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EVALUATION OF FLOOR COVERINGS FROM THE ECOLOGICAL AND ECONOMIC ASPECT IN THE DESIGN STAGE

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Abstract: Measures to reduce the impact of the construction sector on the environment and human health need to be taken at the design stage of the facility and evaluate building materials and products from an ecological and economic aspect. For the research needs, a comparison of floor coverings at the design stage was made to assess their impact during the life cycle. The research uses the life cycle analysis (LCA), a methodology that is the basis for analyzing the impacts during the life cycle of the analyzed construction products. The research covers the life cycle stages from A1 to C4, according to the standard ISO EN 15978: 2011. The software package BEES, the National Institute of Standardization and Technology (NIST), the United States of America is used for the turn. Five types of floor coverings were analyzed, from the aspect of their impact on the environment and human health, but also from the economic point of view. The research has shown that in the design phase, using software packages can be managed with the quality of the environment, and the project design, and hence the quality of the facility. The research also points to the need for a national software package that can analyze construction products and materials. Their application would improve the national construction industry and favored materials that are environmentally and economically acceptable in relation to materials with unfavorable effects on the environment and human health.

Keywords: building materials, life cycle analysis, floor coverings, and environmental impact.

1. INTRODUCTION

The impact of the construction sector on the environment and human health is an important factor recognized by the European Commission as a way to reduce greenhouse gas emissions (GHG). For this reason, the European Commission has adopted a number of measures aimed at putting the construction sector under the control, to implement measures to reduce the impact on the environment and human health [1-2]. Implementing ecological principles, and the use of materials with less impact on the environment and human health, is closely related to the economic factor, the cost of materials, or building components and its lifetime. Both factors are important in selecting, but at the design stage the ecological factor is not clear enough and recognizable, while the economic factor is most often seen through the current price in the market and the lifetime of the construction product is not considered. Architects have the opportunity to take the lead in redefining the principles for the design (design) of low-carbon buildings and contribute to innovation in this area, notes Sturgis (2017) [3]. The role of the architect is crucial in this regard, the authors [3] conclude in their research crucial.

In developed countries, but also in a growing number of developing countries, an ecosystem approach is adopted, which is a strategy for integrated and sustainable land, water and resource management, as well as the promotion of the concept of environmental protection. The principles of sustainable Green Design are based on energy efficiency, sustainable use of water, reduction of greenhouse gas (GHG) and carbon dioxide emissions and the use of renewable energy sources [4].

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Observation by the authors [5] that an object declared as ecological is not checked and the most favorable variant for human health and the environment. Different aspects of "Green Architecture" are considered from a whole series of authors, among which [6] majority of them conclude that more attention should be paid to selecting the material from which the object is being built.

The possibility of applying material is considered from the aspect of its life cycle and the impact on the environment at all stages of production through transport, installation and exploitation, dismantling and as a very important influence in this regard the post configuring aspect [7] is also considered.

The use of traditional, environmentally friendly materials in the human environment, safe for human health, is an important aspect of construction, which gets more and more significant and is applied in an environmentally friendly building. Ecologically acceptable materials are those products that do not contain hazardous substances for health, and can be produced and recycled with low energy consumption or removed safely in the human environment [8].

The European Commission recommended LCA as a methodology for identifying the potential impacts of products or services throughout the life cycle of the environment [2]. The LCA MSTD is ISO 14040: 2006 and is used to identify and evaluate stressful circumstances from products, processes or services by identifying energy and materials used as well as emissions throughout the life cycle [9].

Research on the impact of products used to build using LCA can help deciding which product and system [10-12] to choose to build. The LCA methodology for building construction is defined by the standard EN 15978: 2011 [13]. The standard is the life cycle of the building divided into five phases, and as an extra phase outside the system boundaries, phase (D) is the same.

The impact of global climate changes has indicated the necessity for the reduction in the emissions of greenhouse gases (GHG). In 2008, the building sector in Serbia participated with over 41% in energy consumption [14].

This research will show whether there is a possibility to assess the environmental impact of construction materials at the design stage and evaluate and select from an ecological and economic point of view.

2. DESCRIPTION OF THE RESEARCH

For the needs of the research, five types of floor coverings have been analyzed, which are usually used in the construction of an object to make an assessment of their environmental impacts from A1 to C4 at the design stage. In addition to environmental impacts, the economic aspects of the application of the analyzed floor coatings have been analyzed.

The study uses the Life Cycle Analysis (LCA), a methodology that is the basis for the impact analysis during the life cycle of construction products. In the absence of a national program, the BEES [15] software package is used to calculate the ecological and economic performance of the analyzed floor coverings, which is available on the National Institute of Standardization and Technology (NIST). In the program it is possible to find materials and construction products similar to those used in Serbia for the construction of buildings. In addition, it is possible to adjust the transport distance from the production facility to the construction site, so that emissions from transport are included in the budget. In addition to environmental performance, the software also provides the possibility of comparing the economic aspect of the product. The research analyzed five types of floor coverings, from an ecological and economic point of view. The research covers the life cycle stages from A1 to C4, according to the standard ISO EN 15978: 2011[13]. The system boundaries are shown in Figure 1.

The research intends to check whether it is possible to evaluate the floor coverings from the aspect of their impact on the environment and human health at the design stage, and to choose a product with better ecological and economic characteristics. The aim of the research is to verify the possibility of managing the quality of the environment, air quality, checking the possibility of reducing impacts on human health, design the product life, economic aspect and improve the design, and the quality of the object in the design phase by using software packages.

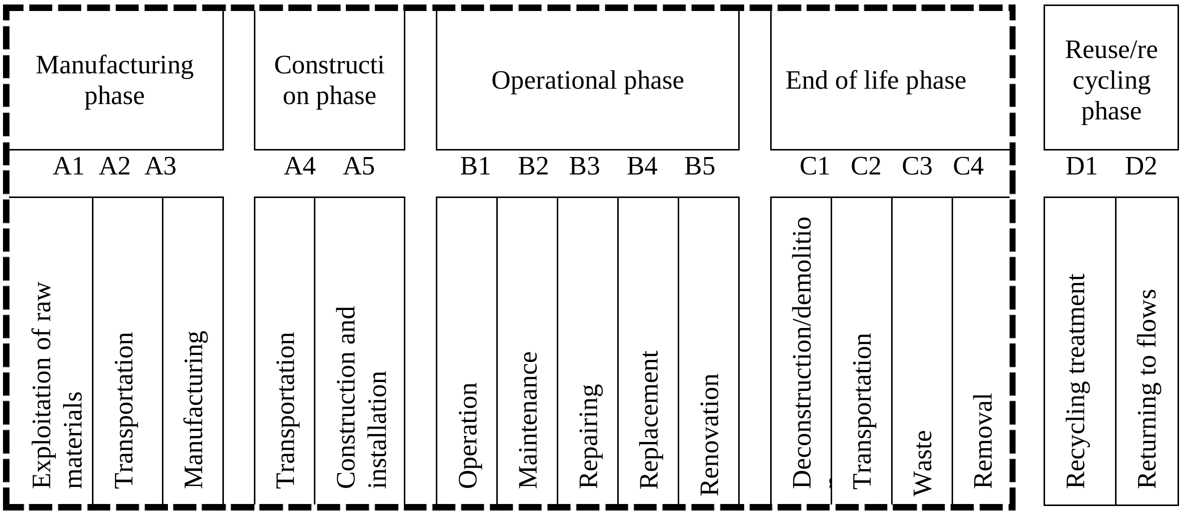

Figure 1. Boundaries of the system

3. RESULTS AND DISCUSION

For the purposes of research, construction products have been selected in the BEES [15] software package to be used as floor finishes, so that by evaluating their environmental and economic performance, the best choice product could be proposed. Five floor coverings were evaluated: (CP1) Comp Marble, (CP2) Medfloor CN, (SP3) NC Parquet, (SP4) NC Floating, and (SP5) PBCush Neut. Materials (construction products) that are valued in the research are shown in Table 1.

Table 1. Materials (construction products) those are valued

Type of material	Units of measure	Construction products
Comp Marble	(m^2)	CP1
Medfloor CN	(m^2)	CP2
NC Parquet	(m^2)	CP3
NC Floating	(m^2)	CP4
PB Cush Neut	(m^2)	CP5

3.1. Analysed influences of materials for floor coverings

In the BEES on the National Institute for Standardization and Technology (NIST) package, selected construction products can be evaluated in terms of impact over the life cycle, but their individual environmental and economic performance can be evaluated. In addition, it is possible to adjust the relationship between environmental and economic characteristics, give greater importance to one or the other in selecting the product that would be the best choice.

The parameters evaluated for the floor coverings in this study are shown in Table 2.

A detailed study of the ecological, LCA and economic effects of the analyzed materials is given in the following tables.

Table 2. Evaluation parameters in research

No	Environmental and Economic parameters
1.	Environmental Impact during LCA
2.	LCA Global Warming
3.	LCA Criteria Air Pollutants
4.	Indoor Air Quality
5.	Environmental Performance
6.	Economic Performance
7.	Overall Performance

3.1.1. Comparison of Environmental Impact during LCA

Comparison from the aspect of environmental impact during LCA is shown in Chart 1. and Table 3. Therefore, according to the obtained results, the best value is (CP3) NC Parquet, (CP4) NC Floating followed by approximate results by (CP2) Medfloor CN, and (CP5) PBCush Neut and six times higher values last (CP1) Comp Marble.

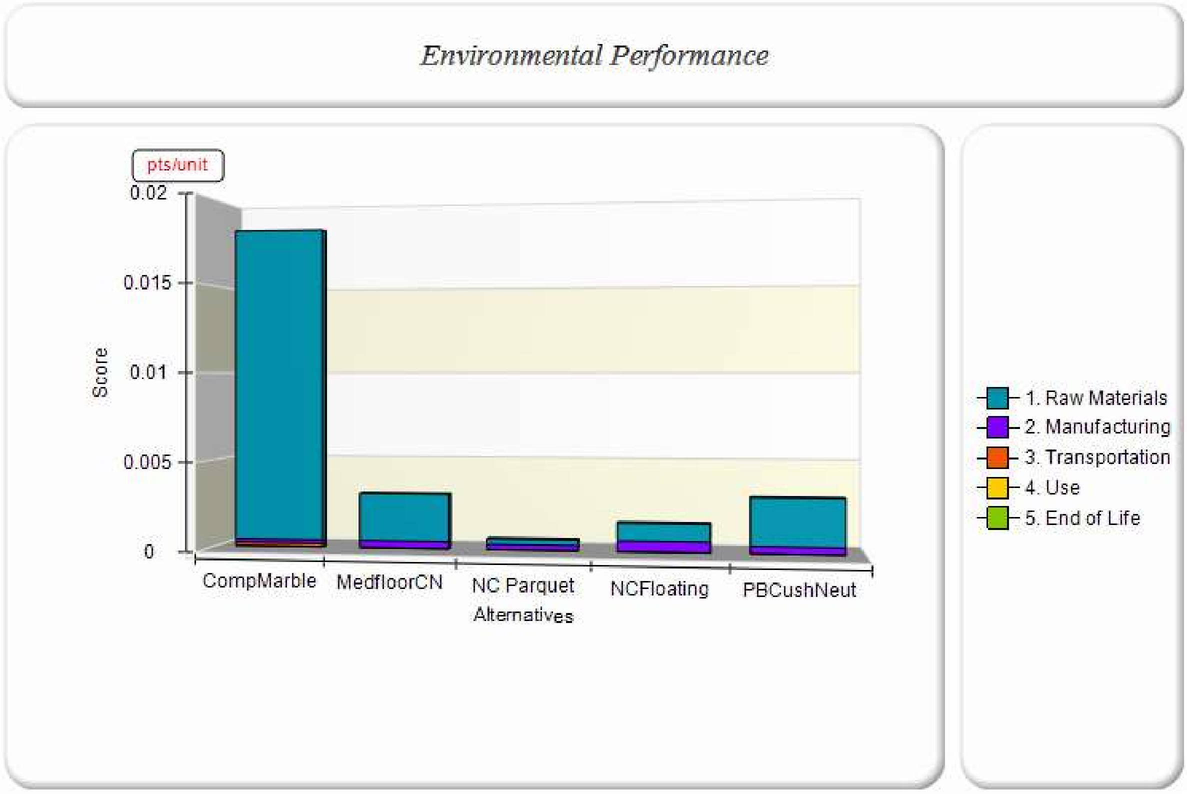

Chart 1. Comparison of flooring in terms of potential for environmental impact by life cycle stages

Table 3. Comparison of flooring in terms of potential for environmental impact by life cycle stages

Environmental Performance*					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
1. Raw materials	0.0178	0.0027	0.0003	0.0010	0.0027
2. Manufacturing	0.0002	0.0004	0.0003	0.0006	0.0004
3. Transportation	0.0002	0.0000	0.0000	0.0000	0.0000
4. Use	0.0000	0.0000	0.0000	0.0000	0.0000
5. End of Life	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	0.0182	0.0031	0.0006	0.0016	0.0031

3.1.2. Comparison of LCA Global Warming

Comparison from the aspect of global warming potential is shown in Chart 2. and Table 4. The best features displayed (CP2) Medfloor CN and (CP5) PBCush Neut, they have no impact, and the third in the series is (CP3) NC Parquet. (CP4) NC Floating with a threefold increase in global warming potential in (CP3) NC Parquet yields. In the fifth place with a 10-fold impact is (CP1) Comp Marble.

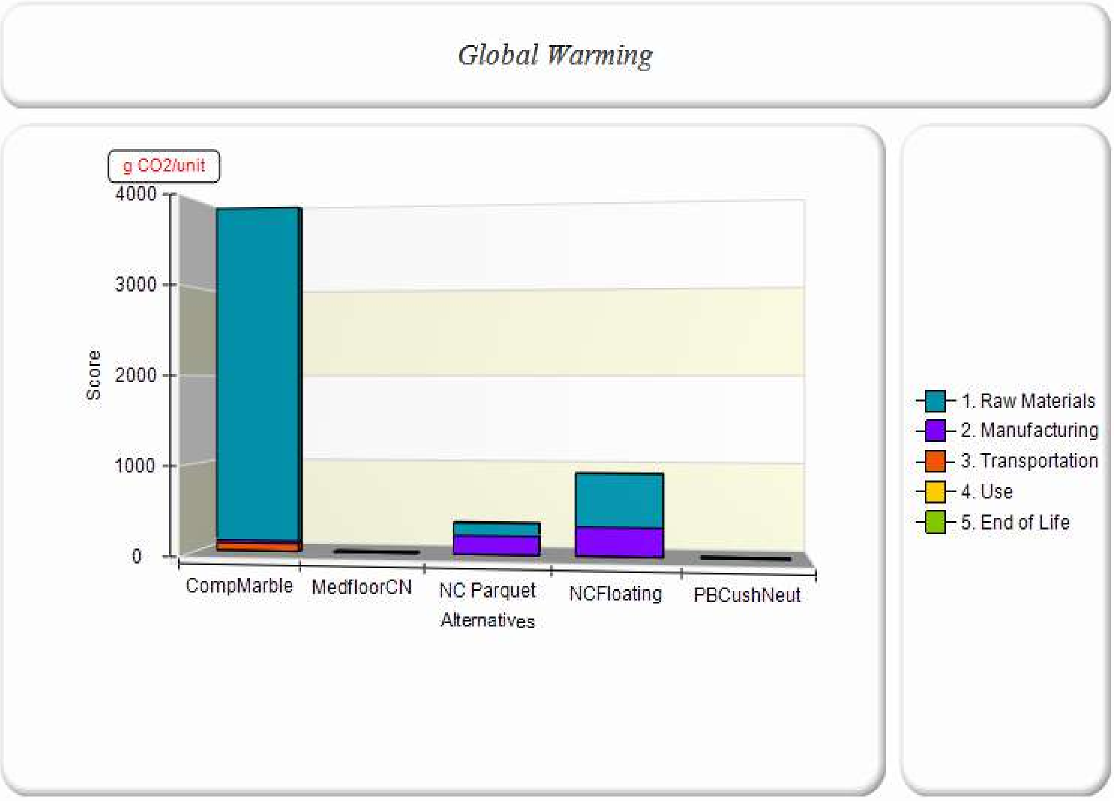

Chart 2. Comparison of floor coverings in terms of the potential for global warming by life cycle stages

Table 4. Comparison of floor coverings in terms of the potential for global warming by life cycle stages

LCA Global Warming					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
1. Raw materials	3793.6067	0.0000	141.3976	590.5421	0.0000
2. Manufacturing	31.7015	0.0000	205.2071	316.1961	0.0000
3. Transportation	86.2010	0.0000	3.0311	6.9316	0.0000
4. Use	0.0000	0.0000	0.0000	0.0000	0.0000
5. End of Life	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	3911.5092	0.0000	349.6358	913.6698	0.0000

3.1.3. Comparison of LCA Criteria Air Pollutants

Comparisons of total air emissions for the analyzed floor coverings are shown in Chart 3. and Table 5. The lowest values of total air emissions over the life cycle are given by (CP3) NC Parquet, followed by (CP4) NC Floating, with the highest emissions by (CP1) Comp Marble. When it comes to materials (construction products) used indoors, emissions into the air during the use phase are important, which indicate a problem with the use of (CP3) NC Parquet and (CP4) NC Floating. This is due to the fact that varnishes are used for finishing these coatings, so this can be overcome by using a water-based coating, thus eliminating the essential parameter for the interior space.

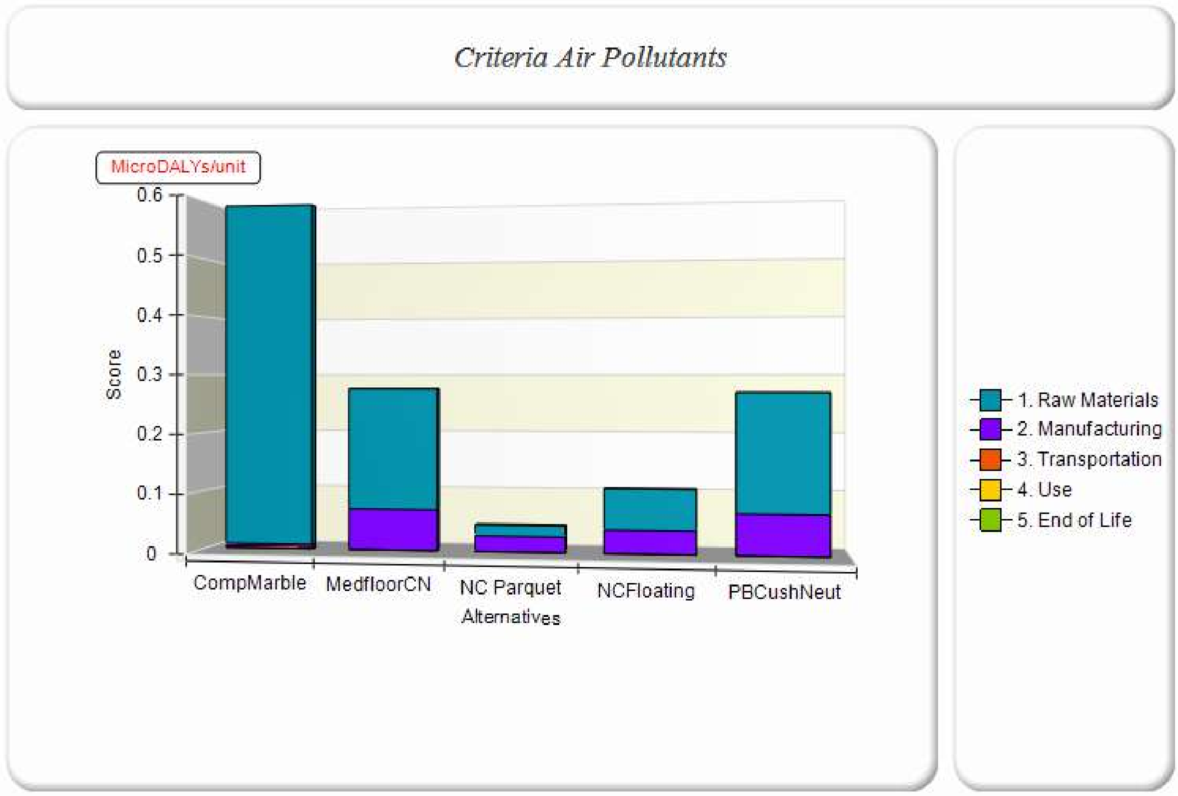

Chart 3. Comparison of floor coverings from the aspect of air emissions by life cycle stages

Table 5. Comparison of floor coverings from the aspect of air emissions by life cycle stages

LCA Criteria Air Pollutants					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
1. Raw materials	0.5849	0.2057	0.0185	0.0691	0.2009
2. Manufacturing	0.0041	0.0700	0.0264	0.0393	0.0693
3. Transportation	0.0038	0.0001	0.0001	0.0003	0.0001
4. Use	0.0000	0.0001	0.0018	0.0018	0.0001
5. End of Life	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	0.5928	0.2758	0.0450	0.1087	0.2703

3.1.4. Comparison of Indoor Air Quality

The effects on indoor air quality for the analyzed building products used indoors during the use phase are shown in Chart 4. and Table 6. The highest values of (CP3) NC Parquet and (CP4) NC Floating indicate a problem arising from the application of finishing varnishes and adhesives for the installation of these floor coverings. This problem can be overcome by using water-based coatings, which eliminates this significant problem for the interior.

Chart 4. Comparison of floor coverings from the aspect of influence on indoor air quality

Table 6. Comparison of floor coverings from the aspect of influence on indoor air quality

Indoor Air Quality					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
(a) Indoor Air Quality	0.0000	0.0001	0.0018	0.0018	0.0001
Sum	0.0000	0.0001	0.0018	0.0018	0.0001

3.1.5. Comparison of Environmental Performance

A comparison of the overall environmental performance of the environment for floor finishing products is shown in Chart 5. and Table 7. The obtained values for (CP3) NC Parquet are the lowest, which means that this product is the best choice in the environmental impact of the environment. Then (CP4) NC Floating has approximately three times greater impact, then (CP2) Medfloor CN and (CP5) PBCush Neut have five times higher impact values than NC Parquet. Thirty times higher impact values have the latest in the (CP1) Comp Marble range compared to the best-rated (CP3) NC Parquet product.

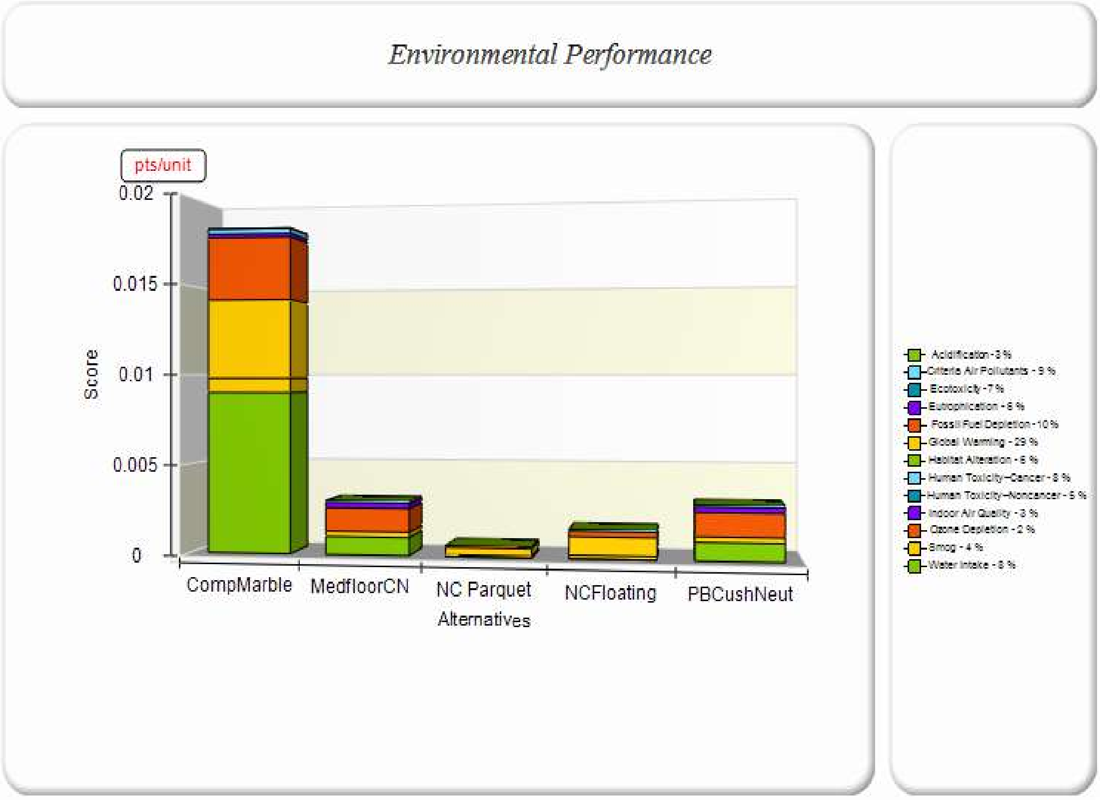

Chart 5. Comparison of total environmental performance of flooring

Table 7. Comparison of total environmental performance of flooring

Environmental Performance					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
Acidification -3%	0.0000	0.0000	0.0000	0.0000	0.0000
Criteria Air Pollutants -9%	0.0003	0.0001	0.0000	0.0001	0.0001
Ecotoxicity -7%	0.0000	0.0000	0.0000	0.0000	0.0000
Eutrophication -6%	0.0002	0.0003	0.0000	0.0000	0.0003
Fossil Fuel Depletion -10%	0.0035	0.0013	0.0001	0.0003	0.0013
Global Warming -29%	0.0044	0.0000	0.0004	0.0010	0.0000
Habitat Alteration -6%	0.0000	0.0000	0.0000	0.0000	0.0000
Human Toxicity- Cancer -8%	0.0000	0.0000	0.0000	0.0000	0.0000
Human Toxicity- No cancer -5%	0.0000	0.0000	0.0000	0.0000	0.0000
Indoor Air Quality -3%	0.0000	0.0001	0.0018	0.0018	0.0001
Ozone Depletion -2%	0.0000	0.0000	0.0000	0.0000	0.0000
Smog -4%	0.0008	0.0003	0.0001	0.0002	0.0003
Water Intake -8%	0.0090	0.0010	0.0000	0.0000	0.0010
Sum	0.0182	0.0030	0.0006	0.0016	0.0030

3.1.6. Comparison of Economic performance

Comparison of economic performance for floor finishing is shown in Chart 6. and Table 8. Despite having a shorter life span (CP2) Medfloor CN and (CP5) PB Cush Neut, they have the best price, (CP3) NC Parket and (CP1) Comp marble are the most expensive (CP4) NC Floating, seven times more expensive unit rates than (CP2) Medfloor CN and (CP5) PBCush Neut.

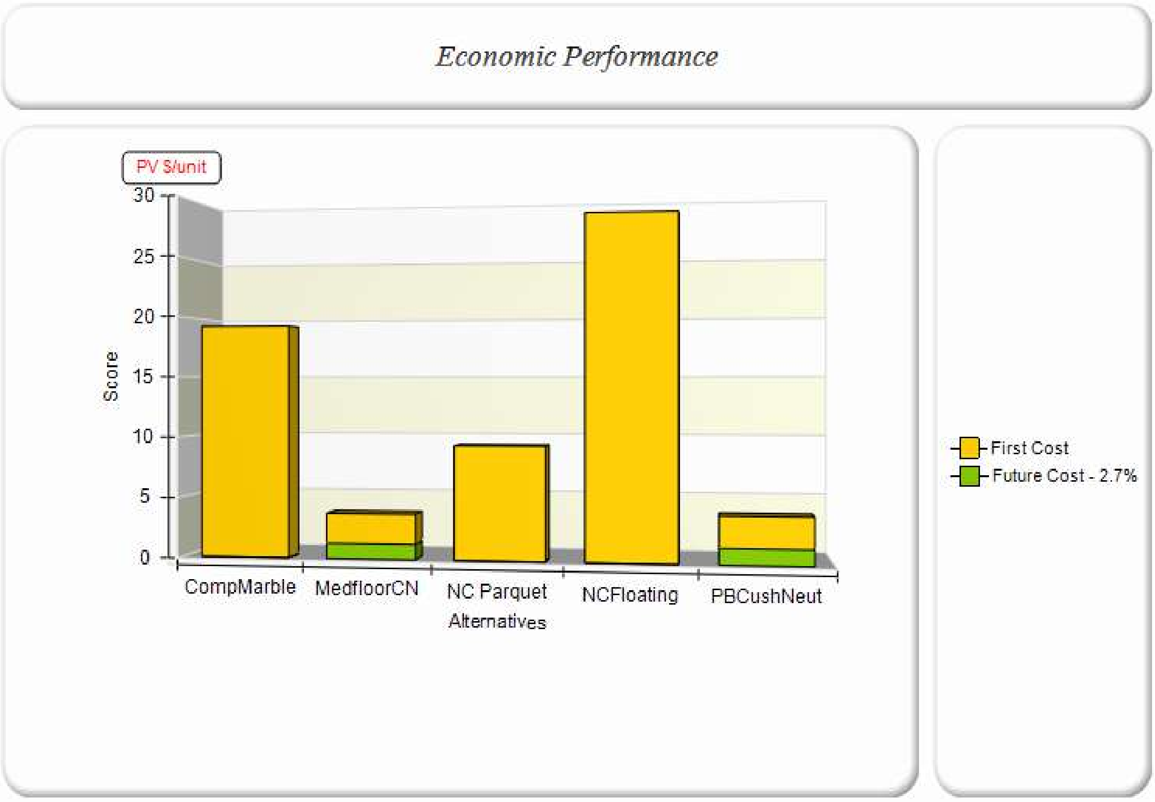

Chart 6. Comparison of economic performance of flooring

Table 8. Economic performance of analyzed floor coverings

Economic Performance					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
First Cost	19.20	2,46	9.36	28.20	2.58
Future Cost-2.7%	0.00	1.26	0.00	0.00	1.33
Sum	19.20	3.71	9.36	28.20	3.91

3.1.7. Comparison of Overall Performance

Comparison of the overall ecological and economic impacts of floor finishing materials is shown in Chart 7. and Table 9. According to the obtained results, the weighting of 50% for the economic and ecological performance of the analyzed products is best valued by (CP3) NC Parquet, then (CP2) Medfloor CN, and (CP5) PBCush Neut with approximate values. The third in the series is (CP4) NC Floating with three times higher results compared to (CP3) NC Parquet, the last in the series has (CP1) Comp Marble six times higher scores.

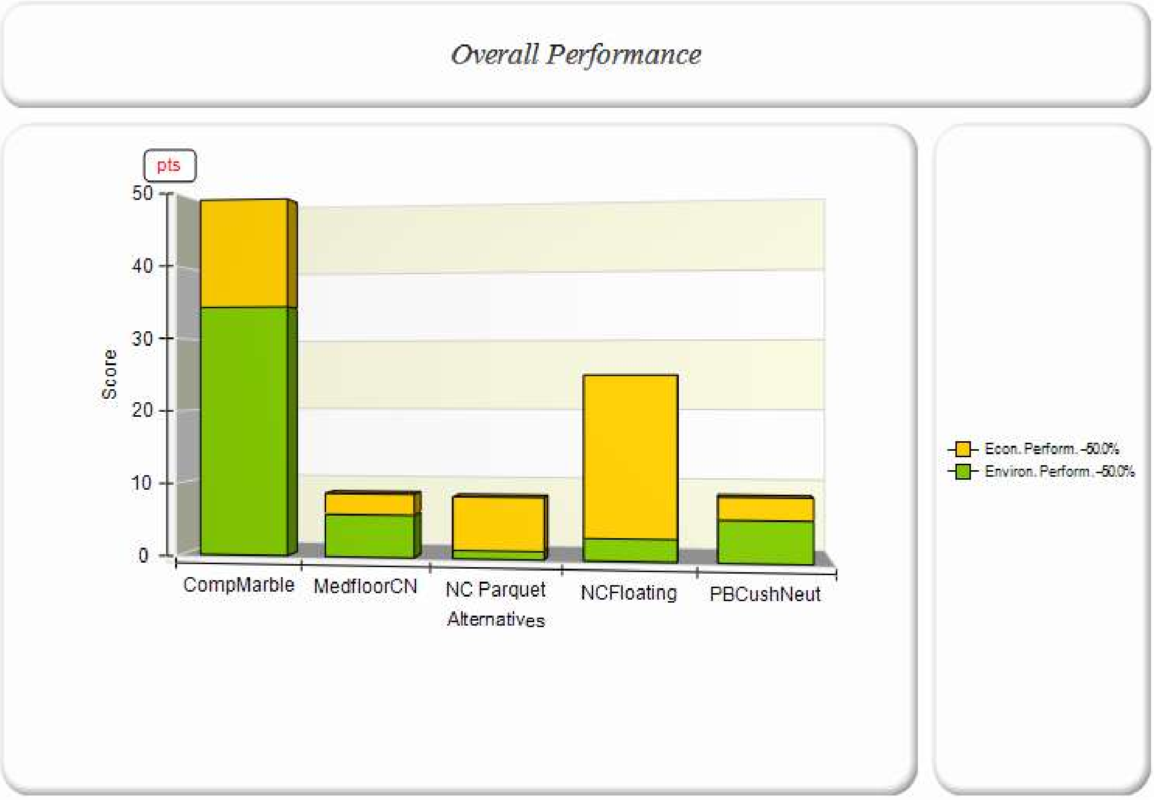

Chart 7. Comparison of the overall impact of flooring, economic and environmental

Table 9. Comparison of the overall impact of flooring, economic and environmental

Overall Performance					
Category	(CP1) Comp Marble	(CP2) Medfloor CN	(CP3) NC Parquet	(CP4) NC Floating	(CP5) PBCush Neut
Econ. Perform.– 50%	14.9093	2.8916	7.2683	21.8981	3.0327
Environ. Perform-50%	34.3608	5.7934	1.1354	3.0143	5.6560
Sum	49.2701	8.6850	8.4037	24.9124	8.7287

3.2. Discussion of the analyzed materials for floor coverings

The best parameters after analysis are the flooring (CP3) NC Parquet, then (CP2) Medfloor CN, and (CP5) PBCush Neut with approximate values. NC Floating (CP4) has three times the environmental impact value of the best-rated product, and Comp Marble (CP4), the worst-rated product of the five floor coverings analyzed, has nearly six times the value. The perceived disadvantage in terms of indoor air impact for (CP3) NC Parquet should be overcome by using adhesive without VOC components and water based varnish to finish this product. NC Parquet flooring (CP3) is not financially advantageous but is the best choice in terms of longevity and environmental performance.

The survey also points to the need for a national program package that can analyze construction products and materials used for construction of the building, which would be improved by the national construction industry in terms of favoring materials that are environmentally friendly in relation to materials with unfavorable impact on human health and the environment and reduction of greenhouse gases to mitigate climate change.

4. CONCLUSION

In the sector of civil-engineering, significant improvements have been made in terms of reducing the environmental impact through a series of measures related to energy efficiency, adoption of regulations in line with EU directives. The next steps to be taken relate to the assessment of materials used to build objects, and favors those who have a lesser impact on the environment and the treatment of people. The research includes an impact analysis during the life cycle of five types of floor coverings, from an ecological and economic point of view. All phases of the life cycle of the five analyzed floor coverings from raw material exploitation, processing, transportation, installation, use, end-of-life disassembly, transportation and waste management are covered. Five floor coverings were evaluated: (CP1) Comp Marble, (CP2) Medfloor CN, (SP3) NC Parquet, (SP4) NC Floating, and (SP5) PBCush Neut. The best parameters after analysis have the flooring (CP3) NC Parquet, then (CP2) Medfloor CN, and (CP5) PBCush Neut with approximate values. NC Floating (CP4) has three times the environmental impact value of the best-rated product, and Comp Marble (CP4), the worst-rated product of the five floor coverings analyzed, has nearly six times the value.

The results of the research indicate the need to analyze the life cycle of building materials, in order to see the benefits for the environment and human health. In addition, the results show the need, in the design phase, to examine and evaluate the environmental impacts of individual materials, human health, and the economic effects of each analyzed material.

The results of the research indicate the need to create a national software and database for construction products used for construction of buildings in Serbia. This would give architects a tool to help evaluate building materials and components from an environmental and economic point of view during the project design phase. This could reduce GHG emissions, but also avoid the installation of materials that have a negative impact on the environment and human health.

By applying software packages at the design stage, the impacts that the construction sector has on the environment, both globally and nationally, can be reduced.

5. REFERENCES

[1] European Construction Technology Platform, *MATERIALS, Vision 2030 & Strategic Research Agenda, Focus Area Materials. Version 1*, Available at: http://www.ectp.org.20.1.2013. Brussels; 2005.

[2] European Commission, Analysis associated with the Roadmap to a Resource-Efficient Europe. Part II. Commission Staff Working Paper. Brussels; 20.9.2011. SEC (2011) 1067 final.

[3] S. Sturgis, *Targeting Zero: Embodied and Whole Life Carbon Explained*. RIBA Publishing. 2017. http://sturgiscarbonprofiling.com/news/targeting-zero-embodied-and-whole-life-carbon-explained/>.

[4] M. Stanković, et al., *Plavo-zeleni dizajn, Prirodna, najstarija i najpoželjnija paradigma na putu ka samoodrživom razvoji grada na Vrbasu; rbana regeneracija braunfild lokacije „Rudi Čajavec“ u Banjoj Luci*; Univerzitet u Banjoj Luci, Arhitektonsko-građevinski fakultet; Univerzitet tehnologije u Beču, Institut za urbani dizajn i pejzažnu arhitekturu; Univerziteta primenjenih nauka u Koruškoj, Građevinsko-arhitektonski fakultet.

[5] X. Zhang, L. Shen, L. Zhang, *Life cycle assessment of the air emissions during building construction process - A case study in Hong Kong. Renew*. Sustain. Energy Rev., Vol. 17 (2013) 160–169.

[6] A. Trevor, A. Joyner, P.J. Wainwright, *Recycling of concrete and demolition waste in the UK*, Second international RILEM Symposium on demolition and Reuse of Concrete and Masonry, Tokyo 2004, 153–160.

[7] D. Garcia, R. Balart, F. Parres, J. Lopez, *Characterization of blends of poly (vinyl chloride) waste for building applications*, J. Mater Sci., Vol. 42, (2007) 10143–10151.

[8]. M. Stanković, et al., *Iskustva graditelja: harmonija i konflikti u prostoru*, Arhitektonsko-građevinski fakultet u Banjoj Luci, 2007.

[9] ISO 14040:2006. *Environmental management – life cycle assessment – principles and framework*. Geneva, Switzerland: International Standards Organization, 2006.

[10] P. Smith, *Architecture in a Climate of Change – A Guide to sustainable design*. Elsevier/Architectural Press. Burlington, 2005.

[11] J.M. Pearce, S.J. Jonson, G.B. Grant, *3D-mapping optimization of embodied energy transportation*. Resources, Conservation and Recycling, Vol. 51 (2007.) 435–453.

[12] R. Klein, *Materials and energy: a story of linkages* (PhD thesis). Leiden University, Leiden, 2012. Available at: https://www.universiteitleiden.nl/en/staffmembers/rene-kleijn/publications#tab-4.

[13] EN 15978:2011 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation methods, Geneva, Switzerland: International Standards Organization, 2011.

[14] Energy balance of the Republic of Serbia, Available at: www.mre.gov.rs/.../EN%20BILANS%20ZA%2014, [accessed: 20. 12. 2017.].

[15] https://www.nist.gov/services-resources/softvare/bees, [accessed: 20. 5. 2019.].

ВРЕДНОВАЊЕ ПОДНИХ ОБЛОГА СА ЕКОЛОШКОГ И ЕКОНОМСКОГ АСПЕКТА У ФАЗИ ПРОЈЕКТОВАЊА

Сажетак: Мере за смањење утицаја грађевинског сектора на животну средину и здравље људи потребно је предузети у фази пројектовања објекта и вредновати грађевинске материјале и производе са еколошког и економског аспекта. За потребе истраживања урађено је поређење подних облога у фази пројектовања ради процене њиховог утицаја током животног циклуса. У истраживању се користи анализа животног циклуса (ЛЦА), методологија која је основ за анализу утицаја током животног циклуса грађевинских производа. Истраживањем су обухваћене фазе животног циклуса од А1 до Ц4, према стандарду ISO EN 15978:2011. За обрачун се користи програмски пакет BEES, Националног института за стандардизацију и технологију (NIST), Сједињених Америчких Држава. Анализирано је пет врста подних облога, са аспекта њиховог утицаја на животну средину и здравље људи, али и са економског аспекта. Истраживање је показало да се у фази пројектовања применом софтверских пакета може управљати квалитетом животне средине, и унапредити пројектовање, а тиме и квалитет објекта. Истраживање указује и на потребу за националним програмским пакетом којим се могу анализирати грађевински производи и материјали. Њиховом применом би се унапредила национална грађевинска индустрија и фаворизовали материјали који су еколошки и економски прихватљивији у односу на материјале са неповољним утицајем на животну средину и здравље људи.

Кључне речи: грађевински материјали, анализа животног циклуса, подне облоге, утицај на животну средину.

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