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Estimated cost of transporting construction and demolition waste in Recife, Pernambuco, Brazil

Estimativa de custo de transporte de resíduos da construção e demolição no município de Recife, Pernambuco, Brasil.

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Abstract

The construction sector has grown significantly in the last decade, also expanding the environmental damage inherent to the activity, especially the production of solid waste, with an annual estimate of over 760,000 tons for the municipality of Recife. Proper disposal of construction and demolition waste (RCD) should be technically and economically feasible, where the collection and disposal process results in an additional cost for any building work, and transportation is a relevant stage of this, where its value is determined by variables such as distance, traffic and access road conditions. This study aims to analyze the variation in the cost of transportation of RCD in Recife, starting with a survey of the destination points on the CPRH page, delimiting three coverage areas, and calculating the minimum mean transport distances (DMT). and maximum in the demarcated regions, being observed the variations of the DMTs in each area, through the Tukey test. As a price reference, the SINAPI table was used, calculating the minimum and maximum costs for each area. Finally, a considerable variation in the minimum cost was observed in one of the areas, while no relevant disparities in the maximum price were detected.

Keywords: Construction Waste; Solid Waste; Transportation Cost; SINAPI

Resumo

O setor da construção civil cresceu significativamente na última década, também se expandindo os danos ambientais inerentes à atividade, destacando-se a produção de resíduos sólidos, sendo estimado um quantitativo anual superior a 760.000 toneladas para o município de Recife. O correto descarte dos resíduos da construção e demolição (RCD) deverá ser viável técnica e economicamente, onde o processo de coleta e destinação resulta em custo adicional para qualquer obra em edificação, sendo o transporte uma etapa relevante deste, onde seu valor é determinado por variáveis como distância, tráfego e condições das vias de acesso. O presente estudo visa analisar a variação do custo de transporte de RCD no Recife, iniciando-se com um levantamento dos pontos de destinação na página da CPRH, delimitando-se três áreas de abrangência, sendo calculadas as distâncias médias de transporte (DMT) mínima e máxima nas regiões demarcadas, sendo observadas a variações das DMTs em cada área, através do teste de Tukey. Como referencial de preço, foi

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empregada a tabela do SINAPI, calculando-se os custos mínimos e máximos para cada área. Por fim, observou-se uma variação considerável do custo mínimo em uma das áreas, enquanto não foram detectadas disparidades relevantes para o preço máximo.

Palavras-chave: Resíduos da Construção; Resíduos Sólidos; Custo de Transporte; SINAPI

1 Introduction

The construction industry has expanded considerably over the past decade, with steady growth from 2008 to 2013, accounting for 4.26% of Gross Value Added in the second quarter of 2019, as reported by the Brazilian Chamber of Construction Industry (CBIC, 2019). According to data from the Annual Construction Industry Survey (PAIC), prepared by the Brazilian Institute of Geography and Statistics (IBGE), between 1990 and 2017, the number of people employed in companies related to the mentioned field of activity continuously increased from 2005 to 2013, reaching a cumulative increase of over 100% at its peak, showing the development of the sector in the specified period. The increased demand for works and services related to the branch also resulted in an increase in the volume of waste produced. In the municipality of Recife, the annual generation estimate is over 760,000 tons (PERNAMBUCO, 2018).

Civil construction is one of the major causes of environmental damage today, both indirectly, demanding various sectors of industry for the production of its inputs from various sources, in addition to the extraction of non-renewable natural resources; directly, through the consumption of water, energy, the emission of pollutants and the generation of waste during the execution of the work, among others. The extraction of alluvial sediments to obtain inert materials used in works, such as sand and gravel, is responsible for modifying the river profile and its balance, introducing several environmental problems (BRASILEIRO; MATOS, 2015). The damage resulting from the inappropriate disposal of Civil Construction Waste (CCW) arises through siltation of water bodies, obstruction of drainage systems, attraction of vectors due to the accumulation of other types of waste at storage sites (VALENÇA; MELO; WANDERLEY, 2008). One solution to the reduction of environmental impacts from Construction and Demolition Waste (CDW) generation would be its recycling which, according to Schneider and Phillipi Jr. (2004), decreases the required volume of final disposal as well as the pressure on natural resources.

To perform both the disposal of CCW in landfills and its destination in a recycling plant, proof of its technical, financial and feasibility is required. Currently, the responsibility of the

CDW generator covers the collection, management, transportation and final disposal (SANTOS; POMPEU, 2014). Such procedures shall be in accordance with Resolution no. 307 of the National Environment Council (CONAMA), which classifies the RCC into four groups, as well as establishes guidelines for the elaboration of the Municipal Plan of Waste Management of Civil Construction (PMGRCC) and of the Civil Construction Waste Management Plan (PGRCC), to be prepared by the large generators, also establishing the responsibility of the municipal government in the analysis of projects and activities not framed by the environmental licensing legislation (BRASIL, 2002). In Recife, the PGRCC guidelines are set by Law No. 17,072 (RECIFE, 2005), while the transportation and disposal of RCC are governed by Law No. 16,377 (RECIFE, 1998), regulated by Decree No. 18,082 (RECIFE, 1998). The whole process for the proper treatment of the CDW implies an additional cost in the execution of the work, which includes operations from its placement in the construction site, to its disposal in a landfill or recycling plant, being the transport an important activity for the viability of the implantation of any undertaking related to solid waste disposal, where it depends on the distance from the generating center, the traffic and the conditions of the access roads to the site. As an example, we cite the study by Souza and D'Agosto (2013), for tire waste generated in the city of Rio de Janeiro, which found that the transportation cost represents approximately 76% of the logistics cost and 50% of its total processing cost.

This paper aims to analyze the variation of the cost of transport of CDW in the city of Recife, from the waste generator to its receiver.

2 Materials and Methods

A quantitative research approach was used, which according to Zanella (2011) is characterized by the use of statistical tools in the collection and / or treatment of data in order to measure relationships between variables.

First, a survey was carried out on the page of the State Environmental Agency (CPRH) of the state of Pernambuco, of the projects related to type 3, related to transportation, treatment and disposal of waste, located in the metropolitan region of Recife.

Subsequently, a check was made on the project's page regarding the receipt of CDW. Landfills and recycling plants were considered. It is noteworthy that there are eleven ecoestations distributed by the municipality, implemented by the Recife City Hall, provided for in Law No. 17,072 (RECIFE, 2005) and regulated by Decree No. 27,399 (RECIFE, 2013) that receive only waste from small works, those with generation daily maximum of $1m^3$. Therefore, they were not considered for the purpose of calculating the average transport distance.

Subsequently, the coverage regions of each receiving site were delimited through the average perpendicular of the linear distance of each point. Then the Average Transport Distance (ATD) from the most unfavorable points of each area was calculated, using the Google Earth software, for the coverage area and the furthest for disposal of CDW. The location of the coverage points was obtained from their address on the CPRH website. The points of greatest linear distance to the CCW delivery sites in each delimited region were considered unfavorable, and were obtained through the map extracted from the Recife Geographic Information System (ESIG).

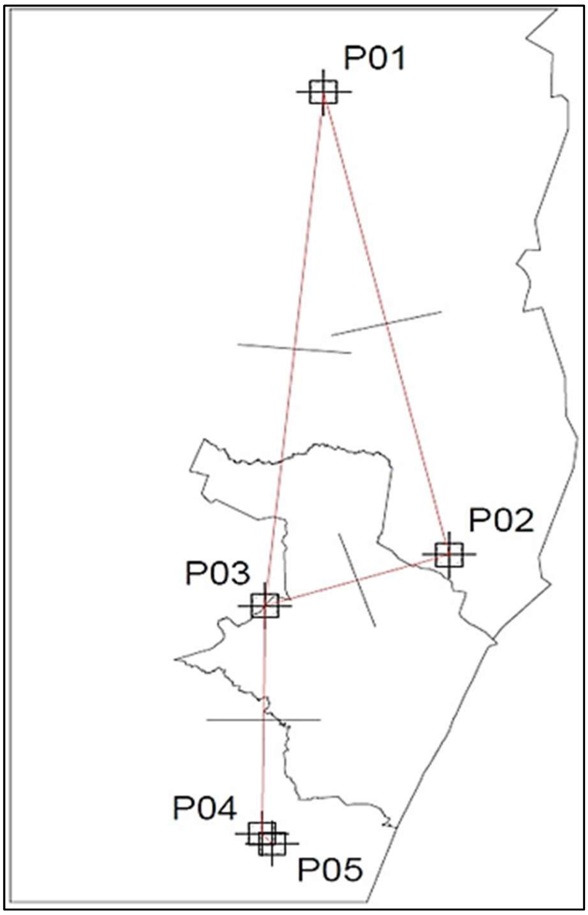
The variation of the average ATDs in the three areas was analyzed by Tukey test, using the Sisvar software. According to Oliveira (2008), this test is based on the total amplitude studied and can be applied to compare contrasts between two treatment averages, being accurate and simple to use when there is the same amount of repetitions for all treatments. Callegari-Jacques (2007) also points out that Tukey's analysis aims to identify which means, taken two by two, differ significantly from each other and that it protects the tests from an increase in significance due to the large number of comparisons made.

As a price reference, we used documentary data from the tables of the National System of Costs and Indexes of Civil Construction (SINAPI), for the transportation service with dump truck on paved road, in units t x km and m^3 x km and data base from September 2019, for the state of Pernambuco, with exempt social charges. The type of information mentioned above can be classified as internal secondary data, found with companies, and external, referring to published references and completed research (ZANELLA, 2011). Vergara (1990) also states that documentary research can use data belonging to public and private agencies of any nature, kept inside.

3 Results and Discussion

Five sites were identified for the final disposal of debris generated in the city, being processing plants for recycling, with two of them operating in conjunction with landfills. Three coverage areas were defined, named A01, A02 and A03, through the intersections between the perpendiculars located in half of the line segments between the final disposition points, according to figures 1 and 2, being adapted from the map extracted from ESIG.

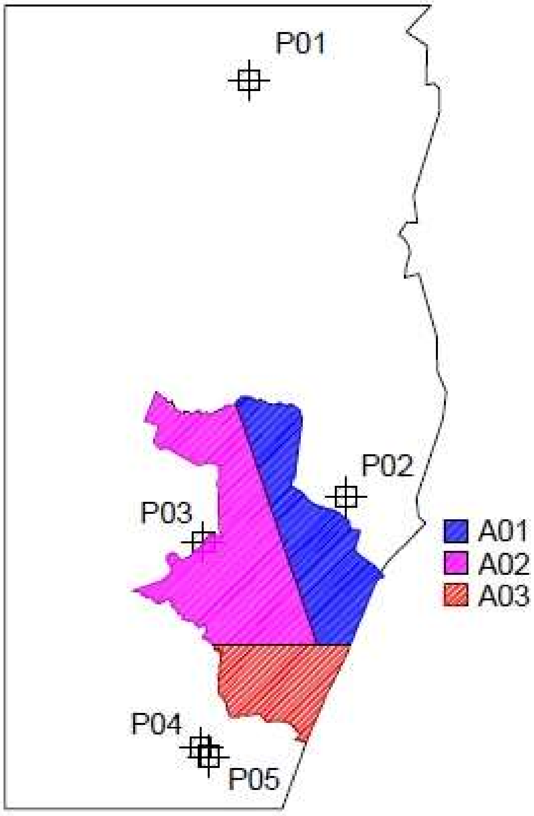
Figure 1 - Intersections between perpendiculars for the formation of areas



Source: Adapted from Recife (2019)

(Continue...)

Figure 2 - RCC coverage areas and destination points



Source: Adapted from Recife (2019)

Subsequently, the most unfavorable points of each area and the locations of destination of coverage and furthest from each area were determined, according to table 1.

Table 1 - Unfavorable points and nearest and farthest places for CCW disposal

Coverage Areas	**Coordinates Unfavorable Points (UTM)**		**Coverage Location**	**Farthest Location**
	X	**Y**		
A01	290554.9324	9105072.7117	P02	P01
A02	290554.9324	9105072.7117	P03	P01
A03	292881.1118	9105070.0492	P04/P05	P01

Source: Prepared by the author

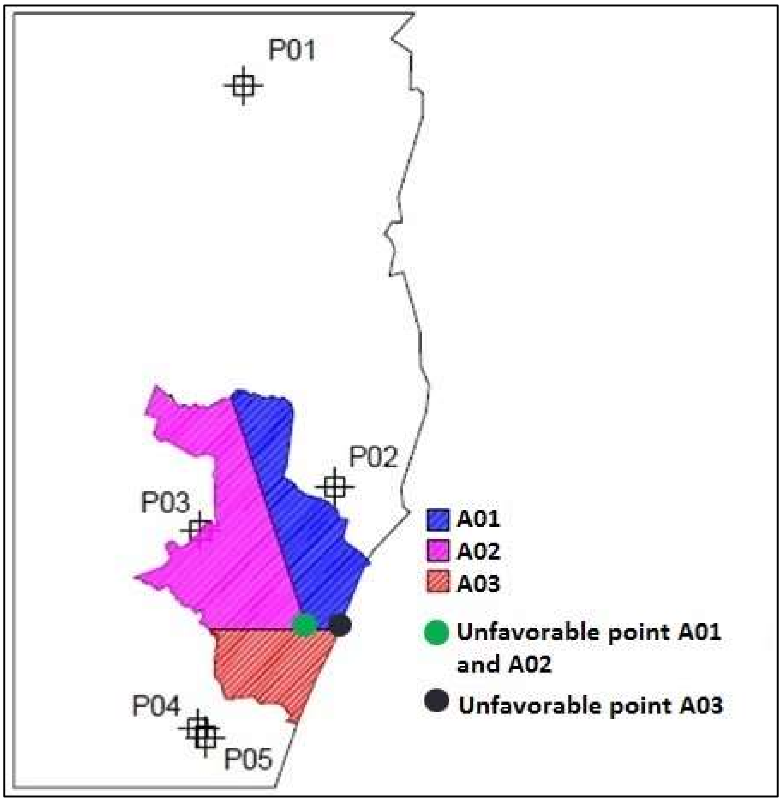
With the above data, we calculated the minimum and maximum ATDs of each region, which consists of the average route between each most unfavorable point to the coverage areas and the farthest, respectively, for disposal of the CCW, as indicated by the Google Earth software, being the same described in table 2 and indicated in figure 3.

Table 2 – Minimum and maximum AMT for each area

Coverage Areas	Coverage Location	Farthest Location	Minimum ATD (Km)	Maximum ATD (Km)
A01	P02	P01	16,20	56,60
A02	P03	P01	16,27	56,60
A03	P04/P05	P01	23,87	55,85

Source: Prepared by the author

Figure 3 - Unfavorable points in relation to RCC coverage areas and destination points



Source: Adapted from Recife (2019)

The Tukey test was performed with a significance level of 5% and three repetitions for minimum ATD and two for maximum ATD, as indicated by Google Earth. The minimum ATDs showed significant difference only for area A03 in relation to the others, while the maximum ATDs showed no significant difference between them. The results are shown in table 3.

Table 3 - Tukey test for the minimum and maximum ATDs of each area

Coverage Areas	**Minimum ATD (Km)**	**Maximum ATD (Km)**
A01	16.200000 a1	56.600000 a1
A02	16.273333 a1	56.600000 a1
A03	23.866667 a2	55.850000 a1

Source: Prepared by the author

To calculate the unit price, the items taken from the SINAPI table of September / 2019, 97914 and 97915 for their determination in cubic meters (m^3), as well as 97018 and 97919 for their definition in tons (t), were considered. The same ones refer to transport with a tipper truck on a paved urban road for distances up to 30 km and beyond, according to table 4.

Table 4 - Price reference used

SINAPI Code	**Description**	**Unit**	**Unit Price**
97914	Transport with 6 m^3 dump truck, on paved urban road, ATD up to 30 km	m^3 x km	R$ 1,69
97915	Transport with 6 m^3 dump truck, on paved urban road, ATD over 30 km	m^3 x km	R$ 1,20
97918	Transport with 6 m^3 dump truck, on paved urban road, ATD up to 30 km	t x km	R$ 1,13
97919	Transport with 6 m^3 dump truck, on paved urban road, ATD over 30 km	t x km	R$ 0,80

Source: Prepared by the author

Finally, by multiplying the above-mentioned values by the DMTs, we find the minimum and maximum prices for each coverage area, as provided in table 5

(Continue...)

Table 5 - Minimum and maximum prices for each area

Coverage Areas	Minimum price	Maximum price
A01	R$ 27,38 / m^3	R$ 67,92 / m^3
	R$ 18,31/ t	R$ 45,28 / t
A02	R$ 27,50 / m^3	R$ 67,92 / m^3
	R$ 18,39 / t	R$ 45,28 / t
A03	R$ 40,34 / m^3	R$ 67,02 / m^3
	R$ 26,97 / t	R$ 44,68 / t

4 Conclusions

With the tests, it was observed that the minimum unit costs of area A03 vary considerably, around 47%, compared to the others, while there is no significant divergence in the maximum values for A01, A02 and A03.

The work carried out made it possible to determine a limit reference range for the unit cost of transportation of CDW in Recife.

It is suggested, in the future, to carry out studies regarding the price variation within each determined area.

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