Life Cycle Assessment as a Tool for Low Waste Building Systems, Case Study Building External Wall

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Abstract. Life cycle assessment (LCA) is defined as decision making method for buildings from “cradle to grave”. Considering the fact that the construction industry produces 38% of total waste and 40% of total CO2 emissions and uses 50% of all natural resources, according to EIB 2015, the building industry has to change this way of thinking to the concept “cradle to cradle”. According to European Commission (Directive 2008/98/EC 2008), the first and preferred option is waste prevention and the second option are other types of recovery. The waste should be prevented in the design phase and LCA should help a lot in this stage. The main goal of this paper is to show how the LCA can be used as a tool in design phase to help decision process in building design of one of the building systems and make that part circular and, if possible, without waste. External wall, as one of the systems of a building, is taken as case study in its different materialization to show LCA use in the construction waste elimination in building practice. The external wall is the system of a building which is the most exposed to external factors, as weather conditions and human. Very often, the wall is damaged before other systems of a building. Hence the design and building of external walls that produce less waste, is a huge step in construction waste management. The LCA software is used to compare two chosen case studies. The first one is prefabricated wooden wall for low energy houses. The second one is the wooden wall made for Green Design Centre in Mostar in 2018. The first results show that in the second case study, the wall made for reversible and transformable building, and designed according to circular building principles, has better chances to last longer, and produce less waste during its transformations and aging. The paper shows main principles for designing the low waste wooden walls and also some remarks how to upgrade the software to be more helpful in the design phase of the wall systems.

1. Introduction

1.1. Defining the environmental problem – construction and demolition waste

The increased pollution, concerning building constructing/demolition processes, at all implementation phases, makes the environmental protection the main concern in building practice. With limited spatial resources, the boom of construction waste disposed is to be considered as a huge problem. According
to EIB 2015 [1] the construction industry produces 38% of total waste and uses 50% of all natural resources. According to European Commission (Directive 2008/98/EC 2008) [2], the first and preferred option is waste prevention and the second option are other types of recovery.

According to M. Kozlovska 2013 [3] “Although, almost all financial funds are directed to supporting of the separation, reusing and recycling of waste, the landfilling presents a main form of waste disposal.” The consequences of this behavior could be fatal.

Bosnia and Herzegovina, as other transition countries, has the opportunity establishing the unique evaluation methods, systems or tools using and upgrading and combining the existing methods, that are relevant available from various EU sources. This country, still recovering after war destruction in every segment of life, has to be included in the global network for environmental protection.

2. Finding the tool for making the decision process easier

There are laws and tools at international level, which help evaluate the building case study in terms of environmental impact, but there are so many unknown or presumed variables, that compromise the final result and endanger its values. Life cycle assessment (LCA) is one of the techniques developed as decision making method used in the building practice.

“For practitioners of LCA, ISO 14044 details the requirements for conducting an LCA. LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave).”[4] The building process is going through: programming, design phase, realization/production/construction phase, use and maintenance phase, transformation and reuse phase and eventually deconstruction/demolition (Figure 1).

![Figure 1. Phases in life cycle of the building project and the building itself](image)

In the final mentioned phase, term “demolition” should be considered as deconstruction or disassembly of the building parts when building life cycle is over, with the goal to bring back all parts to the construction phase again, if possible. LCA should be able to help in this process.

2.1. LCA as a tool to lower construction waste on landfills

The calculations were performed with One Click LCA calculation tool. The life cycles stages, which are used in the mentioned software, according to the standard EN-15978 are shown in Figure 2.
In this research the main focus will be materials used and what happens with them during the building exploitation stage and recommendations on what is possible when it is not possible to use them as they were intended in the first building cycle (in the field of Benefits and loads beyond the system boundary).

3. Choosing the representative case studies
A building is a complex system, with lots of layers: site, stuff, space, services, structure and skin, according to Brand S [7]. What will happen with it, depends on many different factors. In this case, the layer “skin” is in focus.

As it was stated in the paper R. Castro 2018 [8]“As a consequence, building materials associated with these building “layers” will determine material flows within a building’s life cycle, the environmental impacts of replacing these elements, and provide opportunities for the improvement of materials used in the building.”

According to E. Durmisevic 2006 [9], the building system, can be divided into subsystems: components, elements and materials.

It is possible to put all building data into the LCA software and get results, as well as recommendations from the tool, or to consider one of the systems and do more detailed and more precise analyses. In that case, considering the smaller part of the building, we will be able to get more precise data and evidence based conclusion regarding decisions. The possibility to miss something in more complex system is bigger, as the number of variables is bigger, thus it makes the impossible to take all of them into account.

External wall is taken as a case study in its different materialization to show how the LCA can be used in the construction waste elimination in actual practice in the building processes. The external wall is the system of a building which is the most exposed to external factors, such as weather conditions, or human impact. Very often, the wall is damaged before other systems of a building.

3.1 Case studies and software used for calculation
Two external composite wooden walls made in B&H are the two case studies, where the LCA tool is applied to help decision process. The first wall, prefabricated wooden wall for low energy houses, is mostly used in the residential buildings, but can also be used in other building types (Figure 3).
1. Three layer reinforced façade 6mm
2. Styrofoam 200 mm
3. OSB board 12 mm
4. Solid wood frame 160 mm
5. Rock wool 160 mm
6. PE foil
7. OSB board 12 mm
8. Insulation-installation wooden grill 45 mm
9. Rock wool 45 mm
10. OSB board 12 mm
11. Gypsum cardboard board 12,5 mm

**Figure 3.** Existing façade system made of wood [10]

The second GDC wall is used in Pilot Project Green Design Center Building in Mostar, which final goal is to be used as educational hub (Figure 4).

**Figure 4.** Façade system made of wood developed for Green Design Center in Mostar [11], [12]

Specific default conditions have been chosen in the OneClick LCA tool. In both cases, the assumed building areas are the same, as well as the transport distances (European, set as default in software), and the same transport vehicles. Both walls are designed for low energy buildings, so the assumption is that they will have the same energy consumption during the use stage. 1m² of the wall will be analyzed regarding use of materials and environmental impact. The chosen service life values for materials is the same for the same material - technical service life (“represents how long a type of material lasts in good condition”) [6].
Used trial OneClick LCA software tool [6], in compliance with BREEM International, is considering the following environmental impact categories:

- Global warming (GWP)
- Acidification (AP)
- Eutrophication (EP)
- Nonhazardous waste disposed (NHWD)
- Biogenic carbon storage (Bio-CO2 storage).

In this study, the nonhazardous waste processing is in focus.

4. Discussion about results

Mentioned two case-study walls in BiH are analyzed in terms of reuse potential in study conducted by Androsevic R., and presented in the paper 2019. [12]. That study compared the two case-study walls (Figure 3 and Figure 4) in terms of their reuse potential and waste creation during transformations. That study showed that the GDC wall has very high reuse potential and less waste during its use, maintenance and transformation, comparing to the other prefabricated wall. It also shows less environmental impact of the GDC wall, in terms of less construction waste.

In the OneClick LCA simulation, comparing the two walls, the GDC wall 2 (Figure 4) shows slightly less environmental impact than wall 1 (Figure 3) in all categories, except quantity of nonhazardous construction waste (Figure 5).

![Figure 5. Results of environmental impact of two case study walls](image)

The conclusion about used materials shows that the GDC walls are slightly better but the amount of nonhazardous waste is showing just a total weight in both cases.
Figure 6. Results of non-hazardous waste disposed, by stage, for the two case-study walls

So, in the first cycle of buildings system life, during the production and usage phase, the environmental impact seems almost the same for two walls, but when it comes to the concept of “cradle to cradle” and second cycle of life of building system and its elements, we have to be sure which system allows us to take out and store elements we can use again and which system does not. Also, the LCA should consider what the consequences and environmental impacts are for reusing the parts or for dumping the materials on the land field.

5. Conclusions

Construction demolition waste is one of the most important indicators of environmental pollution and economic, environmental and social sustainability and comfort directly from it. It should be considered very seriously and decision making tools should be developed for that purpose.

Considering the available literature and software based on LCA, LCA tools have brought much improvement in pushing the toxic and hazardous materials from the industry, giving the right data for the materials used and making the decision process easier.

Used OneClick LCA software helps users to find better choice of materials used, providing and using the EPD (environmental product declaration) with the purpose of lower environmental impact regarding their production in terms of ingredients used (environmentally friendly substances used), energy and water consumption during production and use. But, also in case that there are all environmentally friendly materials chosen and put together in one of the building systems – in this case the wall, where such wall can get mentioned certificate (LEEDS, BREAM etc.), that doesn’t mean that there will be suggestions what to do with the calculated quantity of nonhazardous waste in the building.
The LCA analysis needs improvement and should include the component or system disassemble possibilities, so the users can really benefit from the final results/scores/ and get suggestions how to choose wisely to have longer and healthier building life.

The possibility of material separation can be added as one of the factor in the whole process, and this can be monitored specifying the connections between the building and building system parts and suggesting the connections and disassembly possibilities in design phase.

Also, there should be environmental impact calculation for two case scenarios:

- storing and incorporating the parts in new structure, and
- dumping the parts of the system.

In the first scenario we have “green” and usable product after the first cycle of building’s/system’s/life and in the other scenario we have construction demolition waste which goes to the landfill.

LCA should be a tool for a circular sustainable building systems and its definition should consider concept “cradle to cradle”.

It will lead to the transition from linear to circular economy, the waste should be prevented in the design phase and guidance of LCA should continue through all other phases of the building project from “cradle to cradle” with the recommendations and decision making suggestions.

6. References

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