# MAPEAMENTO DA CADEIA DE RESÍDUOS DA CONSTRUÇÃO CIVIL EM FORTALEZA

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**RESUMO**
A construção civil figura entre as principais causadoras de impactos ambientais, não somente em virtude do consumo de recursos naturais, como também pela disposição indiscriminada dos Resíduos de Construção Civil (RCC). Dessa forma, esse estudo buscou mapear o fluxo de processos do RCC desde a geração até a reinserção no mercado ou disposição final. A metodologia da pesquisa se pautou na realização de entrevistas semiestruturadas com representantes do setor público e privado do processo de gerenciamento de RCC. A pesquisa contribuiu para a caracterização das atividades individuais e coletivas de empresas locais envolvidas na logística reversa do RCC e dos intervenientes do processo, além da listagem dos seus principais entraves. Conclui-se que existe a necessidade de maior conscientização dos *stakeholders* (principalmente as construtoras), desburocratização para implantação de usinas de reciclagem, desenvolvimento de técnicas para tratamento de outros materiais como o gesso e a madeira, incentivos para os produtores e compradores de produtos reciclados, maior fiscalização da triagem, transporte e destinação final do RCC. O estudo da logística reversa do RCC se faz necessário para a criação de novos planos de ação, políticas de incentivos, leis e aplicação de sanções que permitam o avanço da atuação sustentável.
Palavras-chave: Gerenciamento do RCC. Logística Reversa. Sustentabilidade.

**ABSTRACT**
Civil construction is one of the main causes of environmental impacts, not only due to the consumption of natural resources, but also due to the indiscriminate disposal of Construction and Demolition Waste (CDW). Thus, this study sought to map the flow of CDW processes from generation to reinsertion in the market or final disposal. The research methodology was based on semi-structured interviews with public and private sector representatives of the CDW management process. The research contributed to the characterization of the individual and collective activities of local companies involved in the reverse logistics of the CDW and of the stakeholders of the process, in addition to listing its main obstacles. It is concluded that there is a need for greater awareness of stakeholders (mainly construction companies), reduction of bureaucracy for the implementation of recycling plants, development of techniques to treat other materials such as gypsum and wood, incentives for producers and purchasers of recycled products, greater supervision of the sorting, transportation and final destination of the CDW. The study of CDW reverse logistics is necessary for the creation of new action plans, incentive policies, laws and application of sanctions that allow the advance of sustainable performance.
Keywords: CDW Management. Reverse logistic. Sustainability.

## 1 INTRODUCTION

Currently, the Construction Industry is among the main causes of environmental impacts, not only due to the consumption of natural resources in its production chain, but also due to the indiscriminate disposal of construction and demolition wastes (CDW) (BOHNENBERGER et al., 2018). The CDW not only represents the largest share of solid waste existing in urban areas (CHILESHE et al, 2016) but also makes construction industry the largest contributor to landfill growth (MANOWONG, 2012).

As a result, there is a growing interest in sustainable issues, where supply chains are complex in structure and number of participants (PERO et al, 2017). Increasing pressure to improve quality, productivity, efficiency, effectiveness and sustainable development has guided the new behavior of these companies (SAIEG et al, 2018). Therefore, it is crucial the study of the reverse distribution channels, also known as reverse logistics, which deal with actions ranging from the reduction of raw materials used to the correct destination of products, materials and packaging (PEREIRA et al, 2012).

In this context, this research aims to propose improvements to the CDW reverse logistics process through the analysis of the waste generation chain in the city of Fortaleza, Ceará, under environmental, logistics, political and economic perspectives. It is important to emphasize that this study does not focus on the chemical analysis of materials, their reactions or technological innovations. Nor is it intended to investigate the details of the material life cycle. Despite its environmental, financial and technical characteristics, its approach is focused on aspects of reverse logistics, through the study of several stakeholders in the Metropolitan Region of Fortaleza.

## 2 SUSTAINABILITY IN CONSTRUCTION INDUSTRY

Over the last decades, it has been noted that economic and production systems cannot be separated from environmental aspects. Increased awareness about sustainability has become a priority in the design and operation of supply chains (SUNDARAKANI et al, 2010). Green supply chain management practices, such as reverse logistics, ensure that environmental and ecological objectives are aligned with the chain's operational objectives (NASIR et al, 2017).

Considering that the construction industry is able to absorb almost all its residues (BOHNENBERGER et al., 2018), the Resolution of the National Environmental Council (CONAMA) No. 307 was implemented with the purpose of facilitating the reuse of waste through the use of a classification according to the CDW reuse or recycling capacity.This resolution was further supported by the approval of the Solid Waste National Policy (SWNP) (ABRECON, 2015), which establishes guidelines for the integrated management of solid waste to generators, public authorities and economic instruments (MIRANDA et al., 2016).

CDW management is possible only through the detailing of information such as the composition and quantification of the waste generated (BRASIL, 2010a). Regarding the composition, Mália et al. (2013), Contreras et al. (2016) and Lockrey et al. (2016) point out that concretes, mortars, soil, plaster, bricks, and wood are the main building rubble components generated in the world. In the Brazilian context, Oliveira et al. (2011) and Kazmierczak et al. (2006) observed that concrete, mortar, ceramics, rocks and soils constitute the main constituents of CDW. According to Cabral (2007), such information is compatible with the Brazilian constructive culture, which concentrates its greatest losses in the concreting, masonry, plaster / plaster and coating phases.

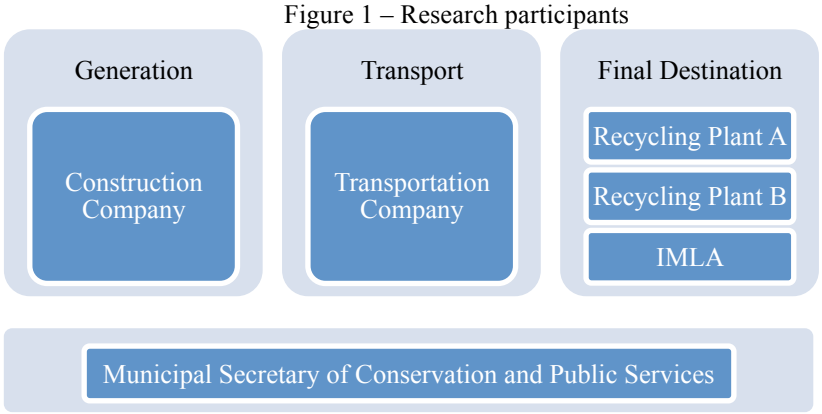
With respect to the waste reuse capacity, there are several possibilities of using CDW components as filler, sub-base of highways, insulation products, among others (COELHO; DE BRITO, 2013). Recycled aggregates, for example, can be used in infrastructure works or landfills, and are sold mainly to public agencies, individuals and construction companies (ABRECON, 2015). Regarding the plants responsible for recycling, the decision about the

type of waste treatment depends on the ease of commercialization of the product generated, as well as the operating costs involved, such as energy, maintenance, cost of rejected materials, transportation (FORTALEZA, 2015).
In accordance with studies carried out by ABRECON (2015), the main causes of the difficulty in the sale of recycled products are the lack of legislation to encourage consumption, a high tax burden, a lack of knowledge by the market, a low waste quality and a lack of commercial access by the recycling company. As a result, most of the CDW is still sent to landfills, reused or cremated precariously (NAGALLI, 2014).

## 3 METHODOLOGY

The research in question focuses on the analysis of the individual and collective activities of the CDW 's reverse logistics in the city of Fortaleza – Ceará, aiming to describe all phases and members from generation to reuse and reinsertion of the waste into the construction industry. According to Figure 1, public and private sector representatives from the CDW management process were interviewed. The choice of the research participants was based on the need to know at least one representative from each group that is part of the reverse productive chain, with the purpose of extracting information about their role, responsibilities, obstacles and interaction with other stakeholders. To do so, the methodology involved a construction company, two recycling plants, an inert material landfill area (IMLA), a transportation company and the Municipal Secretary of Conservation and Public Services (MSCPS).

Figure 1 – Research participants




Fonte: Author (2019)

The stakeholder research was conducted through the application of semi-structured interviews, composed by legal questions (eg.: accreditation, licensing, compliance with environmental norms, penalties), logistics (eg.: disposal, transportation, waste segregation, online collection operation) and financial (eg.: recyclable products operation, treatment and sale costs). The data, both quantitative and qualitative, were treated and concatenated, giving rise to information such as the characterization of each participating company, the main CDW components generated in Fortaleza, the description of the entire reverse process, as well as the main difficulties of each participant .

## 4 RESULTS AND DISCUSSION

This chapter has been divided into three sections in order to better organize the results and comments, as it follows: Characterization of the CDW production chain actors of Fortaleza; Steps for CDW reverse logistics; Obstacles to the progress of waste management in the city of Fortaleza.

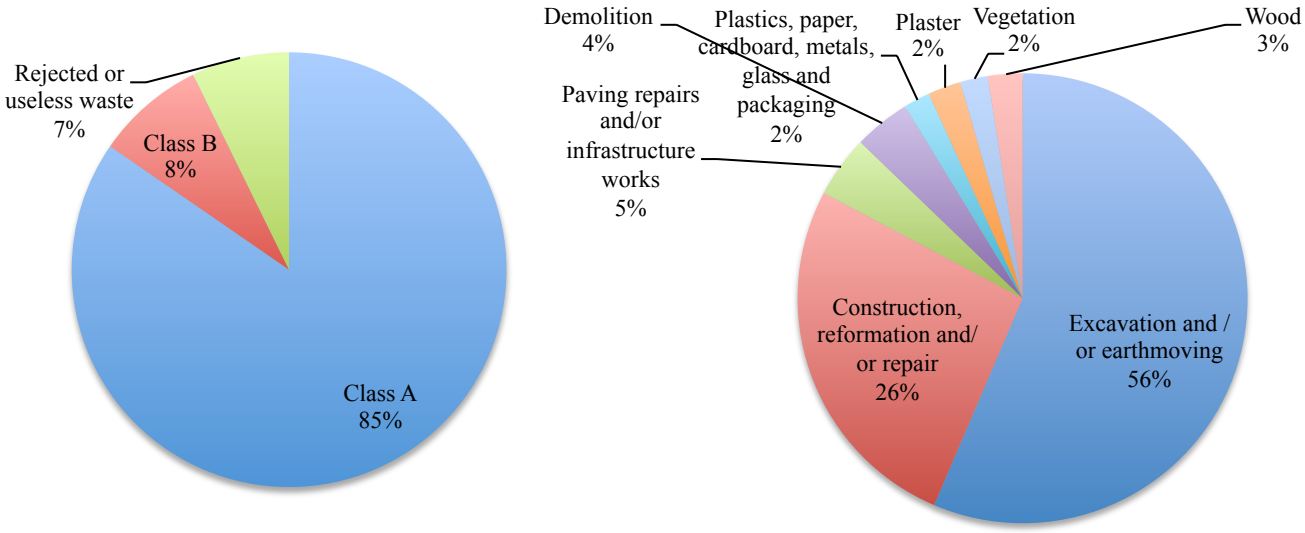
## 4.1 Characterization of the CDW production chain actors of Fortaleza

The construction productive chain consists of basically three actors: generators, conveyor and waste disposal area. It is important to emphasize that, although each actor performs his role individually, a shared responsibility related to the product life cycle should predominate.

### *4.1.1 Generators*

The waste generators, in this case represented by the construction company, are firms responsible for activities or businesses that generate CDW. Its role was described in the interviews as essential for the achievement of a satisfactory sustainable standard through the disposal of waste at licensed sites, in addition to prioritization for non-generation of waste, followed by reduction, reuse, recycling and final disposal. According to the responsible for the Integrated Management System of the construction company investigated, the Civil Construction Waste Management Plan (CCWMP), required by the Law No. 12.305 (BRASIL, 2010a), is the main step taken by the company to properly manage the CDW. Through this plan, many actions that will guide the management of waste throughout the execution of the work are defined, such as: training focusing on issues such as selective collection, environmental awareness, rational consumption of water and energy; practice of selective collection; creation of a eramic blocks cutting center; pagination of ceramic tiles; use of remaining of concrete, among others.

Figure 2 – Class and composition percentage of reusable waste (classes A and B) of Fortaleza 2016 - 2018




Fonte: Author (2019).

According to data provided by the Fortaleza City Council (PREFEITURA DE FORTALEZA, 2019), the CDW average volume generated monthly in the city has been relatively stable in the last three years, with volumes of 81,400 t, 69,265 t and 80,776 t CDW in 2016, 2017 and 2018, respectively. Regarding the percentage of waste generated by class between these years (Figure 2), the same data suggest that of all the CDW produced in Fortaleza, 85% correspond to class A materials and 8% correspond to class B materials. The percentage of class C and D waste is negligible, causing the remaining 7% of CDW to be represented by rejected and useless waste. Considering only the reusable residues (classes A and B), 56% of its composition corresponds to sandy materials resulting from the preparation and excavation of

land; 26% of ceramic components, mortar and concrete; 4% of demolition materials; 5% of materials generated in infrastructure repairs (asphalt, curb, parallelepiped); among others. This information corroborates with researches related to the composition of CDW in the country (CABRAL, 2007) previously presented and reveals a pattern for buildings based mainly on the use of concrete structures and ceramic components.

*4.1.2 Conveyors*

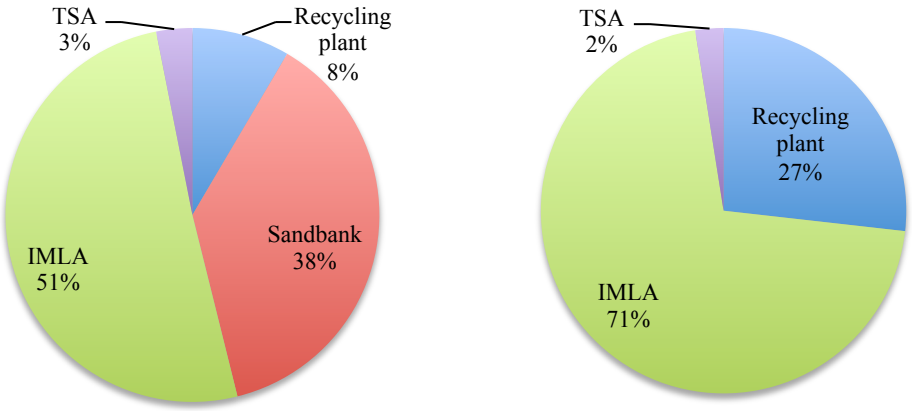
The conveyors correspond to the companies responsible for collecting and transporting the waste between the builders and the destination areas. Due to the need for accreditation with the city hall - which entails various legal and operational requirements - in Fortaleza there are only 19 companies registered in the city hall website for the collection of CDW in general (PREFEITURA DE FORTALEZA, 2018b). Of this total, ten companies are responsible for the collection of vegetable waste and construction with the supply of stationary buckets, that is, they are destined to the collection of solid waste from pruning and cutting of trees or of civil construction works. Another seven companies carry out the collection of vegetable and construction waste from excavation, demolition and earthmoving services through dump buckets. Finally, two of these companies are accredited for both functions described above.

In order to transport the CDW, the transportation company interviewed uses multicranes with a maximum age of ten years old, and can use bucket trucks in cases of transportation of excavation, demolition and earthmoving waste. In addition, in order to better control solid waste collection and transport services, the vehicles have a GPS tracking and monitoring system capable of providing MSCPS real-time access to the primary geo-referencing data as well as the display of the historical tracking data of all accredited vehicles.

*4.1.3 Final destination areas*

The areas of waste disposal are sites designated for the processing or disposal of waste. In this research, these areas are represented mainly by recycling plants, IMLAs, transhipment and sorting areas (TSA) and sandbanks. According to data from the city council of Fortaleza (PREFEITURA DE FORTALEZA, 2019), it is noticed that about half of the total CDW generated in the city is destined to IMLAs, where class A waste is reserved in soil. Subsequently, the sandbanks correspond to 38% of the destination of the CDW. In the local context, the sandbanks do not refer to actual destinations, but regard the commercialization of excavation sand directly between the conveyor and the consumer of the material, monitored by a waste transportation declaration (WTD), in which the conveyor makes a self-declaration of the destination of the sand, followed by the proof of receipt. Recycling plants, which are responsible for the waste treatment, correspond to 8% of waste disposal destination, followed by TSAs, which are responsible for the correct sorting and disposal of 3% of the material (Figure 3).

Figure 3 – All classes waste and class A (except A1) waste percentage according to its final destination 2016 - 2018




Fonte: Author (2019) .

The inclusion of sandy materials resulting from the preparation and excavation of land – nominated A1 by the City Council – greatly interferes in the results, due to the large volume of landfill and earthworks coming from the buildings. In general, this material has adequate conditions of reuse, without needing treatment, being destined for the sandbanks described above. Therefore, considering only class A waste (Figure 3), except class A1 waste, about 71% are destined to IMLAs, followed by recycling plants (27%) and TSA (2%). It can be seen that most of the CDW is focused on the deposit of the material, since class A1 does not demand large investments in equipment or specialized labor – unlike the recycling plants – are considered inert, that is, not harmful to the environment. In addition, the Metropolitan Region of Fortaleza has only two recycling plants in operation – one in the initial stage of the exercise, as described below - leaving the TSAs and IMLAs to the final destination of the waste.

It should be noted that the data presented only cover the numbers registered by the City Council, that is, do not consider waste dumped irregularly in empty lots, clandestine landfills, water bodies, among others, accounting only those that were legally destined for licensed sites. Thus, despite the considerable percentage of CDW reused, the information may not faithfully reflect the global reality of waste generation in the city. In addition, although they are properly destined to recycling plants, the treatment of the material is not always guaranteed due to the low quality of the waste delivered by the constructors or by the lack of specific technology for the treatment of each material.

*a) Recycling Plants*

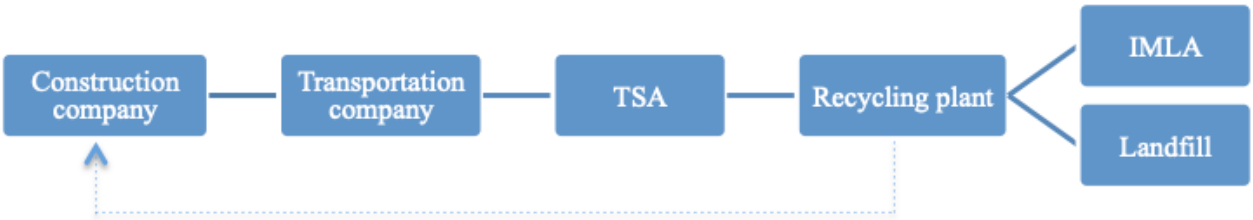
In the case of recycling plants, it was decided to investigate the performance of two representatives, named here as plants A and B, since they are the only companies in the industry in activity until the collection of these research data (December/2018). The city of Fortaleza is served by two recycling plants in operation, one located in the city itself (plant A) and another located in the neighboring city of Aquiraz (plant B). By definition, recycling plants should prioritize the process of transforming solid waste into inputs or new products (PREFEITURA DE FORTALEZA, 2018b). In practice, however, little progress has been made in this sense, since the lack of correct segregation of the material on site makes it difficult or even impossible to reuse the CDW.

For being new to the market, the plant B still has certain limitations of performance, as a clientele restricted to two companies of collection and transportation. Until now, the company has been receiving mainly Class A demolition and excavation waste, such as paving stones

and asphalt slabs, which are crushed in a mobile plant, giving rise to aggregates for use in building works and infrastructure. The final product is kept in the plant itself, while other materials such as wood and steel are transferred to other licensed plants.
On the other hand, operating for 20 years with demolition and CDW treatment, the plant B has space limitations for eventual segregation of the material, which justifies the requirement for receiving residues that are already adequately segregated on site and preference for receiving waste from excavations and demolitions works. Another disadvantage resultant from the insuficient space is the lack of storage space for recycled products, which leads to the production of its products only according to market demand. Thus, while virgin products are mass-produced at attractive prices, recycled materials require a request in advance, resulting in a delay that most construction companies are unwilling to submit to.
Class A waste, treated on site, gives rise to coarse aggregates, fine aggregates and stone dust, as well as recycled bricks . Other materials that may be contained in Class A waste containers, such as wood, steel, paper and plastic, are sold to companies specialized in their treatment.

*b) Landfill areas and transhipment and sorting areas*
In general, the waste generated by the construction companies is primarily transported to recycling plants due to the prioritization of the reuse and the shorter distance traveled compared to the landfill located outside the city. In essence, landfills should not receive construction waste and are the last solution to the CDW, after being considered as waste to builders, TSAs and recycling plants. In addition to these sites, IMLAs are also common destinations for Fortaleza's CDW, according to the Coletas Online system (Figure 4).

Figure 4 – CDW Reverse Logistics Path in Fortaleza




Fonte: Author (2019).

In theory, while TSAs are destined to receive waste, for sorting, temporary storage of the segregated materials, eventual transformation and subsequent removal for proper disposal, the IMLAs consist of places for the disposal of Class A waste in the soil, aiming for the reservation that allows its future use or future use of the area, in the lowest volume possible, without causing damage to public health and the environment. However, the application in practice has pointed to a certain definition problem of these functions.
Considering the above concepts, the IMLA investigated has merged the tasks of both final destinations mentioned. Although there is confinement of part of the class A waste on site, for ground leveling and temporary plaster reserve, most of the CDW - which is delivered in a mixed manner - undergoes a manual sorting. Materials such as cardboard, plastic and metal are separated and destined to recyclers or recycling cooperatives, while wood and tree pruning undergoes an on-site processing, giving rise to chips or wood chips.
The company has plans to rent a crusher in order to expand its activities by reusing Class A waste delivered to IMLA. One of the obstacles to the acquisition of machinery for such activity is the uncertainty of the quality of the material delivered by the builders. Ensuring the quality of recycled gravel becomes difficult, since the raw material is usually of poor quality. As a result, much of this material is used as the base and sub-base of the plant's own site.

*4.1.4 Public authority*

MSCPS plays a key role in the waste management policy of the city of Fortaleza. An example of this is the creation of the Solid Waste Management Action Program, characterized by the implementation of progressive actions in various districts and regions of the city, involving solutions in areas such as environmental legislation review, ecopoints creation, the electronic system Coletas Online control, accreditation and monitoring of transportation vehicles, among others.

In order to strengthen the public authorities' instruments of action in relation to violations and encourage compliance, MSCPS has been involved in reviewing the legislation of the large generators through the following measures:

- creation of new types of infractions and penalties;
- increased penalties for violators;
- incorporation of new measures, such as administrative closures, removal of vehicles and equipment;
- linking the maintenance of the operating license to compliance with the legislation;
- possibility of inclusion of the debtor in a public register of defaulters.

To meet the needs of small volume waste generators and conveyors, ecopoints were created, consisting of a set of areas available to the population for the voluntary delivery of CDW's such as debris, prunings, cardboard, plastics, glass and metals. In this way, preventive collection has been prioritized, where the material is deposited in suitable places, instead of the corrective collection, where the residue is collected in inappropriate places.

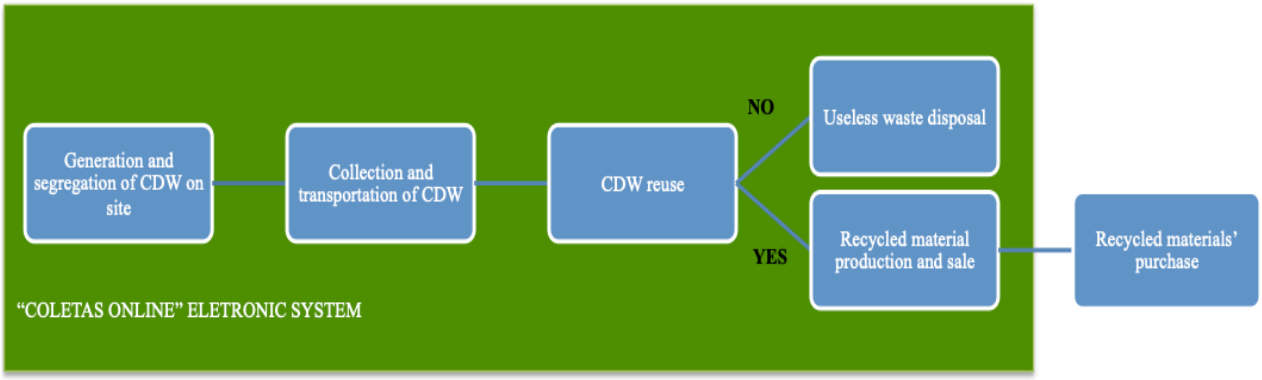
The implementation of the electronic system Coletas Online is another action recently developed by MSCPS. Based on the CDW management system of the city of Jundiaí – SP, this system was implemented in Fortaleza in 2015 with the objective of integrating the actions of the City Council and the service providers through online accreditation, service request, inspection and monitoring of CDW transportation, among others. Further details about this CDW management system will be provided in section 4.2.

Finally, the accreditation of transportation companies to the City Council evaluates several aspects, such as their technical, operational and financial capacity, for the adequate provision of the service. Thus, the authorization of the transportation activity is conditioned to the fulfillment of documentary requirements and fleet inspection. From this, MSCPS draws up a list of accredited transportation companies, that is, suitable and authorized servers for the collection of solid waste characterized as non-hazardous (ABNT, 2004) and generated by commercial, industrial and servisse providers' activities with volumes equal to or greater than 100 liters per day.

## 4.2 Steps for CDW reverse logistics

The CDW's reverse logistics consists of a sequence of activities performed by the actors described above, in order to know its operation, identify failures and propose improvements for the system. According to Figure 5, which portrays the reality of Fortaleza, the builder starts the process by generating waste, seeking to reduce volumes, segregating the waste on site and depositing it in containers supplied by the conveyors. The CDW transported by a licensed and accredited company may or may not be reused, depending on the class of the waste.

Figure 5 – Processes' flow

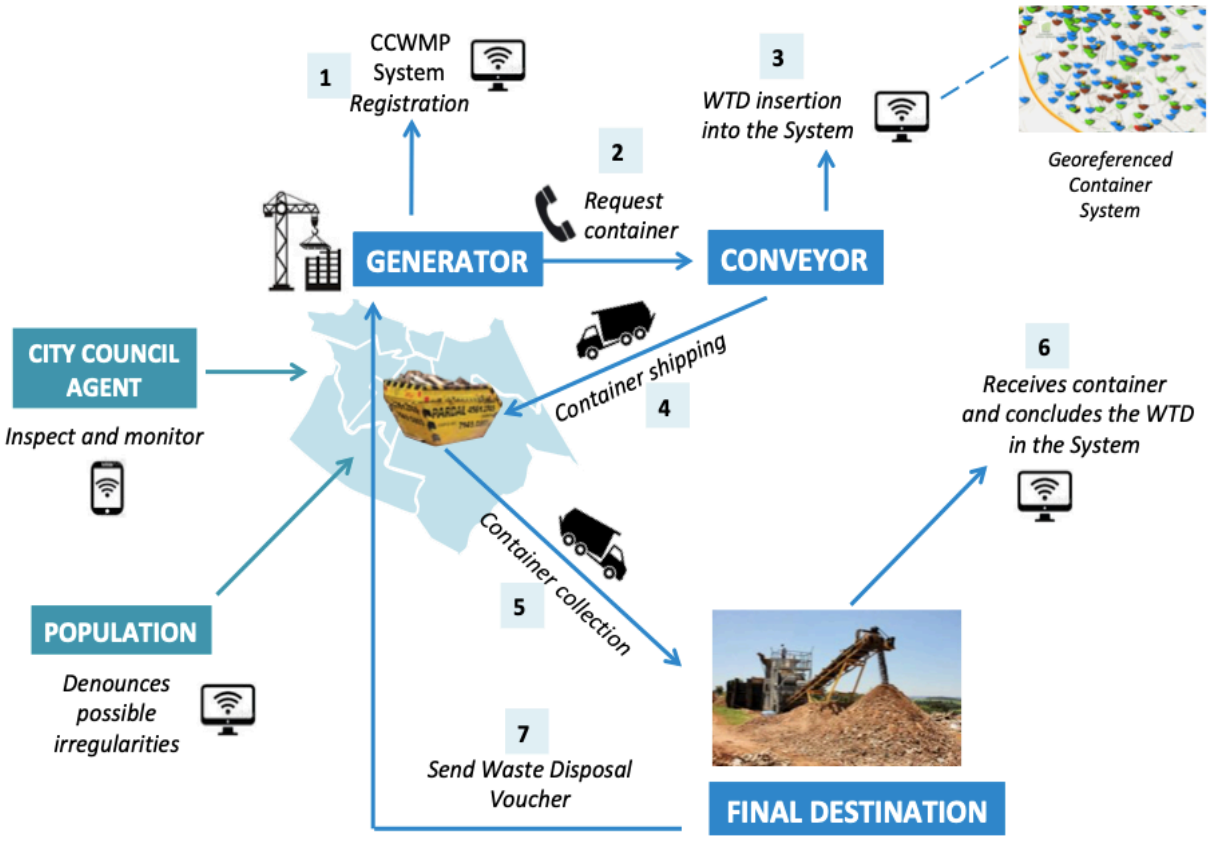



Fonte: Author (2019).

In cases of impossibility of treatment, the waste is disposed on landfill areas. Otherwise, the material is allocated for recycling plants, TSAs or IMLAs according to the waste reversibility potential. Finally, the production and sale of recycled products is responsible for the return of the material to the consumer market inside and outside the construction industry.

Throughout this reverse chain, the Coletas Online system works as a tool to support the management of these activities. In general, the use of this system occurs with the help of the internet, which makes waste management faster and more practical by sharing information in real time by its members.

Figure 6 – Solid waste control electronic system's implantation

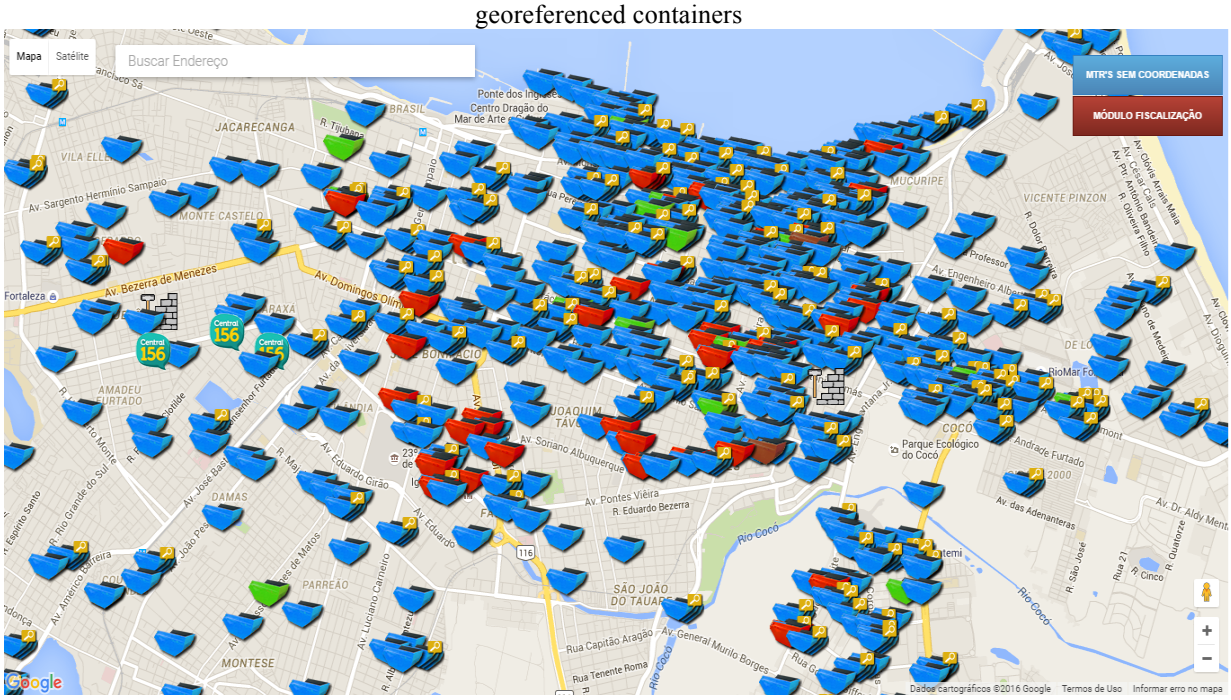



Fonte: Prefeitura de Fortaleza (2016).

Figure 6 illustrates the actions made possible by the use of this tool. The first step consists of the CCWMP registration in the system by the construction company, followed by the choice of an accredited company available on the City Council website. The WTD input – containing

characteristics, quantification, origin and final destination of the waste – begins with the notification of the dispatch of the requested containers, which must contain the identification and the location of the generators and conveyors through the containers georeferencing located on site. When the shipment records and/or the removal of buckets are made in the system, both the municipality and the other stakeholders have control of the location of the parked, in transit and delivered buckets, as well as the delays for removal and transportation of the CDW to the landfill (Figure 7).

Figure 7 – Real-time identification and location of generators and conveyors through the of the site located georeferenced containers




Fonte: Prefeitura de Fortaleza (2016).

The traceability of the CDW also enables the visits of inspectors and the sending of photographic records that prove the conditions of the containers and the CDW collected. The colors informed in the Coletas Online system indicate the situation of each container at the time of the survey, namely: green – regular bucket and waste; blue – bucket to be inspected; brown – irregular waste, subject to further inspection; red – clandestine company bucket; white – missing bucket; black – seized bucket.

The WTD confirmation is given after the container delivery and the checking of the CDW classification at the final disposal site. According to the interviewees, this verification is due to the frequent incompatibility between the class of residue in the WTD and the content, in fact, transported. In case of classification conflict, "Delivery with divergence" is registered in the system, which causes the CDW to be reclassified at the final destination. After completing this step, the waste destination confirmation is sent to the participants.

All the system data allow a better planning of preventive and directive actions capable of debureaucratizing and organizing the information of all the companies and entities involved. Among its functionalities, there are: accreditation of conveyors and final destinations; ease of choice of authorized conveyors and drive for the dispatch or removal of buckets; registration of WTD request; quick access to system information to search for notifications and generate infringement notices; container georeferencing, which allows the low cost inspection of vehicles and buckets; inhibition of the action of clandestine companies; control of final destination; monitoring of the TSA's situation regarding the volume of exceeding waste; and

generation of indicators, responsible for assisting in the elaboration of more effective public policies.

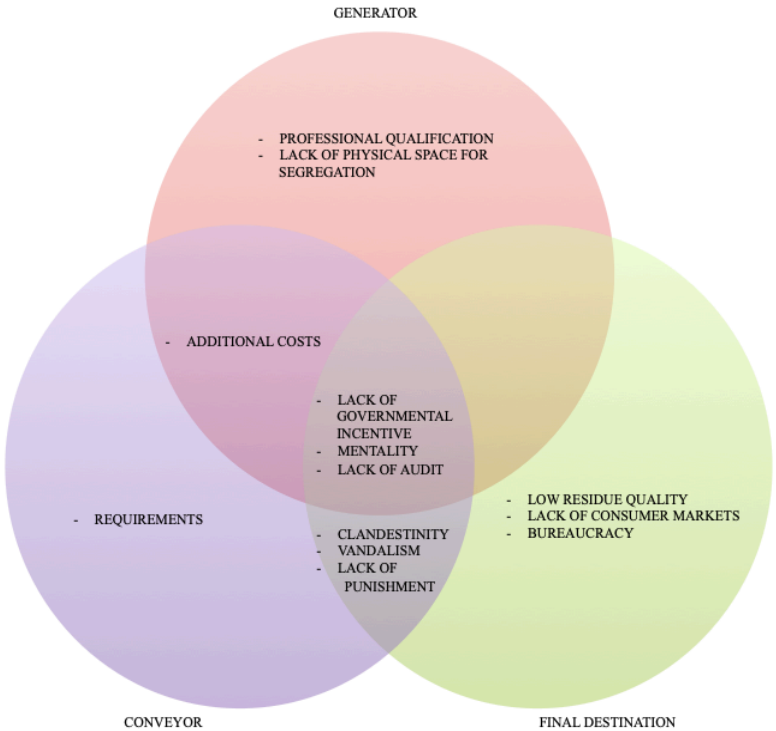
### 4.3 Obstacles to the progress of waste management in the city of Fortaleza

The CDW management is often characterized by several obstacles that hinder or even impede its full deployment and/or optimization. The stakeholders activities' chain ends up interfering significantly in the flow of the process, since the results of the actions of one stakeholder affect directly or indirectly the actions of its successor in the chain. Figure 8 shows, in a didactic way, the main obstacles mentioned by interviewees for the maturation of the reverse chain.

It widely known among the parties interviewed that the lack of concern or mentality regarding environmental issues is one of the main obstacles to improve the construction waste management. The lack of knowledge and interest on the subject and the prevalence of financial issues over environmental aspects can also be included. During the interviews, all the participants mentioned the difficulty in changing the thinking of managers and construction workers as the possible cause of other problems, such as lack of supervision and government incentives.

In theory, any construction and infrastructure activities should contain data such as waste classification and quantification, waste volume generated monthly (Fortaleza, 2004), as well as segregation on site and destination for recycling plants (Fortaleza, 2011). However, the preferential – which implies a non-obligation – segregation or sorting of the waste at the origin, described in CONAMA resolution No. 307, leads the generators to a discretionary attitude regarding the separation of the CDW components. In addition, in practice, the Fiscalization Agency of Fortaleza is also knows by its deficiencies in the inspection of such requirements, which makes it difficult to take preventive and corrective measures. According to the interviewees, this is mainly due to the disqualification of the prosecutors to the execution of their role.

Figure 8 –Waste management obstacles according to its stakeholders




Fonte: Author (2019).

The absence or inefficiency of supervision ends up being compromised with companies that act in an irregular way. Examples include the lack of a license for the execution of Works and the non-reduction and non-segregation of waste on site by the builders. The delay in the useless waste disposal and the receiving of waste outside the Coletas Online system is also a recurring issue among the interviewees. In addition, in the case of conveyors, the activities of several non-accredited companies, not sending the WTD and the use of uncredited vehicles to increase the operational capacity of accredited companies are some of the complaints presented by the interviewees.

It is perceived that the expenses that a regularized company spends to meet sustainable goals end up making its contracting financially less advantageous than an irregular company. According to MSCPS data, garbage collectors and unlicensed transportation companies offer services at prices that correspond to one-third of the prices practiced by the regular market. As a result, the third obstacle, which deals with the lack of government incentives, becomes more understandable, since the implementation of various advantages, such as tax deductions, ends up making companies adhering to environmentally sound practices more competitive than the others .

According to those responsible for transportation and final destination, the lack of punishment inexorably drives the action of clandestine companies to remain active in the market. However, at the same time as the survey participants reveal a loosening of the law enforcement to fight clandestinity, they point out excessively heavy penalties on companies with legal action in the market.

If this were not enough, such actors cite vandalism as another way of discouragement to their activity. The theft products hiden by employees and the deposit of all kinds of waste by employees or third parties, without the knowledge of those responsible, in the containers, as well as graffiti of the stationary buckets – which can result in fines for its supplier, because of the impediment of the container identification – are some of the occurrences mentioned by the interviewees. There are also cases where the deliberate camouflage of mixed waste in the lower part of the bucket is practiced by the arrangement of segregated waste at the top to reduce the transportation costs. Thus, sometimes the waste classified as recyclable – which has a lower cost in both the construction-conveyor transaction and the final conveyor-destination – may require appropriate segregation and reclassification – which leads to a readjustment of the prices to be paid and an increase of work – or even the disposal of the materials, since they have been irreversibly contaminated, making them useless for future treatments.

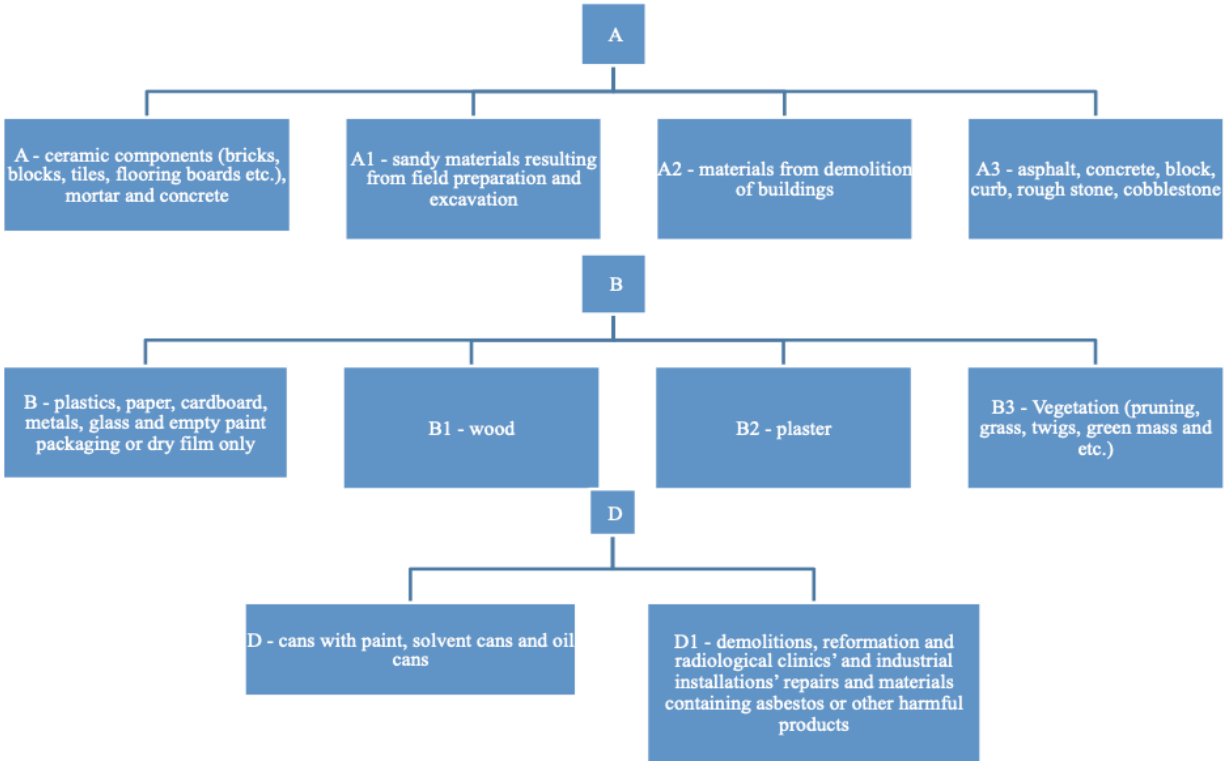
In fact, the performance of some construction companies in disagreement with the SWNP (BRASIL, 2010a) prescription was strongly emphasized during the survey, being considered the main responsible for not reusing much of the CDW. In addition, cases where only part of the waste is transported by licensed companies during the day while another part is disposed of in irregular locations at night have been mentioned as frequente, as they represent a significant reduction of costs. It is noticed that shared responsibility is not always considered, since there is no concern on the part of the construction company in knowing the end given to the residue.

In addition, a common concern among generators and conveyors, the additional costs related to sustainable measures were cited as barriers to compliance with environmental guidelines. The purchase of materials for the waste segregation, a larger number of containers rental, personnel training, the need for eventual purchase of vehicles and expenses with the recycling plant and/or landfill area are examples of requirements that burden substantially the expenses of the stakeholders.

Finally, the final waste disposal sites face specific problems, even though they have strategies to combat them. If on the one hand these residues have a scientifically proven potential to act

as substitutes for construction materials, on the other hand, the poor quality of their contents, lack of techniques or high treatment costs limits the production of recycled materials that attract the consumer market, both in terms of quality and in relation to uncompetitive prices. Added to this, the bureaucratization for the opening and maintenance of this type of company has served as a great discouragement for the growth of this market in the city.
According to MSCPS member, the classification used by CONAMA (classes A, B, C and D) is considered deficient, since each class covers a too wide range of diverse natures components that make the destination of the residue difficult. As a result, the MSCPS uses subclassification according to the future use that will be given for each material, as shown in Figure 9.

Figure 9 – Subclassification for the management of the CDW by Fortaleza City Council




Fonte: Author (2019).

## 5 CONCLUSION

The research proved the need to study the CDW reverse chain – including its actors, functions and activities – to propose appropriate solutions to the obstacles listed by its participants. This need is due, in large part, to the interdependence of the actors in the chain, which ends up conveying the positive or negative consequences of an action for other participants, such as price increases, less use of waste, less production of recycled products or supply of recycled materials of inferior quality, greater occupation and consequent diminution of the useful life of landfill areas, among others.
Through the analysis of the processes' flow, it was verified that financial incentives such as reduction of taxes for producers and consumers of recycled products are necessary. Regarding compliance with environmental standards, it seems that the economy conquered with illicit practices still seems to compensate for the fines imposed by the inspection body. There is a need for greater severity in the imposition of penalties and the establishment of an environmental target plan that stimulates accountability. Along with this, awareness policies, the normalization of sustainable behaviors, such as the mandatory segregation of CDW on

site; the subdivision of the CDW classes; the mandatory minimum consumption of recycled products and the investment in research to make the reuse of the CDW feasible are measures capable of mitigating the negative impacts of the reported obstacles.

Methods of waste quantification, such as the Coletas Online system, also represent useful aid instruments for generators and inspectors. This type of tool assists both in the estimation of volumes produced – capable of facilitating decision making and minimization, segregation and packing action plans – as well as in the verification of the estimated and the actual CDW volume transported to the final destination. In addition, systematization of data on the actual generation of waste by work, by surveying the exit volumes of the builders and entering the mills and landfills, would facilitate the control and investigation of possible deviations for irregular destinations.

The interviews allowed the knowledge of the generated waste, as well as the first components reused in the recycling plants; the actions taken to reduce waste on site; and the ways of treatment and reinsertion of the recycled product in the production chain. It is concluded that there is preference for the treatment of debris, wood and plaster, to the detriment of plastic materials and papers. It is noteworthy that, especially in relation to rubble, reuse techniques are already quite popular. Wood has also become useful as biomass used in factories. However, plaster still has not aroused so much interest in reuse research and it does not have so many techniques or specialized companies in the region.

Thus, it was concluded that the objectives of analyzing the waste generation chain in Fortaleza under a sustainable perspective and proposing improvements to the reverse logistics process were achieved. For future research, it is suggested the search for a greater number of stakeholders, such as other companies, inspection body, recycling cooperatives, that can ratify and aggregate information on reverse logistics. The creation of local indicators would also be useful for predicting the average composition of the CDW generated, which would facilitate palliative and preventive management decisions. The survey of international legislation on the subject, with the purposes of comparing it with local legislation, are also useful for the development of efficient practices.

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