

## Waste Management at Construction Sites in the Municipality of Manaus, Amazonas, Brazil: Characterization of the Current Situation

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### Abstract

This research aimed the characterization of the current production of construction waste in the city of Manaus, Amazonas, Brazil, and its impacts on the environment of the Amazon Region. The significance of this research work is to contribute to the improvement of the environmental management of waste in the construction sites of the city of Manaus, with the aim of preserving the Amazonian environment. This research also sought to characterize the existing problems in the environmental management of construction waste in four construction sites, with areas greater than 9,000 square meters. The methodology adopted was based on the application of an in situ survey in four construction sites in the city of Manaus, Amazonas, Brazil, administered by three companies representing the construction sector in the Amazon Region. Data were collected at the construction sites in question in the second half of 2018, regarding the types of construction waste produced, respective volumes, destination and associated costs. A comparison was made between constructed areas and volumes of waste produced, characterizing the current situation of construction waste production in the city of Manaus. After analysing the results obtained, it was concluded that due to the high associated costs, companies avoid recycling construction waste, and opt to discharge it in municipal or clandestine landfills, with significant environmental impacts. For this reason, a greater participation of the Public Administration is recommended regarding the adequate management of waste in construction sites, namely offering financial incentives for companies to promote the recycling and reuse of construction waste.



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## Introduction

Civil construction has its origins in artisanal works that have been progressing through the ages, therefore, the generation of waste in construction is considered normal by workers in the area, but all agree that there is a need to reduce the volumes of these wastes at the construction sites. This reduction in waste volumes is an urgent need for companies to "rethink progress", often choosing to invest in "eco-projects", which aim to minimize and reuse construction waste.<sup>1</sup> The European Commission has already defined that by 2020 a 70% reduction in construction waste should be achieved, on the basis of recycling,<sup>2</sup> which demonstrates the importance of the subject for the Society. China is also concerned about the reduction of construction waste volumes, given the increasing uncontrolled urbanization that consumes the planet's natural resources. Therefore, modelling studies have been carried out to reduce waste during the design phase and the implementation phase of construction work, reaching results of 40.63% reduction in the generation of waste<sup>3</sup>. Adequate management of waste is the most important factor in reducing the volumes generated at construction sites, since reuse, recycling and disposal policies depend directly on the management practices. The European construction sector produces 820 million t of construction and demolition waste (CDW) every year, leading to the need of creating strategies and guidelines for the implementation of good practices in the management of construction waste<sup>4</sup>. The best practice definition involved consideration of the entire value chain of the construction sector, and follow a sequence along the chain. In the first instance, best practices address the definition of management strategies in a preconstruction phase (project inception and design), then techniques around prevention and collection are proposed

in a second category, and re-use, treatment and material recovery practices are discussed in the third and fourth category.<sup>4</sup> These good practices can be applied in the city of Manaus, Amazonas, Brazil, since it is surrounded by the Amazon Rainforest, a world heritage site, which must be preserved as a biodiversity richness for all humanity. The poor management of construction waste in the city of Manaus affects the Amazon Forest environment, justifying the importance of the present study. Similar studies are reported in China and Brazil: in the city of Hangzhou a study was carried out<sup>5</sup> during the years 2007 to 2016 on the solid waste generated in that city and its serious consequences for the environment, while in the municipality of Sobral, Ceará, a study<sup>6</sup> on construction waste production was also carried out, and the results demonstrated the relationship between municipal waste generation and the degradation of the environment in its surroundings. Currently the civil society is no more accepting companies that do not have environmental responsibility,<sup>7</sup> because CDW affect the environment in multiple ways: they contaminate soil, water and air, and change the natural environment, among other ecosystem degradations.<sup>8</sup> In order to change the Environmental Policy of the civil construction sector, first it is necessary to change individual's recycling attitude and behaviour<sup>9</sup>. Environmental education at the construction site is very important to change the individual attitude of each construction worker, which will contribute to a better environmental management of construction companies. The reducing and reusing of CDW should be carried out by stakeholders and professionals in building design and construction, and the implementation of the Circular Economy Model clearly improves CDW management in the construction industry.<sup>17</sup> The Circular Economy Model is not yet implemented



**Fig.1: Location of the city of Manaus on planet Earth**

in Brazil, and therefore there is a large amount of waste generated in the construction industry that is indiscriminately disposed in landfills. Similar environmental and economic problems regarding CDW have been reported in Africa, Nigeria,<sup>18</sup> and in Saudi Arabia.<sup>19</sup> The present research, regarding the generation of construction waste in the city of Manaus, located in the center of the Amazon Forest, has the main objective of investigating the final destination of waste in the construction sites of the city, focusing the costs generated with the management of these wastes.

**Materials and Methods**

The methodology adopted was based on on-site visits and the application of on-site surveys at four construction sites in the city of Manaus, Amazonas, Brazil, with a construction area of over 9,000 square meters, managed by three companies representing the construction sector in the Amazon Region. The city of Manaus has a population of 2,145, 444 people<sup>10</sup> and is located in the geographic coordinates 3 ° 6 '0 "S, 60 ° 1' 0" W, according to Fig. 1:

The main objective of the present research was to identify best practices to increase waste prevention,

waste minimization and waste recycling, according to a case study carried out in Spain.<sup>11</sup> Data were collected through technical visits to the four construction sites under study during the second half of 2018, classifying the types of waste generated, their respective volumes and destination. After the costs and volumes analysis, a comparison was made between constructed areas and volumes of waste produced, characterizing the current situation of construction waste production in the city of Manaus. The survey was carried out using a spreadsheet to collect information, namely: construction area, work phase, waste volume, types of waste generated in the work, financial cost with waste destination and transport from construction sites.<sup>12</sup> The surveyed construction sites included two thermoelectric plants and two residential buildings. The methodology applied in the construction sites of the thermoelectric power plants was based on studies carried out in India<sup>13</sup> regarding construction sites of nuclear power plants, with the aim of identifying causes of waste generation and proposing measures to minimize waste through adequate management practices.<sup>14</sup>

**Results and Discussion**

The research was carried out in four construction sites, located in the municipality of Manaus,



**Fig.2: Construction Site of a Thermoelectric Plant**



**Fig.3: Construction site for residential buildings**



**Fig.4: Wooden bins for the collection of construction waste**

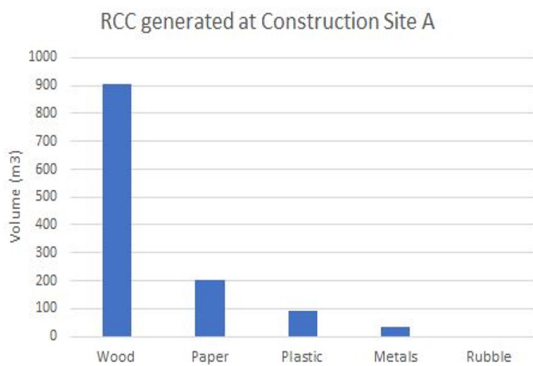
Amazonas, Brazil, in the period from 2014 to 2018, during the execution of the works under study. Two of the construction sites were related with the construction of thermoelectric power plants, and the other two with the construction of residential buildings. Fig. 2: shows the construction site of one of the thermoelectric power plants and Fig. 3: shows the construction site for the construction of residential buildings.

The environmental permits of the construction sites studied in this research were granted by the Institute of Environmental Protection of the Amazon (IPAAM), which requires the elaboration and execution of environmental programs by the construction companies. Similar environmental policy is adopted by the European Commission to grant environmental permits in Europe,<sup>15</sup> and by the Environmental Protection Department (EPD) in Hong Kong.<sup>16</sup>

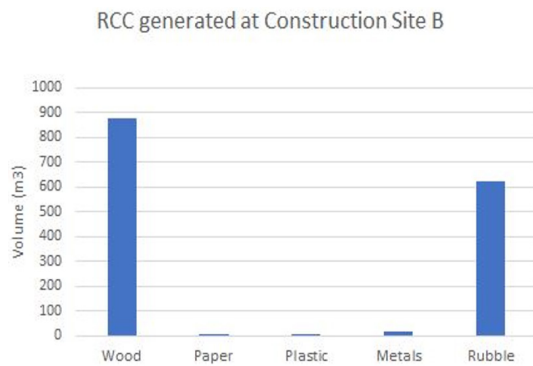
At the construction sites, waste deposits were built through wooden bays to store different types of waste, duly identified with colours and names, as shown in Fig. 4:, but each worker should have an attitude to assist in the use of these construction waste deposits, according with environmental education given in construction site.

**Cost Incurred With Waste Management In The Construction Sites**

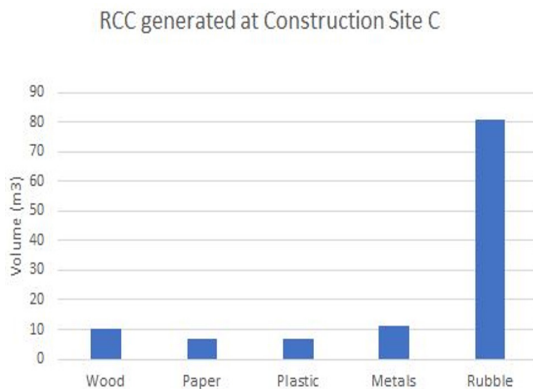
At construction site A, with 57,000.00 m<sup>2</sup> of constructed area of a thermoelectric plant, the volume of waste produced during the entire construction period was 1,234.00 m<sup>3</sup>, with a total cost of waste management reaching US\$ 13,262.00. The main waste produced in this construction site were Wood (V = 73.34%), Paper / Cardboard (V = 16.29%), Plastic (V = 7.62%), Metals (V = 2.59%) and Rubble (V = 0.16%). All waste



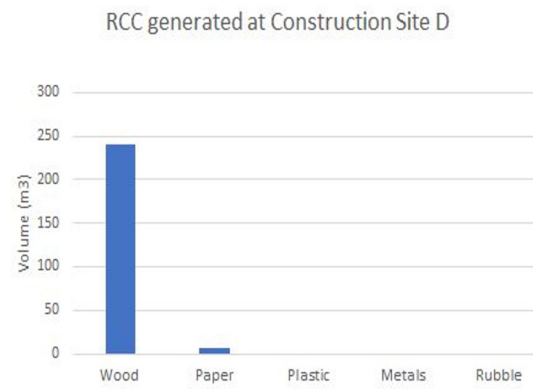
**Fig.5: Civil Construction Waste generated at Construction Site A**



**Fig.6: Civil Construction Waste generated at Construction Site B**



**Fig.7: Civil Construction Waste generated in Construction Site C**



**Fig.8: Civil Construction Waste generated at Construction Site D**

(100%) generated in this construction site were discarded by outsourced companies with final destination for recycling, incineration or reuse.

At construction site B, with 12,381.00 m<sup>2</sup> of constructed area of residential buildings, the volume of waste produced during the entire construction period was 893.00 m<sup>3</sup>, with a total cost of waste management reaching US\$ 13,805.00. The main waste produced in construction site B were Wood (V = 98.43%), Paper (V = 0.78%), Plastic (V = 0.34%), Rubble (V = 0.22%) and Metal (V = 0.22%). The waste generated in this construction site had its final destination carried out by the company itself, where 59% were destined for companies that work with recycling, 1% for companies specialized in waste treatment and 40% were destined to the municipal landfill.

At construction site C, with 10,480.00 m<sup>2</sup> of constructed area of residential buildings, by July 2018 the volume of waste produced from the beginning to the current phase of construction was 661.00 m<sup>3</sup>, with a total cost of waste management of US\$ 1,110.00. The waste produced in construction site C, so far, since the work is still underway, were Wood (V = 1.51%), Paper (V = 1.21%), Plastic (V = 0.76%), Metals (V = 2.27%) and Rubble (V = 94.25%). The waste generated in this construction site had its final destination carried out by the company itself, where 38.58% were destined

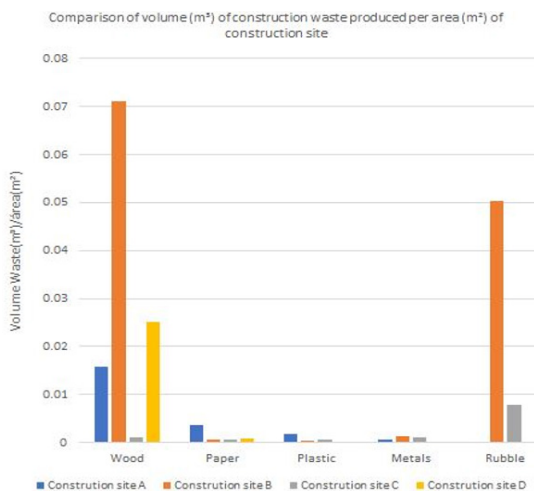
to companies that work with recycling and 61.42% were destined to the municipal landfill.

At construction site D, with 9,527.00 m<sup>2</sup> of constructed area of a thermoelectric plant, by September 2018 the volume of waste produced from the beginning to the current phase of construction was 346.00 m<sup>3</sup>, with a total cost of waste management of US\$ 2,191.00. The waste produced in construction site D, so far, since the work is still in progress, were Wood (V = 69.36%), Paper / Cardboard (V = 2.02%), Plastic (V = 2.02%), Metals (V = 3.18%) and Rubble (V = 23.41%). The waste generated at this construction site had its final destination with 100.00% destined to the municipal landfill.

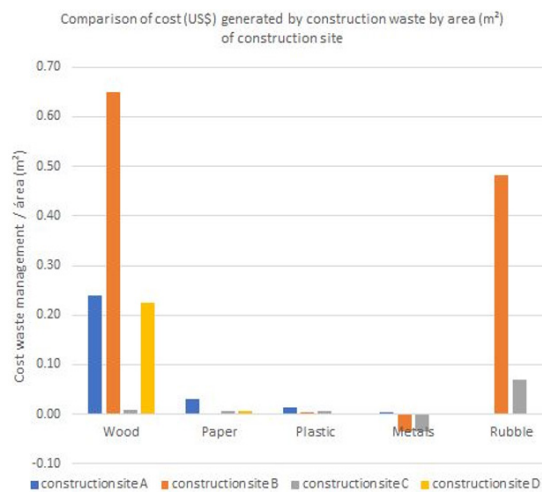
Table 2: summarizes the cost data for waste management at each site under investigation.

Table 3: shows the comparison between the four construction sites, where Alpha Company is responsible for the development of construction site A (Thermoelectric), Betha Company is responsible for the developments of construction sites B (residential buildings) and C (residential buildings) and the Omega Company is responsible for the D (Thermoelectric) venture.

Alpha Company recycled construction waste, but contracted three outsourcing companies, not



**Fig.9: Comparison of waste produced by construction site area**



**Fig.10: Comparison of costs with construction waste management (US\$) by area (m²) of construction site**

legalized to public agencies, and had the highest cost with the waste from the construction site. The Betha and Omega companies destined part of the waste in the municipal landfill, exposing the environment to contaminations and negative environmental impacts, but did not hire outsourcing companies and had the lowest cost with the waste from the construction site.

The collected data shows that the main waste produced in the construction sites under study were wood, paper, rubble, plastic and metal.

Analysing the waste generated in construction site A and construction site D, referring to the construction of two Thermoelectric Plants, wood and paper represent the most prominent waste. Construction

**Table 1: Summary of construction site data**

Construction Site	Type of Work	Work Phase	Built Area (m <sup>2</sup> )	Volume of waste generated (m <sup>3</sup> )
A	Thermoelectric power plant	Completed (100%)	57,000.00	1,234
B	Residential buildings	Completed (100%)	12,381.00	893
C	Residential buildings	50%	10,430.00	661
D	Thermoelectric power plant	70%	9,527.00	346

**Table 2: Summary of data on waste costs per construction site**

Construction site	waste for recycling	waste for municipal landfills	Cost estimate with waste (US\$)
A	100%	0%	13,262.00
B	60%	40%	13,805.00
C	38.58%	61.42%	1,110.00
D	2.90%	97.00%	2,191.00

**Table 3: Comparison between the four construction sites**

Construction site	Name of the company responsible for the development	Outsourced companies for waste disposal	Waste disposal in landfill	Distance to landfill (km)
A	Company Alpha	3	-	-
B	Company Betha	0	Landfill Region 1	23
C	Company Betha	0	Landfill Region 1	5
D	Company Omega	0	Landfill Region 2	3

site A showed more planned works regarding waste management, including recycling technology. The smaller amount of paper waste generated in site D is justified because the work is still in progress, while the work in site A is already completed.

Analysing the waste generated in construction sites B and C, referring to the construction of two residential buildings, wood and rubble are also the most prominent waste produced. The large amount of rubble produced in construction site C is explained by the artisanal processes that still predominate in the construction techniques of the Amazon Region. The generation of large amounts of wood waste in construction site B is typical of the Amazon Region due to the proximity of the forest.

The graphs in Fig.9: and 10 show five types of construction waste - wood, paper, plastic, metals and rubble - whose volumes (m<sup>3</sup>) are compared to the construction areas (m<sup>2</sup>) of the four sites, A, B, C and D.

It was found that in the construction sites of thermoelectric power plants (A and D) no waste of bricks and metals were detected, due to the technology applied in the design of these works., However, in the construction sites of residential buildings (B and C) the amount of rubble produced is significant, due to the artisanal form of construction used in these sites. The results presented in Fig.9: show that construction sites B and C had a financial gain in the commercialization of metal waste. The high cost generated in the thermoelectric plant A was due to the management of wood and paper waste, since these materials were 100% recycled. The collected data shows that the amount of plastic waste generated in the construction sites under study is negligible, both in volume / m<sup>2</sup> and cost / m<sup>2</sup>.

Table 4: shows a comparison between the results of waste generated at construction sites A and D, corresponding to thermoelectric plants, and construction sites B and C, corresponding to the construction of residential buildings, with other studies: Bravo *et al.*, (2019)<sup>8</sup> report a case study

**Table 4: Comparison between the results found and the studies of other authors<sup>8,13</sup>.**

Construction site	Construction and demolition waste (CDW)	Waste reported in the present study (m <sup>3</sup> /m <sup>2</sup> )	Cost impact Waste management in the present study (% of the total cost)	Waste reported by Bravo <i>et al.</i> , (2019) (m <sup>3</sup> /m <sup>2</sup> )	Cost impact of waste management reported by Seethapathy & Henderson (2017) (% of the total cost)
A and D	Wood	- 0.03 to 0.07	0.03 to 0.04	-	
	Paper	- 0.016 to 0.019	0.0013 to 0.11	-	
	Plastic	- 0.008 to 0.009	0.000 to 0.003	-	
	Rubble	-	0	-	0.007 to 0.008
B and C	Wood	0.0009 to 0.07	-	0.011	-
	Paper	0.0006 to 0.0007	-	0.001	-
	Plastic	0.0004 to 0.0007	-	0.003	-
	Rubble	0.007 to 0.05	-	0.079	-

regarding the production of CDW in residential buildings in Chile, and Seethapathy & Henderson (2017)<sup>13</sup> discuss waste management procedures in the construction of thermo power plants in India.

Table 4: shows that the values found in this study for the cost impact of waste management at the construction sites of thermoelectric plants are at the same level as those reported in a the case study of in Indian power plants.<sup>13</sup> Regarding the generation of construction waste in residential construction sites, the volumes found in the present study are considerably less than those reported in the case study carried out in Chile,<sup>9</sup> with the exception of rubble waste.

### Conclusions

The results obtained in this study show that

- Most construction companies discard all or part of their waste in municipal or clandestine landfills, and for some construction companies the final destination of their waste is unknown. The main reason for this situation is the high cost associated with waste recycling, which makes constructions companies opt for alternative ways of waste disposal, for free or at least at much lower costs. The Law n<sup>o</sup> 4,457/2017<sup>20</sup> deals with the Environmental Policy in Amazonas, however, there is still no organized system for the collection, treatment, disposal or recycling of construction and demolition waste (CDW), which makes it difficult to supervise the disposal of waste in the city of Manaus.
- Among the waste produced at construction sites, wood and paper were distinguished by the quantity generated and the cost involved in the disposal of these materials. These results show the importance of adequate public policies regarding the valorisation of these construction waste, which are being discarded in spite of their high reuse and recycling potential. In the city of Manaus, most of these wood and paper residues are disposed of in brick factories to burn ceramic products. However, it is a low value-added activity with little technological sophistication. The Environmental Policy established in Law

4.457<sup>20</sup> leaves a gap on a better use in the recycling of these types of construction waste.

- The waste of plastic represented little quantity and low management costs in the construction sites under study. Specialized companies on solid waste management techniques are able to adequately recycle this type of waste or dispose it in a sustainable way. The metal waste generated in the construction sites is commercialized and therefore adequately recycled, and this represents financial gains for the companies.
- Municipal landfills end up being overloaded with waste, which could be reused or recycled, and this affects the environment around the municipality. At the moment, in the city of Manaus only metal waste originated from the construction and demolition has commercial value. The implementation of an organized system of collection, segregation and recycling would add value for the commercialization and recycling of non-metallic wastes in the city of Manaus.
- There is a clear need for the development of adequate public policies regarding construction waste management, including financial incentives for companies that are willing to manage their waste sustainably. Public administration must assume responsibilities by the environmental problems generated by the inadequate disposal of construction waste in landfills.

As suggestion for future works in the area of construction waste management, the application of waste management models like Circular Construction should be considered. This model is being explored in Europe,<sup>15</sup> aiming to be an economic solution with environmental improvements for construction companies. It involves a plan of education actions directed and applied along the associated chain of construction waste, ranging from the project phase to the conclusion of the construction work, considering the prevention of waste production, and promoting its recovery and valorisation through incorporation in the construction industry. In Brazil, there is still no Environmental Policy for implementing a Circular Economy System. Nevertheless, the



results obtained in this paper highlight the economic and environmental potential of using the Circular Economy Systems in the management of waste generated in the construction sector, justifying the need for further research in this topic. For example,

the possibility of using new cellular application technologies to enhance the correct environmental management of construction and demolition waste is currently under study by our research group.

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