Waste Management 136 (2021) 295–302

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

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

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ARTICLE INFO

Keywords:
Construction sector
Construction companies
Construction and demolition waste (CDW)
Waste management
Behavior

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 regarding waste. Previous researchers have assessed construction company attitudes and behaviors 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 on 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 reevaluate the strategies for CDW management and adapt the strategies to the specific conditions of the construction sector, including the size of construction companies.

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 (European Commission, 2011; Huang et al., 2018); 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 (European Commission, 2016; Eurostat, 2018). To reduce environmental impacts, specifically about waste, it is important to analyze the determining factors influencing CDW management. In general, construction companies have a major role concerning their attitudes and behaviors (Teo & Loosemore; 2001; Li et al., 2015; Li et al.; 2018), and in more specific terms, their technical knowledge (Bakshan et al., 2017; Li et al.; 2018), their individual or collaborative approaches with other stakeholders and authorities (Ajayi et al.; 2016; Chen, Hua, & Liu, 2019; Mak et al., 2019), and their onsite construction practices (Begum et al., 2006; Begum et al.; 2009; Ramos et al., 2014; Ding et al., 2016; Tam et al.; 2018).

Although CDW management practices and the results achieved diverge across the European Member States (Gálvez-Martos et al., 2018; Zhang et al., 2021), the construction sector has been considered as a main driver in the European Circular Economy Action Plan (European Commission, 2015; European Comission, 2020). 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

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https://doi.org/10.1016/j.wasman.2021.10.032
Received 23 July 2021; Received in revised form 14 October 2021; Accepted 24 October 2021
Available online 1 November 2021

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.

2. A brief review of construction and demolition waste management by construction companies

2.1. Attitudes and behavior determinants for better construction and demolition waste management

In terms of behavioral evaluation, construction company attitudes differ between organizations (Teo & Loosemore, 2001; Ding et al., 2016) 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 behavior; 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 behavior (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 behavior related to CDW management, compared to subjective norms, attitudes, personal norms and perceived behavioral control. In turn, Waziri, Yusof, & Osmadi (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. Wu, Yu, & Shen (2017) have already stated that this behavior 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.*, Wang et al., 2014; Udawatta et al., 2015; Tam et al., 2018; Ding et al., 2018) 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.

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 behavior.

Begum et al. (2009) concluded that construction contractor attitudes and behaviors 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 behavior (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, Joseph & Tawie (2016), who also added the purchase of material that does not meet defined technical specifications or appropriate storage conditions.

2.3. Knowledge gap identification

Within the analyzed 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 analyzed 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 of Lisbon. In specific, performed research addresses the Portuguese framework of CDW management, within a European characterization (European Commission, 2017); the study of regional strategies or demonstration projects for CDW management (Martinho et al., 2013; Ramos et al., 2014; Ramos at al., 2020); the analysis of Portuguese CDW official data analyzing 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. Method

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 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 waste monitoring guides printed on paper; iii) commitment to meeting the goal of incorporating at least 5% recycled materials in public construction works, as determined by the Portuguese Law on Waste in force; 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, and the answers were statistically treated using IBM SPSS Statistics software.

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 M€); small company (fewer than 50 workers and equal to or less than 10 M€); medium company (fewer than 250 workers and equal to or less than 50 M€); and large company (equal to or more than 250 workers and more than 50 M€).

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 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).

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 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 2. For a 95% confidence interval, the margin of error was 4% for group A, 8% for group B, and 14% for group C.

Table 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					Group definition criteria, considering [A] and [B]
					Representativeness of the construction permit titles attributed (by predominant construction titles, %) [B]					
		N.°	%	N.°	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	Greater than 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).

Table 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.°	%, in relation to the existing construction companies (online database)	N.°	%, in relation to construction companies contacted	N.°		%, in relation to valid contacts		The margin of error for 95% confidence interval level (%)
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		

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).

3.4. 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 3.1. 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.

4. Results and discussion

4.1. Construction sector characteristics about environmental knowledge

To evaluate if environmental knowledge can somehow play a role in worker behavior 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 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 ($F(2, 609) = 128.682$; $\rho \leq 0.000$).

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 behavior of CDW management by construction companies (Ajayi et al., 2016; Bakshan et al.; 2017; Li et al.; 2018), and these results for Portuguese construction companies complement the existing data.

Table 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	$F(2, 609) = 100.548$; $\rho \leq 0.000$

4.2. Registration of the quantity of CDW 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 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 analyze 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 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).

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

Table 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	

versus waste management operators). This is important, for instance, when analyzing the reality in Portugal that substantial amounts of illegally dumped CDW (Martinho et al., 2013; Ramos et al., 2020) do not appear in the official data unless reported as cleaning actions executed by municipalities or contracted waste management operators. This context of CDW illegal dumping, although referred few times, is becoming a relevant concern for other studies (Chen et al., 2019; Islam et al., 2019; Liu et al., 2021).

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 (six months) trial period 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 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 4.0% 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 section (subchapter 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 they 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.

4.3. Legal framework compliance

For effective CDW management practices 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% of recycled materials or materials incorporating recycled components in relation to the total materials used in the respective construction work (this target increased to 10% in 2021). 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; $\rho \leq 0.000$). The results 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 of them (42.7%) answered that they do perform it.

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 materials. 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 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 5
Incorporation of recycled materials in public construction works by Portuguese construction companies.

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.

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.

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 6).

Table 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 construction companies 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 behaviors, 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 behavior; 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.

5. Conclusions

Since other previous studies were dedicated mainly to construction company attitudes and behavior, 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 behavioral 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 reevaluating 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 address 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. As a fact, the results of this research reveal that the absence of external oversight actions 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. This reality was more relevant in the case of micro construction companies, compared to medium/large ones, in that the latter 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. This reality can distort the statistical data, namely through illegally dumped CDW not being recorded. This justifies 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 comprehend what type of knowledge is necessary to transmit to construction companies, especially to micro and small companies, and to realize how to communicate with them more effectively. Moreover, it is necessary to understand the behavior regarding the often-identified CDW illegal dumping reality in Portugal, because it influences the statistics but, above all, it limits the high potential for CDW recovery. Finally, it is necessary to modify strategies for CDW management at local scales, namely for municipalities and small construction companies.

Declaration of Competing Interest

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

Acknowledgments

This study was supported by the Marine and Environmental Sciences Centre – MARE, which is financed by Portuguese national funds from FCT/MCTES (UIDB/04292/2020).

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