Development of a Circularity Assessment Tool with Local Stakeholders from Strasbourg

Emmanuel Dufrasnes[1(✉)], Louise Eich[2], and Fanni Angyal[3]

[1] Architecture School of Strasbourg, 67000 Strasbourg, France
emmanuel.dufrasnes@strasbourg.archi.fr
[2] IMT Nord Europe, Institut Mines-Télécom, Centre for Energy and Environment, Université de Lille, 59000 Lille, France
[3] Direction du Développement Economique et de l'Attractivité de l'Eurométropole de Strasbourg, 67000 Strasbourg, France

Abstract. Our research focuses on the reutilization of construction materials and how we could foster growth in this sector. It deals with the specific case of the re-use sector around Strasbourg, France, providing a comprehensive overview of the local landscape. Indeed, the research was conducted in partnership with the School of Architecture of Strasbourg, the City of Strasbourg, and an engineering consultant called "BOMA" specialized in circular building. This project is supported by the "Campus des Métiers et des Qualifications Eco-construction et Efficacité Energétique Grand Est", the Grand Est Region, the "Région Académique Grand Est" and the "Banque des Territoires". To encourage innovative programs around circular economy, we gave particular attention to analysing feedbacks from pilot projects. In addition to the interview with key local stakeholders, a literature review focusing on assessment of circularity in buildings was carried out. Through a methodology developed in a separate scientific paper, we selected 10 key indicators adapted to the area to measure the circularity of a building, focusing mostly on social, environmental, and economical aspects of the project. Thanks to these indicators, a digital tool was developed to calculate the relevant data concerning the circularity of the project, creating analysed feedback of the construction. Five of those indicators have been implemented in this tool, although suggestions have been made to cover more topics. Moreover, in the future, there is the possibility for it to be transformed into a decision-making tool in order to boost the structuration of the re-use sector around Strasbourg.

Keywords: Construction · Re-use · Circular Economy · Strasbourg · Tool · Evaluation

1 Introduction

Until the beginning of the 20th century, reutilization of constructions material was a common practice. The high cost of extraction and transportation and transformation of raw material forced builders to give priority to the resources already present in town [1]. This organization of building materials has evolved through time, with new technologies, low cost of energy and higher labour cost.

V. Ungureanu et al. (Eds.): CESARE 2024, LNCE 489, pp. 436–445, 2024.
https://doi.org/10.1007/978-3-031-57800-7_40

Nower days construction methods are facing several issues, one of them is the major amount of construction waste. In France, the construction industry is responsible for 46 million tons of waste, that represents 53% more than household waste [2].

In this context, the development of circular economy and specifically the re-use of construction materials is a major lever to reduce construction waste and promote existing materials. The European commission defines re-use as "*any operation by which products or components that are not waste are used again for the same purpose for which they were conceived*." [3] The Belgian research group [1] highlighted three main arguments for the practice of re-use:

- reduction of the environmental impact, the effects of each step of the "extraction of raw materials" and "production of the product";
- creation of local and social employments by also bringing value to existing professions such as building wreckers who's missions will evolve into the sustainable deconstruction and re-use of materials;
- preservation of the architectural heritage.

This practice with several positive impacts is re-emerging, thanks to local stakeholders and national regulations. The creation in 2022 of the Professional Union for Reuse in the Construction Industry in France, is an example of the national structuration. However, the structuring is taking place in different ways across the country.

The Strasbourg case study is an interesting example given that it is a medium sized town, at the centre of the European landscape, willing to structure and develop the re-use sector in the area. In the following paper, we will focus on the levers used by those involved in the re-use sector in and around the Strasbourg area and the main obstacles they face. In response to this state of the art, we will describe the analysis tool developed as part of this study.

This research was conducted in partnership with the Research Unit of the Architecture School of Strasbourg, the "Eurométropole de Strasbourg" and BOMA, an engineering consultancy in circular economy in the building sector. This partnership has firmly rooted the study at a local and regional scale and enabled us to identify the stakeholders' main needs. One of these needs is to receive feedbacks from pilot projects in order to collect data and give the project owner the opportunity to value its investment. Moreover, in France as in Spain and in Italy the project owner must cover the 10 years period after delivery of the project with a decennial liability, the circularity assessment is also a way to reassure same building stakeholders that the practice is doable and safe. In this context, we worked on a digital tool that analyses feedbacks from pilot projects.

The recent thesis from Ambroise Lachat [3] provided a solid foundation for the research conducted here. His study cited the comprehensive article by Nuñez-Cacho et al. [4] which also describes a method to identify the key indicators to measure circularity in a project. Finally, the paper published in 2023 from S. Clavier et al. [5] studies the re-use rate by using the Material Flow Analysis method. This research underlines the necessity and interest for the topic today.

2 State of Art

The structuration of the re-use sector in France is heterogeneous and depends on different factors. In this study, we focus on the Strasbourg situation, a city located on the border with Germany and side by side with the Rhine River. This location makes it a European city which can participate to European program such as the INTERREG finance program, FEDER or LIFE.

The re-use sector today has a strong sense of community and a great willingness to share experience. In the context of the Waste2Build project financed by the European program LIFE, the French city of Toulouse received funding to develop the re-use sector. LIFE project implies the sharing of knowledge with other European territories.

Moreover, we noticed that the re-use sector structuration will also operate thanks to the support of public policies and territorial collectivities. Examples of other territories show that the first lever to accelerate the development of a re-use sector is to implement effective public policies. In the territory of Plaine Commune in the Paris Region, the stakeholders signed a charter, with numerous goals to support the re-use sector. National measures can also be an effective lever. Indeed, since the 1st of July 2023, for most demolitions, the project owner must do a resource diagnostic in order to identify the reusable building materials. This measure provides considerable leverage for identifying possible local resources.

Finally, through this research and interviews with local stakeholders, we were able to point out the urgent need to share knowledge. Most consultancies specializing in circular building offer educational programs for companies or schools.

There is a need to gather knowledge and analyse pilot projects, so that the project owner can communicate and share solutions that function. In the following article, we will try to find a solution that fulfils this need.

Concerning the research sector, we noticed a growing interest for the development of circularity in buildings. Marie de Guillebon [6] in her thesis in 2019 worked on experimental construction projects using re-used materials and on the value of the materials. Another key research is the work of the Belgium research group which includes the catholic University of Louvain, the Vrije Universiteit Brussel, the CSTC and Rotor [1], on the case study of Brussel, which took place from 2015 to 2017.

Concerning the assessment of circularity, the literature review from Hossain & Ng [7] shows that there is a global interest for this subject. The authors highlight the importance of considering circular economy in LCA analysis: *"Although some important research gaps were highlighted from different perspectives of building assessment, none of those studies has considered integrating a circular economy (CE) with LCA for more sustainable building construction."*

The focus of the state of the art was made on the different research working on the circularity assessment. First, the study from Nuñez-Cacho et al. [4] suggests a method to select circularity indicators using a literature review. This method has been used to define the indicators adapted to the circularity assessment in Strasbourg and adapted to the maturity of the local sector.

Lachat [3] in his thesis also pointed out this urge to include CE in the building assessment, he adds that we can't study a perfect cycle of a product but multiple ones, since through reusing process, some of the values of the materials are lost. This study

focuses on the evolution of circularity assessment through time, questioning the method exposed by Zhang et al. [8]. In addition to those studies, a work has been recently published on reusability [5], the study program focused on a methodology to calculate the re-use rate of a material, their first case study is about the re-use rate of bricks.

The Scientific and Technical Center for Building, CSTB, updated in 2018 their research program for 2025 through four strategical guidelines. One of these guidelines is "the circular economy and resources for construction" and CSTB organized in July 2023 a research day on this topic, presenting their ongoing research.

The need to collect and analyse feedback is more and more present and we notice a lack of tools on the assessment of the circularity of an entire building.

3 Methodology – Development of a Circularity Assessment Tool

The development of a circularity assessment tool is essential for the projects in and around Strasbourg, through several aspects:

- Raising awareness about circular economy (CE) in the construction sector;
- Helping to define the key indicators of circular economy;
- Collecting feedback and learning collectively from them;
- Helping the development of a CE certification.

The methodology used for the development of an assessment tool was inspired by the methodology called the e-delphi technique which can be found in the study from Nuñez-Cacho et al. [4]. Using literature review and report analysis, they identify 234 indicators that can fit with the assessment of circularity. By eliminating duplicates and interviewing stakeholders, they manage to reduce to a seven indicators list.

A similar methodology was used to define the adapted indicators for the Strasbourg area, going from 62 to 10 indicators through two different scales (see Fig. 1 and Fig. 2). The first list of indicators was completed thanks to multiple resources such as interviews with local stakeholders, indicators from other calculation tools and research work.

This list was divided into two distinct scales: the building level and the sector level. This partition serves to shed light on a broader perspective on circularity, including both micro and macro viewpoints. Then we erased the duplicates and gathered the indicators into 6 categories described in the following Table 1 and Table 2.

Table 1. Categories selected on a re-use sector scale.

Sector scale		
Category	Indicator	Description
Skill valorization	Creation of local job	Creation of reinsertion jobs
	Development of one or several re-use platforms	Systematizing the use of reusable components will help to encourage the emergence of new initiatives
Valorisation avec the projects	Pilot project	Exemplary projects provide inspiration and show the way to other projects

Table 2. Categories selected on a building scale.

Building scale		
Category	Indicator	Description
Environmental impact	CO_2 emissions	CO_2 emissions saved thanks to the integration of re-used materials in a building
	Raw material management	Mass of building raw material saved
Economic impact	Economic impact	Economic impact through the implementation of reuse materials
Social impact	Social awareness	Awareness/information/training of construction stakeholders and development of common knowledge
Future resources management	Reusability and recyclability	Planning the change of usage or the end of the life of the building

Eight of those ten indicators have been implemented in the digital tool using two specific methods.

Firstly, the qualitative indicators (Social impact, Skill valorisation, Valorisation of the project), those which can't be calculated have been implemented in the Part 1 of the tool.

The weighting given to each criterion in Table 3, was discussed with a CE project chief from the "Relais 2D"[1]. They are adapted to the needs of the sector, valuing the

[1] Organization in charge of the inclusion of social and environmental clause in public market of Strasbourg.

Table 3. Social impact assessment of the project.

Building scale	*Selected*	*Calculated*
Awareness for the re-use sector		
Project owner	No action/Informing/Awareness/Training	0/1/2/3
Project manager	No action/Informing/Awareness/Training	0/1/2/3
Building workers	No action/Informing/Awareness/Training	0/1/2/3
Users	No action/Informing/Awareness/Training	0/1/2/3
Creation of reintegration jobs	No/Yes	0/3
Creation of an apprenticeship	No/Yes	0/3
Sector scale	*Selected*	*Calculated*
Support for the development of a physical or digital re-use platform	Blank = no help /*/**/***	0/2/3/4
Exemplary construction including re-use technology *Here, we call an exemplary re-use project, an innovative project, that is valued by a specific communication (visits, presentation, public reports, etc.)*	No/Yes	0/2

most ambition projects. Nevertheless, this weighting is still experimental and requires to be updated in the following years.

Secondly, we focused on the quantitative indicators such as carbon footprint, raw material resources management, economic impact, and future resource management.

- In the French legislation, for new constructions, the carbon footprint of re-used equipment or material is counted as 0 CO2-equivalent (CO2e), it is a political decision to support circular economy in the country. The tool suggests a first calculation of the overall carbon savings thanks to the integration of re-used products with this calculation method. A second calculation is suggested, the "real" carbon footprint of the material. For this calculation, we used the method developed by Cycle Up, an engineering consultancy in circular economy in the building sector, and the agency Riverse.
- Concerning the raw material resources management, we calculated the weight of trash saved thanks to the re-use operation using the Eq. (1).

$$w_{tot} = \sum_{i}^{n} w_{unit\ product\ i} * q_i \tag{1}$$

w_{tot}: *total weight of trash saved*
$w_{unit\ product\ i}$: *weight per unit of the material i, using the data based of the tool*
q_i: *quantity of the product i*

n: *quantity of different re − used products*

- The economic analysis consists only for now, on a comparison between the new and re-used product price, which has been led. A deeper study could be done in order to get a better view of the economic impact of the integration of reused materials.
- Finally, the evaluation of the future resources management hasn't been implemented yet so far as this notion is still uneasy to measure. However, it is a crucial information to collect for the reusability in the future of integrated products. Incoming French research studies are working on the calculation of the reusability rate of some products, but no general data base has yet been provided.

4 Methods Application - Case Study: Pilot Project Around Strasbourg

4.1 Description of the Project

This case study was focused on a technical unit in the town of Schirmeck owned by the "Collectivité Européenne d'Alsace". The public project owner wanted to include re-used products in order to reduce the environmental impact of the project. The technical unit includes 3 main buildings, a shelter for road salt, a garage and an administrative building. In the following paper we will focus on this last building, which included the largest amount of reused products.

Fig. 1. Picture of the finished the administrative building of Schirmeck (left), pictures of the re-used material (right).

Most re-used materials are originally from interior construction so far, as they are easier to be insured by insurance companies. In the new building, many materials have been reused (see Fig. 1) and we will now see what results we get using the methodology explained above.

4.2 Project Analysis

To deconstruct and store the re-used materials, the Collectivité Européene d'Alsace called a social organization helping people to find jobs after long periods without any

and having been through difficult situations. The project was communicated over the media thanks to a regional news program. It achieved 46% of the social goals defined above.

Concerning the carbon indicator, we chose to compare the impact of a new material to the impact of a re-used one, using the method developed by Cycle up (see Fig. 2).

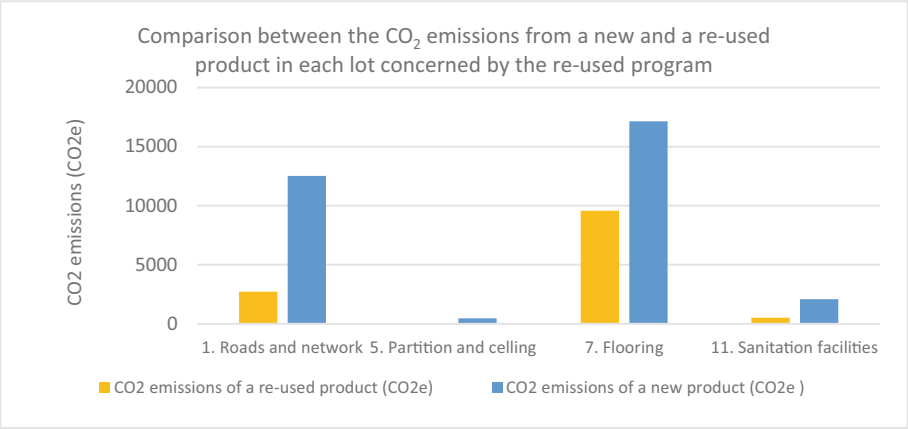

Fig. 2. Carbone emissions with both scenarios, re-used and new products.

We can clearly acknowledge the positive impact of re-used materials in this context. Moreover, the French legislation considers the carbon impact of a re-used equipment or material to be 0 CO2e, an incentive measure that digs the gap between a new and a second-hand construction product. Concerning the economic impact, the following graph has been generated (see Fig. 3).

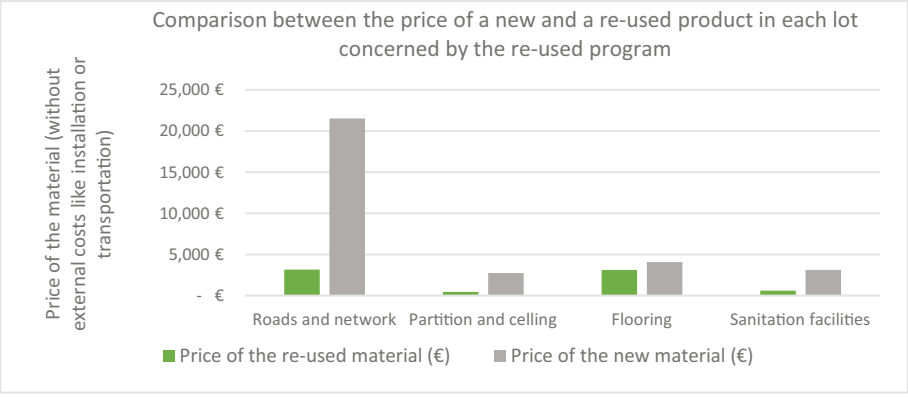

Fig. 3. Carbone emissions calculated with two different methods.

In practice, additional costs are generated on the cost of the material (intellectual cost connected to the specified engineering office for example). The study provides a flow chart of these costs to be considered in order to define the overall price of the product.

Further research needs to take place to define this exact price. Nevertheless, this shows the economic potential of reused products and the importance of expanding the practice to minimize external costs.

5 Conclusion

A tool for analysing the circularity of projects has been developed to support the emergence of the re-use sector in the "Eurométropole de Strasbourg". The creation of this software meets the need to collect the best local practices and to study the overall impact of a project. Indeed, this study shows the necessity of covering a range of factors rather than focusing only on the carbon footprint of each material or the energy efficiency of the building. Following this guideline, many questions arise concerning the scope of the assessment, the criteria to be considered and the calculation methods to be adopted. Bearing in mind that the development period has taken place over less than 6 months, the main goal of the study was to propose the start of a global analysis of the circularity of a project. This tool also provides a proposition to the "Eurométropole de Strasbourg" in its role as project owner, offering tools for feedback, analysing possible modifications in the circularity of their project and, why not, introducing goals into government procedures.

To make this tool fully operational, two main areas of development must be pursued. First, there is a need to keep testing the software with further case studies. These tests will assist in the development of a fair social evaluation and could help refine assessments for other indicators. Secondly, the economic and future resources management indicators could be improved to better match the expectations of local stakeholders.

However, we have observed that conducting a comprehensive study of the circularity of a project is a complex task that raises many issues. Nevertheless, we can agree on the low rate of reused construction materials in the overall building. The difficulty in reusing more materials may also stem from the design of the building itself, which, in most cases, rarely considers the building's end-of-life. Furthermore, a design that is too rigid does not allow the building to be repurposed, or its materials to be reused. These considerations for future re-use needs to seriously begin now. The "Eurométropole de Strasbourg", as project owner, recently included clauses in their procedures stipulating that the fact that the building will be dismantled in the long run should be considered from the moment it is built - an innovative initiative coming the local authority.

The current limitations for the re-use sector to be developed on a more global scale are the lack of operational and digital tools, and the question of whether circular economy principles should be integrated into current design tools, such as BIM6D and AI methods. This would imply the widespread acceptance of such specialized efficient tools among architectural agencies, which is not currently the case. Moreover, this technology currently still requires a great deal of energy, which can contradict in certain cases the main goal of reducing the impact of construction on our resources. The key may lie in the implementation of several different solutions, from the data collecting to the circular design using adapted tools.

Acknowledgement. This research received support from the COST Action Implementation of Circular Economy in the Built Environment (CircularB) under reference CA21103.

References

1. Ghyoot M, Devlieger L, Billier L, Warnier A, Rotor (2017) Déconstruction et réemploi: Comment faire circuler les éléments de construction, Presses polytechniques et universitaires romandes, Bruxelles
2. Minister of Ecological Transition (France). https://www.ecologie.gouv.fr/dechets-du-batiment. Accessed 10 May 2023
3. EUR-Lex, access to European Union Low. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008L0098. Accessed 08 Sept 2023
4. Nuñez-Cacho P, Górecki J, Molina-Moreno V, Corpas-Iglesias F (2018) What gets measured, gets done: development of a circular economy measurement scale for building industry. In: MDPI
5. Clavier S, Bendahmane N, Gondran N, Chevalier J (2023) Méthode de quantification des flux des mines urbaines: cas des briques en terre cuite en Ile de France. In: EPIsciences
6. De Guillebon M (2019) Vers une pratique du réemploi en architecture: expérimentations, outils, approches. In: Laboratoire Cultures Constructives - AE&CC/ENSAG, Grenoble
7. Hossain M, Ng S (2018) Critical consideration of buildings' environmental impact assessment towards adoption of circular economy: an analytical review. In: ScienceDirect
8. Zhang N, Han Q, De Vries B (2021) Building circularity assessment in the architecture, engineering, and construction industry: a new framework. In: MDPI