

Sustainable construction management practices in a Brazilian medium-sized city

Práticas sustentáveis de gerenciamento da construção em uma cidade brasileira de médio porte

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Abstract

The construction industry has a great impact on the environment worldwide. The diffusion of sustainability concepts has led the industry to improve environmental performance in building projects. This paper aims to identify sustainable practices adopted by managers in the construction industry in a medium-sized city in Brazil. An online survey with 17 questions regarding knowledge and application of environmental sustainability strategies in project design and construction management was applied to managers in the industry. The sample considered 20 construction companies, members of the city's Civil Construction Union. Results show that, despite being aware of sustainability principles and their importance, only 30% of the companies apply at least one strategy related to waste management, waste production, sound, visual, water and soil pollution and energy and water consumption. This paper may contribute to the development of strategies to encourage sustainability in the construction sector.

Keywords: Sustainable practices. Construction management. Sustainable strategies.

Resumo

A indústria da construção tem um grande impacto no meio ambiente. A difusão dos conceitos de sustentabilidade levou o setor a buscar edifícios com melhor desempenho ambiental. Este artigo tem como objetivo identificar as práticas sustentáveis adotadas por agentes do gerenciamento da indústria da construção em uma cidade de médio porte no Brasil. Para isso, foi aplicado um questionário on-line com foco em agentes de gestão da construção civil, composto por 17 questões referentes ao conhecimento e aplicação de estratégias de sustentabilidade ambiental no gerenciamento de projetos e obras. A amostra considerou 20 empresas de construção associadas ao Sindicato da Indústria da Construção Civil do município. Os resultados mostram que, apesar de estarem cientes dos princípios de sustentabilidade e de sua importância, apenas 30% das empresas aplicam pelo menos uma estratégia relacionada à gestão de resíduos, produção de resíduos, poluição sonora, visual, da água e do solo e consumo de energia e água. Este artigo também pode contribuir para a definição de estratégias para incentivar a sustentabilidade no setor da construção.

Palavras-chave: Práticas sustentáveis. Gerenciamento da construção. Estratégias sustentáveis.

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Introduction

In recent decades, the construction industry has been increasingly involved in sustainable development. Activities related to building construction, operation and demolition cause environmental degradation, whether due to excessive natural resource consumption or waste generation. However, the spread of concepts related to sustainability have led to improvements in the environmental performance of the industry. Minimizing environmental impacts generated by building construction and operation is a growing concern (ABIDIN, 2010; BOB; DENCSAK; BOB, 2016).

The process of urbanization can contribute to environmental degradation. The urban population rapidly grew from 751 million people in 1950 to 4.2 billion in 2018. Projections suggest that by 2050, 6.7 billion people will occupy urban areas (UNITED..., 2019). In order to support this demand, building construction and infrastructure projects must increase proportional to this growth.

Despite attempts to mitigate carbon dioxide emissions in the world, reports show that 33.2 billion tons of greenhouse gases (GHG) were released into the atmosphere in 2019. The construction industry has a major influence on CO₂ emissions. In 2019, building construction and operation accounted for 36% of energy use and 39% of energy-related CO₂ emissions worldwide (INTERNATIONAL..., 2019).

Among the materials used by this industry, steel and concrete stand out. These are produced from non-renewable materials and consequently have a high environmental impact (RUUSKA; HÄKKINEN, 2014). Waste production is another consequence of civil construction development (FORMOSO *et al.*, 2002). Construction and demolition activities produce 1.68 kg/inhabitant/day of waste on the planet (KAZA *et al.*, 2018). Solid waste management practices can provide economic, quality and sustainability benefits, and improve productivity and safety on construction sites (UDAWATTA *et al.*, 2015).

Although specialists highlight that the application of sustainable principles reduces any environmental impact (ADABRE; CHAN, 2021; CHAN *et al.*, 2018), studies show that they are not taken into consideration by many construction companies (HWANG; TAN, 2012; OPOKU; AHMED, 2014), even when sustainability integration can be done at the level of project content or processes (HUEMANN; SILVIUS, 2017).

In recent years, studies have sought to identify the main barriers to the application of sustainable techniques in civil construction. The factors that make the application of sustainable technologies in civil construction difficult vary according to a country's level of development. The most significant barrier is the high cost of such strategies. Then, on different scales, the lack of knowledge about the subject, the lack of incentives and support (governmental, for example), the lack of interest and demand from customers, as well as insufficient legislation to implement strategies in construction have been identified (DARKO; CHAN, 2016).

This is a relatively new topic for the Brazilian construction industry. Guidance and certification related to sustainable buildings started to be applied in 2007. These include LEED, AQUA, Procel Edifica, Casa Azul and PBQP-h (DE CONTO; OLIVEIRA; RUPPENTHAL, 2017). Several studies point to the benefits of sustainable strategies applied to building construction in this context (MARQUES; GOMES; BRANDLI, 2017), however, there remain obstacles to the adoption of sustainable strategies. Projects often apply economic strategies without considering water, energy, and waste management (QUEIROGA; MARTINS, 2015). The data collected from certified building is not used to improve waste management (FROUFE; MELLO; SOARES, 2020). Furthermore, Brazilian literature lacks knowledge on sustainable principles applied in construction management.

This work aims to present an overview of sustainable practices adopted by construction managers in a Brazilian medium-sized city. The study was developed through quantitative research, focusing on the application of environmentally sustainable technologies on the construction site.

Since the local context influences the way sustainability is approached in the construction industry (HOSSEINI *et al.*, 2018), studies should be developed aiming to identify the realities of different locations. This process may help to understand the barriers to the application of sustainable practices and contribute to the development of guidelines that encourage such actions. Understanding the role of construction management agents can open a field of studies on controlling and improving practices adopted at construction sites (resource management and energy savings, for example). Therefore, the construction industry can function respecting environmental preservation and satisfying local needs at the same time.

The research can contribute to the decision-making process regarding building sustainability, guiding customers, developers, designers, builders, suppliers, users, and other agents interested in decision making at each stage of a project's cycle.

Theoretical framework

A method to identify, classify and prioritize sustainability indicators was proposed by Fernández-Sánchez and Rodríguez-López (2010) and applied with civil construction agents in Spain. The five most important points determined by the survey were:

- (a) energy consumption;
- (b) waste management;
- (c) ecological footprint;
- (d) carbon dioxide emissions; and
- (e) security and health.

Pham and Kim (2019) carried out an empirical investigation on the relationships of sustainable practices related to sustainability and management agents of construction companies in Vietnam. Results showed that environmental, economic, and social practices have a positive influence on companies' sustainability performance, and that the skills of construction managers can reinforce this relationship.

Bal *et al.* (2013) studied the engagement of construction agents in the application of sustainable practices in the United Kingdom. The method used in this research included interviews with different agents, such as project managers, sustainability consultants, civil engineers, environmentalists, designers, and contractors. A six-step process was set up to encourage sustainable actions among professionals.

Thomas and Costa (2017) developed a set of criteria for the adoption and assessment of sustainable management practices at construction sites, based on a literature review on environmental assessment methods and a case study in Brazil. Results point to a dependency of all parties involved in the implementation of sustainable construction sites, as well as a need to encourage training programs, use of local labor and linking construction industry, academy and government through public policy agendas and forums.

Studies conducted in Hong Kong (SHEN; TAM, 2002), Singapore (HWANG; TAN, 2012), United Kingdom (OPOKU; AHMED, 2014), Vietnam (NGUYEN *et al.*, 2017) and China (CHANG *et al.*, 2018) aimed to identify barriers to sustainable management construction practices. Shen and Tam (2002) found that management agents value short-term more than long-term benefits from investments in environmental management. Also, Hwang and Tan (2012) show that although the cost of the project is one of the main barriers, in Singapore there is no lack of knowledge, but encouragement from the government is needed.

Also, Chan, Darko, and Ameyaw (2017) conducted a study to identify strategies to promote green building technologies (GBT) in the construction industry. In addition to a literature review, the authors surveyed 104 green building experts from around the world. The main promotion strategies found were: "financial and further market-based incentives for GBTs adopters", "availability of better information on cost and benefits of GBTs", "mandatory governmental policies and regulations", and "green rating and labelling".

According to the study conducted by Opoku and Ahmed (2014), the greatest challenge faced by construction companies in adopting sustainable practices is cost. Nguyen *et al.* (2017) identified the need to provide sustainability-related training to employees and owners. Chang *et al.* (2018) suggest that the most important sustainable aspects for construction companies is quality management and customer service. Abidin (2010) investigated awareness and application of sustainable construction by Malaysian developers and identified a gap between information and implementation of sustainability. The study also identified different challenges faced by big and medium or small-sized companies for sustainability applications.

The scenario of sustainability application can be affected by legislation, available techniques, material and human resources, stakeholder awareness on sustainability, and other contextual factors. There is a lack of knowledge on the overview and obstacles related to the application of sustainable practices by construction managers in Brazil, mainly outside of big cities.

Additionally, green rating systems are used worldwide to evaluate sustainable building practices (DOAN *et al.*, 2017). The construction industry in Brazil has acknowledged that the application of sustainable

management methods results in improvement of building performance. However, the use of sustainable solutions requires investment and therefore needs to be communicated to the user in the form of environmental, social, and economic gains. A green rating system has become an instrument to enhance building performance (GRÜNBERG; MEDEIROS; TAVARES, 2014).

Zeule *et al.* (2019) conducted a comparative study of environmental certifications in the project phase in Brazil. Based on BREEM, LEED, AQUA and Selo Casa Azul environmental certifications, the proposed assessment model evaluated the application of sustainable practices related to the sustainable construction site, rational use of water, energy, materials and resources, environmental quality and innovations and processes. Six social housing construction sites were evaluated to validate the method. Results showed that buildings with environmental certifications had better levels of implementation of sustainable practices on construction sites.

Studies in construction sites in big urban centres have identified as main barriers for sustainability application: lack of a proper project and construction planning; lack of compliance with technical standards; inappropriate choice of applied techniques and lack of industrialization for more efficient technologies; and the engagement of all parties involved (THOMAS; COSTA, 2017; TRINDADE, 2018). When applied to medium-sized cities, research usually focuses on specific aspects of construction management (MARQUES; GOMES; BRANDLI, 2017). Understanding the present state and challenges for sustainability adoption by construction management agents can help provide support to developers, contractors, consultants, manufacturers, clients and other agents involved in the construction to achieve sustainable goals.

Focusing on medium-sized cities is important in urban sustainability studies as nearly half of the world's urban population live in urban settlements with fewer than 500,000 inhabitants. It is predicted that by 2050, less developed regions will be home to 83 percent of the world's urban population (UNITED..., 2019). Africa and Latin America will be home to 32.5 percent of the total urban population growth from 2011 to 2050 (ZHANG, 2016).

According to Cohen (2006), medium-sized cities in developing countries can offer greater potential for sustainable transformations than large cities. He argues that medium-sized cities have a smaller ecological footprint but tend to grow rapidly, so they are more flexible in terms of urban expansion and the application of sustainable practices can have a greater impact.

Sustainable development levels of megalopolises, large cities, and small or medium-sized cities in China were evaluated by Sun *et al.* (2017). Indicator values for socioeconomic development, ecological infrastructure construction, and comprehensive sustainability in 277 Chinese cities were analyzed from 2000 to 2010. Results show that the smaller the scale of the city, the greater the potential to improve comprehensive capacity for sustainable development. In their conclusion, they point out that additional effort should be made to promote the development of small and medium-sized cities.

Santa Maria is a medium-sized city in southern Brazil, with more than 260,000 inhabitants (INSTITUTO..., 2011). The economy is based on commerce and services, corresponding to 80% of local formal jobs while 4.40% of jobs are related to the civil construction sector (INFORMAÇÕES..., 2019). The presence of universities in the city can contribute to implement innovation and sustainable development practices in local companies (GOMES *et al.*, 2016). Previous studies have suggested that companies may be interested in adopting sustainable strategies at some level (FIGHERA *et al.*, 2018; TREPTOW *et al.*, 2019). However, there are still barriers to effective application in the construction sector.

Cattelan, Noro and Magalhães (2012) analyzed the decision-making criteria of a PBQP-h certified building company in Santa Maria and identified a greater focus on reducing costs, as social and environmental strategies were being developed for future application. To investigate how three construction companies in Santa Maria were promoting a shift to more sustainable practices, Teixeira *et al.* (2016) interviewed the company directors. Results indicated that tacit strategies adopted by two companies were more related to the directors' previous knowledge, and that there was no effort to share and improve collective knowledge with the team. Furthermore, even though there was an interest in applying sustainable strategies, practices were incipient and the way they were applied may not have had a significant impact.

Method

This study arises from the need to identify practices adopted by management agents regarding principles of sustainability in the building construction process. The methodological procedure of this research was qualitative/descriptive, elaborated in three main stages:

- (a) definition of the key sustainability strategies adopted by construction companies;
- (b) elaboration and application of a questionnaire to management agents; and
- (c) analysis of the results, identifying barriers and proposing solutions to improve sustainability in construction management in medium-sized cities.

Questionnaire application

The literature review was undertaken to understand the factors that influence the application of sustainability strategies in construction management. The theoretical foundation for the development of a pilot questionnaire was built through a study of technical standards, resolutions, academic and scientific papers, and certification seals.

The guidelines that structured the elaboration of the questionnaire were based on the research of Silva (2003) who developed a methodology for the Brazilian context, in which environmental, social, economic and management indicators were outlined in consultation with stakeholders in the civil construction industry in the state of São Paulo. Through this model, it was possible to establish some aspects of sustainability to be analyzed throughout the building construction process. The second stage of the research consisted of elaborating a questionnaire, divided in two phases:

- (a) elaboration and application of the pilot questionnaire; and
- (b) elaboration and application of the final questionnaire.

Observations made from the application of the pilot questionnaire served as a basis to correct small flaws throughout the text, as well as adaptations for the application through an online tool – Google Forms platform. After suggested adjustments, the final version of the questionnaire was prepared and consisted of 17 questions. The questions were divided into the following topics: sample characterization, sustainability background, sustainability initiatives, and sustainability strategies adopted by managers in the construction industry.

Like in the pilot questionnaire, questions were in the form of rating scales, multiple-choice, and open questions. The questionnaire was applied in digital format so as to obtain a greater number of respondents. Along with the link to access the questionnaire, a letter of introduction and confidentiality terms were included to explain the origin and objectives of the survey, and ensuring that the data provided would be kept confidential. Table 1 shows a summary of the subjects surveyed.

Sampling

The questionnaire was applied to civil construction managers working in Santa Maria, a medium-sized city in Brazil, located in the state of Rio Grande do Sul. According to SINDUSCON (Civil Construction Industry Union), which gathers information about the construction industry in the city, there are 42 associated companies in the construction sector operating in the city. Therefore, the final questionnaire was sent to all 42 companies, members of SINDUSCON, via email. Construction managers, office staff and freelance engineering and architecture professionals who work with construction and management were considered managers.

Results and discussion

From the 42 questionnaires sent for the SINDUSCON-SM members, 20 respondents completed the questionnaire, which represents 47.62% of the sample. Results are presented according to the questionnaire sections: sustainability background, sustainability initiatives and sustainability strategies adopted by managers.

Table 1 - Summary of questions

Category	Item	Description
Sample characterization	1	Company's main activity
	2	Size of the company (according to staff)
	3	Company's working experience (years)
	4	Projects currently in progress
Sustainability background	5	Prior knowledge of green building standards
	6	Application of green building certifications
	7	Justification for not adopting green rating systems
Sustainability initiatives	8	Company's decisions according to sustainability principles
	9	Encouragement of employee training and development
	10	Promotion of environmental sustainability discussions
Sustainability strategies	11	Waste management
	12	Waste production
	13	Sound pollution
	14	Visual pollution
	15	Water and soil pollution
	16	Energy consumption
	17	Water consumption

Sample characterization

In the first part of the survey, respondents identified the area in which the organization operates, number of employees, company age, and number of projects in progress (Table 2). Respondent's name, name of the company they work for, and e-mail address were not requested to avoid bias of any form.

Sustainability background

When asked about having prior knowledge on green building standards and certification systems in Brazil, 85% of respondents said they knew some of the green rating systems and 15% said they did not know any of them. Table 3 shows the knowledge reported by respondents about the certifications listed.

While most respondents reported awareness of green rating systems, only 30% of the companies surveyed apply at least one of these systems. The reasons for not adopting a certification system, reported by the other 70%, were: they do not see the need yet (45%), they are a small business and do not have enough clients to make it profitable (15%), or they lack knowledge on the systems (10%).

Sustainability initiatives

Respondents also answered questions about the consonance between environmental sustainability and the company's operation practices (Table 4). Seventy-five percent said that the managers and the company's decisions are made according to some sustainability principles. Companies apply waste management techniques (60%), use sustainable or recycled materials (40%), design rainwater reuse (27%) and use photovoltaic generation (13%). Paula, Arditi, and Melhado (2016) evaluated sustainability efforts in design, consulting, construction, and facility management companies and show that the greatest efforts are related to the companies' strategic positioning, reputation and experience, and hiring policies, while profit margins are not high in sustainable projects compared to conventional projects.

As can be seen, 65% of the companies do not encourage employee training and professional development, mainly because of the lack of instructors (30%), lack of interest (23%), or the amount of time and cost required (15%). Despite this, half of the companies promote discussions on environmental sustainability among employees. Darko and Chan (2016) identified 61 barriers to the adoption of green buildings. The five most reported barriers are lack of information, increased cost, deficiency of incentives/support, lack of interest/demand and scarcity of green building codes and regulations. While big companies tend to implement sustainable building strategies through planning, design, and budget allocation, medium and small-sized companies face limitations such as initial cost, lack of sustainability awareness of local buyers, and shifting conventional construction modes (ABIDIN, 2010).

Table 2 - Summary of sample characteristics

Variable	Number	Percentage
Organization		
Construction Company	14	70
Engineering and/or architecture office	6	30
Size of Organization (according to staff)		
< 9	6	30
10 – 49	9	45
50 – 99	2	10
> 100	3	15
Organization's experience (years)		
< 5	4	20
6 – 10	3	15
11 – 20	7	35
21 – 30	4	20
> 30	2	10
Projects in progress		
< 2	6	30
3 – 5	3	15
6 – 10	8	40
> 10	3	15

Table 3 - Knowledge of green rating systems

Green Rating System	Number	Percentage
LEED	11	55
AQUA	7	35
Selo Casa Azul	11	55
PBE Edifica	8	40

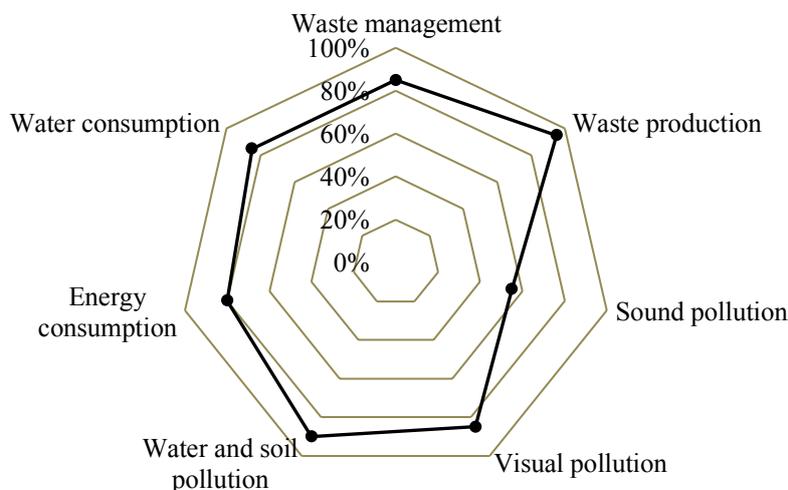
Table 4 - Adoption of sustainability initiatives

Question	Answer	Number	Percentage
Are construction management and the company's decisions made according to any sustainability principle?	Yes	15	75
	No	5	25
Is employee training and professional development in environmental sustainability encouraged?	Yes	7	35
	No	13	65
Do discussions on environmental sustainability take place in the company?	Yes	10	50
	No	10	50

Sustainability strategies

Companies were asked about the sustainable strategies they adopt in their projects. A list of strategies was presented, organized into seven categories: waste management, waste production, sound pollution, visual pollution, water and soil pollution, energy consumption and water consumption. Figure 1 shows the percentage of companies that adopt at least one strategy, separated into the respective categories.

Figure 1 - Sustainability strategies applied by companies



Strategies to mitigate excessive noise are those that are the least adopted by the managers interviewed (55%), despite the fact that noise pollution potentially leads to health problems such as hearing impairment, hypertension and ischemic heart disease (PASSCHIER-VERMEER; PASSCHIER, 2000). Additionally, the Brazilian standard of performance NBR 15575-3 (ABNT, 2013) requires minimum sound insulation, which means some of the companies do not worry about this. On the other hand, more than 80% of the companies adopt at least one strategy in the other categories. Table 5 presents the affirmative answers for each strategy.

Most of the respondents (75%) consider doing constant maintenance of sidings on the construction site. However, the other strategies regarding visual pollution had much fewer positive answers. This might indicate that siding maintenance is not a visual pollution concern.

Overall, it can be said that most strategies are not applied in construction management in medium-sized cities. In the waste management category, 38% of the strategies are applied by more than half of the respondents. This is repeated in other categories. In water and soil pollution, 43% of the strategies are used by more than 50% of the respondents. Regarding water consumption, 20% of the strategies are applied by more than half of the companies. Although respondents were free to add any other strategy adopted regarding each category, in the field "other", only one additional answer for each category was identified. This points to a lack of information on alternative sustainable strategies that could be applied.

Waste production, energy consumption, and waste management categories had high frequency of adoption. These categories are related to the main impact generated by the construction industry and are widely researched. Furthermore, these strategies can reduce costs through reuse and reduction of material loss and energy consumption. Strategies related to economic viability and short-term benefits tend to facilitate their adoption (SHEN *et al.*, 2010).

Barriers and recommendations

The survey provided an overview of the construction management practices for sustainability which are used in a medium-sized city. Barriers and possible solutions to facilitate the implementation of sustainable practices in the construction industry were identified. Next, barriers will be presented, as well as recommendations for greening construction management practices.

Table 5 - Sustainability strategies

Strategy	Number	Percentage
Waste management		
Waste separation to optimize waste reuse and recycling	13	65
Reuse of formworks and props on the construction site	13	65
Special procedures for handling and disposal of toxic substances	10	50
Reuse and recycling of on-site generated waste	8	40
Identification, qualification, and quantification of the waste	6	30
Commitment of employees working on the construction site	6	30
Appointment of a person responsible for waste management or inspection	5	25
Operational control (forms, weighing certificates, counting containers)	4	20
None	3	15
Waste production		
Project compatibility	13	65
Modulation of construction components to prevent losses	11	55
Standardization of formworks to avoid waste of wood	11	55
Choice of products and systems that produce less waste	11	55
Packing of waste in appropriate containers	11	55
Waste management plan integrated with the construction site plan	4	20
Use of sustainable materials to reuse or recycle in the construction	2	10
None	1	5
Sound pollution		
Planning tasks to minimize disturbance in the neighborhood	7	35
Choice of materials and machines to reduce acoustic disturbance	6	30
Positioning fixed or noisy devices to avoid noise reverberation	3	15
Planning a vehicle traffic schedule at the construction site	1	5
None	9	45
Visual pollution		
Constant maintenance of sidings on the construction site	15	75
Conservation and protection of existing green areas during work	7	35
Limitation of areas in the waste production and storage sectors	6	30
Soil irrigation and installation of equipment or system to reduce dust	4	20
Paving stones from the construction site pathways	3	15
None	3	15
Water and soil pollution		
Sewage treatment and correct disposal	13	65
Preservation of existing watercourses	12	60
No release of polluting residues in sanitation networks	10	50
Specific and well-marked storage for potentially polluting products	5	25
No burial of waste on site	5	25
Signaling tanks, vats, and pumps according to their contents	2	10
Installation of recovery and treatment systems for polluting effluents	2	10
None	2	10
Energy consumption		
Monitoring electricity consumption	9	45
Adoption of corrective measures to avoid waste	9	45
Choice for materials and machines that consume less energy	7	35
None	4	20
Water consumption		
Adoption of corrective measures to avoid waste	11	55
Monitoring water consumption	9	45
Collection of rainwater to wash the construction site	9	45
Reduction in water consumption in the quarters of the construction site	5	25
Choice for materials and machines that consume less water	3	15
None	3	15

The reasons given by the respondents for not adopting green building certifications varied and are related to similar studies conducted in other countries. Some of these were company size, which was also identified by Abidin (2010). Medium and small-sized companies face challenges related to costs, lack of human resources, and clients who prefer affordable constructions and who are not aware of sustainable principles. However, studies show that greening project management practices can add significant value to a project if it is delivered with acceptable cost constraints (AMIRI *et al.*, 2020; ROBICHAUD; ANANTATMULA, 2011). Hence, companies should increase their knowledge of environmental seals and green building certifications in order to make decisions regarding sustainable principles.

Another barrier pointed out by respondents is the lack of knowledge and training, also found by Nguyen *et al.* (2017). Most companies do not have specialists or time for the training of people involved in building construction. The distribution of strategies adopted concentrated mainly in 3 categories, in a third of the strategies. Other strategies not in the survey also indicate a lack of training in alternative sustainable practices and practices focused on sound, visuals, water and soil consumption. This reveals a need to develop guidance and training focusing on these categories.

Furthermore, our results point to the need for commitment from all parties involved, as suggested by Thomas and Costa (2017). Some respondents justified that sustainable practices were not adopted because they are just a part of the construction process, leaving the responsibility for other stakeholders. Therefore, the relationship between companies and training centers and universities should be strengthened so as to promote professional development, resulting in operational training programs on waste production and management, sound, visual, water and soil pollution, and energy and water consumption. There is also a need for the Civil Construction Industry Unions and Councils to offer guidelines for applying sustainable strategies.

Conclusions

The environmental impact caused by civil construction has led to greater attention being given to the adoption of sustainability strategies in recent years. Although the subject is already widely addressed in the academic environment, there is a gap in the application of sustainability principles. The difficulty of applying sustainable strategies can be even more significant in developing countries and outside major urban centers. It is necessary to have an understanding of the current sustainability practices adopted by construction managers in the construction industry. The present study has sought, through empirical research, to identify the sustainable strategies adopted and the main barriers faced by construction managers.

A questionnaire about sustainable principles/practices adopted on site was applied to 20 companies, among them construction companies (70%) and engineering and/or architecture offices (30%). Results showed an inconsistency between the understanding of the importance of sustainable practices and the companies' actual practices.

When asked about sustainability strategies adopted in the company's projects, results showed that 80% of the companies adopt at least one of the strategies in the questionnaire. Sustainability strategies were grouped into seven categories: waste management, waste production, sound pollution, visual pollution, water and soil pollution, energy consumption and water consumption. Each category had some strategies, but respondents could add another if necessary. However, the adoption of strategies remains incipient and most companies apply the same ones. For example, more than half of the companies apply 20% of the strategies listed for water consumption, and the same is observed in the other categories.

The survey served to identify barriers to applying sustainable principles in construction management practices in a Brazilian medium-sized city. Respondents said that the company size is one of the reasons for not adopting green building certifications, however, studies show that greening project management practices can add value to a project. Moreover, the lack of knowledge and training was identified as a barrier to adopting sustainable practices, nevertheless, they also said that companies do not have the specialists nor time to train the staff. This reveals the need for commitment from all parties involved, including Civil Construction Industry Unions and Councils to clarify any misinformation and help Companies to apply sustainable strategies. This paper can contribute to spread concepts and endorse the application of sustainable construction. The research can collaborate in the dissemination of sustainable strategies, which can be applied in projects of different types and scales. The recommendations in this paper can support the decision-making process in the construction industry and encourage the adoption of sustainable strategies. Additionally, future field studies on the operation of construction sites and on the adoption of sustainability principles could be compared with the results presented here. This comparison could complement the

contribution of the study, and further clarify the panorama of sustainability in civil construction in a Brazilian medium-sized city.

References

- ABIDIN, N. Z. Investigating the awareness and application of sustainable construction concept by Malaysian developers. **Habitat International**, v. 34, n. 4, p. 421–426, 2010.
- ADABRE, M. A.; CHAN, A. P. C. Modeling the impact of barriers on sustainable housing in developing countries. **Journal of Urban Planning and Development**, v. 147, n. 1, p. 05020032, 2021.
- AMIRI, A. *et al.* Economic and technical considerations in pursuing green building certification: A case study from Iran. **Sustainability**, v. 12, n. 2, 2020.
- ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 15575-3**: edificações habitacionais: desempenho de edificações habitacionais: parte 3: requisitos para os sistemas de pisos. Rio de Janeiro, 2013.
- BAL, M. *et al.* Stakeholder engagement: achieving sustainability in the construction sector. **Sustainability**, v. 5, n. 2, p. 695–710, 2013.
- BOB, C.; DENCSAK, T.; BOB, L. Sustainability of buildings. **Advances in Energy Planning, Environmental Education and Renewable Energy Sources**, p. 69–74, mar. 2016.
- CATTELAN, V. D.; NORO, G. de B.; MAGALHÃES, A. C. de M. Sustentabilidade em gestão de projetos: um estudo de caso em uma empresa de construção civil de Santa Maria-RS. In: ENCONTRO NACIONAL DE ENGENHARIA DE PRODUÇÃO, 32., Bento Gonçalves, 2012. **Anais [...]** Bento Gonçalves: ENEGEP, 2012.
- CHAN, A. P. C. *et al.* Critical barriers to green building technologies adoption in developing countries: the case of Ghana. **Journal of Cleaner Production**, v. 172, p. 1067–1079, 2018.
- CHAN, A. P. C.; DARKO, A.; AMEYAW, E. E. Strategies for promoting green building technologies adoption in the construction industry-An international study. **Sustainability**, v. 9, n. 969, p. 1–18, 2017.
- CHANG, R. D. *et al.* Sustainability attitude and performance of construction enterprises: a China study. **Journal of Cleaner Production**, v. 172, p. 1440–1451, 2018.
- COHEN, B. Urbanization in developing countries: current trends, future projections, and key challenges for sustainability. **Technology in Society**, v. 28, p. 63–80, 2006.
- DANTAS QUEIROGA, A. T.; MARTINS, M. de F. Indicadores para a construção sustentável: estudo em um condomínio vertical em Cabedelo, Paraíba. **Revista de Administração da UFSM**, v. 8, p. 114–130, 2015.
- DARKO, A.; CHAN, A. P. C. Review of barriers to green building adoption. **Sustainable Development**, v. 25, n. 3, p. 167–179, 2016.
- DE CONTO, V.; OLIVEIRA, M. L. de; RUPPENTHAL, J. E. Certificações ambientais: contribuição à sustentabilidade na construção civil no Brasil. **GEPROS. Gestão da Produção, Operações e Sistemas**, Bauru, v. 12, n. 4, p. 100–127, 2017.
- DOAN, D. T. *et al.* A critical comparison of green building rating systems. **Building and Environment**, v. 123, p. 243–260, 2017.
- FERNÁNDEZ-SÁNCHEZ, G.; RODRÍGUEZ-LÓPEZ, F. A methodology to identify sustainability indicators in construction project management: application to infrastructure projects in Spain. **Ecological Indicators**, v. 10, p. 1193–1201, 2010.
- FIGHERA, D. *et al.* Práticas de inovação para a sustentabilidade em empresas de Santa Maria-RS. **Revista Brasileira de Gestão e Inovação**, Santa Maria, v. 5, n. 3, p. 72–94, 2018.
- FORMOSO, C. T. *et al.* Material waste in building industry: main causes and prevention. **Journal of Construction Engineering and Management**, v. 128, n. 4, p. 316–325, 2002.
- FROUFE, M. M.; MELLO, L. C. B. de B.; SOARES, C. A. P. Indicadores de sustentabilidade em canteiros de obras, segundo o PBQP-h. **Brazilian Journal of Development**, Curitiba, v. 6, n. 3, p. 10149–10163, 2020.

- GOMES, T. E. de O. *et al.* Inovação e sustentabilidade: uma análise bibliométrica dos trabalhos publicados no Fórum Internacional Ecoinovar. **Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental**, Santa Maria, v. 20, n. 1, p. 187-199, 2016.
- GRÜNBERG, P. R. M.; MEDEIROS, M. H. F. de; TAVARES, S. F. Certificação ambiental de habitações: comparação entre LEED for Homes, Processo Aqua e Selo Casa Azul. **Ambiente & Sociedade**, v. 17, n. 2, p. 195-214, 2014.
- HOSSEINI, M. R. *et al.* Sustainable delivery of megaprojects in iran: integrated model of contextual factors. **Journal of Management in Engineering**, v. 34, n. 2, 2018.
- HUEMANN, M.; SILVIUS, G. Projects to create the future: managing projects meets sustainable development. **International Journal of Project Management**, v. 35, n. 6, p. 1066-1070, 2017.
- HWANG, B. G.; TAN, J. S. Green building project management: obstacles and solutions for sustainable development. **Sustainable Development**, v. 20, n. 5, p. 335-349, 2012.
- INFORMAÇÕES PARA O SISTEMA PÚBLICO DE EMPREGO E RENDA. **Dados por Município**: Santa Maria, Número de empregos formais em 31 de dezembro de 2019. Brasília: Ministério da Economia, 2019. Available at: https://doi.org/https://bi.mte.gov.br/bgcaged/caged_isper/index.php. Access: 07 mar. 2020.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Censo Demográfico - 2010**. Rio de Janeiro: IBGE, 2011.
- INTERNATIONAL ENERGY AGENCY. **Global Status Report for Buildings and Construction 2019**. 2019. Available at: <https://www.unep.org/resources/publication/2019-global-status-report-buildings-and-construction-sector>. Access: 25 Feb. 2020.
- KAZA, S. *et al.* **What a Waste 2.0**: a global snapshot of solid waste management to 2050. Urban Development. Washington: World Bank, 2018. Available at: <https://openknowledge.worldbank.org/handle/10986/30317>. Access: 18 Jan. 2020.
- MARQUES, C. T.; GOMES, B. M. F.; BRANDLI, L. L. Consumo de água e energia em canteiros de obra: um estudo de caso do diagnóstico a ações visando à sustentabilidade. **Ambiente Construído**, Porto Alegre, v. 17, n. 4, p. 79-90, out./dez. 2017.
- NGUYEN, H. D. *et al.* Influence of participants' characteristics on sustainable building practices in emerging economies: empirical case study. **Journal of Construction Engineering and Management**, v. 143, n. 8, p. 1-11, 2017.
- OPOKU, A.; AHMED, V. Embracing sustainability practices in UK construction organizations: challenges facing intra-organizational leadership. **Built Environment Project and Asset Management**, v. 4, n. 1, p. 90-107, 2014.
- PASSCHIER-VERMEER, W.; PASSCHIER, W. F. Noise exposure and public health. **Environmental Health Perspectives**, v. 108, sup. 1, p. 123-131, 2000.
- PAULA, N. de; ARDITI, D.; MELHADO, S. Managing sustainability efforts in building design, construction, consulting, and facility management firms. **Engineering, Construction and Architectural Management**, v. 24, n. 6, p. 1040-1050, 2016.
- PHAM, H.; KIM, S. Y. The effects of sustainable practices and managers' leadership competences on sustainability performance of construction firms. **Sustainable Production and Consumption**, v. 20, p. 1-14, 2019.
- QUEIROGA, A. T. D.; MARTINS, M. de F. Indicadores para a construção sustentável: estudo em um condomínio vertical em Cabedelo, Paraíba. **Revista de Administração da UFSM**, v. 8, p. 114-130, 2015.
- ROBICHAUD, L. B.; ANANTATMULA, V. S. Greening project management practices for sustainable construction. **Journal of Management in Engineering**, v. 27, n. 1, p. 48-57, 2011.
- RUUSKA, A.; HÄKKINEN, T. Material efficiency of building construction. **Buildings**, v. 4, p. 266-294, 2014.
- SHEN, L. Y. *et al.* Project feasibility study: the key to successful implementation of sustainable and socially responsible construction management practice. **Journal of Cleaner Production**, v. 18, n. 3, p. 254-259, 2010.

- SHEN, L. Y.; TAM, V. W. Y. Implementation of environmental management in the Hong Kong construction industry. **International Journal of Project Management**, v. 20, p. 535–543, 2002.
- SILVA, V. **Avaliação da sustentabilidade de edifícios de escritórios brasileiros**: diretrizes e base metodológica. São Paulo, 2003. Tese (Doutorado em Engenharia) – Escola Politécnica, Universidade de São Paulo, São Paulo, 2003.
- SUN, X. *et al.* Comprehensive evaluation of different scale cities' sustainable development for economy, society, and ecological infrastructure in China. **Journal of Cleaner Production**, v. 163, p. S329–S337, 2017.
- TEIXEIRA, M. G. *et al.* Processo de mudança para uma orientação sustentável: análise das capacidades adaptativas de três empresas construtoras de Santa Maria-RS. **Revista de Gestão Ambiental e Sustentabilidade**, v. 5, n. 1, p. 45–60, 2016.
- THOMAS, N. I. R.; COSTA, D. B. Adoption of environmental practices on construction sites. **Ambiente Construído**, Porto Alegre, v. 17, n. 4, p. 9–24, out./dez. 2017.
- TREPTOW, I. C. *et al.* Práticas de inovação sustentável em empresas incubadas da cidade de Santa Maria, RS. **Revista Metropolitana de Sustentabilidade**, São Paulo, v. 9, n. 1, p. 82–97, 2019.
- TRINDADE, E. **Avaliação de barreiras para implantação da sustentabilidade na construção civil**. Recife, 2018. Dissertação (Mestrado em Engenharia de Produção) – Universidade Federal de Pernambuco, Recife, 2018.
- UDAWATTA, N. *et al.* Improving waste management in construction projects: an Australian study. **Resources, Conservation and Recycling**, v. 101, p. 73–83, 2015.
- UNITED NATIONS, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, POPULATION DIVISION. **World Urbanization Prospects: the 2018 revision**. New York: United Nations, 2019. v. 12 Available at: <https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf>. Access: 18 Jan. 2020.
- ZEULE, L. D. O. *et al.* Model for sustainability implementation and measurement in construction sites. **Environmental Quality Management**, v. 29, n. 2, p. 67–75, 2019.
- ZHANG, X. Q. The trends , promises and challenges of urbanisation in the world. **Habitat International**, v. 54, p. 241–252, 2016.

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