Closing the loop with construction and demolition waste. Approaching the circular economy

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ABSTRACT

Colombia currently recycling 22.5% of construction and demolition waste -CDW in contrast to the recycling rate of 70% on average in Europe and 89% if material for filling is considered. It is expected that the national integral public policy will allow an increase in the materials treated and used to be reincorporated again into the construction life cycle and thus guarantee an approach to the circular economy. The model considers the relationship between the growth of construction and the growing demand for materials, which in the end-of-life stage can be treated and reincorporated as a substitute material for raw materials, thus generating economic and environmental advantages. By introducing the policy of greater capacity in the recyclers, it is possible to increase the recycling material by 230%, reduce the CO2 equivalent by 196% and economic benefits of 20% for the constructors over a 35-year horizon. But it is not possible to achieve the goals stipulated in resolution 1257 of 2021, advocating for more initiatives.

KEY WORDS

Construction and demolition waste, circular economy, system dynamics, closing cycles

1 INTRODUCTION

The path from a linear economy to a circular economy - CE in Colombia begins to take the first steps. In Bogotá, the capital, CDW is generated through two streams, the public sector and the building sector. Between 1998 and 2007, according to available data, 22,155,144 million tons were generated from the public construction sector and 60,181,959 million tons from the private construction sector (UAESP, 2009), which implies an annual production of 8,233,710 million tons of CDW, where 73% comes from the construction of buildings. For the period from July 2012 to December 2015, 29,113,532 tons were reported, which means that 8,318,152 tons/year of CDW were generated and in the same period 4,647,573 million tons were recovered, which constitutes 1,327,878 tons/year, which represent 16% of what is generated. (SDA, 2016), (Cerchiaro, 2018). The amount of CDW generated has increased by 26%, given that in 2017 11,375,079 tons/year were generated (SDA, 2018). On average from 2017 to 2019, 11,667,183 tons/year were generated (or controlled between those treated and disposed of), and these figures dropped to 6,736,100 in 2020 (SDA, 2021).

Until 2011, the policy focused on the disposal of debris, as the CDW were called at that time, and the lack of adequate sites and the insufficiency of measures to achieve its recycling became evident. This allowed for a shift towards the zero debris policy and reverse logistics to reach a focus on the recovery and recycling of CDW, where the implementation of CDW management plans on site and the design of an integral public policy were promoted. The latter is in process, since the result of utilization is still low and is far from the recovery rate of 70% on European average and 89% if material for filling is considered (Eionet, 2020).

Therefore, the objective is to determine how to increase the recovery and incorporation of CDW to close the cycle through the inclusion of policy instruments in a system dynamics model that represents the stages of the construction life cycle and thus the construction sector is consolidated as an example of CE.

2 ESTADO DEL ARTE

When the strategies that different countries have developed regarding the CDW associated with the CE are mentioned, the need for actions in the different stages of the construction cycle is reported. In the absence of preventive measures during the early stages of construction, the waste generated increases, its control is difficult, and the cost and time of waste management are affected. (Jin et al., 2018). If it is designed to be deconstructed or disassembled, this leads to less labor time and lower costs in contrast to demolition. Even more so when high landfill or disposal fees are considered, then deconstruction is favored (Chau et al., 2017). Therefore, recycling instead of sending the material to a landfill becomes very important, since it reduces costs by mitigating environmental damage, damage to human health, and avoids the cost of building new landfills (Marzouk and Azab, 2014). However, the essential purpose is to reincorporate recycled material back into the production chain, but this is mainly influenced by the cost of the material. Therefore, when seeking to reduce end-of-life costs, reduction, reuse and recycling practices are prioritized (Wang et al., 2018). In contrast, it is known that reuse and recycling activities generate additional costs associated with storage and transportation, respectively (Zhang et al., 2019). Specifically, from an economic perspective, the production costs of recycled aggregates could be higher than natural aggregates, due to the additional processing methods required, which represent around 64% of the production costs. However, this condition varies according to the scale of the industry and can result in lower costs for recycled products (Wijayasundara et al., 2016). On the other hand, raw materials are taxed, which allows to stimulate the demand for secondary construction materials (Ghisellini et al., 2018). Therefore, cost is a determining variable in the CE of the construction cycle (López et al., 2019). From the above it is determined that the economic and environmental benefits depend on each context and even more so on the materials being considered.

The amount of CDW that is generated varies according to the construction activity that is carried out, for example, in the USA, demolition generates 48%, being the one that generates the most waste, followed by remodeling with 44% and construction barely contributes a 8% (EPA, 2006). In European Union -EU CDW arise from demolition (27%), renovation (57%) and new construction (16%), (EC, 2011). Which allows less than remodeling and demolition are the currents that generate the greatest amount of CDW.

The EU, motivated to achieve a 70% recovery by 2020, recognizes that the results achieved were driven by the Waste Framework Directive of 2008. While in Colombia, legislation has been established at the national level given by the Environment and Sustainable Development - MADS and district given by the District Secretary of Environment-SDA, the latter being the pioneer of said process at the country level, as shown in Table 1. This also with the support of other entities such as the District Secretary of Habitat, the Mayor's Office and the Special Administrative Unit for Public Services - UAESP.

Table 1. CDW legislation in Colombia

Model	Law	Entity
Management, transport and final disposal of debris	Res. 541 1994	MADS
	Res. 357 1997	SDH
Utilization and treatment of CDW	Res. 2397 2011	SDA
	Res. 1115 2012	SDA
	Res. 715 2013	SDA
	Dec. 586 2015	Alcaldía
Integral CDW Management	Res. 932 2015	SDA
	Res. 472 2017	MADS
	Res.013 2018	UAESP
	Res 1257 2021	MADS

Source: (MADS, 2021) (SDAa, 2021)

Resolution 1257 of 2021 established for Bogotá and main cities a recovery goal of 25% by January 2023, 50% by 2026 and 75% by 2030. Showing a greater demand, with respect to resolution 472 of 2017 that established to achieve 30% to 2032, since it expected annual increases of 2% from 2018, (MADS, 2021). Demands that will be increasingly greater given the interest in implementing the CE strategy, (Government of the Republic of Colombia, 2019) and the need to apply other informational and economic instruments and not only legislative ones, (Rodríguez-Bello et al, 2019).

3 STAGES OF THE CONSTRUCTION CYCLE

The model is a representation of the construction life cycle, which includes 5 stages: 1. Materials stage, 2. Design stage, 3. Construction stage, 4. Use and repair stage, 5. End of life stage CDW. The purpose is not only to simulate the flow of the material, but also to determine the policies that would guarantee the use and reincorporation of the CDW again within the cycle, as raw materials. Although stripping material and excavations are generated in the construction stages, the document focuses on stone materials.

Materials stage. In Colombia, between 2014 and 2017, 176.9 million tons of crushed aggregates, river sand, gray cement, dead rock, and fired ceramics were required in the construction industry (ANDI, 2018). This allows us to conclude that most of the construction materials are of stone origin, which are obtained from quarries and supply both large and small constructions. This, recognizing that a large construction is those larger than 2000 m2, which receive the materials directly from the suppliers of the material, while small construction do so through marketers. The amount of stone materials consumed per m2 of construction is 2 m3/m2, with an average density of 1.4 tons/m3. Source (UPME &UIS, 2018), (ANDI, 2018). In 2013, the demand for construction materials considering the main cities was more than 13 million tons, which represents a per capita consumption of 1.95 tons/year and by 2023 it is expected that said demand will rise to 46 million tons, that is, 2.56 ton/years per capita, representing an increase of 31% per capita and 353% total, (UPME, 2014).

Design stage. At the design stage, there are national and international standards for sustainable construction. At the national level, various standards such as EDGE and CASA are distinguished. Internationally, the most popular are LEED and BREEAM, followed by VERDE and DGNB. However, none of these is oriented to the realization of constructions to disassemble, although it is aimed at efficient use and operation. The demand for materials for a construction varies depending on the construction system, thus the industrialized system demands 1269 kg/m2, the structural masonry 1412 Kg/m2 and the confined masonry 2407 Kg/m2. (UPME, et al., 2012). Where each system has a share of 19%, 15% and 62% respectively in 2012 and these shares change in 2017, being 31%, 6% and 60% respectively (DANE, 2017), thus showing the growth of the structural system.

Construction stage. In the construction stage, CDW can be generated by demolishing existing construction or by generating it during construction process. Resolution 0472 of 2017 obliges the generator, the transporter, as well as the treatment and disposal companies to report the amount of CDW generators, transported or treated or disposed of, (SDA, 2021). Which has made it possible to determine that 1.42m3/m2 are generated, (UAESP, 2009), (Cerchiaro, 2018), (Marin, 2019). Since 2015, the works have had an administrative instrument or booklet called the Guide for the preparation of the CDW management plan at the work, which aims to adopt strategies to minimize the final disposal and maximize the use of CDW. The classification of CDW requires space and management for subsequent reuse on site, so many times they are disposed of before being reused on site. The amount of CDW generated by a new construction is 120 kg/m2 (SDA. 2012). According to DANE for 2018, the built area in Bogotá was 6,774,873 m2, of which the new area was 3,689,108 m2 (54%) and the existing area 3,085,765 m2 (46%), that is, it was prior demolition was necessary, which was 2,690,147m2. (DANE, 2018).

Housing construction cost index – ICCV, historically presents the variations of the costs of materials, machinery and equipment, labor, being the materials the ones that have had the greatest variation and is the item that increases the most, in contrast to the machinery and equipment and labor that fluctuate in close values and finally fall in that period of those 7 years, as can be seen in Table 2.

Table 2. Behavior of Housing construction cost index

Ítem	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Materials	1	5.97	2.73	4.38	3.58	3.71	5.09
Machinery and equipment	3.62	4.24	4.28	5.94	2.04	2.52	3.43
Labor	1.26	2.17	1.91	2.6	1.47	1.43	1.05
ICCV anual variation	1.81	5.25	3.16	4.77	2.49	2.84	4.38

Source: DANE, 2021

Stage of use and repair. The useful life of a construction is very long, it can take up to 20 years, before the first remodeling or interventions for its conservation are carried out. Only when they are structural remodeling, such as the construction of new flats or rooms, changes to the façade, is the owner forced to report the work to the urban curator. But remodeling associated with replacing windows and internal doors, changing the tile, ceiling or veneers, improving or expanding public service networks, do not require permits. According to the Planning Secretariat, for the period of 2017 and mid-2018, of 973 construction licenses in the modification modality destined for different uses, 578 correspond to residential uses (housing), which corresponds to 59%. Therefore, most renovations are not required to be reported. It is considered that a remodeling generates 338.7 kg/m2 of CDW, (SDA. 2012), which is 2.8 more than what is produced in a new construction.

End of life stage. The ideal is to guarantee that the material continues within the construction cycle, so it should become raw material again and thus avoid its disposal in dumps. In Colombia, they have sought to characterize the potential of CDW, which depend on the type of construction, the materials used, the construction habits, being also influenced by the climate and socioeconomic conditions. These are classified into usable and non-usable waste. The usable ones are subdivided into organic, common inert, common non-inert and metallic, as shown in Table 3. The non-usable ones are hazardous waste. This classification is aligned with the directory of final disposal sites, although they should be called end-of-life, since it includes the treatment of CDW. The disposal sites are approved by the MADS, the CAR, ANLA, Municipal government, and the SDA. In Table 3, appears a comparison of various sources of the composition of the CDW. Which show many differences, Chaves et al, 2019 characterizes and quantifies the CDW that arrives at a processing center. Guzmán, 2019 relates a study of SDA where excavation or organic material is not related, so inert common waste is the highest proportion. According to SDA, 2014 excavation material is the most significant, as in the case study of Marín, 2019, where 3,331 m2 are built, the amount of CDW generated is quantified and excavation material again has the highest proportion.

Table 3. Characterization of the CDW in percentage

Material	Chaves et al., 2014	SDA, 2014	Guzmán, 2019	Marín, 2019
Orgánic Material	18.86	78.8	0	89
Common Inert Waste (stone)	64.77	20.0	75	8
Non-inert Common Waste (plastic, Wood, Glass)	7.66	0.12	6.5	3
Metallic	0.26	1	2.5	0
Dangerous	4.18	0.1	0	0
Others	2.17	0	11	0

Source: Chaves et al., 2014, SDA, 2014, Guzmán, 2019, Marín 2019

Demolition, as part of the end of life of a building, is the source that generates the largest amount of CDW, 1129 Kg/m2, that is, 9.4 times more than the construction of a new home. If this is done selectively, windows, doors or materials such as wood, plastics, paper and cardboard, plasterboard and even aggregates, ceramics, concrete, bricks can be recovered. The recovery companies are in charge of processing the material and guaranteeing that they meet the specifications, to be incorporated again as materials and thus be able to replace the raw materials and this allows closing the cycle and guaranteeing CE.

CDW from demolition, remodeling and construction should be recycling and reincorporated. In Colombia, the percentage of CDW used from 2012 to 2020 is 17.5% on average, with 22.5% being the highest percentage reached in 2019 and the average of the last four years close to 20%, except for the last year that is atypical due to the Covid-19 pandemic, as shown in Table 4. On the other hand, information on reincorporated material has not yet been reported, but it is used to produce recycled granular bases type A, B and C, Sub granular bases A, B and C with or without plasticity, concrete sand, rubble sand, gravel from ¾" to 3" in diameter. In addition, prefabricated concrete elements such as kerb stone and curbs are produced with flexural strength of 4.0 MPa

A phenomenon that occurs is the inadequate disposal of solid waste in different parts of the city, which generate health damage and deterioration. These have been censused since 2016 and on average there are 700 points per year, as shown in Table 4. The mixed waste of the critical points from 2018 to date totals about 900 tons and since 2020 a clean point was established by the Special Administrative Unit for Public Services (UAESP) in the "Buenos Aires" property, which is part of the Doña Juana landfill and mixed waste is discharged there. Being the CDW, the waste with the highest percentage is found in the critical points with 66.9% in 2020 and 86.7% in 2021, see Table 4.

Table 4. End of life of CDW

Year	% CDW Recycled	Critical points	Mixed waste at critical points (ton/year)	CDW at Clean Point (ton/year)
2012	12,9	-	-	-
2013	14,7	-	-	-
2014	15,4	-	-	-
2015	17,9	-	-	-
2016	18	576	-	-
2017	20,6	827	-	-
2018	15,8	634	201.113	-
2019	22,5	738	299.450	-
2020	20,03	739	244.229	30.528
2021	10	749	150.350	25.058

Source: (UPME, 2018), (SDA,2021)

The practice of final disposal in landfills is the most common today. The information on the capacity of the disposal sites is partially available, San Antonio-Rex Engineering had a capacity of 1,905,399 m3 as of February 2018, which implies a useful life until July 2026, and Las Manas- Maquinas Amarillas useful life until 2024, (Agudelo, 2018). Based on this information, a capacity of 240,000 m3/year is assumed in each of the 6 approved final disposal sites in Bogotá. For treatment centers, the installed capacity depends on the available machinery, since this can vary from 20 ton/hour to 100 ton/hour (ANDI, 2018). In total, there are 7 disposal sites in Bogotá and 31 in neighboring municipalities, although they have always been considered insufficient and excessively distant, given that most are south of the city.

3.1 SOCIO-ECONOMIC CONDITIONS

The demand for materials is directly associated with the demand for housing, according to the growth in the number of households. For 2018, the existence of 2,564,897 households was determined and according to DANE's projection to 2050 there will be 4,671,970 households, that is, a growth of 82%, which represents 65,803 new households each year (DANEa, 2018). Likewise, the houses can be grouped by ranges according to their cost in: social interest housing - SIH, which must be less than 155 CLMMW (current legal monthly minimum wages); dwellings between 155 – 355 CLMMW and dwellings greater than 355 CLMMW, the latter two being Non-VIS dwellings. The intention to purchase a new home is influenced by the cost of the property and family income, as shown in Table 5.

Table 5. Intention to Buy a New Home according to Family Income in percentage

Home Value vs. Income (Millions $)	**Less than 4** CLMMW	**4-6** CLMMW	**More of 6** CLMMW
Less than 135	73	13	14
135 - 355	42	41	17
More of 355	36	32	32
Total	151	86	63

Source: Adapted from Camacol, 2018. Note: CLMMW 2021 is equivalent to US$236

The projected housing demand will increase, given the growth of households, for 2018 22,655 SIH units were demanded, with a historical annual increase of 287 units/year and 13,863 non-SIH units, with a historical annual increase of 710 units/year. In addition, the housing deficit in Bogotá is 4.9 and for the surrounding municipalities 9.1. (Camacol, 2018).

4 METHODOLOGY

The data to feed the model was obtained from secondary sources of the government authorities in charge of CDW management, such as the SDA and the Special Administrative Unit for Public Services - UAESP. And these were complemented with other data from different studies on the subject. Since they are not consolidated or published by a single entity. On the other hand, the model presents a series of considerations to fill in the missing data. The socioeconomic data are taken from statistics and projections of the National Administrative Department of Statistics - DANE.

The modeling is done using system dynamics, which is a methodology for modeling and analyzing complex systems. The model is made up of the interrelation of the actors involved and activities, whose interaction creates additional information that is not visible to the naked eye. It is used as Vensim modeling software. Through a causal diagram, the interrelationships of the variables of the construction life cycle are visualized, identifying the feedback loops. Where the flows and the deposits or tanks are identified, being the flows, the input and output variables of the deposits and the latter represent the result variables. A base model was established for the year 2015, to which policies are introduced, to know the impact of these in a period of 35 years and thus determine the necessary actions to be carried out to obtain the desired results in the system.

5 MODEL DESCRIPTION

The model is designed with the objective of contemplating both the physical flow of materials, as well as the socioeconomic conditions that surround them. The demand for housing is associated with the need for raw materials or recovered CDW material for the construction projects. This housing demand depends on population growth and the characterization of households. These constructions are carried out on empty or demolished spaces and their construction gives rise to an increase in the flow of CDW, which must be temporarily stored on site, in clean points, it can be taken to treatment points (recyclers) or disposed of in dumps.

This implies the intervention of other actors in the chain, such as environmental authorities, municipalities, transport, storage, treatment and disposal managers. This with the purpose of closing the cycle through the incorporation of recovered CDW as cycle materials. The model presents two cycles of reinforcement, and two of balance. Reinforcement cycles occur when larger amounts of recovered materials are reincorporated into construction sites, which in turn generate more CDW and can increase the amounts of material that can be collected and thus recovered. Balance cycles are observed when more quantities of materials are reincorporated, since the quantities of raw materials used in construction projects are reduced, which causes less CDW to be generated and ultimately less quantities of material to be recovered.

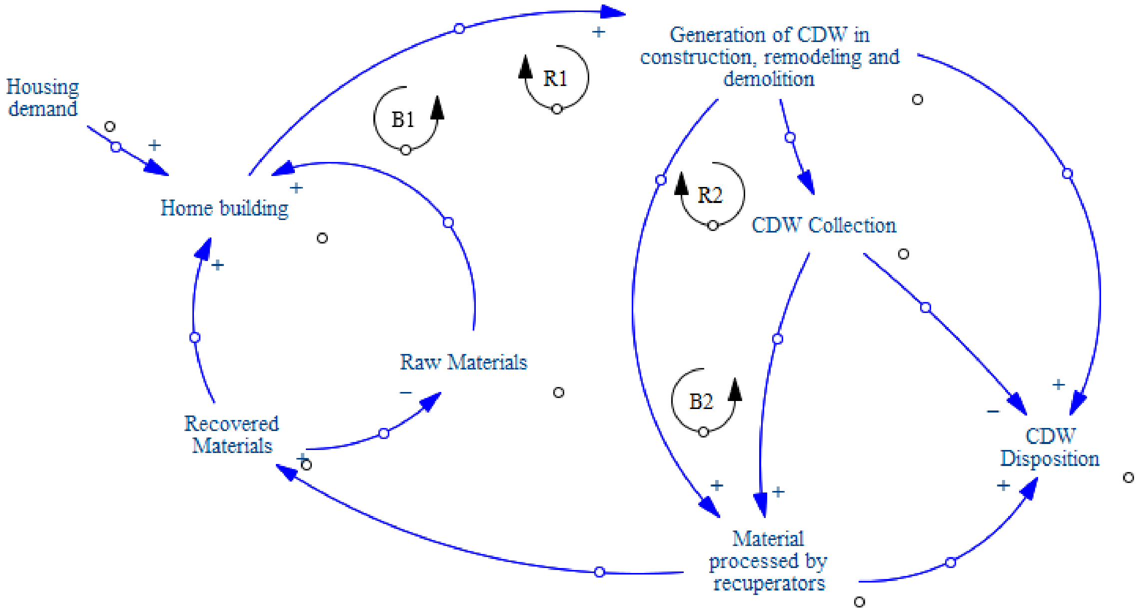

Figure 1. Causal model of the life cycle of CDW.

5.1 VALIDATION

To carry out the validation of the model, the behavior of physical variables was evaluated, such as the amounts of recovered CDW, the amount of CDW taken directly to the recoverers and the amount of CO2 that is reduced by taking CDW to the recoverers. By making changes to the growth rate of new area construction. The considerations taken into account are listed below:

- It is expected that in the year 2050 the city of Bogotá and its surroundings will go from 30% recycling of CDW to 70%, increasing the proportions of participation of both clean points and treatment centers.
- 99% of the installed capacity of the CDW recovery centers is used, that is, 29.7% of the CDW generated annually is processed.
- Construction demands 70% of recovered CDW, considering an increase in the amounts generated, since the number of homes built is expected to increase by 90% by 2050.

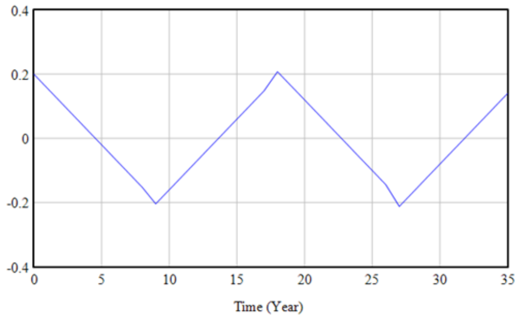

Figure 2. Construct growth rate.

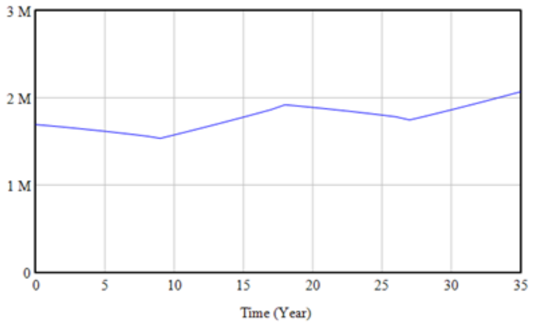

Figure 3. CDW generated under construction.

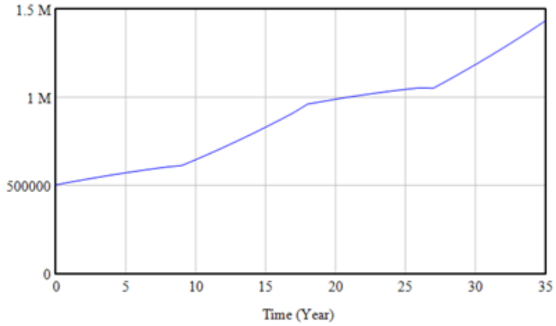

Figure 4. Material taken directly to recoverers.

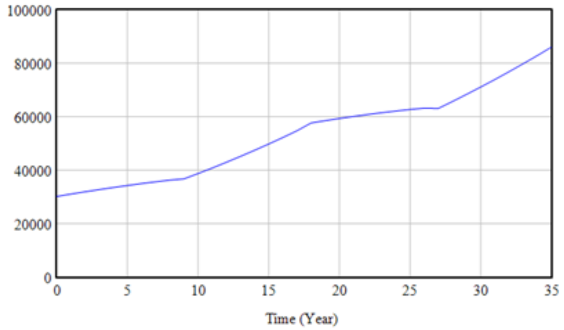

Figure 5. Reduction of CO2 emissions

A variation in the growth rate of constructions is presented in an interval between –0.2 and 0.2, as evidenced in Figure 2. In addition, a logical behavior was observed in all the variables. In Figure 3, a reduction or an increase in the growth rate of constructions generates reductions or increases in the amounts of CDW generated, as well as in the growth slopes of the CDW taken to recyclers and the reduction of CO2, which is seen in Figure 4 and 5 respectively. This allows ratifying the validation of the model.

5.2 SCENARIO WITH THE POLICY IMPLEMENTED

The evaluated policy is the increase in the capacity of recovery companies, the capacity of clean points and other variables that are listed in Table 6. These affect variables of interest such as: Economic benefit for builders, CO2 reduction by CDW taken to recyclers, Total costs for new built area, CDW taken directly to dumps, Amount of CO2 generated by dumps, generated CDW, CDW in reclyclers, potential CDW or that could be used.

Table 6. Altered variables in the model to simulate scenario

Affected variables	Changes
Recyclers capabilities	Double capacity increase
Clean point capacity	4500 m3/annual, increased to 7500 m3/annual
Clean point rate	Linear increase from 0.003 to 0.007 in 35 years
Recycling rate from clean points	0.9
Recycling rate	Lineal Increase lineal from 0.297 to 0.693 in 35 years
Dump rate	Lineal decrease from 0.7 to 0.3 in 35 years
% saving to builders for reincorporating CDW	5% increase every year
ICCV	Increase according to DANE data, 2021

6 RESULTS

The results obtained are shown at the level of physical, economic and environmental flow, the latter associated with the recovered materials and the impact generated by the CDW that goes to dumps. Changes in the physical flow are identified when implementing the policy of increasing treatment sites and results are noted in the different stages of the CDW life cycle, from the generation of CDW, the amounts of CDW that reaches the treatment sites recovery, the amount of CDW that reaches dumps and the potential CDW or that could be recycled. The results obtained are found in Table 7.

Table 7. Results of the physical flow

Variables	**Scenarios**	**CDW Quantity (m3) 2015**	**CDW Quantity (m3) 2030**	**CDW Quantity (m3) 2050**	**% Annual average change**	**Total Increase**
Generated CDW	Base	1,571,510	1,755,500	1,994,540	1%	27%
	Politics	1,571,510	1,755,500	1,994,540	1%	26.92%
CDW to dumps	Base	1,100,050	1,228,850	1,396,180	1%	27%
	Politics	1,100,000	928,132	598,960	-2.00%	-46%
CDW recycled	Base	456,782	521,500	594,269	1%	30%
	Politics	456,797	886,178	1,508,360	3.40%	230%
CDW potencial	Base	1,115,800	1,234,000	1,400,270	1%	25%
	Politics	1,115,780	869,321	486,183	-2%	-56.43%

The scenario with policy allows us to see changes in the increase in the capacities of the recoveree's, thus obtaining a positive perspective in the behavior of CDW in Bogotá, since the model showed a reduction of -46% of CDW that is taken directly to dumps, a 230% increase in the amounts of recovered CDW and a 56% reduction in potential or unrecycled CDW, over a 35-year period.

Economic benefit for builders. The increase in the amounts of CDW that reach the recovery plants will generate increases in the supply of this material, which causes a reduction in the sale price and thus the material becomes a substitute for natural raw materials, for which the recycled material is more attractive to builders. This behavior in the medium and long term is reflected in the increase in profits for builders who reincorporate CDW in their works. As a result, economic increases for builders are achieved by 2050 in a phased manner until reaching 20%.

Total costs for new built area. Based on the behavior data of the ICCV obtained from Table 2, the behavior of the total costs for the built area was modeled, where the rate of new area for construction is considered. Figure 6 shows the annual percentage increase over a period of 35 years. Generating an average growth of 2% per year, which is caused by the constant increase in raw materials, machinery and equipment.

CO2 generated by dumps. Negative environmental impacts are generated in the final disposal of CDW, which must be mitigated. This problem encompasses two main variables. The first, CO2 generated by dumps, understood as the equivalent amount of CO2 that is not reduced, associated with no recycled CDW. For the base scenario, increases in the reduction of CO2 were obtained by 27% in the equivalent amount over a period of 35 years, with an average annual increase of 1%. For the scenario with the implemented policy, the amount of CO2 generated by dumps is reduced by -47%, see Figure 7. The second variable focuses on the reduction of CO2 emissions, for the base model a decrease in the reduction of CO2 is contemplated. 27% in a period of 35 years, for the scenario with the implemented policy the changes were 196%, with an average annual increase of 3%, as shown in Figure 8.

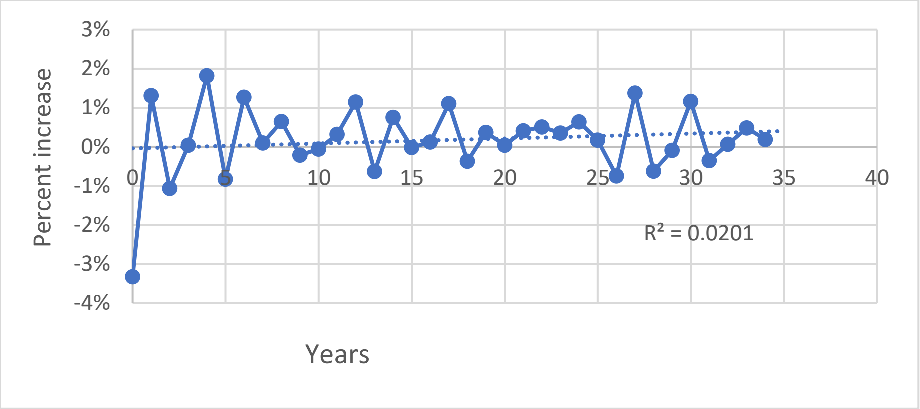

Figure 6. Annual Percentage Increase in Costs per New Construction Area

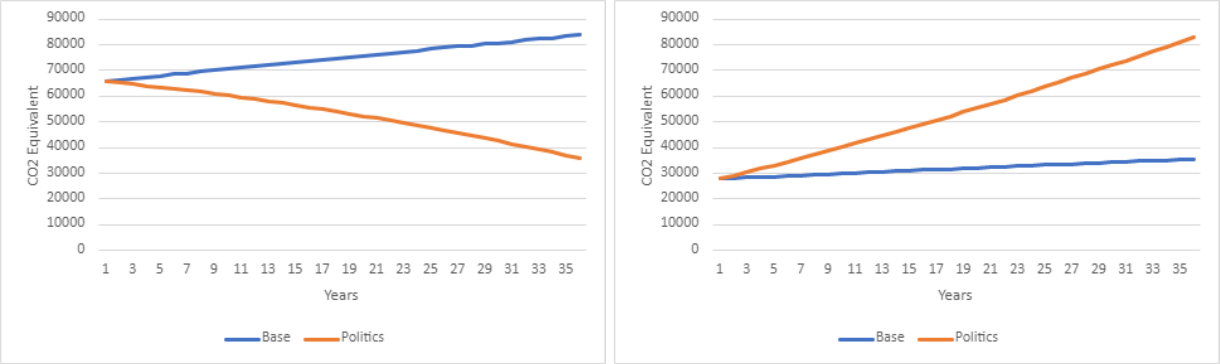

Figure 7. CO2 generated by CDW in Dumps

Figure 8. Reduction of CO2 emissions

7 CONCLUSIONS

The increase in the construction of new homes and renovations that meet the housing demand associated with population growth, causes an increase in the volumes of CDW generated for the next 35 years. And if the current trend of 20% recycled of this waste is followed, it implies that 1,202,065 m3 will not be recycled, which will be a problem, due to the insufficient capacity of the final disposal points and the continuous expansion of the city. Therefore, the need to recycled material is ratified. By increasing the capacity of the recoveree's, a greater amount of recovered CDW is guaranteed, which causes an increase in their supply. This allows an initial increase in benefits for builders, who reincorporate recovered CDW, since they are cheaper than raw materials, which promotes their substitution.

Although the amount of recovered CDW increases by 230% in 35 years, this value would allow meeting the goals of resolution 472 of 2017, but it is not enough to meet the goals stipulated in resolution 1257 of 2021, since the goal must be reached the 75% recovery by 2030, which would imply quadrupling the capacity in the recovery plants and obtaining annual increases of more than 5% to increase the recovery percentage and at the same time treat the growing amount of CDW that is generated year after year. On the other hand, there is an opportunity associated with the deficit of the clean points, since the current ones will not be able to meet the annual growth of the amounts of CDW. These should become temporary staging sites for CDWs, especially those coming from remodeling which are the ones generating 700 hotspots annually. And thus, avoid all the negative impacts that these generate.

The transition of CDW final disposal sites, from dumps to a treatment and recycled center, should be contemplated in the medium term, which generates greater environmental, social and economic benefits. At an environmental level, the reduction of CO2 associated with the material used is close to 200%, since the recovered material replaces natural sources and avoids the emissions of the material, when it goes to landfill. Given that the amount of CDW generated is more for demolition and remodeling, prioritized actions should be carried out towards these activities. Although, to achieve an adequate demolition, actions must be carried out in the initial stages of the construction life cycle, such as the design and materials to achieve deconstruction. In remodeling, the current requirements imposed on large projects should be extended to all construction projects and thus guarantee greater control and use of CDW.

The demand for recovered CDW ensures that the cycle is dynamic and growing, so regulations are required to know how to reincorporate them and guarantee a favorable cost compared to materials from natural resources. Aspects that could be contemplated from a more detailed perspective of the implemented policy, which considers all the economic and social aspects that surround the model. These considerations are expected to be incorporated in future works to achieve a more detailed analysis and with a greater number of scenarios associated with future policies to be implemented, seeking a greater rapprochement with the EC and the Blue Economy.

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