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ORIGINAL ARTICLE

Reverse supply chain practices for construction and demolition waste in the Brazilian Amazon: a multi-stakeholder view

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Abstract

Construction and demolition waste (CDW) is an environmental problem that affects all regions of the world. Particularly in the Brazilian Amazon Forest region, the volume of CDW generated almost doubled between 2007 and 2019. Indeed, despite Brazil having environmental regulations for waste management, these have been insufficient to solve the environmental problem because there is no CDW reverse supply chain (RSC) properly developed in the Amazon region. Previous studies have proposed a conceptual model of a CDW RSC but have hitherto failed to apply them against real world practice. This paper, therefore, attempts to test existing conceptual models that describe a CDW RSC against real industry practice prior to developing an applied model of a CDW RSC for the Brazilian Amazon. To modify the conceptual model for CDW RSC, qualitative data through 15 semi-structured interviews with five different types of stakeholders of the Amazonian CDW RSC were collected and analyzed using qualitative content analysis methods using NVivo software. The proposed applied model includes present and future reverse logistics (RL) practices, and strategies and tasks necessary for the implementation of a CDW RSC in the city of Belém of Pará, in the Brazilian Amazon. Findings reveal that several overlooked problems, particularly the limitations of the existing legal framework in Brazil, are not enough to promote a robust CDW RSC. This is perhaps the first study to examine CDW RSC in the Amazonian rainforest. Arguments provided in this study highlight the necessity for an Amazonian CDW RSC that must be promoted and regulated by the government. This can be addressed by the utilizing public–private partnership (PPP) for developing a CDW RSC.

Keywords Construction and demolition waste · Reverse supply chain · Reverse logistics · Construction and civil engineering industry · Brazilian amazon

Introduction

Globally, construction and demolition waste (CDW) represents an inherent by-product of the building's lifecycle (from construction through to demolition). Waste per se may constitute raw waste, processed waste and anything in between. Moreover, construction activities have the unenviable and infamous reputation of generating rapid and high volume waste—an issue further exacerbated by low recycling rates [1]. This issue of voluminous waste is

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compounded by low profits margins and low stakeholder interests which cumulatively contribute to almost irreparable environmental damage due to anthropogenic activities [1]. Data from the Brazilian Association of Public Cleaning and Special Waste Companies [ABRELPE in Portuguese] reveals a growing trend in the total amount of CDW collected by region per year in Brazil, with a 68% growth in the daily volume of CDW during the period 2007 to 2019. In the North region, where the Amazon Forest is located, the growth was of 96.5% for the same period [2]. Therefore, there is a compelling need to effectively manage CDW management implementation premised upon robust scientific research.

To regulate the construction sector, the National Council for the Environment [CONAMA in Portuguese] created resolution 307/2002 which aimed to "*establish guidelines, criteria and procedures for the management of civil construction waste, disciplining the necessary actions in order to minimize environmental impacts*" [3]. In addition, the National Solid Waste Policy (PNRS in Portuguese) provided new legislation (viz. 12,305/2010), which defines that the outsourcing of waste management does not exempt generating companies from liability for damages that may be caused by inadequate management of the respective waste [4]. The Decree 7.404/10 is also responsible for regulating the implementation of the National Solid Waste Policy (PNRS) [5]. This decree establishes, among numerous measures, that reverse logistics systems are implemented and operationalized through: sectorial agreements; regulations issued by the Government; or terms of commitment." Despite the existing legislative framework, a significant number of municipalities and waste-generating companies still fail to effectively manage their waste or resort to illegal disposal methods.[6–11]. Several factors contribute to irregular disposal including lack of public awareness regarding the discarding of CDW generated and absence of clearly delineated criteria for waste segregation. Moreover, CDW from small generators are collected together with domestic waste, thus making it difficult to collect and reuse given contamination by organic materials [12].

Reverse logistics (RL) provides a solution to this problem because it involves the process of revaluing post-sale or post-consumer waste [13]. This process takes place through collection, pre-treatment, manufacturing and redistribution, seeking to reintroduce waste materials to the supply chain or direct them to the appropriate final destination. It seeks to minimize waste and concomitant negative impacts, and simultaneously maximize positive impacts (whether environmental, social or economic) by contributing toward a circular economy model. Reverse logistics (RL) includes integrating operational, management and support activities, and involves several actors that structure and enable the implementation of the most appropriate solutions for waste [12]. Outsourcing the CDW management is a recurrent practice among companies in the state of Pará [11, 14, 15]. CDW management is commonly undertaken by companies specialized in waste management, but they only transport waste from construction sites to the city's landfill and the appetite for recycling or reusing is minimal [16, 17]. To optimize the different forms of CDW management on a large scale, the implementation of RL for CDW is essential. However, current research on RL implementation for CDW fails to consider different stakeholder views for the RL practices. Prominent academic authors usually focus solely on construction companies perspective [18–21]. Because RL practices must be treated with a more systemic approach and aimed at achieving global optimal results, a reverse supply chain (RSC) approach to RL practices toward CDW recovery must be considered. Moreover, RSC practices must account for a multi-stakeholder view given the various parties involved in the waste management supply chain [13].

Reverse logistics for CDW

Rogers and Tibben-Lembke (1999) [22] define reverse logistics (RL) as: "*the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal*." The term commonly used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials is waste logistics. However, a broader perspective encompasses all logistics activities related to source reduction, recycling, material substitution, reuse, and disposal [23] RL for construction and demolition waste (CDW) has been extensively studied in prevailing extant literature for example: literature reviews [24–28]; surveys on barriers and drivers [20, 29, 30]; case studies [21, 31, 32]; and mathematical modeling [33–35]. Previous research has indicated that effective management of the quantity of salvaged materials, potential collection points, recovery options, markets, and demand is necessary among the actors of the construction industry [36].

However, [37] was the first to propose a theoretical reverse supply chain (RSC) conceptual model for CDW. In their conceptual work (*ibid*), eight key actors involved were identified together with their roles and objectives within each of the seven nodes (e.g., CDW Generation Points, Waste Transportation Organizations, CDW Regional Separation Centres, Recycling/Remanufacturing Centres, Landfills, Consumption Points and Government) of the RSC (refer to Fig. 1). Moreover, the interaction between nodes, flow paths and government strategies involved were also delineated in terms

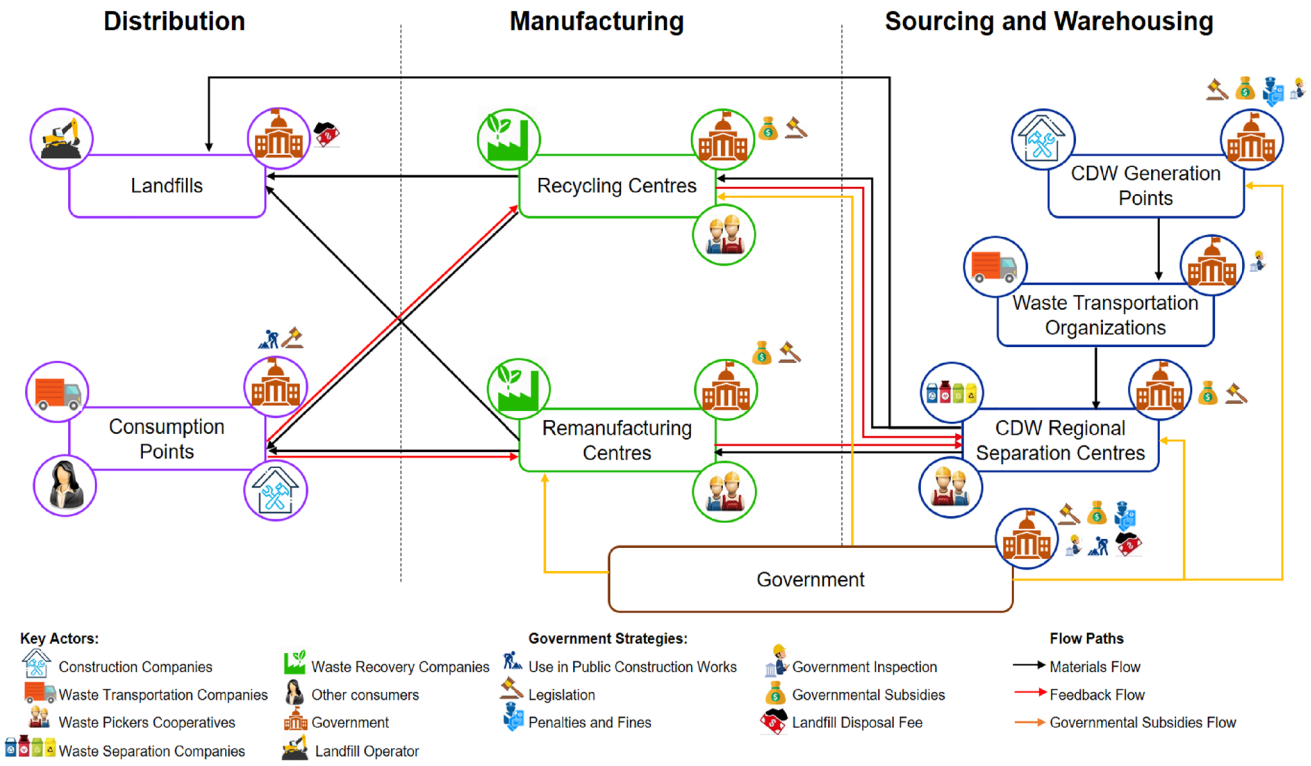

Fig. 1 Reverse supply chain conceptual model for construction and demolition waste

of materials, feedback and/or government subsidies flow. Specifically, six government strategies necessary for the RL implementation were identified and elucidated upon. As a product of a systematic review, this RSC conceptual model encapsulates all industry best practices necessary toward RL implementation for CDW. It also highlights the challenging nature of RL implementation practices in the RSC and identifies the government as a prominent actor of the RSC—being the only one with responsibilities at all the nodes. This reverse supply chain conceptual model for construction and demolition waste will serve as the theoretical foundation for this research.

Research aim and objectives

Given this contextual backdrop, this present research implements qualitative grounded theory and inductive reasoning approach to studying the RL phenomena and its impact upon the CDW market in Brazil. Specifically, a case study of the Amazon city of Belém (capital of the Pará state) is used as an exemplar that seeks to harmoniously integrate sustainable built environment development within the natural environment. Associated objectives are to:

1. Engender polemic debate and sample industry stakeholder views on RL practices employed within the contemporary CDW supply chain;
2. Determine how current practices could evolve to realize a sustainable balance between economic, environmental, social and political agendas;
3. Create a viable roadmap (as a product of this research) to incite ecologically transformative RL practices for handling CDW.

Methodology

The epistemological positioning of this exploratory research encapsulates aspects of pragmatist and interpretivist philosophical lenses to conduct inductive reasoning to develop new theories on the phenomena under investigation [37]. Couched within this overarching design, a qualitative grounded theory strategy was employed set within a case study context of the Brazilian city of Belém-PA. Belém-PA was chosen because of its important geographical positioning within the Amazon rainforest and the compelling needs to harmoniously integrate sustainable built environment development within the natural environment [38]. This

approach delineated has been widely used in similar and related research [39–41].

Data collection methods

From an operational perspective, interpretivism was adopted to analyze extant literature (as a secondary data source) and premise the development of a data collection instrument upon knowledge inherent within pertinent publications reviewed. A research hypothesis is a statement that suggests a potential explanation for a specific phenomenon or problem, which can be tested through scientific investigation. A well-defined research hypothesis serves as the foundation of a research study, guiding the research design, data collection, and analysis. Therefore, the following hypothesis is proposed: The lack of a properly developed CDW reverse supply chain (RSC) is contributing to the environmental problem of Construction and Demolition waste (CDW) in the Brazilian Amazon Forest city of Belém-PA. Semi-structured interviews were then developed which consisted of a series of open questions and supplementary prompts (to each question posed) within a framework of thematic discussion points, where prompts ensured that a complete response to each question posed was obtained. Semi-structured interviews represent an ideal method of collecting primary qualitative discourse because they offer interviewees an opportunity to digress from core questions posed and raise alternative avenues of investigation and/or propagate new theories [42, 43]. Interviews conducted were audio recorded and handwritten notes were also taken as a fail-safe precautionary measure. Thematic areas of investigation (obtained from the literature) were: reverse supply chain (RSC) current practices foreseen in the original RSC conceptual model (CM) [37]; new present RSC practices; and future RSC practices toward industry improvement. The thematic areas were developed as an attempt to validate the original RSC CM using primary data sourced from a case study. A total number of 15 interviews were conducted over the period October 2020 to March 2021 using the record feature on Google Meets to avoid face-to-face contact with interviewees given restrictions imposed by the global COVID-19 pandemic (refer to Table 1 which codifies participants so that they can be specifically referred during the analysis and discussion). Interview durations ranged between 30 to 90 min. Data saturation was deemed to have been achieved when interviews conducted generated no new theoretical insight or lines of additional information enquiry—in this instance, following the 15th interview [44]. This interview end-point is founded upon the notion that the depth of results acquired is far more important than the number of respondents [45–48]. Previous literature reviewed reveals that the sample size for this present study is within acceptable tolerances which range between four to 16 interviews (cf. [49–52] During the interview, the proposed reverse channel conceptual model was presented so that participants could contextualize the questions posed to the processes and actors involved in the infographic. Each category of company/institution was interviewed with a different form, based on the standard classification of the Construction and demolition waste (CDW) RSC conceptual model from [37]. Seven types of forms were consequently used viz: CDW Generation Points; CDW Regional Separation Centres; Waste transport organizations;

Table 1 Description of interview participants

Code	Job description	Node category	Market area	Experience
1GP	Chief executive officer	CDW generation points	Residential civil construction	5 years
2GP	Chief executive officer	CDW generation points	Construction of public works	26 years
3GP	Chief executive officer	CDW generation points	Commercial, residential and industrial civil construction	32 years
4GP	Chief executive officer	CDW generation points	Construction of public works	35 years
5GP	Chief executive officer	CDW generation points	Residential civil construction	14 years
1SC	Chief executive officer	CDW regional separation centres	Commercial, residential and industrial civil construction	32 years
2SC	Chief executive officer	CDW regional separation centres	Construction of public works	35 years
3SC	Chief executive officer	CDW regional separation centres	Residential civil construction	14 years
4SC	Waste selective collection coordinator	CDW regional separation centres	Municipal sanitation secretariat	18 years
1P	Former municipal secretary	Government	Municipal environment secretariat	12 years
2P	Civil engineer	Government	Municipal sanitation secretariat	34 years
3P	Sanitary engineer	Government	Municipal sanitation secretariat	35 years
1L	Civil engineer	Landfill	Municipal sanitation secretariat	34 years
2L	Sanitary engineer	Landfill	Municipal sanitation secretariat	35 years
1CP	Chief executive officer	Consumption points	Building supply store	15 years

Government; CDW Recycling/Remanufacturing Centres; Landfills; and Consumption Points. This ensured that all prominent actors involved in the processes delineated could positively contribute to the ongoing outputs of the present research undertaking.

Sampling

Sampling procedures adopted utilized a non-probability purposive approach to select five initial interviewees who were deemed to have sufficient knowledge and experience of the subject domain [53]. Snowballing was then adopted to expand the sample size using the recommendations of interviewees participating in earlier round of interviews ([42]). Survey entry criteria for interviewees stipulated that all participants must: (1) be institutional representatives and professionals who have practical experience in any node of the CDW RSC and in the context of the Brazilian amazon city of Belém-PA; and (2) have a minimum of five years of practical experience in the sector [49, 54, 55]. [42] explains that sampling involves a purposeful selection of sample participants who can elucidate upon the central phenomenon being investigating. Thus, the number of people required to participate varies according to each research design, rather than having a predetermined number to verify its viability.

Among the states in the northern region, Pará contributes the highest gross domestic product (GDP), accumulating the equivalent to 40 billion US dollars in 2016. During 2014–2016, the state's construction sector, also contributed the highest level of Gross Added Value (GVA)—an index that measures the value of products and services in a sector over a given period (IBGE 2019). Pará is therefore the most economically important state in the Brazilian Amazon Forest region. A geographical map of the Brazilian amazon city of Belém-PA is shown in Fig. 2

All participants were contacted via telephone, messaging app and e-mail. They were sent an information sheet detailing the nature and purpose of the research study together with details of the research team. All participants were assured that: their (and their employer's) identity would remain strictly confidential and not divulged now disseminated to any third party willing or otherwise; all data collected would be stored in a secure location and securely disposed of at the end of the study; participants had to right to withdraw at any time during the research undertaking; and the results would be shared with participants upon written request.

Analysis

Both content and thematic analysis was adopted on 15 transcripts recorded; such an approach facilitated an in-depth analysis of the interview discourse and grouping of emergent themes arising. First, the lead researcher developed initial

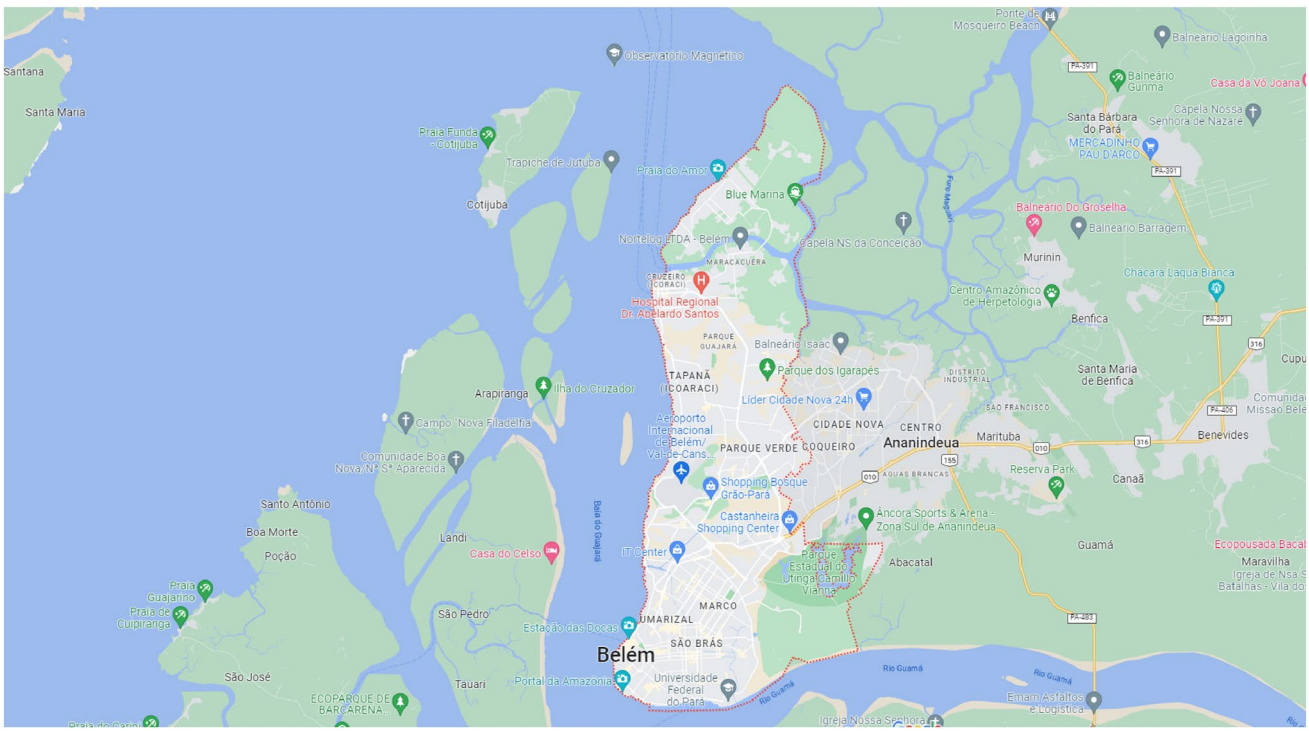

Fig. 2 Geographical map of the investigation area: Brazilian amazon city of Belém-PA

codes and their operational definitions based upon the CDW RSC conceptual model. Codes for the present and future practices were created using the six steps of the coding process advocated by [42] viz: (1) read all of the transcriptions carefully; (2) iteratively review the transcripts; (3) code the transcripts; (4) make a list of all code words; (5) take this list and go back to the data; and (6) reduce the list of codes to themes. The results were then triangulated using both previous scientific literature, technical reports and official public documents to ensure validity of the research findings.

Results

Current practices and improvements suggestions

Data analyzed using the thematic analysis procedure asked interviewees about practices within their own node and other nodes within the Construction and demolition waste (CDW) reverse supply chain (RSC). This enabled a cross comparative analysis to be undertaken if differences were observed.

Comparison of the original CDW RSC conceptual model to present practices

All of the hypothetical practices described in the original CDW RSC CM [37] were initially compared to the described current practices by the interviewed specialists. This then served to determine whether the theoretical construct accurately replicated industry practices. Interviews revealed that some of the hypothetical practices (derived from literature) do occur in practice and were thus confirmed as proved hypothetical (PH) practices. Other hypothetical practices did not occur and were categorized as disproved hypothetical (DH) practices. For remaining practices emergent from literature, there was insufficient data to either prove or disprove and so these were marked as uncertain hypothetical practices. Tables 2, 3 and 4 presents the proved disproved and uncertain hypothetical practices respectively. A graphical demonstration of this comparison is also illustrated at Fig. 3. The proved practices remained as the original CDW RSC CM, the disproved were greyed out, while the uncertain were highlighted by the yellow color.

Government practices

Government uses CDW management public policies (1PH) was confirmed by only two interviewed specialists from the public administration sector. However, surprisingly other government practices were not mentioned by any of the professionals viz.: *Government uses other CDW management laws* (2PH); *Government use laws to promote utilizing the recycled CDW* (5PH); and *Government defines quality standards for recycled CDW* (4PH). The existence of these practices could be confirmed by secondary source data research, more specifically, documental research on Brazilian federal, state and municipal legal databases.

In Brazil, the National Environment Council (CONAMA) created resolution 307/2002 aiming to "*establish guidelines, criteria and procedures for the management of construction waste, disciplining the necessary actions in order to minimize environmental impacts*" [3]. In addition, a National Solid Waste Policy (PNRS), provided for the Federal Law 12.305/2010 [5] was created by the federal Government. In the Amazonian region, the State Plan for Integrated Solid Waste Management in the State of Pará [56] and a State Policy for Recycling of Materials [57] represent two legal instruments to govern CDW. A Municipal Basic Sanitation Plan was also issued to provide guidance on how legal requirements could be met [58]. Collectively, these documents focus upon promoting reverse logistics (RL) practices toward recovering waste but none of them actually define enforcement criteria or penalties for noncompliance. Two reasons are proffered for this lack of knowledge on government related practices toward CDW recovery. First, excessive bureaucracy discourages CDW recovery (reported by interviewees 2GP, 3GP, 4GP, 2SC and 3SC), for example, participant 3SC reports that "*we are obliged to buy wood registered with city's government. Is three times more expensive than the normal market price, just because the guy has the license (…) it is very difficult to register these companies in these city's public departments. So, the registered companies charge what they want*." And second, any kind of environmental legal requirement, is outsourced by construction companies (CC), (reported by interviewees 1GP, 2GP and 2SC). A similar problem occurs with *a network of small CDW disposal points distributed throughout the city is better for small CDW generators* (8PH). This was proved as both the State Plan for Integrated Solid Waste Management in the State of Pará [56] and the Municipal Basic Sanitation Plan [58] proposed the creation of Voluntary Delivery Point (VDP) or Ecopoints. The documents characterized VDP as a place within the urban area for receiving small amounts (max of $1m^3$) of CDW such as small generators and other recyclable waste. This solution has been in effect since January 2021. *Government uses Governmental Subsidies* (3PH), was only applied at Waste Pickers Cooperatives (WPC). The Waste Selective Collection Coordinator for the Municipal Sanitation Secretariat (interviewee 4SC) stated that: "*City halls provide support for transportation, and warehouses where these cooperatives are installed. It's all up to the city hall. There is no cooperative of its own. They all receive support from the city in some way (trucks and warehouses are from the city hall).*"

Table 2 Description of the proved hypotheses from the CDW RSC CM

Nº	Proved hypotheses	CDW RSC nodes and description code of interview participants					
		GP	SC	P	L	CP	SSD
1PH	Government uses CDW management public policies			2P, 3P			F, S & M LD
2PH	Government uses other CDW management laws						F, S & M LD
3PH	Government uses governmental subsidies	4GP,5GP	1SC, 2SC, 4SC	1P, 2P, 3P			
4PH	Government defines quality standards for recycled CDW						QS
5PH	Government use laws to promote utilizing the recycled CDW						F, S & M LD
6PH	CC don't transport and/or recover their generated CDW	1GP, 2GP, 3GP, 4GP e 5GP	1SC				
7PH	Waste Transportation operations are limited by the CDW composition, technology available and local market	2GP, 3GP, 4GP	1SC	1P, 2P		1CP	
8PH	A network of small CDW disposal points distributed throughout the city is better for small CDW generators	2GP					F, S & M LD
9PH	CC don't sort most of their generated CDW, because:	1GP, 2GP	1SC, 2SC, 3SC, 4SC	3P			
10PH	*Absence of productive capacity*	*2GP, 4GP, 5GP*	*2SC, 3SC, 4SC*				
11PH	*Absence of duly trained employees for this task*	*2GP, 4GP, 5GP*	*2SC, 3SC, 4SC*				
12PH	*Absence of dedicated space for this*	*2GP, 4GP, 5GP*	*2SC, 3SC, 4SC*				
13PH	*Presence of costs associated with the process*	*2GP, 4GP, 5GP*	*2SC, 3SC, 4SC*				
14PH	*Lack of alternative revenue-generating destinations*	*2GP, 3GP, 4GP, 5GP*	*1SC, 2SC, 3SC*				
15PH	Waste pickers sort some kinds of CDW	5GP	3SC, 4SC	1P, 2P, 3P		1CP	
16PH	Quality standards are required by the recycling centres	5GP	3SC, 4SC			1CP	
17PH	Quality standards for recovered CDW are a major issue in for CC	1GP, 2GP, 3GP, 4GP e 5GP	1SC, 2SC, 3SC, 4SC			1CP	
18PH	Waste pickers cooperative work with sorting waste	5GP	3SC, 4SC	1P, 2P, 3P		1CP	
19PH	Landfilling is cheaper then recovering CDW	1GP, 2GP, 3GP, 5GP	1SC, 2SC, 3SC		1L, 2L		
20PH	The city's CDW landfill is managed by the city's government				1L, 2L		F, S & M LD

GP CDW generation points, *SC* CDW regional separation centres, *P* public administration or government, *L* landfills, *CP* consumption points, *SSD* secondary source data, *F*, *S* & *M LD* federal, state and municipal legal databases, *QS* quality standards for recycled aggregates from CDW BRASIL (2012b)

Sorting practices

From the six options of barriers (which hinder sorting processes), only *absence of adequate technology* (11DH) was discarded by interviewees, as most declared that advanced technology is not required (interviewees 3SC and 5GP) or that existing technology is available for CC to use (interviewees 1SC, 2SC, 3GP, 4GP). Another reported problem was that construction workers change at each stage of the construction work, and for different construction sites for the same CC. That makes it more difficult to keep training construction workers into sorting technologies and environmental awareness. To exacerbate matters further: nine professionals of three different RSC nodes confirmed that *landfilling is cheaper then recovering CDW* (19PH); and *lack of alternative revenue-generating destinations* (14PH) received seven complaints from all stakeholders.

Regarding *waste pickers cooperative sort some kinds of CDW* (15PH), professionals reported that they only sort paper, plastic, metal and wood as these items of CDW are

Table 3 Description of the disproved hypotheses from the CDW RSC CM

Nº	Disproved hypotheses	GP	SC	P	L	CP	SSD
1DH	Government uses laws to enforce a level of deconstruction			2P, 3P			F, S & M LD
2DH	Government uses laws to enforce a level of recycling			2P, 3P			F, S & M LD
3DH	Government uses recovered CDW in public construction Works	2GP, 3GP, 4GP, 5GP				1CP	
4DH	Government uses penalties and fines			2P, 3P			F, S & M LD
5DH	Government effectively uses government inspection	4GP,5GP	3SC	2P, 3P	2L		
6DH	Government controls the landfill disposal fee		3SC	1P, 2P, 3P	2L		
7DH	CC plan their CDW generation	2GP, 3GP, 4GP, 5GP	1SC, 2SC, 3SC	3P, 2P			
8DH	Waste pickers cooperative could work with recycling/remanufacturing centre			1P, 2P, 3P			
9DH	CC buy recovered CDW	1GP, 2GP, 3GP, 4GP e 5GP					
10DH	Landfills operators are properly disposing CDW		3SC	1P, 2P, 3P	2L		F, S & M LD
11DH	CC don't sort most of their generated CDW, because of Absence of adequate technology	2GP	4SC				

GP CDW generation points, *SC* CDW regional separation centres, *P* public administration or government, *L* Landfills, *CP* consumption points, *SSD* secondary source data, *F*, *S* & *M LD* federal, state and municipal legal databases

Table 4 Description of the uncertain hypotheses from the CDW RSC CM

Uncertain hypotheses
Government defines quality standards for the CDW delivered to the recycling/remanufacturing centres
Recovered CDW is usually more expensive than raw materials
Transportation companies are key actors at consumption points
Recycling/remanufacturing Centre sort CDW
Environmental impact of the CDW recovery process is problematic

the only ones with a local recovery market. They also have to comply with quality standards, as indicated by *quality standards are required by the recycling/remanufacturing centres* (16PH), since the recycling/remanufacturing centres reportedly pay different prices depending on the quality of the waste sorting process—interviewee 4SC reported that: "*It has a value for wet waste. It has a value for dry, others for clean and another for pressed waste.*"

Landfilling practices

An omnipresent problem with the current CDW management in Belém is related to the city's official CDW landfill, which is *operated by the city's government* (20PH). The problems is related the fact that landfills operators are 'not' properly disposing CDW (10DH). Interviewees 1P (a former Environment Municipal Secretary Municipal) and 2L reported that there is no proper CDW landfill for the city's generated CDW; information that was confirmed by the Municipal Basic Sanitation Plan [58], which is prepared by the Department of Solid Waste (DRES) of the Municipal Sanitation Secretariat (SESAN). This document clearly states that the city's CDW landfill (namely Aurá landfill) does not have an environmental operating license, which (from a legal perspective) means that all of the city's CDW is actually illegally dumped. To further exacerbate this matter, the Municipal Basic Sanitation Plan reports the presence of informal waste pickers working in the waste collection at Aurá landfill. According to Federal Law No. 12,305/2010, this activity should have been deactivated from all landfills in the national territory, in support of international commitments to the International Labor Organization, World Health Organization and others [5]. Finally, all uncertain practices are more related to transportation companies or recycling/remanufacturing centre as those stakeholders were not accessible for interviews.

New RSC present practices in the Brazilian amazon

Interviews conducted revealed new information of the Brazilian amazon RSC. These included industry practices viz: *CC mainly sort paper, plastic, metal and wood* (4PP), perceptions such as *the city government is not interested in the CDW recovery* (8PP) and others were setting and context such as *there is no local companies to recover most types of CDW* (14PP). Because all refer to the present context of the RSC, they were all grouped and categorized as newfound present practices (PP). Table 5 presents the 15 mapped

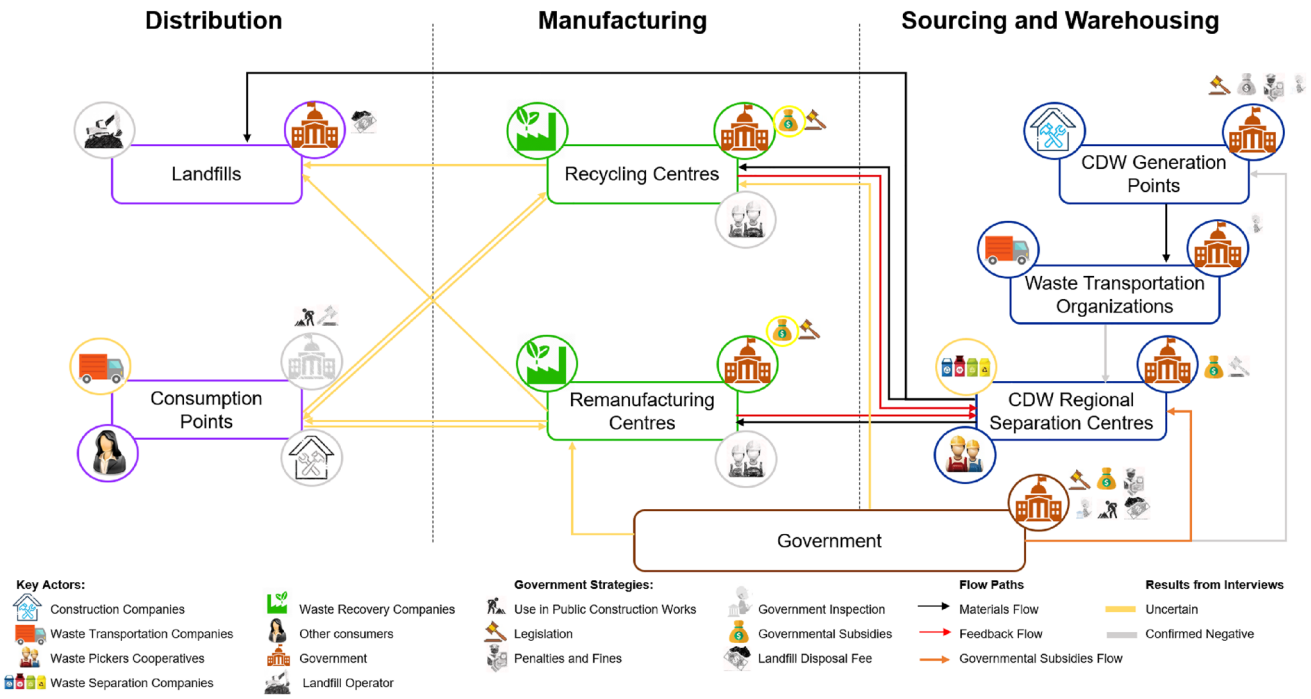

Fig. 3 Original CDW RSC Conceptual Model compared to current practices

Table 5 Description of the newfound present practices of the amazonian CDW RSC

Nº	Present practices	GP	SC	P	L	CP
1PP	CC outsource the development and execution of their CDW Management Plans	1GP, 2GP, 3GP, 4GP e 5GP	1SC	3P, 2P		
2PP	CC would like to have recovery options available	2GP, 3GP, 4GP, 4GP	3SC			
3PP	Small generators are the biggest source of illegal dumping	2GP, 3GP, 4GP	2SC, 4SC	1P, 2P, 3P	2L	
4PP	CC mainly sort Paper, plastic, metal and wood		2SC, 3SC, 4SC			
5PP	CC don't reuse CDW		2SC, 3SC, 4SC			
6PP	The government is currently concerned only with regulating and inspecting the CC	3GP,4GP, 5GP	3SC	1P, 2P, 3P	1L, 2L	1CP
7PP	The government is currently concerned only with collecting CDW from illegal dumping	3GP	1SC, 4SC	1P, 2P, 3P	1L, 2L	1CP
8PP	The city government is not interested in the CDW recovery	2GP, 3GP, 5GP	1SC, 3SC	3P	2L	
9PP	Waste transportation companies will divert CDW from proper disposal	2GP, 3GP, 4GP	1SC	1P, 2P		1CP
10PP	CDW is sold at unregulated markets by Waste transportation companies	2GP, 3GP, 4GP	1SC	1P, 2P		1CP
11PP	CDW is illegally dumped by Waste transportation companies	2GP,5GP	1SC, 3SC	3P	2L	
12PP	Waste transportation cost is high	2GP, 4GP		3P	2L	1CP
13PP	Waste pickers receive more training than CC workers		1SC, 2SC, 3SC, 4SC			
14PP	There is no local companies to recover most types of CDW	2GP, 4GP, 5GP	1SC, 2SC, 3SC, 4SC	1P, 2P, 3P	2L	1CP
15PP	The landfill tax doesn't cover the landfill operational costs			3P	1L, 2L	

GP CDW generation points, *SC* CDW regional separation centres, *P* public administration or government, *L* Landfills, *CP* consumption points

newfound PP of the CDW RSC in the Brazilian Amazon. Figure 4 depicts the compared CM presented in Fig. 3 with a few modifications; the already proved newfound PP are in a lighter tone, the DH were removed, the uncertain remained the same, and the newfound PP were included with the same color pattern from the original CM.

CDW generation points

Starting with *CC outsource the development and execution of their CDW Management Plans* (1PP), all CC reported that they seek minimum conformance with legal requirements and that environmental issues are outsourced. This confirms the earlier work of [59] who found that CC in the Brazilian Amazon do not take responsibility for the CDW management generated by the construction sector. Small generators were included as RSC stakeholders because they were frequently mentioned as relevant by different key actors. Interviewees 2GP and 2P suggest that they are problematic for the municipal public administration because *small generators are the biggest source of illegal dumping* (3PP). Moreover, CDW from small generators is typically collected by the municipal waste collection service, and those CDW are usually expensive to collect and properly dispose. In addition, and due to *Government effectively uses Government inspection* (5DH), small generators are unsupervised by government, the practice of free municipal waste collection service indirectly promotes illegal dumping—interviewee 2P states that this can lead to clogging of the municipal micro and macro drainage system. For the sorted CDW, CC *mainly sort paper, plastic, metal and wood* (4PP) [11, 14, 17]. All CC that sort their CDW reported zero reuse of their waste (5PP) albeit, interviewee 2P reported that this practice is quite the opposite for small generators "(…) *there is this culture in the state to reduce costs in low-cost homes. It is common for low-income people to build their own homes, and to reduce costs, it is common to reuse as much material as possible*." Previous research partially contradicts this present practice and perhaps shows a growing environmental awareness amongst practitioners (cf. [11].

Government

Present practices such as: *the government is currently concerned only with regulating and inspecting the CC* (6PP); and *the government is currently concerned only with collecting CDW from illegal dumping* (7PP) are validated as all RSC nodes mentioned these practices. The National Solid Waste Policy (PNRS), provided for the Federal Law 12.305/2010 [5], states that the CDW management responsibility resides with CC not the government. CDW from illegal dumping is eventually categorized as domestic waste, and the city's government is responsible for this under Federal Law 11.445/2007 [5]. Present practice viz. *the city*

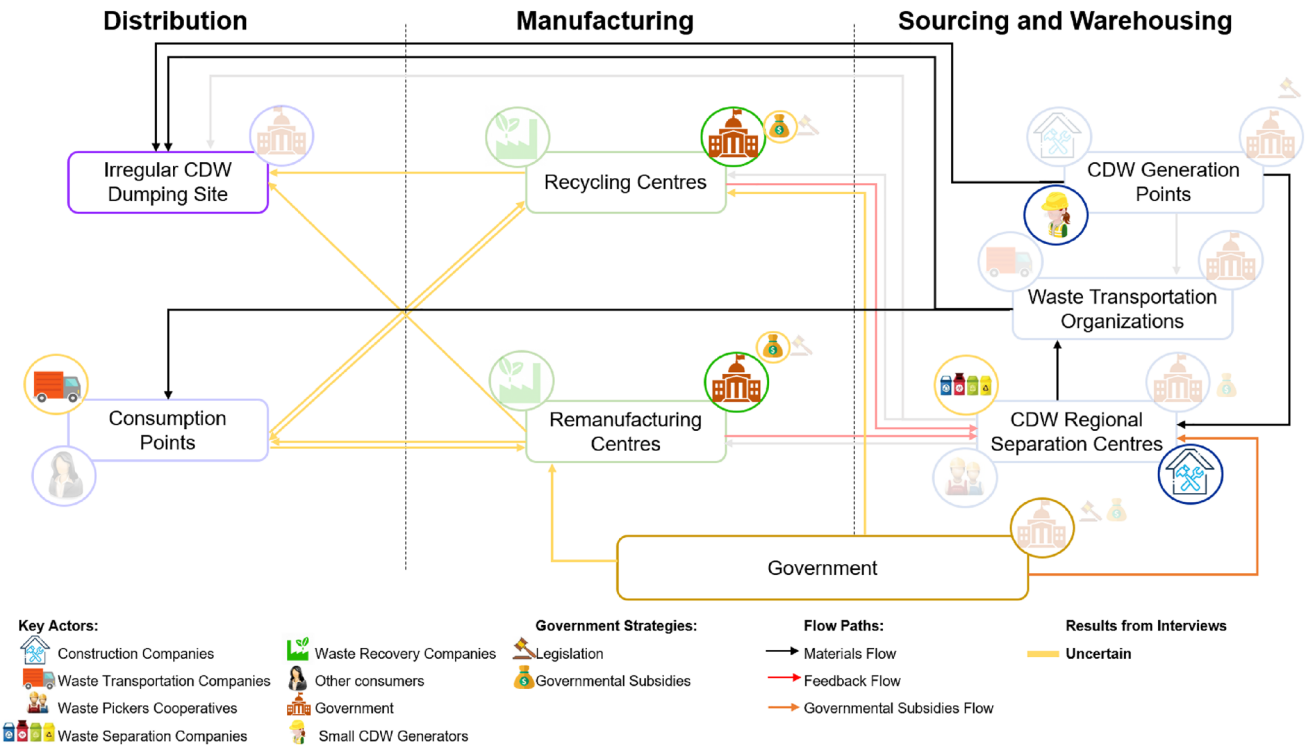

Fig. 4 The new present practices of the Amazonian CDW RSC

government is not interested in the CDW recovery (8PP) is reported by seven stakeholders from four different perspectives. This information is confirmed through analyzing the Municipal Basic Sanitation Plan [58]. The document's only guideline is how to reduce irregular disposal and issues such as alternatives for the recovery of these residues are not covered. This practice also indirectly discourages the CC from seeking any type of CDW recovery. 1SC reported that since the city government does not even properly dispose of its own collected CDW, they should not demand the same behavior from CC.

Waste transportation companies

Seven stakeholders from four different nodes confirmed that waste transportation companies contribute to problems within the RSC. Specifically, *waste transportation companies will divert CDW from proper disposal* (9PP), mainly because *CDW is sold at unregulated markets by Waste transportation companies* (10PP) or *CDW is illegally dumped by Waste transportation companies* (11PP). Interviewee 2GP reported that "*CC know that that waste will not have the correct destination, because it will either dump irregularly, or it will sell to a third party (…) transport company, which some irregular ones even dump in the channels. Now accredited and regular companies, they will store at the company's location to later sell these CDW in the parallel market. Main customers are the population of poor neighbourhoods.*" CDW *transportation cost is perceived as high* (12PP) by five different stakeholders from CC, Government, landfills and consumption points. For example, interviewee 2GP reported that the purchase price of sand bucket costs R$30.00/$m^3$, and the transportation cost of wasted sand is R$50.00/$m^3$. High transportation costs in the Pará state is due to high petrol costs and poor or absent road infrastructure [60, 61]. Hence, *CC would like to have recovery options available* (2PP).

Waste pickers cooperatives and the local CDW RSC

Regarding *waste pickers receive more training than CC workers* (13PP), CC described that their employees receive little or no training on CDW sorting process. While the Waste Selective Collection Coordinator (4SC) reported that WPC receive ample training on the separation process and how to inform the population about selective collection. When CC do sort their CDW, they reportedly do it roughly as their objectives were: to directly sell metal, or donate wood, or to facilitate present practice—thus supporting the notion that *CDW is sold at unregulated markets by Waste transportation companies* (10PP). Conversely WPC, execute a more detailed separation because they sell their waste to different recovery companies at different prices, as reported by interviewee 4SC: "*waste is taken to the sorting centres. There they do the processing, even to add value to the products they are going to sell. For example, inside the sorting centre they will separate what types of plastic are there, what is aluminium, what is iron. Each of them has a value there. So even after the separation at the generating source, when they arrive at the sorting centre they do a second level of separation.*"

Finally, even though all nodes complained that *there is no local companies to recover most types of CDW* (14PP), four stakeholders (namely 1P, 1SC, 2P, 3P) were completely unaware of the existence of any kind of CDW recycling centre in the state. However, three of them (2SC, 3SC and 4SC) reported the presence of a metal recycling company, and of a regional reception company for paper, plastic, metal and wood, called RioPel. Interviewee 4SC reported that RioPel is "*only processes it there, by compacting it and sending it to another place, sending it to another state.*" This information was confirmed through the official company's website as it states that "*acting in the purchase, processing and resale of recyclable materials*" with several pictures displaying compacted waste in large blocks.

The future practices for the amazonian CDW RSC

Participating professionals also described their opinions as to how the Amazonian RSC should evolve as an industry to move toward establishing a complete circular industry. Akin to new present practices, some of the suggested future practices (FP) were industry practices (e.g., *macro level on-site sorting and micro level off-site sorting* (1FP)), others were strategies (e.g., *Government should use PPP to promote local CDW recovery industry* (5FP)) and others were setting and context (e.g., CDW recovery needs to be more profitable (6FP)). Because all encapsulate future RSC, they were all grouped and categorized as future practices. Table 6 presents the 13 mapped future practices uncovered by the present study. Figure 5 finally represents the new conceptual model of a CDW RSC now adjusted for the Brazilian Amazon context. It includes all of the PH found the scientific literature [37], all of the new PP that should continue and FP. This new and revised version of Fig. 4 better reflects prevailing practices adopted with some changes; the proved and the new practices are in a lighter tone, and future practices were added using the same color pattern from the original CM. These changes were made to highlight the current discussed future practices.

The future of the sorting process

The first notable difference in the CM is the CDW route change. In the original CM from [37]'s version, CC forwards CDW to waste transportation companies that then send it to separation centres. In view of present practices, e.g., *CC*

Table 6 Description of the future practices of the amazonian CDW RSC

Nº	Future practice	GP	SC	P	L	CP
1FP	Macro level on-site sorting and micro level off-site sorting	2GP, 3GP, 4GP, 5GP	1SC, 2SC, 3SC, 4SC			
2FP	CC should have environmental and/or social awareness	2GP, 5GP	3SC, 4SC			1CP
3FP	Waste pickers cooperative need more government supervision and business structure	2GP, 4GP, 5GP	2SC, 3SC, 4SC	1P, 2P, 3P		
4FP	Waste pickers cooperative require government subsidy	3GP, 5GP	1SC, 4SC	2P, 3P		
5FP	Government should use PPP to promote local CDW recovery industry	3GP, 5GP	1SC, 3SC	1P, 3P		
6FP	CDW recovery needs to be more profitable	2GP, 3GP		3P		1CP
7FP	The government should control the Landfill Tax to promote CDW recovery	2GP		2P, 3P	1L, 2L	
8FP	The government should install a CDW Landfill			1P, 3P	2L	
9FP	A CDW RSC needs to be promoted and regulate by the Government	2GP, 3GP, 4GP, 5GP	1SC, 2SC, 3SC, 4SC	1P, 2P, 3P	1L	1CP
10FP	Government should invest in R&D for CDW recovery	2GP, 3GP, 4GP, 5GP	2SC, 3SC			1CP
11FP	The government needs to set quality standards for recovered CDW	1GP, 2GP, 3GP, 4GP e 5GP	1SC, 2SC, 3SC, 4SC			1CP
12FP	Government should invest in environmental education	3GP, 4GP, 5GP	1SC, 2SC, 3SC, 4SC			
13FP	If there is a local CDW RSC, CC should be legally required to recover CDW	3GP, 5GP	1SC, 3SC			1CP

GP CDW generation points, *SC* CDW regional separation centres, *P* public administration or government, *L* landfills, *CP* consumption points

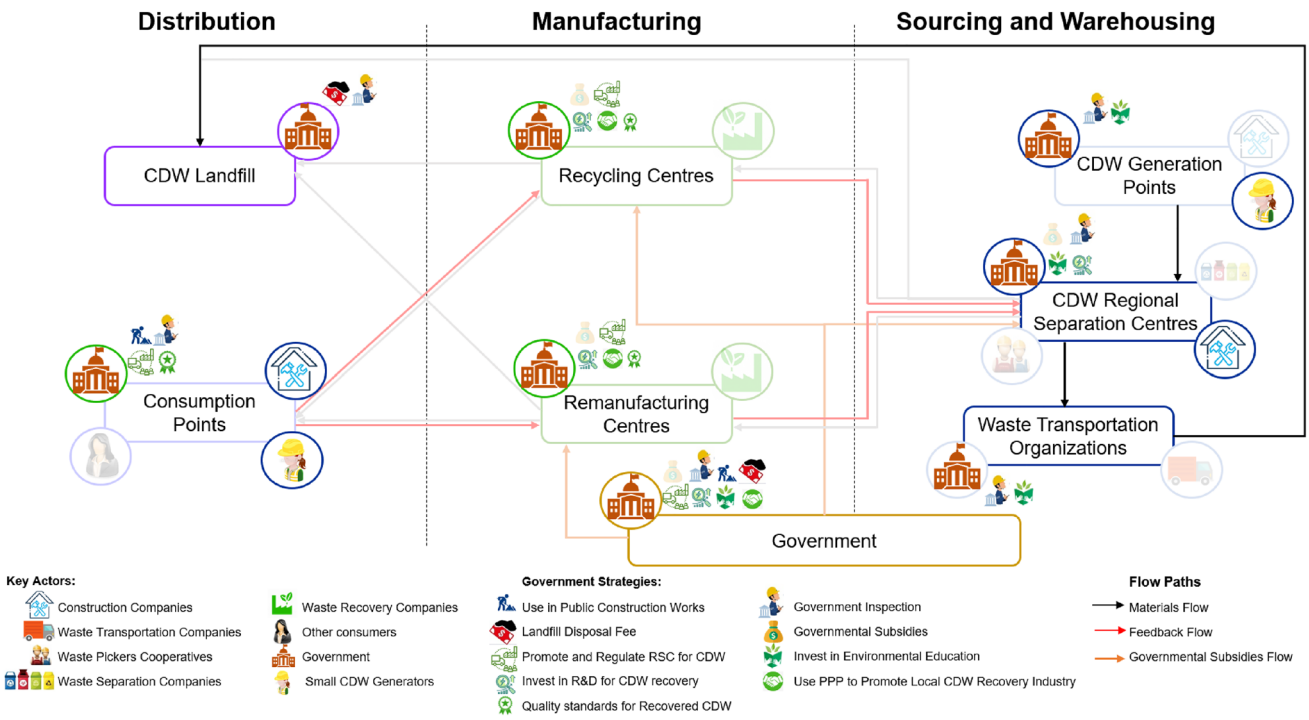

Fig. 5 The future practices of the Amazonian CDW RSC

don't sort most of their generated CDW (9PH) and *waste pickers receive more training than CC workers* (13PP), the sorting process should ideally occur on *macro level on-site sorting and micro level off-site sorting* (1FP). CC agree that it is possible to perform a macro-level on-site sorting at minimum cost. Then WPC should collect and transfer the macro sorted CDW to their public funded sorting warehouses to execute a micro level sorting. CC even agree to provide their

sorted CDW for free as *waste transportation cost is high* (12PP). This strategy is validated by National Solid Waste Policy (PNRS), provided for the Federal Law 12.305/2010 (cf. Brasil 2010), that affirms that CC are required to form partnerships with WPC.

To implement this new future practice to work, *waste pickers cooperative(s) need more government supervision and business structure* (3FP). Interviewee 3P reported that: "*Cooperatives need management, because today they do what they want, when they want, in a very disorganized way. They need regulation and enforcement*." From the CC perspective, interviewee 2GP comments that: "*Companies do not know how to deal with recyclers' cooperatives. We don't have that contact. Then what happens, delays the work, there is that material at the front, we have to get that material out of the front (…) the presence of residue hinders our work (…) so you can't stay waiting*." *Similar* issues have been mentioned in previous Brazilian studies [62, 63]. Furthermore, *waste pickers cooperative require government subsidy* (4FP). This a practice already happens today, as interviewee 2P reported that: "*the city government and the federal government, through the ministries of cities, have huge administrative expenses with recycling cooperatives. The federal government is responsible for the construction of large separation centres, and the municipality helps with the costs of operating the sorting system.*" But it was classified as a future practice as several stakeholders stated that they need much more funding.

The need for environmental education

An interesting suggestion is that *CC should have environmental and/or social awareness* (2FP). Interviewed specialists reported that local culture is a major issue with CDW recovery because the local population is not concerned with preserving the environment, and that reflects on the CC behavior. Interviewee 1CP stated that: "*it will depend a lot on my client if he becomes aware that the recycled one will be good for him/her.*" The creation of laws per se to promote CDW recovery are insufficient, as concluded by the disproved hypothetical practice *Government effectively uses Government inspection* (5DH). Both interviewees 4GP and 5GP reported that alongside laws a change in the population culture and behavior is needed. This is firmly related to *Government should invest in environmental education* (12FP). CC state that the government is not concerned with reducing landfilled CDW, since the CDW it is responsible for (from small generators), is sent straight to landfill by public transportation companies. Furthermore, the public administration does not apply any kind of environmental education policy for reducing CDW from small generators. [63] proffers that environmental education is especially important because waste generators must learn how to properly sort out recyclables.

Promoting a local CDW RSC

Clearly *Government should use PPP to promote local CDW recovery industry* (5FP) because it was stated that *if there is a local CDW RSC, CC should be legally required to recover CDW* (13FP). CC believe that the government should establish long term relationships with CC and other CDW recovery businesses to be able to apply CDW recovery laws. Therefore, the government must first enlarge the number of local CDW recovery companies, to develop a local CDW RSC, and then after that require any kind of CDW recovery from CC.

Regarding the use of PPP to promote local CDW recovery industry, interviewee 1SC reported that in past times this suggestion was delivered to government. The Construction Industry Union of the State of Pará (SINDUSCOM) and the Association of Directors of Companies in the Real Estate Market (ADEMI) came together to offer a PPP to install a rubble recycling factory inside the city's landfill. However, the proposal received little interest from the city's hall. Interviewee 3P also reported a similar situation where the city's hall received an offer of federal funding to operate a local recycling centre and refused to take on the responsibility. These reported situations also contribute for the present practice viz: *the city government is not interested in the CDW recovery* (8PP).

Utilizing PPP for developing RSC is a ubiquitous recommendation in the waste literature [64–66]. The use of solid partnerships with the government for establishing a RSC is a basic requisite as private CDW related organizations need regulatory and financial support to operate efficiently [1]. Moreover, *CDW recovery needs to be more profitable* (6FP) to encourage waste commerce and new routes to wealth generation for the local populous. This is partially explained by interviewee 2P, who declared that: "*the residues are not profitable, so the profile of the* (WPC) *workers is of low income and low education (…) there is no revenue to maintain a strong cooperative structure, it is only to pay for the staff to maintain themselves.*" Such as strategy should be augmented by practices that support *CC would like to have recovery options available* (2PP), *CC do not sort most of their generated CDW, because of a lack of alternative revenue-generating destinations* (14PP) and *landfilling is cheaper than recovering CDW* (19PH).

Another suggested future practice is *the government should install a CDW landfill* (8FP), because of the disproved hypothetical practice landfill's operators are properly disposing CDW (10DH). Moreover, *the government should control the landfill tax to promote CDW recovery* (FP7) because *the landfill tax does not cover the landfill*

operational costs (15PP). *A CDW RSC needs to be promoted and regulated by the Government* (9FP). This would address recurrent complain from CC that the federal government is starting to require CDW recovery, but the local market does not have necessary infrastructure to receive the biggest parcel of CDW (i.e., rubble). All CC affirm that the RSC for CDW must be promoted and regulated by the government, as the main interested key actor in reducing landfilled CDW. Reportedly the government only promotes infrastructure for one of the four types of CDW, according to the classification from the Brazilian Association of Technical Standards (ABNT) [3]. At present there is only a local market for type B recyclable waste for other destinations (such as plastics, paper, cardboard, metals, glass, wood, empty packaging of real estate paints and plaster). There is no market for: types A (reusable or recyclable waste as aggregates); type C (wastes for which technologies have not been developed or economically viable applications that allow recycling or recovery); and/or type D (hazardous waste from the construction process).

Investments in R&D and quality standards for CDW

It is clear that to engender a circular economy approach to managing CDW, *Government should invest in R&D for CDW recovery* (10FP). Different areas of R&D were suggested, for example, interviewees 1CP, 2SC and 4GP suggests the development of new CDW recovered products in partnerships with public funded universities. Interviewee 2GP and 3GP refers to the development of cheaper rubble recovery machinery to be used within the construction sites. Interviewees 2GP, 5GP and 3SC proposed that the government should explore new CDW recovery industries that could be installed in the local market.

Quality standards for recovered CDW are a major issue in for CC (17PH) is the main reason for future practice i.e., *the government needs to set quality standards for recovered CDW* (11FP). This future practice (11FP) was the only unanimity among all CC and SC interviewees. Quality standards for recovered CDW stand as another basic requisite for a CDW RSC, as recovered CDW is perceived as of lower quality in comparison to raw materials (as reported by interviewees 1CP and 2SC). This problem was reported previously [20, 67–69]

Discussion

Study contribution

It was found that 20 of the 36 (equivalent to 55.55%) suggested best practices (hypothetical practices) by the scientific literature [37] already occur in the Amazonian Construction and demolition waste (CDW) reverse supply chain (RSC). By adding this result to the new found 15 present practices and 13 future practices suggested by the specialists, this study was able to develop a comprehensive plan with strategies and tasks necessary for the implementation of a CDW RSC in the context of the city of Belém of Pará, in the Brazilian Amazon. It solves the current literature's fundamental flaws by encapsulating together all significant important information on nodes, key actors at each node, flow channels between nodes, and necessary government initiatives at each node of the Amazonian CDW RSC. Other features that emerge include: how each node provides value to the material flow; the parties in charge of managing each node's operations; the various roles and objectives that each key actor has at each node; and government plans for supporting reverse logistics (RL) practices in the Amazonian CDW RSC. And finally, as it demonstrates the limitations of the existing legal framework in Brazil, the results could work to act as a catalyst to engender positive change.

An interesting finding is that the professionals empirically theorize that the CDW from small generators is individually low in volume. To reduce costs, they hire individuals who transport (as so called 'carriers') CDW in small volumes informally often in a wooden pushcart. These carriers (due to the informal and unlicensed nature of their profession), probably lack a well-articulated parallel market, so they do not resell the waste. Furthermore, because landfill site is located on the outskirts of the city, carriers are inclined to illegally dump their collected waste in peripheral regions of the city. This then creates 'true waste' (defined as that which is not recycled or reused) thus consuming new resources needlessly and simultaneously damaging the precious (and now increasingly fragile) Amazonian rainforest.

Because all practices presented in this study were analyzed and discussed by professionals who have practical experience in any node of the CDW RSC and in the context of the Brazilian amazon city of Belém-PA, the study's results have major practical contributions. Professionals could use these results to implement RL practices within their nodes and Government could use such as a roadmap to implement a CDW RSC in the Amazonian context.

Limitations

Five present practices do not have a clear explanation as to why they occur, so future research could focus on investigating the causes for such scenario to resolve future problems with implementing a CDW RSC. Namely, *CC outsource the development and execution of their CDW Management Plans* (1PP), *CC would like to have recovery options available* (2PP), *waste pickers receive more training than CC workers* (13PP), *there is no local companies to recover most types of CDW* (14PP) and *the landfill tax does not cover the*

landfill operational costs (15PP). Another limitation refers to the sample of interviewed experts. Unfortunately, it was not possible to interview specialists from the waste transport companies and from the recycling and/or remanufacturing centres, due to lack of access to these companies. The number of specialists, their positions and their geographic coverage limited the representativeness of this study. Despite such restrictions, given scant published empirical investigations on RL in the construction industry, this study provides a basis for further investigation of this important area of research [29].

Further research recommendations

Interviews conducted embraced specialist professionals sourced from both of strategic and tactical areas associated with CDW. Therefore, perspectives were taken far from the operational point of view hence, future research could focus on the operational scientific lens (i.e., waste pickers or clients). Also, future studies could also interview State and Federal executive governments, as well as legislators to see what additional measures could be taken to minimize CDW and/or generate new sources of income from such. The latter would create new business by giving waste a commercial value. Future research studies to analyze the reasons behind each proved, disproved and new present practices for the Amazonian CDW RSC can extend the findings of the present study. Moreover, future studies can investigate the different impacts of the practices for each different stakeholder, as well as for the different conflicting objectives that occur between stakeholder. Furthermore, by using other theoretical frameworks such as "circular economy," "waste management hierarchy model," and "construction waste management" researchers can gain a more comprehensive and nuanced understanding of the data being analyzed, as well as improve generalizability and reliability.

Conclusions

While a few studies consider different stakeholder views for the reverse logistics (RL) practices toward implementation of Construction and demolition waste (CDW) reverse supply chain (RSC), the study presented here is the first systematic effort in identifying the RL present and future practices executed by five different stakeholders of a CDW RSC, based on empirical data. Innovative views, fresh insights and trends as the outcome of this study, encapsulated in the form of a model of future practices for the Amazonian CDW RSC, as the first empirically validated model of its kind. Examination of the model reveals that while all future practices are important toward implementation of an Amazonian CDW RSC, some are considered fundamental. The sorting process of CDW should occur on a macro level on-site sorting and micro level off-site sorting. For that to occur effectively, another important future practice should be prioritized, as Waste Pickers Cooperatives need more government subsidy, supervision and business structure. The professionals all agree that the government is the main stakeholder of the Amazonian CDW RSC. All interviewees agree that it is primary that the Government needs to promote and regulated a CDW RSC and it needs to set quality standards for recovered CDW.

Perhaps to enact environmental changes urgently needed to protect the Amazon rainforest (and other pristine habitats internationally), the concept of 'waste' should be changed to augment society's growing environmental perceptions and awareness anthropogenic climate change. Waste implies 'no inherent value' when in fact the converse is true – construction materials and products have an afterlife following their intended use and in this respect 'construction demolition resource' (CDR) is a far more apt terminology of the twenty-first century and the challenges collectively faced by humanity. This new terminology identifies the economic value of CDR materials and so acts to open new markets for business trading and at a more affordable cost for society. If a value is placed on CDR, then the propensity to throw 'money' away is largely removed and the environmental impact of construction activities is reduced to a more sustainable level.

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Declarations

Conflicts of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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