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Understanding the perceptions of stakeholders on selective demolition

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ABSTRACT

Selective demolition (or deconstruction) is important for achieving efficient circular principles in the construction sector, involving various stakeholders in the whole life cycle of buildings. Several studies have been conducted in recent years about it, but an assessment concerning the stakeholders involved was never undertaken to explore the criteria chosen here. This study aims to explore the practices of companies, but also the perception of individuals regarding this theme. A Portuguese case study was chosen, submitting an online structured questionnaire. As a result, 79 responses were received and an independent variable concerning profession was selected to divide the sample into three groups (architects, engineers, and other staff), to explore whether statistical differences between groups exist. Regarding the activity of companies, 22.8% have never conducted a selective demolition process, and the remaining respondents predominantly do so due to contract specifications. Also, 37.7% of respondents confirmed a need to subcontract, demonstrating dependence on cooperation. Assessing individual perceptions, architects have a more accurate understanding of the concept of selective demolition in the life cycle of buildings, and yet clearly state a greater need for information and awareness regarding the process than engineers and other staff. Architects also identified, most firmly, the need to promote the design of construction materials that better facilitate reuse and recycling. These results are relevant to decision making processes and for effective policy design, to form strategies that boost selective demolition, using a behavioural change approach, identifying a need to reinforce education and awareness, for instance about pre-demolition audits.

1. Introduction

The construction sector is an important vector for achieving the principles of the circular economy [1,2] and the waste hierarchy [3,4]. For this, it is essential to invest in processes that prevent the generation of construction and demolition waste (CDW), reusing as many materials as possible [5], and optimising the recovery of waste that cannot be avoided [6]. In this sense, selective demolition (or deconstruction) of buildings, is an essential method for the construction sector to adopt [7–9] because, as an inverse to the process of construction [10], it will mean that the principles of a more circular construction sector could be achieved in an easier and more efficient way.

The European Union has outlined its vision of achieving a circular economy within the construction sector, and the built environment, creating the legal requirements for its implementation [11,12]. However, the performance of the Member States has not been as expected regarding, for instance, the implementation of the principles, the management of CDW [13,14], and also the effective

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application of tools such as pre-demolition audits [15,16]. Moreover, the digitisation systems and tools, although consensual for their utility, have also shown restrictions [17–19].

Many of these limitations concerning circularity in the life cycle of buildings may relate to the link between research and the subsequent awareness acceptance and operational application of it [20,21]. So, it is important to involve stakeholders [22–24] and educate them about the economic, social, and environmental advantages of the adopted strategies [23]. Thus, the main objective of this research project is to explore the perceptions and contributions of stakeholders involved in the life cycle of buildings, especially those whom, as Volk et al. [25] demonstrated, work with them most frequently, namely architects and engineers, exploring their perspectives on the barriers and challenges that arise in the pursuit of a circular economy in relation to deconstruction, specifically to consolidate their contribution to design, the reuse of materials and proper waste recovery.

This evaluation considered, through a case study in Portugal, the feedback on the experience of the companies where these technicians work, but also their individual perceptions as professionals in this area. Ultimately, the context described relates to the legal framework and practices adopted in the countries of the European Union. Also, it attempts to understand whether there are differences between the perceptions of the actors, which could inform and orientate future initiatives and policies, from the perspective of behavioural change [26,27].

2. Selective demolition as a driver for circularity in the construction sector

2.1. The concept of selective demolition

A demolition process can be classified as conventional, partially selective, or fully selective [10]. Essentially, the main difference between conventional and selective demolition, also known as deconstruction, is that the latter reverses the traditional construction process, involving a dismantling phase [8], and is intended to recover as much material as possible [14,28], avoiding its contamination with hazardous substances [10], recovering the materials for reuse, but also waste for recycling, in this way achieving the principles of circularity for buildings [5,28].

This is especially important with the CDW mineral fraction, the predominant material in many cases [29,30], and with mixtures of waste, as contamination makes the treatment process more expensive [31,32]. Cost is also particularly relevant if the waste must be transported over significant distances to reach treatment facilities [31,33]. In selective demolition, specialised workers are required, often from local regions [34], as well as specific equipment to perform more detailed work, which almost always leads to a more expensive and time consuming execution process, with higher energy consumption [10], which has negative environmental effects.

A literature review oriented towards the transition to deconstruction processes, conducted in 2023 by Allam and Nik-Bakht [7], concluded that 80% of the studies consulted have focused on topics such as the circular economy, CDW management, or the implementation of demolition, and only 20% of them were dedicated specifically to selective demolition processes and oriented towards the study of design for deconstruction, application of technology in end of life, and deconstruction planning.

2.2. The legal framework at the European level and in Portugal

In the European Union, the Waste Framework Directive (Directive 2008/98/EC, of November 19th; [12]) legislated that 70%, in weight, of non-hazardous CDW (excluding soil and stones without hazardous substances), must be prepared for reuse, recycling, and other material recovery, including backfilling operations, requiring compliance by 2020. This has relevance to this research project due to the anticipated circularity achievements it demands. Subsequently, this Directive was amended by Directive (EU) 851/2018, of May 30th [11], establishing that "Member States shall take measures to promote selective demolition to enable removal and safe handling of hazardous substances and facilitate reuse and high-quality recycling by selective removal of materials, and to ensure the establishment of sorting systems for CDW at least for wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastic and plaster."

In Portugal, Decree-Law 102-D/2020, of December 10th [35], transposing the latter Directive, outlined that the planning of projects and the intervention phase should favour the adoption of practices that favour construction methods that facilitate selective demolition, oriented towards the application of the principles of prevention and reduction and the hierarchy of waste, and design for deconstruction, to recover and allow the reuse and recycling of the maximum amount of materials. In addition, it stated that the mechanisms for controlling the completion of construction works, and the selective demolition plan for works subject to prior control, must be provided for in municipal urbanisation and building regulations (in this case, only applicable at the municipal level, for private works).

Regarding execution, the current outcomes in the European Member States are not in compliance with what was planned, especially regarding waste treatment and the development of markets for secondary materials [13]. But this reality reflects the global trends, for example in China there is a large focus on construction, but cleaner production of CDW has not yet been implemented due to legal and economic barriers, as noted by Ghisellini et al. [36]. Overall, this is largely because the construction sector is traditionalist [13], resistant to innovation, and implementation of these changes requires technical knowledge to be up to date [23], which, so far, has failed to happen in many cases [37].

2.3. From planning to intervention

From a planning point of view, stakeholder awareness and regulation should be strengthened, to make CDW management more effective during the construction phase [4,20]. But selective demolition entails an important objective for building circularity, related to reuse, as stated by Mhatre et al. [5]. In this sense, van den Berg et al. [38] demonstrate that the intention to recover an element for reuse depends on who intervenes in the construction phase, even if the building was designed to be deconstructed, considering, in

general, three factors: locating the element to be reused, identifying routines to disassemble the element, and controlling the element until it is attributed a new use. In this context, ecodesign is important [28], but also information about the existing materials in buildings. The use of materials passports is an essential tool to encourage this [39,40]. In addition, the use of prefabricated elements for buildings should be assessed [23,41,42], as they have been shown to facilitate effective deconstruction processes.

Furthermore, the results by Christensen et al. [43] demonstrate the need for local markets for materials to be reused (further endorsed, in general, by Ramos et al. [37]). Furthermore, Anastasiades et al. [44] state that there is no legal framework for the reuse of components, which makes the whole process more difficult. The planning phase of buildings should also focus on the use of buildings after their first life cycle ends, envisioning new uses for it or the reuse of resulting materials [45].

In general, during the intervention phase, recycling can bring environmental benefits, while the disposal of waste in landfills leads to environmental costs [31,32,46,47]. It is also important to consider the recycling of different waste streams, but with emphasis on metals, due to the associated energy and cost savings [48,49]. Some specific materials, such as non-recoverable mixed plastics and gypsum-based building materials must be considered [50], since these are more challenging to be absorbed by markets. Moreover, for the effectiveness of selective demolition, processing facilities ought to be situated within distances of up to 30 km from the intervention sites [51].

Lu et al. [52] add that even green building rating systems, concerning waste, do not perform better than buildings without certification in all cases, which may relate to the design of the rating systems, but also to the lack of incentives. Furthermore, Di Maria et al. [14] point out that, regarding the management of CDW, the goals in the European Union have been achieved based on downcycling practices, so the paradigm will have to change to achieve better circularity.

2.4. Barriers to selective demolition

Rameezdeen et al. [53] categorised the barriers to the implementation of selective demolition, many of them being supported by other authors, namely: high costs, the design of existing buildings and their long lifespan, the use of hazardous substances [10], the diversity of materials and components and complex supply chains [43], the lack of market conditions and insufficient characteristics of existing infrastructures [54], a lack of knowledge and awareness [4], a lack of regulatory framework [55], and costs related to the treatment of CDW [31,32,47]. Additionally, Akhimien et al. [20] outline multiple barriers to achieving a holistic approach to circularity in buildings, including the immaturity of the market and the absence of standardisation for the reuse of construction materials, as well as for the recycling of CDW.

Not all studies reveal advantages for selective demolition over conventional processes [56]. For instance, Machado et al. [57] indicate that it should be selected as a method whenever acceptable conditions exist, which include economic and environmental criteria, considering the feasibility of the reuse of the materials. Overall, the environmental impacts of selective demolition are lower than conventional processes but, in some instances, they may be higher due to the longer period of use of suitable machinery for disassembly and the deconstruction process itself [58]. Also, economic data reveals that selective demolition can be negatively affected by local factors, since these greatly influence labour and equipment costs [59], but also the market prices for recycled materials, in addition to transport costs [34], all of which may not be offset by simply replacing the extraction of virgin materials [51].

To resolve the constraints identified for selective demolition, it is essential to establish metrics that stakeholders can use, to have a more solid basis for decision-making processes [19,60]. Additionally, Zhang et al. [3] state that financial incentives must be considered to strengthen prevention, reuse, and recycling, such as the reduction of fees, or grants for research and the development of innovation in the market.

2.5. The contribution of digitisation

The reinforcement of digitisation in the construction sector is fundamental, allowing the use of large amounts of data to plan and control the processes of selective demolition [23]. The use of the Building Information Modeling (BIM) tool is consensual, in which architects, engineers, and other staff have played an essential role in its implementation and development [25]. The body of research on BIM has been increasing since 2017 [61], in which China appears as the country with the widest dissemination in scientific terms, Germany with the highest number of citations, and England as the largest network of co-citations [62]. It is also a tool that can serve to support decision-making for policymakers and designers [63] , although Norouzi et al. [61] recommend a wider availability of training opportunities to improve its effectiveness.

A problem with BIM models is that they cannot overcome existing data gaps about buildings, so to address this limitation, complementary technology has been developed, namely through the creation of 3D models obtained by sensors [64], or laser scanning technology, in this case increasing the potential for the reuse of materials by about 5% [17].

2.6. The role of stakeholders

The vision of all stakeholders has to be included, because often those who manage the processes and the creation of new tools are not aware of the daily routines of those who create novel, useful solutions through reflective learning [21]. This is an example of the importance of the stakeholder participation in the promotion of the green building industry, where their motivation is a key determining factor [22]. Moreover, Hegzi and Abdel-Fatah [65] observed that, in terms of planning, junior technicians have a more comprehensive perception of deconstruction than senior technicians, which should be considered from the perspective of changes in education.

Li et al. [26], investigating according to behavioural theories, demonstrated that the attitudes of those who plan has an important effect on the change in their behaviour regarding the creation of solutions for waste minimisation at the intervention phase, so awareness must be reinforced. Bakshan et al. [66] add, for construction workers, that experience gained, as well as social pressure, are

decisive determinants for behavioural change. And Li et al. [55] demonstrate that a reduction in CDW generation is related to knowledge acquired.

Overall, visual demonstration, education, information and awareness, and legal framework are tools that Li et al. [26] consider essential for reshaping the behaviour of stakeholders. Also, better results can be obtained through collaborative processes between different actors and different specialities [28,67].

3. Methods

3.1. Research design

This research project was designed to achieve a more comprehensive understanding of the perceptions and contributions of the stakeholders most directly involved in the planning and execution of the selective demolition of buildings, namely architects and engineers, but also considering a third group, which includes other technicians involved, to promote an improvement of its effectiveness.

The contributions were studied on a corporate level, identifying characteristics intrinsic to them, but also individually, focusing on the perceptions of the technicians working in these companies. To accomplish this, a behavioural approach was considered, based on trying to understand how these contributions can intervene in a relevant way in the sphere of the interventions and policies to be implemented (Fig. 1), considering the Behavioural Change Wheel developed by Michie et al. [27].

The Behavioural Change Wheel is an integrated and widely applicable tool which is useful for understanding and encouraging behavioural change, identifying the barriers and determinants of action, considering the Capability, Motivation, and Opportunity components of Behaviour ("model COM-B"). This baseline information is essential to the design of effective interventions and policies when interacting with stakeholders and motivating cooperation between them. In the current research, it was instrumental in the study of stakeholders' perceptions of and contributions to the practice of selective demolition. To this end, and as a case study, a sample of stakeholders practising in Portugal was assessed through an online survey by questionnaire.

3.2. Questionnaire

A structured questionnaire was the chosen research method because it allows for comparisons between normalised data, to achieve descriptive or explanatory research data [68]. The questionnaire was developed and submitted online, to evaluate different dependent variables with relevance for the implementation of interventions and policies that can improve the processes of the selective demolition of buildings, contributing to circularity. This analysis was carried out considering three sets of questions, selected to present the relevant results for this research.

These questions included variables that seek to understand, on the one hand, the practices of companies, namely: the timeline to which they work (*e.g.,* project phase, construction phase), the frequency with which selective demolition projects or interventions are carried out, the reasons to be involved in selective demolition processes, the type of work in which these processes are applied (*i.e.,* public or private), and whether this practice requires the entity to subcontract other companies. On the other hand, the questions about the perceptions and contributions of individuals regarding selective demolition were considered: a self-assessment of their degree of knowledge about it, their perception of the phases involved in the process (*e.g.,* design phase, construction site preparation phase, construction phase), barriers for implementation, factors that can determine its effectiveness, and initiatives that can promote policies.

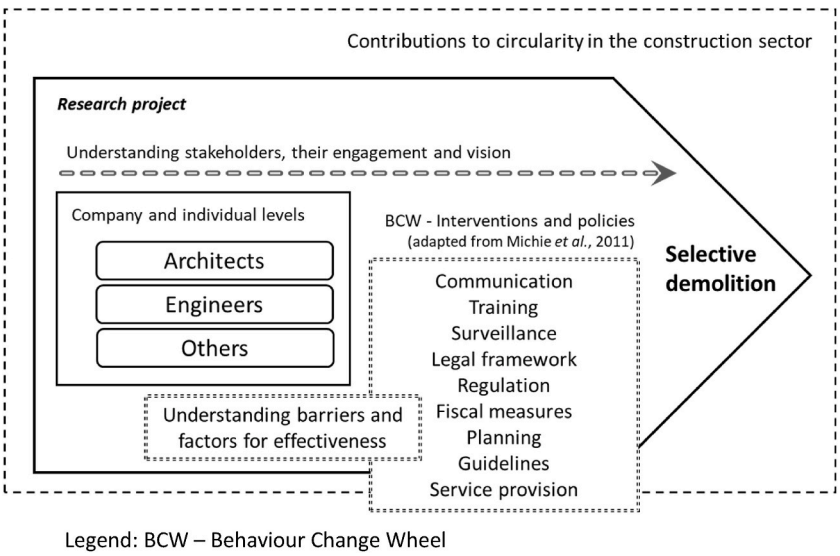

Fig. 1. The conceptual design of the research project.
Legend: BCW – Behaviour Change Wheel.

The last group of questions was related to the characterisation of respondents.

A 5-point Likert-type scale was used, ranging between "1" (not important), and "5" (very important), to evaluate the barriers, the factors that determine effectiveness, but also the initiatives that promote interventions and policies about selective demolition.

The hypotheses of the research project relate to the existence of statistically significant differences between the respondents according to their professional categories, considering the dependent variables mentioned above, alongside the criteria explained in subchapter 3.4.

3.3. Sample

The questionnaire was sent to 4,528 contacts. Firstly, the database from the website of the *Instituto dos Mercados Públicos, do Imobiliário e da Construção* (Portuguese Institute of Public Markets, Real Estate, and Construction) [69] was used, focusing on construction companies of classes 5 to 9, that is, construction companies of greater magnitude in terms of number of workers and turnover, those capable of planning and executing selective demolition works, totalling 1,100 contacts. In turn, 118 questionnaires were sent through the database of the *Associação Portuguesa de Projetistas e Consultores* (Portuguese Association of Engineering and Management Consultants) [70]. Finally, the *Portal da Construção Sustentável* (Portuguese Portal of Architecture and Sustainable Construction) [71] disseminated the questionnaire to its contacts, accounting for 3,400 valid submissions. In the latter case, although it is thought that the incidence was predominantly architectural offices or architects working individually, it certainly also included some construction companies. However, it is not possible to specify the number for each group within this total, or their characteristics.

Of the total contacts made, there were 30 refusals to respond, and 79 completed responses were received and validated. The response rate, calculated through the quotient between the number of questionnaires validated and the number of contacts made, was 1.8%. Considering the size of the population and the sample size, the margin of error is 10.9% for a confidence level of 95%, and 9.2% for a confidence level of 90%, In this case, the assurance that the questionnaire results are representative of the population under analysis is low. This limitation is mainly to do with the fact that, in Portugal, it is not possible to currently establish a methodology that can cover the professionals in question in a representative way, since many of them, especially in the field of architecture, work independently, without being registered in sector associations, and without their contact details being available in a systematic way. Due to the limitations described, which were not possible to overcome, this research should be considered as an exploratory study of the stakeholders involved in the processes of selective demolition. However, it presents data that is important for providing clues to inform decision making processes, for policy design, and for future research.

3.4. Data treatment and results presentation

The responses to the questionnaire were coded, and then imported to the IBM SPSS Statistics program for statistical treatment.

As one objective was to test whether there are statistically significant differences between the respondents, the question related to professional activity was selected as an independent variable, selecting three groups: architects (G1), engineers (G2), and others (G3). The latter group included various professionals such as technicians and administrative staff with professional activities related to the selective demolition process and, as such, they were able to respond informatively.

The statistical tests were used to assess whether the differences between groups, for each dependent variable, are statistically significant or not. Pearson's chi-square (χ^2) was applied for sample frequencies; in a complementary way, in samples where it was not possible to use the Chi-square, due to presenting counts below 5, corresponding to more than 20% of the total, the likelihood ratio (G^2) was employed. One-way ANOVA was used for sample means. For both tests, a value of $\rho \leq 0.05$ was considered as the minimum acceptable level of significance, corresponding to a confidence level of 95%.

The results are always presented in descending order of the total responses and separated by stakeholder group.

4. Results and discussion

4.1. Characterisation of respondents

The independent variable used to test the hypotheses of this research project was profession. In this case, and of the sample of 79 respondents, 31 (39.2%) belong to the group of architects (G1), 30 (38.0%) to the group of engineers (G2), and 18 (22.8%) to the group of others (G3), meaning, essentially, the groups G1 and G2 are similar in terms of the number of respondents.

As for gender, 47.0% are female and 53.0% male. The differences between the groups are statistically significant (χ^2 (2) = 13,343; $\rho \leq 0.001$). In the groups of architects (G1) and engineers (G2), the percentage of men is higher than for women, while the group of others (G3) is predominantly women. The average age of respondents is 42.1 years, with the difference between groups not being statistically significant ($\rho > 0.05$).

Regarding the nature of the professional activity of respondents, 81.0% are employed by others, while only 25.3% of respondents are self-employed. However, the groups differ in a statistically significant way: architects (G1) present most cases of working individually, with 48.4% (χ^2 (2) = 14,723; $\rho \leq 0.001$); engineers (G2) and others (G3) work mostly for others (96.7% and 94.4%, respectively; χ^2 (2) = 17.503; $\rho \leq 0.001$).

Regarding the participation of respondents in projects involving the selective demolition of buildings, 47.2% have already worked on them, 30.6% currently work on them, but 31.9% have never worked in projects involving deconstruction. Differences between the groups are not statistically significant in any of the cases ($\rho > 0.05$).

The responses regarding where the respondents undertake selective demolition projects or interventions cover the entire country of Portugal (considering its seven NUTS II regions), with several respondents working in various regions. However, the regions of the Lisbon Metropolitan Area, the North, and the Centre constitute the majority (40.5%, 35.4%, and 30.4%, respectively), representing, in

general, predominantly urban areas. The regions with less representativeness are the regions of the Algarve, the Alentejo, the Autonomous Region of the Azores, and the Autonomous Region of Madeira, representing, in total, 36.7%.

4.2. Practices of companies about selective demolition

Generally, the companies tend to carry out their activities in various phases of the life cycle of buildings, although architecture-oriented companies (G1) develop more of their interventions in the design phase (56.0%), and engineering companies (G2) develop most of their activity in the intervention phase (53.0%).

Regarding the frequency that selective demolition processes are carried out by the companies, the results are the following: 18 responses (22.8%) for "never", 26 responses (32.9%) for "a few times", 23 responses (29.1%) for "sometimes", and 12 responses (15.2%) for "often".

Respondents who stated that selective demolition processes are never implemented by the company in which they work were asked to identify the reason for this. For 10 respondents, the main reason is that it is not the usual practice of the company, so past practices are important in reinforcing behaviour, as stated by Ramos and Martinho [72], in reference to the incorporation of recycled aggregates in construction works. Other categories of response were selected by only 3 respondents: 2 of them stated that contract specifications do not obligate these procedures and there is a lack of technicians with professional skills in this area, illustrating an absence of awareness [23], and of cooperation between stakeholders [21], and that the execution of this practice hinders the competition in the market; the third respondent mentioned the absence of licensed destinations for CDW to be transported to, and that there are no competitive economic incentives. The remaining 5 respondents stated they do not know the reasons.

Respondents who affirmed that the company they work for performs selective demolition "a few times", "sometimes" or "often" (61 responses, corresponding to 77.2% of the total), were asked to indicate the reasons, the results of which are presented in Fig. 2. It was observed that, in general, the main reason indicated by the respondents is the contract specification (55.7%, in total), as also stated by Ramos and Martinho [72]. The least relevant reason is the certification requirements (11.5%, in total), in line with explanations presented by Lu et al. [52], regarding accreditation systems of buildings.

There are statistically significant differences in only two response categories, namely in the most selected one, corresponding to contract specification (χ^2 (2) = 16.777; p ≤ 0.001), but also the one related to cost-effectiveness (G^2 (2) = 6.952; $p \leq 0.031$). In the first case, it denotes the importance that these tools have regarding the implementation of good practices, even if they are direct translations of mandatory legal requirements (observed by Ramos and Martinho [72]). In the latter case, it was expected to be a topic identified most firmly by all respondents, in line with literature (for instance [33,37,59]). For both contract specification and cost-effectiveness, it is the group of engineers (G2) that most frequently selected these options, perhaps this is because these topics are more dependent on the intervention phase.

As for the type of work in which selective demolition processes are implemented (Fig. 3), they are carried out predominantly for private construction works (75.4%, in total), but also in public works (60.7%, in total). However, it is only in the case of public construction works that statistically significant differences between groups appear (χ^2 (2) = 9.051; $p \leq 0.011$), with a higher percentage of engineers (G2) selecting this option (83.3%) compared to the remaining groups (41.7% of architects and 53.8% of others; G1 and G3, respectively). This result might express the importance that public initiatives, even regulatory stipulations, have in leading behaviour change, in terms of accomplishing circular principles regarding buildings, as suggested by Munaro et al. [23], in this case with a greater impact on the group of engineers. So, to focus the attention of all stakeholders towards selective demolition, public policy must be reoriented and better integrated among all stakeholders participating (as corroborated by Kokkonen and Alin [21]).

Evaluating whether the processes of the selective demolition of buildings lead the companies to subcontract other services (Fig. 3),

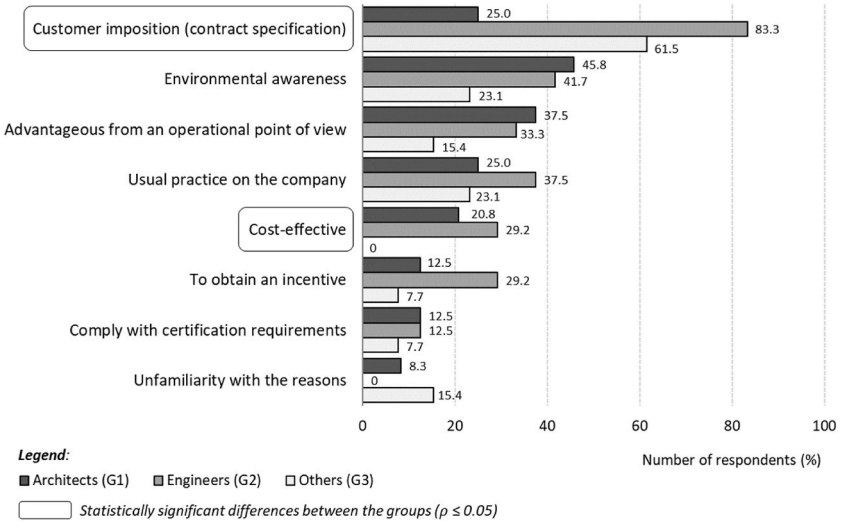

Fig. 2. The reasons that lead the companies to carry out selective demolition.

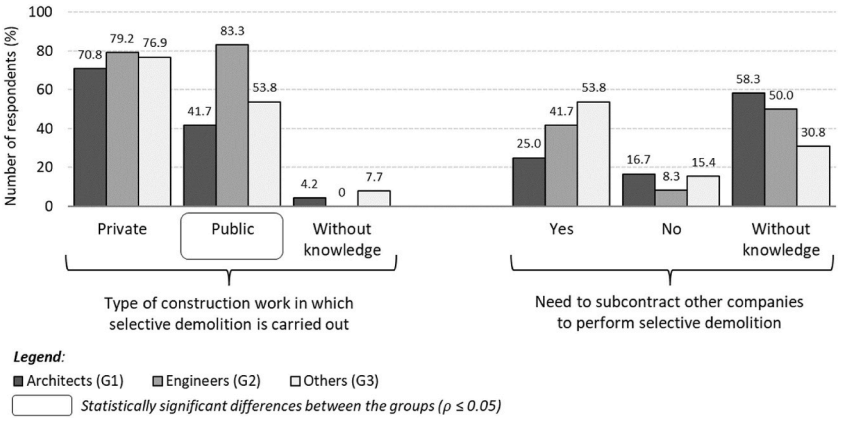

Fig. 3. The intrinsic characteristics to the execution of selective demolition.

37.7% of respondents, in total, stated that there is such a need. However, 13.1%, in total, indicated that it is not necessary, and 49.2%, in total, do not know if the entity requires this practice. These results do not reveal, however, statistically significant differences between groups ($\rho > 0.05$), but might demonstrate the need to have specific labour specialists for specific tasks, as a characteristic of the selective demolition process itself [10,34]. It may also express the need to be aware of the contract specifications established between companies, to safeguard responsibilities and, when possible, to allow for the transference of awareness, knowledge, and liability.

4.3. Perceptions of individuals about selective demolition

Regarding the self-evaluation of the degree of knowledge that respondents have about the concept of selective demolition, measured on a 5-point Likert-type scale, with the extremes between "1" (I do not know anything) and "5" (I know everything), it was verified that the general self-evaluation of respondents is moderate (average value of 3.25). However, the differences between groups are statistically significant ($F(2, 76) = 6.269$; $p \leq 0.003$), with the group of engineers (G2) achieving a higher average value (3.77) than architects (G1; 3.10), and with the group of other professionals (G3) registering the lowest result (2.67). This may be related to the fact that when selective demolition processes take place, they are more visible in the construction phase, although the planning of the process has to start beforehand.

Concerning knowledge about what the selective demolition process consists of (Fig. 4), in general, it was observed that most respondents (89.0%, in total) selected the most complete and correct option, covering of the life cycle of buildings in a selective demolition process, from the dismantling phase to the proper reuse of materials and proper recovery of CDW. However, the differences between groups are statistically significant ($G^2(6) = 13.840$; $p \leq 0.031$): the group G1 (architects) only selected the most accurate and complete option (100.0%), while amongst those in group G2 (engineers), all the options were selected by at least one respondent, although the majority (76.7%) selected the most complete description. The divergence in the responses provided by engineers may be somehow biased, for instance in terms of education (as demonstrated by Hegzi and Abdel-Fatah [65]), acquired habits, or frequent practices (corroborated by [72,31]).

The perception of respondents about which phases are involved in selective demolition was also evaluated. The respondents state that the design and intervention phases (77.8% and 76.4%, in total, respectively) are the most important for the selective demolition

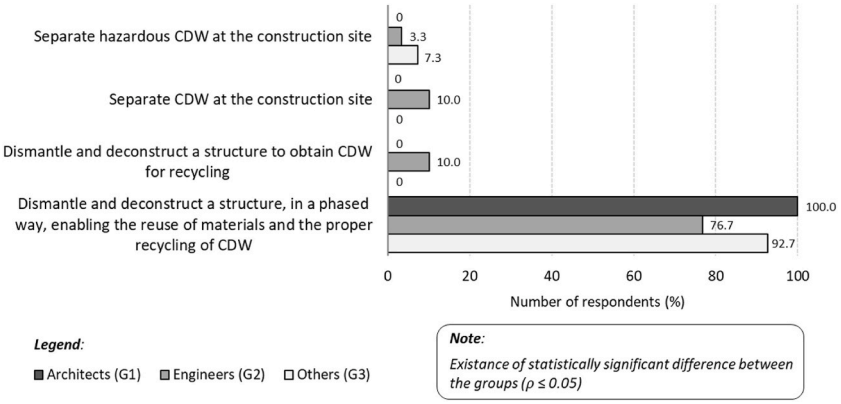

Fig. 4. The concept of selective demolition.

process, followed, in a less conclusive way, by the preparation of the construction site and the waste treatment component (65.3% and 58.3%, in total, correspondingly). Statistically, the differences between groups are not significant ($\rho > 0.05$). But it demonstrates, that some respondents hold an incomplete vision of the selective demolition process concerning the whole life cycle of buildings, which may be a result of the lack of knowledge observed by Esa et al. [4], the lack of motivation or participation referred to by Li et al. [22], or the absence of reflective learning identified by Kokkonen and Alin [21].

Regarding the perception of the barriers to implementing selective demolition (Fig. 5), measured on a 5-point Likert-type scale, between "1" (not important) and "5" (very important), it is observed that the absence of information and awareness is considered the most relevant topic for respondents (with an average value of 4.15, in total), and also the only one that presents statistically significant differences between groups ($F(2, 69) = 3.551; p \leq 0.034$). This result is corroborated by Akhimien et al. [20] and Esa et al. [4]. With this option, the group of engineers (G2) attributed less importance to the barrier than the architects (G1) and others (G3). The average values are high for all categories, but the lowest value relates to the probability of a more time-consuming intervention. Although the literature presents it as a main disadvantage of the process [10], the respondents surveyed in this research project seem not to value this constraint on the process as significantly. This may relate to specific experiences or even a lack of detailed knowledge regarding the process of selective demolition.

As for the degree of importance that the respondents attributed to the factors that could contribute to the efficient selective demolition of buildings (Fig. 6), also measured on a 5-point Likert-type scale, between "1" (not important) and "5" (very important), it was verified that there are no statistically significant differences in any category. The average values obtained are all positive and very similar in the three groups.

The two categories that respondents selected as most relevant are generically related to CDW management. This contradicts the previous findings regarding the respondents' perception of the concept of selective demolition, in which the options related to the CDW separation at the construction site were the least frequently selected. This discrepancy should be explored in more detail in future studies to better understand its causes.

According to the literature review, the categories involving the planning of selective demolition were expected to be selected as more relevant (stated, for instance, by [4,13,23]), as well as hiring technicians with specialised knowledge (denoted, for instance, by [10,34,61]). The category related to implementing pre-demolition audits was the least selected, which can be explained by the respondents lacking information on this subject (substantiated by [16,37]). This might relate to the fact that the concept was only implemented in the European legal framework in 2018, and more time is needed to achieve results. But it may also be necessary to boost the educational component, through a holistic approach, as stated by Akhimien et al. [20].

Respondents were also asked to rate the measures that can promote policies oriented to the selective demolition of buildings (Fig. 7), using a 5-point Likert-type scale, between "1" (not important) and "5" (very important). All potential measures to promote selective demolition were highly valued by respondents, with emphasis, however, on the category related to informing and raising

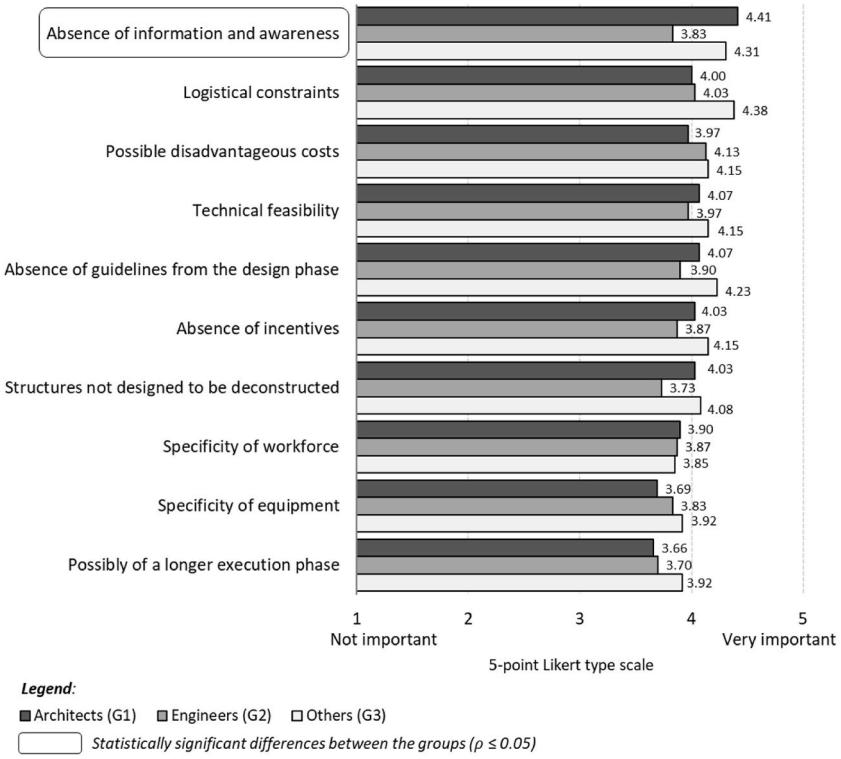

Fig. 5. The barriers to selective demolition.

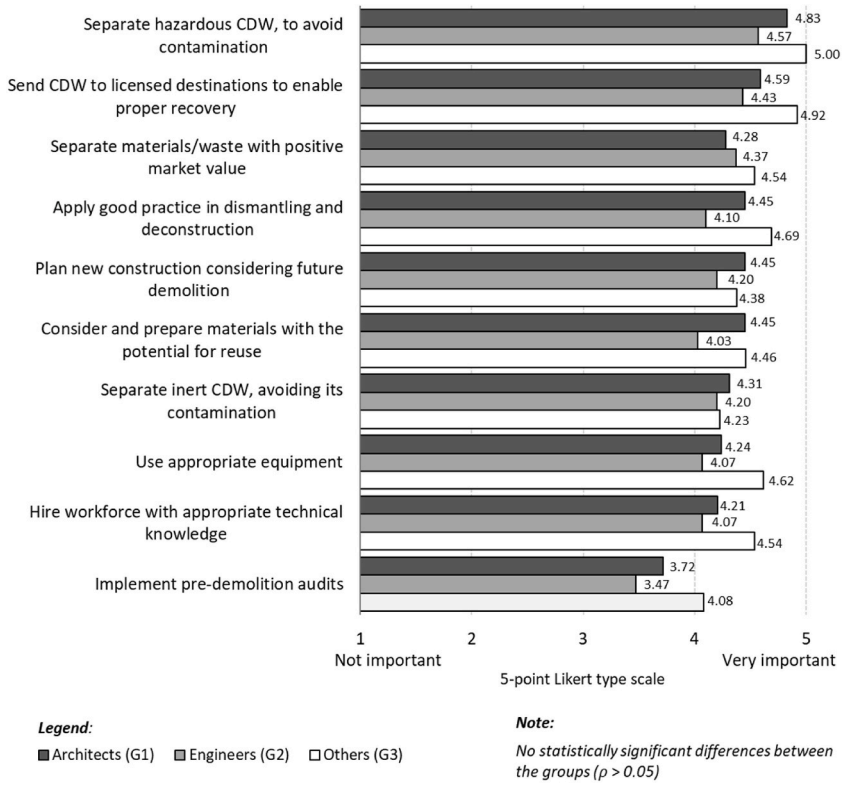

Fig. 6. The factors that may determine the effectiveness of selective demolition.

awareness (average value of 4.39, in total). This is in line with the literature, pointing out the need to update knowledge (for example [23,26,61]).

Results reveal that there are statistically significant differences between the groups for topics regarding gathering information and raising awareness ($F(2, 69) = 3.684$; $p \leq 0.030$), which was the most selected, and with regards to promoting the design of construction materials that allow reuse and recycling ($F(2, 69) = 8.298$; $p \leq 0.001$). The group of engineers (G2) attributed less importance to both topics than the other groups, perhaps because they feel that generally there are fewer barriers to selective demolition in the first place (see Fig. 5). This might be achieved by promoting local initiatives, not only focusing on infrequent awareness and training actions, but instigating frequent supervision and training routines. This will be important not only to transmit knowledge in a more consistent and detailed manner, with equality between stakeholders and an integrated approach, but also to create conditions that allow practitioners to feel comfortable to express their doubts, in an environment that encourages cooperation and co-construction, and seeks to improve solutions, which is only possible through initiatives that develop gradually, over time (as demonstrated Ramos et al. [32]).

In global terms, the measure that the respondents valued the least was the one related to obligations, via legal requirements, for pre-demolition audits, which reveal the existence of an information gap that need to be addressed and reinforced (stated by [4,16,37]).

5. Conclusions

This research project focused on exploring the perceptions and contributions of stakeholders involved in the life cycle of buildings, specifically considering the process of selective demolition (or deconstruction) namely: architects, engineers, and other professionals. The responses were assessed from the perspective of the practices employed by the companies in which they work, complemented by an evaluation of individual perceptions.

In terms of company practices, it is concluded that 22.8% have never carried out selective demolition processes. Regarding the remaining companies, the main reason for executing it is related to contract specifications. In addition, most companies state that they subcontract to implement selective demolition. Regarding individuals, architects have, in general, a more accurate understanding of the concept of selective demolition, compared to engineers and other staff.

Concerning the barriers to implementation, the absence of information and awareness was the most frequently offered response, with engineers considering that this to be less important than other groups of professionals. Additionally, respondents think that informing and raising awareness, and also promoting the design of construction materials to allow reuse and recycling are two of the most important measures to promote selective demolition. In both cases, engineers value these options less than architects and other staff.

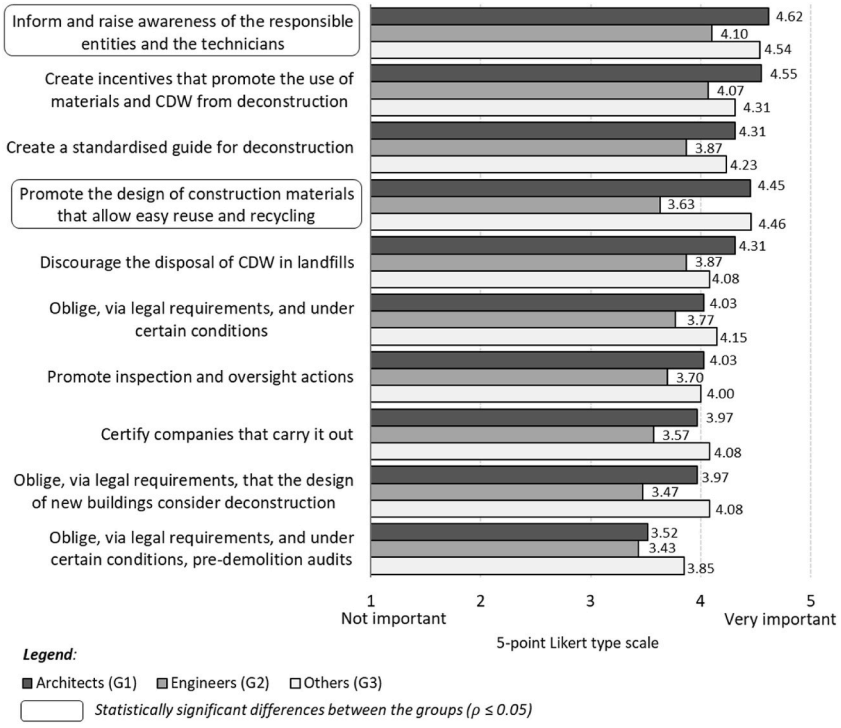

Fig. 7. The initiatives to promote interventions and policies for selective demolition.

In wider literature, cost-effectiveness seems to be generally accepted as one of the main constraints but, in the present case study, information and awareness appear to have a greater impact on what stakeholders in the life cycle of buildings feel they need to improve. This might be a result of the attempt of this research to involve and achieve a deeper understanding of the perception of stakeholders, instead of focusing on measuring the effects of the demolition process. And it also reveals that the research approach followed here offers different insights into what is needed to reshape the effectiveness of the circular economy in buildings through selective demolition, which includes taking a wider approach and has relevance for different realities. So, these results are important, for the redesign of initiatives and policies, with a view to achieving behavioural change and adapting practices in daily routines, not only of individuals, but also by creating habits in companies.

In future studies, it will be important to explore more thoroughly what appear to be contradictory responses, namely the lack of importance respondents gave to tools such as pre-demolition audits. Also, educational and training actions must be reshaped bearing in mind the recognition about the lack of knowledge, and the importance of a cooperative vision adapted to each specific context.

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CRediT authorship contribution statement

Mário Ramos: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Ana Paiva:** Formal analysis, Investigation, Writing – review & editing. **Graça Martinho:** Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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