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Ecologic Impact Analysis of Construction Materials

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ABSTRACT

This research's purpose is to assess the ecological effect produced by the building materials, by means of the ecological impact analysis implementation. The study aims to investigate the ecological impact of the main construction materials based on various criteria exist in the literature. The effect of eight different fundamental construction materials (glass, shingles, ceramics, iron-steel, wood, concrete, copper, aluminum) on the environment is of big concern and environmentally conscious designed constructions are essentially demanded. By considering the construction materials' nine different environmental impacts (photochemical oxidation, terrestrial eco-toxicity, freshwater aquatic eco-toxicity, human toxicity, stratospheric ozone depletion, climate change, water demand, global warming potential, primary energy demand) and two other physical properties (density, thermal conductivity), a comparison between the alternatives is presented based on the mentioned criteria. Finally, the eco-friendliest construction material based on the criteria is determined.

1. Introduction

The construction and building sector consumes big quantities of energy and raw materials. The share of the sector in the worldwide raw material consumption is approximately 24% according to Bribian et al. [1]. The conventional construction materials involving glass, aluminum concrete, and steel are big energy content substances [2]. The buildings' effect on the ecology in the course of their overall life cycle and the choice of used materials determine their effectiveness. These construction materials are utilized in diverse steps, from preliminary construction by means of the running step when the construction are refurbished and maintained to keep their familiar operating until their service life's end [3]. Thus, it is a field that planners can have important ecological data if they are appropriately familiarized with the inclusion of environment friendly construction materials' field into the building's plan [4].

According to Franzoni (2011) the construction material selection plays a significant role in accomplishing the sustainable-environmental advancement aim in the building sector [5]. The selected materials with embodied energy's high contents entail the energy consumption's preliminary high level in the generation procedure, which is related to the greenhouse gas emissions' great levels [6]. With the power effective plan application, the construction materials' preliminary process power turns a more significant solicitude. Thormark furthermore expresses that more consideration should be designated not only to the building's functioning power but to the construction material selection as well [7]. Nonetheless, by Teshnizi and Saghafi (2011) the sustainable-environmental construction material choice for a structure is the most challenging and difficult work [8]. It is out of the skill and time of the

plan designers to include ecological perspective of structure technologies and building materials. With the environment, the continuum will contain developing and analyzing construction materials' environmental profiles and their interaction. This is a field that is greatly unfamiliar because of the variations' and variables' high level [9].
There are a lot of search papers dealing with troubles with materials' ecological impact.

2. The Model Structure

To obtain a framework for relations with multi criteria decision-making issues, a hierarchical model is structured. Among decision levels, the model adopts a unidirectional hierarchical connection among the criteria. The selected methodology permits the hierarchical tree building and weighing each indicator through pairwise comparison between indicators and criteria by a matrix to obtain a coherent and consistent administration of both qualitative and quantitative data. To determine weights of criteria, such a method is used in this paper.
In the hierarchy for determining the ecological impact of construction materials, the ultimate goal would be choosing the most appropriate materials that satisfy various sets of criteria. These criteria are often subdivided into several sub-criteria. This study involves two main criteria of top level. Physical characteristics involve density and thermal conductivity. Ecologic characteristic of analyzed materials are considered as the second main group of criteria. Global warming potential, primary energy demand, water demand, human toxicity, stratospheric ozone depletion, climate change, freshwater aquatic ecotoxicity and photochemical oxidation are evaluated within this group. Eight different construction materials are compared from the perspective of each criteria mentioned. The hierarchy composed of these criteria is constructed as shown in Table 1 below:

Table 1. Hierarchy of Criteria

Main Criteria	**Physical Properties**	**Ecologic Impact**
Sub-criteria	Density	Primary energy demand
	Thermal Conductivity	Global warming potential
		Water demand
		Climate change
		Stratospheric ozone depletion
		Human toxicity
		Freshwater aquatic ecotoxicity
		Terrestrial ecotoxicity
		Photochemical oxidation

While measurements for some criteria are readily available, some others can only be estimated with respect to other variables. As it is the case in all multi-criteria decision making methods, the relative priorities of such criteria need to be determined. This is accomplished by pairwise comparison of the factors, starting with the main criteria. Below are the resulting physical and ecological properties shown in Figure 1. The figure indicates the relative importance of the physical versus ecological factors. The result indicates that the physical factors are twice as important as the ecological counterparts.

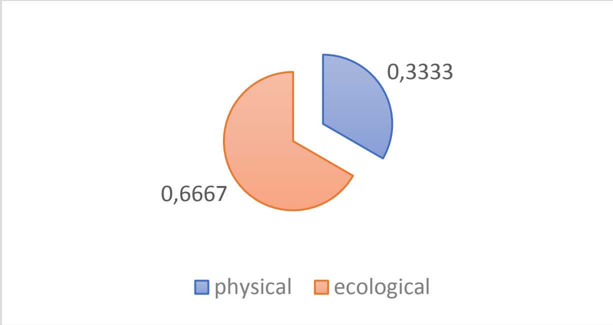


Figure 1. Priorities of main criteria

In the next step, there are groups of sub-criteria under each main criterion to be compared two by two. Each pair of sub-criteria related to the physical characteristics is compared based on their impact on physical property criterion.

At this point, the comparison for physical property criteria has been made, and the method has derived the sub-priorities for this group. These priorities reflect on how much it contributes to the priority of its parent, thus we need to calculate the global priority of each sub-criterion which shows the impact of each sub-criterion on the overall goal of determining the ecological impact of the selected materials. The global priorities throughout the hierarchy should add up to one. The global priorities of each sub-criterion are calculated by multiplying their sub-priorities with the priority of its parent criterion which results in the following values for the sub-criteria under physical property. Table 2 shows the resulting global weights for these criteria based on pairwise comparisons.

Table 2. Sub-group priorities

	Composition	
Sub-criteria	Density	Thermal Conductivity
Global Priority	0,055556	0,277778

The second group of sub-criteria involves the ecological impact characteristics that are measured under the categories of *global warming potential*, *primary energy demand*, *water demand*, *stratospheric ozone depletion*, *climate change*, *freshwater aquatic eco-toxicity*, *human toxicity*, *photochemical oxidation.* All these elements are compared as to how significant impact they have on the overall goal. Figure 2 shows the global priorities of the mentioned group of sub-criteria. The factor weights are within the range from 0 to 1.

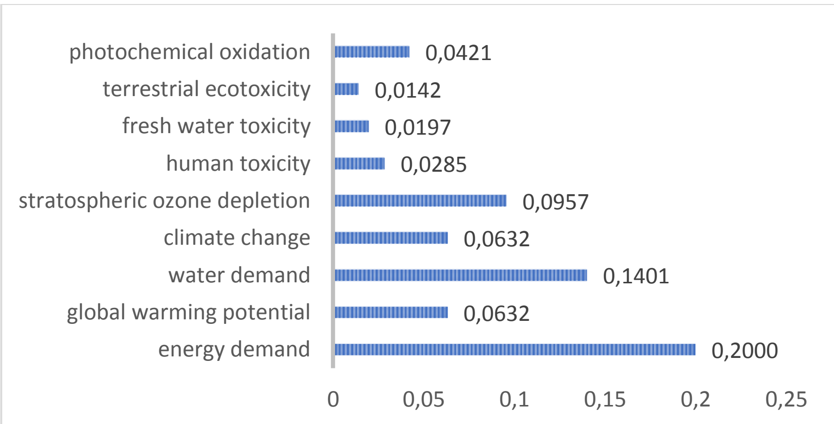
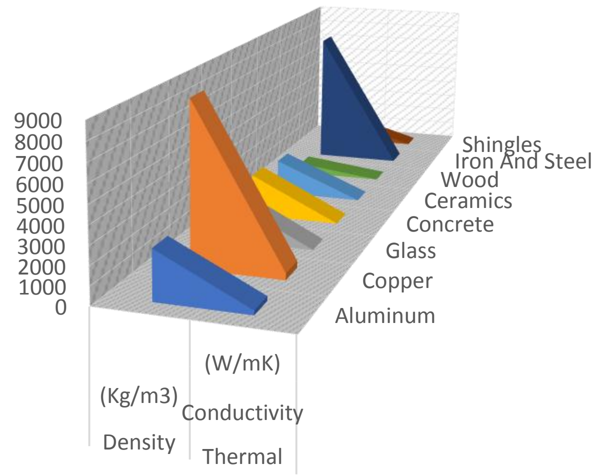


Figure 2. Global priorities of sub-criteria under physical properties

After determining the priorities of the main criteria in regard to the overall purpose and priorities of each sub-criterion with respect to their own main criterion, the construction materials are compared two by two with respect to each sub-criterion. 8 different materials are used for the purpose of this investigation to be evaluated.

The properties of the selected materials are presented in Table 3 and 4 below:

Table 3. Physical properties



	Density (Kg/m3)	Thermal Conductivity (W/mK)
Aluminum	2700	239
Copper	8920	380
Glass	2500	0,95
Concrete	2380	1,65
Ceramics	2000	1
Wood	600	0,13
Iron And Steel	7900	50
Shingles	1400	0,17

Table 4. Ecological impacts

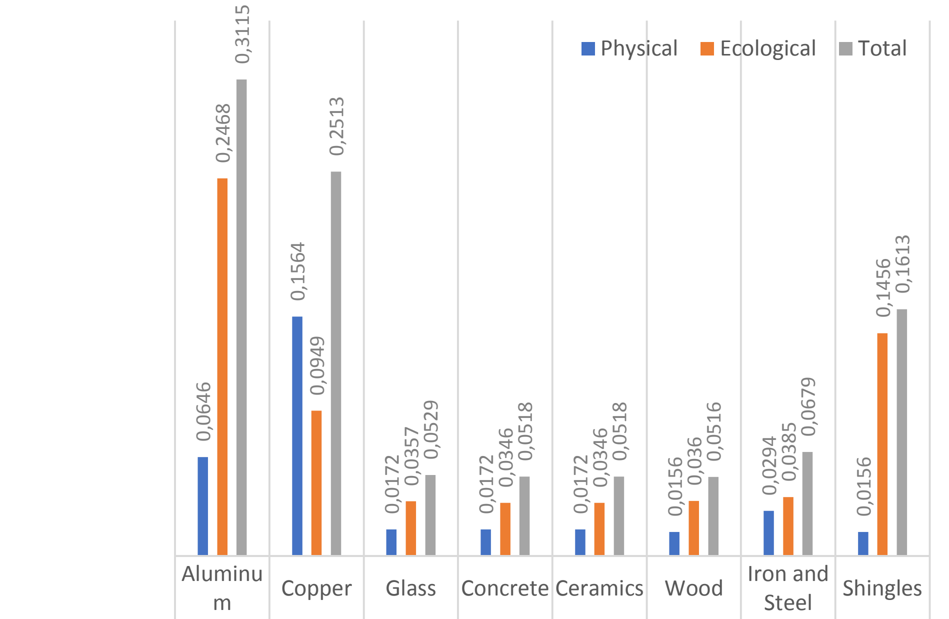
	Primary energy demand (MJeEq/kg)	Global Warming Potential (kg CO2eEq/kg)	Water demand (l/kg)	Climatechange_GWP 100a (CO2 biogene and esource GWP=1, NMVOC average) [GLO]	Stratospheric ozone depletion ODP steady state(NMVOC average)[GLO]	Human toxicity_HTP infinite(PAH average, Xylene average, NMVOC average)[GLO]	Freshwater aquatic ecotoxicity_FAETP Infinite (PAH average, Xylene average, NMVOC average)[GLO]	Terrestrial ecotoxicity_ TAETP infinite (PAH average, Xylene average, NMVOC average)[G LO]	Photochemical oxidation (summer smog)_high NOx POCP(NOT NOx average, NMVOC average)[RER]
Aluminum	136.803	8.571	214.341	8.01	5.5E-07	16.9	3.87	0.0983	0.00192
Copper	35.586	1.999	77.79	2.01	2.3E-07	88.2	2.54	0.369	0.00582
Glass	15.511	1.136	16.53	0.563	9E-08	0.252	0.0586	0.0016	0.00034
Concrete	1.105	0.137	2.045	0.123	6.7E-09	0.0243	0.0201	0.00023	1.7E-05
Ceramics	15.649	0.857	14.45	0.23	2.1E-08	0.0739	0.023	0.00029	6.6E-05
Wood	20.996	0.3	5.119	-0.597	2.6E-08	0.05675	0.0186	0.00059	0.00016
Iron and Steel	24.336	1.526	26.14	1.65	4.2E-08	0.36	0.263	0.00384	0.00113
Shingles	73.207	4.267	511.999	4.61167	1.2E-07	1.23275	1.85	0.00587	0.00135

The final step in applying the technique is alternatives' pairwise comparisons in regard to each sub-criterion. In order to design an objective scheme for this purpose, the minimum and maximum values of the options for each sub-criterion are determined. This range is divided into nine even ranges on a scale from 1 to 9. Finally each material type is placed in one of these ranges based on their values to compare them with each other.

3. Results and Discussions

The list of criteria is evaluated and divided into two groups. Each criterion is appointed a relative priority based on expert evaluations. Finally, the solution method is applied to the resulting scheme. Based on the calculations above, the relative priorities corresponding to the ecological impact of each material about all factors are presented below:

Table 4. Materials



	Aluminum	Copper	Glass	Concrete	Ceramics	Wood	Iron and Steel	Shingles
Physical	0,0646	0,1564	0,0172	0,0172	0,0172	0,0156	0,0294	0,0156
Ecological	0,2468	0,0949	0,0357	0,0346	0,0346	0,036	0,0385	0,1456
Total	0,3115	0,2513	0,0529	0,0518	0,0518	0,0516	0,0679	0,1613

The obtained results indicate that the Wood with a global priority of 0.0516 is the eco-friendliest material based on the criteria selected. Concrete and ceramics follows the wood with a slight difference. On the other hand, Aluminum obtains the largest score of 0.3115 presenting itself as a hazardous material to the environment compared to the rest of the materials studied here. Similarly, high score of shingles under ecological criteria presents itself as an environmental problem although its physical characteristics are at the desired levels.

4. Conclusions

This study aims to investigate the ecological impact of the main construction materials based on various criteria exist in the literature. These criteria cover a wide range of potential ecological impact categories. Aside from providing a quantitative method to evaluate the alternative fuels, this study brings together a wide range of properties that are grouped under a set of criteria.

The model developed within the scope of this study can further be enhanced or improved to cover different aspects of materials for the construction industry and serve both the policy-makers and the industry itself.

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