International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979; Impact Factor: RJIF 5.72
Received: 08-07-2020; Accepted: 25-07-2020; Published: 02-08-2020
www.allsubjectjournal.com
Volume 7; Issue 8; 2020; Page No. 40-47

Cost analysis in construction and demolition waste Management in public works in the state of Pernambuco, Brazil

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Abstract
Activities related to civil construction works and reforms generate several types of waste that need adequate treatment, minimizing the damage caused to nature and its resources. In public works, the need to control spending on the inadequate management of this waste is highlighted. It is of utmost importance the environmental adequacy of the waste management of these works, to minimize negative environmental impacts. This research aimed to analyze and propose cost reduction for the management of Civil Construction and Demolition Waste (RCCD) in public works in the State of Pernambuco, Brazil. Data were collected on 20 works, including 18 from the public administration, for construction / renovation. It was observed that in most of the public works visited, there is a disregard in relation to the correct destination. The simulation demonstrated that proper management is possible to reduce management costs by up to 68.18%.

Keywords: construction site; environmental management; recycling; solid waste; sustainability

1. Introduction

Among the main components of the environmental crisis in which the planet lives, the population increase, the scarcity of natural resources and the gradual increase in pollution are considered fundamental and, to achieve the balance between these three elements, everything depends on the level of quality of life that the population desires. [1] points out that a renewable resource becomes non-renewable to the detriment of the specific situation, occurring when a utilization rate exceeds the maximum capacity for sustaining the system.

As the consequences of inadequate discharges do not interfere with the soil, surface and groundwater and stimulate the proliferation of pathogenic agents and synanthropic animals, which are those that live with man in an undesirable way, being also like pests. Add the fact that it also changes undesirable changes in the landscape, which negatively affects people's quality of life, according to [2].

Civil Construction is an industrial sector that produces large quantities of hazardous waste, called Civil Construction Waste (RCC), which are used for construction activities and which, in the great majority, are discarded in an irregular and degraded way in the environment. environment. The lack of management causes an increase in the process of destination of these residues and, consequently, an increase does not discard them, generating isolated environmental impacts [3].

The waste in construction sites, for example, originating from building demolitions or demolitions resulting from disasters, presents a heterogeneous composition of RCCDs, which may contain bricks, concrete, soil, mortar fragments, metals, paint and plastic residues, plaster among others, which has been used inappropriately in Brazil, according to [4]. According to the authors, construction companies and municipal administrations are responsible for the lack of waste management, causing environmental degradation in thousands of areas due to irregular disposal of construction and demolition waste (RCCD). The waste generator, both private and public, expresses its environmental responsibility and the correct performance in its actions when it uses recycling, promoting savings, in addition to advancing the result of its processes and products. It is a fact that the deterioration of the quality of the environment has been aggravated using natural resources as raw material and the generation of waste. However, the application of an effective Civil Construction Waste Management Plan - PGRCC will provide cost savings, contributing positively to the environment, according to [3].

According to [5], it is necessary to distinguish RCCD management from its Management. Management directs the performance of the sector's agents through public policies, laws, and regulations. Management controls and manages the entire process of handling construction waste through actions carried out by construction companies and entrepreneurs. Waste management in construction and demolition works must be accompanied by a qualified professional.

It can be observed that, very often, it is at the construction site that companies fail to address the problems caused to the environment, since in these places the operational processes of the work occur, where all materials and waste produced in the site are stored. enterprise. It is worrying that a considerable part of the companies, present a reactive posture, leaving in the background the damage that they may cause to the environment with regard to the generation of waste produced, linked to the lack of adequate management during the work.

It is known that the environmental concern in the whole society grows every day, since the quality of life and human health depend on the environment and its preservation. Anthropic activities that generate solid waste need adequate management and management so that they do not cause problems to the functioning of ecosystems. Their potential has an impact on their functioning and should therefore be treated with a view to sustainability, as stated by [6].

The appearance of laws regarding the allocation of RCCDs changes the posture of private companies and public administration regarding the correct management of these resources, according to [7]. The importance of the [8] certification process is highlighted because it promotes intense changes in the organization and the resulting difficulties originate from resistance to such changes and the lack of awareness of the impacts caused on society, although its total viability is pointed out as a way of reinforce compliance with current legislation, referred to above: [9] and [10], as well as the technical standards (NBR) in force.

So that employees are trained and have knowledge of the classification of waste, with the purpose of satisfactorily executing its segregation and, also, due to the importance that this task represents for the environment, Environmental Education is of great relevance, as it is impossible not to associate such a disciplinary issue with waste disposal, according to [11].

This research aimed to analyze the costs of RCCD management in public works in the state of Pernambuco, proposing reduction measures through correct waste management.

2. Materials and Methods

This work is described as exploratory and descriptive, based on the bibliographic review on environmental legislative aspects, such as CONAMA assessments and environmental management requirements with a focus on technology, as well as performance assessment tools for adopted practices and medical articles. Data collection was carried out during 2019.

A set of 76 works was analyzed, 66 of which were public works and 10 were private works focused on the generation and destination of RCCD waste. As 20 works were selected according to the following characteristics: civil construction works, vertical and horizontal, reinforced concrete structure with closing masonry, small and medium size, standard type A finish, and which represent, in this universe, a majority, 86%, public works. It should be noted that the inspection of some of these works was also a decisive factor in their choice, considering that the necessary information is not always used by Organs contracted agencies.

To achieve the objective of the study, analyze a waste management form of 20 works / reforms located in the State of Pernambuco, 18 from the public administration and 2 from private companies, through the analysis of their PGRCC. It was found that only 03 of the registered works described the PGRCC, one public (work C) and two privates. The PGRCC were analyzed, where all aspects related to their monitoring were verified, which is carried out through the monthly checklist on the construction site and through monthly histories performed by the Department of Quality, Environment, Safety and Occupational Health, or sector similar to the companies they have adopted. It is also noteworthy, which were the periodic records, such as audits, to verify the functioning of the company's management system, use the correct cleaning in the works, as well as the quality of the segregation of the waste and the correct destination. Finally, it was found that, at the end of the work, the technician responsible for implementing the PGRCC, assisted by the work engineer, will divert the Final Civil Construction Waste Management Report, a final presentation to the municipal body responsible for control programs and as proven or complying with the stipulated in the work's PGRCC. Information on these procedures is contained in the analyzed Plans.

Management cost scenarios were simulated for three of the analyzed public works, works C, E and H, to obtain comparative costs in the different situations presented. The most satisfactory results were presented, with regard to the reduction of the listed costs, as well as proposals for positive actions to reduce the generation of waste in the construction sites, with the importance of the PGRCC being highlighted, as the most effective tool for the implementation of the Companies' Environmental Management Program, as shown in the flowchart shown in Figure 1. The data collected in the aforementioned public works, for the analysis of the costs of managing RCCD were based on the information in the final measurement bulletins for each work, referring to total waste generation, built area, land area, construction term and amount of waste sent to final destination, as shown in Table 1.

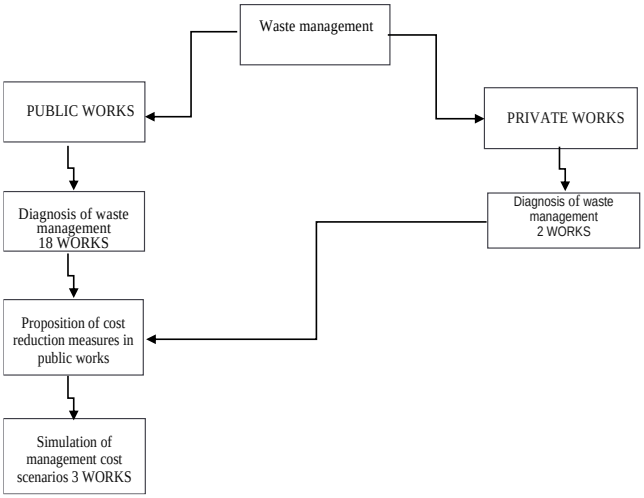

Fig 1: Flowchart of the research steps. Source: The authors.

As visits that take place in public and private works had the objective of diagnosing waste management actions, regarding segregation, according to classes of [9], initial and final storage and internal transport.

In the second stage, a diagnosis of waste management was carried out in two private works, certified by [8], and a comparison was made with public works, where you can check the procedures for waste management, sorting, transport and destination, identifying actions that can be put into practice in public works.

Table 1: Characteristics of public works. Source: the authors.

Code	Land Area (m^2)	Built Area (m^2)	Construction time (days)	RCCDD Generation (t)
Work A	19.114	7.413	360	196,22
Work B	40.050	11.202	820	134,00
Work C	40.015	9.765	486	1.985,33
Work D	7.235	8.668	1.740	67,00
Work E	11.772	1.931	450	2.405,30
Work F	10.863	7.678	628	1.145,70
Work G	6.000	1.205	573	3.151,68
Work H	14.648	1.931	630	1.776,84
Work I	2.851	1.030	360	2.464,26
Work J	3.993	1.025	270	1155,08
Work K	7.500	1.514	213	1.034,48
Work L	9.600	1.514	300	1.413,70
Work M	5.859	1.205	365	3.119,52
Work N	4.996	1.205	365	393,96
Work O	3.624	1.216	300	454,26
Work P	1.426	1.086	360	830,8
Work Q	9.938	8.668	840	144,72
Work R	7.038	8.668	810	1.315,88

Subsequently, in the third stage, a simulation of management cost parameters was carried out in 3 (three) public works (Works C, E and H), which has different levels of waste management, where transportation and disposal costs are available waste, simulating situations of disposal of waste from sanitary waters or plants, and from the implementation of environmental certification by [8].

In the simulation, consider the following scenarios:

Scenario 1: current situation of waste management.

Scenario 2: adequate segregation and disposal to sanitary land.

Scenario 3: adequate segregation and destination for use of processing.

Scenario 4: work certified by [8] - 30% reduction in waste generation (percentage based on research such as [12] and [13].

The costs of collection and disposal of RCCD were provided by transport companies and final disposal in the region. Data were also obtained from two landfills, an inert landfill and two RCCD processing plants.

For each management scenario, the calculation was performed by multiplying the generation of waste by the cost of transportation and destination, according to the destination scenario used, identifying the percentage of cost reduction that can occur if there is an improvement in segregation and destination of the RCCD.

A spreadsheet was prepared to estimate the costs necessary to implement a waste management system in 04 public works C, D E and H, in the preparation of which the following items were considered: project to raise the masonry; acquisition of suitable containers for the materials according to the classification in the colors specified in [14]; acquisition of raffia bags for storing construction waste; construction of bays at the construction site and / or rental of stationary buckets for storage; internal transport in wheelbarrows at the construction site; labor (servant) to perform the proper segregation of waste in all locations of the work; environmental engineer, calculated the permanence in hours according to the size of the work; transport of waste to the final destination and, finally, the cost of disposing of it in landfills or processing plants.

3. Results & Discussion

From the diagnosis of the waste management carried out in 18 public works, it was possible to observe that the works do not comply with the criteria established by [9]. Waste is not classified and classified, and most works do not have PGRCC. Some of the companies transport their waste in single trucks, and others outsource or transport, loading the waste that was disposed on the construction sites, in disagreement with [9]. After the collection, most of the works not proven or the destination place with weighing tickets, noting that they were possibly launched indiscriminately in irregular areas, disrespecting them as distinct classes. There was an absence, in many public editors, of display clauses by builders, of the creation of a PGRCC before the beginning of the work, or what is described as outdated of the current environmental environment, that is, what probably facilitates the inspection stage by the public manager.

Civil servants and inspectors of works involved in this area can be affected through improvement courses in the environmental area, and the public manager must import how to record in their editors or comply with all environmental standards. Examples of the absence of adequate segregation and storage of waste are presented in Figure 2. There is a disorder in the management of waste at the construction site, without any procedure for segregating it.

Fig 2: Inadequate provision of RCCD in a public work. Source: the authors.

In the two private works inspected, it was found that the construction sites were more organized when compared to the public works. The care and procedures presented in the segregation of reusable and recyclable waste occurred in accordance with environmental standards, by waste classification, obeying the color criteria established for the

separation of materials by selective collection [14].
Comparing the operability of the private works visited, in relation to public works, it was possible to verify the potential benefits with the good practices of waste management in construction sites (Figure 3), such as reduction in waste generation, reduction in transport costs and in destination costs after waste segregation, providing for recycling, leading them to construction recycling plants. It was observed, then, that the companies that have [8] environmental certification contribute to the reduction of environmental impacts, protecting the environment.
The incentive for the reinsertion of reusable or recycled waste in the production cycle [9] and the good practices of reuse, recycling and reuse of unused materials in construction sites, would allow to obtain quality certificates in addition to results in collection financial support for municipalities. Awareness-raising actions must be carried out to companies and the population regarding the process of irregular waste disposal, clarifying the damage caused to the environment, which, in addition to being irreversible, can often take years to recover [15].

Fig 3: Masonry design at a construction site - service optimization – [8]. Source: the authors.

Public works can put into practice actions such as: the reuse of wood used in the works for making benches or for supplying industrial ovens; the use of white bricks in the works, elements that present a new composition of a refractory nature and less aggressive to the environment, easing the high temperatures, to which the buildings are subject [16]; the elaboration of masonry projects and other projects, optimizing the materials to be used in the constructions, avoiding tears in already executed walls and, consequently, minimizing the generation of waste.
It is also proposed, for works that contain large demolition areas, the installation, when possible, of crushing plants on the construction site itself, facilitating the crushing processes of the materials, in order to achieve an ideal granulometry so that they can be reused in the work itself. These materials can be used to produce mortars, non-structural concrete, pavement bases, sidewalks, etc. These decreases both the use of raw materials, as well as the cost of transport and delivery of waste in legalized areas [17].
It is evident the importance of works having an environmental management system (SGA) based on [8], as this way they can have greater control of waste management due to the standardization of operational procedures, which result in greater efficiency of the process. According to [7], in a paper presented on the diagnosis of RCCD management in the city of Recife, construction companies that had certification [8] were more effective in the methodology adopted for waste control than companies that did not have certification. The author revealed that the care with the waste management went from its generation to its destination, and that some projects had an environmental manager, who was responsible for the actions of orientation to the employees for the accomplishment of the segregation, the packaging and the transportation of waste in construction sites, specific to management.
Finally, as in the case of private works, public works must carry out a greater control of the final destination of the waste, guaranteeing its traceability through the Waste Transport Control (CTR) and weighing tickets, as well as seeking a lower-cost destination, such as inert landfills and processing plants, for Class A waste.
From the survey of the final disposal costs of RCCDs from companies in the region, it was observed that the average cost of disposal in landfills is $ 11.30/ton, class A, while for disposal in a RCCD processing is $ 6.48/ton, which represents a 57% reduction in final destination, as shown in Table 2.
It is observed that the average cost of destination of waste as class A in landfills is $ 11.30/ton, 26% lower than the destination of waste as waste where the average value is $ 14.26/ton.

Table 2: Costs of final disposal of RCCDD in the region by type of waste. Source: the authors.

Cost ($/ton)						
Destination	**Class A Machine gun / Concrete**	**Reject**	**Excavated**	**Plaster**	**Wood**	**Iron**
Landfill A	10.18	14.81	11.11	13.70	13.70	13.70
Landfill B	12.41	13.70	12.41	14.82	14.81	14.81
Plant A	8.35	-	7.41	10.18	10.19	-
Plant B	4.63	-	4.63	-	8.33	8.33
Inert Landfill	6.48	-	5.56	7.41	7.41	-

For the simulation of waste management scenarios, based on cost reduction proposals, as it was verified that the works did not segregate waste by class, it was considered that 90% of the total waste is Class A, according to [18].
Works C, E and H were selected. The choice of these works followed the following criteria: work C was the only one that presented the PGRCC among the 18 public works visited and works E and H, presented high generation of tailings, however in different amounts of waste for the same project, that is, they are similar works with the same construction area. This shows that in addition to the topographic conditions of the land, the production system of the work can also alter the generation of waste.
Table 3 shows the simulation of the four scenarios referring to “Work C”, and figures 9 and 10 present the situation of the waste management of this work. In this work it was found that 66% of the waste was segregated and destined as Class A waste, while 34% of the waste was destined as waste, both to landfills.
As for the simulation of the scenarios related to work C, the situation of construction waste management was presented, where scenario 4 stands out, which presents a reduction of waste in the work by 30%. In scenarios 2, 3 and 4, the simulation shows that there would be no waste generation.

Table 3: Simulation of the scenarios - WORK C. Source: The authors.

Scenarios	Waste	
	Class A (tons)	Reject (tons)
1 – Real Situation	1.985,3	1.015,12
2 – Segregation of waste – Landfill	3.000,5	
3 – Segregation of waste – Plant	3.000,5	
4 – ISO 14.001	2.100,3	

The company prepared the PGRCC, started the process of segregating its waste in the first months of the work, but did not continue with the recommendations, which caused a large amount of waste in the work. There was the intention, but not the continuity in the process of attending the PGRCC until its conclusion.

Table 4 presents the simulation of costs in the 4 scenarios (Work C) mentioned referring to the generation of waste (Table 3), taking as a base the average cost of disposal to landfills and plants, through a survey of the final disposal costs. RCCD from companies in the region.

Table 4: Simulation of waste management costs in the scenarios - WORK C

Total Waste (Tons)			Costs of Transportation and Waste Destination (Total Value)			
Class A Waste	Reject	ISO 14001 Reduction 30%	Real Situation	Segregation + Landfill	Segregation + Plant	ISO 14001
1985	1015	2100	$ 36,901.66	$ 33,893.88	$ 19,447.41	$ 13,613.15

The company prepared the PGRCC, started the process of segregating its waste in the first months of the work, but did not continue with the recommendations, which caused a large amount of waste in the work. There was the intention, but not the continuity in the process of attending the PGRCC until its conclusion. It appears that the greatest relevance is the change in the destination of waste segregated in landfills ($ 36,901.66) for processing plants ($ 19,447.41), showing a reduction in the final cost of $ 17,454.25. It should be noted that the real situation, when compared to the ideal situation, that is, the situation in which the company meets [8] and destines the waste to a beneficiation plant, shows a reduction of $ 23,288.52 in the total cost of destination.

The simulation of the four scenarios for Work E is shown in Table 5, and Figure 4 shows the situation of the waste management of this work. The real situation of this work was the destination of 100% of the waste to landfills, as waste.

Work E did not prepare the PGRCC, it conditioned the waste without any segregation, which caused a large amount of waste in the work, increasing the costs with its destination.

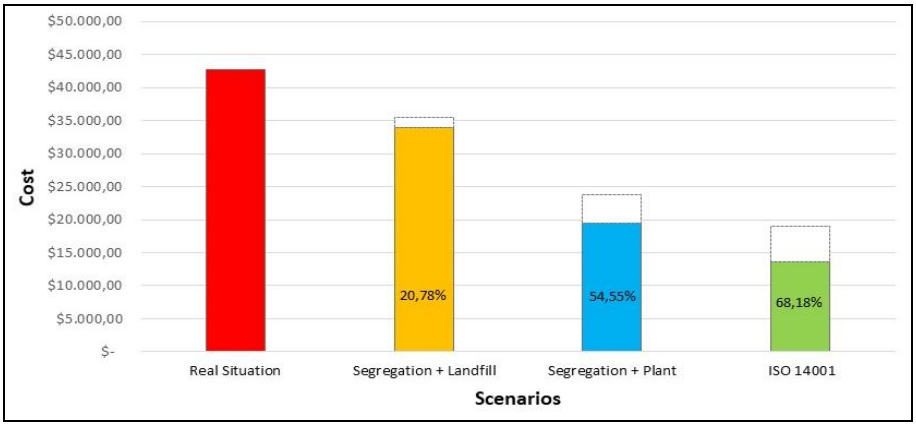

Fig 4: Simulation of the management cost of construction C.

Table 5: Simulation of the scenarios - WORK E.

Scenarios	Waste	
	Class A (tons)	Reject (tons)
1 – Real Situation		2.405,3
2 – Segregation of waste – Landfill	2.405,3	
3 – Segregation of waste – Plant	2.405,3	
4 – ISO 14.001	1.683,7	

Table 6 presents the simulation of costs in the 4 cited scenarios (Work E) referring to the generation of waste, taking as a base the average cost of disposal to landfills and plants, through a survey of the final disposal costs of RCCD from companies in the region. The company did not prepare the PGRCC and there was no waste segregation process, which generated a large amount of waste in the work.

Table 6: Simulation of waste management costs in the scenarios – Work E.

Total Waste (Tons)			Transport and Waste Destination Costs (Total Value)			
Class A waste	Reject	ISO 14001	Real Situation	Segregation + Landfill	Segregation + Plant	ISO 14001
0	2405	1684	$ 34,297.80	$ 27,170.98	$ 15,589.91	$ 10,912.94

As shown in Figure 5, it appears that the greatest relevance is the change in the destination of waste segregated in landfills ($ 27,170.00) for beneficiation plants ($ 15,589.91), showing a reduction in the final cost of $ 11,581.07. It is noteworthy that the real situation ($ 34,297.80), when compared to the ideal situation ($ 10.912.94,00), that is, a situation in which the company meets [8] and destines the waste to a beneficiation plant, presents a reduction of $ 23,384.86 in the total destination cost.

According to [19], the factors that cause waste in civil construction are associated with the variation of the project, selection of materials and construction methods. Therefore, it is common to have requests for changes in the project, resulting in rework and waste.

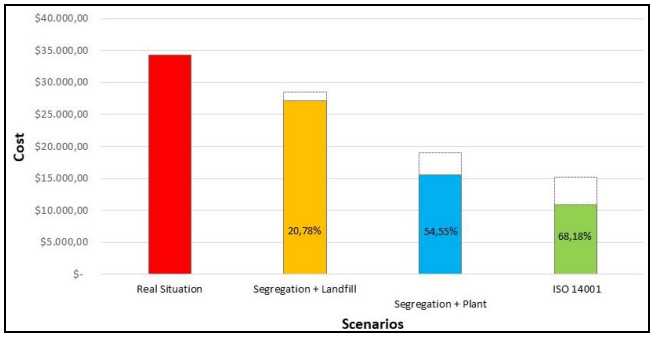

Fig 5: Simulation of the cost of managing construction E.

Table 7 shows the simulation of the four scenarios related to Work H. In this work, all the waste was destined as waste. The company did not present the PGRCC, packed the waste without segregation, generating an excessive number of tailings in the work and, consequently, presented a high cost of disposal. Nor did it present the tickets referring to the delivery of waste, despite the reported information that the waste was destined for landfills. Table 8 shows the simulation of costs in the 4 scenarios (Work H).

Table 7: Simulation of scenarios - WORK H.

Scenarios	Waste	
	Class A (tons)	Reject (tons)
1 – Real Situation		1.776,84
2 – Segregation of waste – Landfill	1.776,8	
3 – Segregation of waste – Plant	1.776,8	
4 – ISO 14.001	1.243,8	

It appears that the greatest relevance is the change in the destination of waste segregated in landfills ($ 20,071.71) to beneficiation plants ($ 11,516.56), presenting a reduction in the final cost of $ 25.336,42. It is noteworthy that the real situation ($ 25.336,42), when compared to the ideal situation ($ 8.061,59), that is, the situation in which the company meets [8] and destines the waste to a beneficiation plant, presents a reduction of $ 17,274.81 in the total destination cost.

Table 8: Simulation of waste management costs in the scenarios - WORK H.

Total Waste (Tons)			Transport and Waste Destination Costs (Total Value)			
Class A waste	Reject	ISO 14001	Real Situation	Segregation + Landfill	Segregation + Plant	ISO 14001
0	1777	1244	$ 25.336,42	$ 20.071,71	$ 11.516,56	$ 8.061,59

From the results obtained with the simulation, the best result is when the destination for landfills is replaced for the destination for processing plants. However, it is known that this destination is not always feasible, depending on the location of the work as well as the existence of processing plants in the vicinity of the municipality where the work is located.

Work C was the work of the largest construction and waste generation area. However, it did not obtain the highest percentage of cost reduction (63.11%) due to the fact that part of the waste was sent as Class A at the beginning of the work, and part of the waste as waste during construction. If all waste generated as waste was simulated, an even greater reduction in management costs would be obtained (68.2%).

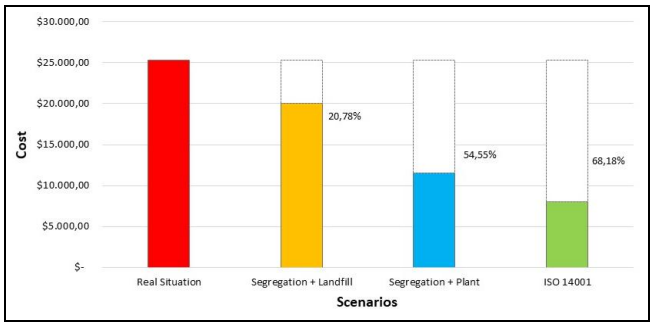

Fig 6: Simulation of the cost of managing the work H.

It is also verified that the work E presented greater rejection in relation to work H, despite having the same construction area and, consequently, a higher destination cost.

The results of Scenario 3 (segregation + plant) show that it is possible to reduce management costs by up to 54.5%, based on segregation and destination in beneficiation plants. With the application of [8], it is also possible to achieve a reduction of up to 68.2% in waste disposal costs.

It is emphasized that the ISO standard is optional, but that in the private sector this certification is relevant and significantly influences the company's positive reputation. However, as a requirement for technical qualification in a public tender, there is no requirement that the company be certified by ISO or any other type of standardization, with the risk of representing an undue restriction on the right to participate in the bidding.

It was observed, then, in the light of the jurisprudence of the control body for the execution of public works, that the standards listed in the ISO standards end up influencing public contracts, with the requirement of the same in competitions. Although the Brazilian law, which deals with bids, considers that there is no legal requirement for the public entity to require ISO standards as a technical qualification requirement, the requirement for this certification is admitted in the proposal's judgment phase, according to the case law related to the matter.

4. Conclusions

From the results obtained, it was possible to glimpse the benefits with the proper implementation of PGRCC in public works. The possibility of analyzing the main advantages of this implementation was demonstrated, by

mitigating the environmental impacts for future societies and contributing directly to sustainable development.

With visits to construction sites, it was found that there was no adequate inspection by public bodies, which would encourage the adoption of more sustainable practices in waste management. It was also possible to verify the scarcity of alternatives for proper disposal of waste in works far from the Metropolitan Region of Recife, where there are few landfills, and RCCD processing plants.

From the analysis of data collected from RCCD transport and final disposal costs, it can be concluded that, when there is no segregation of waste, in the situation where it is accumulated as waste, the cost of waste disposal is considerably increased. This could be verified in the public works visited, where the destination for landfills generated an increase of 57% when compared to the destination for processing plants.

Of the 03 scenarios presented, the following waste disposal costs stand out:

Work C: 8.15% reduction, when segregation and disposal to landfills occurs; 47.30%, when segregation and destination to beneficiation plants occurs; and reduction of 63.11%, when there is a Waste Management with reference to [8].

Works E and H: when segregation occurs for disposal in landfills, there is a reduction in the destination of waste of 20.78%; when the destination is for processing plants, the reduction is 54.55%; and when there is waste management at the construction site with reference to [8], the reduction in destination costs is 68.18%.

Finally, as in the case of private works, public works must carry out a greater control of the final destination of the residues, guaranteeing their traceability through the Waste Transport Control (CTR) and weighing tickets, as well as seeking a lower-cost disposal unit, such as inert landfills and processing plants, for Class A waste

The simulation of RCCD management costs points to the need to modify the bidding processes for construction / renovation works in the State, so that the works are required to implement an environmental management system, and reduce costs with transportation and destination of waste.

In the construction of public environmental policies, conditions that favor the RCCD recycling market must be included, encouraging new companies to emerge and operate in more distant areas of the State.

In the private works, it was evidenced that those that have [8] environmental certification, modified the guidelines of their activities especially in the construction sites, due to the apparent significant reduction in the generation of this waste. It was demonstrated through an estimation that the costs for implementing the [8] recommendations for works C, D, E and, H represented a percentage that can vary from 2% to 4% of the cost of these works.

Thus, it is concluded that it is essential to prepare a PGRCC in all engineering works, whether public or private, with the prioritization of waste forwarding (RCCD), whenever possible, to processing plants and, in the impossibility of this form of destination, forwarding to regularized landfills in the region, preceded, of course, by the segregation of residues at the construction sites, as directed by CONAMA resolutions. Thus, the importance of satisfactory implementation of the PGRCC is evidenced, as the most effective tool for the implementation of the Companies' Environmental Management Program, and of guarantee to reduce costs with the RCCD.

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