Comparing of the external bearing wall using three cultural perspectives in the life cycle impact assessment

M Wolfova, A Estokova, M Ondova and A Monokova

Department of Environmental Engineering, Faculty of Civil Engineering, Technical university of Kosice, Vysokoskolska 4, 042 00 Kosice, Slovakia

Abstract. The main aim of this research is to perform cultural perspectives analysis of a Life Cycle Assessment (LCA) case study to understand if the use of different Life Cycle Impact Assessment (LCIA) approaches may lead to a very different conclusions. A LCA was applied to analyse the environmental impacts of external bearing wall of two different compositions. In this study, the environmental comparison of the constructions was performed using the ReCiPe method in software SimaPro while considering three approaches of cultural theory: the hierarchist, the individualist, and the egalitarian. The results were compared using midpoint and endpoint indicators. The endpoint LCIA showed that each approach provided a different conclusion except for the hierarchist and egalitarian approach in the Resources indicator. The results for midpoint LCIA were in all impact categories the same with the exception of the terrestrial acidification and marine acidification.

1. Introduction

Life Cycle Assessment (LCA) is a methodology for evaluation the environmental impacts of service, product or a process all through its life cycle (ISO, 2006a) [1]. ISO characterizes between four phases in LCA framework: the goal and scope definition, the inventory analysis, the environmental impact assessment and the interpretation. Product life cycle includes all processes that may be related to the production, use and disposal of the product [2].

The building sector is considered to be the largest contributor to environmental pollution and resource depletion because it produces globally for 33% of greenhouse gases (GHG) emissions and consumes for 40% of the primary energy. Nevertheless, in line with the United Nations Environment Program, construction has the greatest potential to significantly reducing GHG emissions compared to other sectors that also emit emissions into the environment, in particular by reducing the operating energy of buildings, especially in cities [3]. The global urbanization trend, which is predicted to exceed 70% of all urban people by 2050, requires more comfort in the living space. Nowadays, cities represent approximately 67% of the global energy consumption, accounting for over 70% of all GHG emissions and consuming about 75% of all natural resources [4]. Another way to reduce the environmental loads of buildings is connected to the selective choice of the building materials which are environmentally suitable. LCA is the optimal method to evaluate the environmental impacts of the materials and constructions in order to provide their environmental performance.

This paper is focused on the LCA analysis of the environmental impacts of external bearing wall of two different compositions from three cultural perspectives. Both mid-point and end-point indicators have been taken into consideration.
2. Material and methods

2.1 Evaluated construction
The external bearing wall consisting of two different core materials, light clay bricks and aerated concrete block, was evaluated regarding its environmental impacts. The material compositions of the walls, expressed in function unit of 1 m², are given in tables 1 and 2.

Table 1. The materials used in the bearing wall consisting of light clay bricks.

| Material           | Density [kg/m³] | Thickness [mm] | Mass per 1 m² [kg] |
|--------------------|-----------------|----------------|--------------------|
| Base plaster       | 600             | 10             | 6.0                |
| Light clay brick   | 680             | 440            | 299.2              |
| Polystyrene foam   | 10              | 100            | 3.0                |
| Lime mortar        | 400             | 30             | 12.0               |

Table 2. The materials used in the bearing wall consisting of aerated concrete blocks.

| Material                     | Density [kg/m³] | Thickness [mm] | Mass per 1 m² [kg] |
|------------------------------|-----------------|----------------|--------------------|
| Base plaster                 | 600             | 10             | 6.0                |
| Aerated concrete block       | 500             | 300            | 150                |
| Polystyrene foam             | 160             | 160            | 25.6               |
| Cellulose fibre              | 230             | 40             | 2.0                |
| Acrylic binder               | 1850            | 3              | 5.6                |

Schemes of the analysed walls are presented in figure 1.

Figure 1. a) Light clay brick wall composition, b) Aerated concrete block wall composition.

2.2 The ReCiPe method
The ReCiPe method (SimaPro software) was used to evaluate the environmental impacts of the constructions. Characterization models can use two types of impact indicators, midpoint indicators and endpoint or damage indicators. Figure 2 shows the characterization framework addressing both midpoint and endpoint and illustrates the impact categories for the ReCiPe methodology [5].

Endpoints (or damages) typically refer to three areas of protection: human health, ecosystem health and resources. Damage to human health caused by different types of environmental stressors are quantified by changes in mortality and morbidity. The indicator commonly used to quantify human health is disability-adjusted life years. The DALY concept in LCA was introduced by Hofstetter (1998) on the base of Murray and Lopez (1996) for the WHO (World Health Organization) [6]. The unit for ecosystem quality is local relative species loss in terrestrial, freshwater and marine ecosystems, respectively, integrated over space and time (potentially disappeared fraction of
species×m³×year or potentially disappeared fraction of species×m³×year). To aggregate the impacts of terrestrial, freshwater and marine ecosystems into one single unit (species×year), we included species densities for these three types of ecosystems in the same way. The unit for resource scarcity is dollars ($), which represents the extra costs involved for future mineral and fossil resource extraction. Endpoint characterisation factors (CFe) are derived from midpoint characterisation factors (CFm) with a constant mid-to-endpoint factor per impact category [7].

![Diagram of impact categories for characterisation at midpoint and endpoint level]

**Figure 2.** List of impact categories for characterization at midpoint and endpoint level [5]

### 2.3 Approaches of Cultural Theory

Cultural Theory has evolved over the last 20 years to become an important framework for understanding how groups in society interpret dangers and build confidence or mistrust in institutions that create and regulate risk. Cultural Theory has been used as a tool within framework LCA. This Cultural Theory reflects vision of society and view on nature. Cultural theory distinguishes five perspectives generally three of these perspectives are used in environmental decision making. They are: individualist, hierarchist and egalitarian perspectives. Each archetype reflects the composition of ideologies, cultural prejudices, social relationships or moral convictions. The individualist is characterized by weak group coherence and prescriptions for social relations, and considers nature to be stable and able to recover from any intervention. In contrast with the individualist, the hierarchist is characterized by strong group coherence with obligatory prescriptions for social relations. In this perspective, nature is considered to be equilibrium. The egalitarian perspective has strong group coherence and considers nature to be breakable and unstable [2]. Overview of the different visions among the individualist, hierarchist and egalitarian perspectives as used in the evaluation are presented in table 3.

| I (Individualist) | H (Hierarchist) | E (Egalitarian) |
|------------------|-----------------|-----------------|
| **Time perspective** | Balance between short and long term (20 yrs) | Balanced time perspective (100 years) | Very long term (infinite) |
| **Vision on society** | Market - driven economic production | Development within natural limits | Equality and social governance |
| **Manageability** | Flexible management | Preventive and complex style of leadership | Control and limitation style of leadership |
| **Vision on nature** | Considers nature robust | Considers nature tolerant | Considers nature vulnerable |
| **Level of proof** | Ultimate reserve | Only proven effects | All possible effects |
The individual agrees with the view that humanity has a high adaptive capacity through technological and economic development and that the short-term perspective is justified. The hierarchical view coincides with the view that the effect of regular management can be avoided and that the choice of what is to be included in the model is based on the (scientific) consensus level. The egalitarian is consistent with the view that nature is strictly responsible, that the long-term perspective is justified and that the worst scenario is needed [2].

3. Results and discussion

3.1 Midpoint indicators
Modeling choices were analyzed by defining three coherent scenarios, based on Cultural Theory perspectives. Figure 3 presents the results of the environmental impact of 1 m² of the external bearing wall materials using light clay brick and aerated concrete block, calculated by ReCiPe method, in midpoint categories considering three cultural approaches I, H, E as mentioned above. Individual, hierarchist and egalitarian perspectives had their own contextual and preferential values.

![Figure 3. Comparison of the percentage share of the material on the midpoint category.](image)

The significant differences in the environmental impacts, evaluating I, H, and E cultural approaches, have been found for two indicators: human toxicity and ecotoxicity (figure 3). In our study, the overall ecotoxicity indicator included terrestrial, freshwater and marine ecotoxicity. In individualist and hierarchist perspective, the values calculated were almost the same, however, in egalitarian perspective the results achieved were 200 times higher for light clay brick and even 600 times higher for aerated concrete block. In egalitarian approach, ecotoxicity refers to the potential for biological, chemical, or physical stressors to affect ecosystems in infinite time perspective.

Small differences in the results, considering the cultural approaches, have been also noticed for climate change and terrestrial acidification. In all others environmental indicators, the calculated values were comparable for all approaches and the choice of the time horizon was negligible.

3.2 Endpoint indicators (damage assessment)
In this section, a comparison between the three cultural approaches is made using the results from the calculations of the endpoint indicator in three damage categories (figure 4).
The individualist and hierarchist approaches proved very similar and comparable results for both material compositions in two damage categories: human health and ecosystems (figure 4). Significant difference was observed when comparing these results to the results using egalitarian approach. Similarly as for the midpoints, the egalitarian-based calculation provided much higher score and thus much more negative environmental impacts.

Surprisingly, in the resources indicator, the hierarchist and egalitarian approaches resulted in the same environmental scores (422 for light clay brisk and 1200 for the aerated concrete) which were several times higher than those of calculated for the individualist approach.

3.3 Comparison of both material compositions of the bearing wall

The impact assessment results for the external bearing wall of both material compositions calculated by ReCiPe are presented in figure 5. Hierarchist method was applied to compare the environmental impacts of the constructions since this approach is most often used in the LCA analysis [8,9].

As it can be seen in figure 5, the wall with the aerated concrete blocks reached worse environmental score than the wall with light clay brick in all damage categories. The calculated values were higher 2.6, 1.9, and 2.8 times for human health, ecosystems and resources, respectively. Considering only these results without any additional technical parameters, use of light clay brick is
better environmental alternative than use of aerated concrete blocks what is in accordance with [10]. However, to make a clear conclusion, the multi criteria analysis, including other parameters, is of importance.

4. Conclusion
The paper presented a comparative LCA study of the environmental impacts of the construction of external bearing wall with light clay brick and aerated concrete block. Special attention was paid to evaluation of the results when applied three different cultural approaches (individualist, hierarchist and egalitarian). In order for the different LCA cultural theory to be compared, the results of the midpoint and endpoint impact categories have been calculated by ReCiPe. The external wall with the light clay brick was evaluated to be the better alternative than the wall with the aerated concrete blocks. The results point to the importance of choosing the optimal approach for the environmental evaluation in building industry. The proper choice of method or perspective should be dependent on the purpose of the evaluation and way of utilization of the results. Another point is that not only the results calculated by the same method but by the same cultural perspective as well can be compared each other.

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