, under controlled conditions. And which, by not complying with circular economy principles, does not add value.

6.3 Method

6.3.1 The methodological approach used in the study

The methodological approach was developed to help close gaps in the current research and to meet the need to consider the reality of the local scale (Figure 6.1). This research was carried out in a region of Portugal called *Baixo Alentejo* – European Nomenclature of Territorial Units for Statistics, level 3 (NUTS 3) – an area of 8,543 km², comprising 13 municipalities. It is a rural region, where the area of municipalities varies between 168 km² and 1,293 km², with a median of 648 km². It is a region with low population density, averaging 14 inhabitants per km². For contextualization, the average population density for Portugal is 112 inhabitants per km² (adapted from INE, 2020). Additionally, it is a flat territory, with sparse vegetation, and few main roads.



Legend: H - Hypothesis

Figure 6.1 - Methodological approach to the monitoring process in the local scale context.

The lack of infrastructure and solutions for CDW management is identified as a challenge in Portugal (Martinho *et al.*, 2015). This problem is particularly relevant in the *Baixo Alentejo* region, where the main solutions are far from most of the municipalities and construction sites. Other important constraints are the lack of human resources available to municipal services, and knowledge gaps recognized by stakeholders (APA, 2018a). Moreover, the reality of the construction sector, which makes up over 95% of micro and small construction companies, is pertinent (IMPIC, 2020).

6.3.2 Hypotheses

In this research project, five hypotheses (H) were framed to acknowledge the reality of illegal CDW dumping (Figure 6.1): H1 – Illegal CDW dumping occurs equally on publicly and privately owned land; H2 – Illegal CDW dumping is a more recurrent situation at pre-existent dumpsites than at new dumpsites; H3 – The physical composition of CDW differs according to the size of the dumpsite; H4 – Proximity solutions for CDW management avoid illegal dumping; H5 – Municipalities contribute with an important portion of the total cost of CDW abandoned cleaning actions.

6.3.3 Monitoring criteria

Trial Monitoring period

After deciding on the scope of the research project, a municipal representative was selected in each municipality to be responsible for internally coordinating the monitoring process, which was carried out monthly for 15 months. The first three-months was a trial period, during which technicians received instruction in monitoring. Dedicated sessions were held with a few municipalities at a time, mostly by videoconference because this took place in 2021, during the Covid-19 pandemic.

In May 2021, it was possible to travel to the study area to oversee the CDW dumpsites with the municipal representatives, and adjustments were made to certain procedures to ensure the harmonization of criteria. The capacitation approach was maintained during the entire monitoring period.

Dumpsite characterization and monitoring reporting

Each municipal representative received instructions concerning the identification and evaluation of CDW dumpsites: a) to register as a dumpsite any site where CDW was abandoned; b) to identify and register all known CDW dumpsites within the municipal boundary; c) to visit all known CDW dumpsites every month; d) to register new dumpsites; e) to visit the new dumpsites monthly; f) to photograph the dumpsites; g) to identify each different type of CDW present; and h) to estimate the respective quantity.

Every month, each municipal representative sent a *Microsoft Excel* file with their results for the dumpsites and for estimating CDW. They were also asked to gather information from existing data on illegal CDW dumping in the past, and on construction sector dynamics.

For each dumpsite, the following was required: a) an ID, and b) site ownership status (*i.e.*, public or private). For technical reasons, it was not possible to carry out local georeferencing of each dumpsite. With regard to estimating CDW dumping, the following data was required: a) date of the visit; b) types of CDW in each dumpsite, in accordance with the six-digit codes of the European List of Waste (ELW) (European Commission, 2014); c) estimation of the volume of CDW (cumulative approach); d) a calculation of the weight of CDW, using a pre-established dataset on the density of materials; and e) whether a cleaning action overseen by the municipal services or other entities has occurred. In the last case, the action date was requested, as well as the destination for the CDW and respective cost.

The quantity of CDW present at each dumpsite was estimated by volume. To harmonise the estimation criteria among municipalities, it was explained during training that a unit of volume familiar to each technician, depending on their experience, should be used for reference. For instance, a 1 m^3 big-bag or a 6 m^3 multibenne container. With regard to the types of CDW present, this was assessed considering only the surface of each CDW dumpsite.

6.3.4 Criteria for performance indicators

The first group of indicators was aggregated into two main subgroups. The first relates to the total amount of CDW currently accumulated in the area under study. The second considers only CDW accumulated during the monitoring period of one year.

Considering the characteristics of the region, together with the geographical determinants identified in the literature (Vaverková *et al.*, 2019; Seror & Portnov, 2018), the municipalities were aggregated into three categories according to area size: area inferior to 500 km^2 (5 municipalities), area equal or superior to 500 km^2 but inferior to 1,000 km^2 (5 municipalities), and area equal or superior to 1,000 km^2 (3 municipalities).

Because waste management facilities have been shown to have an impact on CDW illegal dumping (Mihai, 2019; Ichinose & Yamamoto, 2011), this assessment included whether the

municipalities provided local solutions for CDW management. Among these solutions is the provision of big-bags to individuals or micro and small construction companies, the rental of multibenne containers, or making available municipal controlled spaces for preliminary storage of CDW.

The second group of indicators attempts to understand the relationship between CDW illegal dumping and the construction sector dynamics. Data on construction sector activity for the period between 2017 and 2020 were provided by the municipalities, and municipal average values were calculated.

6.3.5 Cost evaluation for construction and demolition waste illegal dumping

For raising awareness purposes, this evaluation consisted of calculating an indicator of cost, for the amount of CDW abandoned. However, a lack of organized operational information at a municipal level (also stated by De Melo *et al.*, 2011) makes that challenging. For this study, one difficulty arose from the different unit values recorded by the municipalities for vehicles (*e.g.*, vehicles for transportation of personnel and equipment versus vehicles for transportation of waste). Nevertheless, effort was taken to maintain the estimation as close as possible to the reality under study, and to the defined objectives. In any case, the municipal technicians involved were asked to provide a validation of the unit costs used, as well as the methodological approach taken.

To calculate the indicator of cost (C), by unit of mass (€ per tonne), two components were assumed. First, the municipal component (CM), where CDW is removed from dumpsites using their resources, and delivered to municipality controlled spaces for preliminary storage, before gaining scale to optimize the cost of transportation. It was decided to use an intermediate point for preliminary storage because the majority of dumpsites consist of small amounts of CDW. The second part involved the transportation of the CDW to an intermediary or final waste management operator (CF) (Eq. 1).

$$C = CM + CF \quad \text{(Eq. 1)}$$

Each component of cost considers the sum of the cost calculated individually for different CDW groups since they have significant physical characteristics and different treatment costs.

For estimation purposes, the following CDW groups (g) were established: mineral fraction, bituminous mixtures, CDW mixtures, and hazardous CDW.

To calculate the first component (CM), the variables concerning the CDW cleaning action at the dumpsite and transportation to the municipal controlled site were used (Eq. 2). The calculation specifically for the cleaning action involved: the total quantity of CDW in each CDW group (Q); the working time required to remove a unit of mass (T); the human resources income per unit of time, taking into account the number of workers assigned to the cleaning action (W); and the cost for the equipment allocated to the service, per unit of time, but excluding the vehicle for CDW transportation (E). For the transportation of CDW to a municipal site for preliminary storage, the calculation involved: the quantity of CDW transported each time, in reference to the vehicle capacity used for CDW transportation (q1); the distance to each dumpsite, bearing in mind a round trip (d1); and the cost of transportation to the vehicle responsible for this service, per unit of distance (c1).

$$CM = \sum_{g=1}^{n} \left(Q_g \times T_g \times W_g \times E_g\right) + \sum_{g=1}^{n} \left(q1_g \times d1_g \times c1_g\right) \quad \text{(Eq. 2)}$$

Regarding the second component of cost (CF) (Eq. 3), the calculation involved: the quantity of CDW transported each time, considering the vehicle capacity used (q2); the distance to the waste management operator (d2); the transportation cost to the vehicle responsible for this service, per unit of distance (c2); and the environmental fee for each group of CDW, per unit of mass (F).

$$CF = \sum_{g=1}^{n} \left(q2_g \times d2_g \times c2_g \times F_g\right) \quad \text{(Eq. 3)}$$

6.4 Results and discussion

6.4.1 General considerations

For the monitoring work, 12 out of the 13 municipalities of the *Baixo Alentejo* region participated consistently and in accordance with the monitoring criteria defined. Given that the municipality that did not participate corresponds to only 2% of the total regional area, it was deemed to be of scarce relevance, so the assessment was made considering the entire region.

Another reason for this decision was because it is important to be aware that is not possible to distinguish whether the CDW dumpsites observed in a municipality area result from that same territory, or from illegal behaviours by individuals or construction companies from nearby municipalities.

6.4.2 Construction and demolition waste dumpsite identification

With regard to the characterisation of CDW dumpsites, Figure 6.2 presents the evolution of those currently in existence. For the trial period, between March and May of 2021, 110 dumpsites were registered. The data collected are more variable because the municipal technicians responsible for this monitoring work were learning the reality of CDW illegal dumping in the territory.

Within the monitoring period, 136 dumpsites, mainly small-sized in terms of estimated volume, were observed (Figure 6.4). Of these, 26 were dumpsites discovered between June 2021 and May 2022, which represents an average of 2.2 new dumpsites per month. That number remained stable after the trial period, which denotes a tendency for the reoccurrence of CDW dumping at existing dumpsites (noted by Niyobuhungiro & Schenck, 2021).

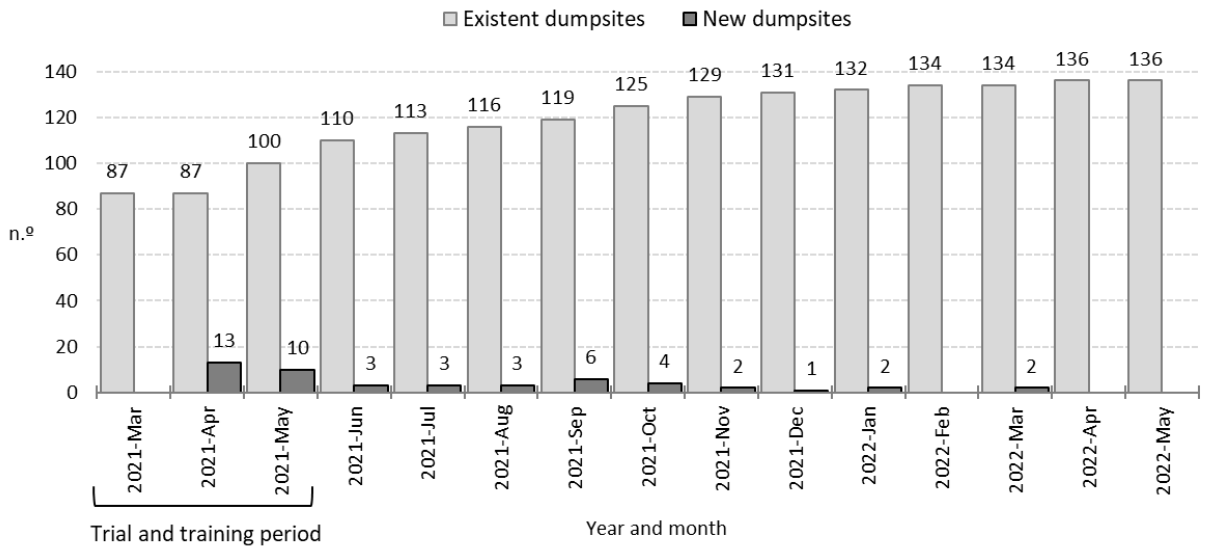


Figure 6.2 - Evolution of the number of existing construction and demolition waste dumpsites.

In general, CDW dumpsites are located strategically, in more isolated zones and near roads (corroborated by Vaverková *et al.*, 2019; Matos *et al.*, 2012), and sometimes just outside the controlled sites for preliminary storage of CDW because the area is fenced. This might be due to a lack of environmental awareness (Hao *et al.*, 2022). In addition, oversight actions are limited and penalties are rarely applied (APA, 2018a). While it might be easier for municipal services to pay more attention to those locations, scant human resources does not facilitate this type of intervention (Seror & Portnov, 2020; APA, 2018a).

Municipal technicians were asked to register whether the dumpsites were located on public or private land, in order to determine who might be responsible for the cleaning action. In May 2022, it was observed that 65% of the dumpsites were located on public land and the remaining 35% on private land.

6.4.3 Estimation of dumped construction and demolition waste

To estimate overall CDW it was first necessary to know the existing situation in the region and then add to that the CDW accumulated over one year. Municipal representatives were asked to register data about CDW cleaning actions that occurred during the monitoring period. There were, however, few actions and those that did occur dealt with small amounts of CDW, and municipal representatives were unable to register data from the operational staff. Thus, it was decided to perform the analysis without discounting these portions, since the estimated CDW would not differ significantly from the reported situation.

Although data were collected every month for each municipality, Figure 6.3 presents the analysis by quarter, allowing a general perception of the tendency. This assessment excludes the trial period. Thus, the estimation performed in volume, for the existing situation in May of 2022, represents 10,401 m^3, corresponding in the present case study to 18,603 tonnes of CDW.

There is a specific CDW dumpsite to report that has different characteristics from the others. It is a consolidated site for CDW illegal dumping that remained unchanged for a long period. This is a reality of illegal dumping (*e.g.*, Hidalgo *et al.*, 2019), that is sometimes overlooked in

the territories. The estimate for this dumpsite was 6,300 m^3, corresponding to 11,340 tonnes of CDW.

However, if considering only the accumulated abandoned CDW for one year, it represents 1,263 m^3, equivalent to 1,867 tonnes. On average, this works out at 105 m^3 per month in the region, equivalent to 156 tonnes.

Excluding the specific CDW dumpsite mentioned before as an outlier, 61% of the total amount of CDW, in weight, is present on public land. For the accumulated CDW for one year, from June 2021 to May 2022, the equivalent proportion rises to 90%.

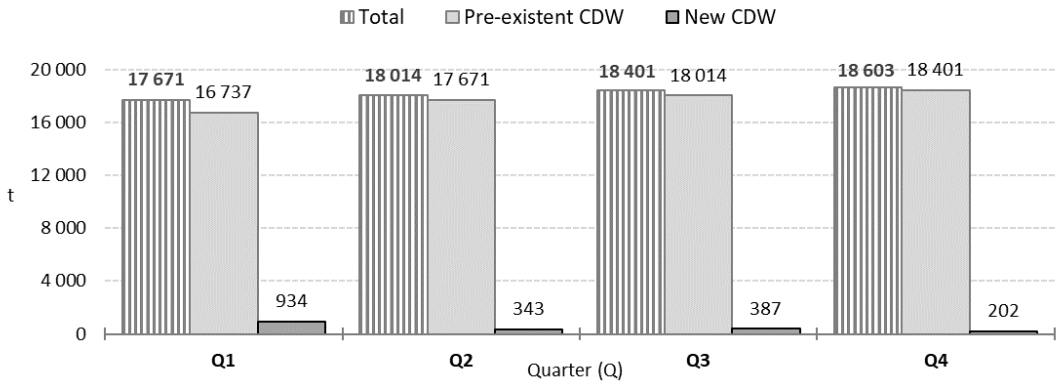


Figure 6.3 - Evolution of estimated construction and demolition waste accumulated in dumpsites, by quarter, between June 2021 and May 2022.

6.4.4 Physical composition of dumped construction and demolition waste

The physical composition of the CDW observed is presented in Figure 6.4, in accordance with data registered in May of 2022, and excluding the consolidated dumpsite mentioned in subchapter 6.4.3, which in that specific case, comprises the mineral fraction of CDW.

Although the estimates were reached considering the surface area of the CDW piles, around 1.5% corresponds to hazardous waste, being a mixture of CDW containing hazardous substances, contaminated soil and stones, or construction materials with asbestos. It is plausible, however, that more mixtures of CDW with hazardous substances exist. This is corroborated by the fact that, in smaller dumpsites where it is easier to identify and detail the different types, more hazardous CDW is discerned.

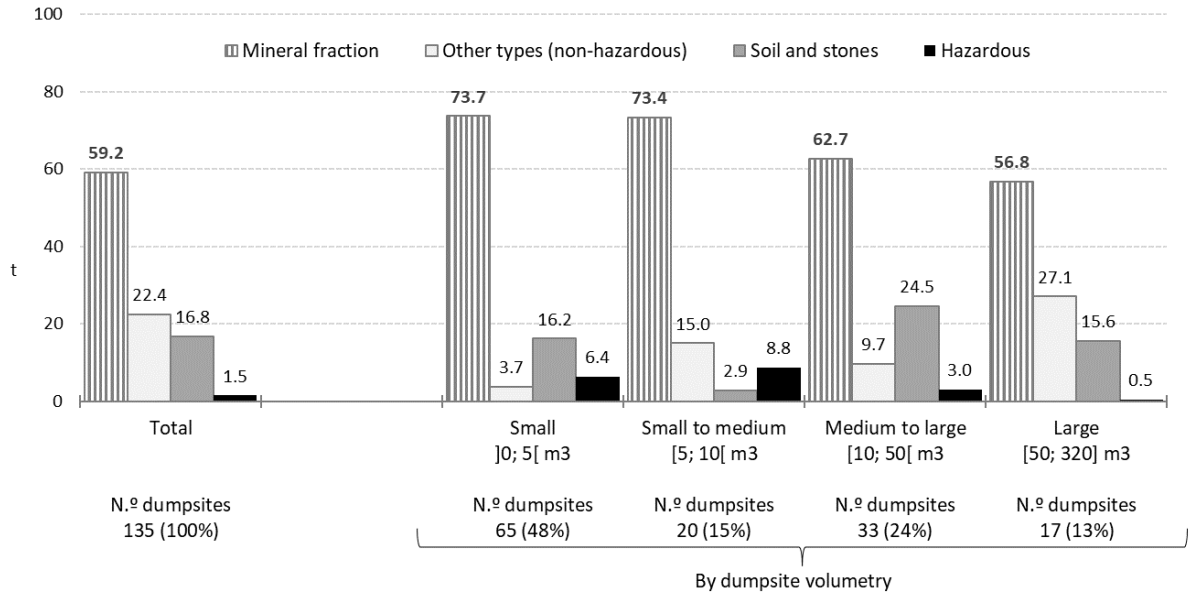


Figure 6.4 - Estimated physical composition for dumped construction and demolition waste, total and by dumpsite volumetry.

Around 59% of the estimated CDW corresponds to the mineral fraction (ELW 17 01 07), particularly comprising mixtures of concrete, bricks, tiles, and ceramics. This type of CDW has a high potential for recycling (data on the physical composition of CDW in illegal dumpsites corroborated by Nagpure, 2019; Rahim *et al.*, 2017; Ichinose & Yamamoto, 2011). These mixtures may contain some lightweight materials, for instance little pieces of plastic, insulation materials, and wood. These results express the current reality in the construction sector, where the mineral fraction is predominant (Sormunen & Kärki, 2019; Coelho & De Brito, 2010). Furthermore, they reflect that the reality of illegal dumping is a huge constraint given the loss of material that could otherwise be reincorporated into the construction sector.

Less significantly, other types of CDW (*e.g.*, parcels of mixed CDW, bituminous mixtures, and wood) represent 22.4% of the total. Soil and stones, on the other hand, represent 16.8% of the total, and it is this category that has a high potential for reuse as long as it complies with specific regulations to determine whether it can be considered waste or a by-product.

Concerning the categories relating to the volume estimated for each dumpsite, it was observed that while the physical composition varies according to the size of the dumpsite, the mineral fraction predominates. Nevertheless, this fraction is more prevalent in smaller dumpsites, which may be due to CDW arising from small repairs and minor do-it-yourself construction

and demolition activities. In medium-large and large dumpsites, other types appear, which can be related to the CDW accumulated over time from different sources.

6.4.5 Performance indicators for illegal construction and demolition waste dumping

The performance indicators of illegal CDW dumping in the *Baixo Alentejo* region are presented in Table 6.1. First, the indicators were calculated for the existing CDW, excluding the dumpsite that was considered an outlier (subchapter 6.4.3). Second, they reflect the CDW accumulated for a year. An analysis was performed for the volume, since the results may be useful for other sites where the physical composition may differ, and the weight was also analysed for this case study.

On examining the analysis of existing CDW up to May 2022, the number of dumpsites, as well as the amount estimated per unit area, is higher in smaller sized municipalities. This may be because of the dilution factor of larger areas, since smaller areas favour the discovery of sites which, in turn, could result in a more accurate assessment (supported by Seror & Portnov, 2018). Also, in the municipalities with a larger area, the amount of existing CDW in each dumpsite is higher, denoting existing dumpsites with more significant amounts of waste. With regard to indicators calculating CDW accumulation for one year, it appears that, in general, there is no clear evidence associated with the area range. However, the amount of CDW abandoned in each new dumpsite is less significant in larger areas, which could be because it takes more than one year for occurrences to become more significant.

On the other hand, municipalities with local solutions for CDW management achieve better results in terms of less illegal dumping (also supported by Gálvez-Martos *et al.*, 2018; Ichinose & Yamamoto, 2011). This is true even if municipalities perceive the well-known constraints associated with the management of CDW on a local scale, and the attendant high costs (Blaisi, 2019; APA, 2018a), or even problems with onsite sorting by construction companies (Gálvez-Martos *et al.*, 2018).

Table 6.1 - Indicators for construction and demolition waste illegal dumping, considering the area size of each municipality.

Group of indicators		Indicator	Area range, for each municipality (km²)	Total	CDW local solutions (municipalities)	
					Without	With
Existing CDW abandoned	By unit area	Existing dumpsites (n.º/100 km²)	[1,000; 1,300]	1.2	2.0	0.7
			[500; 1,000[	1.8	2.1	1.5
			[160; 500[	2.2	1.0	3.1
			Total	**1.6**	**1.9**	**1.4**
		Volume of CDW (m³/km²)	[1,000; 1,300]	0.4	0.7	0.2
			[500; 1,000[	0.5	0.9	0.1
			[160; 500[	0.7	1.3	0.3
			Total	**0.5**	**0.9**	**0.2**
		Weight of CDW (t/km²)	[1,000; 1,300]	0.6	1.2	0.3
			[500; 1,000[	0.9	1.8	0.2
			[160; 500[	1.2	2.1	0.5
			Total	**0.9**	**1.6**	**0.3**
	By existing dumpsite	Volume of CDW (m³/site)	[1,000; 1,300]	33.8	36.6	28.8
			[500; 1,000[	27.3	44.5	8.8
			[160; 500[	0.7	128.7	8.3
			Total	**30.4**	**49.1**	**14.2**
		Weight of CDW (t/site)	[1,000; 1,300]	56.2	59.5	50.4
			[500; 1,000[	0.9	86.8	15.9
			[160; 500[	1.2	209.0	14.6
			Total	**53.8**	**87.1**	**25.0**
CDW illegally accumulated during 1 year	By unit area	New dumpsites (n.º/100 km²)	[1,000; 1,300]	0.5	1.1	0.1
			[500; 1,000[	0.1	0.1	0.1
			[160; 500[	0.5	N.D.	0.9
			Total	**0.3**	**0.4**	**0.2**
		Volume of CDW (m³/Km²)	[1,000; 1,300]	0.1	0.2	0.1
			[500; 1,000[	0.1	0.1	0.1
			[160; 500[	0.4	0.7	0.1
			Total	**0.1**	**0.2**	**0.1**
		Weight of CDW (t/Km²)	[1,000; 1,300]	0.2	0.1	0.2
			[500; 1,000[	0.1	0.2	0.1
			[160; 500[	0.6	1.0	0.2
			Total	**0.2**	**0.3**	**0.2**
	By new dumpsite	Volume of CDW (m³/site)	[1,000; 1,300]	13.3	15.0	1.5
			[500; 1,000[	16.7	30.0	10.0
			[160; 500[	3.9	N.A.	3.9
			Total	**11.2**	**16.0**	**4.5**
		Weight of CDW (t/site)	[1,000; 1,300]	11.5	12.7	2.7
			[500; 1,000[	28.5	48.0	18.8
			[160; 500[	6.3	N.D.	6.3
			Total	**12.1**	**15.1**	**7.9**

Indicators regarding the construction sector dynamics were also calculated from the perspective of the number of construction works completed (Table 6.2). This calculation took into consideration the accumulation of CDW abandoned over the one-year period. Only private construction works subjected to a municipal process of licensing or prior notification were studied. It was not possible to obtain consistent data for public construction works at the municipal level. In any case, such interventions are usually carried out by medium and large construction companies, with more established procedures in terms of CDW good practice and compliance with legal requirements (Ramos & Martinho, 2022, 2021). Moreover, data on construction works carried out by the municipalities were not consistent. They were also not considered in this case because the perception is that small amounts of CDW are generated, which are sent to municipal controlled sites.

Municipalities executing fewer construction works appear to face more problems regarding illegal CDW dumping per completed construction. These municipalities are categorized in the lower area range (Table 6.1), which might help to justify the results. However, the analysis of municipalities with local solutions to CDW management shows they have better outcomes which, in this case, translate as less significant CDW abandonment in relation to each private construction work completed.

Table 6.2 - Indicators for construction and demolition waste illegal dumping, considering the number of private construction works for one year.

Group of indicators		**Indicator**	**Private construction works completed (n.º)***	**Total**	**CDW local solutions (municipalities)**	
					Without	With
CDW illegally accumulated during 1 year	By private construction work completed	Volume of CDW (m^3/work)	[60; 85]	2.7	N.D.	2.7
			[40; 60[	1.0	1.4	0.5
			[20; 40[	2.5	3.5	1.9
			[0; 20[	27.6	25.5	N.D.
			Total	**2.8**	**4.3**	**1.8**
		Weight of CDW (t/work)	[60; 85]	4.6	N.D.	4.6
			[40; 60[	1.7	2.4	1.0
			[20; 40[	3.1	3.0	3.2
			[0; 20[	42.2	38.4	N.D.
			Total	**4.2**	**6.0**	**3.1**

Legend: * Considering the average for 1 year, to each municipality evaluated, from 2017 until 2020; N.D. – No Data

6.4.6 Cost evaluation for illegal construction and demolition waste dumping

This cost evaluation (Table 6.3) is intended to raise awareness about one major challenge that municipalities frequently face, which is the cleaning of CDW from dumpsites with its attendant high costs (Santos *et al.*, 2019, APA, 2018a; Martinho *et al.*, 2015). At this level of analysis, no distinction was made between land ownership status (public or private), although this matters with regard to legal responsibility for the cleaning action and the respective cost of removing the dumped CDW.

Concerning cleaning actions carried out by the municipality, it takes three men 15 minutes to clean-up 1 tonne of CDW, with each man earning €7 per hour. A vehicle to transport the workforce to the dumpsites, and the use a medium-sized backhoe was considered necessary, giving unit values of €10 and €35 per hour, respectively. The estimated cost of transport between the dumpsites and municipal preliminary storage sites was based on average distances that reflected the size of the area covered by each municipality. This led to an average of around 9 km (considering 5 km for municipalities with a smaller area, 10 km for medium, and 15 km for the rest). A medium-sized vehicle costing €2 per km was considered for CDW transportation, since that is the reality of most municipalities in the region.

With regard to transporting CDW to a waste management operator, a larger vehicle with greater handling capacity was contemplated at a cost of €3 per km. For estimation purposes, calculations were based on an average of 45 km being the distance from the city hall of each municipality to the waste management operator specified by municipal representatives. For the cost for CDW treatment, a market consultation was carried out in the region. The values used are indicative but intended only to represent an order of magnitude of the regional standards and are dependent on the contracted conditions. The following values were applied: €35 per tonne for the mineral fraction (with some lightweight material incorporated); €75 per tonne for bituminous mixtures; €90 per tonne for non-hazardous CDW mixtures; and €200 per tonne for hazardous CDW. Soil and stones were excluded from the calculation because, in general, they can be reused. Wood was also excluded since there were few observations of this material at dumpsites and it often disappears, possibly because it can be useful in other

contexts. The environmental fee respects what is stipulated in Portugal to reduce landfilling of materials with recovery potential, and was set at €22 per tonne for 2021 and 2022.

Considering these assumptions, a cost indicator was calculated for two scenarios: including or excluding the consolidated CDW dumpsite referred to in subchapter 6.4.3. Including this dumpsite led to a cost of €84 per tonne. However, if that dumpsite was excluded, the cost rises to €99 per tonne, since it mainly comprises the mineral fraction. This cost differs from municipality to municipality, depending essentially on the distances involved, the operational conditions, and on the physical composition of CDW.

The results concerning the evaluation of each portion of costs are expressed in percentages since the objective is to raise awareness of the different components that make up the municipalities' contribution to overall costs. In this context, the municipal component directly involving their equipment and human resources, corresponds to 27% to 29% of the total cost.

Table 6.3 - Estimation of cost for construction and demolition waste cleaning actions on dumpsites.

Estimated CDW (%)		**Estimated cost range (%)**						**Indicator (€/t)**
		Municipality		Final destination (Waste operator)			Total	
		Cleaning	*Transport*	*Transport*	*Treatment*	*Fee*		
Including the large scale consolidated CDW dumpsite								
Mineral fraction	90.6	17.9	8.0	19.6	37.9	0	83.3	77
Bituminous mixtures	3.9	0.8	0.3	0.8	3.5	0	5.4	117
CDW mixtures	4.9	1.0	0.4	1.1	5.3	1.3	9.0	154
Hazardous CDW	0.6	0.1	0.1	0.4	1.5	0.2	2.2	300
Total	**100.0**	**19.7**	**8.8**	**21.9**	**48.1**	**1.5**	**100.0**	**84**
Excluding the large scale consolidated CDW dumpsite								
Mineral fraction	72.6	13.9	5.4	13.2	25.7	0	58.3	79
Bituminous mixtures	11.2	2.2	0.8	2.1	8.5	0	13.6	119
CDW mixtures	14.3	2.7	1.1	2.6	13.0	3.2	22.6	156
Hazardous CDW	1.8	0.3	0.1	1.0	3.7	0.4	5.6	303
Total	**100.0**	**19.2**	**7.5**	**18.9**	**50.9**	**3.6**	**100.0**	**99**

This component is often diluted in other municipal costs, and so does not raise awareness about the problem of illegal CDW dumping. Also, it does not contribute to the shift in the vision of policy-makers, encouraging them to recognise that the current cost burden for clean-up actions of abandoned CDW may be more effectively spent investing in local solutions to promote effective CDW management. For now, in the *Baixo Alentejo* region there are neither consistent initiatives nor is there data available at a municipal level which would allow an estimation of the benefit of implementing local solutions for CDW management instead of dealing with the illegal dumping of CDW. In this instance, it was not possible to proceed with in-depth analysis, simply opting to raise awareness of the problem through the results obtained.

6.5 Conclusions

The main objective of this research was to study the dynamic of CDW dumpsites on a local scale, and also to increase awareness of this issue through performance indicators and cost evaluation. The monitoring work was performed in a rural region, characterized by larger distances between most of the municipalities and the final CDW management waste operators. To achieve this objective, data were collected to evaluate the situation at the start of research and its evolution over one year.

In total, 136 CDW dumpsites participated in the study, of which 65% are located on public land. The estimate overall of abandoned CDW at these sites is approximately 18 thousand tonnes, with 59% corresponding to the mineral fraction. This portion, which has great potential for recycling, is always predominant regardless of the dumpsite size, which is an indication of how much circularity potential is lost because of illegal CDW dumping. With regard to the existing dumpsites, the perception is that there is a considerable recurrence of CDW abandonment. Between June 2021 and May 2022, 26 new CDW dumpsites were recorded, with an estimated 72 tonnes per new dumpsite.

CDW illegal dumping usually implies considerable costs for municipal services. Despite the many constraints resulting from gaps in information, it was estimated that a value between €84 and €99 per tonne would be needed to resolve CDW abandonment into the region, with

the component directly associated with municipal equipment and human resources estimated at between 27% and 29% of the total. Municipalities are not aware of these costs, because they are not registered independently. So, this component is often neglected by municipal services since it is diluted in other costs.

When performance indicators were calculated to understand the dynamics of dumpsites, the conclusion was that municipalities with local solutions for CDW management have a less severe CDW abandonment problem. This statement is valid even though the municipalities are not satisfied with their alternatives. These solutions should be encouraged on a local scale, and awareness should be raised about the relationship with the aforementioned cost that is often borne by municipal services.

In this context, the findings of this research are useful in terms of filling gaps in the literature about data on the illegal dumping of CDW, in this specific case is addressing the problem in a rural area. The results are also important for tackling gaps in less developed countries characterised by facing similar challenges. Furthermore, the results are relevant for decision-makers in the areas mentioned, since one of the main purposes was to raise awareness and provide technical knowledge that did not previously exist. This is important to better understand what vision should be addressed, and how to tackle the main problems, specifically promoting local solutions to allow CDW waste to be properly collected and stored until it is sent to its final authorised destination.

However, it will be essential in further research to test intervention strategies and policies on a local scale, to comprehend which initiatives might contribute to better and more effective CDW management in this context, namely: CDW preliminary storage under municipal responsibility; awareness and oversight actions; and procedural control on licensing processes, assessing whether CDW was transported to authorised final destinations in the quantities expected. It will also be important to understand how local scales can contribute to the more general goal of achieving the circular economy principles in the construction sector, where all types of scales of intervention must contribute towards a common goal.

Moreover, since frequent and systematic monitoring work is time-consuming and demanding in terms of resources, future research needs to explore alternative ways to study illegal CDW dumpsites. This could perhaps be achieved using new technologies, or even with the involvement of those closest to the problem, such as local stakeholders and citizens, to identify occurrences and locate the sources.

7

Strategies to promote construction and demolition waste management in a context of local dynamics [7]

Abstract

Achieving a broad analysis of construction and demolition waste (CDW) management without considering local scale dynamics, and its detailed characteristics, is a constraint that has made it challenging to optimally engage in an integrated assessment of the circular economy principles in the construction sector. In this sense, this research demonstrates that investing in local strategies is important, involving municipalities and micro and small construction companies. Firstly, the results reveal the importance of having controlled sites, under local responsibility, for the preliminary storage of CDW, creating in waste producers the habit of separating waste onsite, reducing costs and limitations for municipalities. Secondly, frequent supervision actions at construction sites are also important at this scale, as they facilitate progress in terms of encouraging compliance with mandatory legal procedures and good practices for CDW management. But it is easier to improve practice through direct onsite procedures than it is with bureaucratic legal requirements alone. Thirdly, procedural control, implemented by municipal technicians in conjunction with other strategies, also helps to promote CDW management, this being associated with processes of public and private construction works subjected to license or prior control, in opposition to what has been accomplished so far. But the research also demonstrated that regular awareness, training, and supervision actions might increase the likelihood of improvements in behaviour on the local scale, in the sense that stakeholders acquire new habits, which, over time, might lead to better results locally and, as a consequence, influence other scales of intervention.

Keywords

Circularity in the construction sector; Construction and demolition waste (CDW); Local scale strategy; Micro and small construction company; Municipality.

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[7] Published as a peer-reviewed article:

Ramos, M., Martinho, G., Pina, J. (2023). Strategies to promote construction and demolition waste management in a context of local dynamics. *Waste Management.* 162, 102-112. https://doi.org/10.1016/j.wasman.2023.02.028

7.1 Introduction

Construction and demolition waste (CDW) policies and practices are very important subjects to be considered in the context of the efficiency of the construction sector (Kabirifar *et al.*, 2020a), specifically when considering a circular economy approach (Oluleye *et al.*, 2022). Since 2007 research has increased substantially in this area (Li, Li & Sang, 2022), focusing mainly on environmental sciences, engineering, green and sustainable science, and technology. In general, these challenges are important to frame in terms of future research, but also it is vital to frame CDW management within the respective scale of analysis (Santos *et al.*, 2019; Gálvez-Martos *et al.*, 2018), where different types of actions can be considered for implementation to improve sustainability mechanisms (Kabirifar *et al.*, 2020b; Cruz, Gaspar & de Brito, 2019).

On larger scales, for example in Europe (Zhang *et al.*, 2022), the challenges to promoting circularity in CDW management are closely related to generalist policies and trends of action and research (Wu *et al.*, 2019; Umar *et al.*, 2017), although strategies are usually adapted or implemented at different rhythms in each country, considering its specific characteristics (Luciano *et al.*, 2022; Aslam *et al.*, 2020; European Commission, 2017; Rodríguez *et al.*, 2015). Around the globe there are realities where companies actively seek to take part in sustainable markets to be competitive, adding a green value, but also other realities where environmental awareness is not yet mature (Doussoulin & Bittencourt, 2022). These trends are often related to the balance between costs and the effectiveness of solutions for waste recovery (Ichinose & Yamamoto, 2011); the interconnection with new technologies (Li *et al.*, 2020); or even the cooperation between actors with different levels of responsibility, also including determinants of behaviour (Chen *et al.*, 2019; Bakshan *et al.*, 2017; Wu *et al.*, 2017; Li *et al.*, 2018, 2015). But particular challenges appear at smaller scales. For instance, issues arise relating to the proximity of facilities, and modifications of behaviour often require collaboration between stakeholders (Ramos *et al.*, 2023; Santos *et al.*, 2019; Martinho *et al.*, 2015). In this context, it is important to realise that without the local scale working properly, it is unlikely that the major objectives of circularity in the construction sector will be fulfilled.

From this perspective, this research project emerged considering specific constraints and knowledge gaps that were identified concerning the dynamics of CDW management on a local

scale reality, from an operational point of view. This perspective means, specifically, studying the relationship between municipalities (Santos *et al.*, 2019; APA, 2018a) and micro and small construction companies (Ramos & Martinho, 2022, 2021) based on the fact that particular constraints make CDW management even more challenging on this scale (Ramos *et al.*, 2023). This research project focused on the implementation of three local strategies, in terms of operationalisation and cooperation. The implementation of these local strategies was accompanied by capacitation, training, and supervision.

7.2 Construction and demolition waste management within smaller scales perspective

7.2.1 Constraints and challenges

The main purpose of this subchapter is to identify the driving factors that are most often recognised at smaller scales, for instance regions or municipalities, because they have specific constraints for CDW management when compared to national scales or wider territories. On the other hand, on smaller scales, it is important to recognise the challenges that local stakeholders face, in terms of their capacity to act. In this sense, and because specific literature for CDW management on smaller scales is scarce, in terms of detailing specific experiments, or solutions, some of the references used describe general problems that are recognised, but are more often discussed in reports by local authorities or stakeholders rather than in scientific literature.

In the context described, CDW management challenges arise most of the time because of a lack of proximal infrastructure and its resulting relationship with cost efficiency (Penteado & Rosado, 2016; Sobotka & Sagan, 2016); limited budgets; staff availability, in terms of time; and the absence of a workforce with expertise (Swetha *et al.*, 2022; Ramos & Martinho, 2021; Seror & Portnov, 2020). For instance, in Australia, Crawford *et al.* (2017) propose that for small communities it can be difficult to tackle some challenges, in terms of CDW management solutions, project priorities, financial incentives, and even company culture, because each group has its distinct characteristics.

Results from Wu *et al.* (2017), in this case referring to mainland China, express that CDW management intention is not a significant determinant of the subsequent behaviour of construction companies. The most important factors are economic viability, followed by the implementation of oversight actions and an organisation's background with environmental awareness, as also stated in the last case by Li *et al.* (2022). However, Jin *et al.* (2019) identified that there is a research gap regarding human factors in CDW management that needs more attention in the future. And Li *et al.* (2022) also state that more investigation is needed into different project stakeholders.

Additionally, it is vital to assess the availability of waste treatment facilities, especially intermediate waste management solutions, as proposed by Ichinose & Yamamoto (2011) for the case of Japan, or the cross-regional alternatives for CDW management, suggested by He *et al.* (2022) for China, that might have positive results in improving operational aspects. With a complementary perspective, Ma *et al.* (2020) reflect on the constraints of recycling plants in China, for instance the variable sources of CDW for recycling, the lack of design for minimisation, the absence of regulation for onsite sorting, the lack of coordination from government administration, and the need of a traceability system.

Also, Bao *et al.* (2020) discuss, for Hong Kong, the importance of considering a circular approach to the construction sector, with onsite recycling opportunities, and reincorporating CDW directly into the construction work, although identifying several challenges: site space constraints, the difficulties in trading recycled products within a narrow window of opportunity, the lack of support from off-site facilities, a lack of a demand-supply platform for exchanging information, and levels of government support. Specifically, recycled materials might have a higher cost than comparable raw materials, due to logistic conditions, for example the distances between buyers, suppliers, sellers, and consumers, as stated in a comparison between Brazil and France (Doussoulin & Bittencourt, 2022). So, it is also essential to consider this in the project phase, to plan real costs for materials and CDW management, and savings as a result of recycling, as supported by Ibrahim (2016), when assessing policies and practices in Massachusetts, in the United States of America. Furthermore, because CDW

generated often ends up as mixed waste, this complicates the implementation of circularity principles into the construction sector (Crawford *et al.*, 2017).

The discussion about the success of environmental taxes also plays an important role in terms of policy decisions, for instance in China (Wang *et al.*, 2018). It is necessary to consider that higher taxes might lead to consequences that are harder to control, such as the reality of illegal dumping, a serious problem observed in several countries (Ramos & Martinho, 2023; Rodríguez *et al.*, 2015; Yuan *et al.*, 2011). This frequent CDW abandonment in some realities represents a loss of material that otherwise could be recycled (Ibrahim, 2016) because the mineral fraction is its main component (Ramos & Martinho, 2023; Sormunen & Kärki, 2019; Coelho & De Brito, 2011).

In these conditions, generally, reinforcing compliance with good practices on construction sites is needed (Mahajan *et al.*, 2017; Ibrahim, 2016), including CDW separation (Menegaki & Damigos, 2018; Lockrey *et al.*, 2016; Saez *et al.*, 2013; Begum *et al.*, 2009), presenting the advantages that can outweigh the disadvantages of a time-consuming activity (Rondinel-Oviedo, 2021). This can be performed by explaining that the treatment cost will be more affordable (Mahajan *et al.*, 2017), and negative environmental impacts might be mitigated, for instance carbon dioxide emissions (Jung *et al.*, 2015). For these purposes, effective communication tools are vital in achieving collaboration and improvement, implementing training actions to resolve knowledge gaps for all levels of workers (Al-Otaibi *et al.*, 2022; Begum *et al.*; 2009), including addressing specific difficulties with legal framework compliance, as stated for Spain by Gangolells *et al.* (2014).

Furthermore, it is common to identify the non-existence of systematised data about CDW at these smaller scales (De Melo *et al.*, 2011). Nevertheless, new methods have been developed to overcome the constraints, for instance those created by Kleemann *et al.* (2017) for the city of Vienna, in Austria, for the estimation of demolition waste in areas for which local data does not exist, using remote image matching for different periods. Or even harnessing data retrieved by Bernardo *et al.* (2016), for *Área Metropolitana de Lisboa* (Lisbon Metropolitan Area), in Portugal, using data collected from real demolition works and statistical information to determine CDW outputs, depending on the variables considered for the study area, such as

correlations with population density, buildings ageing index, buildings density, and land occupation type. These new tools can improve supervision in different phases, but overall, improve planning supervision.

7.2.2 The Portuguese context

As in other European countries (European Commission, 2017), the construction sector was also identified in Portugal as an important, intensive use economic activity, and the Portuguese plan to encompass a circular economy strategy (PCM, 2017) points to regional and local agendas to promote solutions trying to mitigate constraints and inspire capacities. Also, Portugal has, since 2008, a specific legal framework for CDW management. That legislation was replaced by the new Portuguese law on waste (Decree-Law n.º 102-D/2020, of December 10th, with subsequent amendments) (PCM, 2020), which now incorporates the subjects related to CDW.

Although the legal framework has existed for more than a decade, different constraints regarding CDW management have been identified by stakeholders at a political level, responsible for associations of the sector, or waste management operators (Ramos *et al.*, 2023; European Commission, 2017; Martinho *et al.*, 2015), namely: the need to reinforce legal procedures; the necessity to enhance recycling processes, resolving heterogeneity in the territory regarding the existence of CDW management solutions; the availability of a consistent market for recycled materials; and a lack of synergies between stakeholders.

On a level involving municipalities, the main constraints were identified through a survey conducted in 2018 by the national waste authority (APA, 2018a): the absence of proximal solutions for CDW preliminary storage; gaps in information about cost issues; lack of oversight actions regarding legal procedures or good practices onsite, exacerbated by the lack of workforce, resources, and technical expertise; and procedural control regarding legal requirements.

Moreover, in Portugal, more than 95% of construction companies are micro and small companies (IMPIC, 2020): micro companies include entities with less than 10 workers and a turnover equal to or less than €2 million, while small companies present less than 50 workers

and a turnover equal to or less than €10 million. These companies face many constraints associated with accomplishing good practices onsite and legal framework compliance, which is a challenge to the implementation of the circular economy principles in the smaller scale construction sector (Ramos & Martinho, 2022, 2021).

7.3 Method

7.3.1 The research approach

The case study

A region in Portugal was selected as a case study for the assessment of the local scale context for CDW management, named *Baixo Alentejo*, composed of 13 municipalities. It is a rural area of 8,543 km², with 115,326 inhabitants, leading to a low population density, averaging only 13.5 inhabitants per km² (INE, 2020). This region is characterised by a lack of final and intermediate infrastructure for CDW recycling (Martinho *et al.*, 2015), making the costs of transporting CDW difficult to afford (Ramos *et al.*, 2023). Although some local solutions have been tested over time, in a few municipalities, attempts to make equipment available or to create controlled sites under municipal responsibility for CDW storage have always experienced numerous limitations. Also, the reuse of components or construction materials is not yet a common practice in the region. Moreover, knowledge gaps exist in information regarding CDW management on a local scale context (Ramos *et al.*, 2023,) making more difficult the decision-making process.

The study area and the results presented refer to part of a wider research project, where in a previous phase diverse activities were implemented: the assessment of the influence of construction company size in CDW management practices (Ramos & Martinho, 2022, 2021); several workshops were developed during 2021 with municipal technicians and representatives of micro and small construction companies, concluding that the absence of cooperation between local stakeholders was influenced by important technical knowledge gaps, and a lack of local facilities or equipment for CDW management (Ramos *et al.*, 2023); and the assessment of a serious problem in local scale contexts, both in terms of cost for

municipalities, but also concerning the loss of material resources to the construction industry, namely the illegal dumping of CDW (Ramos & Martinho, 2023).

The terminology

The territorial typologies criteria from Eurostat (2019) were applied, considering the classification of the regions into: predominantly urban regions, intermediate regions, and predominantly rural regions. For the local scale context, within the current research project, the criteria for predominantly rural regions was applied, corresponding to the European Nomenclature of Territorial Units for Statistics, level 3 (NUTS 3), where at least 50% of the population lives in areas outside of urban clusters, with a population density usually less than 300 inhabitants per km^2 and/or fewer than 5,000 inhabitants.

The waste studied in this research project is composed of all the waste resulting from the construction activity, interpreted within the Statistical Classification of Economic Activities in the European Community (NACE), namely section F ("Construction"). In this context, the use of the terminology "construction" in the present research refers to a wider range of specific activities related to the construction sector, including the site preparation, new construction, rehabilitation, demolition, amongst others. With the same approach, terminology such as "construction work", "construction site", and "construction company" was used with the same wide-ranging approach.

Furthermore, a distinction was not made between construction waste, rehabilitation waste, and demolition waste, although differences exist in terms of the quantities generated and its physical composition (Coelho & De Brito, 2010). This approach was made following the definition of this waste stream in the European Directive 851/2018, of the European Parliament and of the Council of May 30th, amending the Directive 2008/98/EC on Waste (European Parliament, 2018): "waste generated by construction and demolition activities". Moreover, in the field, during the research project, it was not possible to determine whether the CDW delivered to facilities under municipal responsibility or illegally dumped CDW was a result, for instance, of new construction activity or demolition activity.

Objective and hypotheses

Within the research approach mentioned, and to tackle the identified local challenges facing CDW management on a local scale, the main objective of the research project was to test strategies, in cooperation with local stakeholders, to try to overcome the identified constraints and understand the factors that can lead to success.

From this perspective, three hypotheses were formulated: H1 – Municipal controlled solutions dedicated to CDW preliminary storage, with criteria established for its reception, help to mitigate municipal constraints; H2 – Supervision actions, executed by municipal technicians with expertise, on construction sites, improve the implementation of good practices and legal requirements by micro and small construction companies; and H3 – Procedural control is a vital instrument that, if implemented in coordination with legal requirements and established criteria, could improve CDW management control.

7.3.2 Local strategies

The identification of local strategies and the involvement of stakeholders

In this research project, three strategies were defined to test the improvement of CDW management in the context of local dynamics: i) Local Strategy 1 (LS1), to promote the CDW preliminary storage under municipal responsibility (hereinafter referred to as "Preliminary storage"); ii) Local Strategy 2 (LS2), to capacitate and to supervise good practices and legal procedures on construction sites managed by micro and small construction companies (hereinafter specified as "Supervision onsite"); and iii) Local Strategy 3 (LS3), referring to procedural control with respect to construction works, depending on the legal criteria applicable (hereinafter stated as "Procedural control").

Municipalities were free to choose the strategies they wanted to be involved with, in order to both support ideas that the municipalities had already developed but needed improvement, and to maintain motivation amongst decision-makers as municipal leaders were to be interacting with causes they believed in. The implementation of the strategies started in

November 2021 and finished in October 2022, although some adjustments were needed, which are outlined below on a case-by-case basis.

An initial period to train and inform the municipal staff about CDW management topics was established. During the first stage, this capacitation component was implemented via videoconference, because of Covid-19 pandemic restrictions, with a small number of municipalities at each session, to facilitate answering questions and clarifying doubts. At the second stage, capacitation and training actions were reinforced in person. In the third stage, frequent awareness, training, and supervision initiatives took place in the region studied, together with local stakeholders, for 30 days in 2022, distributed between April and October. In this last phase, communication with the municipal staff and waste producers was implemented to try to improve CDW management.

From the 13 municipalities of the *Baixo Alentejo* region, only six accepted to test the local strategies. The non-participating municipalities declined due to constraints about the available resources, and for political reasons.

The concept behind the design and implementation of the local strategies

The design for the local strategies considered the main objective of understanding how it is possible to improve CDW management on a local scale dynamic, on an operational level, involving municipalities and micro and small construction companies and interconnecting this with a behavioural change approach. To accomplish this objective, the conception and implementation of the local strategies were inspired by the "COM-B Model of Behaviour", established by Michie *et al.* (2011), which considers three main drivers for behavioural change study: capability, motivation, and opportunity. The adaptations made to the original conceptual model relies on the reality of the construction sector, specifically in the context of proximity dynamics. In this perspective, Figure 7.1 presents the concept behind the research project.

Some examples are given to better illustrate the relation between the local strategies and the behavioural change drivers, whether for municipalities or micro and small construction companies. First, the component "capability" relies upon the comprehension that behaviour

arises from the physical capability to execute (*e.g.*, the physical capability of the employees from the company to deliver separated CDW to the municipality) and from the knowledge to accomplish (*e.g.*, the expertise of municipal technicians to supervise CDW management good practices). Second, the component "motivation" tries to understand whether the behaviour is a result of acquired habits (*e.g.*, procedures implemented by municipal supervisors as a habit) or if it is a reflection of an action (*e.g.*, if procedures are undertaken by companies because it is understood that doing so can reduce CDW treatment costs). Third, the component "opportunity" attempts to comprehend whether the behaviour modification is dependent on the physical resources available (*e.g.*, a municipal site for CDW preliminary storage) or motivated by the influence of external forces (*e.g.*, "pressure" placed on construction companies by municipal technicians, through communication about compliance with legal requirements).

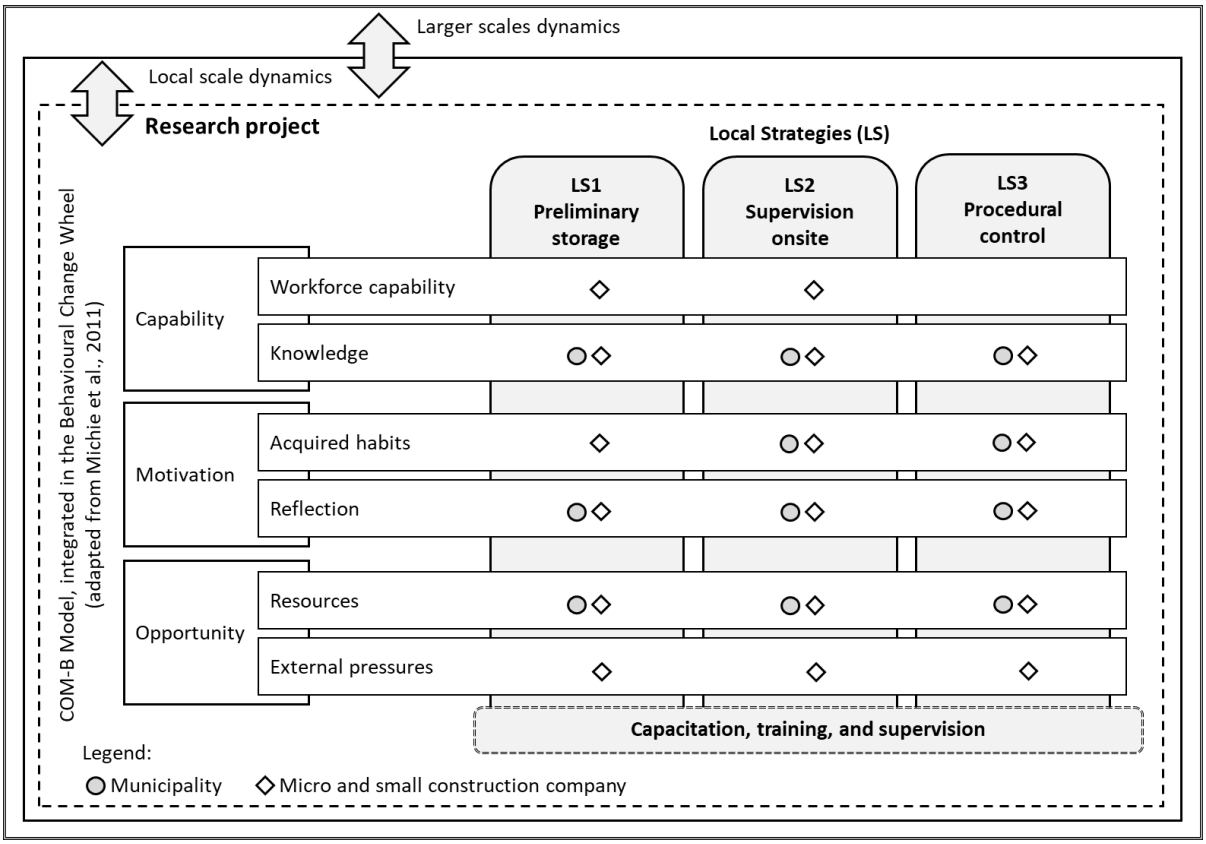


Figure 7.1 - The conceptual model for the implementation of the local strategies within the research project.

Description of local strategies and criteria for implementation

LS1 – Preliminary storage

For LS1, the main objective was to evaluate the different variants of local solutions previously implemented by the municipalities for CDW preliminary storage arising from individuals, smaller amounts generated by construction companies, and CDW generated as a result of municipal construction works. Specifically, it involved dedicated spaces with differing criteria, but also the provision of equipment, such as multibenne containers for local CDW storage on construction sites before its transportation to municipal facilities. The recording of data regarding CDW management under municipal responsibility, in most cases non-existent before the implementation of the strategy, was proposed and implemented to comply with the objectives of the research project, collecting quantitative data. It was also recommended to reinforce oral communication about good practices concerning CDW management.

For operationalising LS1, the following data was requested each month: the type of waste received, classified with the 6-digit codes of the European List of Waste (ELW) (European Commission, 2014); the respective estimated quantity (or weight, if CDW was delivered to an authorised waste management operator, equipped with a weighbridge); and the perception of the onsite separation of CDW, due to the implications on costs it has for municipalities.

LS2 – Supervision onsite

The LS2 aimed to involve municipal technicians in the supervision of CDW management good practices on construction sites, predominantly the adherence to legal requirements. It was established that the focus would be on frequent visits to pre-selected private construction sites with municipal responsibility, subjected to a license or prior notification, and were being executed by micro and small construction companies, because it is the reality in which municipal technicians intervene most often. Moreover, construction works without a licensing process are difficult to track, and public construction works are habitually executed by medium and large construction companies, who are more familiar with compliance with legal procedures and good practices (Ramos & Martinho, 2022; 2021).

The evaluation in each visit was made considering two groups of criteria. In the first group, concerning an operational perspective at the construction sites, the following topics were assessed: i) organization of the construction site, regarding CDW; ii) separation of non-hazardous CDW; iii) management of hazardous CDW; and iv) confirmation of an authorised final CDW destination. The second group of aspects considered the following from the point of view of legal bureaucratic compliance: v) data registration of CDW management; and vi) electronic waste monitoring guides for CDW transportation.

LS3 – Procedural control

Concerning LS3, the objective was to evaluate the level of control for CDW management on licensing processes, under municipal responsibility. In this case, two different realities were considered: public construction works, and private construction works subjected to a municipal license or prior notification. These CDW management requirements are expressed directly in the new Portuguese law on waste (PCM, 2020) and are interconnected with Portuguese legislation concerning the construction sector.

To implement it, the following information was required for each specific process evaluated, whether private or public: i) characteristics of the intervention; ii) the CDW estimated for the intervention (supported by the indicators of Coelho & De Brito, 2011, 2010); and iii) the CDW declared at the end of the process.

7.3.3 Criteria to evaluate progress

Evaluation criteria were created to measure the progress of the implementation of each local strategy, with the aim of being minimal and easy to implement. The objective was to have a clear perception of what was happening at each point in time, as well as to reduce the subjective evaluation of criteria among municipal technicians. A 3-points ordinal scale was used for the subjects to be evaluated, always using entire numbers: "1" (bad) if there was evidence that none or the very few of the requirements were implemented; "2" (medium) if it was observed or demonstrated that part of the requested strategies were executed, and "3" (good) if there was evidence that most or all of the main requirements were understood and

implemented. For some aspects, a qualitative approach was also used to assess and discuss the results.

A *Microsoft Excel* format file was prepared and shared with each municipality, systematised to align with the criteria to be evaluated. A support document was also prepared, with instructions tailored to each of the local strategies, instructions about their operationalisation, and also complementary information about the legal framework or good practices applicable. All data was reported monthly, with supervision and feedback provided before starting the new data collection period.

7.3.4 Statistical analysis

To support the interpretation of results obtained during the field work of this research project, a statistical analysis was made on LS2 and LS3, performing the Wilcoxon signed-rank test, for two-tailed exact *p*-values, regarding differences in mean response. This test was chosen bearing in mind the sample size, leading to non-normality in most cases when inspected with the Shapiro-Wilk test, but also the ordinal scale of evaluation considered for each case (see subchapter 7.3.3). A value of $p \leq 0.05$ was considered as the minimum acceptable significance level, corresponding to a 95% confidence level.

For the two aforementioned local strategies, two specific moments were considered for evaluation. For LS2, with the objective of assessing if evolution has occurred, the matched-pairs chosen were: the first visit to private construction works subjected to a municipal license or prior notification, and then the behaviour measured between the second and the fifth visits. Regarding LS3, a comparison of each process of public construction work was undertaken between the project phase and the conclusion of the work, where legal procedures are mandatory.

7.4 Results and discussion

7.4.1 Preliminary storage

Four municipalities were involved in LS1 (*i.e.*, LS1-M1, LS1-M2, LS1-M3, and LS1-M4). It was not possible to consider all of them using identical criteria, mainly because it was not feasible

to adapt their pre-existing solutions during the timescale of the project, due to investment constraints and a lack of political will. Nevertheless, these multiple conditions allow for the qualitative evaluation of different instances of the problem.

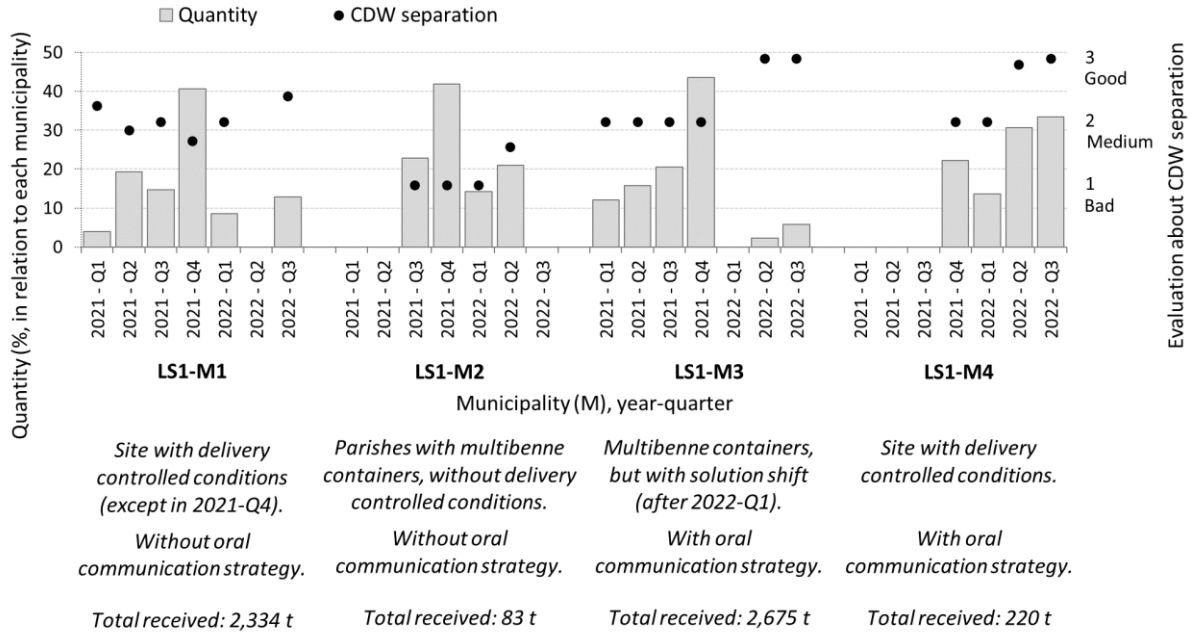
In Portugal, if reuse is not possible, it is mandatory to separate CDW on construction sites, into the following types: the mineral fraction (*i.e.*, concrete, bricks, tiles), wood, metal, glass, plastic, and gypsum. However, it is common that CDW appears as mixtures, mainly composed of the mineral fraction, but including other light-weight materials. In this context, for LS1 the CDW is evaluated in terms of the quality of the mixture received determined by the cost of the treatment that the municipality pays to the waste management operators, when this data is available or, when cost is unavailable, using the perceived quality, as a qualitative measure of the CDW received in municipal equipment or at controlled sites. Specifically, the evaluation was quantitative for municipalities LS1-M2 and LS1-M3. The approach was mostly quantitative, but also complemented with a qualitative assessment, in municipalities LS1-M1 and LS1-M4.

In the two aforementioned cases, criteria were established to harmonize criteria among municipal staff, related to the cost of the different types of CDW (*i.e.*, the mineral fraction is much more affordable to treat than CDW mixtures of the mineral fraction with high amounts of plastic, wood, or other types of waste). According to a market consultation performed for the region in 2022, in cases where the mineral fraction is clean, the cost for CDW treatment is about €20 per tonne. However, if the mineral fraction has high amounts of other waste, the treatment cost can rise to €90 per tonne or more.

In this perspective, Figure 7.2 presents the amount of CDW, as the percentage of the total amount received by each municipality, because different realities had to be examined individually, avoiding distortions when behaviour was the key aspect to be assessed.

Regarding LS1-M1, there has been a controlled and secured site for preliminary waste storage since 2021, including CDW. The site is used by individuals, but more frequently by micro and small construction companies, who can deliver CDW without being charged any tariffs. However, the employee responsible for controlling the site was not present in the fourth

quarter of 2021, for personal reasons, when a high volume of mixtures of CDW was accumulated. In this case it is possible to recognise that when a site is not adequately controlled, it presents disadvantageous results for the municipality, in terms of the amounts of CDW received (even from other neighbouring municipalities), uncontrolled mixtures of CDW, and the resultant higher costs for treatment. Nevertheless, although this site does not charge a tariff, this situation demonstrates the need that waste producers from a local scale dynamic have for intermediate CDW management solutions (corroborated by Ichinose & Yamamoto, 2011).



Legend: LS1 - Local Strategy 1 (Preliminary storage)

Figure 7.2 - Municipal local solutions for construction and demolition waste preliminary storage.

For LS1-M2, multibenne containers for CDW preliminary storage have been available in each parish since the third quarter of 2021, without control concerning who delivers CDW, although the sites have a fence, and a key has to be requested. CDW is delivered without any associated tariffs. Is it possible to recognise that when equipment is dispersed throughout the territory then CDW collection works. But again, when the solution does not involve control over CDW separation, it results in receiving uncontrolled mixtures of CDW, leading to in high costs for the municipality regarding its treatment.

Concerning LS1-M3, multibenne containers for construction companies executing construction works without a municipal license or prior notification process were available from 2005 until the end of 2021. The service had a cost for waste producers, although it did not cover the full costs of providing the CDW collection service and subsequent treatment. In this case, there is a perception that charging a low cost for CDW management is not a deterrent in terms of conditioning the behaviour for delivering CDW to controlled sites (supported, in general, by Wu *et al.*, 2017; Penteado & Rosado, 2016; and Sobotka & Sagan, 2016). Nevertheless, since the beginning of 2022, the decision was made to limit the preliminary storage service to only CDW arising from small repairs and minor do-it-yourself construction and demolition activities, within private households. It is evident that although the amount of CDW received decreased significantly, since most construction companies were not allowed to use the site anymore, the unsorted mixtures of CDW also decreased, benefiting the municipality in terms of the cost of CDW treatment. Since it is a recent change, it is not possible to study the wider effect of this shift, for example an increase in the illegal dumping of CDW (as stated by Rodríguez *et al.*, 2015; and Yuan *et al.*, 2011).

At LS1-M4, three controlled sites have existed since 2017, one in each parish, although there is little control over the quantities received, the conditioning of the CDW, or even the quantities that are eventually delivered to final waste management operators in terms of a lack of internal registers (also observed by De Melo *et al.*, 2011). Nevertheless, the municipality agreed to implement the LS1, but only in the most representative site in terms of the CDW quantity received, beginning in the fourth quarter of 2021. On this site there is no charge for CDW producers, and an employee is responsible for controlling the reception of CDW in multibenne containers, by individuals or by micro and small construction companies, where the employee provides frequent oral instruction about the specific criteria of CDW accepted (in line with what is substantiated by Al-Otaibi *et al.*, 2022; and Mahajan *et al.*, 2017). It is evident that in this case, the quality of the CDW received benefits from the controlled conditions existing, namely from the oral awareness, avoiding constraints for the municipality in terms of the cost of treatment.

7.4.2 Supervision onsite

The Portuguese law on waste (PCM, 2020) establishes that the reuse of construction materials must be encouraged. When not possible, waste producers must guarantee CDW separation on construction sites. Disposal of CDW in a landfill is only allowed after it has been subjected to separation. In addition, good practice in terms of hazardous CDW, recommends that they are stored for the minimum period possible at the construction site, and that they are sealed in appropriate containers for each material, properly identified, in a ventilated place, protected from atmospheric agents, on a waterproofed floor, and with retention recipients.

A complementary legal framework exists regarding the regulation of waste transportation, including for CDW, where the waste generated should always be accompanied by an electronic waste monitoring guide, for traceability and supervision purposes. It is mandatory to keep a register onsite detailing a summary of the CDW generated and its transportation.

In this context, LS2 relies on the implementation and supervision of legal requirements and good practices regarding CDW management on construction sites by micro and small construction companies, specifically at private construction works with a municipal license or an associated prior notification process. Four municipalities were involved (*i.e.*, LS2-M1, LS2-M2, LS2-M3, and LS2-M4).

This supervision work implemented by municipal technicians relied on constant awareness, training, and supervision. This component was oriented towards municipal technicians, but also the representatives of micro and small construction companies involved, due to transversal and consistent knowledge gaps identified, but also with a view to replicating the knowledge at other present and future construction sites.

In the beginning, no criteria were established regarding which specific companies should be visited. The purpose was to allow municipal technicians to try out the procedures and gain confidence in supervision actions over time, including in public construction works, although these are beyond the scope of the research project, it would allow them to train in other realities and procedures.

From May 2021, the objective was to revisit five pre-selected private construction sites subjected to a municipal licensing process or prior notification, in each municipality involved, making five visits to each construction site in total, until October 2022, trying to encompass a conjoint evolution over time. This evidence is presented in Table 7.1.

The number of visits established for each municipality was a compromise due to the lack of staff available to implement this strategy, but also the small number of construction works in progress in the area studied that were expected to last for the entire monitoring period, allowing to evaluate the evolution over time. In this case, the main research goal was to provide an example to replicate in the future, even if it was not necessarily fully representative.

Table 7.1 - Construction companies visited during the local strategy about supervision onsite.

Municipality	**Construction companies visited initially (n.º)**		**Subsequent visits to construction companies (n.º)**	
	Executing a public construction work	Executing a private construction work *	Construction works visited *	Total visits
LS2-M1	1	14	5	25
LS2-M2	3	9	5	25
LS2-M3	1	7	5	25
LS2-M4	1	10	5	25
Total	6	40	20	100

Legend: LS2 – Local Strategy 2 (Supervision onsite); M – Municipality; * Private construction work (with a municipal licensing process or prior notification)

Because it was the main objective of LS2 to measure the evolution of the pre-selected criteria over time, the objective of the first visit was to register the current situation on construction sites, before any training. Frequent visits were then implemented to raise awareness and teach the participants how to comply with the legal procedures and good practices required for effective CDW management. The results are presented in Table 7.2, with average values, for each visit. The evolution was not linear in all visits and between municipalities, but exhibits a general improvement over time.

Table 7.2 - Results of the supervision of onsite actions for private construction works, for each visit.

Visit	Conformity analysis (average) *					
	Operational aspects (on construction site)				Legal bureaucratic aspects	
	Construction site organisation	*Non-hazardous CDW separation*	*Hazardous CDW management*	*Authorised final destination*	*Procedures (onsite records)*	*Transport (traceability records)*
1	1.35	1.50	1.05	1.60	1.05	1.25
2	1.80	1.90	1.05	1.70	1.20	1.35
3	1.90	2.05	1.15	1.75	1.25	1.40
4	2.05	2.15	1.20	1.90	1.35	1.45
5	2.10	2.20	1.25	2.10	1.50	1.60

* Using a 3-points ordinal scale: "1" (bad), "2" (medium), and "3" (good)

In more in-depth analysis, the evolution was scored, using average values, to measure the development observed between the second and the fifth visits. The results are presented in Figure 7.3.

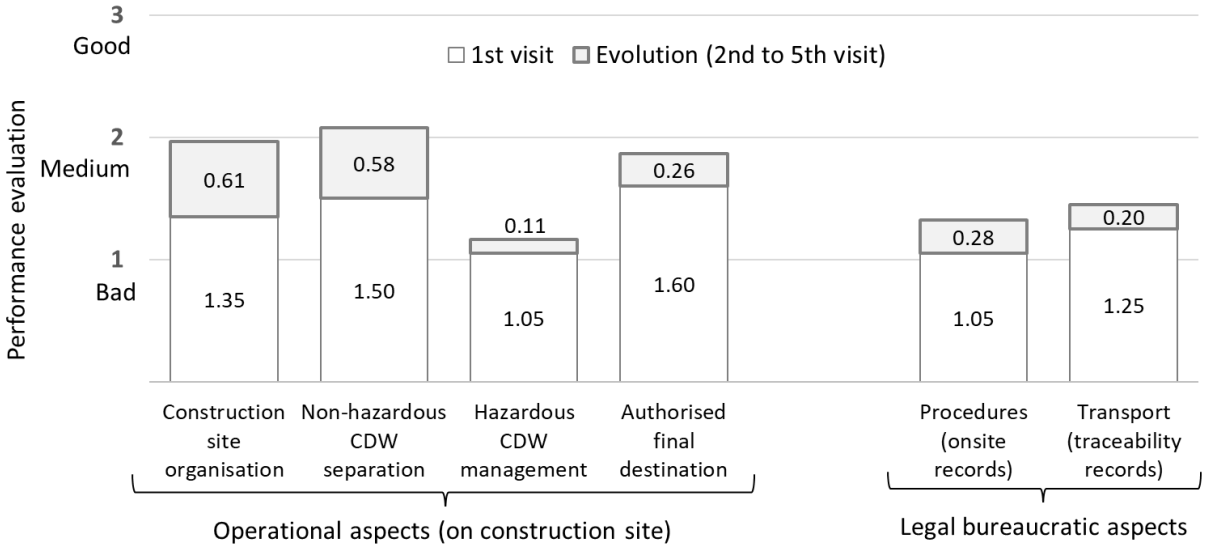


Figure 7.3 - The evolution of results following the supervision of onsite actions for private construction works.

In general, it can be observed that compliance with the operational aspects onsite (*i.e.*, construction site organization, non-hazardous CDW separation, hazardous CDW management, and licensed authorised final destination) achieved, in general, a better score in

the first visit then the legal bureaucratic issues did (*i.e.*, onsite registers and traceability), with an average of 1.38 against 1.15, respectively. These results are closer to the worst evaluation ("1" – bad) than the average ("2" – medium).

When measuring the evolution between the second and the fifth visits, the results have the same tendency, with the operational aspects achieving a general average improvement of 0.39, against the legal bureaucratic aspects, with a general average improvement of 0.24, demonstrating, in the latter case, a slower tendency to evolve, and a resistance to comply with these types of procedures.

A clear improvement in the compliance with CDW operational management practices over time can be observed. Comparing the first visit with the period between the second and the fifth visits, in general, statistically significant differences are evident ($p \leq 0.001$). Evaluating each element, it can be concluded that the majority of cases present statistically significant differences between the two periods considered, namely: construction site organisation regarding CDW management ($p \leq 0.003$); non-hazardous CDW separation ($p \leq 0.002$); and authorised final destinations for the CDW generated ($p \leq 0.011$). Only the test for hazardous CDW management onsite was not statistically significant ($p \leq 0.066$). During the supervision process, it became evident that the management of this type of waste is particularly difficult to implement, due to knowledge gaps, relevant and consistent doubts about how to classify CDW as hazardous or not (*e.g.*, through the packaging labels), and how to store it in the proper conditions, as previously mentioned.

When comparing the legal bureaucratic aspects between the two previously mentioned time periods, statistically significant differences are evident ($p \leq 0.018$). Moreover, the differences remain statistically significant when the aspects are considered individually, namely for the procedures regarding the recording of CDW management data onsite ($p \leq 0.027$), but also the existence of documentation evidencing the CDW transport to an authorised final destination ($p \leq 0.017$).

Considering the results of LS2, there is the perception that more awareness and training must be done, to achieve better results over time (supported by Ramos *et al.*, 2023; Li *et al.* 2022; Jin

et al., 2019; and Wu *et al.*, 2017), focusing on the application of good practices onsite (corroborated by Rondinel-Oviedo, 2021; and Mahajan *et al.*, 2017). This is because both municipal technicians and more significantly micro and small construction companies had not had sufficient opportunities in the past to cooperate and to demonstrate their doubts and seek clarification to address them (Ramos *et al.*, 2023). Also, the pre-existence of substantial technical knowledge gaps is a challenge (Ramos & Martinho, 2022; 2021).

7.4.3 Procedural control

In general, the Portuguese legal framework for CDW is considered solid (European Commission, 2017). In terms of procedural control, it makes distinctions between private construction works subjected to a municipal licensing process or prior notification and public works. In private construction works, it is only mandatory to have records about CDW management during the construction phase (*i.e.*, data proving the CDW generated and transported to an authorised site), delivering it when required for the conclusion of the licensing process. In the project phase of public construction works, it is necessary to outline a specific CDW Prevention and Management Plan. Within the conclusion of the process, this Plan may also restrict the administrative acts that would license the project as complete, in cases of non-compliance with CDW management legal requirements.

The reality is that, in general, Portuguese municipalities are not assessing legal procedures to comprehend if CDW is being controlled in terms of procedural control (APA, 2018a). Moreover, when documentation is delivered for evaluation, it is necessary to verify whether the declared CDW complies with the expectations for the construction work executed. But this analysis is infrequently undertaken. This context justifies, specifically in this research project, the importance of LS3 in raising awareness and improving the capacity on a municipal level for municipal technicians to implement this type of procedure. The LS3 was implemented with three municipalities (*i.e.*, LS3-M1, LS3-M2, and LS3-M3) and the results are presented in Table 3.2.

The outcomes demonstrate, for the private construction works analysed, that the applicants do not present evidence of CDW management when seeking the conclusion of the licensing

process. Although only one municipality decided to be involved in this analysis, the insight acquired through the supervision process in the *Baixo Alentejo* region, also supported by the literature review (APA, 2018a; Martinho *et al.*, 2015), is that this reality is replicable for Portuguese municipalities in general, with the exception of some existing good examples.

Table 7.3 - Processes assessed and results regarding the local strategy for procedural control.

Type of Construction work	**Phase evaluated**	**Assessment (in relation to each phase/processes evaluated)**						
		Processes evaluated (n.º)	**CDW generation**					
			Predicted (project) or declared (conclusion) (%)	Conformity analysis **				
				General (average)	*Distribution, by category (%)*			
					1	*2*	*3*	*Total*
Private * (LS3-M1)	Conclusion	11	0	1.00	100.0	0	0	100.0
Public (LS3-M2, LS3-M3)	Project	32	81.3	1.94	50.0	6.0	44.0	100.0
	Conclusion		84.4	1.56	66.0	12.0	22.0	100.0

Legend: LS3 – Local Strategy 3 (Procedural control); M – Municipality; * Private construction work (with a municipal licensing process or prior notification); ** Using a 3-points ordinal scale: "1" (bad), "2" (medium), and "3" (good).

The fact that the CDW Prevention and Management Plan is mandatory for public construction works, which are frequently executed by medium to large construction companies, with more technical knowledge (Ramos & Martinho, 2022, 2021), might indicate that the pre-existing knowledge of the companies might be an essential condition for better conformity with mandatory legal requirements. It means that, in the project phase, the aforementioned Plan is being presented together with the required documentation in 26 of the 32 assessed processes. Nevertheless, 50% of these applications have a bad conformity evaluation regarding the correct presentation of the document. For instance, in some cases the Plan is presented as a blank template, without any information about the predicted CDW to be generated during the construction phase, as it should be.

Regarding the conclusion phase of public construction works, 27 of the 32 processes assessed presented the mandatory Plan. However, 66% of these processes had a bad conformity

evaluation. In this case, the errors relate to the lack of documentation proving the correct transportation of CDW to an authorised site (in Portugal, an electronic waste monitoring guide, or proof that the declared CDW is below an acceptable level of conformity for the type of intervention executed). In the present research (Table 7.3), it means that if the CDW declared was less than 20% of the expected quantity, the classification attributed is bad; if the CDW declared is between 20 and 49% of the expected quantity, the classification is medium; and it is determined to be good for the remaining cases.

Performing a statistical analysis comparing the project phase versus the conclusion of the process, there is not a statistically significant difference between them ($p > 0.05$). This corroborates that in both phases it is necessary to reinforce the implementation of procedures in public construction works, in conjunction with a strong awareness and training component, involving municipal technicians and the applicants to the processes.

In this situation, it is essential to capacitate and try to implement the assessment of these processes, whether referring to private or public construction works because, without this component, CDW management on a local scale will not be possible to improve substantially, cooperating with other stakeholders (Ramos *et al.*, 2023), and changing habits.

7.5 Conclusions

The legal framework regarding CDW management is well-established in several countries and contexts. Nevertheless, various constraints and challenges remain, and several of them relate to local dynamics. In these cases, without the contribution of smaller scale organisations, namely municipalities and micro and small construction companies, it will not be possible to successfully realise the principles of the circular economy, as these principles were designed to meet the demands of other contexts and realities, namely larger scales of analysis. At a smaller scale there are unique challenges regarding the lack of knowledge, habits, cooperation and an absence of solutions reducing distances and costs.

Specifically, the existence of controlled sites under municipal responsibility for CDW preliminary storage is essential to establish a reduction in distances to facilities, and the respective costs of the process, eventually minimising the reality of the illegal dumping of the

CDW generated. In all cases, the sites must have controlled conditions in terms of access and an oral communication strategy to inform waste producers, teaching them how to use the facility and why it is important. The reception of sorted CDW is advantageous to municipalities because of the cost of treatment, and this is the main justification for investment in this strategy, not only in terms of the present benefits but also when considering the future, creating habits.

For supervision onsite of private construction works subjected to a licensing process or prior notification, which are often controlled by municipalities, the results show that with the frequent supervision of municipal technicians, it is possible to achieve an evolution in the procedures implemented onsite by micro and small construction companies. However, changes in behaviour regarding the mandatory legal bureaucratic aspects might be more difficult to achieve, or at least take more time to present results than the operational aspects at construction sites. Also, hazardous CDW management needs to be reinforced through awareness and training.

Municipal technicians are also frequently involved in the assessment of processes regarding private and public construction works but are not consequent at the evaluation of the processes to penalise applicants that are not declaring mandatory documentation about CDW management. It is crucial to raise awareness about the importance of this strategy, in cooperation with other strategies, to better lead CDW management on a local scale to a higher level of performance.

In this research, it was demonstrated that the implementation of local strategies is essential to effectively promote CDW management in a context of proximity, at an operational level, involving municipalities and micro and small construction companies. Though it is vital to cooperate with the stakeholders involved in this specific reality, through frequent awareness, capacitation, training, and supervision actions, to help them to evolve continually, be motivated to achieve results, and learn to be independent.

These findings are important not only for rural areas, as is the context of the Portuguese study undertaken and evaluated here, but also for less developed countries, or regions where there

is evidence of the same contextual conditions, such as the lack of proximity solutions for CDW management and gaps in cooperation between local stakeholders. The results obtained are also useful for areas where there are important gaps in local information, not facilitating political decisions based on technical information, which would serve as a driving force for positive changes to the planning process.

In a complementary way, society must be integrated into the strategies and solutions since occurrences such as the illegal dumping of CDW are difficult to catch. From this perspective, the involvement of citizens with a strong awareness of environmental problems might play an important role, together with more frequent supervision actions onsite, so the feeling of impunity in terms of illegal behaviour and best practices can be shaped by new circumstances.

8

Conclusions and recommendations

8.1 Context about the research project

Although there is a growing interest in research considering the principles of the circular economy applied to the construction sector, and especially the constraints associated with construction and demolition waste (CDW) management, there are knowledge gaps regarding the challenges associated with scales of proximity. In this sense, this research project focuses its analysis on the context of the local scale dynamics, in rural areas, understood as the existing reality, in operational terms, associated with municipalities and micro and small construction companies, as well as the relationship between these stakeholders.

The research project was designed to analyse the determining factors and strategies that allow the promotion of CDW management on a local scale, with a view to inducing behaviour change, but also trying to contribute to the capacitation and training of those involved, increasing motivation for the initiatives to be supported in the future to promote success. For this approach, the "Behaviour Change Wheel", developed by Michie *et al.* (2011), was considered an inspiration for the conceptual model that guided the present research project.

A transdisciplinary research strategy was implemented, to obtain diversified and complementary results to understand the reality being studied, as well as to allow for the involvement of different stakeholders, through quantitative and qualitative approaches, which are reflected in the selected research methods. For this, a review of the initial literature was carried out, strengthened throughout the research process to frame the specific themes that were being analysed; a questionnaire survey was used to study Portuguese construction companies; several workshops were developed with the selected stakeholders; and fieldwork was carried out to try to address the knowledge gaps and obtain results to support future operational and procedural initiatives. This approach was designed to answer the initial questions defined in the research project, although they underwent minor adjustments

throughout the process, as a result of the data that was being obtained, but also due to the practical constraints encountered.

The three Research Questions (RQ) selected, as well as the respective Specific Objectives (SO) associated with each one, are based on the following concerns about the local scale dynamics: i) which determining factors are relevant for CDW management?; ii) how to assess the reality of CDW illegal dumping?; and iii) which intervention strategies might be most appropriate to promote and lead to successful CDW management? These RQ, although defined individually, also presuppose their interconnectedness. This is because they start from the analysis of the factors that determine the local dynamics regarding CDW management, they assess a relevant and common problem for the selected stakeholders and, finally, they seek to understand ways to enhance the improvement of the identified problems regarding an operational point of view.

The field work was undertaken in the context of a rural Portuguese region, namely in *Baixo Alentejo*, composed of 13 municipalities, with specific characteristics regarding CDW management, for instance the lack of facilities for the CDW treatment, at affordable operational distances, and consequent costs.

8.2 Summary of key findings

To understand the reality of the CDW management within local dynamics, it was decided at the outset of the research project, from the point of view of the methodological approach, to study two types of stakeholders, both with a direct relationship to the problem, namely municipalities and micro and small construction companies. This was particularly the case for the latter group, hence, at the beginning of the research project, special attention was devoted to the size of construction companies and consequent practices, allowing decisions to be taken to corroborate research methods and strategies pursued later on.

This understanding came also from insights developed during other projects undertaken in the past, from specialist debates about the problem, as well as from the results and observations of other studies and official documents. However, there was a lack of data and knowledge to substantiate the reality of the local dynamics and the understanding of the

interconnection between the selected stakeholders, from an operational point of view. The main results obtained at the conclusion of this research project are presented below, which address the RQ from the perspective described above.

Determinants for construction and demolition waste management

Regarding the first research question (RQ 1), the results outlined in chapters 3 and 4, obtained through a survey by questionnaire submitted to Portuguese construction companies, demonstrate that construction company size is a determining factor for CDW management (SO 1.1).

The specific reality for micro and small companies acquires particular importance as the results show that they present more constraints than larger companies in terms of employing workers specialised in the environmental component; accessing or having information about legal procedures or good practices to implement on construction sites; and that they also have relatively fewer visits from authorities supervising their work. Specifically regarding the use of recycled aggregates, although the insight acquired throughout the research project is that this reality is transversal to most themes, there is a weak self-evaluation about the knowledge the smaller companies have, with them assuming that they know less than medium or larger companies. The guarantee of safety conditions and the customer's perception regarding the use of recycled materials are aspects that also concern these companies less. This reality was one of the main reasons why, in the participatory process developed with the municipalities and construction companies (chapter 5), this group was selected to participate actively, as they face specific obstacles that make CDW management more challenging in local dynamics, also emphasising the role and the responsibility that municipalities have.

Involving municipalities in the aforementioned participatory process meant engaging the municipal technicians directly involved in CDW management, including the areas of the environment, urbanism, and oversight actions, as it was considered that all these areas make important contributions to the understanding of the challenges being studied and have solutions to propose (SO 1.1).

The municipalities identify individually, without any relation to the opinion of the companies consulted, that cooperation between stakeholders is an essential determining factor in the achievement of better CDW management on a local scale, although other factors such as the need to carry out oversight actions and concerns about circularity issues in the construction sector were identified solely by this group. Perhaps because municipalities are resigned to the reality that they assume legal responsibility for the management of at least part of the CDW generated and delivered to their facilities, often involving high costs for transport and treatment, which leads them to emphasise these aspects.

It is also important to note that, when asked about training needs, municipal technicians draw less attention to the processes and tools made available most recently, such as the materials passport or pre-demolition audits and selective demolition processes, which might denote gaps regarding the updating of technical knowledge of municipal staff. This was also corroborated by the observations made during the supervision work carried out.

While there are determinants that relate to each specific group, there are nevertheless aspects that are common concerns (SO 1.2). This is the case regarding the lack of facilities and equipment to carry out CDW preliminary storage; its subsequent treatment at distances capable of reducing costs; as well the need to resolve knowledge gaps, with issues relating to good practices standing out. This knowledge update component is understandable, although a lack of proactivity is present in both groups because whilst some procedures and requirements changed at the end of 2020, some entities continue to have several doubts: from the point of view of execution onsite (companies), but also of the point of view of the responsibilities to assume (municipalities).

The reality of construction and demolition waste abandonment

An interrelated problem shared by the two groups of stakeholders being analysed is the illegal dumping of CDW, which is a recurring problem in Portugal, although also in other countries, both in Europe and beyond. Legal mechanisms have not been sufficient to ensure this reality disappears, nor are the occurrences sufficiently studied in the literature regarding CDW, which is why it became pertinent to explore the second research question (RQ 2). In this

research project, the contribution focused on the study of these occurrences in a context of proximity, over one year, in a rural area (*Baixo Alentejo* region), based on data collection, the calculation of performance indicators and cost evaluation, which also aimed to understand the underlying causes of the occurrences, as well as raise awareness and inform technicians and, consequently, policymakers (chapter 6).

From the point of view of diagnosis (SO 2.1), 136 illegal dumpsites were identified, of which 65% were located on publicly-owned land, with direct environmental effects and, in most cases, with consequences for municipalities in terms of cost, or even operationally, if cleaning actions have to take place. There are consolidated sites for CDW abandoned, with large amounts of waste, although the tendency is for these occurrences to appear in smaller quantities, in pre-existing locations. These sites have the characteristics of being isolated, close to roads, or in the proximity or outer limits of CDW controlled sites for preliminary storage under municipal responsibility. In turn, considering the one-year monitoring period, 26 new illegal dumping sites were recorded, with an estimation of 72 tonnes per new dumpsite.

Regarding the factors that determine the CDW abandonment (SO 2.2), there is the perception that the characteristics of the companies that operate in the reality of the local scale, as previously identified, combined with the lack of proximity of treatment facilities, and finally the perception that oversight actions are practically non-existent, contributing towards the proliferation of these occurrences. Additionally, it was possible to demonstrate, through performance indicators, that in the municipalities where there is some type of proximity solution for CDW management, even if the municipalities are not completely satisfied with their solutions, CDW dumpsites occur on a smaller extent.

To raise awareness of the problem (SO 2.3), it is important to understand that in terms of physical composition, 59% of illegal deposits correspond to the mineral fraction, meaning a resulting loss of material for the construction sector due to its potential for recovery, especially through material recycling. A cost indicator for CDW abandoned was also estimated for 2022, which for the region is between €84 and €99 per tonne of CDW abandoned. In respect to the total cost estimated, around 28% is directly associated with the municipality, with expenditures on human resources, equipment, and transport. However, municipalities are not

aware of this portion directly associated with the services they provide, because data gathering is not organised to address these types of issues or planning concerns.

Local strategies to promote construction and demolition waste management

To understand how to intervene to improve CDW management on a local scale dynamic, and considering the results obtained previously by the different research methods considered, three local strategies were proposed within the scope of the third research question (RQ 3). This work was carried out with six municipalities in the *Baixo Alentejo* region for approximately one year, considering the period of preparation and training of municipal technicians (chapter 7). These local strategies were developed in association with a capacitation, training, and supervision component, essential to solving several identified knowledge gaps that had to be met over time to allow the execution of the monitoring work.

The first local strategy that was chosen is related to the conditions for the CDW preliminary storage, through controlled sites or equipment, usually made available under the control and responsibility of the respective municipal parishes (SO 3.1). This local strategy was tested with four municipalities. With the results obtained, it was concluded that the conditions associated with secured sites are essential to ensure that CDW is delivered under pre-defined conditions, in terms of CDW separation. In addition, there is the perception that it is essential to couple this with a communication strategy, preferably oral, to orientate waste producers, and try to achieve a clean mineral fraction of CDW, decoupled from the rest of the waste, as an essential condition to lower the costs that the municipality has with its treatment, regardless of whether or not the municipality has a tariff associated to the service. Another essential factor relates to the creation of good habits in waste producers, and their reinforcement over time, so CDW can be delivered in ways that benefit municipalities.

The second local strategy was related to oversight actions, where there was a focus on regular visits to construction sites where construction works were being executed by micro and small companies. The intention was to inform and make them aware of the operational and procedural control requirements at construction sites, encourage compliance with legal requirements, and facilitate CDW management in terms of reducing costs and avoiding

penalties (SO 3.2). It was possible to test this strategy with four municipalities. The visits to construction sites were carried out by municipal technicians, who had frequent capacitation and training actions, as well as supervision onsite, to train them and harmonise criteria in the region for the evaluation and transmission of knowledge. Throughout the monitoring process, it was possible to observe that, in general, micro and small companies can improve the aspects related to CDW management practices onsite, but that bureaucratic aspects related to CDW generation registration and control of CDW movements did not evolve as positively. An attempt was made to combine a component of monitoring visits to construction sites with SePNA - *Serviço de Proteção da Natureza e do Ambiente* (Protection Service for Nature and Environment), to raise awareness, but also to try to improve procedures with pressure from law enforcement authorities, but this initiative was not well received by some municipalities, for fear of future consequences. In this way, and in order not to compromise the trust gained with municipal technicians over time, this alternative was abandoned without being tested.

The third local strategy was related to the assessment of procedural control of CDW management, to understand how to ensure that the control of procedures required by law, with the criteria in some cases being different for public and private construction works, is being fulfilled at a municipal level (SO 3.3). It was possible to test this strategy with three municipalities. However, there was resistance to advancing with it, for two main reasons: firstly that municipal technicians perceive that it is a strategy that involves more consequent technical knowledge from the regulatory point of view (which is different from only attending training or supervision sessions); and secondly because there is a perception that this control has not been carried out over the years, although it is mandatory by law, causing technicians to be unwilling to demonstrate this reality. Therefore, this strategy focused more on training and raising awareness, as the likelihood is that there was almost no control over past procedures. In any case, examining the processes where it was possible to analyse their compliance, it can be noted that there were omissions in the submission of documentation by the applicants, for proving the delivery of the CDW to licensed waste management operators, as well as declaring CDW in amounts below expectation for the interventions executed. In this sense, the need for capacitation in future procedures was reinforced, illustrating that without

this component, in combination with the other strategies, the success of CDW management in the context of local scale dynamics will be limited.

8.3 Other contributions from the research project

To make it possible to implement and monitor the development of the field work identified and described above, it was necessary to accompany it with a capacitation, training, and supervision strategy (SO 3.4), without which it would not have been possible to address the knowledge gaps detected among the municipal technicians, as well among the representatives of the micro and small construction companies that were involved. Without this complementary initiative, it would not have been possible to advance the project since the municipal technicians did not have the knowledge and autonomy to execute their roles according to the newest guidelines. With this in mind, clarification sessions were created and tailored to each municipality, since the knowledge gaps were inconsistent between technicians and municipalities.

Also, a proposal for regulatory clauses regarding CDW management was created (Annex I), based on the current situation of the municipalities in the *Baixo Alentejo* region, but also considering good examples from other Portuguese municipalities. This proposal sought to assist in updating the regulations for the municipalities of *Baixo Alentejo*, considering the new legal obligations that have come into force in the meantime, as well as the best practices and examples available. Another objective was to harmonise procedures in the region, avoiding entropy derived from inconsistent criteria.

In addition, a supporting document was created, specifically for local strategies, identifying and clarifying regulations and best practices, as well as guidelines for the implementation of the initiatives (Annex II).

Finally, a written proposal for a flyer on CDW management was created to guide producers (individuals and companies) in the region, as well as a text content proposal with harmonised information for the websites of municipalities (Annex III), as these communication channels had gaps detected. The proposals were put up for consideration to municipalities, although few contributed with suggestions for improvement. However, it is believed that after this

information is harmonized at the regional level, it will make it easier for CDW producers to be informed, regardless of the area of the territory in which they move or work, facilitating compliance with the requirements, and also creating habits for the future.

8.4 Limitations

The limitations of this research project were related, in the first instance, to the Covid-19 pandemic, which made it difficult, especially during 2021, to have frequent in-person contact with the municipal technicians, as had been planned in the research project design. Nevertheless, several sessions and meetings through videoconference, and the constant clarification by other means of frequent doubts that arose, successfully overcame the constraints associated with the pandemic.

Secondly, the municipalities in which the fieldwork was carried out have several limitations in terms of the availability of human resources, so it was often difficult to obtain data in a timely manner or with the required detail. These gaps or delays sometimes conditioned the results obtained, which had to be adapted based on estimates or values from other regions.

In addition, in several municipalities there was no involvement of technicians, which may have been due not only to a lack of time or resources, but also a lack of interest and support from the head offices. It is possible that they did not realise the importance of the research project, not to mention the benefits that the municipality would have gained, as the project to promote the improvement of CDW management on a local scale included a training component for the municipal technicians, which would have benefited them in the present, as well as in the future.

8.5 Recommendations

The selected strategies to promote CDW management on a local scale dynamic have managed to have a positive effect, educating stakeholders, creating habits, and achieving better results than in the past. In this way, concertation is recommended, to effectively apply strategies at a regional, or even national level, by replicating the good examples that resulted from this research project. It is recommended these strategies are enacted in unison and not in isolation

because, although some elements have been tested separately, this was predominantly related to the availability and interests of the municipalities. It is believed that the strategies will only generate more substantial and longer lasting effects when implemented together. However, proximity strategies must be accompanied by frequent capacitation, training, and supervision actions, as it was observed that the results are more consistent when reinforced with this regular monitoring. This also has a positive effect on creating a confident relationship between supervisors and participants that motivates and encourages the achievement of more consistent results.

It is important to involve actors at the political level, raising awareness, as without their support most of the decisions are never implemented. It is understood that this implementation does not take place for several possible reasons, due to a lack of ambition or an unwillingness to take risks, due to a lack of technical knowledge, or due to the influence of inertia with identical situations in adjacent areas, in which everyone recognises the problems, but nobody wants to assume or share responsibility for them. In this sense, it is also important to raise awareness of the fact that the practices adopted or rejected by a municipality may have effects on neighbouring municipalities, since physical borders might be insignificant in terms of CDW illegal dumping.

Therefore, it is believed that the results of this research project have raised awareness of the possibility of improving the management of CDW on a local scale dynamic. It is expected that technicians, together with policymakers, can leverage changes in day-to-day practices, in combination with gradual, day-by-day, behavioural changes. These changes are not possible without ambition, effort, and dedication, taking advantage of or adapting what already exists, competing for funding, or even joining projects or other initiatives that can help make a difference. And it is in this context that it is also very important to raise awareness so that the paradigm actively shifts in the circular economy principles applied to the construction sector. Meaning that without the local scale change, improvement, and contribution, it may never be possible to achieve the outlined goals at national, continental, or global scales.

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ANNEX I

Proposal of regulatory clauses for the *Baixo Alentejo* municipalities [8]

[8] This proposal of regulatory clauses was elaborated by Mário Ramos, within the project "(De)construct for Circular Economy", WP 2 - Regulatory Framework.

Proposta de cláusulas regulamentares para melhorar a gestão dos resíduos de construção e demolição à escala local e para potenciar a aplicação dos princípios de circularidade no setor da construção

Preâmbulo

A presente proposta de cláusulas regulamentares para melhorar a gestão dos resíduos de construção e demolição (RCD) à escala local, e para potenciar a aplicação dos princípios de circularidade no setor da construção, na região do Baixo Alentejo, considera o seguinte:

- A alteração do quadro regulamentar europeu, designadamente a partir da Diretiva 2018/851, de 30 de maio, que altera a Diretiva 2008/CE/98, de 19 de novembro, reconhecida por Diretiva Quadro de Resíduos (DQR);
- A transposição para o direito interno português do quadro regulamentar europeu mencionado no ponto anterior, nomeadamente para o designado novo Regime Geral da Gestão de Resíduos (nRGGR), publicado no Anexo I do Decreto-Lei n.º 102-D/2020, de 10 de dezembro, alterado pela Declaração de Retificação n.º 3/2021, de 21 de janeiro, e pela Lei n.º 52/2021, de 10 de agosto (e com a consequente revogação do Decreto-Lei n.º 46/2008, de 12 de março);
- A articulação das orientações portuguesas para o setor da construção e para a gestão dos RCD, contempladas no nRGGR, com o Código dos Contratos Públicos (Decreto-Lei n.º 18/2008, de 29 de janeiro, alterado e republicado pelo Decreto-Lei n.º 111-B/2017, de 31 de agosto, com posteriores alterações) e com o Regime Jurídico da Urbanização e Edificação (Decreto-Lei n.º 555/99, de 16 de dezembro, com alterações subsequentes);
- A desatualização dos regulamentos municipais da região do Baixo Alentejo, com foco nas áreas de gestão de resíduos, higiene e limpeza urbana, e urbanismo, no que concerne às questões relacionadas com a gestão dos RCD, dos mecanismos de controlo de obra, e de outros aspetos relacionados com a aplicação de conceitos que procuram promover a aplicação dos princípios da economia circular no setor da construção, com foco na demolição seletiva;

- A visão de proceder a uma harmonização do quadro regulamentar municipal no que concerne aos assuntos elencados no ponto anterior, com reajustamento da definição das responsabilidades e ações;
- A opção de apresentar uma proposta de cláusulas contratuais abrangentes, de âmbito regional, que consideram as orientações regulamentares atualizadas, assim como uma reflexão sobre as orientações de outros regulamentos municipais, embora sem foco em questões específicas que recaem no âmbito das escolhas dos municípios para as soluções disponibilizadas na sua área de influência;
- A preferência por apresentar uma proposta única de cláusulas regulamentares, sem especificar as áreas específicas de atuação em que cada uma delas pode ser enquadrada, deixando esta decisão para ser avaliada posteriormente, face à realidade de cada município, desde que os requisitos legais e a definição de responsabilidades estejam asseguradas, assim como a consulta prévia das entidades competentes, nomeadamente a Entidade Reguladora dos Serviços de Águas e Resíduos (ERSAR).

Proposta de cláusulas regulamentares

A. Âmbito

A1. A presente proposta de cláusulas regulamentares aplica-se à gestão dos resíduos de construção e demolição (RCD) cuja responsabilidade recai, de acordo com o enquadramento legal em vigor, sobre o sistema municipal responsável pela gestão de resíduos urbanos (RU) [doravante designado apenas por "sistema municipal"], com particular incidência no serviço para a sua recolha seletiva nos locais de produção, assim como a sua armazenagem preliminar em centros de receção de resíduos do município;

A2. A proposta incide também em matérias complementares relacionadas com a aplicação dos princípios da economia circular ao setor da construção, através da promoção dos procedimentos e requisitos relacionados com a demolição seletiva, com o intuito de incentivar a preparação para a reutilização e a reutilização dos materiais de construção, assim como a valorização dos RCD;

A3. Em todas as questões em que esta proposta for omissa, devem ser observados os requisitos do novo Regime Geral da Gestão de Resíduos (nRGGR) e, sempre que aplicável, a sua devida articulação com o Regime Jurídico da Urbanização e Edificação (RJUE), para o caso das obras particulares sujeitas a controlo prévio, e do Código dos Contratos Públicos (CCP), para o caso das obras públicas, para além de regulamentação complementar com incidência no setor da construção e nas compras públicas ecológicas.

B. Definições

B1. Para efeitos do disposto na presente proposta de cláusulas regulamentares, entende-se por:

a) Abandono: a renúncia ao controlo de resíduo sem qualquer beneficiário determinado, impedindo a sua gestão;

b) Armazenagem preliminar: a deposição controlada de resíduos em instalações onde os resíduos são descarregados a fim de serem preparados para posterior transporte para efeitos de tratamento, como parte do processo de recolha;

c) Centro de recolha de resíduos: o local onde os resíduos separados são depositados e onde se procede à armazenagem e/ou triagem preliminares desses resíduos para posterior encaminhamento para tratamento;

d) Demolição seletiva: a sequenciação das atividades de demolição para permitir a separação e a seleção dos materiais de construção;

e) Detentor: o produtor de resíduos ou a pessoa singular ou coletiva que tenha resíduos;

f) Eliminação: qualquer operação de tratamento de resíduos que não seja de valorização, nomeadamente as incluídas no anexo I ao nRGGR ainda que se verifique como consequência secundária a recuperação de substâncias ou de energia;

g) Gestão de resíduos: a recolha, o transporte, a triagem, a valorização e a eliminação de resíduos, incluindo a supervisão destas operações, a manutenção dos locais de eliminação após encerramento, e as medidas tomadas na qualidade de comerciante de resíduos ou corretor de resíduos;

h) Operador: qualquer pessoa singular ou coletiva que procede à gestão de resíduos;

i) Preparação para reutilização: as operações de valorização que consistem no controlo, limpeza ou reparação, mediante as quais os produtos ou os componentes de produtos que se tenham tornado resíduos são preparados para serem reutilizados, sem qualquer outro tipo de pré-processamento;

j) Produtor de resíduos: qualquer pessoa singular ou coletiva cuja atividade produza resíduos, isto é, um produtor inicial de resíduos, ou que efetue operações de pré-processamento, de mistura ou outras que alterem a natureza ou a composição desses resíduos;

k) Reciclagem: qualquer operação de valorização, através da qual os materiais constituintes dos resíduos são novamente transformados em produtos, materiais ou substâncias para o seu fim original ou para outros fins, incluindo o reprocessamento de materiais orgânicos, mas excluindo a valorização energética e o reprocessamento

em materiais que devam ser utilizados como combustível ou em operações de enchimento;

l) Recolha: a coleta de resíduos, incluindo a triagem e a armazenagem preliminar dos resíduos, para fins de transporte para uma instalação de tratamento de resíduos;

m) Recolha seletiva: a recolha efetuada de forma a manter os resíduos separados por tipo e natureza com vista a facilitar o tratamento específico;

n) Resíduo de construção e demolição: o resíduo proveniente de atividades de construção, reconstrução, ampliação, alteração, conservação e demolição e da derrocada de edificações;

o) Resíduo urbano: o resíduo proveniente de i) recolha indiferenciada e de recolha seletiva das habitações, incluindo papel e cartão, vidro, metais, plásticos, biorresíduos, madeira, têxteis, embalagens, resíduos de equipamentos elétricos e eletrónicos, resíduos de pilhas e acumuladores, bem como resíduos volumosos, incluindo colchões e mobiliário; e ii) de recolha indiferenciada e de recolha seletiva provenientes de outras origens, caso sejam semelhantes aos resíduos das habitações na sua natureza e composição;

p) Reutilização: qualquer operação mediante a qual produtos ou componentes que não sejam resíduos são utilizados novamente para o mesmo fim para que foram concebidos;

q) Tratamento: qualquer operação de valorização ou de eliminação de resíduos, incluindo a preparação prévia à valorização ou eliminação;

r) Triagem: o ato de separação de resíduos mediante processos manuais ou mecânicos, sem alteração das suas características, com vista ao seu tratamento;

s) Valorização: qualquer operação de tratamento de resíduos, nomeadamente as constantes do anexo II do nRGGR, cujo resultado principal seja a utilização, com ou sem transformação, dos resíduos de modo a servirem um fim útil, substituindo outros

materiais que, caso contrário, teriam sido utilizados para um fim específico ou a preparação dos resíduos para esse fim na instalação ou conjunto da economia.

C. Responsabilidade pela gestão dos RCD

C1. Compete ao sistema municipal assegurar a recolha, transporte e/ou receção dos RCD resultantes de pequenas reparações e obras de bricolage em habitações, realizadas pelo proprietário ou arrendatário, mediante a aplicação da respetiva tarifa, se aplicável;

C2. Nas obras particulares isentas de controlo prévio, nos termos do RJUE, o sistema municipal é responsável pela gestão dos RCD com amianto (RCDA), mediante o pagamento da correspondente tarifa, se aplicável;

C3. Sem prejuízo do sistema municipal optar por acautelar a gestão de outros RCD com proveniência não mencionada nos pontos anteriores, compete ao produtor do resíduo, em primeira instância, ou ao seu detentor, sem prejuízo da corresponsabilização de todos os intervenientes no ciclo de vida dos produtos na medida da respetiva intervenção no mesmo, acautelar o destino final daqueles RCD.

D. Serviço de recolha de RCD

D1. O sistema municipal disponibiliza um serviço de recolha seletiva e transporte para os RCD provenientes de pequenas obras de reparação e bricolage em habitações, realizadas pelo proprietário ou arrendatário;

D2. Compete ao produtor dos RCD com a proveniência mencionada no ponto anterior informar antecipadamente o sistema municipal da necessidade de encaminhar RCD para os centros de recolha de resíduos;

D3. Todos os movimentos devem ser acompanhados de guias eletrónicas de acompanhamento de resíduos (e-GAR), em cumprimento da legislação e procedimentos aplicáveis;

D4. O sistema municipal acautela a devida informação e sensibilização dos intervenientes, através de canais de comunicação de proximidade, com o intuito de agilizar o cumprimento dos procedimentos.

E. Centros de recolha de RCD

E1. O sistema municipal disponibiliza centros de recolha de resíduos, que incluem a armazenagem preliminar de RCD cuja responsabilidade de gestão lhe esteja atribuída, para além dos provenientes de obras de administração direta, e dos resultantes da limpeza do abandono daqueles resíduos, desde que por período não superior a três anos;

E2. A armazenagem preliminar referida no ponto anterior deve focar-se na fração mineral resultante da triagem dos RCD no local de produção (betão, tijolos, ladrilhos, telhas, materiais cerâmicos e pedra), por ser produzida em maior quantidade e por possuir grande potencial de reciclagem, e que por estas razões deve incentivar-se a que seja entregue ao sistema municipal sem estar misturada com outros resíduos;

E3. Complementarmente, e sempre que se justifique, o sistema municipal deve acautelar condições de armazenagem preliminar para outros tipos de RCD com gestão da sua responsabilidade, com enfoque no metal, no vidro, no plástico, na madeira e no gesso;

E4. O sistema municipal tem o direito de recusar receber os RCD que não estejam em conformidade com as orientações de receção estabelecidas;

E5. Os RCD apenas podem ser rececionados se forem acompanhados de e-GAR, em cumprimento da legislação e procedimentos aplicáveis;

E6. Sempre que pertinente e exequível, o sistema municipal disponibiliza, no mesmo espaço utilizado para a armazenagem preliminar dos RCD, condições para acondicionar materiais de construção para posterior preparação para a reutilização e reutilização, pelo próprio sistema municipal ou por outros intervenientes, mediante a cedência dos materiais em causa, nas condições que vierem a ser estabelecidas entre as partes;

E7. O sistema municipal acautela a devida informação e sensibilização dos intervenientes, através de canais de comunicação de proximidade, com o intuito de agilizar o cumprimento dos procedimentos.

F. Processamento de RCD e especificações técnicas

F1. Os RCD podem ser utilizados em obra desde que cumpram os princípios da segurança e da proteção da saúde humana e do ambiente e satisfaçam as exigências técnicas para as aplicações a que se destinam, cuja validação dos procedimentos é da responsabilidade do diretor de obra ou, em alternativa, do responsável pela obra;

F2. A Autoridade Nacional de Resíduos define e publicita, no seu sítio da Internet, especificações técnicas com relevância para diversas aplicações de RCD.

G. Controlo procedimental

G1. No âmbito de obras particulares sujeitas a controlo prévio, em articulação com o RJUE:

G1.1. Os pedidos de licença administrativa, assim como a comunicação prévia, devem indicar, sob responsabilidade do dono de obra, os tipos e quantidades de RCD que se estima produzir para a intervenção em causa, bem como a solução de gestão de RCD a adotar, privilegiando a sua valorização e evitando a eliminação;

G1.2. É condição para a emissão do alvará de autorização de utilização ou da receção provisória de obras a limpeza da área, a correta gestão dos RCD produzidos, em articulação com o nRGGR, e a eventual reparação de estragos ou deteriorações que tenha causado;

G1.3. Para o cumprimento do disposto no ponto anterior, os pedidos devem ser instruídos com uma declaração que ateste a correta gestão dos RCD em fase de obra, e o seu encaminhamento para operador de gestão de resíduos autorizado, incluindo informação quanto aos tipos de RCD e às respetivas quantidades produzidas, relacionando com o previsto inicialmente para a intervenção em causa, e anexando as respetivas e-GAR ou outra documentação que comprove os procedimentos adotados;

G1.4. O montante da caução destinada a assegurar a boa e regular execução das operações previstas no ponto 2 do artigo 86 do RJUE contempla uma parcela consignada à correta gestão dos RCD de modo que, em caso de incumprimento, o sistema municipal substitui-se à gestão que era devida.

G1.5. Deve maximizar-se a utilização de materiais reciclados ou que incorporem materiais reciclados, relativamente à quantidade total de matérias-primas usadas em obra.

G2. No âmbito de empreitadas e concessões de obras públicas:

G2.1. O projeto de execução é acompanhado de um Plano de Prevenção e Gestão de RCD (PPGRCD);

G2.2. A correta execução do PPGRCD condiciona os atos administrativos associados à receção da obra, nos termos previstos no CCP, nomeadamente na receção provisória;

G2.3. Para o cumprimento do disposto no número anterior, os pedidos devem ser instruídos com uma declaração que ateste a correta gestão dos RCD em fase de obra, e o seu encaminhamento para operador de gestão de resíduos autorizado, incluindo informação quanto aos tipos de RCD e às respetivas quantidades produzidas, relacionando com o previsto inicialmente no PPGRCD para a intervenção em causa, e anexando as respetivas e-GAR ou outra documentação que comprove os procedimentos adotados;

G2.4. Deve maximizar-se a utilização de materiais reciclados ou que incorporem materiais reciclados (sendo obrigatória a utilização de, pelo menos, 10% desses materiais), relativamente à quantidade total de matérias-primas usadas em obra, no âmbito da contratação de empreitadas de construção e manutenção de infraestruturas, ao abrigo do CCP.

H. Demolição seletiva

H1. A elaboração de projetos e a respetiva execução em obra devem privilegiar a adoção de metodologias e práticas que favoreçam os métodos construtivos que facilitem a demolição seletiva, orientada para a aplicação dos princípios da prevenção e redução e da hierarquia dos resíduos, e a conceção para a desconstrução;

H2. No âmbito do preconizado no ponto anterior, as obras sujeitas a controlo prévio devem apresentar, em fase de projeto, um plano de demolição seletiva;

I. Tarifário

I1. O custo da entrega dos RCD nas instalações dos sistemas municipais está dependente do cumprimento das condições concertadas a nível regional;

I2. O custo correspondente à entrega nos sistemas municipais de RCD resultantes de pequenas reparações e obras de bricolage em habitações, realizadas pelo proprietário ou arrendatário, deverá ser tendencialmente gratuito, desde que atestada a veracidade da sua origem, nas quantidades expectáveis para intervenções com aquelas características;

I3. Os RCD resultantes das restantes intervenções, designadamente os provenientes das atividades desenvolvidas por empresas de construção, estão sujeitas a tarifário que cubra os custos reais das respetivas operações de gestão, estabelecendo-se valores distintos para as seguintes quatro classes: RCD perigosos, RCD da fração mineral sem contaminantes, RCD da fração mineral com contaminantes, e outros RCD.

I4. Os sistemas municipais reservam-se ao direito de alterar, quando devidamente justificado, as condições definidas na alínea anterior, desde que com o objetivo de salvaguardar e promover a triagem dos RCD na origem, assim como a mitigação das deposições ilegais de RCD.

J. Contraordenações

J1. Aplicam-se as contraordenações mencionadas no nRGGR referentes à gestão de RCD, ou outras decididas pelos municípios.

ANNEX II

Guidelines to implement local strategies for the *Baixo Alentejo* municipalities [9]

[9] These guidelines were elaborated by Mário Ramos, as a complementary task for the project "(De)construct for Circular Economy" (in articulation with WP 1 - Baseline Situation and Follow-up, and WP 7 - Information, Awareness, and Training).

Nota prévia

São apresentadas quatro estratégias para promover a gestão dos resíduos de construção e demolição (RCD) sob responsabilidade municipal, nomeadamente:

- Estratégia E1 - Armazenagem preliminar dos RCD;
- Estratégia E2 - Sensibilização e fiscalização nos locais de obra;
- Estratégia E3 - Controlo procedimental;
- Estratégia E4 - Comunicação oral.

Estratégia E1 – Armazenagem preliminar dos RCD

A implementação da Estratégia E1 deve ter em atenção, de forma geral, o seguinte:

- A Estratégia tem como objetivo principal acautelar que existe, numa lógica de proximidade, um serviço de recolha e/ou meios de acondicionamento e/ou espaços para a armazenagem preliminar dos RCD, cumprindo as exigências legais em vigor, mas respeitando critérios que permitam a diminuição dos custos para o município;
- O município deve acautelar que os locais para a receção dos RCD, ou os equipamentos para o seu acondicionamento, estão em local vedado, com controlo de entrada;
- Esta Estratégia deve estar em estrita articulação com a Estratégia E4 (comunicação oral), para tentar melhorar a separação dos RCD na origem, com o objetivo do município receber a fração mineral separada dos restantes RCD, diminuindo os custos de tratamento para o próprio município, quando estes lhes forem devidos;
- Para cumprir o disposto no ponto anterior, o município deve garantir que recebe RCD classificados como 17 01 07 (misturas de betão, tijolos, ladrilhos, telhas e materiais cerâmicos) e não como 17 09 04 (mistura de RCD), pelo efeito direto que tem na diminuição dos custos;

- Sempre que possível, o município deve acautelar meios de acondicionamento adequados para além da fração mineral dos RCD, como é o caso da madeira, do plástico, do vidro, do plástico e do gesso;
- O município deve manter um registo atualizado dos movimentos de RCD, que inclua as quantidades rececionadas e expedidas, os intervenientes, os custos associados, assim como outra informação que julgue pertinente.

Estratégia E2 – Sensibilização e fiscalização nos locais de obra

A implementação da Estratégia E2 deve ter em atenção, de forma geral, o seguinte:

- A Estratégia tem como objetivo principal capacitar os técnicos dos municípios, com destaque para os fiscais, para as regras subjacentes à gestão dos RCD, assim como informar e sensibilizar as empresas de construção e os cidadãos, para que melhorem a gestão dos RCD produzidos, nomeadamente ao nível dos requisitos da separação na origem, acondicionamento, transporte e encaminhamento para destino final autorizado;
- Deve atender-se à visita ao maior número possível de empresas de construção e/ou obras, diversificando entre obras públicas e particulares, capacitando o maior número possível de intervenientes, com prioridade para as micro e pequenas empresas, e para as entidades que têm uma atividade mais intensiva;
- Recomenda-se a visita periódica das empresas de construção e/ou obras que, por terem maior dificuldade ou resistência em implementar os procedimentos, necessitam de um acompanhamento mais cuidado e frequente;
- A Estratégia E2 deve ter em conta, em tudo o que for possível, a Estratégia E4 (comunicação oral), no sentido de informar, sensibilizar e contribuir para uma melhoria contínua e consistente das práticas de todos os envolvidos.

São apresentadas de seguida orientações concretas que devem ser verificadas nas visitas às obras, relacionadas com o fundamento legal ou com as principais boas práticas aplicáveis:

2A. Organização do estaleiro

Considera-se um estaleiro com boa organização para a gestão dos RCD aquele onde, no mínimo:

- Exista um espaço reservado para o acondicionamento dos RCD (se não for o caso, que o seu encaminhamento para destino final autorizado esteja acautelado);
- Embora atendendo às características da obra, o espaço para a gestão dos RCD tenha área suficiente e características que permitam o correto acondicionamento dos RCD;
- Não exista mistura de RCD com materiais de construção.

2B. Separação dos RCD em obra

Considera-se que a separação dos RCD em obra é boa quando:

- Existam meios de acondicionamento apropriados para os vários tipos de RCD e atendendo às suas características (*e.g.*, big-bag, contentor *multibenne*, outros);
- Os RCD não perigosos sejam alvo de triagem em obra (*i.e.*, fração mineral, incluindo betão, tijolos, ladrilhos, telhas e materiais cerâmicos e pedra; metal; vidro; plástico; e gesso – ver nRGGR, artigo 51)[10], ou então que esteja assegurado o envio de misturas de RCD não perigosos para operador de tratamento de resíduos licenciado para proceder à sua triagem e tratamento;
- Os RCD (perigosos e não perigosos) estejam devidamente identificados com a respetiva designação, mas preferencialmente com o código de 6 dígitos da Lista Europeia de Resíduos (LER)[11].

[10] nRGGR (novo Regime Geral da Gestão de Resíduos), publicado no Anexo I do Decreto-Lei n.º 102-D/2020, de 10 de dezembro, com posteriores alterações: https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

[11] LER (Lista Europeia de Resíduos), Decisão 2014/955/UE, da Comissão, de 18 de dezembro: https://eur-lex.europa.eu/legal-content/PT/TXT/PDF/?uri=CELEX:32014D0955&from=PT

2C. Gestão dos RCD perigosos

Considera-se que existe uma boa gestão dos RCD perigosos quando:

- Os RCD perigosos estejam separados dos RCD não perigosos;
- Os RCD perigosos estejam acondicionados em recipientes fechados, sobre piso impermeabilizado, com bacia de retenção com capacidade apropriada, em local arejado e, quando necessário, protegidos de agentes externos (*i.e.*, sol, chuva, vento);
- Os RCD perigosos estejam armazenados em obra o mínimo de tempo possível.

2D. Registos sobre RCD

Considera-se que os registos sobre RCD em obra estão em conformidade quando:

- Nas **obras particulares sujeitas a controlo prévio**, exista o registo de dados de RCD devidamente preenchido e atualizado, acompanhando o livro de obra (nRGGR, artigo 54)[12];

  Nota 1: a Agência Portuguesa do Ambiente (APA) disponibiliza um modelo de registo de dados de RCD para as obras particulares sujeitas a controlo prévio[13]*;*

- Nas **obras públicas**, exista um Plano de Prevenção e Gestão (PPG) dos RCD disponível em obra, devidamente atualizado (nRGGR, artigo 55);

  Nota 2: a APA disponibiliza um modelo de PPG-RCD para obras públicas[14]*;*

[12] nRGGR (novo Regime Geral da Gestão de Resíduos), publicado no Anexo I do Decreto-Lei n.º 102-D/2020, de 10 de dezembro, com posteriores alterações: https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

[13] Modelo de registo de dados de RCD (obras particulares sujeitas a controlo prévio): https://apambiente.pt/residuos/minutas-de-documentos

[14] Modelo de Plano de Prevenção e Gestão de RCD (obras públicas): https://apambiente.pt/residuos/minutas-de-documentos

- Exista informação em obra sobre os movimentos de RCD, designadamente sobre se os RCD são efetivamente transportados para destino final licenciado, justificado pelas guias de acompanhamento eletrónico de resíduos (e-GAR)[15].

2E. Destino dos RCD

Considera-se que existe boa informação sobre o destino dos RCD quando é possível justificar:

- Que os destinos finais dos RCD são conhecidos e estão planeados;
- Que existe informação em obra que comprova o encaminhamento dos RCD para destinos licenciados para os receberem (*i.e.*, informação das e-GAR).

> *Nota: Como apoio, pode ser utilizada a informação do Sistema de Informação do Licenciamento de Operações de Gestão de Resíduos (SILOGR)[16], da APA.*

Estratégia E3 – Controlo procedimental

A implementação da Estratégia E3 deve ter em atenção, de forma geral, o seguinte:

- A Estratégia tem como objetivo principal capacitar os técnicos dos municípios, nomeadamente os que analisam e validam os processos de obras públicas e obras particulares sujeitas a controlo prévio, para as regras subjacentes à gestão dos RCD, assim como informar e sensibilizar os requerentes dos processos para que melhorem a gestão que fazem dos RCD produzidos em fase de obra;
- A avaliação deve considerar as quantidades previstas de RCD face ao tipo de intervenção, mas também os requisitos do seu transporte e encaminhamento para destino autorizado (em articulação com o controlo procedimental – Estratégia E3);

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[15] e-GAR: Portaria n.º 145/2017, de 26 de abril (https://dre.pt/dre/detalhe/portaria/145-2017-106926975), alterada pela Portaria n.º 28/2019, de 18 de janeiro (https://files.dre.pt/1s/2019/01/01300/0037300375.pdf)

[16] SILOGR: https://silogr.apambiente.pt/pages/publico/index.php

- Deve ser dada prioridade à avaliação do maior número possível de processos em fase de conclusão (diversificando entre obras públicas e particulares), para que a ação dos técnicos possa ser consequente, no sentido de poderem questionar e capacitar atempadamente os requerentes sobre os procedimentos adotados para a gestão dos RCD, corrigindo tudo o que ainda for possível alterar;
- A Estratégia E3 deve ter em conta, em tudo o que for possível, a Estratégia E4 (comunicação oral), no sentido de informar, sensibilizar e contribuir para uma melhoria contínua e consistente das práticas de todos os envolvidos.

São apresentadas de seguida orientações concretas que devem ser verificadas no controlo procedimental de obras particulares sujeitas a controlo prévio ou obras públicas, apresentando o fundamento legal ou outras orientações complementares:

3A. Registos sobre gestão de RCD

Nas obras particulares, sujeitas a controlo prévio:

- Em fase de obra, é obrigatório efetuar e manter com o livro de obra, o registo de dados de RCD (nRGGR, artigo 54)[17];

  Nota 1: a Agência Portuguesa do Ambiente (APA) disponibiliza um modelo de registo de dados de RCD para as obras particulares sujeitas a controlo prévio[18].

  Nota 2: o Regime Jurídico da Urbanização e Edificação (RJUE)[19] *dispõe sobre os RCD: artigo 7 (pontos 6 e 9), artigo 53 (ponto 1, alínea a), artigo 57 (ponto 1), artigo 86.*

[17] nRGGR (novo Regime Geral da Gestão de Resíduos), publicado no Anexo I do Decreto-Lei n.º 102-D/2020, de 10 de dezembro, com posteriores alterações: https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

[18] Modelo de registo de dados de RCD (obras particulares sujeitas a controlo prévio): https://apambiente.pt/residuos/minutas-de-documentos

[19] RJUE (Regime Jurídico da Urbanização e Edificação), o Decreto-Lei n.º 555/99, de 16 de dezembro, com posteriores alterações: https://www.pgdlisboa.pt/leis/lei_mostra_articulado.php?nid=625&tabela=leis

Nas obras públicas:

- É obrigatório existir, em fase de projeto, um Plano de Prevenção e Gestão (PPG) de RCD (nRGGR, artigo 55[20]; e Código dos Contratos Públicos – artigo 43, ponto 5, alínea f);
- É obrigatório, na fase de receção provisória, atestar o cumprimento do PPG-RCD (Código dos Contratos Públicos – artigo 394, ponto 2, alínea b; artigo 395, ponto 2, alínea b; e artigo 395, ponto 4).

Nota: A APA disponibiliza um modelo de PPG-RCD para obras públicas[21].

3B. RCD previstos/produzidos

Para edifícios, sugere-se utilizar o simulador desenvolvido no âmbito do Plano de Ação para a Gestão Sustentável dos RCD na Área Metropolitana do Porto[22], designada por "Modelo de estimativa das quantidades de RCD", onde são utilizados indicadores de produção de RCD por tipo de edifício (habitacional e comercial), tipo de atividade (construção nova, reabilitação e demolição) e tipo de área (área habitacional, área útil e área total).

O simulador deverá ser utilizado na perspetiva de percecionar se a quantidade dos RCD declarada pelos produtores diverge pouco ou muito da expetável para o tipo de intervenção em causa. Deverá privilegiar-se uma análise que foque a fração mineral dos RCD (*i.e.*, betão, tijolos, ladrilhos, telhas, cerâmicos), por ser a que é habitualmente produzida em maior quantidade e a que possui elevado potencial de reciclagem.

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[20] nRGGR (novo Regime Geral da Gestão de Resíduos), publicado no Anexo I do Decreto-Lei n.º 102-D/2020, de 10 de dezembro, com posteriores alterações: https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

[21] Modelo de Plano de Prevenção e Gestão de RCD (obras públicas): https://apambiente.pt/residuos/minutas-de-documentos

[22] Plano de Ação para a Gestão Sustentável dos RCD na Área Metropolitana do Porto: http://portal.amp.pt/pt/2/temae/526#FOCO_2

Para outro tipo de obras, deve ser considerada a sensibilidade de técnicos mais experientes naquele tipo de intervenção, também com base em controlo procedimental de processos cuja gestão de RCD em obra tenha sido adequado às exigências legais em vigor.

3C. Transporte e destino final dos RCD

Considera-se que existe boa informação sobre o transporte e destino final dos RCD quando é possível justificar:

Na fase de projeto:

- Que existe informação sobre quais os destinos finais dos RCD a produzir em fase de obra e se estão licenciados para recebê-los.

Na fase de obra ou com o término da obra:

- Se os RCD foram efetivamente enviados para destinos finais licenciados, através do controlo das e-GAR[23].

  Nota: Como apoio, pode ser utilizada a informação do Sistema de Informação do Licenciamento de Operações de Gestão de Resíduos (SILOGR)[24] da APA.

Estratégia E4 – Comunicação oral

A implementação da Estratégia E4 deve ter em atenção, de forma geral, o seguinte:

- A Estratégia tem como objetivo principal capacitar os produtores de RCD para a correta gestão deste fluxo específico de resíduos, atendendo aos requisitos legais em vigor, mas também às soluções de tratamento (incluindo a armazenagem preliminar) existentes na região do Baixo Alentejo, sobretudo no que diz respeito às disponibilizadas em contexto de proximidade, sob responsabilidade dos municípios;

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[23] e-GAR: Portaria n.º 145/2017, de 26 de abril (https://dre.pt/dre/detalhe/portaria/145-2017-106926975), alterada pela Portaria n.º 28/2019, de 18 de janeiro (https://files.dre.pt/1s/2019/01/01300/0037300375.pdf)

[24] SILOGR: https://silogr.apambiente.pt/pages/publico/index.php

- Para as micro e pequenas empresas de construção, devem privilegiar-se canais de comunicação de proximidade, por via presencial/oral (*e.g.*, operador responsável pela vistoria na entrega dos RCD ao município, fiscal municipal, técnico municipal, linha telefónica), com conteúdos focados em atos consequentes (*e.g.*, informação sobre soluções disponibilizadas para a gestão dos RCD, e práticas orientadas para a redução dos custos);
- As orientações desta Estratégia pretendem desenvolver/fortalecer procedimentos internos de comunicação nos municípios que funcionem de forma regular e eficaz, transmitindo diretrizes que podem ser aplicadas de raiz ou que podem servir para adaptar práticas já existentes (a avaliar caso a caso).

São apresentadas de seguida orientações concretas que devem ser atendidas nos procedimentos de comunicação a implementar, em relação aos canais de comunicação considerados prioritários:

4A. Operador municipal (relação com E1)

O operador responsável pela vistoria na entrega dos RCD ao município deve orientar o conteúdo da comunicação oral atendendo aos seguintes critérios, preferencialmente pela ordem exposta:

- 4A.1. Informar das condições para a receção dos RCD no município (em articulação com a Estratégia E1, quando aplicável), em termos de localizações, horário e regras de utilização;
- 4A.2. Informar da obrigação de entregar ao município os RCD separados, com foco na fração mineral (*e.g.*, betão, tijolos, ladrilhos, telhas, cerâmicos, ou a mistura dos RCD anteriores), para tentar diminuir os custos (para os particulares, para as empresas e, consequentemente, para os municípios);
- 4A.3. Informar das soluções para a entrega dos RCD em outras instalações que não as do município, informando da relação entre a separação dos RCD e a redução de custos;

- 4A.4. Informar da obrigatoriedade de todos os movimentos de RCD necessitarem de ser acompanhados de guias eletrónicas de acompanhamento de resíduos (e-GAR) (Estratégia E3).

4B. Fiscal municipal (relação com E2)

O fiscal municipal deve orientar o conteúdo da comunicação oral atendendo aos seguintes critérios, preferencialmente pela ordem exposta:

- 4B.1. Informar das condições para a receção dos RCD no município (em articulação com a Estratégia E1, quando aplicável), em termos de localização, horário e regras de utilização;
- 4B.2. Informar da obrigação de entregar ao município os RCD separados na origem, com foco na fração mineral (*e.g.*, betão, tijolos, ladrilhos, telhas, cerâmicos, ou a mistura dos RCD anteriores), para tentar diminuir os custos (para os particulares, para as empresas e, consequentemente, para os municípios);
- 4B.3. Informar das soluções para a entrega dos RCD em outras instalações que não as do município, informando da relação entre a separação dos RCD e a redução de custos;
- 4B.4. Informar da obrigatoriedade de todos os movimentos de RCD necessitarem de ser acompanhados de guias eletrónicas de acompanhamento de resíduos (e-GAR) (ver orientações da Estratégia E3);
- 4B.5. Informar da necessidade de controlar e registar os movimentos dos RCD, no registo de dados de RCD (obras particulares sujeitas a controlo prévio, em articulação com o RJUE) ou no Plano de Prevenção e Gestão de RCD (obras públicas, ao abrigo do CCP) (Estratégia E3).

4C. Técnico municipal (relação com E3)

O técnico municipal deve orientar o conteúdo da comunicação oral atendendo aos seguintes critérios, preferencialmente pela ordem exposta:

- 4C.1. Informar da necessidade de controlar e registar os movimentos de RCD, no registo de dados de RCD (obras particulares sujeitas a controlo prévio, em articulação com o RJUE) ou no Plano de Prevenção e Gestão de RCD (obras públicas, ao abrigo do CCP) (Estratégia E3);
- 4C.2. Informar que o controlo procedimental referido no ponto anterior pode condicionar a emissão de licenças/autorizações;
- 4C.3. Questionar sobre os RCD previstos para determinado tipo de intervenção, face aos RCD que foram declarados, em fase de conclusão da intervenção (Estratégia E3), pedindo justificação ao requerente quando as discrepâncias forem consideráveis;
- 4C.4. Informar da obrigatoriedade de todos os movimentos de RCD necessitarem de ser acompanhados de guias eletrónicas de acompanhamento de resíduos (e-GAR) (Estratégia E3);
- 4C.5. Informar das condições para a receção dos RCD no município (em articulação com a Estratégia E1, quando aplicável), em termos de localização, horário e regras de utilização (podendo esta informação ser complementada, sempre que se julgue adequado, com a informação referida anteriormente para os fiscais municipais);
- 4C.6. Informar das soluções para a entrega dos RCD em outras instalações que não as do município, informando da relação entre a separação dos RCD e a redução de custos.

4D. Linha telefónica (relação com E1)

A linha telefónica do município deve orientar os conteúdos a divulgar atendendo aos seguintes critérios, preferencialmente pela ordem exposta:

- 4D.1. Informar das condições para a receção dos RCD no município (em articulação com a Estratégia E1, quando aplicável), em termos de localização, horário e regras de utilização;
- 4D.2. Informar da obrigação de entregar RCD separados na origem, com foco na fração mineral (*e.g.,* betão, tijolos, ladrilhos, telhas, cerâmicos, ou a mistura dos RCD

anteriores), para tentar diminuir os custos (para os particulares, para as empresas e, consequentemente, para os municípios);

- 4D.3. Informar das soluções para a entrega dos RCD em outras instalações que não as do município, informando da relação entre a separação dos RCD e a redução de custos;
- 4D.4. Informar da obrigatoriedade de todos os movimentos de RCD necessitarem de ser acompanhados de guias eletrónicas de acompanhamento de resíduos (e-GAR) (Estratégia E3).

4E. Outros canais de comunicação (relação com E1, E2 e E3)

Outros canais de comunicação podem ser utilizados em complemento dos anteriores, designadamente (e com as seguintes funções essenciais):

- 4E.1. **Panfletos** (ver Anexo III): para divulgar informação genérica sobre boas práticas para a gestão dos RCD, as soluções do município para a entrega dos RCD, os requisitos para o transporte (e-GAR), disseminar o número de telefone para esclarecer dúvidas, entre outros (a avaliar caso a caso);
- 4E.2. **Sítio da Internet do município** (ver Anexo III): para divulgar informação sobre obrigações legais, boas práticas para a gestão dos RCD, as soluções do município (ou outras soluções) para a entrega dos RCD, os requisitos para o transporte (e-GAR), disseminar o número de telefone para esclarecer dúvidas, entre outros (a avaliar caso a caso);
- 4E.3. Outros (a avaliar a efetividade caso a caso).

ANNEX III

Content proposal for a flyer and websites for the *Baixo Alentejo* municipalities [25]

[25] These content proposals were elaborated by Mário Ramos, as a complementary task for the project "(De)construct for Circular Economy" (in articulation with WP 7 - Information, Awareness, and Training).

A. Content proposal for a flyer

Identificação do município

RCD

Resíduos de construção e demolição

Resíduos produzidos por particulares ou empresas de construção, em intervenções de construção nova, reabilitação ou demolição, como por exemplo o betão, os tijolos, as telhas, os metais, a madeira, o plástico, o vidro e o gesso.

Contacte-nos sempre que tiver dúvidas

Sítio da Internet (RCD): xxxx.xx

e-mail: xxxxxx@xxxx.xx

Telefone: xxxxxxxxx

Particulares

Se produzir RCD numa pequena reparação ou obra de bricolage, numa habitação, em que é proprietário ou arrendatário:

- Separe os RCD nos seus diferentes tipos e acondicione-os individualmente;
- Informe-se junto do município acerca do destino que deve dar aos RCD;
- Não deposite os RCD nos ecopontos para resíduos urbanos;
- Evite coimas, acompanhando o transporte de RCD com guias eletrónicas de acompanhamento de resíduos (e-GAR);
- Ajude o município denunciando o abandono ilegal de RCD.

Empresas de construção

Se produzir RCD no âmbito da sua atividade profissional:

- Antes do início da obra, planeie a logística e os custos relacionados com os RCD;
- Em fase de obra, mantenha o estaleiro organizado, colocando os materiais de construção e os RCD em zonas distintas;
- Para reduzir custos, separe os RCD não perigosos: fração mineral (betão, tijolos, telhas), plástico, vidro, madeira e gesso;
- Acondicione os RCD perigosos pelo mínimo de tempo possível, em recipientes fechados, sobre piso impermeabilizado, em bacias de retenção, protegidos do sol e da chuva, e em local arejado;
- Evite coimas, acompanhando todos os movimentos de RCD com guias eletrónicas de acompanhamento de resíduos (e-GAR), incluindo para o estaleiro central;
- Organize o registo documental, para facultar aos fiscais e entregar na instrução dos processos:
  - Os comprovativos do transporte (e-GAR); e
  - O registo de dados (obras particulares); ou
  - O Plano de Prevenção e Gestão de RCD (obras públicas).
- Ajude o município a promover a equidade entre empresas, denunciando o abandono ilegal dos RCD.

Imagem de deposição ilegal de RCD

B. Content proposal for the websites of the *Baixo Alentejo* municipalities

B1. Enquadramento

Os resíduos de construção e demolição (RCD) são os resíduos gerados pelas atividades de construção nova, reabilitação e demolição, incluindo os resíduos provenientes de pequenas reparações ou obras de bricolage, que envolvam atividades de construção e demolição em habitações, efetuadas pelo proprietário ou arrendatário. No geral, estes resíduos podem ser produzidos por empresas de construção ou por particulares, existindo alguns aspetos que distinguem, do ponto de vista do enquadramento legal, as responsabilidades inerentes a cada caso.

[devem aparecer três opções, que remetem para 3 páginas distintas (B2, B3 e B4)]

B2. Breve enquadramento legal (opção de regressar a esta página de enquadramento)

B3. RCD produzidos por particulares (*idem*)

B4. RCD produzidos por empresas de construção (*idem*)

No geral, importa ainda estar informado dos seguintes aspetos:

- Estima-se que os RCD representam mais de um terço de todos os resíduos produzidos na União Europeia durante um ano;
- São resíduos com um grande potencial de valorização, especificamente de reciclagem, uma vez que a maioria é constituída por betão, tijolos, ladrilhos, telhas e materiais cerâmicos, que podem ser processados, dando origem a agregados reciclados;
- O setor da construção é também responsável por uma quantidade importante de extração de materiais virgens, e pela emissão de gases de efeito de estufa resultantes das intervenções de construção, mas também da respetiva fase de utilização;

- É prioritário tentar evitar a produção de RCD e, quando tal não for possível, deve ser promovida a gestão dos RCD produzidos nas melhores condições possíveis, num contexto de circularidade no setor da construção, pelo que:
    - Todos os materiais que possam ser recuperados devem ser devidamente acondicionados e preparados para a sua reutilização;
    - Quando a opção anterior não for possível, devem ser acauteladas as melhores condições para a triagem, o acondicionamento, o transporte e, por fim, o encaminhamento para destino final autorizado dos RCD produzidos;
    - Os RCD devem ser eliminados apenas em último recurso.
- Os custos relacionados com a gestão dos RCD desempenham um papel importante, e também as taxas ambientais, para promover melhores práticas e dissuadir daquelas que são ambientalmente desfavoráveis; no entanto:
    - Muitos destes custos podem ser reduzidos por via do hábito de planear e executar de acordo com obrigações legais, mas também das melhores práticas existentes.

É ainda muito importante estar ciente do seguinte:

- Todos temos a responsabilidade de evitar as deposições ilegais de RCD e contribuir para condições mais justas para os cidadãos, municípios e empresas, denunciando estas situações às entidades competentes (município, GNR/SePNA, PSP, entre outros);
- As coimas associadas são elevadas, para tentar evitar que tais situações continuem a existir, por haver um desperdício importante em cada uma daquelas ocorrências, pois o material abandonado poderia ser novamente incorporado no setor da construção em condições devidamente controladas.

B2. Breve enquadramento legal

Nesta seção apresenta-se um breve enquadramento legal relacionado com a gestão dos RCD, não dispensando, contudo, a consulta dos diplomas legais em vigor.

B2.1. Gestão de RCD (geral)

O enquadramento legal referente à gestão dos RCD está definido no novo Regime Geral da Gestão de Resíduos (nRGGR), mais precisamente no Anexo I do **Decreto-Lei n.º 102-D/2020, de 10 de dezembro** (alterado pela Declaração de Retificação n.º 3/2021, de 21 de janeiro, e pela Lei n.º 52/2021, de 10 de agosto). As orientações que dizem respeito especificamente aos RCD estão definidas no capítulo VI, nomeadamente entre os artigos 49º e 56º:

> DL 102-D/2020: https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

- Responsabilidade pela gestão de RCD (artigo 49º);
- Metodologias e práticas a adotar no projeto e execução de obras (artigo 50º);
- Triagem e fragmentação de RCD (artigo 51º);
- Utilização de RCD em obra (artigo 52º);
- Especificações técnicas para valorização de RCD (artigo 53º);
- Gestão de RCD em obras particulares (artigo 54º);
- Gestão de RCD em obras públicas (artigo 55º);
- Caução (artigo 56º).

Outras normas transversais à política de gestão de resíduos, mas com incidência nos RCD, estão registadas em outras partes do Anexo I, mais precisamente nos artigos 27º (meta de valorização de 70%), 28º (incorporação de 10% de materiais reciclados em obras públicas), 31º, 36º (recolha seletiva de RCD para pequenas reparações e obras de bricolage em habitações), e 117º (contraordenações ambientais).

O **Decreto-Lei n.º 46/2008**, de 11 de março, foi revogado pelo nRGGR.

B2.2. RCD com amianto

A gestão dos RCD com amianto carece de normas específicas. Neste sentido, a **Portaria n.º 40/2014, de 17 de fevereiro**, estabelece as normas para a correta remoção dos materiais

contendo amianto e para o acondicionamento, transporte e gestão dos respetivos RCD gerados, tendo em vista a proteção do ambiente e da saúde humana.

> *Portaria 40/2014: https://dre.pt/dre/detalhe/portaria/40-2014-572439*

B2.3. Transporte de resíduos

As regras aplicáveis ao transporte de resíduos, incluindo dos RCD, estão definidas na **Portaria n.º 145/2017, de 26 de abril** (alterada pela **Portaria n.º 28/2019, de 18 de janeiro**), que cria as **guias eletrónicas de acompanhamento de resíduos (e-GAR)**, a emitir no Sistema Integrado de Registo Eletrónico de Resíduos (SIRER), integrado no Sistema Integrado de Licenciamento do Ambiente (Siliamb), disponível no sítio da Internet da Agência Portuguesa do Ambiente.

> *Portaria 145/2017: https://dre.pt/dre/detalhe/portaria/145-2017-106926975*

> *Portaria 28/2019, de 18 de abril: https://dre.pt/dre/detalhe/portaria/28-2019-117919464*

B2.3. Lista Europeia de Resíduos

A **Lista Europeia de Resíduos (LER)** constitui uma lista harmonizada que tem em conta a origem e a composição dos resíduos. Esta lista está publicada na **Decisão n.º 2014/955/UE, da Comissão, de 18 de dezembro** (altera a Decisão n.º 2000/532/CE, da Comissão, de 3 de maio), estando os RCD listados no seu capítulo 17.

> *LER: https://eur-lex.europa.eu/legal-content/PT/TXT/PDF/?uri=CELEX:32014D0955&from=PT*

B2.4. Contraordenações ambientais

A **Lei-Quadro das Contraordenações Ambientais** está definida na **Lei n.º 50/2006, de 29 de agosto**, com posteriores alterações. No que se refere aos RCD, as contraordenações estão tipificadas no artigo 117 do Anexo I do **Decreto-Lei n.º 102-D/2020, de 10 de dezembro**, e também nos regulamentos municipais.

> Lei 50/2006: https://dre.pt/dre/detalhe/lei/50-2006-540820

> DL 102-D/2020: https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

>> Regressar à página de Enquadramento (B1).

B3. RCD produzidos por particulares

Os RCD com origem em pequenas reparações e obras de bricolage em habitações são, de forma geral, executadas por particulares (proprietário ou arrendatário) e, pelas suas características, produzem pequenas quantidades de resíduos. Apenas para estes casos, os sistemas municipais têm a obrigação de recolher estes RCD seletivamente, a partir de 2025, fazendo refletir no produtor a respetiva tarifa.

Porém, importa que qualquer particular que execute estas obras esteja consciente de algumas boas práticas e obrigações legais para os procedimentos que tem de implementar, de preferência com a seguinte ordem de preocupações:

- Informar-se previamente acerca dos destinos finais autorizados para receberem os RCD, nas imediações da obra em questão;
- Informar-se previamente sobre eventuais soluções de acondicionamento disponibilizadas para os RCD, na área de intervenção, e da respetiva tarifa aplicável;
- Planear um espaço na obra para armazenar os RCD não perigosos, em zona distinta dos materiais de construção, se possível separando-os nos seus diferentes tipos;
- Estar consciente de que uma boa separação dos RCD não perigosos pode ter influência nas condições da sua receção ou significar uma redução importante na tarifa, quando aplicável;
- Acondicionar os RCD perigosos, ou embalagens com pictograma de perigosidade, quando existentes, em local distinto, em recipientes fechados, sobre piso impermeabilizado, em bacias de retenção, protegidos da chuva e do sol, e em local devidamente arejado;
- Saber que para transportar os RCD é obrigatório por lei, e sem exceção, estar na posse, durante o movimento, de uma guia eletrónica de acompanhamento de resíduos (e-GAR), sendo que a sua inexistência constitui uma contraordenação grave, com coima associada de valor elevado;

- Estar consciente que o abandono de RCD constitui uma contraordenação muito grave, com coima associada também de valor bastante elevado;
- Colaborar com as entidades competentes (município, GNR/SePNA, PSP, entre outros), denunciado infratores e situações irregulares, designadamente o abandono de RCD.

>> Regressar à página de enquadramento (B1).

B4. RCD produzidos por empresas de construção

Os RCD produzidos por empresas de construção, no contexto da sua atividade profissional, são variáveis em termos de quantidade e tipologia, atendendo às características das intervenções em causa. Por ser a atividade profissional destas entidades, mas também pela diversidade que importa acautelar, é importante que estejam conscientes das obrigações legais a que estão sujeitas e que foram sendo adaptadas, em alguns casos, ao longo do tempo.

Estas obrigações estão relacionadas com questões referentes à fase de projeto, com a intervenção propriamente dita, assim como com a salvaguarda de questões de controlo procedimental, por exemplo para efeitos de fiscalização ou da instrução de processos.

B4.1. Planeamento da logística e dos custos

Antes da intervenção propriamente dita, e independentemente das suas características (construção nova, reabilitação ou demolição), importa acautelar o seguinte:

- Planear um espaço em obra para a triagem e acondicionamento dos RCD (perigosos e não perigosos);
- Equacionar os meios de acondicionamento adequados para os RCD não perigosos e para os RCD perigosos, precavendo a necessidade de alugar estes equipamentos;
- Acautelar que todos os RCD serão transportados para operadores de gestão licenciados para o efeito, consoante os casos (transporte e/ou tratamento);

- Considerar que há um custo associado ao transporte de resíduos para destino final autorizado, que está diretamente relacionado com as distâncias em causa e com o número de movimentos que serão realizados, assim como com o custo do combustível;
- Estar informado sobre a atualização dos custos de mercado, tendo em conta que o tratamento dos RCD separados é, por norma, mais barato do que o tratamento dos RCD misturados.

B4.2. Execução da obra

Durante a execução da obra importa acautelar um conjunto de obrigações e procedimentos, ao nível da organização do estaleiro, da separação dos RCD não perigosos, da gestão dos RCD perigosos, do transporte e do destino final, descritos de seguida.

- *Organização do estaleiro*
    - Existirem espaços com características adequadas para o acondicionamento dos RCD não perigosos e para os RCD perigosos (quando existentes), que devem estar em zonas distintas;
    - Não haver mistura de RCD com materiais de construção.
- *Separação dos RCD não perigosos*
    - Existirem meios de acondicionamento apropriados para os vários tipos de RCD e atendendo às suas características (big-bag, contentor metálico, ou outro);
    - Fazer a triagem dos RCD não perigosos, em obra, da seguinte forma (**nRGGR**, artigo 51º): fração mineral (betão, tijolos, ladrilhos, telhas, materiais cerâmicos e pedra), metal, vidro, plástico e gesso;

        > nRGGR (Anexo I do DL 102-D/2020): https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

    - Na impossibilidade de acautelar o exposto no ponto anterior, deve assegurar-se o envio das misturas de RCD não perigosos para operador de tratamento de resíduos licenciado para proceder à sua triagem e tratamento;

- Os RCD (perigosos e não perigosos) devem estar devidamente identificados com a respetiva designação e com o código de 6 dígitos da **LER**;

  > LER: https://eur-lex.europa.eu/legal-content/PT/TXT/PDF/?uri=CELEX:32014D0955&from=PT

- *Gestão dos RCD perigosos*
  - Devem estar acondicionados em local distinto dos RCD não perigosos;
  - Devem estar acondicionados em recipientes fechados, sobre piso impermeabilizado, com bacia de retenção com capacidade apropriada, em local arejado e, quando necessário, protegidos de agentes externos (sol, chuva, vento);
  - Devem ficar armazenados em obra pelo mínimo de tempo possível.
- *Transporte*
  - Todos os movimentos de RCD, sem exceção (incluindo movimentos para estaleiro central) são acompanhados de uma **guia eletrónica de acompanhamento de resíduos (e-GAR)**;

    > e-GAR (Portaria 145/2017): https://dre.pt/dre/detalhe/portaria/145-2017-106926975

  - Para emitir uma e-GAR, o produtor dos RCD deve estar registado no Sistema Integrado de Registo Eletrónico de Resíduos (SIRER), integrado no **Sistema Integrado de Licenciamento do Ambiente (Siliamb)**, disponível na plataforma eletrónica da Agência Portuguesa do Ambiente.

    > Siliamb: https://siliamb.apambiente.pt/pages/public/login.xhtml

- *Destino final*
  - Os destinos finais autorizados para os RCD devem estar planeados e ser do conhecimento dos principais intervenientes nas intervenções;
  - Como apoio ao planeamento e validação dos destinos finais, pode ser utilizada a plataforma do **Sistema de Informação do Licenciamento de Operações de Gestão de Resíduos (SILOGR).**

    > SILOGR: https://silogr.apambiente.pt/pages/publico/index.php

B4.3. Controlo procedimental

O controlo procedimental é distinto consoante se trata de uma obra particular sujeita a controlo prévio, em articulação com o Regime Jurídico da Urbanização e Edificação (RJUE), ou uma obra pública, em articulação com o Código dos Contratos Públicos (CCP):

- Nas **obras particulares, sujeitas a controlo prévio**, é obrigatório efetuar e manter com o livro de obra, o **registo de dados de RCD** (nRGGR, artigo 54º);

  > nRGGR (DL 102-D/2020): https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

  - A Agência Portuguesa do Ambiente disponibiliza um **modelo de registo de dados de RCD para obras particulares sujeitas a controlo prévio**;

    > Modelo de registo de dados (APA): https://apambiente.pt/residuos/minutas-de-documentos

  - Complementarmente, o RJUE dispõe sobre gestão de RCD: artigo 7º (pontos 6 e 9), artigo 53º (ponto 1, alínea a), artigo 57º (ponto 1), e artigo 86º.

- Nas **empreitadas e concessões de obras públicas**, é obrigatório existir, em fase de projeto, um **Plano de Prevenção e Gestão (PPG) de RCD** (nRGGR, artigo 55º; e CCP artigo 43º, ponto 5, alínea f);

  > nRGGR (DL 102-D/2020): https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

  - A Agência Portuguesa do Ambiente disponibiliza um **modelo de PPG- RCD para obras públicas**;

    > Modelo de PPG-RCD (APA): https://apambiente.pt/residuos/minutas-de-documentos

  - De acordo com o CCP (artigo 394º, ponto 2, alínea b; artigo 395º, ponto 2, alínea b; e artigo 395º, ponto 4), é obrigatório, na fase de receção provisória, atestar o cumprimento do PPG-RCD;

- Em todos os casos mencionados, deve existir informação em obra que comprove o encaminhamento dos RCD para destinos autorizados para os receberem (e-GAR).

B4.4. Procedimentos específicos

Nesta seção apresenta-se informação sobre a isenção de licenciamento para operações de gestão de RCD, utilização de RCD em obra e gestão de solos e rochas.

Isenção de licenciamento para operações de gestão de RCD

- De acordo com o **Decreto-Lei n.º 102-D/2020, de 10 de dezembro** (nRGGR, artigo 66º), podem ser isentas de licenciamento determinadas operações, desde que previstas por **Regras Gerais**. Estas regras foram aprovadas pela Agência Portuguesa do Ambiente, e publicadas no seu sítio da Internet, a saber:

  > nRGGR (Anexo I do DL 102-D/2020): https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

  > Regras Gerais (APA): https://apambiente.pt/residuos/regras-gerais

  - Triagem mecânica e fragmentação em obra ou em local afeto à mesma pertencente ao produtor do resíduo;
  - Fresagem e britagem de RCD;
  - Resíduo de balastro da via-férrea;
  - Incorporação de resíduos de betão;
  - RCD mistos.

Utilização de RCD em obra

- De acordo com o **Decreto-Lei n.º 102-D/2020, de 10 de dezembro** (nRGGR, artigo 52º), os RCD utilizados em obra têm de cumprir os seguintes requisitos:

  > nRGGR (Anexo I do DL 102-D/2020): https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012

  - Ser provenientes da própria obra, de outra obra do mesmo produtor, ou de um operador de tratamento de resíduos;
  - Cumprir o princípio da proteção da saúde humana e do ambiente e satisfazer as exigências técnicas para as aplicações a que se destinam, sendo estes procedimentos atestados pelo **diretor de obra ou, em alternativa, pelo responsável pela obra**;

- A Autoridade Nacional de Resíduos definiu **Especificações Técnicas** para a valorização de RCD consoante o fim a que se destinam, publicando-as no seu sítio da Internet:

  > Especificações técnicas: https://apambiente.pt/residuos/especificacoes-tecnicas

  - Especificação LNEC E485 – 2016: Guia para a utilização de materiais provenientes de resíduos de construção e demolição em preenchimento de valas;
  - Especificação LNEC E484 – 2016: Guia para a utilização de materiais provenientes de resíduos de construção e demolição em caminhos rurais e florestais;
  - Especificação LNEC E483 – 2016: Guia para a utilização de agregados reciclados provenientes de misturas betuminosas recuperadas para camadas não ligadas de pavimentos rodoviários;
  - Especificação LNEC E474 – 2009: Guia para a utilização de materiais reciclados provenientes de resíduos de construção e demolição em aterro e camada de leito de infraestruturas de transporte;
  - Especificação LNEC E473 – 2009: Guia para a utilização de agregados reciclados em camadas não ligadas de pavimentos;
  - Especificação LNEC E472 – 2009: Guia para a reciclagem de misturas betuminosas a quente em central;
  - Especificação LNEC E471 – 2009: Guia para a utilização de agregados reciclados grossos em betões de ligantes hidráulicos.

- Os RCD valorizados de acordo com as Especificações Técnicas mencionados anteriormente deixam de ser considerados resíduos.

Gestão de solos e rochas

- A gestão de solos e rochas deve acautelar o cumprimento de requisitos específicos, designadamente no que se refere à classificação como resíduo ou subproduto, tendo a Agência Portuguesa do Ambiente publicado **documentos de apoio**:
  - **Nota técnica: classificação de solos e rochas como subproduto**;

    > Nota técnica: https://apambiente.pt/sites/default/files/_Residuos/Producao_Gest%C3%A3o_Residuos/Nota%20t%C3%A9cnica_solos%20e%20rochas_v3_site.pdf
  - **Perguntas Frequentes sobre a classificação dos solos e rochas como subproduto**.

    > FAQ solos e rochas: https://apambiente.pt/sites/default/files/_Residuos/Producao_Gest%C3%A3o_Residuos/FAQ%20Solos%20e%20Rochas%2010012021.pdf

B4.5. Metas

- Relativamente a metas para a gestão dos RCD, com implicação para os donos de obra e produtores de RCD, o **Decreto-Lei n.º 102-D/2020, de 10 de dezembro** (nRGGR), define as seguintes:

  > nRGGR (Anexo I do DL 102-D/2020): https://dre.pt/dre/detalhe/decreto-lei/102-d-2020-150908012
  - Meta de **70%, em peso, relativamente à preparação para a reutilização, à reciclagem e outras formas de valorização material, incluindo operações de enchimento** que utilizem resíduos como substituto de outros materiais, de RCD não perigosos, com exclusão dos materiais naturais definidos na categoria 17 05 04 da LER (solos e rochas não contendo substâncias perigosas) (nRGGR, artigo 27º, ponto 1, alínea b);
  - É obrigatória a utilização de pelo menos **10% de materiais reciclados ou que incorporem materiais reciclados** relativamente à quantidade total de matérias-primas usadas em obra, no âmbito da contratação de empreitadas de construção e de manutenção de infraestruturas ao abrigo do CCP (nRGGR, artigo 28º, ponto 5).

Com implicação para os sistemas municipais, foi definida a seguinte meta:

- **Até 1 de janeiro de 2025**, as entidades responsáveis pelo sistema municipal de gestão de resíduos urbanos disponibilizam uma rede de recolha seletiva para os seguintes resíduos: a) resíduos têxteis; b) resíduos volumosos, incluindo colchões e mobiliário; c) resíduos perigosos; d) óleos alimentares usados; e) **RCD resultantes de pequenas reparações e obras de bricolage em habitações** (nRGGR, artigo 31º, ponto 1)

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2023

MÁRIO ANTÓNIO PACHECO RAMOS

DETERMINING FACTORS AND STRATEGIES TO PROMOTE
CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT ON A LOCAL SCALE