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INTEGRATION OF CIRCULARITY STRATEGIES INTO ARCHITECTURAL DESIGN THROUGH BIM

INTEGRACIÓN DE ESTRATEGIAS DE CIRCULARIDAD AL DISEÑO ARQUITECTONICO MEDIANTE BIM

INTEGRAÇÃO DE ESTRATÉGIAS DE CIRCULARIDADE AO PROJETO ARQUITETÔNICO POR MEIO DO BIM

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RESUMEN

La industria de la construcción representa gran parte del consumo de recursos naturales, proyectándose el aumento de residuos de construcción y demolición (RCD) a nivel mundial en un 70% al año 2050 si no se toman medidas urgentes. La aplicación de economía circular en la construcción, requiere selección de productos en base a su potencial circular, en la fase de diseño, para optimizar la reutilización y minimizar residuos. Se propone metodología mixta combinando componentes cualitativos, explorando cómo los actores involucrados en la construcción integran, múltiples factores que influyen en la recuperación del material, asignándoles valores porcentuales que reflejan el potencial circular del producto. Esta información cuantitativa, se visualizará gráficamente en BIM (Building Information Modeling), obteniendo cuantificación sintética en porcentaje de RCD. Se compara la circularidad del modelo de estudio, con uno más favorable, y otro menos favorable. Detectándose diferencias sustanciales en la circularidad, y una determinación en porcentaje de RCD, para formular diseños informados.

Palabras clave
diseño circular, recuperación de materiales, escala transición circular, BIM

ABSTRACT

The construction industry represents a large part of the consumption of natural resources, with construction and demolition waste (CDW) projected to increase worldwide by 70% by 2050 if urgent measures are not taken. Applying circular economy in construction requires product selection in the design phase based on their circular potential, optimizing reuse to minimize waste. A mixed methodology is proposed, combining qualitative components and exploring how the actors involved in construction integrate multiple factors that influence the recovery of the material, assigning them percentage values that reflect the circular potential of the product. This quantitative information will be displayed graphically in BIM (Building Information Modeling), obtaining a synthetic quantification of the percentage of CDW. The circularity of the study model is compared with a more favorable one and a less favorable one, detecting substantial differences in circularity and determining the CDW percentage to formulate informed designs.

Keywords
circular economy, materials recovery, circular transition scale, BIM

RESUMO

O setor de construção é responsável por uma grande parte do consumo de recursos naturais, com a projeção de que os resíduos globais de construção e demolição (CDW) aumentem em 70% até 2050, se não forem tomadas medidas urgentes. A aplicação da economia circular na construção exige a seleção de produtos com base em seu potencial circular, na fase de projeto, para otimizar a reutilização e minimizar o desperdício. Propõe-se uma metodologia mista que combina componentes qualitativos, explorando como os atores envolvidos na construção integram vários fatores que influenciam a recuperação de materiais, atribuindo valores percentuais que refletem o potencial circular do produto. Essas informações quantitativas são visualizadas graficamente no BIM (Building Information Modelling), obtendo-se uma quantificação sintética em porcentagem de RCD. A circularidade do modelo de estudo é comparada com um modelo mais favorável e outro menos favorável. São detectadas diferenças substanciais na circularidade e uma determinação em porcentagem de RCD, para formular projetos informados.

Palavras-chave:
projeto circular, recuperação de materiais, escala de transição circular, BIM

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INTRODUCTION

The construction industry's assembly line production system worldwide has led the planet to unsustainable production models (Lacouture, 2013). This model consumes large volumes of raw materials (Fiel, 2022) and generates significant Construction and Demolition Waste (CDW) (Mora, 2021). This has resulted in a 40% depletion of natural materials, 40% of the world's energy consumption, and the loss of 15% of freshwater resources (Akanbia et al., 2018).

According to Kibert (2008), 50% of the waste generated by the construction industry worldwide is due to demolition (Ghisellini et al., 2018), while its indirect impacts are related to the disposal of construction waste (Ossio, 2021). Therefore, the construction industry is crucial for transitioning to a circular economy (CE) (Prieto-Sandoval et al., 2017).

According to a World Bank report, "If urgent measures are not taken, global waste will increase by 70% by 2050" (Climent Salvador, 2021). The objective is to prevent the overexploitation of raw materials and waste before they are produced and implement sustainability and circularity concepts in the design process (Mora, 2021).

Circular Economy seeks sustainable development through collaborative work and the closure of energy and material flows (Mercader Moyano et al., 2019), designing products to be reused and recycled (Climent, 2021). To achieve this, indicators that promote circularity (Corantioquia, 2022) in the design and use of recyclable materials (Potting et al., 2017) must be considered.

Evaluating materials' resilience, focusing on the perception and experience of construction company representatives, can be an innovative method that supports a holistic framework for defining resources' circular potential (Ulgiati, 2018). However, many companies lack the information (Ca et al., 2013) necessary to select the right tools and techniques for their needs (Enshassi et al., 2014).

Integrating circular strategies in the conceptual design through the BIM (Building Information Modeling) Revit software would facilitate the graphic visualization of material circularity, allowing a better choice through an integrated geometry database with numerical data (Climent, 2021).

This research studies and applies circular strategies (CS) using BIM to measure constructive elements' circular potential (Salehabadi & Ruparathna, 2022). It considers factors that help optimize reuse and recycling to minimize the volume of waste and the complexity of recycling materials (Zhang & Jia, 2021).

That is why a simple methodology is reviewed, integrating a perception survey database applied to construction company representatives. These representatives have a holistic knowledge of local values and projects and can converge multiple factors that influence the recovery of materials into a single indicator (Mesa & Esparragoza, 2018). After this, the resulting quantitative information will be integrated into the BIM environment through a generic application for the graphical visualization of the models and synthetic quantification in the percentage of CDW.

METHODOLOGY

The research will adopt a mixed approach that combines qualitative and quantitative components to understand the feasibility of incorporating (CE) from the BIM conceptual design.

Sustainable designers must measure the circular potential of materials using available methods and tools.

Linder et al. (2017) and Prieto-Sandoval et al. (2017) recommend that a circularity metric focuses on measuring circularity, "the recoverable fraction of a product that comes from used products," as a unique attribute of the quality of each material (Lacouture, 2013).

To measure circularity, a proposal from the Report by Potting et al. (2017), which states "to collect semi-quantitative data and compile them into indicators that provide meaningful information, semi-quantitative indicators can be organized into classes; 'red, yellow, green' (Mora, 2021), will be considered.

Based on this, the measurement of the recoverable fraction of the material will be determined in three attributes (Nieroa & Kalbar, 2019), which will define the circular potential: (a) Almost everything is recoverable (b) Some parts are recoverable (c) Almost nothing is recoverable. Information about the materials' circular potentials is obtained through fieldwork, applying a perception survey to the representatives of the construction companies to gain their holistic knowledge of the multiple factors that affect the recovery capacity of a material.

Table 1. Strategies of circularity. Source: Political report by Potting et al. (2017).

Circular Economy		Circular Strategies	Circular strategies concepts
Increasing circularity	Smarter use and manufacturing of products	R0 Reject	Use the discarded product or its parts in a new product with a different function.
		R1 Rethink Redesign	Make the product use more intensive by sharing products or putting multifunctional products on the market.
		R2 Reduce	Increase efficiency in manufacturing or using products by consuming fewer natural resources and materials.
Rule of thumb: The higher the level of circularity, the fewer natural resources and less environmental pressure	Extend the shelf life of the product and its parts.	R3 Re-Use Recover	Reuse by another consumer of the discarded product that is still in good condition and fulfills its original function.
		R4 Repair	Repair and maintain the defective product to be used for its original function.
		R5 Restore Renew	Restore an old product and update it.
		R6 Remanufactured	Use parts of the discarded product in a new product with the same function.
		R7 Reuse	Using parts of the discarded product or its parts in a new product with a different function.
Linear Economy	Useful application of materials	R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality.
		R9 Recover	Collect materials or products that have already been used but maintain their usefulness and reintroduce them into the production process.
		R10 Valorize energetically	Incineration of materials with energy recovery.

QUALITATIVE COMPONENT

The qualitative research is adapted to the content analysis, and the survey explores how the players involved in construction conceptualize and understand the meanings of circularity.

PERCEPTION SURVEY STRUCTURE; POTTING TRANSITION SCALE

Known as 10R strategies, this framework will structure the survey (Javier & Xavier, 2019) by measuring the resilience of materials, collecting semi-quantitative data, and compiling them into indicators that provide meaningful information (Table 1).

The CEs, R0 to R2, will not be the subject of study and are not directly related to the implementation phase (Mora, 2021). The research will be defined according to the CEs, R3 to R10.

PERCEPTION SURVEY METHODOLOGY

An expert, a professor at UBB, reviewed the content. The writing and comprehension of pilot survey questions were validated by applying them to three construction companies in the area, different from the sample. The survey questionnaire was supplemented with a definition of CE from the Report by Potting et al. (2017) to pool sample response criteria.

Table 2. Quantification of CDW percentages. Source: Preparation by the authors.

WALL STRUCTURE CUBICATION TABLE								
			A	B	C	D	E	F
HOUSING	ITEM	CONSTRUCTIVE ELEMENTS	VOLUME (m3)	% OF WASTE (%) (c)	(A)*(B) %CDW BY MATERIAL	AVERAGE SPECIFIC WEIGHT (Kg/m3)	(D)*(A) CALCULATION OF TOTAL WEIGHT OF MATERIALS (Kg)	(E)*(B) CALCULATION OF TOTAL WEIGHT OF THE WASTE (Kg)

Table 3. Circular potential cut-off ranges in Revit. Source: Preparation by the authors.

Constructive Item	Material	(c) Almost nothing %	(a) Almost everything %	(b) Some parts %	% Total circular potential (a)+(b)
Data	(Include from the project)	(Include of perception survey results)			(sum total)
	% Cut-off Range	xx			yy
		Max. Low circularity			Min. High circularity

The survey was structured in three categories. The first measures perceptions of materials' resilience. The second is complemented by factors that affect the materials' recovery capacity. The third asks for the interviewee's personal information (Appendix A). These were performed over five days. The author gave a brief verbal introduction and instructions on completing the measuring instrument, resolving doubts, and reading the informed consent form before asking questions.

SAMPLE UNIVERSE

A non-probabilistic sampling method was used to select 10 representative construction companies, covering 67% of the companies in the Province of Arauco with experience in rural social housing projects. The sample is not random; it was chosen from the researcher's professional contacts. For confidentiality reasons, the names of specific companies have been excluded here.

QUANTITATIVE COMPONENT: VALUATION ATTRIBUTES (A), (B), (C)

The multiple factors that influence material recovery are framed in three circular attributes reflecting the frequency of a circular perception;
(a) Almost everything…
(b) Some parts... ... of that fraction of the residual material is recoverable
(c) Almost nothing…
The tabulated values are represented in percentages, facilitating objective interpretation.

Table 4. Traffic light-type cut-off ranges; Revit display. Source: Preparation by the authors.

Circular Indicator	Color Assigned	Cut-off range %
(a) Almost everything	Green	yy% to 100%
(b) Some parts	Yellow	xx+1% to yy-1%
(c) Almost nothing	Red	1% to xx%

The dependent variables include the circularity indicator, the materials' recovery capacity, and the CE, which are independent variables.

Non-recoverable fraction (b)

Percentage of the material that can improve its recoverability, incorporating factors to enhance the design.

Non-recoverable fraction (c)

The tabulated data from the surveys will be used to calculate the weighting percentage of the construction site waste. Together with the specific weight of the materials in the Revit database (Fernández & Raposo, 2022), they will allow determining the recycling weight of each item on site (Table 2), approaching the waste management protocols in Chile; "Roadmap CDW-2035", as in all countries of the European Union; European Directive Standard 2008/98/EC.

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Table 5. Case study materials. Source: Preparation by the Authors.

Constructive Item		Base	Proposal 1	Proposal 2
Structure	walls	2"x3" Partition	Metalcom Partition	Reinforced concrete walls
	roofing	2"x4" Truss 2x2" Girt	Metalcom truss and girt	2"x4" Truss 2x2" Girt
	floor	8cm concrete floor slab	Wooden board	8 cm concrete floor slab
Foundation		Foundation run	30x30x60 concrete sill 3"x8" wooden beam	80x80x40 concrete capstones
Roof		Zinc alum	0.35cm zinc alum tile.	0.35 cm asphalt tile
Interior Finish		Plasterboard (Z.S) Fiber Cement (Z.H)	Wooden board. (Z.S) Fiber Cement (Z.H)	Exposed concrete
Exterior Finish		Fiber cement siding	Tongue-and-groove wood	Fiber cement siding
Windows		4 Aluminum 130x120cm 1 Aluminum 100x100cm 1 Aluminum 60x60cm 1 Aluminum 60x90cm	4 PVC 130x120cm 1 PVC 100x100cm 1 PVC 60x60cm 1 PVC 60x90cm	4 wooden 130x120cm 1 wooden 100x100cm 1 wooden 60x60cm 1 wooden 60x90cm
Doors		1 Solid Wood 90x200cm 5 plywood (placarol) 70cm	1 metallic 90x200cm 5 metallic 85cm	6 solid wood 85x200cm

CUT-OFF RANGES; INTEGRATION TO REVIT

A color will be assigned through the Revit software (Jalaei & Jrade, 2014) to facilitate graphical visualization. The total circular potential of the material will be the result of (a) + (b). The percentage value is proportional to its circularity, while in (c), its percentage is inversely proportional to the circularity of the element. This variable is individualized as the residual material or percentage of CDW (Table 4).

Defining the average of the highest percentages of the total circular potential of the materials through a simple mathematical equation (a)+(b) will give the cut-off range of the highest circularity. The average of the higher percentages of (c) will provide the lowest circularity cut-off range (Table 3).

Each range (Table 3). to be incorporated in the "filter rules" box of the Tutorial step; IV.) should be assimilated to colors according to:

IMPLEMENTATION OF CASE STUDY TO REVIT

A tutorial will be provided on integrating materials' circular potential into Revit software by associating "traffic light"-type indicators (Appendix D). The method's feasibility was verified by consulting two experts in the 3D modeling tool. For this purpose, basic housing was compared with a more favorable proposal 1 and a less favorable proposal 2 (Table 5).

PLANIMETRY OF CASE STUDY

Wooden house of 62.24 m^2, design features in (Figures 1, 2, and 3). The model will be developed with Autodesk Revit.

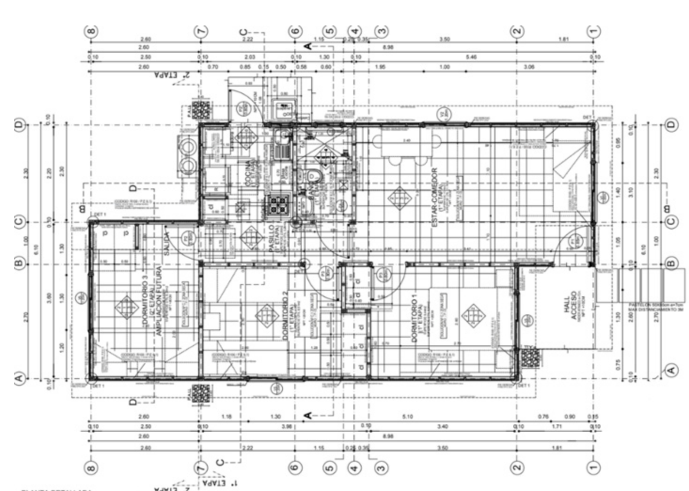


Figure 1. Architecture floor plan, mass construction typology. Source: Preparation by the authors

Figure 2. Main and left side view. Source: Preparation by the authors

Figure 3. Cross-section and right-side view. Source: Preparation by the authors

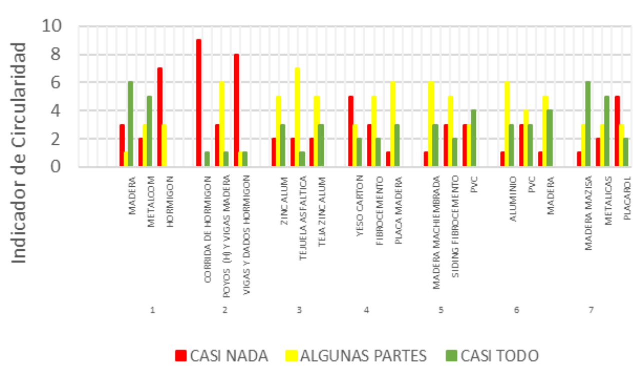


Figure 4. Recover Tabulation. Source: Preparation by the Authors.

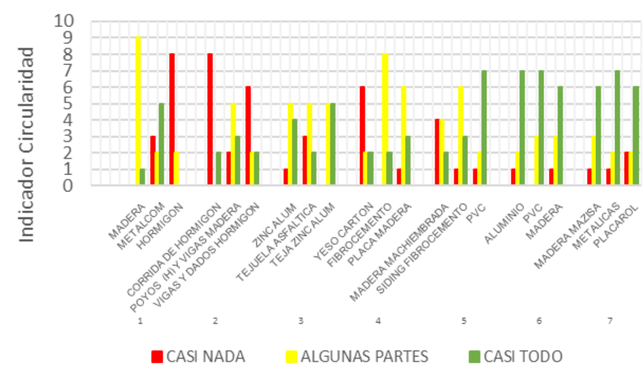


Figure 5. Reuse Tabulation. Source: Preparation by the Authors.

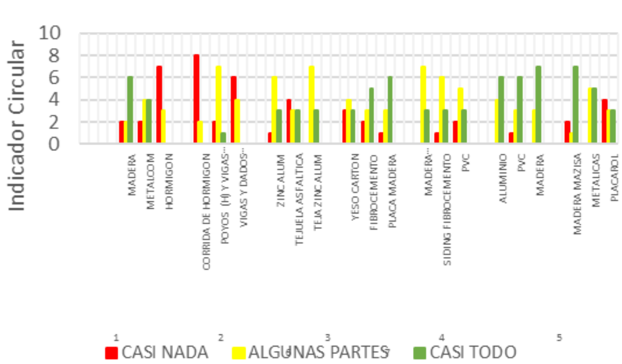


Figure 6. Recycle Tabulation. Source: Preparation by the Authors.

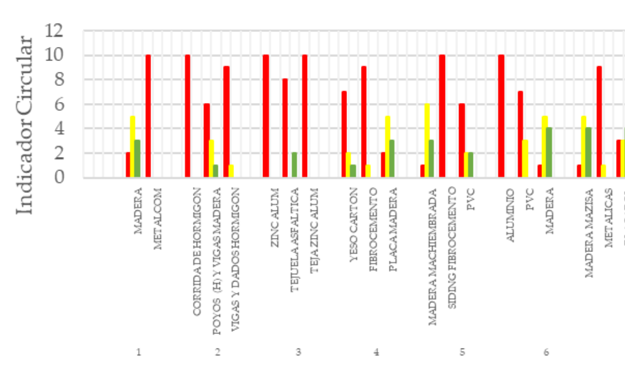


Figure 7. Incinerate Tabulation. Source: Preparation by the Authors.

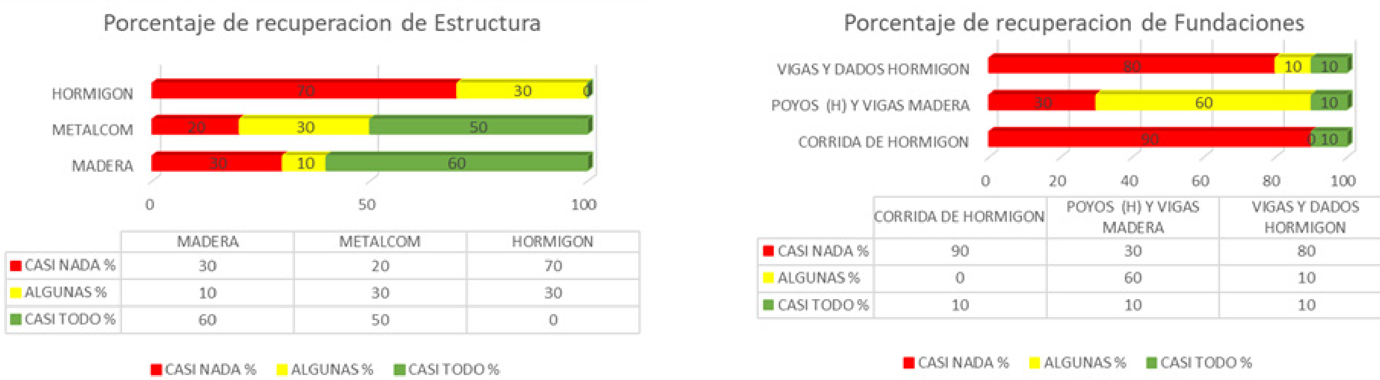


Figure 8. Structure and Foundation. Source: Preparation by the authors.

Figure 9. Roof and Interior Finish. Source: Preparation by the authors.

RESULTS AND DISCUSSION

The companies considered the same concept for the Recover (Figure 4) and Reuse (Figure 5) strategies. It should be noted that concrete in the structure and foundation items has a low percentage of circularity; on the contrary, wood has a high potential for reuse.

Repair and Restore refer to recovering the historical value due to lack of maintenance. The results defined these as non-binding CEs for construction.

Remanufacture. The concept indicates that the CE is not applied in the construction phase, as the votes are inclined to option (c): almost nothing.

Recycle. The CE best known and applied by contractors. We see a tendency toward medium-high circularity. (Figure 6)

The respondents in the Recover, Reuse, and Recycle CE recognize concrete as the heaviest element and elements of lower quality in their composition, such as plasterboard and the placarol (plywood) door, as having less circular potential.

Incinerate. The responses reflect a tendency to avoid incorporating this Strategy (Figure 7). The tendency to incinerate is medium-high only in the alternatives that consider wood.

Given the results, "not all Circular strategies can be inherently sustainable; it requires a previous analysis that defines where to place this strategy....". This analysis found equality between the 100% Recover and Recycle and 57% Recover and Reuse results. Although recycling building materials is common, it requires more energy use, and reuse is value-oriented. Recovery is then considered over recycling (Salehabadi & Ruparathna, 2022), understanding that this occurs only when the material can no longer be recovered.

MEASURING CIRCULARITY

Determining an absolute percentage of recovery for each material is impossible.

Therefore, numerical values are assigned to the answers, translating the ranges of circular attributes into percentages and establishing how much "can be recovered."; (a) Almost everything, (b) Some parts, (c) Almost nothing (Figure 8, Figure 9, Figure 10 y Figure 11).

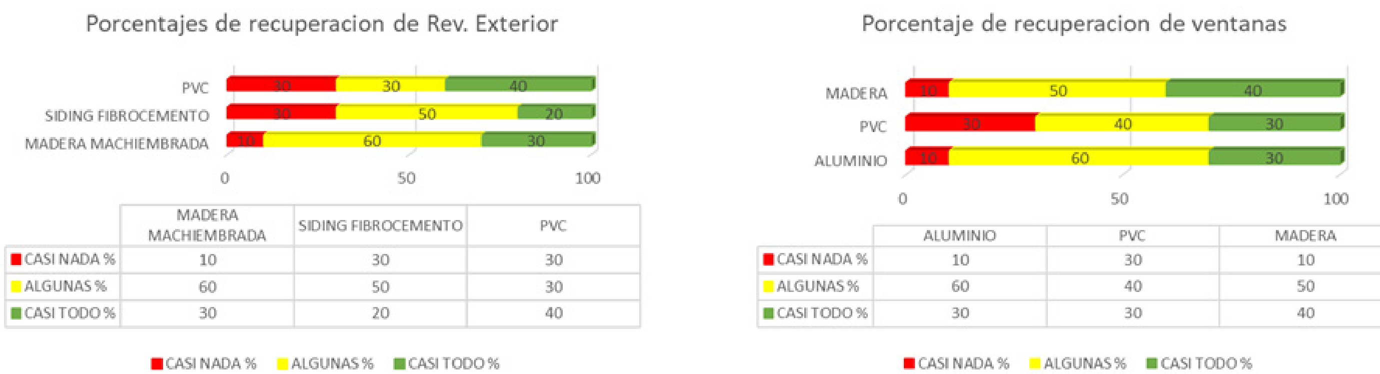


Figure 10. Exterior finish and windows. Source: Preparation by the authors.

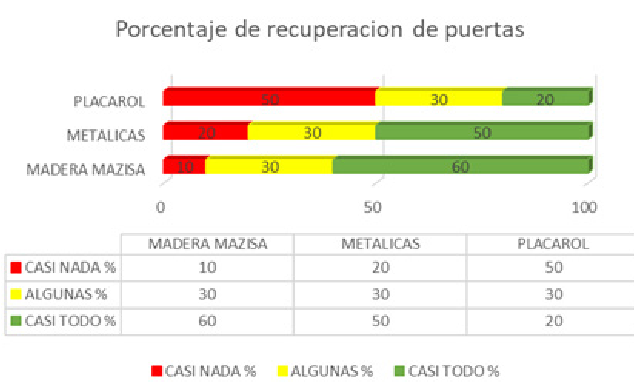


Figure 11. Doors. Source: Preparation by the authors.

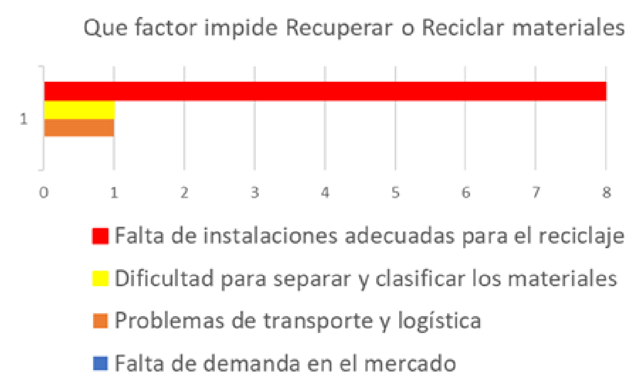


Figure 12. Factors that prevent recycling. Source: Preparation by the authors.

The "traffic light-type" graphic reiterates concrete, placarol (plywood), and plasterboard as the materials with the lowest circularity.

DESIGN FACTORS THAT ENHANCE RECOVERY

The trend in Construction Companies' actions is to include basic factors that influence the resilience of materials. The survey shows a strong trend towards sustainability, both in its incorporation in the design of assemblies, stratification, quality, etc. and in the incorporation of actions in the field of material separation.

The lack of recycling facilities in the area is strongly evidenced (Figure 12).

INTEGRATION OF CUT-OFF RANGES TO REVIT

The total circular potential will be determined as the result of (a) + (b) (Table 6). The average of the highest percentages of the total circular potential of the materials will give the cut-off range of the percentages with the highest circularity. Meanwhile, the average of the higher percentages of (c) will give the cut-off range of the lowest-rated percentages (Table 7).

GRAPHICAL VISUALIZATION IN REVIT AND SYNTHETIC APPROXIMATION.

With Revit's geometric information and the incorporation of the percentages of (c), the volume of the project›s materials and the percentage of CDW emitted by the material are obtained. To meet the goal proposed in the Circular Economy under Construction CDW Roadmap. "At least 30% of the volume of the CDW is recovered: Reuse…" While the goal, by 2035, should reach 70% of the volume of the CDW recovered, as detailed in Table 8.

Thus, the valuation of such materials and/or construction systems should increase by an average of 3.7% by 2025 and 8.65% by 2035.

We analyze housing based on the European Union's policies. By 2020, 70% of the total weight of waste from CDW should be recycled or reused. This gives a weight of 31,257.28 CDW; the 70% should be valued at 21,880.96 CDW by 2020 to meet the proposed goal according to European Directive 2008/98/EC.

The Revit graphic visualization and the database

Table 6. Calculation of cut-off ranges. Source: Preparation by the authors.

Constructive Item	Material	(a) Almost nothing %	(b) Almost everything %	(c) Some parts	Total circular potential
Structure	Wood	30	10	60	70
	Metalcom	20	30	50	80
	Concrete	70	30	0	30
Foundations	Concrete Run	90	0	10	10
	Sills and beams	30	60	10	70
	Beams and concrete capstones	80	10	10	20
Roof	Zinc alum	20	50	30	80
	Asphalt shingle	20	70	10	80
	Zinc alum plate	20	50	30	80
Interior Finish	Plasterboard	50	30	20	50
	Fiber Cement	30	50	20	70
	Wooden board	10	60	30	90
Exterior Finish	Tongue-and-groove wood	10	60	30	90
	Fiber cement siding	30	50	20	70
	PVC	30	30	40	70
Windows	Aluminum	10	60	30	90
	PVC	30	40	30	70
	Wood	10	50	40	90
Doors	Solid wood	10	30	60	90
	Metallic	20	30	50	80
	Placarol	50	30	20	50
% Cut-off Range		48.5			84.2
		Max. Low circularity			Min. High circularity

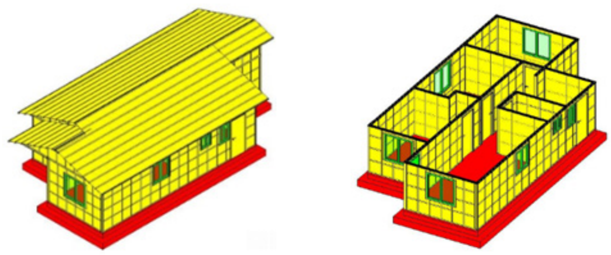
Table 7. Traffic light indicator cut-off ranges. Source: Preparation by the authors.

Circularity Indicator	Color	Value Ranges %
Almost Everything	Green	84% to 100%
Some Parts	Yellow	50% to 83%
Almost Nothing	Red	0% a 49%

Table 8. CDW volume and weight percentage calculation. Source: Preparation by the authors.

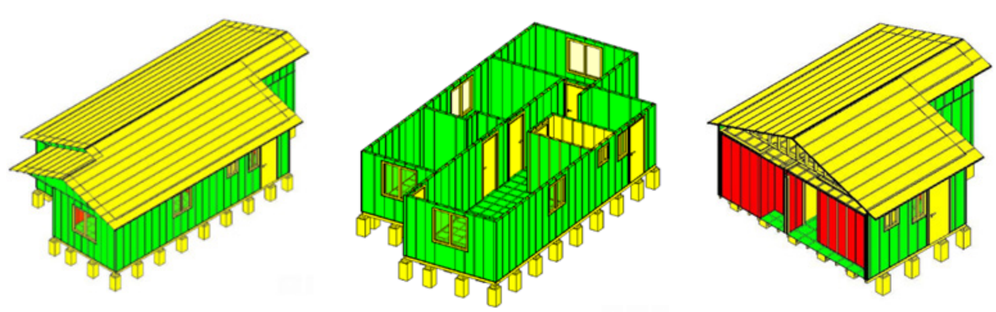
		Roadmap Goal (CORFO, 2020b). Chile.		European Union Regulations	
Model	Total CDW Volume per dwelling (v)*(c)	30% CDW volume by 2025 (v)*0.3	70% CDW volume by 2035 (v)*0.7	CDW Total Weight (p)	70% of the CDW weight by 2020 (p)*0.7
Basic Housing Wooden Structure	14,328	4.2984	10.0296	31257.28	21880.096
Proposal 1 Lightweight structure	2,159	0.6477	1,513	7574.02	5301.814
Proposal 2 Concrete Structure	20,518	6.1743	14.4067	48022.68	33615.876

Table 9. Basic housing. Source: Preparation by the authors.



Basic housing model	Materials	%Total Circular Potential (a)+(b)	Total Volume (v)	Percentage CDW (c)	% CDW by material (v)*(c)	D Total Weight materials (v)*(pe)	CDW Total Weight D*(c)
Structure	Wood	0.7	8.84	0.3	5,64	14319,71	11462,62
Foundation	Concrete run	0.1	8,49	0.9	7,641	20367,36	18330,62
Roof	Zinc alum	0.8	0.3	0.2	0.06	2130.74	426.15
Exterior Fin.	Plasterboard	0.5	0,53	0.5	0,159	640,34	192,1
Interior Fin.	Fiber cement siding	0.7	1.55	0.3	0,755	1604,43	771,71
Windows	Aluminum	0.9	0.18	0.1	0.018	20,35	2,04
Doors	1 wood 5 placarol	0.5	0.19	0.5	0,055	176,39	72,04
Totals			20.08		**14.328%**	39259.32	**31257.28**

Table 10. Proposal 1. Source: Preparation by the authors.



Proposed Model 1	Materials	%Total Circular Potential (a)+(b)	Total Volume (v)	Percentage CDW (c)	% CDW by material (v)*(c)	D Total Weight materials (v)*(pe)	CDW Total Weight D*(c)
Structure	Metalcom	0.8	3.81	0.2	0.717	22257.53	4430.73
Foundation	Concrete sills	0.7	3.55	0.3	1.065	8511.6	2553.47
Roof	Zinc alum tile	0.8	0.3	0.2	0.06	2130.74	426.15
Exterior Fin.	Tongue-and-groove wood	0.9	0.54	0.1	0.054	352.57	35.26
Interior Fin	Wooden boards	0.9	1.51	0.1	0.171	928.4	123.34
Windows	PVC	0.7	0.18	0.3	0.054	16.28	4.88
Doors	Metallic	0.8	0.19	0.2	0.038	0.93	0.09
	Totals		10.08		**2.159%**	34198.05	**7573.92**

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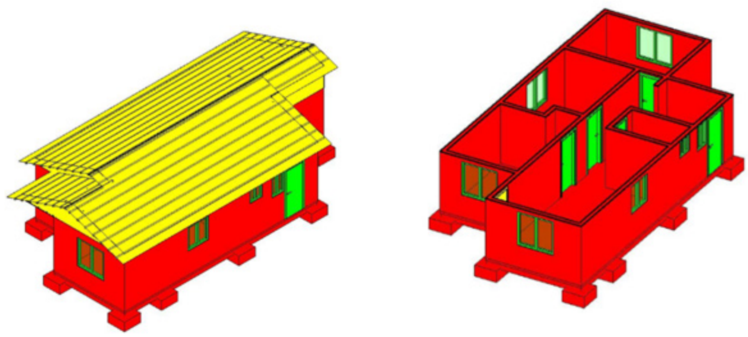
Table 11. Proposal 2. Source: Preparation by the authors.



Proposed Model 2	Materials	%Total Circular Potential (a)+(b)	Total Volume (v)	Percentage CDW (c)	% CDW by material (v)*(c)	D Total Weight materials (v)*(pe)	CDW Total Weight D*(c)
Structure	Reinforced concrete	0.3	20.89	0.9	17.553	46352.82	40904.97
Foundation	Concrete Capstones	0.3	3.58	0.8	2.864	8601.6	6881.28
Roof	Asphalt shingle	0.8	0.3	0.2	0.06	600.21	120.04
Exterior Fin.			0.09	0.3	0.027	107.22	32.17
Windows	Wood	0.9	0.18	0.1	0.018	15.47	1.55
Doors	Wood	0.9	0.19	0.5	0.059	193.08	82.67
Totals			25.23		20.581%	55870.4	48022.68

(Table 9) show that the structure and foundations, by their volume and weight, generate the highest CDW, followed by the roof and then the Interior Finish. These are defined as the main items that must improve their selection and factors that allow their recovery.

Proposal 1 fails to eliminate 84.93% of CDW compared to the base case. The choice of materials in the foundations is complemented to reduce the volume of heavy materials and include removable systems, increasing the recovery potential of the materials (Table 10).

Regarding the CDW volume of the base, the volume of proposal 2 is 30% higher. The low level of circularity in the graph, where structure and foundation are displayed in red (Table 11), is corroborated.

When comparing the base model with the most favorable and another less favorable one, it was found that the methodology detects clear trends between the different construction systems analyzed with a graphical visualization of the models and a synthetic quantification of the percentage of CDW.

The approaches to the national and international standards allow us to highlight the gap in the construction sector's circular transition.

REFLECTIONS OF THE USERS

As a BIM Modeler in project planning and coordination, a recyclability template is a valuable tool that adds value to design in construction. Implementing this tool in the Revit software would improve the use of sustainable resources in construction planning.

DISCUSSION

This research seeks to overcome the lack of knowledge and/or technological integration by offering an experience-based approach to assess the resilience of resources in an accessible way in construction projects.

Incorporating CE through the qualification of sustainable attributes of materials is effective for construction companies. Multiple data are integrated into an indicator that thoroughly evaluates the CE. The experience of the construction companies provides holistic information integrated into the Revit software database through Tutorial, which provides graphical visualization.

The methodology supports the Circular measurement using significant indicators (Potting et al., 2017). This approach simplifies the transition to greater circularity (Calzolari & Genovese, 2022). The objective is to provide a more straightforward but more rigorous and accessible indicator for project development actors by bringing CE closer to designers in the initial design stages.

The BIM platform provides graphical results, facilitating the comparison of solutions and the making of informed decisions; in combination of BIM with information provided by the actors involved in the process opens new possibilities to promote sustainability in construction and facilitate the implementation of CE strategies in projects, associating the low adoption of circular economy tools to their complexity and lack of information (Dufrene et al., 2013).

CONCLUSION

The integration of CE in the conceptual design stage using BIM in the context of housing construction was explored. The research included the leading players of the construction process to evaluate the circularity potential of different construction elements and their application in a BIM housing model.

The assigning of numerical values to the survey determined the fluctuation of percentage ranges, obtaining high average and low circularity, where the average range allows incorporating factors that improve circularity through the use of removable connections, pins, bolts, etc.

When complementing this information with Revit's geometric data, it was seen that the structure and the foundation define the highest percentage of the CDW by concentrating on the highest volume and weight of the house. The base house has a 9.35% CDW volume, the house of Proposal 1 has a 2.15% CDW volume, while Proposal 2, structured in concrete, has a 15.63% CDW volume when analyzing the values for the fulfillment of the 2025 goal of the 2025 Roadmap.

On analyzing the alternatives by construction item, it is evident that involving concrete in the items, low-quality materials such as sheet metal doors, or fragile materials such as plasterboard increases the percentage of low circularity. Conversely, incorporating wood in any format increases the high circulation valorization percentage.

In lightweight materials, the high circular potential is strongly enhanced with the percentage of the partial potential of the material, generating a greater opportunity to improve the recovery of these materials by incorporating systems that favor the recovery of the project's parts. In short, (b) represents the potential to maximize recovery through design.

Despite the study's contributions, it has limitations since it was based on a qualitative appreciation of the materials through surveys without a detailed specification of the factors considered to evaluate the elements' resilience. It is suggested that future research integrates factors such as assemblies and fixings into Revit modeling for a more complete assessment of the circular potential.

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