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THE LCA OF A BUILDING AS A TOOL TO IMPLEMENT THE CIRCULAR ECONOMY MODEL IN MEXICAN CONSTRUCTION

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Abstract: In order to apply the Circular Economy model in the construction sector, multiple tools are required to measure the circularity of its products and processes. This work proposes to use the Life Cycle Analysis for this purpose, modifying it to be able to adapt it to the study of buildings, transforming the way in which resources are managed in each of the stages of the life cycle: planning and design, construction, use and maintenance, and end of life. The evaluation of the economic and social impacts is not left aside, as well as the text explains how we can guarantee the greatest efficiency in each of these. There are still several barriers that prevent the full development of this methodology, such as the lack or inefficiency of communication between the agents involved, the inexistence of indicators to measure ecological, social and economic performance, as well as the fact that there are very few technological tools that can be applied for this analysis. However, there are already actions that are being carried out to guide us towards this transformation, in 2021 the General Law of Circular Economy was issued, which demonstrates Mexico's interest in adapting to new needs, where a balance is achieved between the innovation, social welfare and environmental sustainability.
Keywords: construction, sustainability, circular economy, life cycle analysis, buildings, resource optimization

INTRODUCTION

Each organism in an ecosystem has connections with others and with its environment, and human beings are no exception, we deliberately alter the ecosystem in which we live, which has led human civilization to face enormous environmental conflict, since Although the quality of life has undoubtedly increased, so have the impacts on the environment.

The construction industry represents around 7% of Mexico's GDP, and although it is a great generator of wealth, it also contributes 23% of air pollution, 40% of drinking water pollution and 50% of the waste in landfills. These data indicate that it is time to reorganize ourselves as a society and develop a model to respond strategically to the needs of the modern world, promoting the use of legislative tools.

We then propose the so-called Circular Economy (CE) Model, which simulates the cycles that occur naturally in ecosystems: all "waste" is reintegrated as resources in other processes of the same cycle, creating a closed system that maximizes the useful life of the agents involved. It is in stark contrast to the Linear Economy, which is a "Traditional Model where to make products raw materials are extracted, produced, and then discarded, without taking into account the environmental footprint and its consequences. This type of economy prioritizes economic benefit, ignoring sustainability, since the products are manufactured with the purpose of being used and thrown away ". (Santander, 2021)

Today we can say that the market is more aware of the environmental impact of the production and consumption of various products, which has led to the development of methodologies to understand the effects they entail. In the case of construction, the biggest challenge is to find a tool that can measure its potential for circularity, so this paper proposes the use of Life Cycle Analysis (LCA) for this purpose, suggesting modifications to overcome its limitations, since it only assesses the impact on the environment, ignoring others such as social and economic.

The idea of linking the CE model with LCA is based on the understanding that the principles behind both are the same: reduce waste and the environmental impact of a process, increase the useful life of the resources in it and ensure the Return of a value to the loop once its lifetime is over. The purpose of using this analysis is to be able to make decisions on how to prevent environmental contamination by intervening in the processes of a production chain, optimizing the use of resources.

It is important to point out that this study was carried out taking into account the conditions in Mexico, where we identified several barriers that prevent the application of LCA in buildings, such as the lack of a regulatory framework. While it is true that there is already a General CE Law in the approval process, this is of a general nature and there is still a long way to go before specific regulations are developed for this industry.

The focus of LCA as we know it is believed to be biased and almost exclusive to the packaging sector (nearly 50% of all studies carried out are concentrated there), followed by the chemical industry, building materials and energy systems.

The origins of ACV go back to the 1970s in the United States and the United Kingdom, during an oil crisis that generated a desperate search for alternative energy sources, having to develop a method to find the most efficient one.

Once the crisis passed, interest in developing the technique waned and it was not until 1993 that the Society of Toxicology and Environmental Chemistry (SETAC) resumed the study and published the "Code of Practice for LCA", whose objective was to standardize all studies related to energy efficiency, resources used and GHG emissions associated with manufacturing, using a multi-criteria analysis.

The research was based on the ISO 14040:2006 and ISO 14044:2006 standards, to define and describe the LCA methodology, both belonging to the ISO 14001 series of standards, which regulates environmental management issues. With this we can obtain the most precise definition of the Life Cycle Analysis: "It is the technique of collecting and evaluating the inputs, outputs and possible environmental impacts of a product throughout its entire life cycle".

It must be made clear that this analysis is not used to compare products directly, but to establish a comparison using a basic functional unit.

The four phases to consider within an LCA are the following:

DEFINITION OF THE OBJECTIVE AND SCOPE

It is important to have a clear objective to develop the study, and thus be able to apply decision-making with the conclusions of the study. The scope of the study depends on the following:

- The functional unit, a measure determined by the evaluator according to a defined indicator, associated with a numerical unit. "It is a reference with respect to which the inputs and outputs of the system can be normalized in a mathematical sense to be able to compare two different systems" (Díaz and Escárcega, 2009). For example, the amount of wood needed per m2 of set concrete.

- The stages of the life cycle, taking into account the unitary processes that lead to obtaining the final product and how it advances along the value chain until it reaches the end of its useful life (where it is not that it has lost value, but that it will change the way in which its use is conceived).

LIFE CYCLE INVENTORY ANALYSIS

The Life Cycle Inventory (LCI) basically deals with the elaboration of a list with all the inputs and outputs of the system to be analyzed, expressed in such a way that it can be quantified. This is represented in a simple diagram, starting with the inputs, where the use of raw materials, energy and water consumption are reflected. Then the stages of the life cycle with the unitary processes carried out in each one, as well as the impacts they cause. In the end, the outputs, which consist of the products and by-products of the process, as well as the pollution produced from the air, water, and any type of solid waste.

Each company can add or remove metrics that make up the study. In this sense, another parameter used in the LCI is Eco-Indicator 95, which also measures the impacts that damage human health and ecosystems through ozone depletion, global warming, pesticides, eutrophication and other impacts. Damage can be measured in terms of human disease, loss of flora and fauna, or mortality associated with any of these, including ecosystem degradation.

LIFE CYCLE IMPACT ASSESSMENT (LCIA)

The objective of this phase is that the results of the LCI become interpretable, since we remember that the data collected does not directly determine if a product is environmentally better than another, but rather creates a database of energy use, materials, its performance and the associated impacts, in relation to a functional unit. This is reflected in the so-called "impact table", where all the evaluated effects and the quantified results of the product analysis are reported.

These tables can serve as a basis for comparing products, but it is not so easy to consider the results of a single indicator and draw conclusions based on it, rather all these results must be weighed to make decisions, paying attention to the criteria that have more weight or importance in the interests of the company and society.

INTERPRETATION OF THE LIFE CYCLE

The results of the LCIA are summarized and identified according to the proposed objective and scope, in order to propose possible solutions or improvements through critical analysis.

Proposals for improvement in production processes must be more respectful of the environment, not contribute to the current level of pollution and optimize the use of resources, being aware of the environmental impact of these processes. In addition, the critical review confirms the validity of the LCA in the method and data collection used.

DEVELOPMENT

LCA is a methodology that was designed to be applied to products, not to processes, as is the case with the construction of a building. This is because it is based on the useful life and the raw materials consumed for the manufacture of an object. Hence, this work proposes to perceive the complete building as the product to be elaborated, separating its process into stages in order to identify the inputs and impacts that intervene in each of these.

Taking into account the previous proposal: like any product, it is necessary for the building to have an Environmental Product Declaration (EPD), since this is the one that communicates its environmental performance to clients throughout the cycle of life. In this case, an EPD is an essential tool for projects seeking sustainable construction certification (such as LEED, BREEAM, LEVEL(s), DGNB, WELL, etc.), identifying impact processes that go beyond the stage manufacturing of the materials with which it is built and its possible improvements.

The use of ACV in construction has a wide potential to implement eco-efficient strategies, involving various managers throughout the entire value chain involved in the construction and arrangement of a building. This potential can be expanded by enforcing strong tax laws and policies that encourage builders to take environmental responsibility and avoid taking shortcuts in pursuit of immediate and personal benefits that carry high environmental costs.

In addition, construction engineers and architects are not the only agents that must bear the burden of creating a sustainable building, but there must be a shared responsibility between manufacturers, suppliers, developers, users, etc. During each stage of the life cycle of a key product to pave the way towards a Circular Economy, we are talking about a space where the urban population spends 80% of their time.

For this, the standards (especially the voluntary ones) must be clear if they intend to be easily complied with by the aforementioned agents, where a common objective is imposed among them simultaneously, jointly inviting them to adapt to the regulatory requirements and avoiding that if one comes to have the initiative to adopt the CE criteria, it is not possible for him to maintain his aspirations within a market that does not support him.

Considering this, we present below the stages in which the building process will be divided, together with the considerations that we believe are important to complement the traditional LCA and transform it into the driving tool for the transition towards CE that construction needs.

1. Planning and design

This is the most important stage, since it is here where the most relevant aspects will be defined in terms of what inputs are going to be used, the processes, machinery, etc. All this must be done based on the use that you want it to have (residential, offices, services, industrial), the years that it is intended to be maintained with that same use, and consequently the maintenance and the recurrence with which it must be carried out.

Although it is true that the manufacture of construction materials generates impacts, the person responsible for analyzing them and generating strategies to mitigate them is the manufacturer. The consumer's commitment is then to find out about the different alternatives available on the market and choose the one that best suits their needs, generating the least impact on the environment where it will be used, and always give preference to the products of those responsible companies in their manufacturing process.

In order to make this choice, it is important first of all to establish what type of users are going to occupy the facilities, to know the amenities and needs that must be considered, taking into account how the energy performance of the building will be affected. For example, there are paintings that achieve better thermal insulation, which will generate less consumption of services such as heating or air conditioning, which means less energy consumption, being especially important in places with extreme temperatures. This reasoning also applies to services or devices that require water, and even more considering the growing scarcity of it in all the states of the country. Other considerations may be the implementation of automatic lights in the parking lot, rainwater harvesting for use in WC, etc.

Other recommendations for the preparation of the LCA in this phase come from specifications contained in the Environmental Impact Statements (MIA), an environmental instrument whose objective is to prevent, mitigate and restore damage to the environment. One of your proposals that we want to take up again is to make a summary of each of the activities of the work, with the possible environmental impacts that may derive from each one of them.

This Environmental Impact Assessment (EIA) requires an exhaustive study of the biotic components, climate and natural phenomena in the area, as well as other aspects such as geomorphology, water and soil quality, identifying how each of them will be affected to subsequently propose mitigation measures when it is not possible to avoid altering them.

What is interesting is that the EIA also considers it important to carry out an analysis of the economic environment, where the main activities carried out in the area must be identified, as well as the socioeconomic indicators that reflect the quality of life of the population in the surroundings of the site., and recognize the direct, indirect, cumulative and residual effects of the construction to be carried out. These effects suffered by people outside the construction project are known as externalities, where they pay costs that builders somehow save, with their health and integrity. In the best of cases, these social damages are sought to be compensated through financial compensation, but the answer lies in foresight.

Within these affectations, the form of transportation that ensures that the occupants of the building can access it must be considered, depending on its location and their availability, which has multiple impacts to assess for the region where the construction is located.

Nor must economic considerations be set aside, since we know that all projects seek to be profitable. In this phase, the quotes and budgets of the direct and indirect costs of the work are made, but as such the only costs in this stage are those related to the architects, engineers and other professionals in charge of planning, who provide the intellectual work. necessary to be able to take all these aforementioned considerations and deliver a sustainable, profitable, and quality project that benefits society and the reputation of the company that owns the property.

As already mentioned, this stage serves to define the course that we want the project to follow, so it is also necessary to consider what will happen once the building reaches the end of its useful life. Although it is impossible to predict exactly what conditions it will be in at that moment, it is possible to run simulations and examine different scenarios.

A good practice to implement is to integrate rehabilitation proposals that the building may have into the ACV, these can only be done when the building does not threaten the safety of the people who use it, or against neighboring buildings. In the case of Mexico, a country with high seismicity in general, the pertinent examinations must be carried out to guarantee this.

If it is unsafe, the building must be partially or totally demolished. This scenario must also be considered in the analysis, as a section on RCD Management.

The demolition of a building is not only making the decision and carrying it out, there must be a prior planning process if we want to implement it with CE criteria, so that from the acquisition of materials an estimate of the useful life is already conceived, so that once this is achieved, actions related to the collection and use of waste are applied through selective demolition, which consists of carefully dismantling the materials to use most of what is recovered in some other production process, either directly reintegrating them to a construction process or as secondary raw materials to be used in processes even unrelated to building. To carry out this task, it is convenient to consider that the prefabricated elements make up the structure,

This scenario evaluation must be carried out during the early stages of construction such as planning, where even the waste management plan issued by the Mexican Chamber of the

Construction Industry (CMIC) exposes the importance of incorporating the costs of collection and transportation of waste to the final disposal site in the budget, therefore considering the total generation of waste once the project has been executed, the corresponding explosion of inputs and the proposed management for each of them.

2. Construction

This stage is where all the strategies proposed during planning will be applied, so in order to know if the proposed objectives were achieved or not, it is necessary to keep a very good traceability of how the construction progress is going with respect to the work program, the expenses according to the assigned budget, as well as the consumption of energy, water and RCD generation. This will only be possible if there is strict management control.

Additionally, we propose that the environmental impacts continue to be measured and compared with those that had been originally foreseen; In the same way, the social ones, studying the reaction of the surrounding population as progress is made in the project, seeking to cause as little inconvenience as possible, working during daytime hours, avoiding closing roads, guaranteeing the safety of passers-by, among others.

It is advisable to review these indicators every two weeks, and if there is too large a variation, apply the corrective measures deemed necessary.

The costs that have to be covered during this phase are the salaries of the workers, the rent and inputs of the machinery, transport of the materials to the site, as well as to dispose of the residues.

3. Use and maintenance

Now the responsibility is transferred from the builder to the client, and it will be the client who inherits the commitment to do everything possible to continue keeping environmental, economic and social impacts to a minimum.

To achieve this, the first step is to structure a maintenance schedule. Prevention is better than correction, so it must always be given priority over repair. This must include having periodic reviews of the building's energy efficiency, that is, knowing if the system or product that best suits your needs is being used throughout the operation of the infrastructure; there is always some area where it can be improved, whether it is changing the lighting for energy-saving bulbs, implementing an automatic lighting system in strategic areas, etc. This action would promote the consumption of materials that meet these requirements and manufacturers to adapt to these requirements, giving priority to environmentally and socially responsible companies when purchasing these products or services.

This stage entails greater impacts in terms of energy and water consumption throughout the life cycle of a building, which is why it is the phase that is commonly assigned the most attention. Proof of this are the product categories that constitute a certification such as LEED. Additionally, it must be taken into account that if this phase continues to be optimized, the impacts of the other phases will be highlighted by their inefficiency in comparison. For this reason, the certifications must be prepared for this emerging situation and begin to include within their sustainable criteria beyond the emissions and consumption associated with the occupation phase.

This stage is also when you will begin to notice if the mitigation measures that were established during the planning and carried out during the construction of the work are giving the expected results, it is very important that they are monitored and that you already have a way of measure the correction achieved.

It is necessary to reiterate the point that we cannot fail to measure the impacts caused in this phase, always having a parameter against which we can compare the values obtained and with people dedicated to analyzing what measures can be applied to achieve the objective in case that they are insufficient.

4. End of its useful life

Once the demolition of a building has been carried out, there will always be leftovers, that is, residues, which due to the selective demolition that had been conceived since before the project was built, it is only a matter of establishing control and surveillance while this task is being carried out, everything so that resources that are still useful for other processes are revalued and do not end up in uncontrolled landfills, losing their value and degrading the environment in the process. The reintegration of materials to the phases of the life cycle covers:

- Reuse: That a product is used to use it as in its first life cycle, without loss of functionality.
- Recycling: For this, remanufacturing is considered, which, unlike maintenance, consists of reconditioning the product, repairing it for reuse or for another industry to take advantage of it for a different use.
- Incineration: Recovering the energy content of a compound, taking advantage of its calorific power and transforming it into an alternative energy source.

It must be noted that, just as all these materials are not usable in the same way, not all the waste generated from work is itself recoverable for its use, so it must be sent to specialized final disposal sites.

There are many alternatives to adequately treat RCD, however, anticipating and reducing the generation of waste will always take precedence over its disposal. Even so, if they are generated, there must be a management plan to deal with this situation.

CONCLUSIONS

The national context implies numerous limitations for the full use of LCA, where its application is even unknown. Therefore, there must be training to use software that standardizes sustainable criteria and methodologies, ceasing to depend on the communication between the agents involved (manufacturers, suppliers, distributors, builders, promoters, users, etc.), which already it is little. In addition, it is not possible to label a solution as ecological if the adverse effects of not using it are not measured, so the recording and analysis of data is key to monitoring improvements.

On the other hand, the issuance of the General Circular Economy Law (LGEC) in Mexico shows that the country intends to adapt to the current needs of society, where sustainability takes on great relevance within the development that every nation seeks and that its legislation is aimed at the responsible use of available resources. This economic transition must encompass the entire production chain, which is why the participation of the three levels of government, civil society and industry is mainly required to implement this systemic change.

This law is still in the process of being approved and it would be a mistake to wait to abide by its regulations until they are issued. This is where the role of LCA comes in, an ideal tool to modify production processes according to what the LGEC dictates, so there is still time to become familiar with this methodology until it is time to comply with its regulations.

There are already studies that have shown that applying efficiency methods in buildings helps to reduce their environmental impacts, such as the one carried out by the Mario Molina Center (a non-profit civil association for strategic studies on energy and the environment), which used LCA as a quantitative measurement tool in two scenarios, one consisting of the construction and operation of a building under a common standard and an efficient one (adaptation of existing buildings and use with optimized technologies from the extraction of materials to the end of their life useful, which was projected to last 50 years). This study ensures that it was possible to reduce the environmental impact from 32% to 45% in residential buildings, from 61% to 72% in office buildings,

So the use of LCA must not be underestimated, on the contrary, its application must be encouraged, as well as the innovation associated with the improvement changes that are sought to be implemented to mitigate environmental impacts during the life cycle of a building, contributing to its decarbonization within the framework of the Circular Economy.

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