Environmental indicators proposal for construction solid waste management plans assessment

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Abstract

Purpose – The civil construction industry has vital importance to Brazil's economy. However, this sector is also responsible for the environmental impacts. Governments have been taking measures aiming to mitigate these impacts. Among these, the elaboration and implementation of civil construction solid waste management plans can be highlighted. However, these plans still lack standardizations and tools for their evaluation. Environmental indicators proposal for construction solid waste management plans assessment is presented to verify the adhesion of these to environmental laws, technical standards and green building certification systems recommendations.

Design/methodology/approach – The construction solid waste management plans of three construction works were evaluated by the proposed indicators to verify the procedures related, generating, in the end, a scale between 0 and 5. After that, plans were compared with each other.

Findings – The proposed indicators have made possible the evaluation of the environmental practices performed for three different construction works. By the proposed indicators, the environmental practices were compared to technical standards and legislation suggested procedures.

Practical implications – As a contribution, the evaluation proposal presented may help the construction industry as well as the public authority to evaluate the construction solid waste management plans currently elaborated, so that these can offer a quality improvement and more effective environmental measures.

Originality/value – Methodologies that guide the evaluation of construction solid waste management plans can be beneficial for the construction companies, which can improve the quality of the plans elaborated internally and verify the effectiveness of the plans elaborated by specialized consultancies. In general, most of the construction solid waste management plans are prepared with the purpose of only complying with the legislation, more specifically of the National Council for the Environment, Resolution 307/2002.

Keywords Construction solid wastes, Civil construction, Indicators of sustainability

Paper type Research paper

Introduction

The civil construction is responsible for a country's social and economic development. According to Maia and Neto (2016), the construction industry has made about 7% of all world jobs in 2015 and reduced housing and infrastructure deficits. According to the Brazilian Institute of Geography and Statistics, the civil construction production chain has represented 5.2% of Brazilian gross domestic product in 2016 (IBGE, 2017). In the meantime, the civil construction is perceived as the principal responsible for pollution and solid waste generation (Menegaki and Damigos, 2018).

However, despite the proportioned benefits, the civil construction sector is responsible for environmental impacts because of its daily activities, such as noise, air pollution, dust, solid waste generation, natural resources impoverishment (Yuan, 2012; Chen *et al.*, 2019). In Brazil, about 50% of all extracted natural resource is destined for construction activities. da Silva and Fernandes (2012) point out that civil construction produces 60% of all urban solid waste daily generated by Brazilian cities. In Salvador (Brazil), the construction and demolition waste (C&DW) is about 45% (by volume) of the total urban solid waste (USW) daily

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generated (Azevedo *et al.*, 2006). In the cities of Rio de Janeiro and São Paulo, it is around 21% (Gomes *et al.*, 2008).

To Yuan (2017), there is still a lack of C&DWs definition, but almost times, it is defined as the solid waste that rises from construction and demolition activities. C&DWs can be defined as a mixture of different materials generated by demolition, renovation and construction activities. Among these, it can be observed as inert waste, non-hazardous waste and hazardous waste (Menegaki and Damigos, 2018).

The amount of C&DW may consist of different sources, such as asphalt, concrete, wood, soil, tiles, ceramic materials. The C&DW accounts for 30–40% of the total mass of produced USW all over the world (Jin *et al.*, 2019). When improperly managed, this waste causes soil, water and air pollution (Mahpour, 2018). The amount and the composition of construction and demolition waste also can vary between different regions depending on many factors such as economic growth, legislation, public policy, constructor expertise, type of constructions, regional planning and others (Menegaki and Damigos, 2018).

The increasing construction activities due to the massive and uncontrolled urbanization have been causing many negative impacts on the environment and society. Among these, the impacts due to incorrect construction and demolition waste management can be highlighted. In many parts of the world, the C&DWs are disposed of at landfills without any treatment or previous recycling (Jin *et al.*, 2019), and it is not so difficult to find places where C&DWs are dumped in rivers and forests.

The high rate of C&DW generation is a crucial issue for civil construction companies (Rosado *et al.*, 2019). For Yuan (2017), C&DW induces negative impacts on the environment, economy and public health. Due to the limited areas for disposal landfills, water pollution, energy consumption, harmful gas emissions, noise pollution, the C&DW management becomes a significant challenge for sustainable development (Jin *et al.*, 2019).

It is estimated that more than 10bn tonnes of C&DW were generated over the world in 2017 (Wang *et al.*, 2019). In 2016, the European Union generated 923,540,000 tonnes of C&DW (Eurostat, 2017), and in the United States, in 2014, approximately 540m tonnes were generated. Australia and China in 2014 generated 19.5m tonnes and 1.13bn tonnes, respectively (Menegaki and Damigos, 2018), and in Saudi Arabia, in the same year, 250m tonnes were generated (Blaisi, 2019). The United Kingdom, in 2012, produced 200m tonnes of waste, of which 50% was produced by construction and demolition works (DEFRA, 2015).

Brazilian municipalities have collected about 45m tonnes of C&DW in 2016, which means a generation rate of 0.6kg/inhabitants/day. Rosado *et al.* (2019) warn that this rate can be higher in many Brazilian regions, because it takes only the collected C&DW by the municipalities, and do not consider the waste dumped off illegally. Many countries do not present public policies for C&DW recycling. As informed by Wang *et al.* (2019), only 5% of the generated C&DW has been recycled, and the remaining is illegally dumped or transported to landfills. This situation is similar in Brazil (Paschoalin Filho *et al.*, 2017) and Saudi Arabia (Blaisi, 2019).

According to Jin *et al.* (2019), C&DW management is an interdisciplinary issue that involves environmental, technical, economic and social aspects. It also covers complicated issues from political, management and engineering perspectives. According to Paschoalin Filho *et al.* (2017), the waste generated in a construction site can represent a significant environmental liability, if not adequately managed and destined. In this way, the management of C&DW has great importance to ensure the correct management through the adoption of techniques in line with sustainability practices. Nagapan *et al.* (2012) suggest that the most significant factors that cause C&DW generation are errors in the design and execution phases, inadequate construction planning, poorly skilled labour and inefficient management of building sites.

Faced with this problem, Brazil instituted legal instruments intending to stimulate the environmentally correct management of C&DW, as well as sustainability in construction sites, through the Resolution of the National Council for the Environment (CONAMA) 307/2002 and the National Policy for Solid Waste – NPSW (Law 12,305/2010). The integrated solid waste management plan of the city of São Paulo establishes the obligation of large generators to prepare and implement construction solid waste management plans (CCSWPs) to obtain a construction license from the municipal agency (PMSP, 2014).

A CCSWP is a technical document that lists procedures for the management of C&DW generated by construction works, as well as guarantees adequate final destination to these. Resolution 307/2002 of CONAMA and NPSW establish CCSWP as a necessary instrument for recycling and reuse of C&DW (Paschoalin Filho *et al.*, 2017).

Environmental, technical, social and economic advantages of C&DW recycling are highlighted in the surveys of Arif *et al.* (2012), Oyedele *et al.* (2013), Paschoalin *et al.* (2017), Tam *et al.* (2009), among others. In the last decade, the feasibility and efficient management of C&DW have been widely studied by many researchers.

However, although construction companies are obliged to elaborate and implement the CCSWP in their works, many of them do not have this document, while others have inefficient procedures concerning management actions and the destination of their C&DW. Paschoalin Filho *et al.* (2017) point out that the CCWSP is not yet fully practiced by all construction companies because they are concerned only with the immediate profits of the work. According to the authors, several construction companies elaborate CCWSP only to achieve scoring in green certification systems, or construction permits, generating documents that are often generic and not very efficient.

Due to this situation, a research was conducted with the purpose of analysing the CCWSP of three construction works located in the city of São Paulo, to verify which practices are being reported and, finally, evaluate them through the proposed environmental indicators. Gomes *et al.* (2015) notice that environmental indicators seek to assess the achieved results by companies based on the strategies established to enable the preparation of new plans or proposals for improvement.

Rosado *et al.* (2019), Mahpour, 2018, Wang *et al.* (2019) and Chen *et al.* (2019) emphasize the need of researches that focus on the reduction of the impacts caused by the operations of the construction sector. Brazilian construction companies are still in the initial stages regarding the application of the culture of sustainability. In this way, initiatives in this direction are even seen as complementary costs, which is not consistent with the truth, given that this cost is overestimated, creating in certain situations barriers to the implementation of sustainability concepts.

To Gomes *et al.* (2015), the management for sustainability contributes in an effective way to the development of business performance, reducing environmental impacts and saving costs. Sustainable strategic management is focussed on results related to innovation, in addition to economic, social and environmental outcomes for the construction companies and its stakeholders. Facing this, the CCSWP performs for the management for the sustainability of construction work. The elaboration of CCSWP and the implementation of the procedures related contribute to environmental impact reduction caused by construction activities, reduce costs with raw materials acquisition and transportation for landfills and make the construction company image better to the stakeholders.

Literature review

The production and consumption patterns have imposed great pressure on the environment. According to Silva *et al.* (2019), this has been creating a risk concerning the absorption capacity of the planet. The management for sustainability has as its premise the incorporation of aspects relating to the sustainable development in the strategy and operations, representing an emerging challenge for companies (Gomes *et al.*, 2015). To Vechi *et al.* (2016), the construction industry consists in an economically and strategic field and also the causative factor of environmental degradation and pollution and will have to overcome obstacles if it does not respond to the new prospects of environmental regulations in an increasingly competitive market.

Society and stakeholders have been valuing companies that adopt an engaged position with the principles of sustainable development and requiring transparency about company behaviour (Gomes *et al.*, 2015). There is a consensus, in both national and international literature, on the issue involving the management of construction waste and concerning the environmental impacts caused. This theme was evidenced in several studies such as Hwang and Bao Yeo (2011), Matter *et al.* (2015), Paschoalin Filho *et al.* (2015), Yu *et al.* (2013). As highlighted by Campos *et al.* (2015), construction companies receive many benefits by environmental management systems implementation: contribution to environmental protection, mitigation of environmental risk, improvement of the company's environmental image and cost savings due to reduced environmental pollution. Nevertheless, Campos *et al.* (2015) also noticed that the high costs associated with an environmental management system implementation, the lack of qualified human resources and insufficient knowledge about the benefits of implementation are the most critical barriers to be run through by construction companies.

The civil construction sector has a high rate of waste of materials; therefore, it generates high amounts of C&DW. According to Esa *et al.* (2017), 40% of industrial waste generated in the world comes from the construction industry. Bernardes *et al.* (2008) have noticed that in Brazil, about the sources of the C&DW generation, 41% (in volume) are related to new construction works and 59% from demolitions, extensions and renovations. de Carmo *et al.* (2012) comment that 64.1% of the C&DW produced (in volume) comes from renovations; 18.2% from new works; 7.1% from demolitions; and 10.6% from other activities.

For Laszlo and Zhexembayeva (2011), most civil construction companies still consider environmental management as a regulatory issue, which must be complied with for the company to operate under current legislation, when it should be treated as a strategic issue, capable of promoting competitive advantages for the company. A considerable number of construction companies still linearly think of their production chain. As noticed by Jabbour *et al.* (2017), the structure of a linear economy (explore–take–make–use–dispose) neglects the fact that natural resources are finite; moreover, this structure has governed most production systems internationally. However, aiming to reduce the environmental impacts caused by their activities, many construction companies are changing the linear structure for a circular one. Jabbour *et al.* (2017) comment that many companies in China and the European Union have supported management tools based on circular economy principles. To Silva *et al.* (2019), the circular economy proposes the reduction of environmental impact and, at the same time, promotes economic growth through business development and new revenue streams.

The circular economy principles can be applied in construction work to reduce pollution and the amount of C&DW generation. In a circular economy system, raw materials and energy are used through multiple stages, and the material flow is closed (Sousa-Zomer *et al.*, 2018). For construction works, the waste generated by any construction activity can be recycled or reused in the construction site and used for bricks manufacturing, drain and sidewalk construction, saving natural raw material acquisition and costs.

According to Miranda *et al.* (2009), until 2008, the volume of recycled C&DWs in Brazil was in the range of 4.8% of the total generated; however, according to research conducted by Paschoalin Filho *et al.* (2015), it is estimated that in the country there is a recycling of up to 21% of the volume of C&DW. In Malaysia, this percentage reaches 15%. In countries such as South Korea, Singapore and Germany, the recycling of C&DW is in the range of 50%–75% of the total generated. In Australia, recycling is 48% of the generated (Esa *et al.*, 2017; Tam *et al.*, 2009).

The CCSWP must be compatible with the municipal civil construction waste management plan. They must be submitted to the competent municipal department for analysis simultaneously with the construction project, as a condition for obtaining the construction permission. As for the projects subject to environmental licensing, the CCSWP must be analysed by the competent environmental department, together with the licensing process.

It should be noted that the CCSWP consists of a technical document that identifies the amount of C&DW generated from construction works, demolitions, renovations, repairs and earthworks. The CCSWP's main goal is to establish the procedures for C&DW correct handling and disposal. The CCSWP must indicate the destination of the waste and its segregation, according to its type, among other aspects. In Brazil, the NPSW (Law 12,305/2010) established the CCSWP as a necessary and mandatory instrument for the environmental appropriate management of the C&DW. Vechi *et al.* (2016) claim there is still a lack of scientific researches approaching methods for environmental management systems used that identify and evaluate environmental impacts.

Methodology section

Indicators proposal

For indicators definition, a bibliographic survey of practices and experiences of environmental management of C&DW was performed. Technical standards and legislation were also investigated, among them, Resolution 307/2002 of CONAMA, NPSW (Law 12,305/2010), Decree 55.747/2014 that establishes the integrated management plan for solid waste of the city of São Paulo. Besides, the requirements of LEED (Leadership in Energy and Environmental Design) environmental management systems were analysed.

After a document analysis, three indicators related to the management of the C&DWs were elaborated (work management, management and destination). Each indicator has described five practices: (1) Construction Work Management: Planning, Execution, Control, Operational and Supplies; (2) Waste Management: Generation, Classification, Conditioning, Cleaning and Transportation; Generator and (3) Destination: Reuse in Construction Work, Recycling in Construction Work, Transportation for Waste Recycling Plant, Transportation for Landfill and Dumping Areas.

After indicators and practices definition, an academic research form was developed by the authors. In this form, professional experts in waste management should determine a ranking of importance among the indicators and distribute weights among them. These should also establish an importance ranking of practices reported in each of the indicators by scoring them on a scale of 1–5 points. Experts also defined weights between practices on a scale ranging from 1 to 100%. The authors invited these experts. However, each one had to prove their professional ability in CCSWP elaboration and must have at least ten years of experience in environmental technical designs for construction works.

Finally, the experts defined ranking and weight for the three proposed indicators, following the same criteria used for the practices. In the first column, they should establish a ranking of importance among the three indicators, scoring them on a scale of 1–3 points. In the second column, they should distribute 100 percentage points between the three indicators according to the degree of importance.

The proposed indicators were sent by email to 15 civil engineers, ten environmental engineers and ten architects. All of these had to prove their ability in construction works and environmental management of at least five years. The authors' convenience defined this sampling. Concerning 35 professionals, 14 returned the completed forms.

After the return of the forms, the answers were analysed and accounted. The ranking and the weights established by the professionals were defined using an arithmetic average. The arithmetic average was used since all the indicators, and all the practices had, initially, equal weights.

Analysis of the studied civil construction solid waste management plans

After defining the rankings, weights of the indicators and practices, analysis of the CCSWP was performed. The next step was to identify if the CCSWP was adherent to the practices in the CCSWP parameterization. Both the applicability analysis of the practices and their compliance with the CCSWP were established based on the recommended environmental practices in legislation, resolutions, green certification systems in addition to bibliographic review and documentary research.

For each of the practices, a score was determined according to the weight established by the experts. The note of each indicator has a range of 0–5 points. These points were defined according to the weight of each practice. After calculating the grade of each practice, the sum of these established the grade of each of the indicators. From these grades, employing the weighted average calculation, a grade was given to the CCSWP. By this grade, a classification was assigned to the CCSWP, according to the scale developed by the authors due to the practices adopted, as shown in Table 1.

Parametrization of civil construction waste management plans

The analysed CCSWPs were elaborated for three residential works located in different districts of the city of São Paulo. The works were carried out by different construction companies. Table 2 shows the characteristics of these works. Based on the bibliographical review and the documentary research, 36 activities related to the 15 practices of the three proposed indicators were identified. Then, these were verified in the CCSWP studied to test the adherence of these concerning the activities founded by document search performed.

Findings

Indicators definition

According to the scale determined by the experts, the "Construction Work Management" indicator was the most important, with an average of 1.29 being denoted as "Indicator A"; in second, with a mean of 2.29, the indicator "Waste Management" was called "Indicator B"; and

Table 1.
Civil construction solid waste management plan rating scale

Grade	0.0–1.0	1.1–2.0	2.1–3.0	3.1–4.0	4.1–5.0
Classification	Very poor	Poor	Regular	Good	Excellent

Table 2.
Characteristics of studied construction works

Construction work	CW1	CW2	CW3
CCSWP elaboration	External environmental consulting	Construction company environmental department	External environmental consulting
Land area (m^2)	4.238.25	3.186.73	2.855.40
Constructed area (m^2)	35.957.63	14.049.33	14.660.05
Purpose	Residential	Residential	Residential

lastly, with an average of 2.43, the indicator "Destination" was denoted as "Indicator C". Table 3 represents the ranking established for indicators A, B and C.

The same procedure was used to establish the practices within each indicator importance ranking, as shown in Tables 4–6.

In calculating the distribution of weights, both the order of the indicators and the practices were maintained. With this distribution, it was possible to evaluate how important the experts judged each of the indicators and practices. In this way, the weights identified in Tables 7–10 were established for indicators and practices.

After establishing the rankings of importance and weights of the indicators and practices, the following tables were obtained.

After defining the rankings, weights of the indicators and practices, the analyses of the CCSWPs were performed. In these, it was identified whether the practices described in Tables 11–13 applied to each of the plans. If they were applicable, the weights distributed by the experts would be maintained; if any of these practices were not applicable and if the weights

Indicator	Professionals 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg	SD	CV (%)
	Position of the indicator attributed by the professionals																
A – Construction work management	1	3	1	1	1	1	1	1	1	1	3	1	1	1	1.29	0.73	0.56
B – Waste management	3	2	2	3	3	2	2	2	2	2	1	3	2	3	2.29	0.61	0.27
C – Destination	2	1	3	2	2	3	3	3	3	3	2	2	3	2	2.43	0.65	0.27

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 3. Indicators ranking definition

Indicator A Construction work management	Professionals 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg	SD	CV (%)
	Position of the practices attributed by the professionals																
Planning	1	1	1	1	2	1	1	1	1	1	5	1	1	1	1.36	1.08	0.80
Execution	3	4	3	3	1	2	3	4	3	4	4	3	3	2	3.00	0.88	0.29
Control	2	3	2	2	3	3	5	5	5	3	1	4	2	5	3.21	1.37	0.43
Operational	4	2	4	5	4	5	2	3	2	2	2	5	5	3	3.43	1.28	0.37
Supplies	5	5	5	4	5	4	4	2	4	5	3	2	4	4	4	1.04	0.26

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 4. Indicator A ranking definition – construction work management

Indicator B Waste management	Professionals 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg	SD	CV (%)
	Position of the practices attributed by the professionals																
Generation	1	1	1	1	1	5	1	1	1	5	1	1	2	1	1.64	1.45	0.88
Classification	3	3	2	2	2	1	2	3	2	1	4	2	1	2	2.14	0.86	0.4
Conditioning	2	4	5	3	4	2	4	2	4	2	3	3	3	3	3.14	0.95	0.3
Cleaning	4	2	3	4	3	4	3	4	3	3	5	4	5	5	3.71	0.91	0.25
Transportation	5	5	4	5	5	3	5	5	5	4	2	5	4	4	4.36	0.93	0.21

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 5. Indicator B ranking definition – waste management

Table 6.
Indicator C ranking definition – destination

Indicator C Destination	Professionals 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg	SD	CV (%)
	Position of the practices attributed by the professionals																
Reuse in construction work	2	2	2	1	2	1	2	2	1	1	2	1	2	1	1.57	0.51	0.33
Recycling in construction work	1	3	1	3	5	2	1	1	2	2	4	2	1	2	2.14	1.23	0.57
Transportation for CDWRP*	3	1	3	2	3	3	4	3	3	3	5	3	3	3	3.00	0.88	0.29
Transportation for landfill	5	5	4	4	4	4	3	4	4	4	1	4	4	5	3.93	1.00	0.25
Dump areas	4	4	5	5	1	5	5	5	5	5	3	5	5	4	4.36	1.15	0.26

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average. *Construction and demolition waste recycling plant

should be redistributed in the same proportion determined by the experts. The items of each CCSWP are shown in Table 14.

The practice relation presented in Table 14 has given support for CCSWP analysis, allowing to identify each one of the procedures, it also made it possible to verify the plan's adherence to the practices reported by each indicator. It was possible to identify that the CCSWPs elaborated by external environmental consulting (CW3 and CW1) have presented more adherence to the practices reported by indicators than the CCSWP elaborated by the construction company environmental department (CW2).

By Table 14, it also can be drawn what practices were more reported by studied plans, such as construction work description, CCSWP goals, waste characterization, while the less reported practices by CCSWP were the following: training programmes, C&DW recycling and reuse, selective collection, the periodicity of revision of the CCSWP.

Studied civil construction solid waste management plans assessment

In this item, the assessment of each studied CCSWP is presented. Figure 1 and Tables 15–18 give the assessment of the CW1 plan; Figure 2 and Tables 19–22– present the evaluation of CW2; and Figure 3 and Tables 23–26 present it for CW3.

According to Figure 1, among the three indicators, Indicator B is the one that the CCSWP showed the highest adherence, performing 70% of practices, followed by Indicator C and Indicator A.

It can be observed, concerning Indicator A, that the "Supplies" and "Operational" practices are those that the CCSWP has been more adherent. However, about the "Execution" practice, the CCSWP did not match any of the requirements, in order not to present training programmes for employees on the management of C&DW.

At Indicator B, the "Generation" and "Classification" practices stood out, presenting 83.33 and 80%, respectively, of the practices. The "Cleaning" practice is the one that showed the least adherence to the CCSWP.

At Indicator C, the "Transportation to landfill" practice was the most adherent. The practice "Transportation to URE" has shown adherence of 80% of the activities, while the practices of reuse and recycling at the construction work have accounted for 57.14% of the activities surveyed. The "Dump areas" practice was not compliant, which is to be expected, as this practice is prohibited by CONAMA Resolution 307/2002 and PGIRS/SP. The following tables demonstrate the CCSWP assessment through the proposed environmental indicators.

According to Table 18, CW1's CCSWP has gotten 2.92 as a final grade and has been labelled as "Regular". The plan has performed 59.81% of all described practices, performing

Table 7. Distribution of indicator weights by the professionals

Indicator	Professionals 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg (%)	SD	CV (%)
	Weight of the indicators attributed by the professionals (%)																
Management of construction work	55	50	50	50	50	50	50	40	50	50	40	50	45	40	48	4.69	0.10
Waste management	20	30	25	25	25	30	30	35	25	20	20	30	35	25	27	5.04	0.19
Destination	25	20	25	25	25	20	20	25	25	30	40	20	20	35	25	6.03	0.24

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 8. Distribution of the weights of Indicator A practices by the professionals

	Professionals																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Indicator A	Weight of the practices attributed by the professionals (%)														Avg (%)	SD	CV (%)
Planning	30	40	30	40	30	50	35	40	40	40	40	40	50	30	38	6.68	0.17
Execution	20	15	15	25	20	10	20	10	20	10	20	15	15	30	18	5.80	0.33
Control	15	15	30	25	20	30	10	10	10	15	10	15	20	10	17	7.23	0.43
Operational	25	20	15	5	20	5	25	20	20	25	15	10	5	15	16	7.38	0.46
Supplies	10	10	10	5	10	5	10	20	10	10	15	20	10	15	11	4.57	0.40

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 9. Distribution of the weights of Indicator B practices by the professionals

	Professionals																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
Indicator B	Weight of the practices attributed by the professionals (%)														Avg (%)	SD	CV (%)
Generation	45	20	30	40	30	15	50	50	30	5	20	45	30	30	31	13.51	0.43
Classification	15	20	25	20	10	25	20	15	30	50	20	25	40	30	25	10.46	0.42
Conditioning	20	20	10	15	15	25	10	20	10	20	20	15	15	20	17	4.64	0.28
Cleaning	10	20	20	15	30	15	15	10	20	15	20	10	5	10	15	6.34	0.41
Transportation	10	20	15	10	15	20	5	5	10	10	20	5	10	10	12	5.41	0.46

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 10.
Distribution of the weights of Indicator C practices by the professionals

Destination	Professionals 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg (%)	SD	CV (%)
	Weight of the practices attributed by the professionals (%)																
Reuse in construction work	30	25	25	50	20	25	25	25	40	50	20	35	20	25	30	10.28	0.35
Recycling in construction work	30	25	25	15	20	20	30	30	30	30	15	25	50	25	26	8.64	0.33
Transportation for URE	25	25	20	15	20	20	10	20	10	10	40	20	15	20	19	7.81	0.40
Transportation for landfill	5	10	20	10	20	20	20	10	10	7	10	15	10	10	13	5.27	0.42
Dump areas	10	15	10	10	20	15	15	15	10	3	15	5	5	20	12	5.32	0.44

Note(s): Where: SD = standard deviation; CV = variation coefficient, Avg = average

Table 11. Indicator A according to the ranking of importance and weights established by the professionals

Indicator A (48%)	Practice description	Ranking	Weight
Planning	It is a tool for managing and controlling the construction work. With it, it can track the execution, costs and revenues of the work, to optimize the use of resources and limit spending, to ensure that the budget is respected	1	38%
Execution	Adoption employees' training for the execution of the services allows minimization of losses in the processes themselves	2	18%
Control	Adoption of control measures for losses monitoring, besides the identification and correction of possible errors	3	17%
Operational	It allows optimizing the processes, guaranteeing the reduction of deadlines, costs, losses and wastes in the transportation of materials in the place	4	16%
Supplies	Sector responsible for raw material acquisition and services, maintaining a continuous flow of materials with minimum investment, allowing waste reduction	5	11%

Table 12. Indicator B according to the ranking of importance and weights established by the professionals

Indicator B (27%)	Practice description	Ranking	Weight
Generation	Control of the generation of construction waste, which comes from construction, renovations, repairs and demolitions of construction works, and those are resulting from the preparation and excavation of land	1	31%
Classification	It consists of separating collected waste according to the corresponding classes of each, as established by CONAMA 307/2002	2	25%
Conditioning	The generator shall ensure the containment of the waste after its generation to the transport stage, providing, wherever possible, the conditions of reuse and recycling	3	17%
Cleaning	Collection, handling and transport of construction waste on-site	4	15%
Transportation	It must be carried out following the previous steps and under the technical standards for the transport of waste that will be destined according to its characteristics	5	12%

Table 13. Indicator C according to the ranking of importance and weights established by the professionals

Indicator C (25%)	Practice description	Ranking	Weight
Reuse in construction work	It is the process of reuse of a waste, without changing its physical characteristics	1	30%
Recycling in construction work	It is the process of reusing a waste after it has been recycled	2	26%
Transportation to CDWRP (Recycling plants)	It is the process of subjecting waste to the operations in recycling plans to give them conditions that allow the wastes to be used as raw material or new products	3	19%
Transportation to landfill	Transportation to an appropriate area where techniques for the disposal of construction waste will be used	4	13%
Dump areas	The term dump area is usually used to designate a place where materials from earthworks that involve excavation and earth removal are discarded, such as construction solid wastes	5	12%

Item	CW1	CW2	CW3
1. Construction work description	x	x	x
2. Civil construction solid waste management plans goals	x	x	x
3. Methodology	x	–	x
4. C&DW characterization by types	x	x	x
5. Specification of generated waste	x	x	x
6. Estimative of C&DW generation (by specific type)	x	–	x
7. Estimative of C&DW generation (by class)	x	x	x
8. Loss minimization	x	–	x
9. C&DW reuse in construction work	x	–	x
10. C&DW recycling in construction work	x	–	x
11. Mitigating measures to minimize environmental impacts	x	–	x
12. Indication of C&DW destination to recycling plants	x	x	x
13. Indication of C&DW destination to licensed landfills	x	x	x
14. Indication of C&DW destination to dumping areas	–	–	–
15. Indication of destination of C&DW to transhipment and sorting area	x	–	x
16. Indication of locations (suppliers) of destination of C&DW (plants, landfill)	x	–	x
17. External collection and transport services (consignees and transporters by type of waste)	x	–	x
18. Conditioning	x	x	x
19. Definition of responsible C&DW collecting (internal transport)	–	–	–
20. Inner transportation	x	x	x
21. Allocation	x	–	x
22. Devices description	x	–	x
23. Device supplier qualification	x	–	x
24. Waste central positioning	–	–	x
25. Wastes vertical transportation	–	–	x
26. Signalling description	x	–	x
27. Waste flux	x	–	x
28. Training programmes	–	–	–
29. Procedures for transport control and waste disposal waste	x	x	x
30. The benefit of CCSWP implementation	–	–	–
31. C&DW generation monthly tracking worksheets	–	–	–
32. The periodicity of revision of the CCSWP	–	x	–
33. To promote C&DW selective collection	–	–	–
34. To promote reverse logistic	x	–	x
35. Construction schedule	–	–	–
36. Control plan	x	x	–

Table 14.
Component items of each CCSWP

more adherence to Indicators B and C. This situation explains why this plan was classified as "Regular", even performing a good percentage of practice's adherence. The CCSWP of CW2 evaluation is presented next.

Figure 2 shows that among the three indicators, Indicator C was the one with the highest adherence, followed by Indicator A and Indicator B. It was identified that, concerning Indicator A, the "Control" and "Operational" practices were those with the highest adherence, accounting for 50 and 40%, respectively, of the activities surveyed. However, concerning the "Execution" and "Supplies" practices, the CCSWP has not presented any adherence. Regarding Indicator B, the "Classification" practice has been the most adherent, accounting for 40% of the activities surveyed, while "Conditioning" has adhered to 14.29% of pointed activities.

At C indicator, the practice of "Transportation to URE" has shown better adhesions, attending 60% of the activities, the "Transportation to landfill" practice has accounted for 50%, while "Reuse" and "Recycling" have accounted for 28.57%. The practice "Dump area",

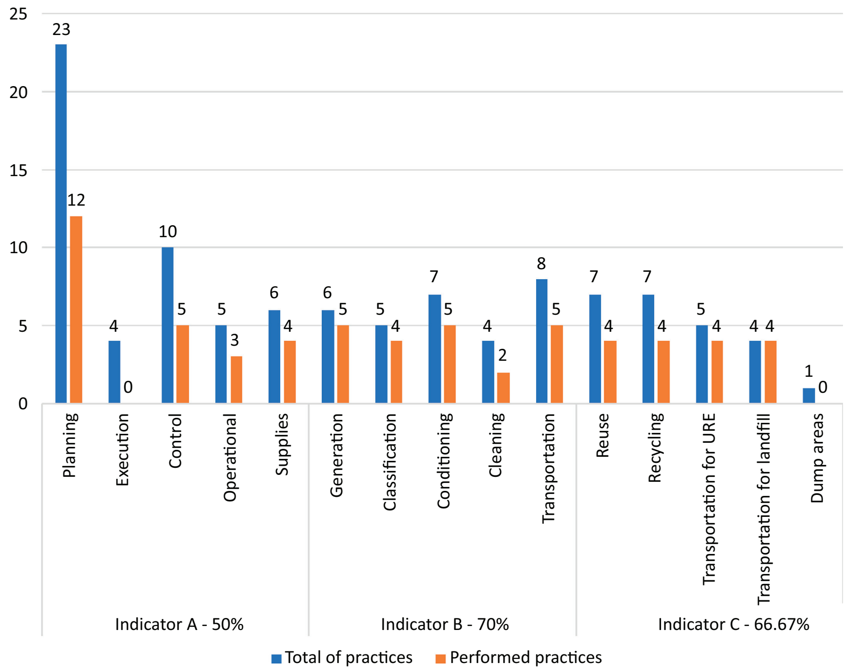

Figure 1.
Component items of CCSWP of CW1

Table 15.
Assessment of the civil construction solid waste management plan concerning Indicator A and its practices (CW1)

Practices	Indicator A (48%) Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Planning	38	ok	38	ok	1.9	23	12	0.99
Execution	18	ok	18	not ok	0	4	0	0
Control	17	ok	17	ok	0.85	10	5	0.43
Operational	16	ok	16	ok	0.8	5	3	0.48
Supplies	11	ok	11	ok	0.55	6	4	0.37
	100	—	100	—	4.1	48	24	2.27

Table 16.
Assessment of the civil construction solid waste management plan concerning Indicator B and its practices (CW1)

Practices	Indicator B (27%) Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Generation	31	ok	31	ok	1.55	6	5	1.29
Classification	25	ok	25	ok	1.25	5	4	1.0
Conditioning	17	ok	17	ok	0.85	7	5	0.61
Cleaning	15	ok	15	ok	0.75	4	2	0.38
Transportation	12	ok	12	ok	0.6	8	5	0.38
	100	–	100	–	5.0	30	21	3.66

as expected, did not have any adherence, since it consists of a practice not allowed. The following tables demonstrate the CCSWP assessment through the proposed environmental indicators.

Table 17. Assessment of the civil construction solid waste management plan concerning Indicator C and its practices (CW1)

	Indicator C (25%)							
Practices	Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Reuse	30	ok	34.09	ok	1.70	7	4	0.97
Recycling	26	ok	29.55	ok	1.48	7	4	0.84
Transportation for URE	19	ok	21.59	ok	1.08	5	4	0.86
Transportation for landfill	13	ok	14.77	ok	0.74	4	4	0.74
Dump areas	12	not ok	0.0	ok	0.0	1	0	0.0
	100	–	100	–	5.0	24	16	3.41

Table 18. The final grade for civil construction solid waste management plan (CW1)

Indicator	Weight	Multiplier	Grade	Weighted grade
A	48	0.48	2.27	1.09
B	27	0.27	3.66	0.98
C	25	0.25	3.41	0.85
Final grade				2.92
Classification				Regular

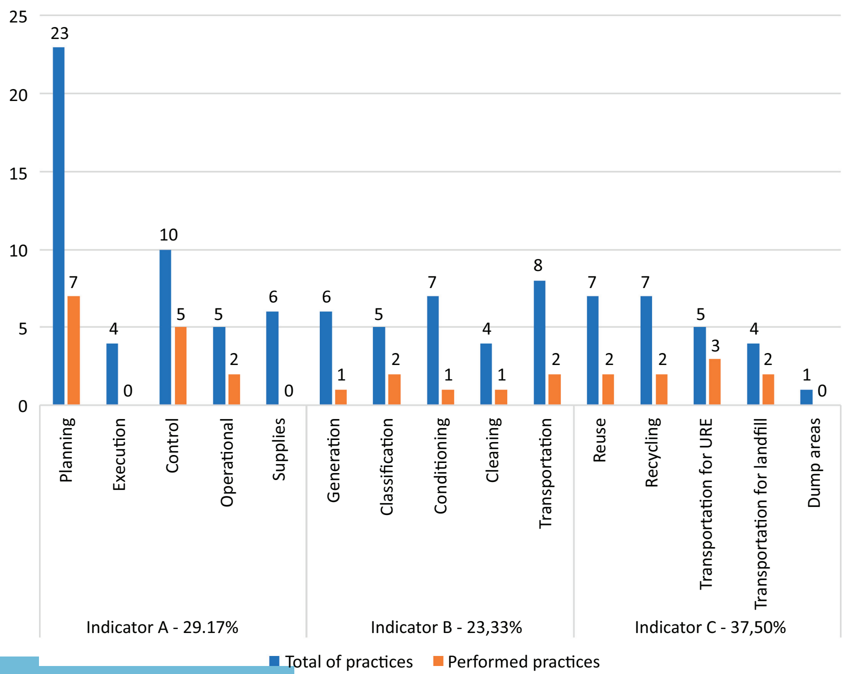

Figure 2. Component items of CCSWP of CW2

Through Table 22, it can be observed that the CCSWP of CW2 has gotten 1.45 of the final grade, being labelled as "Very Poor". The plan was not performed well because it failed to match most of the practices described. Among the 36 activities raised, CW2 performed only 12 of them. Besides, many of the activities performed could be related to the practices

Table 19. Evaluation of the CCSWP concerning Indicator A and its practices (CW2)

	Indicator A (48%)							
Practices	Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Planning	38	ok	38	ok	1.9	23	7	0.58
Execution	18	ok	18	not ok	0	4	0	0
Control	17	ok	17	ok	0.85	10	5	0.43
Operational	16	ok	16	ok	0.8	5	2	0.32
Supplies	11	ok	11	not ok	0	6	0	0
	100	–	100	–	3.55	48	14	1.33

Table 20. Evaluation of the CCSWP concerning Indicator B and its practices (CW2)

	Indicator B (27%)							
Practices	Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Generation	31	ok	31	Ok	1.55	6	1	0.26
Classification	25	ok	25	Ok	1.25	5	2	0.50
Conditioning	17	ok	17	Ok	0.85	7	1	0.12
Cleaning	15	ok	15	Ok	0.75	4	1	0.19
Transportation	12	ok	12	Ok	0.6	8	2	0.15
	100	–	100	–	5	30	7	1.22

Table 21. Evaluation of the CCSWP concerning Indicator C and its practices (CW2)

	Indicator C (25%)							
Practices	Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Reuse	30	ok	34.09	Ok	1.7	7	2	0.49
Recycling	26	ok	29.55	Ok	1.48	7	2	0.42
Transportation for URE	19	ok	21.59	Ok	1.08	5	3	0.65
Transportation for landfill	13	ok	14.77	Ok	0.74	4	2	0.37
Dump areas	12	not ok	0	Ok	0	1	0	0
	100	–	100	–	5	24	9	1.93

Table 22. The final grade for CCSWP (CW2)

Indicator	Weight	Multiplier	Grade	Weighted grade
A	48	0.48	1.33	0.64
B	27	0.27	1.22	0.33
C	25	0.25	1.93	0.48
Final grade				1.45
Classification				Very poor

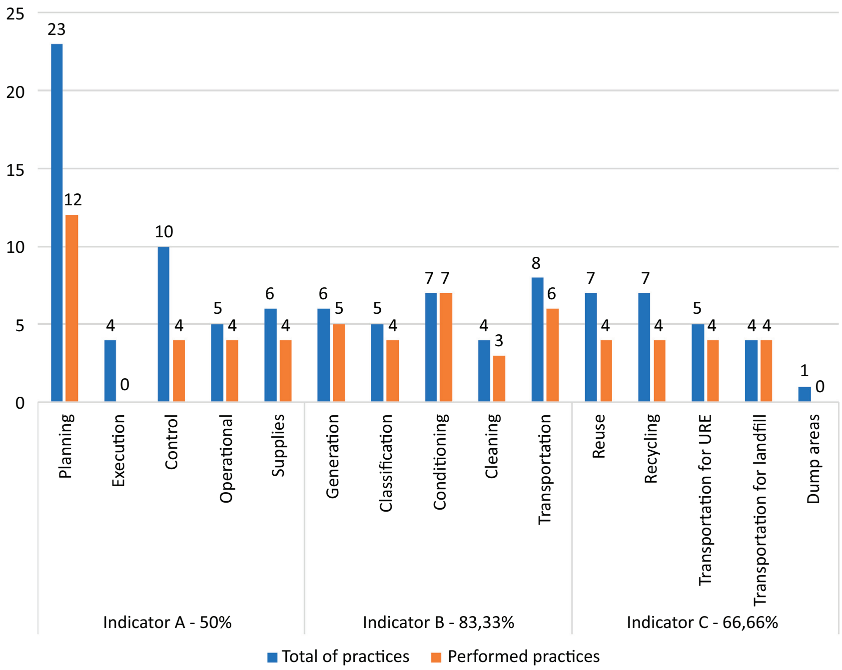

Figure 3.
Component items of CCSWP of CW3

Table 23.
Evaluation of the CCSWP concerning Indicator A and its practices (CW3)

Practices	Indicator A (48%) Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Planning	38	ok	38	ok	1.9	23	12	0.99
Execution	18	ok	18	not ok	0	4	0	0
Control	17	ok	17	ok	0.85	10	4	0.34
Operational	16	ok	16	ok	0.8	5	4	0.64
Supplies	11	ok	11	ok	0.55	6	4	0.37
	100	–	100	–	4.1	48	24	2.34

Table 24.
Evaluation of the CCSWP concerning Indicator B and its practices (CW3)

Practices	Indicator B (27%) Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Generation	31	ok	31	ok	1.55	6	5	1.29
Classification	25	ok	25	ok	1.25	5	4	1
Conditioning	17	ok	17	ok	0.85	7	7	0.85
Cleaning	15	ok	15	ok	0.75	4	3	0.56
Transportation	12	ok	12	ok	0.6	8	6	0.45
	100	–	100	–	5	30	25	4.15

classified by experts as smaller weights, justifying the low score. The CCSWP of CW3 evaluation is presented next.

According to Figure 3, among the three indicators, Indicator B is the one that the CCSWP showed the highest adherence, attending 83.33% of practices, followed by Indicator C (66.67%) and Indicator A (50%).

It can be observed concerning Indicator A that the "Supplies" and "Operational" practices are those that the CCSWP has been more adherent. However, about the "Execution" practice, the CCSWP did not match any of the requirements. In Indicator B, the "Generation" and "Classification" practices have stood out, matching 83.33 and 80% of the practices, respectively. The "Cleaning" practice is the one that has shown the least adherence to the CCSWP.

In Indicator C, the "Transportation to landfill" practice was the most adherent. The practice "Transportation to URE" has matched 80% of the activities, while the practices of reuse and recycling at the construction work have matched 57.14% of the activities surveyed. The "Dump area" practice was not compliant, which is to be expected, as this practice is prohibited by CONAMA Resolution 307/2002 and by PGIRS/SP.

As presented by Table 26, the CCSWP of CW3 has gotten 3.10 as a final grade, has been labelled as Good. The CCSWP has matched 63.73% of the surveyed practices, showing a higher adherence to the Indicators B and C. However, these indicators had smaller importance by expert evaluation.

According to the analyses performed, it was possible to verify that the CCSWP studied was labelled as Good (CW3), Regular (CW1) and Very Bad (CW2). It should be noted that the CW 1 and CW 3 plans were prepared by an external environmental consulting company, while the CCSWP of CW2 has been written up by the sustainability department of the construction company. It can also be assumed that all CCSWPs have presented gaps that were pointed out by the evaluation by the proposed environmental indicators.

It was identified that the CCSWPs of CW1 and CW3 have failed to match any practices that should make their grade better. As an example, the following lacks can be highlighted:

	Indicator C (25%)							
Practices	Weight	Applicable	New weight	Adherence	Initial grade	Described practice	Adopted practice	Final grade
Reuse	30	ok	34.09	ok	1.7	7	4	0.97
Recycling	26	ok	29.55	ok	1.48	7	4	0.84
Transportation for URE	19	ok	21.59	ok	1.08	5	4	0.86
Transportation for landfill	13	ok	14.77	ok	0.74	4	4	0.74
Dump areas	12	not ok	0	ok	0	1	0	0
	100	–	100	–	5	24	12	3.41

Table 25. Evaluation of the CCSWP concerning Indicator C and its practices (CW3)

Indicator	Weight	Multiplier	Grade	Weighted grade
A	48	0.48	2.34	1.12
B	27	0.27	4.15	1.12
C	25	0.25	3.41	0.85
Final grade				3.10
Classification				Good

Table 26. The final grade for CCSWP (CW3)

definition of the responsible for performing waste collection and transportation, employee training programmes, the absence of awareness about recycling importance and absence of monthly spreadsheets for the accompaniment of generation of the C&DW. The CW2 CCSWP has gotten the lowest score (1.45 points). The CCSWP received low scores because it failed to match most of the practices raised by parameterization. Among the 36 practices surveyed, the plan has matched only 12. Aiming to increase its grade, the CCSWP of CW2 must include the following practices: inclusion of the estimated generation of C&DW by specific type (CONANA 307/2002) and monthly worksheets for C&DW generation tracking.

Conclusions

Although experts have determined that "Construction Work Management" is the most important indicator, followed by "Waste Management" and "Destination" (demonstrating agreement with the literature consulted), through the results obtained, it was possible to verify that this was not the order established in the CCSWPs analysed. The indicator "Waste Management" was the one that presented the most prominence concerning the activities reported in the plans, followed by "Destination" and "Construction Work Management".

It was observed that the most cited practices in the CCSWP were: (1) identification; (2) CCSWP goals; (3) characterization of the wastes according to their types; (4) specification of the type of waste that can be generated in construction work; and (5) estimates of C&DW generation by types. The less mentioned practices were related to the training of teams, mainly for recycling and reuse of C&DW, selective collection, methods of control, monitoring of generation of C&DW and periodicity of revision of CCSWP.

The CCSWP assessment through the proposed environmental indicators allowed the technical evaluation of the quality of each studied plan. It should be noted that, despite its importance, it is not usually the use of efficient tools for CCSWPs assessment, even in great construction works, a gap that this research has intended for filling out.

This way, an effort of construction companies in CCWSP development and implementation must be taken. Campaigns to promote the selective collection, implementation of a construction work schedule that allows coordinators to identify periods of higher waste production (allowing greater control) are also items that should be considered in the CCSWP.

The CCSWP analysis model used in this research contributes to the dissemination of the theme of CCSWPs, which is still not widespread enough by technical and scientific means. The main limitation faced by this research can be related to the difficulty in CCSWP obtaining for construction works in progress. It happens mainly by the restrictions imposed by construction companies, even the research compromises itself to keep the anonymity of companies and construction works characteristics.

As suggestions for future research, it is proposed that this analysis should be performed using CCSWPs of another construction works. An economic study about recycling and reuse benefits for construction works itself can be suggested. This study can also account for the economic benefits of C&DW sent to C&DW recycling plants.

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