Maria do Perpétuo Socorro Lamêgo Oliveira

Desenvolvimento de Estratégias para a Gestão dos Resíduos de Construção e Demolição no Município de Manaus (Amazonas-Brasil) com Base no Conceito de Economia Circular

Universidade Fernando Pessoa
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Tese apresentada à Universidade Fernando Pessoa como parte dos requisitos para obtenção do grau de doutora em Ecologia e Saúde Ambiental, sob a orientação da Professora Doutora Ana Margarida Fonseca.

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RESUMO

MARIA DO PERPÉTUO SOCORRO LAMÊGO OLIVEIRA: Desenvolvimento de Estratégias para a Gestão dos Resíduos de Construção e Demolição no Município de Manaus (Amazonas-Brasil) com Base no Conceito de Economia Circular
(Sob orientação da Professora Doutora Ana Margarida Fonseca)

As principais agências governamentais do mundo buscam incessantemente soluções para a geração de Resíduos de Construção e Demolição (RCD), um problema que vem se ampliando ao longo dos anos, em virtude do crescimento da indústria da construção civil nos países desenvolvidos e em desenvolvimento.

Dentre os países em desenvolvimento, o Brasil se destaca com uma estimativa de geração de RCD de 44,5 milhões ton/ano em 2018, correspondente a uma geração média por habitante superior a 200 kg/ano. Atualmente, 4.031 cidades no Brasil possuem serviço de coleta de RCD, num total de 5.564 municípios.

O foco do presente estudo é a cidade de Manaus (Amazonas-Brasil), localizada no centro da Floresta Amazônica, a qual está se transformando em uma grande metrópole com mais de 2 milhões de habitantes, com uma indústria da construção civil em ascensão.

Em Manaus a política da atual gestão pública de RCD não permite o recebimento destes resíduos no Complexo do Aterro Sanitário da cidade, o que favorece o surgimento de aterros clandestinos e ilegais na periferia, com baixo custo para os seus utilizadores.

Estes aterros sanitários clandestinos não possuem profissionais da área ambiental que sejam responsáveis pela mitigação dos impactos ambientais negativos causados. Além disso, estes locais não são fiscalizados pelos setores governamentais competentes.

Todavia, por falta de alternativa, essa é a opção escolhida para o descarte de RCD na cidade de Manaus, quer para pequenos empreiteiros que executam reformas em pequenas construções, quer para construtoras de médio e alto porte que operam em Manaus.

Neste contexto, a presente pesquisa pretende contribuir para a elaboração de novas estratégias para gestão dos RCD, aplicáveis no setor público e privado, através da proposta de ações de boas práticas que incentivam a criação de uma economia circular, beneficiando de forma sustentável os moradores da cidade de Manaus e contribuindo para a preservação da Amazônia.

A pesquisa englobou a coleta de informações, através da aplicação de inquéritos em profissionais da área ambiental, empresas privadas do setor da construção civil e empresas do setor de coleta e transporte de resíduos. Estes inquéritos permitiram identificar a situação de referência no que diz respeito aos procedimentos de produção e gestão de RCD em Manaus. Os estudos evoluiram para o setor público, através da análise dos processos administrativos que tratam das infrações da área ambiental aplicadas na cidade de Manaus com foco nas ações e resultados do atual Plano de Fiscalização do Conselho Regional de Engenharia e Agronomia do estado do Amazonas (CREA-AM) e, em complemento, foram acompanhadas as ações da Prefeitura Municipal de Manaus para gestão dos RCD no Complexo do Aterro Sanitário de Manaus. A análise dos dados coletados levou ao desenvolvimento de propostas de estratégias para uma nova gestão de RCD, abrangendo concretamente:

i. a elaboração de um novo aplicativo de telemóvel com boas práticas para troca, doação, venda e descarte de RCD, incluindo a possibilidade de rastreamento e fiscalização da destinação de RCD pelos cidadãos, empresas e setores públicos responsáveis pela fiscalização na área ambiental;

ii. a atualização do Plano de Fiscalização do CREA-AM para o biênio (2021-2022) com ampliação da área de fiscalização para os aterros

sanitários, legalizados ou clandestinos, inclusive com o rastreamento por GPS das caixas de recolha de RCD; e

iii. a recomendação de boas práticas para a Prefeitura Municipal de Manaus quanto à política de gestão do Complexo do Aterro Sanitário de Manaus, com a implementação de procedimentos que promovam a reciclagem/ reuso dos RCD.

Outrossim, as novas estratégias de gestão de RCD desenvolvidas no âmbito da presente pesquisa – como dito alhures, tiveram como base o caso de estudo do município de Manaus, mas são extensíveis a qualquer outro município no Brasil ou em outros países em desenvolvimento. Espera-se, assim, contribuir para fomentar os princípios da economia circular no Brasil, que atualmente ainda se encontra em estágio embrionário, mas que é essencial à promoção de uma Sustentabilidade que traga co-existência entre o crescimento econômico, social e ambiental.

ABSTRACT

MARIA DO PERPÉTUO SOCORRO LAMÊGO OLIVEIRA: Development of Strategies for the Management of Construction and Demolition Waste in the Municipality of Manaus (Amazonas-Brazil) Based on the Circular Economy Concept.
(Under the supervision of Professor Ana Margarida Fonseca)

The main government agencies in the world are constantly seeking solutions for the generation of Construction and Demolition Waste (CDW), a problem that has been increasing over the years, due to the growth of the construction industry in developed and developing countries.

Among developing countries, Brazil stands out with an estimated CDW generation of 44.5 million ton/year in 2018, corresponding to an average generation per inhabitant greater than 200 kg/year. Currently, 4,031 cities in Brazil have CDW collection services, in a total of 5,564 municipalities.

The focus of the present study is the city of Manaus (Amazonas-Brazil), located in the center of the Amazon Forest, which is transforming itself into a large metropolis with more than 2 million inhabitants, with a construction industry on the rise.

In Manaus, the policy of the current public management of CDW does not allow the receipt of this waste at the city's Landfill Complex, which favors the emergence of clandestine and illegal landfills in the periphery, with low cost for its users.

These clandestine landfills do not have environmental professionals who are responsible for mitigating the negative environmental impacts caused, and in addition, these sites are not inspected by the competent government sectors. However, due to the lack of

alternative, this is the option chosen for the disposal of CDW in the city of Manaus, both for small contractors who carry out small construction works and renovations, and for medium and large construction companies operating in Manaus.

In this context, the present research aims to contribute to the development of new strategies for the management of CDW in the city of Manaus, applicable in the public and private sector, through the proposal of good practice actions that encourage the creation of a circular economy, benefiting the residents of the city of Manaus and contributing to the preservation of the Amazon.

The research included the collection of information, through the application of surveys in private companies in the civil construction sector and private companies in the waste collection and transportation sector. These surveys made it possible to identify the reference situation with regard to CDW production and management procedures in Manaus. The studies evolved for the public sector, through the analysis of the administrative processes that deal with infractions in the environmental area applied in the city of Manaus, focusing on the actions and results of the current Inspection Plan of the Regional Council of Engineering and Agronomy of the state of Amazonas (CREA-AM) and, in addition, the actions of the Manaus City Hall for the management of the CDW were monitored, mainly in the Manaus Landfill Complex. The analysis of the collected data led to the development of strategy proposals for a new management of CDW in the municipality of Manaus, specifically covering:

i. the elaboration of a new mobile phone application with good practices for exchanging, donating, selling and disposing of CDW, including the possibility of tracking and inspecting the disposal of CDW by citizens, companies and public sectors responsible for inspection in the environmental area;

ii. updating the CREA-AM Inspection Plan for the biennium (2021-2022) with an expansion of the inspection area for sanitary, legal or illegal landfills, including GPS tracking of CDW collection boxes; and

iii. the recommendation of good practices to the Manaus City Hall regarding the management policy of the Manaus Landfill Complex, with the implementation of procedures that promote the recycling/reuse of CDW.

The new CDW management strategies developed within the scope of this research were based on the case study of the municipality of Manaus, but are extendable to any other municipality in Brazil or in other developing countries. Thus, it is hoped to contribute to foster the principles of the circular economy in Brazil, which are currently taking their first steps, but are essential for the promotion of Sustainability that brings co-existence between economic, social and environmental growth.

RÉSUMÉ

MARIA DO PERPÉTUO SOCORRO LAMÊGO OLIVEIRA: Développement de Stratégies de Gestion des Déchets de Construction et de Démolition Dans la Municipalité de Manaus (Amazonas-Brésil) sur la Base du Concept d'Économie circulaire.

(Sous la direction du Professeur Ana Margarida Fonseca)

Les principales agences gouvernementales du monde sont constamment à la recherche de solutions pour la production de déchets de construction et de démolition (DCD), un problème qui ne cesse de croître au fil des ans, en raison de la croissance de l'industrie de la construction dans les pays développés et en développement.

Parmi les pays en développement, le Brésil se démarque avec une production de DCD estimée à 44,5 millions de tonnes/an en 2018, correspondant à une production moyenne par habitant supérieure à 200 kg/an. Actuellement, 4 031 villes brésiliennes disposent de services de collecte du DCD, sur un total de 5 564 municipalités.

La présente étude se concentre sur la ville de Manaus (Amazonas-Brésil), située au centre de la forêt amazonienne, qui se transforme en une grande métropole de plus de 2 millions d'habitants, avec une industrie de la construction en plein essor.

A Manaus, la politique de la gestion publique actuelle du DCD ne permet pas la réception de ces déchets au centre d'enfouissement de la ville, ce qui favorise l'émergence de décharges illégales et illégales en périphérie, à faible coût pour ses utilisateurs.

Ces décharges clandestines n'ont pas de professionnels de l'environnement chargés d'atténuer les impacts environnementaux négatifs causés. De plus, ces sites ne sont pas inspectés par les secteurs gouvernementaux concernés.

Cependant, faute d'alternative, c'est l'option choisie pour la cession du DCD dans la ville de Manaus, soit bien pour les petits entrepreneurs qui effectuent des rénovations dans de petits bâtiments que pour les moyennes et grandes entreprises de construction qui opèrent à Manaus.

Dans ce contexte, la présente recherche entend contribuer au développement de nouvelles stratégies de gestion du DCD, applicables dans le secteur public et privé, à travers la proposition d'actions de bonnes pratiques qui encouragent la création d'une économie circulaire, bénéficiant durablement aux habitants de la ville de Manaus et contribuant à la préservation de l'Amazonie.

La recherche comprenait la collecte d'informations, à travers l'application d'enquêtes auprès des professionnels de l'environnement, des entreprises privées du secteur de la construction et des entreprises du secteur de la collecte et du transport des déchets. Ces enquêtes ont permis d'identifier la situation de référence en ce qui concernes les procédures de production et de gestion des DCD à Manaus. Les études ont évolué pour le secteur public, à travers l'analyse des processus administratifs qui traitent des infractions dans le domaine environnemental appliquées dans la ville de Manaus avec un accent sur les actions et les résultats du plan d'inspection actuel du Conseil régional d'ingénierie et d'agronomie de l'état de Amazonas (CREA-AM) et, en outre, les actions de la mairie de Manaus pour gérer les DCD dans le complexe de la décharge de Manaus ont été suivies. L'analyse des données collectées a conduit à l'élaboration de propositions de stratégie pour une nouvelle gestion du DCD, couvrant spécifiquement:

i. le développment d'une nouvelle application de téléphonie mobile avec de bonnes pratiques d'échange, de don, de vente et d'élimination des DCD, y compris la possibilité de suivre et d'inspecter l'élimination des DCD par les citoyens, les entreprises et les secteurs publics chargés de l'inspection dans le domaine environnemental;

ii. la mise à jour du plan d'inspection du CREA-AM pour l'exercice biennal (2021-2022) avec l'extension de la zone d'inspection des décharges sanitaires, légales ou illégales, y compris le suivi GPS des caisses de collecte de DCD; et

iii. la recommandation de bonnes pratiques à la mairie de Manaus concernant la politique de gestion du complexe de la décharge de Manaus, avec la mise en œuvre de procédures favorisant le recyclage/la réutilisation des DCD.

Ainsi, les nouvelles stratégies de gestion du RCD développées dans le cadre de cette recherche - comme mentionné ailleurs, étaient basées sur l'étude de cas de la municipalité de Manaus, mais sont extensibles à toute autre municipalité au Brésil ou dans d'autres pays en développement. On espère donc contribuer à promouvoir les principes de l'économie circulaire au Brésil, qui en est encore à son stade embryonnaire, mais qui est essentielle à la promotion de la Durabilité qui amène la coexistence entre croissance économique, sociale et environnementale.

DEDICATÓRIA

Dedico esta Tese a minha mãe Darcy Lamêgo da Silva e ao meu pai José Diniz da Silva que me ensinaram os primeiros passos nesta longa trajetória da minha vida acadêmica.

"Não sou da altura que me veem, mas sim da altura que meus olhos podem ver."

Fernando Pessoa

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Agradeço em primerio lugar ao Pai Criador dos céus e da terra que nos deu o fôlego da vida.

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A

ABNT – Associação **B**rasileira de **N**ormas **T**écnicas

ABRELPE – **A**ssociação **B**rasileira de **E**mpresas de **L**impeza

ABRS – **A**ssociação **B**rasileira de **R**esíduos **S**ólidos

C

CBIC – Câmara **B**rasileira da **I**ndustria da **C**onstrução

CONAMA – **C**onselho **N**acional do **M**eio **A**mbiente (Brasil)

CREA-AM – Conselho **R**egional de **E**ngenharia e **A**gronomia do **A**mazonas

E

EPA - *Environmental **P**rotection **A**gency***

EUROSTAT – *European **Stat**istics***

G

GPS – ***G**lobal **P**ositioning **S**ystem*

I

IBGE – Instituto **B**rasileiro de **G**eografia e **E**statística

IDH – Índice de **D**esenvolvimento **H**umano

IPCC – *Intergovernmental **P**anel on **C**limate **C**hange***

IPEA – Instituto de **P**esquisa **E**conômica **A**plicada

INFOEMPRESAS – **Info**rmação de **Empresas** de Portugal

O

ODS – Objetivos do **D**esenvolvimento **S**ustentável

ONU – Organização das **N**ações **U**nidas

R

RCC – **R**esíduos da **C**onstrução **C**ivil

RCD – **R**esíduos da **C**onstrução e **D**emolição

S

SEMULSP – **S**ecretaria **M**unicipal de **L**impeza **P**ública

P

PAIC – Pesquisa **A**nual da **I**ndustria da **C**onstrução (Brasil)

PGRSCC - **P**lano de **G**erenciamento de **R**esíduos **S**ólidos da **C**onstrução **C**ivil

PIB – **P**roduto **I**nterno **B**ruto (Brasil)

PORDATA – Base de Dados Portugal Contemporâneo

U

U.S. – ***U****nited* ***S****tates*

UNFCCC – ***U****nited* ***N****ations* ***F****ramework* ***C****onvention on* ***C****limate* ***C****hange*

INTRODUÇÃO

Resíduos de Construção e Demolição - Enquadramento

Ao redor do mundo, a população mundial está se expandindo ao longo das décadas, com a probabilidade de alcançar 11 bilhões de habitantes no ano de 2100 (ONU, 2021), conforme ilustrado na Figura 1. Em consequência, as cidades tendem a crescer, impulsionadas pela expansão dos bairros residenciais, que exigem a ampliação das infraestruturas urbanas, como ruas, avenidas, rodovias, pontes, usinas de energia, portos e represas. Nesta situação, tanto as obras privadas como as obras públicas geram Resíduos de Construção e Demolição (RCD), que necessitam de uma gestão adequada para reciclagem, reutilização, reuso e descarte em local apropriado.

A geração de RCD é uma consequência do desenvolvimento econômico e social de um município (Aslam *et al*., 2020), porque os RCD são um importante subproduto do estilo de vida urbano, crescendo mais do que a própria taxa de urbanização mundial (Hoornweg e Bhada-Tata, 2012). A diversidade e a geração destes resíduos aumentaram juntamente com a intensificação do processo de urbanização (Mesjasz-Lech, 2014), sendo atualmente o descontrole do descarte de RCD um problema global de grande relevância na gestão urbana (Ossa *et al.*, 2016).

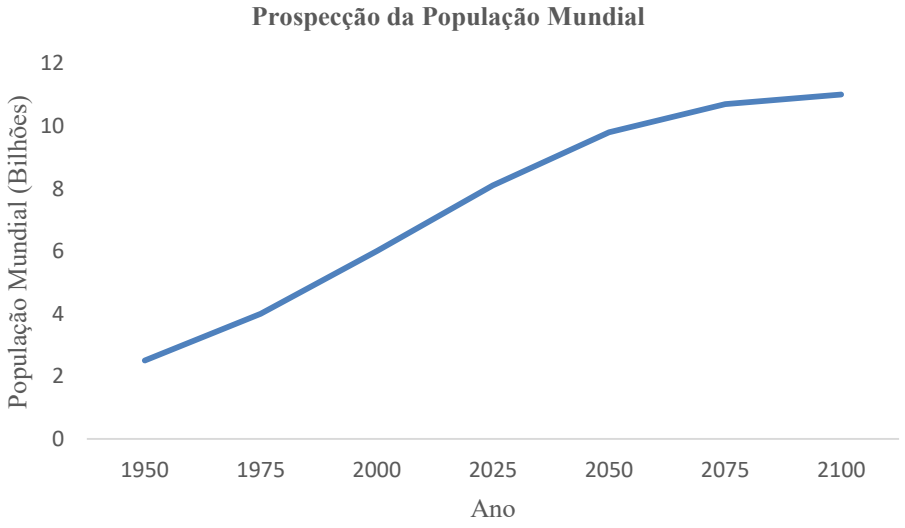

Figura 1. Prospecção de crescimento da população mundial a uma taxa média de 8,2% por ano (Adaptado de ONU, 2021).

A busca incessante pela gestão eficiente dos RCD é uma situação problemática que preocupa todos os países do mundo, porque é um problema que tende a se agravar com o desenvolvimento das cidades ao longo dos anos, principalmente nas metrópoles (Li *et al*, 2020). Na Tabela 1 apresentam-se algumas definições de Resíduos de Construção e Demolição/Resíduos da Construção Civil.

Tabela 1. Definições de Resíduos da Construção e Demolição / Resíduos da Construção Civil.

Definição	Autores
Resíduo de construção e demolição é o resíduo proveniente de obras de construção, reconstrução, ampliação, alteração, conservação e demolição e da derrocada de edificações.	Portugal (Decreto-Lei n.º 102-D/2020)
Resíduos da construção civil são os provenientes de construções, reformas, reparos e demolições de obras de construção civil, e os resultantes da preparação e da escavação de terrenos, tais como: tijolos, blocos cerâmicos, concreto em geral, solos, rochas, metais, resinas, colas, tintas, madeiras e compensados, forros, argamassa, gesso, telhas, pavimento asfáltico, vidros, plásticos, tubulações, fiação elétrica etc., comumente chamados de entulhos de obras.	Brasil (Resolução Conama nº 307/2002)
Os resíduos de construção e demolição (RCD) incluem uma variedade de materiais gerados a partir da construção, renovação e demolição de edifícios, estradas e pontes e outras estruturas.	U.S. Environmental Protection Agency (EPA, 2020)
Os resíduos de construção e demolição (RCD) são um dos fluxos de resíduos mais pesados e volumosos gerados na UE. É responsável por cerca de 25% - 30% de todos os resíduos gerados na UE e consiste em vários materiais, incluindo concreto, tijolos, gesso, madeira, vidro, metais, plástico, solventes, amianto e solo escavado, muitos dos quais podem ser reciclados.	União Européia (EC, 2021a)
Resíduos da construção civil são uma mistura de materiais excedentes gerados a partir de atividades de construção, reforma e demolição, incluindo limpeza do local e obras rodoviárias.	Shen *et al.* (2014)

A *Environmental Protection Agency* (EPA) dos Estados Unidos da América (U.S.A.) mapeia anualmente os principais resíduos constituintes dos RCD e o descarte respectivo, um monitoramento que auxilia nas políticas de reciclagem, reuso e reaproveitamento dos RCD. Nos U.S.A. 54% dos RCD são processados como

agregados, 24% é destinado para o aterro sanitário, 20% é manufaturado como produto e somente 1% é reutilizado como combustível (EPA, 2020).

A Agência Européia do Ambiente (AEA) se dedica ao cumprimento das metas para o alcance dos 17 Objetivos de Desenvolvimento Sustentável (ODS), definidos na Agenda para 2030 da Organização das Nações Unidas (ONU, 2015). Os 8º e 9º ODS tratam do crescimento econômico sustentável e da fomentação da inovação para uma industrialização sustentável, o que se aplica à gestão dos RCD da indústria da construção civil.

A União Européia possui um plano de ações, o *European Green Deal*, com base em estratégias que irão transformar a União Européia numa economia sustentável, moderna e eficiente, em termos de captação de recursos e respeito ao meio ambiente. No *European Green Deal* exitem duas políticas que tratam da gestão de RCD, a política da Indústria Sutentável e a política da Construção e Inovação (EC, 2021a).

A política da indústria sustentável da União Européia pretende modernizar a economia circular através de políticas ambientais que desenvolvam os setores da indústria téxtil, construção, eletrônicos e plásticos, de forma a minimizar a extração de recursos não renováveis da natureza, a qual triplicou do ano de 1970 para 2017, ocasionando mais de 90% de perda da biodiversidade, um aumento de 20% de emissões de gases do efeito estufa (GEE) e, atualmente, somente 12% dos produtos fabricados com estas extrações são passíveis de reciclagem(EC, 2021b).

A geração de resíduos de RCD também é significativa em países de mercados emergentes. Na China, por exemplo, estima-se que cerca de 1,13 bilhão de toneladas de resíduos de RCD foram geradas em 2014, mesmo com a deterioração das atividades de construção civil desde o início de 2010 (Lu *et al*., 2017).

As ações da Agência Ambiental Chinesa para gestão dos RCD são importantíssimas, porque os impactes ambientais negativos destes resíduos ultrapassam

as fronteiras da China.

A indústria de construção civil da China cresceu 57,35%, nas últimas três décadas, o que provocou a geração de 1,0 bilhão de toneladas de RCD ⁄ano (Li *et al*., 2020).

A quantidade de RCD gerados é muito variável de país para país. Por exemplo, em Portugal os RCD representaram 8,8% do total de resíduos produzidos no ano 2018, enquanto que na Espanha no mesmo ano os RCD representaram 29,8% do total de resíduos produzidos (Eurostat, 2018a). Esses números correspondem à geração de 1.398.749 ton de RCD em Portugal e 38.138.409 ton de resíduos de RCD na Espanha, em 2018 (Eurostat, 2018b). Os Estados Unidos da América geraram, em 2018, 600.330.000 ton de RCD, com uma taxa de reaproveitamento de 100%. (EPA, 2020). Em 2019, o Brasil gerou uma média de 44,5 milhões ton de RCD, com uma geração *per capita* de 213,5 kg⁄habitante nesse ano, de acordo com o Panorama de Resíduos Sólido do Brasil 2020 (ABRELPE, 2020).

A Figura 2 compara os dados oficiais relativos à taxa de reaproveitamento de RCD em alguns países da Europa e nos EUA. Essa figura evidencia as diferenças existentes, mesmo entre países da União Europeia, regidos por idêntica legislação.

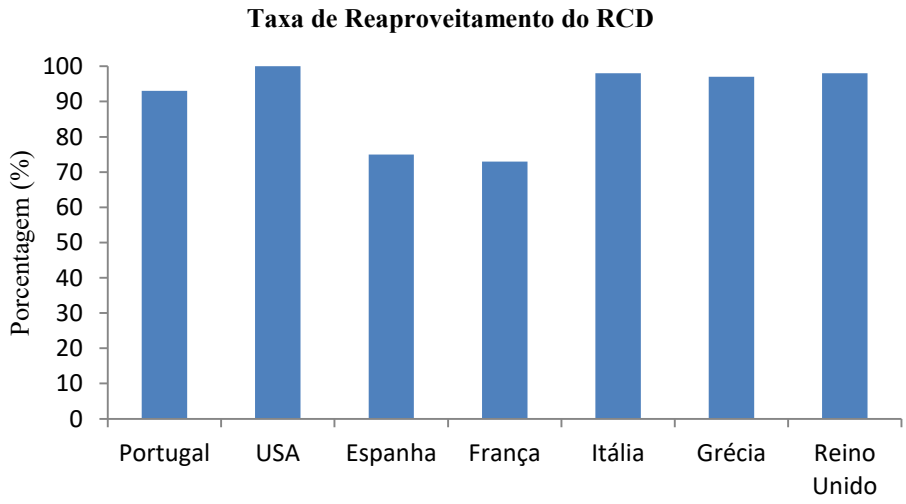

Figura 2. Reaproveitamento dos RCD (Adaptado de Eurostat, 2020; EPA, 2020 e IPEA, 2012).

Portugal possuia uma taxa de recuperação de RCD de 58% em 2010, o qual evoluiu para uma taxa acima de 90% em 2018 (Eurostat, 2020), devido aos esforços de Portugal para melhoria do meio ambiente. A Figura 3 ilustra essa evolução.

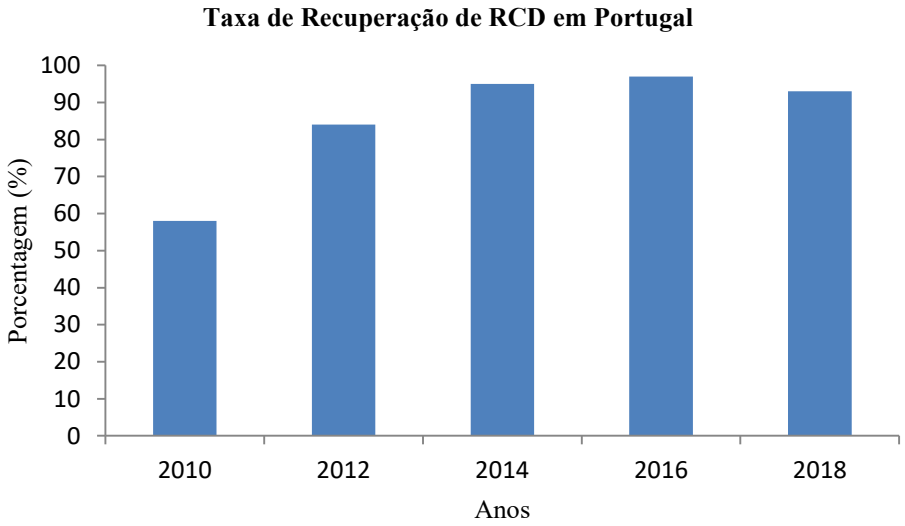

Figura 3. Evolução da recuperação de RCD em Portugal, com um aumento 60% da taxa de recuperação de RCD no período dos anos de 2010 a 2018 (Adaptado de Eurostat, 2020).

Resíduos da Construção e Demolição no Brasil

No Brasil, segundo o último censo realizado pelo IBGE em 2010, cerca de 72,4% dos municípios brasileiros possuem manejo do RCD. No entanto somente 9,7% dos municípios possuem o processamento deste RCD para reaproveitamento, cerca de 392 cidades, num total de 5.564 cidades do Brasil (IPEA, 2012).

A geração de RCD no Brasil expandiu nos últimos anos, devido a um desempenho econômico favorável, no qual a indústria da construção mais do que quadruplicou sua participação no produto interno bruto (PIB) do país (CBIC, 2016). A geração de RCD aumentou 35% do ano de 2010 para 2019, saltando de 33 milhões ton⁄ano para 44,5 milhões ton/ano (ABRELPE, 2020). A geração *per capita* também aumentou em 22,4%, do ano de 2010 para 2019, saltando de de 174,3 para 213,5 kg/habitante/ano (ABRELPE, 2020). A destinação inadequada dos resíduos em praças, ruas, margens de rios e aterros clandestinos aumentou 16% em relação à 2010, o que

afeta a saúde de 77,65 milhões de brasileiros, com um custo ambiental e de tratamento de sáude na ordem de 1 bilhão USD/ ano (ABRELPE, 2020).

No Brasil, o aumento da geração de resíduos sólidos levou autoridades, pesquisadores e a sociedade a direcionar seus esforços para o manuseio e descarte final de resíduos em uma postura reativa (Jacobi e Besen, 2011).

Até ao ano de 2002, os RCD estavam gerando sobrecarga nos sistemas de limpeza pública, porque a recolha dos RCD depositados em aterros clandestinos, áreas públicas, ruas, praças e margens de rios era de responsabilidade dos governos municipais, gerando gastos para o cidadão contribuinte. Contudo, a publicação da Resolução CONAMA nº 307/2002, do Conselho Nacional do Meio Ambiente (CONAMA), constitui um marco legal que denota a importância da Gestão de Resíduos no Brasil, porque estabeleceu imputação de responsabilidades aos geradores, tais como a segregação dos resíduos em diferentes classes e o seu encaminhamento para reciclagem e deposição final adequada. Posteriormente, a Resolução nº 348 de 2004 determinou que as áreas destinadas para essas finalidades, processamento, reaproveitamento e descarte, devem passar pelo processo de licenciamento ambiental e ser fiscalizadas pelos órgãos ambientais competentes. Em 2010, o Governo Brasileiro estabeleceu regras para a gestão de RCD, através da publicação de uma Lei Nacional de Resíduos, que trata da política nacional de resíduos, regulamentada pelo Decreto Nacional nº 7.404/2010 (Decreto 7404, 2010).

Na Tabela 2 apresentam-se os principais dispositivos legais que regem a política da gestão dos resíduos sólidos no Brasil, com especial enfoque nos resíduos da construção civil.

Tabela 2. Dispositivos legais da política nacional de resíduos da construção civil no Brasil.

Diploma Legal	Abrangência
Resolução nº 469/2015	Altera a Resolução CONAMA nº 307, de 05 de julho de 2002, que estabelece diretrizes, critérios e procedimentos para a gestão dos resíduos da construção civil (Resolução469, 2015)
Resolução nº 448/2012	Estabelece regras para a utilização e descarte dos resíduos provenientes das atividades de construção civil – RCC (Resolução448, 2012)
Resolução nº 431/2011	Altera a Resolução CONAMA nº 307/2002
Lei Federal nº 12.305/2010	Institui a Política Nacional de Resíduos Sólidos no Brasil (Lei12305, 2010)
Decreto nº 7.404/2010	Regulamenta a Política Nacional de Resíduos Sólidos no Brasil (Decreto7404, 2010)
Resolução nº 348/2004	Altera a Resolução CONAMA nº 307/2002
Resolução nº 358/2005	Dispõe sobre o tratamento e a disposição final dos resíduos dos serviços de saúde e dá outras providências (Resolução358, 2005)
Resolução nº 307/2002	Dispõe sobre a responsabilidades dos municípios em implementarem seus planos de gerenciamento integrado de RCC, bem com diretrizes, critérios e procedimentos para o manejo adequado destes resíduos
Lei Federal nº 9.605/1998	Lei de Crimes Ambientais que dispõe sobre as sanções penais e administrativas derivadas de condutas e atividades lesivas ao meio ambiente, e dá outras providências (Lei9605, 1998)
Lei Federal nº 6.938/1981	Dispõe sobre a Política Nacional do Meio Ambiente, seus fins e mecanismos de formulação e aplicação, e dá outras providências (Lei6938, 1981)

A definição para Resíduo da Construção Civil (RCC) é encontrada na Resolução CONAMA nº 307/2002, em seu Artigo 2º, como resíduos provenientes de construções, reformas, reparos e demolições de obras de construção civil, e os resultants da preparação e da escavação de terrenos, tais como: tijolos, blocos cerâmicos, concreto em geral, solos, rochas, metais, resinas, colas, tintas, madeiras e compensados, forros, argamassa, gesso, telhas, pavimento asfáltico, vidros, plásticos, tubulações, fiação elétrica etc., comumente chamados de entulhos de obras, caliça ou metralha.

Em seu Artigo 3º, a Resolução Conama no 307/2002, alterada pela Resolução Conama nº 348/2004 (Artigo 3º, inciso IV), propõe a classificação dos RCC, que deverão seguir a seguinte divisão:

> I - classe A - são os resíduos reutilizáveis ou recicláveis como agregados, tais como:
> a) de construção, demolição, reformas e reparos de pavimentação e de outras obras de infraestrutura, inclusive solos provenientes de terraplanagem;
> b) de construção, demolição, reformas e reparos de edificações: componentes cerâmicos (tijolos, blocos, telhas, placas de revestimento etc.), argamassa e concreto;
> c) de processo de fabricação e/ou demolição de peças pré-moldadas em concreto (blocos, tubos, meios-fios etc.) produzidas nos canteiros de obras;
> II - classe B - são os resíduos recicláveis para outras destinações, tais como: plásticos, papel/papelão, metais, vidros, madeiras e outros;
> III - classe C - são os resíduos para os quais não foram desenvolvidas tecnologias ou aplicações economicamente viáveis que permitam a sua reciclagem/recuperação, tais como os produtos oriundos do gesso;
> IV - classe D - são resíduos perigosos oriundos do processo de construção, tais como tintas, solventes, óleos e outros ou aqueles contaminados ou prejudiciais à saúde oriundos de demolições, reformas e reparos de clínicas radiológicas, instalações industriais e outros, bem como telhas e demais objetos e materiais que contenham amianto ou outros produtos nocivos à saúde.

Gestão dos Resíduos da Construção e Demolição na Cidade de Manaus

Na Região Norte do Brasil, encontramos a cidade de Manaus, capital do estado do Amazonas, local onde foram realizados os estudos desta pesquia sobre a gestão do RCD.

A cidade de Manaus localiza-se no Brasil, nas coordenadas geográficas de 3º6'0"S e 60º1'0"W, na margem esquerda do Rio Negro, no metacentro da Floresta Amazônica (Figura 4).

Figura 4. Localização da cidade de Manaus no globo terrestre (Adaptado de Googlemaps, 2020).

O município de Manaus possui uma área territorial de 11.401 km^2 (IBGE, 2020a), aproximadamente 114 vezes a área territorial de Lisboa, com 100 km^2 (Pordata, 2018a) e 275 vezes a área territorial de Porto, com 41,4 km^2 (Pordata, 2018b). A área da cidade de Manaus está exposta na Figura 5.

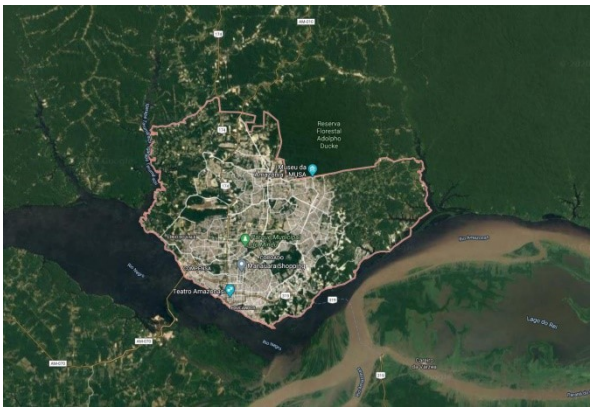

Figura 5. Área territorial da cidade de Manaus (Adaptado de Googlemaps, 2020).

Atualmente a população da cidade de Manaus está com 2.219.580 habitantes (IBGE, 2020a), e pode ser comparada com a população a cidade de Lisboa, com 506.654 (Pordata, 2018a) habitantes, e a cidade de Porto, com 214.936 (Pordata, 2018b), conforme apresentado na Figura 6.

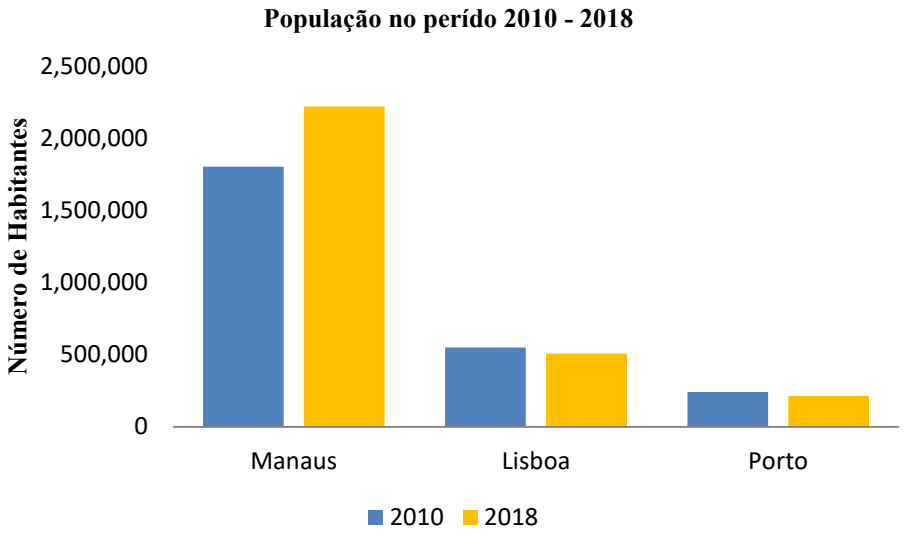

Figura 6. População de Manaus, Lisboa e Porto no período de 2010 – 2018 (Adaptado de IBGE, 2020a; Pordata, 2018a e Pordata, 2018b).

A população de Manaus cresceu 18,81% de 2010 para 2018, entretanto a cidade de Lisboa diminuiu 8,40% e a população da cidade de Porto tambéu sofreu redução em 11,50% de 2010 para 2018. O crescimento da população de Manaus pode ser observado desde a década de 1970, conforme os dados dos censos realizados a cada década pelo IBGE no Brasil (Figura 7).

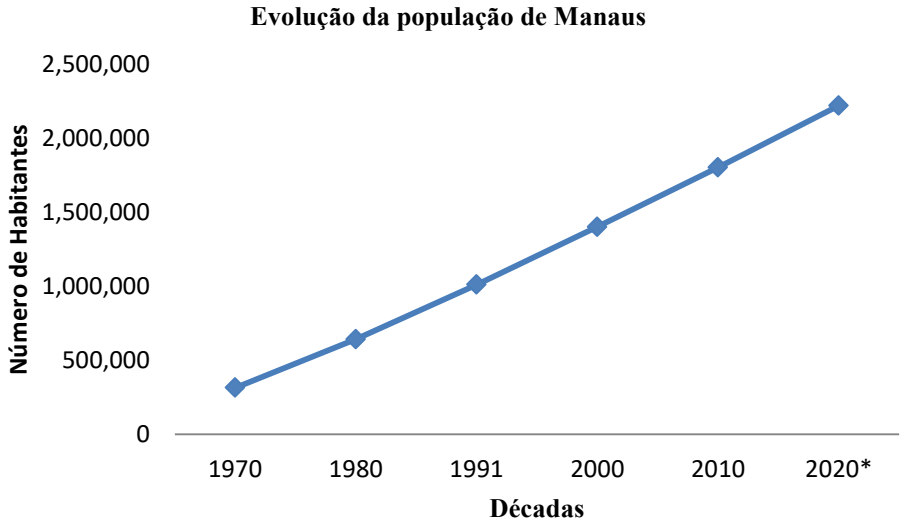

Figura 7. População de Manaus período de 1970 – 2020 (Adaptado de IBGE, 2020a).

O crescimento da população de Manaus, apresentado na Figura 7, desde 1970

até 2020, demonstra a tendência da cidade de Manaus a se transformar em uma metrópole em desenvolvimento na próxima década. Em harmonia com o crescimento populacional de Manaus, o setor da construção civil também apresentou crescimento, impulsionado pela necessidade de residências/moradias e infrastruturas para a população emergente.

A Figura 8 apresenta o crescimento da Indústria da Construção Civil em Manaus no período de 2009 a 2018, conforme a Pesquisa Anual da Indústria da Construção Civil (PAIC) realizada pelo IBGE (IBGE, 2020b).

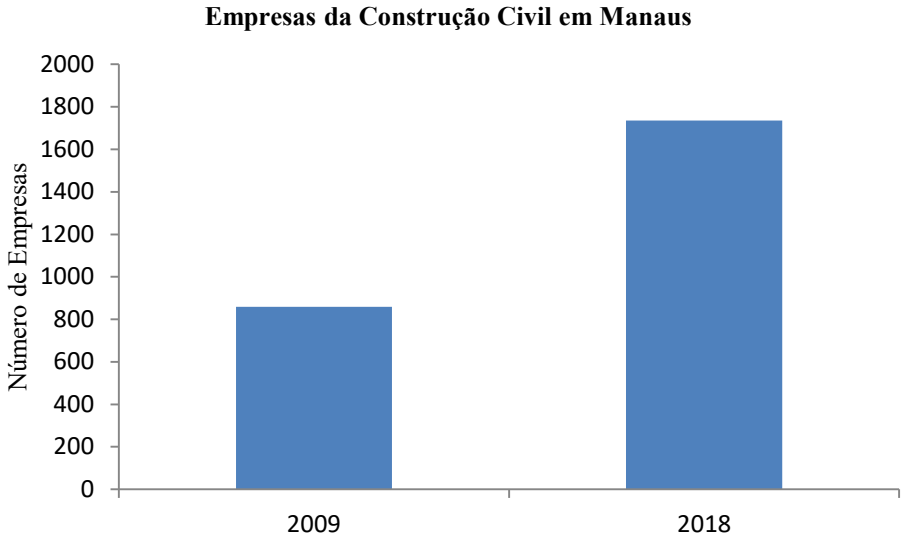

Figura 8. Empresas da industria de construção civil em Manaus (Amazonas) no período de 2009 – 2018 (Adaptado de IBGE, 2020b).

O quantitativo de empresas de construção civil em Manaus duplicou de 2009 para 2018, entretanto ainda é 13% do número de empresas de construção de Lisboa e 54% do número de empresas de construção da cidade de Porto (Infoempresas, 2020).

Em se tratando de uma realidade especifica de Manaus, a Secretaria Municipal de Limpeza Pública (SEMULSP, 2020) destacou que de janeiro a agosto de 2017 foram recolhidas 582.169 toneladas de resíduos sólidos em Manaus, o que representa uma média diária de 2.395,8 toneladas de resíduos sólidos recolhidos.

Dentre os resíduos sólidos encontramos os RCDs, que são descartados em locais

de despejo de descargas ilegais, áreas não aprovadas, terrenos baldios, margens de rio e áreas de preservação permanente (SEMULSP, 2020). Este despejo irregular apresenta impactes negativos para a Amazônia e o meio ambiente urbano, referentes à contaminação do solo e da água. A coleta de resíduos sólidos nas margens dos rios que banham a cidade de Manaus, é realizada através de uma balsa coletora, conforme a Figura 9.

Figura 9. Balsa coletora de resíduos sólidos nas margens dos rios da cidade de Manaus. A taxa de coleta é de 100 ton ⁄ km nas margens dos rios Negro, Solimões e mais 36 igarapés (Adaptado de SEMULSP, 2020).

O aterro sanitário público da cidade de Manaus funciona como local de destinação final dos resíduos sólidos, localizado no km 19 da rodovia AM-010, que liga Manaus a Itacoatiara, no estado do Amazonas, Brasil. O aterro sanitário público possui controle das emissões gasosas, captando o biogás resultante da degradação dos resíduos e procedendo à sua queima. No entanto, o aterro sanitário público de Manaus não possui uma usina de reciclagem e reuso de RCD, e portanto não existe uma gestão especifica da reutilização de RCD. Assim estes resíduos não estão sendo aceites no aterro sanitário de Manaus, o que incentiva o despejo irregular de RCD em aterros clandestinos na cidade de Manaus.

Conforme a SEMULSP (2020), o aterro sanitário de Manaus tem 75 hectares e possui uma área que está no limite de sua vida útil, que chega ao fim em 2021. Somente uma última área do aterro sanitário continua recebendo lixo e os resíduos estão sendo aterrados na terceira das cinco camadas restantes.

Em 2022 será construído um novo aterro sanitário público em Manaus e uma boa prática seria a construção de uma usina de reciclagem e reutização de RCD neste novo local, constituída por processos de separação de materiais e sua preparação (britagem) para reciclagem e, posterior, reutilização em obras e serviços, o que inibiria os despejos ilegais em aterros clandestinso de RCD ou nas margens dos rios.

Atualmente, em virtude da proibição de despejo de RCD no aterro público de Manaus, as grandes construtoras utilizam os canteiros de obra para aplicar o Plano de Gerenciamento de Resíduos Sólidos da Construção Civil (PGRSCC), obrigatório para o licenciamento ambiental das obras, para ações de boas práticas, como a reciclagem e reutilização do RCD, através da aplicação de técnicas que se desenvolvem a cada dia, dentro dos próprios canteiros de obras.

Em sua pesquisa relativa a uma empresa coletora de entulho em Manaus, Cardoso (2010) encontrou as seguintes informações: a empresa recolhe 400 t/mês dos quais 50 % é de material de demolição (alvenaria), 30% de concreto, 10% madeira e papelão, 5% de latas de tintas e solventes, e 5% de metais e gesso. Estes são transportados para o depósito da empresa, e depois de selecionados superficialmente, cerca de 60% destes são direcionados ao aterro sanitário. Segundo Pinto (1999), as despesas com remoção do entulho para aterros são substancialmente maiores que a própria reciclagem.

Segundo Cardoso (2010) o custo desse processo de gerenciamento dos resíduos sólidos de Manaus é bastante elevado e acaba sendo ineficiente, uma vez que muitos entulhos ainda não têm o destino final adequado, e muitos ainda, não são reaproveitados.

Logo esse cenário de gestão desadequada dos RCD na cidade de Manaus acaba sendo um reflexo da necessidade de intervenção, não apenas do Governo, mas de toda a comunidade profissional de engenharia civil, uma vez que é sim responsabilidade social e empresarial, garantir a a reutilização ou reciclagem desses materiais, e também o seu descarte adequado.

Na cidade de Manaus a má gestão de RCD e a ausência de políticas públicas eficientes relacionadas ao manejo e gestão de RCD causa impactes negativos, como poluição visual, obstrução dos sistemas de drenagem urbana, proliferação de animais peçonhentos e vetores de doenças como a malária, febre amarela e dengue (Córdoba, 2014; Marques Neto *et al*., 2004), além dos impactes ambientais decorrentes da contaminação de solos e cursos de água. Um exemplo de RCD despejado em via pública na cidade de Manaus está demonstrado na Figura 10.

Figura 9. Resíduos da construção e demolição depositados em local inadequado, em via pública da cidade de Manaus. (Acervo pessoal, foto tirada em 20/11/2020).

Os principais impactes negativos ocasionados pela ineficiência na gestão de RCD na cidade de Manaus estão apresentados na Tabela 3.

Note-se que, apesar de estarem aqui apresentados para o caso concreto de Manaus, estes impactes são transversais a qualquer outro município no Brasil, sendo também extensíveis à realidade de outros países em desenvolvimento.

Tabela 3. Principais impactes negativos dos resíduos da construção e demolição em Manaus (Adaptado Lamego Oliveira *et al*., 2021c).

Deficiência da Gestão do RCD	Impactes em Manaus (Amazonas-Brasil)			
	Urbanos	**Ambientais**	**Sociais**	**Econômicos**
Caixas de coleta estacionadas de forma irregular nas calçadas e vias públicas (sem sinalização vertical e horizontal)	Destruição de calçadas Obstáculo para passagem de pedestres Obstáculo para passagem de veículos Obstrução de sarjetas e galerias das vias públicas	Emissão de poeiras Poluição visual Poluição sonora Proliferação de doenças devido a insetos e vetores que são atraídos para o local	Acidentes de trânsito Atração de catadores de lixo que revolvem os resíduos da caçamba	Custo de reparos de calçadas e vias públicas Custo de reparos e desobstrução das sarjetas e galerias urbanas
Empresas de coleta de RCD não cadastradas no CREA/AM e Prefeitura Municipal	-	Empresas não possuem responsável técnico engenheiro ambiental	Coleta, transporte e descarte de RCD realizados sem supervisão adequada do CREA/AM e Prefeitura Municipal de Manaus	Impossibilidade de cobrança de taxas, impostos e multas que são revertidos para a melhoria do meio ambiente
Ausência do Processamento do RCD	-	Sobrecarga dos aterros sanitários e encurtamento da vida útil do Aterro Municipal de Manaus	-	A falta de processamento do RCD impossibilita a reciclagem e o reuso, prejudicando a criação de uma economia circular que gere retorno financeiro para cooperativas de catadores, empresas de reciclagem de RCD e a Prefeitura Municipal de Manaus
Descarte Final Irregular (áreas de descarte clandestinos em Manaus)	Enchentes e inundações ocasionados pelo excesso de descarte de RCD nos riachos e rios	Degradação do solo urbano e das margens dos riachos e rios pela contaminação por metais pesados contidos nas tintas,	Dificulta a criação de cooperativas de catadores que reciclem ou reusem os RCD	Prefeitura Municipal realiza um alto custo para limpeza dos locais clandestinos de descarte de RCD.

	vernizes, óleos, entulhos, etc.

Princípios da Economia Circular

São muitos os estudos que demonstram a viabilidade econômica e ambiental do aproveitamento dos RCD através da sua reutilização e/ou reciclagem, contribuindo assim para a preservação dos recursos naturais utilizados na construção civil e reduzindo a quantidade de RCD destinados à deposição final (ver, por exemplo, Yeheyis *et al*., 2013; Ossa *et al*., 2016; Contreras *et al.*, 2016). Assim sendo, há um grande potencial para a aplicabilidade do conceito de Economia Circular à gestão de RCD (Adams *et al*., 2017; Gálvez-Martos *et al*., 2018).

A Economia tradicional consome os recursos naturais que podem faltar para as gerações futuras, além disso, produz de forma desenfreada resíduos que impactam negativamente o meio ambiente, porque degradam o solo e poluem o ar e os oceanos do nosso planeta. O conceito de Economia Circular, introduzido por Boulding (1966) e complementado por Pearce e Turner (1990), representa uma nova abordagem, crucial para a promoção da Sustentabilidade (Lin, 2020).

A Economia Circular considera os resíduos como uma uma fonte inesgotável de matérias-primas para diversos processos produtivos, através da criação de ciclos nas cadeias de suprimento com o objetivo de reutilizar, reformar, reciclar, minimizar, eliminar, compartilhar e otimizar os resíduos produzidos (Nandi *et al.*, 2020). Outros conceitos de Economia Circular estão demonstrados na Tabela 4, na qual se apresentam definições retiradas de estudos recentes sobre o tema.

Tabela 4. Conceitos e definições de Economia Circular.

Autores	Conceito
Lin (2020)	É um sistema de crescimento econômico sustentável, viável e muito promissor, mas exige esforço dos governos.
Nandi *et al.* (2020)	Uma iniciativa política para implementação de estratégias de gestão de resíduos, através da criação de *loopings* na cadeia de suprimento das fábricas e empresas de produção.
Parchomenko *et al.* (2020)	É um sistema econômico onde os materiais, componentes e produtos devem ser mantidos no mais alto nível de funcionalidade, enquanto são evitados os fenômenos de diluição, mistura e contaminação, referidos como perda de recursos.
Ddiba *et al.* (2020)	É uma economia que requer investimentos estratégicos em infraestrutura, mas também requer coerência política, coordenação e colaboração entre as partes interessadas em todos os setores e níveis governamentais.
(CircularColab, 2018)	É um modelo econômico de solução sustentável para dissociar o crescimento econômico contínuo da contínua degradação e poluição ambiental.

A Economia Circular é baseada nos seguintes princípios (Adams *et al*., 2017):

- Aumentar a produtividade dos materiais, fazendo mais com menos;
- Eliminar resíduos através da sua classificação como matéria-prima, criando ciclos materiais fechados;
- Manter ou aumentar o valor económico e ambiental dos materiais;
- Repensar os fluxos de material e energia nos sistemas industrializados, identificando ligações e oportunidades para a criação de circuitos fechados.

A incorporação destes princípios em contexto empresarial pode ser feita com base em diversos modelos de negócio (Tabela 5), com a perspetiva de manter ou aumentar a geração de lucro e a competitividade das empresas (Nandi *et al*., 2020).

Tabela 5. Possíveis Modelos de negócio desenvolvidos com base nos princípios da Economia Circular (Adaptado de Nandi *et al.*, 2020).

Autores	Modelos de Negócio
Stahel (2016)	Modelo que propõe a extensão da vida útil do produto por meio da reutilização, remanufatura, manutenção e reciclagem.
Moreno *et al.* (2016)	Modelo que propõe a utilização do produto de forma compartilhada e com extensão da sua vida útil através de suprimentos circulares.
Bocken *et al.* (2016)	Modelo de simbiose industrial com extensão da vida útil do produto e ampliação do seu valor. Encoraja a suficiência industrial.
Van Renswoude *et al.* (2015)	Modelo de produção sob demanda, sem estoques e com pouca matéria-prima. Os serviços são desmaterializados.
Mentink (2014)	Modelo que visa a manutenção/reparo, a reutilização, a modernização, a remanufatura e a reciclagem do produto com economia de energia.
Lacy *et al.* (2014)	Modelo que oferece os produtos como serviços e a transformação do produto através da reciclagem 2.0 e do consumo colaborativo.
Bakker *et al*. (2014)	Modelos apresentados: a) modelo clássico de extensão da vida útil do produto; b) modelo híbrido (combinar produto durável com consumíveis de curta duração); c) modelo explorador de lacunas (componentes de produtos que duram mais do que o resto); d) modelo de acesso (o cliente paga pelo acesso ao produto); e) modelo de desempenho (o cliente paga pelo desempenho em vez do produto).
Evans and Bocken (2013)	Modelo que oferece os produtos como serviços através do projeto, fabricação, distribuição, uso, manutenção/reparo e reciclagem do produto.

Vários estudos demonstram que a aplicação dos princípios da Economia Circular na gestão de RCD foi já implementada com sucesso em diversos países.

A Alemanha e a China possuem legislações específicas que tratam da economia circular, apesar da adoção de linhas de ações diferentes quanto ao RCD. A China considera a economia circular desde a elaboração dos projetos dos empreendimentos,

projetos *ecodesign* que criam parques e redes eco-industriais com uma geração mínima de RCD. A Alemanha adota ações que minimizam a geração de RCD através da reciclagem no próprio local de geração (Adams et al., 2017).

No México foram realizados estudos para utilização de alternativas sustentáveis, através da utilização de um pavimento asfáltico que contém 40% de agregados de RCD reciclados, com resultados favoráveis para produção e aplicação (Ossa *et al*., 2016).

A Polônia apresentou uma redução de 16,31% na geração *per capita* de resíduos sólidos urbanos, numa comparação de 2004 para 2012, após implementação de boas práticas de desenvolvimento sustentável através de melhoramentos nos métodos de coleta de resíduos, alterações no volume dos recipientes de coleta, criação de taxas de coleta de resíduos e educação ecológica dos moradores das cidades e dos geradores de resíduos (Mesjasz-Lech, 2014).

No ano de 2014, havia em toda a China 20 empresas especializadas em reciclagem de RCD, cujo número aumentou para 70 em 2018. Uma expansão de 350% em 4 anos no setor de reciclagem da China, o que demonstra o sucesso das boas práticas ambientais de reciclagem implementadas (Li *et al.*, 2020).

A Alemanha e Holanda apresentaram sucesso na implementação da Economia Circular, devido uma cultura bem estabelecida de reciclagem dos RCD, incentivada por um regramento legislativo e político favorável às boas práticas de gestão de resíduos (Li *et al*., 2020).

A organização CircularColab reporta os resultados de 202 iniciativas de modelos de economia circular desenvolvidas nos Estados Unidos da América. As conclusões deste estudo demonstram que os princípios da economia circular já estão presentes num grande número de empresas americanas, sendo que a reciclagem de resíduos se apresenta como a iniciativa mais frequente nos casos analisados (CircularColab, 2018).

Um estudo realizado em 52 cidades chinesas, que utilizam reciclagem de RCD em seus modelos de Economia Circular, apresentaram resultados positivos na aplicação de 3 ações concretas de boas práticas: Política de cobrança ou taxa (84,6%), utilização de padrões de qualidade tecnológicos (11,5%) e pela utilização do rótulo-verde (7,7%), conforme Li *et al.* (2020).

É de salientar que a implementação bem sucedida de medidas de promoção da Economia Circular no sector da Construção Civil implica o envolvimento adequado de diferentes atores (Lamego Oliveira *et al*., 2021c), desde o cidadão comum, empresas e corporações até o poder público (Adams *et al*., 2017).

Boas Práticas na Gestão de Resíduos da Construção e Demolição

A União Européia recomenda uma auditoria dos resíduos antes da reciclagem de qualquer material. Esta auditoria deve fazer parte do projeto de obras de demolição ou renovação de edifício e conter recomendações sobre a forma e cuidados a ter na manipulação dos materiais e na avaliação dos processos de reciclagem ou reutilização possíveis para os mesmos. A auditoria realizará um inventário de materiais com informações sobre o potencial valor de reutilização e sugerirá a reciclagem no local ou fora do local, com indicações de economia em termos de energia (EC, 2021a). Em complementação a Auditoria recomendará as seguintes ações para gestão de RCD no local, relacionadas na Tabela 6 a seguir.

Tabela 6. Boas práticas para gestão de RCD no local da geração (Adaptado de EC, 2021a).

Item	Recomendação de Auditoria
1	Devem ser tomadas todas as precauções para destinação segura dos RCD.
2	Durante a fase da desconstrução ou renovação da obra a prioridade será a saúde e segurança dos operários e usuários dos materiais.
3	Identificação de eventuais desvios de resíduos de determinados fluxos de resíduos identificados (reutilização, reciclagem, enchimento, valorização energética e eliminação) e uma estimativa das taxas de desvio. Podem ser apresentadas alternativas diferentes para cada grupo de materiais ou fluxos de resíduos.
4	Identificação (nos planos ambiental e económico) das atividades de triagem favoráveis no local, que podem incluir a descrição dos requisitos de instalação para armazenagem, manipulação, separação e quaisquer outras operações para gerir os diferentes fluxos de resíduos.

A União Européia definiu o Protocolo de Gestão de RCD com o objetivo geral de reforçar a confiança no processo de gestão dos RCDs e na qualidade dos materiais reciclados (EC, 2021b), através das seguintes ações:

i. Melhoria da identificação, da separação na origem e da recolha de resíduos;
ii. Melhoria da logística de resíduos;
iii. Melhoria do processamento de resíduos;
iv. Gestão da qualidade;
v. Condições políticas e de enquadramento adequadas.

O Protocolo de gestão de RCD da União Européia recomenda a implementação de boas práticas em todas as fases do processo de reciclagem de RCD, porque os materiais reciclados necessitam de uma qualidade e de uma garantia da qualidade para serem utilizados pela população. Além disso, certos materiais precisam de atenção especial porque liberam substâncias tóxicas quando manipulados pelos operários, exemplo do amianto, e alguns possuem substâncias nocivas ao meio ambiente, exemplo de materiais que contenham tintas e vernizes (EC, 2021b). As boas práticas sugeridas estão listadas na Tabela 7.

Tabela 7. Boas práticas de gestão nas etapas dos processos de reciclagem de RCD (Adaptado de EC, 2021b).

Etapa 1 Identificação, separação na origem e recolha de resíduos	Etapa 2 Transporte dos Resíduos	Etapa 3 Processamento e Tratamento de Resíduos
Auditoria de pré-demolição comu deteção de materiais nocivos como o amianto.	Transporte seguro.	Controlo de entrada, por exemplo, protocolo do amianto.
Demolição seletiva.	Diligências especiais/declaração sobre os resíduos perigosos.	Autorização para admissão dos resíduos na estação de reciclagem ou no aterro.
Identificação e separação de resíduos perigosos.	Formulário de identificação.	Controlo de produção em fábrica, com a inspeção das características essenciais dos produtos.
	Transportador registado ou aprovado.	Critérios de admissão, por exemplo, matérias-primas utilizadas no fabrico de produtos derivados de resíduos.
		Frequência da colheita de amostras.
		Identificação dos agregados reciclados utilizados num produto/estrutura específicos, através de uma nota de entrega e de ensaios finais aos produtos derivados de resíduos, devidamente documentados.

Objetivos da Tese

No âmbito do enquadramento feito nos pontos anteriores, a presente investigação teve como principal objetivo o desenvolvimento de um novo modelo para a gestão de RCD, com base nos princípios da Economia Circular, envolvendo diversos atores: os produtores dos resíduos, as entidades fiscalizadoras, e as entidades reguladoras. As estratégias aqui propostas têm como base o caso específico do município de Manaus, mas pretendem ser aplicáveis a qualquer outra cidade ou município no Brasil.

Os objetivos específicos desta pesquisa, por sua vez, consistiram nos itens da

Tabela 8 a seguir.

Tabela 8. Objetivos específicos e metodologia aplicada.

Item	Objetivo Específico	Metodologia
I	Caracterizar as práticas em curso na gestão de RCD nos canteiros de obra.	Pesquisa exploratória, qualitativa e quantitativa, recorrendo à aplicação de inquéritos nas principais obras em curso no município de Manaus.
II	Elaborar e propor um novo plano de fiscalização ambiental com boas práticas a serem implementadas pelo Conselho Regional de Engenharia e Agronomia do estado do Amazonas (CREA-AM), com o propósito de monitorar e fiscalizar os descartes de RCD na cidade de Manaus.	Pesquisa exploratória, qualitativa e quantitativa, dos processos administrativos do CREA-AM de notificações e multas de leigos, profissionais e empresas da área ambiental para identificar os principais problemas e possíveis soluções.
III	Propor soluções tecnológicas para uma nova e inteligente gestão ambiental na cidade de Manaus, que auxilie os órgãos públicos de fiscalização ambiental.	Desenvolvimento de um aplicativo de telemóvel acessível a todos os cidadãoes e empresas.
IV	Identificar aterros clandestinos e ilegais na cidade de Manaus, e propor melhorias a implementar na gestão do Aterro Municipal de Manaus de forma a inibir a utilização desses aterros clandestinos	Pesquisa exploratória, qualitativa e quantitativa, dos locais clandestinos na cidade de Manaus, com mapeamento através do GPS.

Organização da Tese

A presente Tese de Doutoramento foi organizada em quatro capítulos, após a introdução e antes das conclusões.

O primeiro capítulo demonstra um artigo publicado na revista *Current Word Environment Journal*, v.14(2), publicado com o título *Waste Management at Construction Sites in the Municipality of Manaus, Amazonas, Brazil: Characterization of the Current Situation*, onde são apresentados estudos de inquéritos aplicados em empresas de construção civil na cidade de Manaus sobre a gestão e a destinação de RCD gerados nos canteiros de obra (Lamego Oliveira *et al.*, 2019a).

O segundo capítulo apresenta um estudo apresentado no *2nd World Symposium on Social Responsibility and Sustainability, Curitiba, Brazil, April 27-29 2020*, com o

título *The role of regional management in promoting social responsibility practices: a case study in the Amazon Region*, e que foi posteriormente publicado como um capítulo de livro da Sustainability Edition Series da editora Springer. Este capítulo foca uma pesquisa sobre as práticas adotadas pelo Conselho Regional de Engenharia e Agronomia (CREA-AM) na fiscalização ambiental da Amazônia (Lamego Oliveira *et al*., 2021a). A investigação abordou os processos administrativos de infrações emitidas pela fiscalização do CREA-AM, que visam coibir o exercício ilegal das profissões sujeitas à fiscalização do sistema CONFEA-CREA. Assim, destaca-se as legislações que tratam do assunto: Lei 5194 (1966); Resolução 1008 (2004); Resolução 447 (2000); e Resolução 1121 (2019).

O terceiro capítulo trata do artigo publicado nas atas do *XIII International Conference on Virtual City and Territory: Challenges and paradigms of the contemporaty city, UPC, Barcelona, October 2-4, 2019*, com o título *Intelligent management of construction waste: mobile application technology in the city of Manaus, Amazonas, Brazil*, que propõe a utilização de um aplicativo telemóvel para utilização de cidadãos e empresas como solução para uma gestão voltada para uma economia circular sustentável na cidade de Manaus (Lamego Oliveira *et. al*., 2019b).

O quarto capítulo apresenta um estudo apresentado na *2nd Conference of Environmental Innovations: Advances in Engineering, Technology and Management, Online Conference, October 19-23, 2020,* com o título *Actions to inhibit clandestine landfills in the city of Manaus, Amazon, Brazil*, e que foi posteriormente publicado na revista científica Procedia Environmental Science, Engineering and Management. O foco deste artigo foi o estudo dos aterros clandestinos e das boas práticas para inibição dos mesmos, através de propostas de melhoria na gestão do aterro municipal sanitário de Manaus (Lamego Oliveira *et al*., 2021b).

A secção das conclusões analisa o roteiro seguido nas investigações e os resultados encontrados ao longo do estudo.

CAPÍTULO I – GESTÃO DE RESÍDUOS EM CANTEIROS DE OBRAS NO MUNICÍPIO DE MANAUS, AMAZONAS, BRASIL: CARACTERIZAÇÃO DA SITUAÇÃO ATUAL

CAPÍTULO I – GESTÃO DE RESÍDUOS EM CANTEIROS DE OBRAS NO MUNICÍPIO DE MANAUS, AMAZONAS, BRASIL: CARACTERIZAÇÃO DA SITUAÇÃO ATUAL

Este primeiro Capítulo da Tese engloba os estudos realizados no segundo semestre de 2018 relativos à obtenção de dados quanto à geração, volume, classificação e destinação dos RCD produzidos nos canteiros de obra da cidade de Manaus (Amazonas-Brasil). A metodologia utilizada foi a aplicação de inquéritos e realização de visitas *in loco* a quatro canteiros de obra abrangendo mais de 90.000 m^2 de área em construção. Foram abrangidas obras privadas de construção de prédios residenciais multifamiliares, e obras públicas para a implantação de usinas termoelétricas. Os dados coletados foram utilizados para caracterizar as práticas de gestão de resíduos das empresas geradoras de RCD na cidade de Manaus, identificando os principais problemas existentes e permitindo visualizar oportunidades de melhorias no descarte de RCD, como a reciclagem no próprio canteiro de obra.

Lamego Oliveira, M.P.S., de Oliveira, E.A., Freitas, R.R., Campos, A.M.L.S., Fonseca, A.M. (2019a). Waste Management at Construction Sites in the Municipality of Manaus, Amazonas, Brazil: Characterization of the Current Situation. *Current World Environment,* 14(2), 326-335.

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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.[1] The European Commission has already defined that by 2020 a 70% reduction in construction waste should be achieved, on the basis of recycling,[2] 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[3]. 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[4]. 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.[4] 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[5] 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[6] 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,[7] because CDW affect the environment in multiple ways: they contaminate soil, water and air, and change the natural environment, among other ecosystem degradations.[8] In order to change the Environmental Policy of the civil construction sector, first it is necessary to change individual's recycling attitude and behaviour[9]. 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.[17] 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,[18] and in Saudi Arabia.[19] 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 people10 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.[11] 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.[12] 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[13] 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.[14]

Results and Discussion

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

Fig.2: Construction Site of a Ther moelectric 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,[15] and by the Environmental Protection Department (EPD) in Hong Kong.[16]

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 m² of constructed area of a thermoelectric plant, the volume of waste produced during the entire construction period was 1,234.00 m³, 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

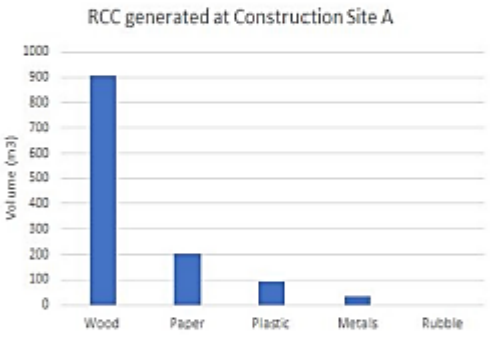

Fig.5: Civil Construction Waste generated at Construction Site A

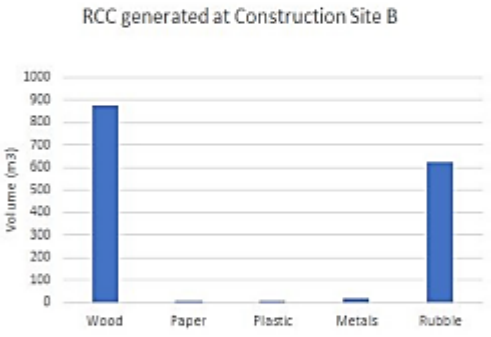

Fig.6: Civil Construction Waste generated at Construction Site B

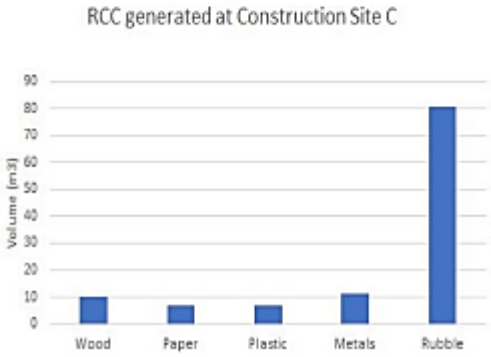

Fig.7: Civil Construction Waste generated in Construction Site C

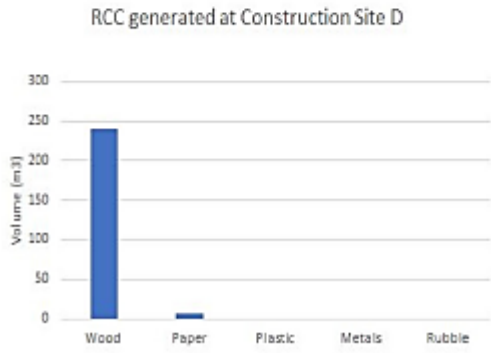

Fig.8: Civil Construction Waste generated at Construction Site D

(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 m² of constructed area of residential buildings, the volume of waste produced during the entire construction period was 893.00 m³, 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 m² 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 m³, 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 m² 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 m³, 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

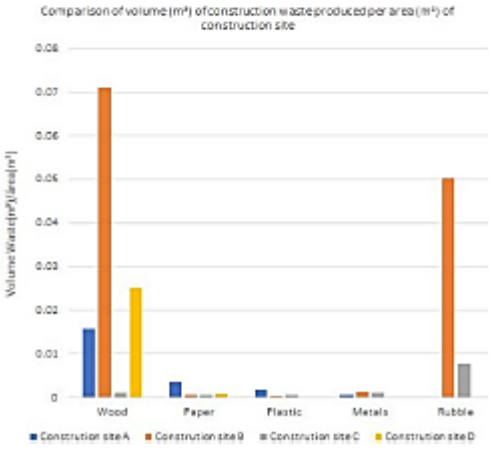

Fig.9: Comparison of waste produced by construction site area

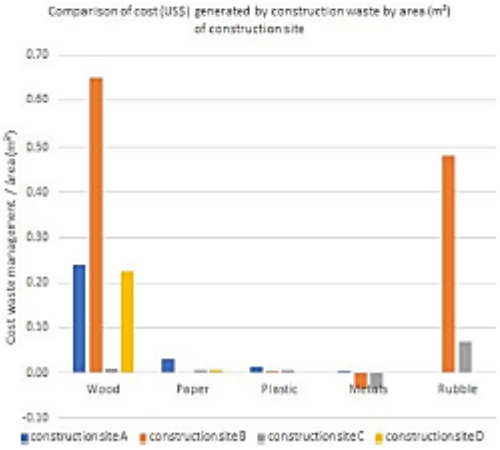

Fig.10: Comparison of costs with construction waste management (US$) by area (m²) of construction site

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^2)	Volume of waste generated (m^3)
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 landfillI	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^3) are compared to the construction areas (m^2) 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^2 and cost / m^2.

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)[8] report a case study

Table 4: Comparison between the results found and the studies of other authors[8,13].

Construction site	Construction and demolition waste (CDW)	Waste reported in the present study (m^3/m^2)	Cost impact Waste management in the present study (% of the total cost)	Waste reported by Bravo *et al.*, (2019) (m^3/m^2)	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)[13] 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.[13] 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,[8] 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 nº 4,457/2017[20] 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[20] 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,[15] 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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CAPÍTULO II – O PAPEL DA GESTÃO REGIONAL NA PROMOÇÃO DE PRÁTICAS DE RESPONSABILIDADE SOCIAL: UM ESTUDO DE CASO NA REGIÃO AMAZÔNICA

CAPÍTULO II – O PAPEL DA GESTÃO REGIONAL NA PROMOÇÃO DE PRÁTICAS DE RESPONSABILIDADE SOCIAL: UM ESTUDO DE CASO NA REGIÃO AMAZÔNICA

O estudo apresentado neste capítulo da Tese trata de uma pesquisa realizada no período de 2017 e 2018 nos processos administrativos da fiscalização do Conselho Regional de Engenharia e Agronomia no estado do Amazonas (CREA-AM), localizado na cidade de Manaus (Amazonas-Brasil), com relação à atuação dos profissionais da área ambiental, das empresas de construção civil que geram os RCD na Amazônia e das empresas de coleta e destinação destes RCD. Os resultados foram utilizados na elaboração do novo Plano de Fiscalização (2021-2022) para o CREA-AM, com estratégias inovadoras de tecnologia para fiscalização da destinação dos RCD, como o rastreamento das caixas de coleta e da fiscalização quanto à legalização dos locais de descarte, boas práticas para se atingir resultados aceitáveis de registos de Anotação de Responsabilidade Técnica (ART) no CREA-AM.

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The Role of Regional Administration on the Promotion of Social Responsibility Practices: A Case Study in the Amazon Region

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1 Introduction

In a society that is increasingly intolerant to unsustainable practices, companies adopt Social Responsibility (SR) to enhance their commitment and contribution regarding sustainability issues. The general public is highly aware of the need to change behaviours to promote environmental and social sustainability, and stakeholders are pressuring companies to integrate these concepts in their practices and management models.

The responsibility of corporations regarding their multiple stakeholders is supported by the Stakeholder Theory (Freeman 1984), defending that sustainable success depends on the satisfaction of stakeholders' needs and expectations. Business strategies that promote the creation of shared value for the organization and its stakeholders have proven to be relevant success factors (Porter and Kramer 2011; Strand et al. 2015).

The adoption of SR strategies leads to the conscious planning and execution of activities, decreases negative impacts and promotes positive interactions, in short-, medium-, and long-term scenarios. The implementation of SR programmes is becoming common practice in organizations at a global level, with several associated benefits: the efficient use of resources leads to cost reductions; competitive

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advantages are obtained through improved public image and reputation; pollution prevention and waste reduction have beneficial impacts both at the local and global scales; SR leads to organizational improvements, namely increased productivity, enhancement of innovation skills, and more efficient communication processes; the promotion of active changes in behaviours and practices has relevant impacts both at internal levels as well as throughout the value chain (Lozano 2015; Sukitsch et al. 2015; Baumgartner and Rauter 2017; Martinez-Conesa et al. 2017).

In 2015 the General Assembly of the United Nations defined 17 Sustainable Development Goals (SDGs) addressing social and environmental challenges currently faced by humanity. In the pathway to achieve the SDGs, deep transformations are necessary in all society levels and activity sectors, and this will require complementary actions by governments, civil society, academia, and business companies (Scheyvens et al. 2016; Leal Filho et al. 2017; Sachs et al. 2019).

To enhance a valid contribution of companies towards Sustainable Development, adequate guidance, regulations and surveillance from governments and public administration are widely important, as recognized in the literature review described in the following section of this paper. The questions that the present study aims to answer are:

- In the context of a developing country with a growing economy (Brazil), how effective are surveillance plans implemented by local administration bodies in the prevention of inadequate practices regarding Sustainable Development?
- In this context, how can local administration bodies effectively promote sustainability-oriented practices among professionals and companies?

As a contribution to answering these questions, the present paper describes a research study on the activities of a local administration body operating in the Brazilian Amazon region—the Regional Council of Engineering and Agronomy of Amazonas (CREA-AM), focusing on environmental surveillance and promotion of adequate sustainability practices. The analysis of administrative processes on detected environmental irregularities, in 2017 and 2018, enables the identification of the most frequent procedures/actions performed by engineering and technical professionals that cause damage to the environment. Through this analysis, improvement opportunities were identified, resulting in the proposal of new procedures regarding environmental inspection and surveillance in CREA-AM, to be implemented in 2021 and 2022.

The results of the present study are expected to contribute to raise awareness of companies and professionals operating in the Amazon region on the importance of adequately planning and executing their activities to reduce negative environmental impacts, and therefore contribute to the preservation of this internationally important region of the globe. It is also expected that the improvement opportunities identified, and the new procedures proposed, can be useful to other local administration bodies with responsibilities in environmental inspection and surveillance, thus contributing to a wider promotion of sustainability-oriented practices.

In the following section of this paper a literature review will be presented regarding the impacts of government policies on the promotion of Social Responsibility practices. Special attention will be given to the construction industry, which was found to be responsible for the main inadequate environmental practices under the scope of CREA-AM surveillance. A detailed description of CREA-AM, its responsibilities and scope of action, will be presented in the subsequent section, followed by the description of the methodology used and the analysis of the results obtained. The conclusions' section ends the paper.

2 Government Policies and the Promotion of Corporate Social Responsibility

Society increasingly expects the integration of corporate social responsibility in corporate governance, based on the premise that in all businesses it is company's responsibility to meet social and environmental expectations, since profit-focused corporate governance is leading to the destruction of the environment and the planet (Aluchna and Roszkowska-Menkes 2019). Local government actions are essential to create social and environmental responsibility in what concerns the achievement of low carbon targets, and local government leaders are successful in creating innovations in environmental policies (Ming et al. 2020). Local governments' policies regarding social and environmental responsibility must be aligned with local economic development (Yu and Huang 2020), therefore a careful assessment of the economic and environmental contexts of local governments must be done before implementing environmental sustainability policies.

The disorderly economic growth of developing countries leads to environmental degradation, and it is fundamental for governments to create incentives, new policies and rules in order to raise awareness on the importance of corporate social responsibility in macro and microeconomic growth environments. The dissemination of knowledge through lectures, seminars and courses, and the encouragement of innovation in new business models integrating corporate social responsibility and environmental responsibility, are key to the sustainable development of growing countries (Bradley et al. 2020). For example, the energy exploitation of coal in Colombia faces a series of social and economic pressures, at the national and international levels, to meet environmental and social goals. A study focusing energy transition and natural resources governance in this Colombian activity sector showed that discursive policies between government officials and coal companies had the greatest influence on political strategies (Strambo et al. 2020). According to this study, the discursive policies were important to make companies aware of their responsibilities to society and the planet, as their managerial focus cannot be solely on financial profits, regardless of the health of their employees and of the environmental impacts of the companies' activities (Strambo et al. 2020).

Governments and public administration can enhance sustainability-oriented behaviours in business companies through policies, regulations and guidance, either providing incentives or charging penalties. Several studies can be found in the literature focusing the relation between governmental policies and corporate social responsibility. According to Mahmoudi and Rasti-Barzoki (2018), in the Indian textile industry the most effective government approach to minimize negative environmental impacts is to impose tariffs. In what concerns construction industry, specific incentive policies, defined by the government, have proven to be effective in the enhancement of sustainable construction practices (Xia et al. 2018; Zhang et al. 2019). A research study conducted in medium and large manufacturing plants in Pakistan concluded that government oversight of the role of corporate social responsibility is essential for companies to achieve satisfactory levels of environmental performance (Abbas 2020). A survey of three energy companies in Denmark showed the need for companies that directly affect the environment to be involved in climate mitigation activities, responding positively to climate change challenges, and meeting government goals set by the Paris Agreement (Toft and Rudiger 2020). According to this study, it is up to government agencies to support compliance with these companies' environmental responsibility and corporate social responsibility actions, so that all environmental and social objectives are met (Toft and Rudiger 2020). Cao et al. (2020) describe the policy of laws and regulations implemented by the Chinese government regarding remanufacturing industries, and recognize its essential role on the supervision of corporate environmental and social responsibilities regarding the increasing industrial waste production. China's policy regarding this subject is having positive and beneficial effects, such as increasing the annual value of remanufacturing production (Cao et al. 2020). The same research study concludes that remanufacturing goals can only be achieved with public awareness and participation from everyone, business and citizens, but environmental actions aimed at recycling and reusing waste need government support, resources and supervision.

The construction sector has a paradoxical relation with social responsibility (Xia et al. 2018): positive social impacts are undeniable due to the effects of the built environment on the wellbeing of communities; but, on the other hand, construction activities are harmful to the environment due to the intensive consumption of energy and resources, and generation of large amounts of waste; also, construction industry generates a large amount of employment, contemplating both skilled and non-skilled workers, thus proving important means of survival to lower social classes; but, on the other hand, since construction activities are generally labour intensive, construction workers are highly exposed to accidents and negative occupational health impacts. Social and environmental responsibility in the construction sector needs governmental incentives and regulation regarding the use of clean energy, the pursuit of energy reduction goals, low carbon targets and environmental conservation (Wen et al. 2020).

New global trends in technological development, such as Industry 4.0, artificial intelligence and emerging markets, including exploration of outer space through space companies, show clearly that a global trend of interconnection between companies needs to go side by side with the development of policy innovations regarding

corporate social and environmental responsibility (Robinson and Mazzucato 2019), under penalty of serious irreparable ethical and environmental damage affecting society and the planet in a near future. These evolutions and revolutions are opening a window to the discussion of new corporate social and environmental responsibility policies that should be implemented as soon as possible. Governments should encourage these new corporate social and environmental responsibility policies and set limits to the development of technological developments when they overcome ethical and moral barriers that harm society and mankind.

3 The Regional Council of Engineering and Agronomy of Amazonas (CREA-AM)

CREA-AM is located in the city of Manaus, Amazonas, Brazil, in the center of the Amazon Rainforest, on the right bank of the Rio Negro.

The history of CREA-AM began in a growth phase of the city of Manaus, due to the expansion of technological sectors and the emergence of the Free Zone. This new economic moment in the Amazonian capital introduced several challenges, mainly urbanistic, and urban growth required Engineering and Architecture professionals. Supervising all these new technical works and activities was a difficult task, since Amazonas was under the jurisdiction of CREA from Pará (PA). At that time, the Amazon region had approximately 300 registered professionals, who had to travel to Pará to perform bureaucratic procedures such as registrations, annuities, visas and Technical Responsibility Annotations (ARTs). In order to claim regionalization of the system in a structured way, it was legally required to have organized professional bodies. Thus, CREA-AM was created with the support of the Engineering, Architecture and Agronomy entities in the Amazon region, with the aim to assure the qualification of technical professionals to the local labour market. Leading this process were the mechanical engineer Raimundo Lopes Filho, then president of the Association of Engineers and Architects of Amazonas (AEAA), the architect Severiano Mário Porto, who presided at the time the Regional Department of the Institute of Architects of Brazil (IAB) and the engineers Arly Coutinho and Valdyr Brito. According to Brazilian legal records (Ordinance n. 4,773), the responsible inspector was the agronomist José Liberato da Silva, assisted by the engineers Carlos Salustiano de Souza Coelho and Gilberto Ferrer de Carvalho. The implementation of new technology schools and the increase of the specialized workforce, together with the struggle of the professional categories involved, resulted in the creation of the Regional Council of Engineering, Architecture and Agronomy of Amazonas/Roraima (CREA-AM/RR) of the 20th Region, on the 30th August 1974, in accordance with CONFEA Resolution 223. The first president elected was mechanical engineer Raimundo Lopes Filho, and CREA-AM headquarters was officially opened in September 18th 1978.

During the following years, CREA-AM advanced, expanding its actuation areas, both in preventive supervision and professional development. In 2015, this administration body entered a new phase with the informatization of its operating system. Prior to this change, procedures and services were performed manually. With the implementation of the new system, CREA-AM services were made available through the Internet, and processes were informatized, providing greater control, agility, and convenience for professionals, companies or ordinary citizens, both in the capital and in interior regions.

A tax officer is appointed by the Regional Council to act as inspector, housed in the unit in charge of the supervision of CREA. This inspector acts according to the guidelines and specific determinations drawn up and decided by specialized chambers. Among the inspector's responsibilities is the assurance that the works and services related to Engineering, Architecture and Agronomy are being performed in accordance with the regulatory standards of professional practice. In the performance of his duties, the inspector must act rigorously and efficiently so that professional practices covered by CREA-AM occur with the participation of legally qualified professionals. CREA-AM's supervision has the prerogative of avoiding improper practices by technology professionals who work in the Amazon region.

According to the provisions of Brazilian Law n. 5,194 of 1966, it is the responsibility of CREA bodies to verify and supervise the professional practices regulated therein. To fulfil this function, CREA should designate collaborators with powers to draw up notices of violation of the legislator provisions, called tax agents. CREA-AM controls the attributions and functions of engineering and technology professionals through the Technical Responsibility Annotation—ART of each technical work/service performed by the engineering and technology professionals working in the Amazon Region, according to article 34 of Brazilian Laws n. 5,194/66 and n. 6,496 of December 7th, 1977. When an irregularity occurs in an ART, CREA-AM formalizes an administrative process to investigate failures and responsibilities, in order to protect society from improper engineering practices that may cause accidents or damage to those involved (Resolution n. 1,025 of October 30th, 2009). CREA-AM is also responsible to investigate public citizens' complaints regarding inadequate professional activities, and to curb unethical practices from professionals and companies, according to the CREA-AM Ethics Council Guidelines (Resolution n. 1,002 of November 26th, 2002, and Resolution n. 1,004 of June 27th, 2003).

When facing a notification from CREA-AM, professionals and companies may present clarifications and counterarguments in their defence. In the scope of a notification, technical professionals may be penalized by CREA-AM through warnings, fines, or the suspension/hindrance to practice. Companies may also be penalized with warnings, fines and suspension of the licence to perform technical activities and to participate in biddings with the Public and Private Sector.

To dully comply with its surveillance functions, CREA-AM establishes periodic inspection plans. Table 1 shows the CREA-AM Inspection Plan executed in 2017 and 2018, including the actions planned, responsible sectors, implementation period and expected results. The responsible sectors for implementing the CREA-AM Inspection

Table 1 CREA-AM inspection plan (2017–2018)

Item	Action to be addressed	Foreseen actions	Responsibilities	Period	Expected outcome
1	Internal inspection	• Official journal (contracts) • ART analysis: verify the declared activities, aiming to detect the need for the registration of complementary activities, possible abusive attribution, or finalization error	SUAFI CEEC	Continuous	Increase ART records
2	External surveillance use of GIS (geographic information system)	Mapping of sector and neighbourhood actions: mapping will be done through graphs of supervised addresses, and other relevant data for each action taken	ASGEO SUAFI	Continuous	Basis for programming the next financial years
3	Online complaints	Verify situation on-site, and return communication to the author of the complaint	SUAFI	Continuous	Increase ART records
4	Detailed inspection of large-scale works	Visit all complementary phases of the work	SUAFI	Continuous	Increase ART records
4.1	Professionals' surveillance	Normative Decision No. 111/2017 (Critical Analysis of ART), Resolution n. 1090/2017, Paragraph 2 of Art. 5 "CREA shall initiate legal proceedings when facing evidence, by any means at its disposal, including news published in appropriate media, of public misconduct, scandal or defamatory crime"	SUAFI	Continuous	Increase ART records
4.2	Waste (generation)	Solid waste management plan	SUAFI	Continuous	Increase ART records
4.3	Prefabricated	Precast concrete (works/manufacturing companies)	SUAFI	Continuous	Increase ART records
4.4	Survey report/testing	Geotechnical surveys	SUAFI	Continuous	Increase ART records
4.5	Waste (final destination)	Solid waste treatment and final destination (companies)	SUAFI	Continuous	Increase ART records

(continued)

Table 1 (continued)

Item	Action to be addressed	Foreseen actions	Responsibilities	Period	Expected outcome
4.6	Bids	Budget and basic project—Bids Technical Guideline n. 1/16 of the Brazilian Institute of Public Works Audit "Every element that integrates the basic project must be prepared by a qualified professional, and the registration of the ART is indispensable, identifying the author and author's signature"	SUAFI	Continuous	Increase ART records
4.7	Justice Forum	Common and criminal justice report	SUAFI	Continuous	Increase ART records
5	Condominiums	Visit 10 condominiums—maintenance	SUAFI	Continuous	Increase ART records
6	Companies	Companies specializing in foundations, structures, concrete and asphalt	SUAFI	Continuous	Increase ART records
7	Cities	Atalaia do Norte, Benjamin Constant, Tonantins, Tabatinga, cities at the Solimões River	SUAFI	Continuous	Increase ART records

Plan were the Deputy Supervisory Superintendence (SUAFI), the Specialized Civil Engineering Chamber (CEEC) and the Geoprocessing Advisory (ASGEO).

4 Materials and Methods

This research was conducted at CREA-AM headquarters, in the city of Manaus, Amazonas, Brazil, through the consultation and analysis of public administrative processes of ART registrations, from January 2017 to December 2018. In 2017, there were 11 companies from the environmental area and 50 environmental professionals registered at CREA-AM. In 2018 the number of registered companies remained the same, but the number of registered professionals raised to 74. The research covered all the physical and digital administrative processes of ART registrations regarding environmental technology professionals and companies operating in the environmental area—202 in 2017 and 541 in 2018—and also the records of administrative notifications regarding inadequate practices—12 in 2017 and 17 in 2018.

In 2015, CREA's Computerized Administrative Processing System (SITAC) was implemented at CREA-AM, and professionals and companies now register their ARTs through the internet in a 100% electronic way. All documents were digitized

and made available for consultation, stored in SITAC database, and all administrative processes are now electronic. To assure transparency, technology professionals and companies have internet access to all the phases of the processes they are involved in.

Since physical paper administrative processes cannot leave CREA-AM, they had to be analysed at CREA-AM's own headquarters, in a suitable room made available for this study. The names of technology professionals and companies have been preserved and kept confidential. The methodology applied to study CREA-AM's administrative processes followed the subsequent steps:

1. All administrative processes in the environmental area were divided into lots I and II, respectively for 2017 and 2018.
2. For each lot the environmental activities involved were identified and catalogued.
3. For each catalogued environmental activity, the potential environmental impacts were studied.
4. For the administrative notifications regarding inadequate practices, the causes were analysed regarding its source and recurrence; it was also registered who was responsible for the failure: the company or the technology professional.

The data collected through the research of the physical and digital processes of CREA-AM were analysed to find the most frequently occurring environmental activities, their potential environmental impacts, and the most frequent inadequate practices identified, in the years 2017 and 2018.

5 Results and Discussion

The analysis of CREA-AM's administrative processes revealed that the main registered inadequate practices in the environmental area are the lack of registration in CREA-AM, the illegal exercise of activities, the lack of hired environmental technicians, and the exercise of activities in the environmental area without the respective ART (Fig. 1). The frequent lack of environmental technician reveals that companies are using unskilled workers for the performance of activities in the environmental area, with consequent risks to the environment that could cause serious damage to the Amazon Forest. In what concerns failures in adequate registration of companies in CREA-AM, Fig. 1 shows that the numbers increased a 100% from 2017 to 2018. This can be explained by the economic crisis that led many professionals to open waste collection companies without being technically and legally qualified to operate in this sector.

The analysis of the ARTs registered in CREA-AM in the environmental area, in 2017 and 2018, showed that the most frequent activities performed by environmental technical professionals include waste collection, waste transportation, waste disposal, waste treatment, environmental monitoring, environmental management and planning, remediation of degraded areas, environmental impact studies, environmental licensing and environmental impact assessment.

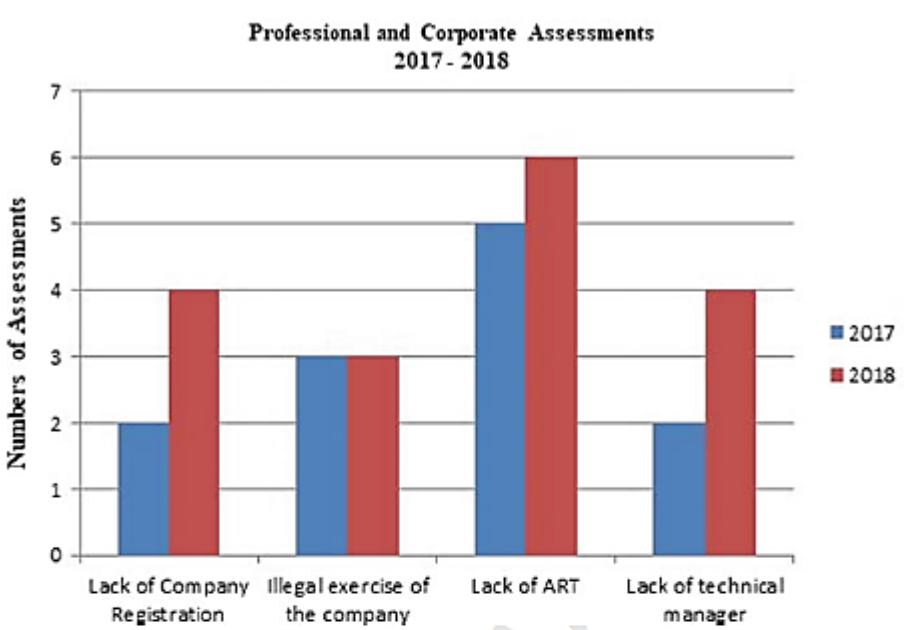

Fig. 1 Assessments of irregular procedures registered in CREA-AM in the years 2017 and 2018

In 2017 the main records of activities performed by environmental professionals registered in CREA-AM were related with construction activities: 160 of the total 202 ARTs registered in CREA-AM (79%) were in the construction industry. Surprisingly in 2018 the number of registered ARTs in the environmental area focusing construction-related activities decreased to 44 in a total of 541 registered ARTs (8%). To identify possible causes of this sudden and relevant alteration, registered ARTs related with construction activities were further analysed. Table 2 shows the specific environmental activities reported in the ARTs associated with construction projects. These results show that the collection of Construction and Demolition Waste (CDW) is frequently referred both in 2017 and 2018, but the remediation of degraded areas shows a drastic reduction from 2017 to 2018, accompanied by a reduction of

Table 2 ARTs registered at CREA-AM in 2017 and 2018, related with construction activities

Activity	2017	2018
CDW collection	9	12
CDW transport	5	1
CDW destination	10	1
CDW treatment	12	6
Environmental monitoring	16	19
Remediation of degraded areas	99	1
Environmental impact studies	9	4

activities related to the transportation, destination and treatment of CDW. This might be explained by the economic situation in Brazil in 2018, aggravated by change of government, which affected construction, leading to a reduction in investments in real estate projects in 2018.

The inadequate disposal of construction and demolition waste has relevant environmental impacts due to the toxicity of metals, paints, varnishes and oils frequently found in CDW. Therefore, special attention must be given to construction activities and this must be taken into consideration in the preparation of a proposal for the new Environmental Inspection and Surveillance Plan from CREA-AM.

The expected result of increasing the registration of ARTs with the CREA-AM Inspection Plan implemented in 2017 and 2018 was not verified in the construction industry, since registered ARTs decreased from 160 in 2017 to 44 in 2018—a 72.5% reduction. This demonstrates that the Inspection Plan was not fully implemented in this activity sector, so improvement suggestions are proposed for a new CREA-AM Environmental Inspection and Surveillance Plan. As presented above (Table 1), in the scope of the 2017–2018 Inspection Plan the actions to be performed internally in CREA-AM were the search for contracts published in the Official Gazette of the Brazilian Government and the analysis of Technical Responsibility Notes in order to find the need for ART registration of complementary activities, possible excessive attributions or finalization error. External actions involved the use of Geographic Information Systems (GIS), the investigation of online complaints, the detailed inspection of large-scale works, the inspection of residential condominiums in the city of Manaus (sampling 10 condominiums), the supervision of engineering companies (foundations, concrete and asphalt), and the supervision of works in the municipalities of the interior of the Amazon region, such as Atalaia do Norte, Benjamin Constant, Tonantins and Tabatinga, in the Alto Solimões gutter region of Amazon. Detailed oversight of large-scale works focused companies manufacturing prefabricated concrete and steel, companies that perform geotechnical survey reporting services, the solid waste management plan, the supervision of bids for the registration of ART regarding the preparation of budgets and the preparation of basic projects, and the inspection of ART records for the preparation of Technical Reports required by the Common Justice. Inspection reports would be biweekly. This former Inspection Plan had also financial purposes, aiming to increase ART registrations in CREA-AM, in 2017 and 2018, and therefore increase CREA's financial resources with ART registration fees.

The new proposal for the CREA-AM Environmental Inspection and Surveillance Plan suggests the intensification of surveillance in the area of CDW collection, transportation, disposal and treatment, to curb illegal companies from causing serious environmental impacts through improper CDW handling. CREA-AM's new Environmental Inspection and Surveillance Plan recommends the registration and tracking via GPS of the CDW collection boxes that are stored in construction sites and renovation works in general. Currently in Manaus there are many clandestine and illegal landfills that receive CDW without the slightest technical condition, causing environmental impacts that affect the Amazon Rainforest and the population of Manaus,

due to the toxicity of CDW containing paints, varnishes, oils, plaster, lead, etc., that can reach streams near these clandestine landfills.

Table 3 shows the proposed CREA-AM Environmental Inspection and Surveillance Plan, to be executed in the coming subsequent years, including the actions planned, responsible sectors, implementation period and expected results.

The proposed Environmental Inspection and Surveillance Plan aims to alert companies to the importance of Corporate Social and Environmental Responsibility, ensuring that company's management is not only tied to profits, but also to the respect for the environment. The proposed plan initially foresees a series of lectures and training courses directed both to professionals and companies, promoting awareness on the need to protect and preserve the Amazon heritage.

6 Conclusions

Results found in this case study demonstrate the vulnerability of the Inspection Plan implemented by the Brazilian regional administration body CREA-AM in the Amazon Region, in 2017 and 2018: the records of activities performed by environmental professionals in the construction sector suffered a 72% reduction, which suggests inadequate practices of companies regarding the collection, transportation, disposal and treatment of construction waste, and the remediation of degraded areas. Also, the illegal professional practices documented in administrative processes show that companies and technicians are acting without the necessary technical knowledge to mitigate the negative environmental impacts associated with the construction industry.

As a result of this research, improvement measures are suggested for CREA-AM to enhance the effective promotion of sustainability-oriented practices. A new Environmental Inspection and Surveillance Plan is suggested, which includes environmental education actions to promote the sustainability of waste management procedures in construction sites, focusing on good operational practices regarding the reuse and recycling of construction waste materials. This new inspection plan is proposed to the Civil Engineering Chamber of CREA-AM to come into force in the 2021–2022 biennium. It is expected to foster good practices among technology professionals and companies operating in the Amazon region, specifically reducing contamination by toxic waste from construction sites in the Amazon Rainforest, caused by inadequate disposal and illegal burning. Given that the territorial area covered by the activity of CREA-AM involves the Western Amazon, on Brazil's border with other Latin American countries, such as Peru, Bolivia and Venezuela, this research study is expected to lead to environmental improvements at an international scale.

As main conclusions of this case study, regional administration bodies have a relevant role in the surveillance and promotion of adequate operational practices in the context of Sustainable Development, particularly important in developing countries with a growing economy. In order to fully achieve the purpose of promoting sustainability-oriented practices among professionals and companies,

Table 3 Proposed CREA-AM environmental inspection and surveillance plan (2021–2022)

Item	Action to be addressed	Foreseen actions	Responsibilities	Period	Expected outcome
1	Internal inspection	• Consultation of corporate social goals through the Official Gazette • ART analysis—verify the declared activities, aiming to detect the need for the registration of complementary activities, possible abusive attribution, or finalization error • Research on the registration and legality of CDW collection, transportation, destination and treatment companies	SUAFI CEEC	Continuous	Increase the legality and regularity of companies
2	External surveillance use of GIS (geographic information system)	• Mapping of actions in each sector/neighbourhood in the city of Manaus, through georeferenced address graphs of the inspected locations, and other relevant data for each action taken • Mapping CDW drop boxes for real-time location tracking and destination tracking	ASGEO SUAFI	Continuous	Basis for programming in the next financial years
3	Online complaints	Verify situation on-site, and return communication to the author of the complaint	SUAFI	Continuous	Increase ART records
4	Detailed inspection of large-scale works	Visit all the complementary phases of the work	SUAFI	Continuous	Increase ART records

(continued)

Table 3 (continued)

Item	Action to be addressed	Foreseen actions	Responsibilities	Period	Expected outcome
4.1	Professional's surveillance	Normative Decision No. 111/2017 (Critical Analysis of ART), Resolution n. 1090/2017, Paragraph 2 of Art. 5 "CREA shall initiate legal proceedings when facing evidence, by any means at its disposal, including news published in appropriate media, of public misconduct, scandal or defamatory crime"	SUAFI	Continuous	Increase ART records
4.2	Waste (generation)	Surveillance at the headquarters of companies supplying CDW collection boxes	SUAFI	Continuous	Increase the legality and regularity of companies
4.3	Prefabricated	Precast concrete (works/manufacturing companies)	SUAFI	Continuous	Increase ART records
4.4	Survey report/testing	Geotechnical surveys	SUAFI	Continuous	Increase ART records
4.5	Waste (final destination)	• Surveillance of clandestine landfills • Remediation of degraded areas	SUAFI	Continuous	Increase the legality and regularity of companies
4.6	Bids	Budget and Basic Project—Bids Technical Guideline n. 1/16 of the Brazilian Institute of Public Works Audit "Every element that integrates the basic project must be prepared by a qualified professional, and the registration of the ART is indispensable, identifying the author and author's signature"	SUAFI	Continuous	Increase ART records

(continued)

Table 3 (continued)

Item	Action to be addressed	Foreseen actions	Responsibilities	Period	Expected outcome
4.7	Justice forum	Common and criminal justice report	SUAFI	Continuous	Increase ART records
5	Condominiums	Visit 10 condominiums in the city of Manaus	SUAFI	Continuous	Increase ART records
6	Companies	Companies specializing in foundations, structures, concrete and asphalt	SUAFI	Continuous	Increase ART records
7	Cities	Inspection of municipalities in the metropolitan region of Manaus and other municipalities in the interior of the Amazon	SUAFI	Continuous	Increase ART records

regional administration bodies should complement their surveillance plans with activities that promote awareness and education regarding Sustainability and Social Responsibility.

In what concerns future research opportunities, attention should be given to the involvement of regional administration bodies in the promotion of practical instruments that enhance the adoption of sustainability-oriented practices. Specifically regarding construction waste management, CREA-AM is contributing to the operationalization of a mobile phone application that is expected to facilitate the reuse and recycling of waste by companies and ordinary citizens, thus opening space for the development of Circular Economy practices in Brazil.

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CAPÍTULO III – GESTÃO INTELIGENTE DE RESÍDUOS DE CONSTRUÇÃO CIVIL: TECNOLOGIA DE APLICATIVO TELEMÓVEL NA CIDADE DE MANAUS, AMAZONAS, BRASIL

CAPÍTULO III – GESTÃO INTELIGENTE DE RESÍDUOS DE CONSTRUÇÃO CIVIL: TECNOLOGIA DE APLICATIVO TELEMÓVEL NA CIDADE DE MANAUS, AMAZONAS, BRASIL

O estudo demonstrado neste capítulo apresenta uma estratégia tecnológica para gestão de RCD, através da utilização de um novo aplicativo de telemóvel que permite a compra, a venda e a doação de RCD gerados em grandes obras ou em pequenas reformas, com acesso para todos cidadãos e empresas na cidade de Manaus. Uma nova ferramenta de gestão ambiental de RCD que permite o cadastramento de empresas prestadoras de serviço de coleta, desde que estejam legalizadas, e contribui para a livre concorrência neste mercado que pode alavancar uma nova Economia Circular na cidade de Manaus.

Lamego Oliveira, M.P.S., de Oliveira, E.A., Wanderley, A., Campos, A.M.L.S., Fonseca, A.M. (2019b). Smart management of construction waste: mobile application technology in the city of Manaus, Amazonas, Brasill. *In XIII CTV 2019 Proceedings: XIII International Conference on Virtual City and Territory: Challenges and paradigms of the contemporaty city, UPC, Barcelona, october 2-4, 2019*. CPSV, 2019, p. 8426.

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SMART MANAGEMENT OF WASTE FROM CONSTRUCTION SITES: MOBILE APPLICATION TECHNOLOGY IN THE CITY MANAUS, AMAZONAS, BRAZIL

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Abstract

This study was carried out in the city of Manaus, Amazonas, Brazil, a municipality surrounded by the Amazon Rainforest. This world heritage site, with a great diversity of fauna and flora, requires the care and attention of both the authorities and the population. The research involved studies on four construction sites to collect data regarding the waste generated and the environmental management practices, especially regarding waste disposal, considering that this item causes major environmental impacts in the Amazon Forest surrounding the city of Manaus. There is only one public landfill, managed by the Municipality of Manaus, and several clandestine landfills, which end up being the final disposal of many construction waste due to lack of inspection and population neglect. The consequences are serious for the Amazon rainforest that suffers the impact of the pollution generated by these residues, such as plastic, paper, metal, and debris which is a major contaminant since it may contain paints, solvents, oils and other materials toxic to nature. Two of the construction sites under study were residential buildings and the other two were thermoelectric power plants (industrial). After data collection through interviews, statistical studies were carried out to analyze and discuss the results obtained, aiming to make the characterization of the current production of construction waste in the city of Manaus, Amazonas, Brazil, and understand how these wastes affect the environment of the Amazon Forest. The collected data enabled the identification of the types of construction waste produced, their respective volumes, and their environmental management practices regarding reuse, sale or disposal. After analyzing the results, it was concluded that the sampled construction companies do not reuse nor recycle construction waste, and discard them in municipal or clandestine landfills. To minimize the identified problem regarding the disposal of construction waste in the city of Manaus, a proposal for the environmental management of construction site waste was developed through mobile application technology, with the aim of mitigating the environmental impacts of these wastes in nature. The mobile application serves as a tool for environmental managers in construction sites, and even for citizens who want to make a renovation in their home and do not know how to allocate the generated construction waste in a responsible and sustainable way. The mobile application was developed on the Android platform and had as premises the main construction waste identified in the construction companies studied in the city of Manaus, which would be plastic, paper, metals, rubble, and demolition remains, such as broken bricks, broken tiles, damaged wood, coatings, paints, mortar and other debris, with potential for contamination and pollution of the environment. The structure of the computer program was developed in order to enable the purchase, sale, exchange, recycling or donation of construction waste through the mobile application itself, which can be acquired for free at the virtual stores. The application was tested by construction professionals, interested in the allocation of small or large amounts of construction waste in safe and legalized sites, controlled either by the municipal or federal government. The application was also presented to and tested by waste disposal companies and urban citizens, to verify the efficiency of the application in the intelligent management of construction waste. Although the application is still in the test phase and not yet commercially available, the results obtained so far demonstrate a higher degree of acceptability and user satisfaction. The results showed

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widespread interest in the mobile app among urban citizens, construction professionals and waste collection companies, although these latter reveal some concern regarding possible increased monitorization and fiscalization associated with a wider use of the mobile application in the urban area of the city Manaus.

Key words: sustainable construction; smart waste disposal; startup company of waste

1. Introduction

Construction and demolition waste (CDW) can be defined as a mixture of surplus materials generated from construction, renovation and demolition activities, including site cleaning, road works and demolition (Shen et al., 2004). Inadequate management of CDW, affects the environment, the economy and society (Jin et al. 2019). Besides increasing construction costs and real estate prices, CDW can have major negative impacts on the environment (Borja et al., 2019), namely the contamination of soil and watercourses with heavy metals that can cause diseases in the population and wild animals. These negative impacts are of major importance in sensitive natural environments, justifying the relevance of this research in the city of Manaus, in the central Amazon, Brazil. A previous study involved the quantification of CDW produced at 4 construction sites in the city of Manaus, and the costs involved in its management and disposal (Oliveira et al., 2019). The results showed that high quantities of wood and paper waste are produced, with considerable disposal costs, in spite of the high potential to recycle and re-use these types of waste. Metal waste was found to be the only CDW that was being adequately recycled in the construction sites under study, showing the importance of the implementation of an organized system to collect and recycle CDW in the city of Manaus (Oliveira et al., 2019). A similar case study conducted in the city of Santiago, capital of Chile, led to a quantification of the CDW volume for further management improvement proposals (Bravo et al., 2019). According to this study, in Santiago the generated volume of CDW per building area is 0.186 $m3/m^2$, with a management cost of 75.47 $US\$/m^3$ (Bravo et al., 2019). These values are of the same magnitude as the ones found in the research study conducted in Manaus (Oliveira et al., 2019). Ogunmakinde et al. (2019) describe CDW management in Nigeria, highlighting the existing corruption and unethical practices of large companies who prefer to dig and bury the CDW in clandestine landfills, refusing to comply with environmental laws to avoid loss of profits. This lack of social and environmental responsibility in construction companies is unfortunately also a reality in Brazil. However, surveillance and monitoring of CDW production and disposal may not be the solution to combat clandestine landfill, as demonstrated in the study of Tsiliyannis et al. (2019), conducted in Athens, Greece. Environmental education and good practice are the best weapons we have in environmental management, and adequate CDW management requires a change in the behavior and attitude of each citizen (Mak et al., 2019). The studies conducted in the present investigation sought to define the current model of CDW management in the construction sites of the city of Manaus, its advantages and disadvantages, in order to verify the possibility of implementing a Circular Economy system (Farooque et al., 2019). This system could result in cost savings in civil construction and in the reduction of negative environmental impacts caused by the illegal disposal in clandestine landfills, which harms the lives of the citizens of the city of Manaus and the surrounding environment, the Amazon rainforest itself. Circular Economy CDW management systems have already been implemented in European cities (Fratini et al., 2019; Kravchenko et al., 2019), so why not extend this practice to cities in Latin America, which are also affected by the environmental and financial impacts of inadequate waste management on urban construction sites. In order to implement a Circular Economy model, construction companies must be adequately involved in

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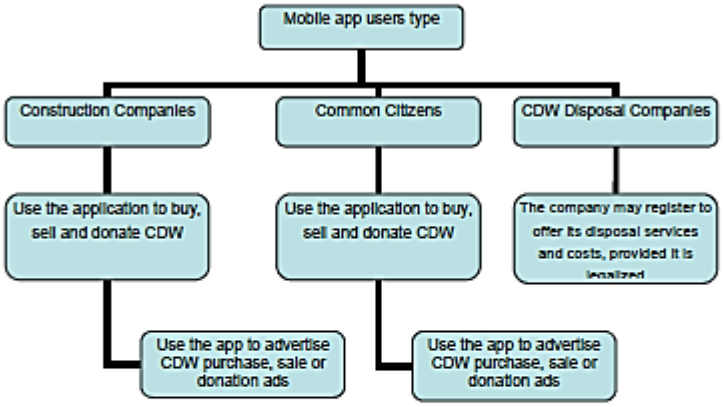
of the construction sites is 57,000 m² for site A 12,381 m² for site B, 10,430 m² for site C and 9,527 m² for site D.

The city of Manaus is an isolated city, surrounded by the Amazon Forest, with access only by air and river, located on the banks of the Rio Negro. This river converges with the Solimões River to form the Amazon River that flows into the Atlantic Ocean, on the Brazilian coast. The city of Manaus has an urban area of 427.085 km² and a population of approximately 2,145,44 inhabitants. In the metropolitan region of Manaus there are approximately 113.2 hectares of land degraded by dumps and a licensed landfill, of this total area we have 66 hectares, equivalent to 58.3%, destined to a licensed landfill and 47.2 hectares, which corresponds to 41.6%, is destined to open dumps. The Manaus City Hall manages this landfill area through machines and equipment for waste removal daily. n the Manaus Metropolitan Region there is not yet an organized system for the collection, treatment, disposal or recycling of CDW waste. Currently, 44 companies are authorized to transport and discard / dispose of CDW waste at the public landfill in the city of Manaus (PRSCS, 2017). Smart cities of the future should manage waste through modern technologies (Esmaeilian et al., 2018). For this reason, the present research adopted mobile application technology to solve the waste management problems in construction sites operating in the city of Manaus. Based on the detected needs, the mobile application software was developed on the Android Studio platform, with the objective of reducing CDW reuse / recycling costs, publicizing the sale, purchase, exchange and donation of CDW to a maximum number of users of CDW applications. and, finally, to increase competition between CDW disposal companies, forcing them to legally regulate and to offer a sustainable service that does not harm the environment and the Society. The action methodology to meet the demands required for smart environmental management of CDWs through a mobile application is shown in the flowchart of Figure 2.

Figure 2. **Mobile app stock flow chart**



Source: Own elaboration.

Upon completion of the algorithms, the codes were written in Java code for compilation in Android Studio. At the conclusion of the mobile application, it was tested using the methodology proposed by (Kaur & Kaur, 2019), through questionnaires applied to construction professionals (Table 1), to CDW disposal companies (Table 2) and also to urban citizens (Table 3). The algorithm has been built on the needs identified for CDW waste management at construction

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sites for transport, disposal, disposal and storage as well as recycling and reuse. CDW waste can be donated, sold or purchased by urban citizens, environmental engineers or construction companies. The application intends to register CDW collection companies, which can offer their specialized services and their differentiated prices, contributing to lower the cost of these services by the free competition in the market.

Table 1. **Mobile app acceptability questionnaire directed to construction professionals**

Number	Question
1	Do you expect this application to be useful for your company?
2	Do you expect this application to contribute to the insertion of the environmental professional in the job market?
3	Do you expect this application to contribute to reducing the disposal costs of construction and demolition waste?
4	Do you expect this application to contribute to reducing construction and demolition waste storage time?
5	Do you expect this application to contribute to environmental protection?

Source: Own elaboration.

Table 2. **Mobile app acceptability questionnaire directed to waste disposal companies**

Number	Question
1	Do you expect this application to contribute to improve the quality of waste disposal in construction?
2	Do you expect this application to contribute to a process of segregation of construction waste, which facilitates the sorting of it for later recycling or disposal, resulting not only in the organization of waste, but in the organization and cleaning of the construction site?
3	Do you agree that currently the greatest difficulty in reducing or recycling solid construction waste is lack of awareness and low skilled labor?
4	Do you expect this application to contribute to reducing construction and demolition waste storage time?
5	Do you expect this application to contribute to environmental protection?

Source: Own elaboration.

Table 3. **Mobile app acceptability questionnaire directed to urban citizens**

Number	Question
1	Do you expect this application to be useful for reducing waste disposal in watercourses and reducing obstruction of urban drainage devices?
2	Do you expect this application to contribute to the insertion of the environmental professional in the job market?
3	Do you expect this application to favor best price options for collecting construction waste?
4	Do you expect this application to be useful for the urban citizen who wants to renovate their residence?
5	Do you expect this application to contribute to environmental protection?
6	Do you expect this application to contribute to the legalization of construction waste disposal companies?
7	Do you expect this application to contribute to the reduction of landfill disposal by urban citizens?

Source: Own elaboration.

The application tests were conducted through lectures for construction professionals, businessmen and urban citizens (Figure 3), who were asked to answer questionnaires at the end of the event.

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Figure 3. **Lecture about the mobile app for professionals, businessmen and urban citizens**

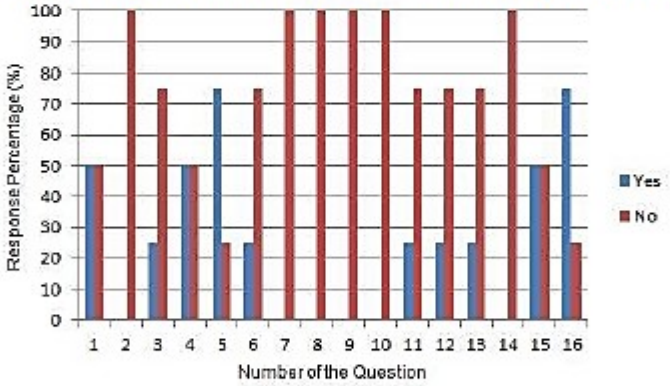
Source: authors.

3. Results and Discussion

3.1 Characterization of the current situation regarding CDW management in Manaus

The results of the questionnaires applied to 4 construction companies in the city Manaus, described in Table 1, are shown in Figure 4.

Figure 4. **Results obtained in the questionnaire applied in 4 construction companies**



Source: Own elaboration.

In questions 2, 7, 8, 9, 10 and 14 the negative statements show a scenario of inefficient recycling and reuse of CDW in the city of Manaus. In questions 5 and 16 the positive statements demonstrate a partial compliance in the transportation legal requirements regarding of CDW, and in the supervision of the final disposal of this waste in the legal landfills of the city of Manaus. In clandestine landfills there is no supervision. The questionnaire showed that companies are deficient in the items covered by questions 6, 7, 10, 11, 12, 13, 14, 15 16, 17 and 18, revealing inadequate management regarding the reuse and recycling of CDW. This lack of organization for reuse and recycling undermines the environmental management of CWD in

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construction companies as it allows this waste to be transported to municipal or clandestine landfills, which harms the city and the environment in its vicinity. Construction companies outsource recycling and disposal services, but poorly oversee these services.

The results of the questionnaire applied to construction companies A, B, C and D demonstrated the need for actions in the environmental management of the CDW of Manaus city construction sites, as follows:

a) Little reuse/recycling of CDW due to the costs involved;
b) There is no disclosure of immediate actions for the sale, purchase and donation of CDW, which hinders the "supply and demand" for its reuse or recycling; and
c) Little competition between CDW disposal companies, which leads to the hiring of companies that make use of clandestine landfills, for lack of social and environmental responsibility.

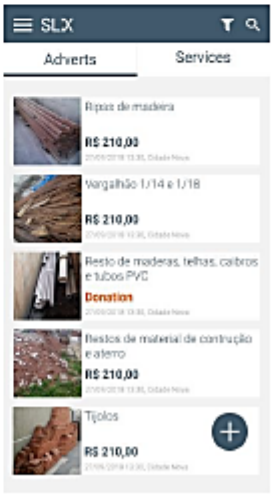
These results show that construction and demolition waste management in construction companies in Manaus needs to be improved through modern management tools, such as Circular Economy, a waste management model implemented in Europe, but not yet in Brazil.

3.1 Development of the mobile application for CDW management

Given the problems detected in characterizing the current situation of CDW management in Manaus, this research proposed the development of a mobile application that can be widely used by all urban citizens and not only by a restricted category of engineers and technicians in the area. environmental, construction companies or companies in the field of disposal and disposal of construction and demolition waste. It is an easy-to-use screen application with interactive user interface that contributes to the generation of a value-added circular economy for the disposal of CDW waste in the municipality of Manaus. The splash screen is shown in Figure 5 and the interaction screen is shown in Figure 6. The search screen for waste types is shown in Figure 7 and the filters for easier search of a waste are shown in Figure 8.

Figure 5. **Mobile App Logo**

Figure 6. **Mobile Application Home Screen**



Source: App

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Figure 7. Searches screen

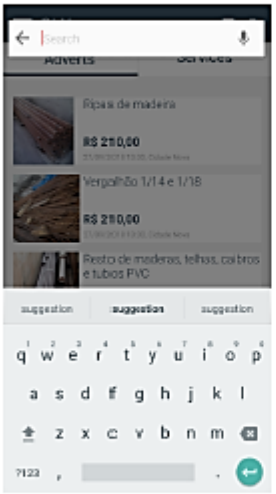
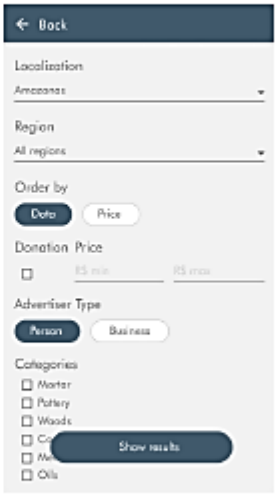


Figure 8. Search filter



Source: App

Through this mobile application the user can access ads dealing exclusively with the donation, purchase and sale of CDW. This enables construction companies to implement environmental management practices interacting with other construction companies, or with companies from other branches that use CDW as raw material for industrial or commercial production. Advertisements can also be accessed by urban citizens who may be involved in the renovation or construction of private buildings and want to dispose their CDW, or to reuse any CDW for landfill in the scope of a foundation, or sidewalk construction.

The mobile application promotes sustainability in the destination of CDW for those companies or citizens who need this raw material for some useful purpose. The idea of the application is to minimize CDW that goes to the municipal landfill or clandestine landfills, promoting the reuse of CDW in the whole municipality of Manaus. Donation announcements are used for quick disposal at no cost to those who need CDW raw material, which contributes to reducing the length of time CDW stays on site. CDW buying and selling announcements are to warm the city's economy through a sustainable CDW reuse and recycling market.

This market for buying and selling CDW using the mobile application may in the future serve as the basis for a Circular Economy model to be implemented in the city of Manaus. As shown in Figure 5, ads are easy to interact, with photos and all the necessary information for mobile app users. The mobile application promotes good practices such as registration of origin, destination, type, class and quantity of CDW moved in the municipality, which serves as a database for environmental management of CDW, public agency supervision, control and even for research that deal with CDW.

In addition to the ads, the app has a CDW destination services tab, as shown in Figures 9 and 10.

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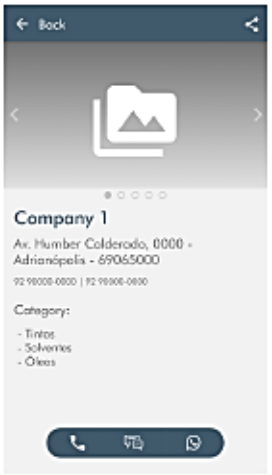
Figure 9. **Mobile App Companies**

Figure 10. **Mobile App Company Service**



Source: App

This part of the services offered by the mobile application presents a list of registered companies, duly legalized at the municipal, state and federal levels, where each company offers its specialized services and costs involved in the collection, transportation, destination and disposal of CDW. Thus, the user, urban citizen or company, can quickly opt for a company registered in the cost-effective mobile application that best meets their physical and economic needs. The app contributes to healthy economic competition among companies providing CDW collection, transportation and disposal services, keeping prices affordable and inhibiting monopolies that benefit few and harm the entire population of the city. If any service provider company registered in the mobile application practices any irregularity, such as disposal in clandestine landfills, the application may exclude it from its marketing register, thereby curbing illegal practices that harm the environment. Public agencies that will be able to use the mobile application for the supervision and control of disposal companies will be favored quickly and reliably.

3.2 Acceptability of the mobile application by potential users

As described in the Material and Methods section, the mobile app was introduced to construction professionals, urban citizens, and business people who were able to test the app and its particularities, handling, and functions related to CDW's environmental management. The app was presented by users through explanatory lectures to target audiences, which followed step-by-step explanations of the mobile app's tools. After the demos users tested the app and asked questions for clarification. The lectures were given to professionals in the construction sector, businessmen from construction companies, businessmen from CDW waste collection companies and to urban citizens. At the end of the presentation, users completed a questionnaire about the acceptability of the application in the Manaus city market and its usefulness for improving the environment. The questionnaire was answered through the participants' mobile phones, which captured a QRCode from the forms platform that contained the questions. After capturing the code by the mobile phones of each survey participant, the

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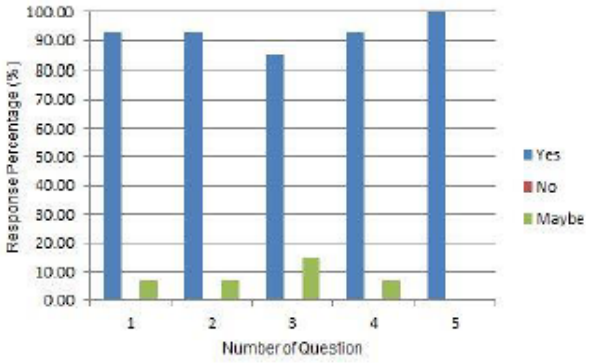
participant answered and sent their answers via their own mobile phone. The lectures had about 80 participants each and were given to a postgraduate audience, to an audience of the Engineering and Agronomy Council and to the construction companies themselves and companies whose main activity is CDW waste collection and disposal. In the audience of the Regional Council of Engineering and Agronomy were present the team of field inspectors, technicians of superior level. The professionals present at the lectures are inserted in the construction labor market in the different modalities of civil engineering, electrical engineering, mechanical engineering, environmental engineering and architecture, showed great interest in the mobile application, especially when it would be made available / commercialized in the mobile application platforms. Representatives of construction companies also showed interest for use on construction sites, in environmental management of construction waste generated in their works, as they noted that the competitiveness generated by the application can have gains and profits for their business. Representatives of CDW collection companies were concerned about the enforcement and legalization required by the mobile application when it is made available for download on platforms.

The results obtained from these questionnaires are shown in Figure 11 (160 construction professionals), Figure 12 (4 waste treatment companies) and Figure 13 (80 urban citizens).

Figure 11. **Responses obtained in the mobile app acceptability questionnaire (construction professionals)**



Source: Own elaboration.

Questions 1 to 5 demonstrate a positive response from companies participating in the mobile app test survey, with over 85% acceptance for mobile app use at their construction sites in the city of Manaus.

Waste disposal companies gave negative answers to questions 3 and 5, probably because the mobile application will favor free competition, price competition and quality of services, besides the pressure that will be exerted regarding legal compliance. Currently, In the city of Manaus, CDW disposal and disposal services at construction sites are performed by only five legal companies, with the permission of the government environmental agency in Manaus. There is a need in the city of Manaus to expand the number of companies that provide CDW waste

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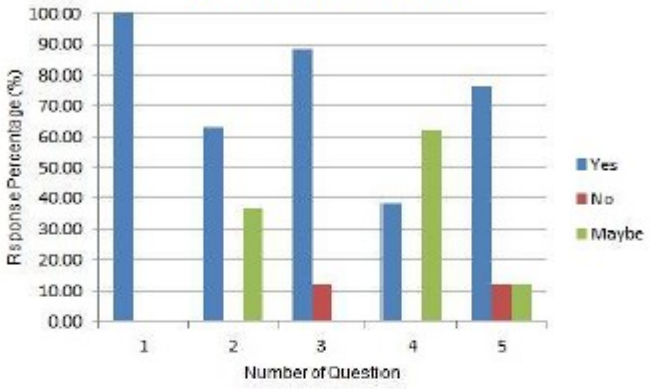
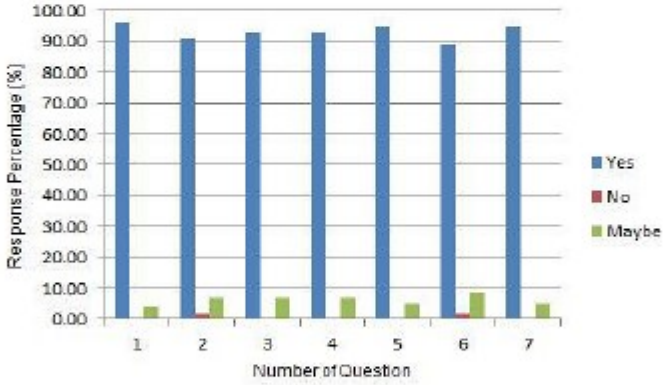
recycling and reuse services to avoid the monopoly that currently occurs in the market in the metropolitan region of Manaus.

Figure 12. **Responses obtained in the mobile app acceptability questionnaire (waste disposal companies)**



Source: Own elaboration.

Figure 13. **Responses obtained in the mobile app acceptability questionnaire (urban citizens)**



Source: Own elaboration.

The answers obtained by urban citizens were 100% positive, with an acceptance rate above 90% for the mobile application usage, which demonstrates public support for the use of mobile technology as an alternative to solve environmental problems caused by the work of construction companies installed in the city of Manaus, with a reflection on the quality of life of the general population. The results obtained in the acceptability tests show that the proposed mobile app has a very high acceptability rate among the group of construction professionals (92,3% on average) and the group of urban citizens (93,1% on average). In what concerns the group of waste disposal companies, the mobile app acceptability decreases to 72,5%, on

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average, probably due to the increased monitorization, and corresponding legal implications, associated with a wider usage of this mobile app.

The main advantage of the mobile application is the possibility of reducing costs in the disposal, disposal, recycling and reuse of construction waste and demolition on the construction site, since the application prioritizes free competition among companies that perform this type of service. Other important advantages are the obligation to legalize CDW waste disposal and disposal service companies and the traceability of CDW waste in urban and rural areas, which facilitates the supervision of government environmental agencies under the disposal ban. in clandestine landfills. The disadvantage of the application is the need for a specialized company to operate and maintain it, resulting in financial expenses to support the company's services, which may be offset by financial income from sponsorship or online advertising within the application itself. The environmental benefits deriving from the mobile application come from the stricter control of this type of CDW waste, by the users themselves, the construction companies, the urban population and the environmental agencies that use the application as an environmental management tool in the urban area of the city Manaus, Amazonia, Brazil.

4. Conclusions

In this research, the main objective was achieved through the insertion of a mobile technology applied directly in the control of construction and demolition waste in the construction sector, which can be used by ordinary citizens, construction companies and waste disposal companies. The mobile application achieved very high acceptability rates, according to the responses of the questionnaires applied to citizens and professionals in the construction sector, and to companies operating in the CDW waste disposal business. The management of CDW produced at construction sites in the city of Manaus can use the mobile application as a decision-making tool, since the mobile application is expected to contribute to the sustainability of the CDW reuse and recycling market, encouraging and mobilizing the economy in this area. The adequate environmental management of CDW will contribute to the sustainability of a segmented market regarding CDW reuse and recycling, and will bring improvements in the environmental area by minimizing the problems currently associated with perceived in the accumulation of waste from both public and private construction sites. This app could serve as a basis for establishing a circular economy in the Amazon region. For future research we suggest activating the app for use by the urban population and monitoring the amounts of CDW waste that is reused, donated, traded (bought or sold) and recycled using the mobile app. The mobile app will increase CDW waste traceability control, which will make it easier to monitor disposal and disposal to avoid the use of clandestine landfills that harm the environment. Based on the results of the high acceptability index of the mobile application, it can be concluded that the implementation of the application will have results that will generate a return not only in the environmental area, through the impact on the urban environment by minimizing the problem related to the residues coming from of construction sites currently perceived as also an economic and social return to the metropolitan region of Manaus.

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CAPÍTULO IV – AÇÕES PARA INIBIÇÃO DE ATERROS CLANDESTINOS NA CIDADE DE MANAUS, AMAZÔNIA, BRASIL

CAPÍTULO IV – AÇÕES PARA INIBIÇÃO DE ATERROS CLANDESTINOS NA CIDADE DE MANAUS, AMAZÔNIA, BRASIL

O último capítulo desta Tese trata das novas estratégias para gestão de RCD na cidade de Manaus, boas práticas que inibirão o surgimento de locais de descarte clandestinos que causam impactes negativos na Amazônia. Estas boas práticas foram propostas à Prefeitura de Manaus como sugestões para a gestão do Complexo do Aterro Sanitário Municipal que recebe todos os resíduos de Manaus e cidades limítrofes. Este artigo cumpre o objetivo específico de mapeamento dos aterros clandestinos de descarte de RCD e a elaboração de propostas para uma gestão mais inteligente dos resíduos pela Prefeitura de Manaus.

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ACTIONS TO INHIBIT ENVIRONMENTAL IMPACTS ON CLANDESTINE LANDFILLS IN THE AMAZON*

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Abstract

This research studies the negative environmental impacts of clandestine landfills in the Amazon, caused by the illegal disposal of construction waste. In the city of Manaus, located in the center of the Amazon, Brazil, there is a public landfill comprising a solid waste collection complex with an area of 660,000.00 m². In 2018, this landfill received approximately 932,927.00 t of solid urban waste, an average of 2,537.20 t/day. Unfortunately, less than 1% of this waste was destined for valorization (0.92% were for composting, and 0.05% were recycled). This legalized public landfill does not accept the disposal of construction and demolition waste, claiming the decrease in the lifetime of the landfill. However, this regional public policy prohibiting the disposal of construction and demolition waste in public landfills favors the use of clandestine landfills with harmful effects on the environment of the Amazon. This research presents proposals for actions to validate a mobile phone application with the authorities responsible for the Manaus landfill for recycling construction waste, with the aim of stimulating the circular economy and inhibiting the negative environmental impacts of illegal clandestine landfills.

Keywords: Amazon region, circular economy, clandestine landfills, construction and demolition waste

1. Introduction

The city of Manaus, Amazon, Brazil, is located in the center of the Western Amazon and reached in 2019 a population of 2,182,763 inhabitants. The Manaus City Hall maintains a landfill for the collection of solid urban waste, however this landfill does not accept the disposal of construction and demolition waste (CDW) by the general population, nor by companies in the construction sector that operate in Manaus. This public policy is favoring

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the emergence of clandestine disposal on the outskirts of the city of Manaus, which leads to concern about the negative environmental impacts on the Amazon Forest. Clandestine landfills serve for the disposal of solid urban waste and, mainly, for CDW originated from renovation and construction works in general.

The negative impacts on the Amazonian environment of these clandestine disposal are related to the contamination of small streams that are connected to the flow of the Amazonian rivers, with heavy metals such as Co, Cu, Fe, Cr, Ni, Mn, Pb and Zn, as already researched and the contamination of groundwater in the Amazon, Alter do Chão aquifer, according to (Mendes et al., 2019). Bacteriological tests and physical-chemical analysis of pH, temperature, conductivity, total solids, dissolved oxygen, alkalinity, hardness, CO_2, acidity, H_2S, chlorides, sulfates, iron, manganese, NH_4, color, turbidity and suspended solids for underground water exploration, have shown constant contamination, mainly of the river that bathes the city of Manaus, Rio Solimões.

According to (de Menezes et al., 2020), contamination of arsenic in soil and groundwater in the Amazon region is a relevant environmental impact, and the continued emergence of clandestine disposal only exacerbates the situation. The Manaus Public landfill is the main final destination complex for the city's solid waste, located at km 19 of the highway AM-010, spatially positioned through the geographical coordinates 02°57'23.86"S and 60°00'47.62W. The complex has an environmental operating license provided by the Environmental Protection Institute of the State of Amazonas - IPAAM. The area of the complex public landfill is estimated at 66 hectares and its operation is carried out using backhoes and tractors, as shown in Fig. 1 and 2. In 2018, this landfill received approximately 932,927.00 t of solid urban waste, an average of 2,537.20 t/day. Unfortunately, less than 1% of this waste was destined for valorization (0.92% were for composting, and 0.05% were recycled).

Fig. 1. Machines operating in the Manaus landfill complex, located at geographic coordinates 02°57'23.86"S and 60°00'47.62W

The policy adopted by the public sector responsible for the management of the Manaus Public landfill, suppresses the disposal of CDW in this public landfill, under the justification that the CDW will reduce its useful lifetime, scheduled to operate until 2023. However, this policy, despite promoting the economy of public coffers, harms the environment because it contributes to the appearance of clandestine disposal that degrade the environment on the outskirts of the city of Manaus, contaminating the Amazon Forest. The main CDW generated in the city of Manaus are common materials used in civil construction, such as wood, paper, plastics, metals and rubber (Lamêgo Oliveira et al., 2019), and taking

into account that on average 35% of all waste generated in the world is CDW, depending on the diffuse nature of construction projects, the impact of contamination of these CDW in the Amazon should not be overlooked by public policies. Brazil is among the signatory countries of the Paris Agreement 2015, so it must follow the prerogatives for reducing CO_2 emissions suggested by the UN based on the scientific studies presented in the reports of the (IPCC, 2020), collaborating for the reduction of pollutants that degrade the soil and air in the Amazon.

Fig. 2. Backhoe operating in the Manaus public landfill

A revision of the literature shows that negative environmental impacts caused by inadequate disposal of CDW can be found all over the world. For example, in China, soil and water pollution indexes due to heavy metal contamination were detected in the Southeast of the country (Li et al., 2020b), and also in the Pearl River Delta, Canton, South China, with high levels of water toxicology (Cui et al., 2020), which led to the adoption of incentive policies and to the development of CDW recycling in China's construction industry in order to reduce soil contamination. Tajikistan, Central Asia, also presented river beds with contamination by heavy metals, an environmental impact that affects the health of fauna, flora and man (Zhan et al., 2020). The countries with the largest world economy, USA and China, have invested in sustainability policies and management of the CDWs originating from their civil construction industries, reducing negative environmental impacts, through recycling, construction of buildings with recycled materials, landfills and the circular. A correct CDW management policy is fundamental to assure sustainability through the minimization of environmental impacts, so artificial intelligence tools should not be discarded, as they are useful in decision-making by public and private managers (Abdallah et al., 2020). Smartphone technologies are also useful tools that assist in the management, control and inspection of waste (Li et al., 2020a).

In this research, it's request the validation of the Manaus City Hall regarding an application for smartphones for the management of CDW, in order to facilitate the exchange, sale and purchase of waste and the control of the conscious disposal of CDW by the population and civil construction companies of the city of Manaus.

The main objective of this research is to present to the local government of the city of Manaus, Amazonas, Brazil, the Municipality of Manaus, proposals for actions to minimize the impacts of clandestine disposal that arise in the neighborhood of the city, responsible for the contamination of rivers in the Amazon with toxic materials from construction and demolition waste (CDW).

The secondary objectives are:

- To map clandestine disposal that are used for illegal CDW discard, causing impacts on the flora and fauna of the Amazon, with toxic CDW materials (plastics, paints and heavy metals);
- To validate a mobile application for use by companies and ordinary citizens, which assists in the exchange, sale and purchase of CDW, with the possibility of assisting environmental inspection by monitoring the disposal of CDW with GPS location technologies.

2. Material and methods

During the search for clandestine landfills, two locations were identified in the Eastern region of the city of Manaus. The mapping of these clandestine disposal sites was performed using devices equipped with global positioning system - GPS. The impacts of these illegal landfills were analyzed, considering their location and the disposal conditions.

After mapping the CDW clandestine disposal sites, this research opted for the development of a mobile application for use by the population, local construction companies and private CDW collection companies, with the aim of contributing to the legalization of private companies that exploit the collection of CDW and enable transparent inspection of the destination of the CDW in the city of Manaus. The methodology used to develop the mobile application followed the technological prescriptions of the Android Studio version 4.4.0 platform and programming using the Java language, meeting the recommendations prescribed by (Manna et al., 2020; Wu et al., 2020). The algorithm was developed according to the following flow of premises:

- the application should be accessible to any ordinary user or to construction companies that intend to donate, sell or buy CDW;
- the application should contain a database with the services provided by private CDW collection companies, as long as they are legalized and have an environmental license to operate;
- the application should provide the possibility of registering ordinary citizens and contractors that want to offer services for donation, sale and purchase of CDW, with photographic record of the CDW and GPS location of the storage and disposal site;
- the application should ensure the possibility of inspection of the disposal of the CDW through real-time monitoring from the origin to the place of destination of the CDW, by the sectors of the Manaus City Hall and other government sectors of the environmental area;
- the application should provide the possibility of registering private companies that explore the collection of CDW, as long as they are legalized and with environmental licensing;
- in the option to sell services, the application should allow CDW collection companies to establish the desired price, in order to favor free market competition for better prices and quality of service for ordinary users and construction companies;
- the mobile application must meet the security requirements for users regarding notifications and privacy, as defined by the methodology proposed by different researchers, for example (Weber et al., 2015);
- the mobile application must be managed for operation through a startup or internet company, with the objective of resolving conflicts and guaranteeing the legal rights of consumers using the application.

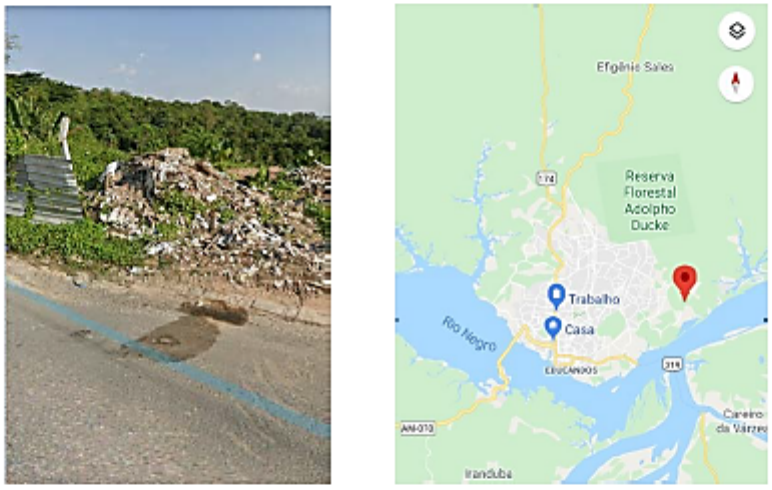
3. Results and discussion

Table 1 shows the results of the mapping of illegal disposal sites in the city of Manaus, with their geographical locations and risks to the Amazon environment.

Table 1. Results of mapping sites of clandestine disposal in the city of Manaus

Sites	*Geographic Coordinates*	*Environmental Risks*
1	03°04'19.5"S and 59°53'13.1"W	Contamination by heavy metals in water and soil Co, Cu, Fe, Cr, Ni, Mn, Pb and Zn, from the CDW (Santana and Barroncas, 2007).
2	03°06'15.0"S and 59°54'52.5"W	Contamination by heavy metals in water and soil Co, Cu, Fe, Cr, Ni, Mn, Pb and Zn, from the CDW (Santana and Barroncas, 2007).

The first location is shown in Fig. 3.



a) b)

Fig. 3. Clandestine disposal in the city Manaus. a) First site of the illegal disposal; b) Located at geographic coordinates 03°04'19.5"S and 59°53'13.1"W

The clandestine disposal shown in Fig. 3 is close to Igapés, a small water course in the Amazon Forest, causing a danger of contamination for the soil and for the nearby waters. The disposal of CDW is mixed with the disposal of solid urban waste, which will generate leachates in a totally inappropriate place, which may affect the health of animals and humans. The geographical location of this illegal landfill is 03°04'19.5"S and 59°53'13.1"W.

The second clandestine disposal site in the city of Manaus is shown in Fig. 4. It is a place of difficult access, used for illegal disposal of CDW. The site is close to the Amazon Forest with a risk of environmental impact due to contamination by toxic materials originating from the CDW irregular disposal. The location is far from the city center of Manaus, and this difficults its adequate inspection by the Manaus City Hall.

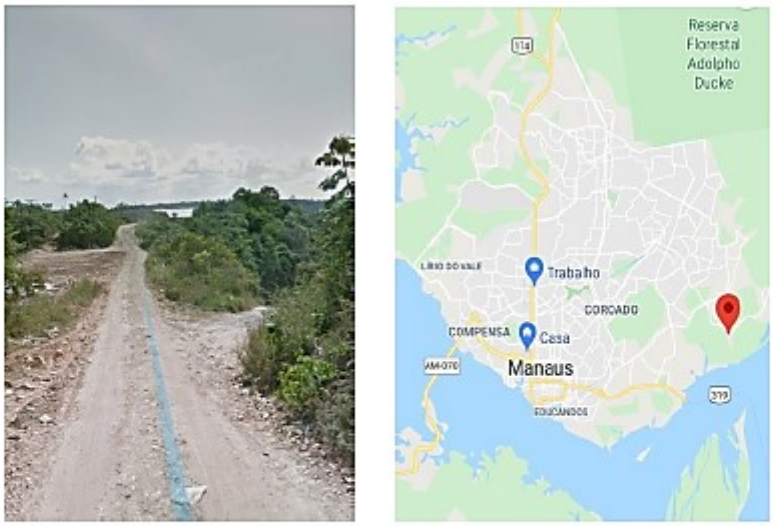


Fig. 4. Clandestine disposal in the city Manaus. a) Second site of the illegal disposal; b) Located at geographic coordinates 03°06'15.0"S and 59°54'52.5"W

The geographic location of the second clandestine disposal site is close to the first one, having the geographic coordinates 03°06'15.0"S and 59°54'52.5"W, as shown in Fig. 4. The area of this second illegal disposal site is 5 times larger than the area of the first site, which aggravates the environmental impact caused in the soil and groundwater.

There are private companies that exploit clandestine disposal in the city of Manaus, transporting CDW collection boxes to these clandestine disposal sites. These private companies operate without an environmental license and without registration with the Regional Engineering Council, and therefore operate illegally and without inspection by the Manaus City Hall. These private companies do not have material separators nor waste crushers, which makes it difficult to recycle CDW. These companies are located close to residential areas (Fig. 5 and 6), which is a danger to local residents, due to contamination of soil and groundwater.

Fig. 5. Inappropriate location for the operation of CDW collection companies, as it is close to residential areas

Actions to inhibit environmental impacts on clandestine landfills in the Amazon

Fig. 6. Private companies that exploit the collection of CDW without adequate supervision

These clandestine disposal sites must be eliminated as they are a danger to the environment of the Amazon, and can cause effects on the health of animals, plants and humans that are in contact with the soil and water close to these places. However, after these sites are eliminated, certainly others will be created as there is no alternative in the city of Manaus for a sustainable disposal of the CDW. In this way it was proposed to the Manaus City Hall to change the current public policy of banning the disposal of CDW in the public landfill of Manaus, so that the public landfill in the city of Manaus can receive the disposal of CDW in its area of operation, enabling the adequate inspection of the final destination of CDW. It was also proposed to install, at the public landfill in Manaus, equipment for crushing and separating CDW, to enable the recycling of materials and its subsequent donation, sale or exchange, aiming to promote the circular economy of sustainable materials originating from CDW. The Manaus City Hall must also insert tax free incentives for construction companies and ordinary citizens to discard their CDW in appropriate places that have the inspection of the environmental preservation sectors in the Amazon.

The development of the mobile application obtained the results shown in Fig. 7.

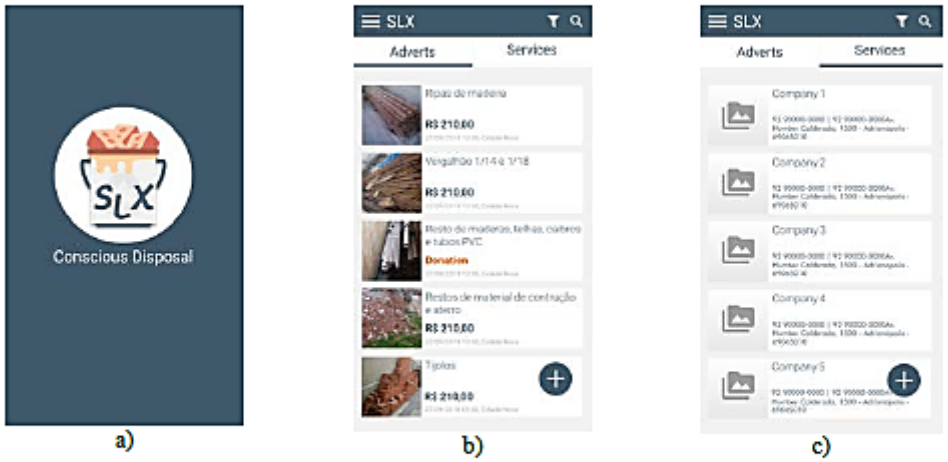


Fig. 7. Screens of the mobile application developed to contribute to the inspection of CDW disposal: a) screen with logo; b) screen of donation or sale of CDW; and c) screen of services offered

Following the methodology proposed by (Kaur and Kaur, 2019), the mobile application was subjected to surveys with users urban citizens, constructions companies and privates companies of the collection CDW, and obtained 93.1% acceptance of the group of 38 urban citizens, 92.3% acceptance of the group of 15 constructions companies and 72.5% acceptance of the group 5 privates companies of the collection CDW. The negative acceptance came from private companies that currently explore the collection of CDW in the city of Manaus, mainly due to the mandatory legalization with the Manaus City Hall and environmental inspection sectors.

4. Conclusions

This research identified several improvement opportunities regarding the management of CDW disposal sites in the city of Manaus, with consequent reduction of the negative environmental impacts caused by the inadequate handling and disposal of these waste in clandestine landfills:

- The reception of construction waste at the Manaus Public Landfill should be authorized;
- The recycling of CDW at the Manaus Public Landfill should be promoted;
- The exchange and sale of recycled materials at the Manaus Public Landfill should be encouraged in order to promote sustainable circular economy;
- Tax free favoring policies for companies and citizens that adhere to the recycling of construction waste should be implemented;
- The validation of the mobile application developed in this research would inhibit the illegal disposal of construction waste in clandestine landfills, as it facilitates the exchange, sale and purchase of CDW, in addition to enabling the mapping of disposal sites, facilitating inspections by public surveillance sectors.

These proposals were presented to the Municipal Secretariat of Urban Cleaning (SEMULSP), a sector of the Manaus City Hall, through virtual means for future evaluation of the Special Commission for the Disclosure and Orientation of Public Cleaning, whose function is to promote environmental education for the population of the city of Manaus. The proposals were received by the Manaus City Hall and will be considered after the end of "social isolation" due to the Coronavirus Pandemic.

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CONCLUSÕES

CONCLUSÕES

A grande quantidade de RCD gerados diariamente no Brasil provoca impactos ambientais negativos ao nível da degradação do solo e águas, devido aos metais pesados e outros elementos potencialmente perigosos contidos nos resíduos, por exemplo, em tintas, solventes, gesso, fibrocimento e embalagens diversas. Para além disso, estes resíduos abandonados no meio ambiente criam um micro-ecossistema, perfeito para vetores patogênicos, como roedores, e favorecem ao acúmulo de águas pluviais que formam depósitos de reprodução de larvas de insetos transmissores de doenças, como a malária, febre amarela e dengue.

A gestão de RCD na cidade de Manaus (Amazonas-Brasil) revela-se de grande importância tendo em conta a sua localização no seio de floresta amazônica, e também o clima quente e húmido desta região, sendo que ambos os fatores agravam a intensidade dos impactos ambientais negativos causados pelos RCD.

Numa primeira etapa do presente estudo foi feita a caracterização da atual gestão de RCD na cidade de Manaus através de inquéritos aplicados em visitas *in loco* a 4 canteiros de obras, com áreas superiores a 9.000 m^2, sob a gestão de 3 empresas de construção civil de grande porte, atuantes na cidade de Manaus. O inquérito abordou informações sobre os tipos de RCD gerados nos canteiros de obra, volumetria, destinação e custos associados.

Dessa caracterização foi possível concluir que os principais materiais presentes nos RCD produzidos em Manaus são a madeira e o papel, que são encaminhados para valorização energética, nos fornos das fábricas de tijolos, apesar do seu alto potencial de reciclagem, que prolongaria o tempo de vida destes materiais.

De entre os RCD produzidos, apenas o metal é comercializado e reciclado de forma adequada. Outros resíduos, como plástico e entulhos, são descartados através de empresas terceirizadas.

No que diz respeito à situação atual na gestão de RCD, foram encontradas diversas deficiências ao nível de práticas realizadas pelas empresas privadas e públicas da cidade de Manaus, dentre as quais se destacam:

a) a falta de um engenheiro ou técnico ambiental, responsável técnico, para o acompanhamento do descarte de RCD gerados nos canteiros de obra;

b) a contratação de empresas terceirizadas de coleta e destinação de RCD que não estão devidamente legalizadas;

c) a reduzida percentagem de RCD encaminhados para reutilização ou reciclagem, apesar das suas potencialidades a esse nível;

d) a atual política de gestão da Prefeitura de Manaus, que proíbe o lançamento de RCD no aterro sanitário municipal, favorecendo ao aparecimento de aterros clandestinos para depósito ilegal de RCD, sem fiscalização e com sérios problemas de contaminação por metais pesados e produtos químicos, nos rios e no solo da Amazônia;

e) na cidade de Manaus os pequenos empreiteiros, médias e grandes empresas construtoras optam por terceirizar o descarte de RCD, devido ao fator econômico, porém, estas empresas terceirizadas descartam em aterros clandestinos;

f) as empresas de coleta e destinação de RCD na cidade de Manaus não possuem registro no CREA-AM, o que subentende-se que no quadro de funcionários destas empresas inexiste profissional habilitado para responsabilizar-se pelas atividades técnicas da área ambiental.

Tendo ficado demonstrado na auscultação feita às empresas a falta de alternativas válidas para a gestão adequada dos RCD, os estudos evoluiram para a elaboração de um aplicativo para telemóvel, como uma ferramenta que contribuirá com a gestão ambiental na cidade de Manaus. O aplicativo de telemóvel foi desenvolvido de forma a possibilitar a compra, venda, troca, reciclagem ou doação de RCD, com particular enfoque nas tipologias de resíduos identificadas no estudo qualitativo

efetuado às empresas construtoras operando em Manaus: madeira, plástico, papel e cartão, resíduos metálicos e entulho. Os gestores ambientais nos canteiros de obra podem utilizar o aplicativo como ferramenta para escolha de empresas terceirizadas de recolha de RCD, além do fácil acesso a informações para doação e compra de RCD.

Foram feitas ações de sensibilização sobre esta temática, incluindo testes com o aplicativo, abrangendo profissionais da construção civil de Manaus, empresas construtoras, empresas especializadas na gestão de RCD e também alguns cidadãos comuns eventualmente interessados em utilizar o aplicativo para gestão de RCD produzidos em pequenas obras de remodelação. O índice de aceitabilidade e satisfação na fase preliminar de testes com o aplicativo, abrangendo 244 utilizadores, foi superior a 90%. O aplicativo está ainda em fase de testes, estando atualmente em estudo a viabilidade de proceder à sua distribuição gratuita pelos interessados.

Os resultados da caraterização da situação atual relativa à gestão de RCD em Manaus demonstraram claramente que há falta de fiscalização do governo local relativamente à deposição dos resíduos em aterros clandestinos, apesar da legislação Brasileira coibir este tipo de prática que afeta o meio ambiente do município de Manaus, através da contaminação da água e do solo. Para agravar a situação, o aterro sanitário público de Manaus não aceita descarte de RCD e não possui uma organização de coleta e segregação para reciclagem, que agregaria valor comercial para os resíduos com potencial de reutilização/reciclagem. A responsabilidade da gestão do aterro sanitário público e da inibição dos aterros clandestinos é do poder público, porém não há fiscalização permanente.

Perante esta situação de ineficiência de fiscalização, fica patente a importância do envolvimento de órgãos da administração pública nos processos de gestão e descarte dos RCD. Neste diapasão, foi realizado um estudo no Conselho Regional de Engenharia e Agronomia do estado do Amazonas (CREA-AM), órgão público que fiscaliza o exercício ilegal das profissões tecnológicas, a fim de prevenir práticas inadequadas. O estudo avaliou a eficácia do Plano de Fiscalização da Câmara Especializada Engenharia

Civil, para o biênio de 2017-2018, do CREA-AM. A investigação abrangeu a coleta de informações de cadastros de processos administrativos na área ambiental e revelou uma redução de 72% no registo de atividades ambientais do ano de 2017 para o ano de 2018. Esta redução confirma a existência de práticas inadequadas das empresas quanto à coleta, transporte, destinação e tratamento de resíduos de construção e remediação de áreas degradadas, e indicia que o CREA-AM não alcançou os objetivos previstos no atual Plano de Fiscalização, no que diz respeito ao acompanhamento de profissionais engenheiros ou técnicos ambientais durante a coleta e descarte de RCD na cidade de Manaus.

O estudo elaborado no CREA-AM incluiu também a análise dos processos administrativos oriundos das seguintes infrações: falta de registro de pessoa jurídica, falta de registro de Anotação de Responsabilidade Técnica (ART) e exercício ilegal da profissão. Os resultados obtidos demonstram a existência de indivíduos atuando ilegalmente em aterros clandestinos, sem conhecimentos técnicos necessários para mitigar os impactes ambientais negativos do descarte de RCD.

Como resultado desta pesquisa, foram propostas medidas de boas práticas no âmbito da esfera de atuação do CREA-AM para a promoção da sustentabilidade na gestão do RCD. Foi especialmente recomendado o reforço da fiscalização nos canteiros de obra assente numa perspetiva educativa, com foco nas boas práticas operacionais quanto ao reaproveitamento e reciclagem de RCD envolvendo a regularização da empresa construtora e da empresa terceirizada para coleta de RCD no CREA-AM além da exigência da contratação de um responsável técnico através de um profissional habilitado registrado no CREA-AM. Foi também proposta a inserção de práticas inovadoras ao nível da utilização do aplicativo de telemóvel desenvolvido e do rastreamento por GPS do descarte dos RCD gerados nos canteiros de obra da cidade de Manaus, promovendo dessa forma uma maior fiscalização dos locais onde os resíduos são descartados. As medidas propostas no âmbito deste estudo foram incorporadas no novo Plano de Fiscalização da Câmara Especializada Engenharia Civil, aprovado para o biênio 2021-2022.

Por último, é de se salientar o papel da Prefeitura de Manaus na promoção da gestão adequada dos RCD produzidos na cidade. Nesse pressuposto, o presente estudo incluiu também a análise das práticas atuais e a proposta de sugestões de melhoria ao nível da gestão do Complexo do Aterro Sanitário de Manaus, responsável pela coleta de 2.538 t/dia de resíduos sólidos. As boas práticas recomendadas incluem a promoção da reciclagem de RCD através da utilização do aplicativo desenvolvido no âmbito do presente estudo; o incentivo de troca e venda dos materiais com potencialidade de reutilização/reciclagem; incentivos fiscais para empresas que aderirem à reciclagem/reuso de RCD; e a inibição dos aterros clandestinos de RCD.

Estas propostas foram apresentadas à Comissão Especial de Divulgação e Orientação da Limpeza Pública e estão a ser analisadas por esta entidade.

Através das propostas de boas práticas desenvolvidas no âmbito do presente trabalho espera-se contribuir para a resolução / minimização dos principais problemas encontrados na gestão de RCD em Manaus, fomentando a atuação cooperativa dos diversos atores intervenientes neste processo. As propostas elaboradas pretendem promover os princípios da Economia Circular, ainda incipientes na cidade de Manaus, porém fundamentais para que a cidade se desenvolva economicamente sem comprometer os recursos naturais da Amazônia e minimizando os impactos ambientais negativos resultantes da inadequada gestão dos RCD.

Como sugestão de trabalhos futuros a desenvolver no âmbito da temática em estudo, destaca-se o acompanhamento da implementação das medidas agora propostas com a monitorização de indicadores apropriados para avaliar os efeitos práticos dessas medidas na melhoria da gestão do RCD.

Na clareza de que a extensa literatura disponível sobre o tema mostra as evidências científicas de que os RCD são um problema a nível mundial, com graves consequências ambientais associadas à sua gestão inadequada, enfatizamos que os estudos realizados no âmbito da presente tese podem ser aplicados em qualquer cidade

do mundo com vista à melhoria das boas práticas de gestão de RCD, contribuindo para a promoção de uma Sustentabilidade que traga co-existência entre o crescimento econômico, social e ambiental.

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