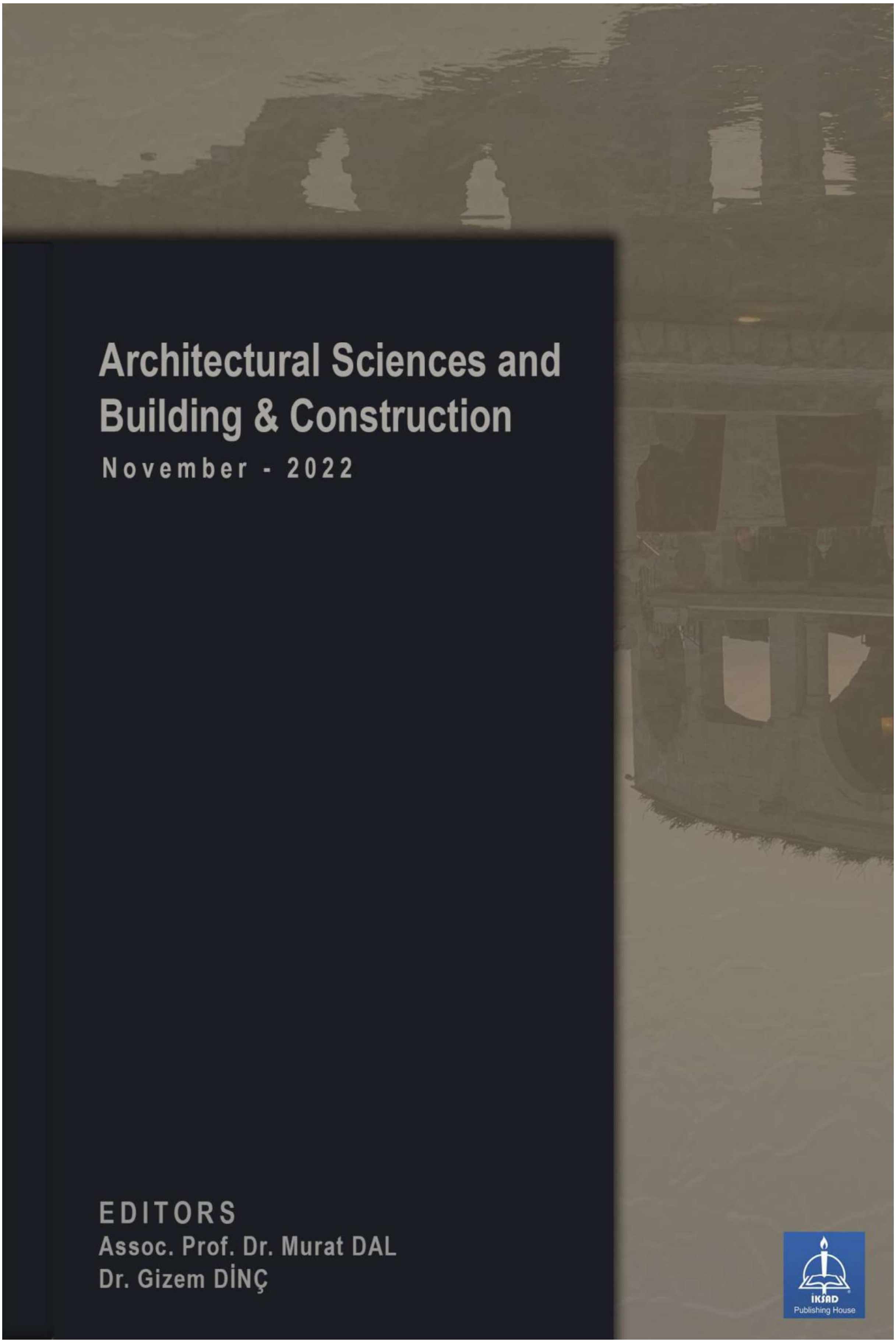
Architectural Sciences and Building & Construction

November - 2022



EDITORS
Assoc. Prof. Dr. Murat DAL
Dr. Gizem DİNÇ

İKSAD Publishing House

Architectural Sciences and Building & Construction
Noveber, 2022
ISBN: 978-625-8213-89-8.

Institution of Economic Development and Social Researches
(The Licence Number of Publicator: 2014/31220)
TÜRKİYE TR: +90 342 606 06 75 USA: +1 631 685 0 853
E mail: iksadyayinevi@gmail.com
www.iksadyayinevi.com
It is responsibility of the author to abide by the publishing ethics rules.

Architectural Sciences and Building & Construction
ISBN: 978-625-8213-89-8.

Cover Design:
Dr. Gizem DİNÇ

November 15, 2022
Ankara / Türkiye

Architectural Sciences and Building & Construction
November, 2022
ISBN: 978-625-8213-89-8.

Architectural Sciences and Building & Construction

November, 2022
ISBN: 978-625-8213-89-8.

CONTENTS	Pages

ISBN: 978-625-8213-89-8.

Architectural Sciences and Building & Construction
November, 2022
ISBN: 978-625-8213-89-8.

PREFACE

The editors of this book believe that a more livable world can be created by conducting interdisciplinary studies of spatial planning and design disciplines together under the umbrella of "Architectural Sciences".

In this context, the "Journal of Architectural Sciences and Applications (JASA)," which is a pioneer in the collective studies of related disciplines was published for the first time in 2016. Afterward, JASA Editors make significant contributions to the creation of various books containing original works and to bring the latest developments in the field to the reader. In addition, this book, which is the continuation of the Architectural Sciences series, aims to present important studies on Building and Construction after the book containing two separate volumes, Architectural Sciences, and Protection & Conservation & Preservation and Architectural Sciences and Sustainability, published in December 2021.

This book named “ARCHITECTURAL SCIENCES and BUILDING & CONSTRUCTION” consists of ten chapters. In the book, the topics named “Environmental Impact Assessment Models For The Selection of Building Products; A Framework Approach Recommendation for the Inspection of the Building Usage Phase; A Conceptual Framework for Stages of Regenerative Built Environments; Biomimetic Architecture for Responsive Building Façade; The Use of Urban Space and Spatial Quality for the Elderly People; Structural Problems Caused by User-induced Changes and Transformations in Historical Baths: The Example of Diyarbakır Melik Ahmet Pasha Bath; Traditional Vaults and Techniques; Analysis of Republican Period Civil Architecture Examples' Plan Typologies by Space Syntax Method; Analyze the Public Buildings of the Early Republic Period by the Space Syntax Method: The Case of Rıza Çergel Cultural Center; Renovation of MSGSU Tophane-i Amire Culture and Art Center Guest House” were discussed in detail. We would like to thank all those who contributed to the completion of the book, the authors, the referees of the chapters, IKSAD Publishing House, and Professor Atila GÜL, who is the General Coordinator of the Architectural Sciences book series.

We hope that our book "ARCHITECTURAL SCIENCES and BUILDING & CONSTRUCTION" will be useful to readers.

EDITORS

Murat DAL, Associate Professor
Gizem DİNÇ, Ph.D. Research Assistant

Environmental Impact Assessment Models for the Selection of Building Products

Nil KOKULU [1]

[1]Antalya Bilim University, Faculty of Fine Arts and Architecture, Department of Architecture, Antalya, Turkey
ORCID: 0000-0002-7057-7601
E-mail: nil.kokulu@antalya.edu.tr

Seden ACUN ÖZGÜNLER [2]

[2]Istanbul Technical University, Faculty of Architecture, Department of Architecture, İstanbul, Turkey,
ORCID: 0000-0001-5975-5115
E-mail: acunsed@itu.edu.tr

Citation: Kokulu, N. & Acun Özgünler, S. (2022). Environmental Impact Assessment Models for the Selection of Building Products. In M. Dal & G. Dinç. (Eds.). ***Architectural Sciences and Building & Construction***. (1-26). ISBN: 978-625-8213-89-8. Ankara: Iksad Publications.

1. Introduction

Today, it is an important decision stage for the people involved in the building design process to choose the material with optimum properties. The increasing environmental impact of building materials has brought with it the necessity of preventing problems such as deterioration of human health, climate changes, depletion of resources, ozone formation and photochemical fog formation. Reducing these negative effects caused by the material is possible as a result of the decision-makers in the material selection process making the right decisions and minimizing the environmental effects throughout the life of the material. Since the 1960s, studies have been carried out at the national and international levels to reduce environmental impacts, conserve resources and lead a healthy life for living things. The focus of the book named Silent Spring on environmental issues, the establishment of the Environmental Protection Agency (EPA), the organization of the United Nations Environment Conference and the establishment of the United Nations Environment Program (SETAC), the discovery of the hole in the ozone layer by scientists in the 1985s and as a result, the Montreal Protocol on Substances that Deplete the Ozone Layer, the publication of the Brundtland Report in 1987, the establishment of the International Institute for Sustainable Development (IISD), the Rio Declaration, the publication of the ISO 14001 Standard, the Kyoto Protocol and the implementation of certification systems such as LEED, DGNB, BREEAM, CASBEE is just a few of the studies carried out for sustainability at the international level. Some of the studies carried out at the national level are; Environmental Law, Environmental Impact Assessment Regulation, Energy Efficiency Law, Energy Performance Regulation in Buildings, Green Certificate Regulation for Buildings and Settlement, Regulation on Construction Materials, Regulation on Environmentally Responsible Design of Energy-Related Products, Energy Efficiency Law, Excavation Soil Construction and Demolition Waste Control Regulation, TS EN ISO 14000 series, TS EN 15804 + A2 standards and the implementation of certification systems such as B.E.S.T, BUD, SEEB-TR. The main purpose of all these studies is to implement the concept of sustainability, which aims to leave a livable environment for future generations. With this concept; human-based problems such as conservation of resources, correctly directing technology, ensuring economic and social welfare, increasing the quality of life, and reducing biodiversity will be prevented. In addition, the evaluation and selection of material alternatives used in the building will contribute to the reduction of environmental loads by creating a method for everyone.

2. Material and Method

In this chapter; LCA was described, model proposals were created using the LCA method, and models that assess environmental impact were examined. Also, some Life Cycle Assessment models are described and evaluated comparatively. At the end of each chapter, the models were evaluated among themselves

3. Findings and Discussion

3.1. Life Cycle Assessment Method

Life Cycle Assessment (LCA) collects and evaluates the inputs, outputs, and possible environmental impacts of a product system throughout its life (TS EN ISO 14044, 2007). There are many accepted LCA methods today. Organizations such as the Environmental Protection Agency (EPA), the American Society for Testing and Materials (ASTM), the American Institute of Architects (AIA), and the International Organization for Standardization (ISO) work to develop LCA methods (Spiegel, 2012). Since the use of different LCA models in different countries causes confusion and incompatible environmental results, Environmental Management Systems- ISO 14000 Standards were created for the first time in 1997 due to the need for a common language union. Among these standards, two important standards dealing with the LCA method are ISO 14040 LCA-Principles and Framework and ISO 14044 LCA-Requirements and Guidelines. Detailed information about what the LCA stages cover is given in the TS EN ISO 14044 standard. An LCA study consists of four stages (Figure 1).

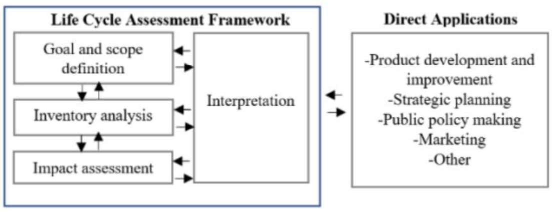


Figure 1. Life Cycle Assessment Framework (TS EN ISO 14044)

3.2. Models Created by using the LCA Method

3.2.1. The Gültekin model

In this study, an open-ended model was produced by using the LCA method to evaluate the environmental loads of building materials and a sample study was made. The relationship between the environmental effects caused by the maintenance and repair of the wallpapers in the usage phase and human health was evaluated quantitatively. In the case study, first of all, the building product system, assumptions, functional unit, system boundaries, distribution methods, and data quality requirements were defined within the scope and purpose; decisions on critical review and report preparation were made. The second phase, the life cycle data analysis phase, covers the creation of data collection methods and calculation methods for the inputs and outputs of the wallpapers, and the finalization of the system boundaries. In this context, a method has been followed in which the data are classified as "data specific to the building products", "data specific to the resource flows", and "data specific to the structure to which the building product will be applied" and "user-specific data". In the third stage, the mandatory and non-mandatory elements considered in the case study element flows were created. The structure of the created model is grouped and subdivided as (a) building products, (b) environmental effects, and (c) life cycle stages (Table 1). In the interpretation phase, important topics (impact classes, class indicators, class endpoints) related to wallpapers were introduced and the results related to these topics were evaluated (Figure 2) (Gültekin, 2006).

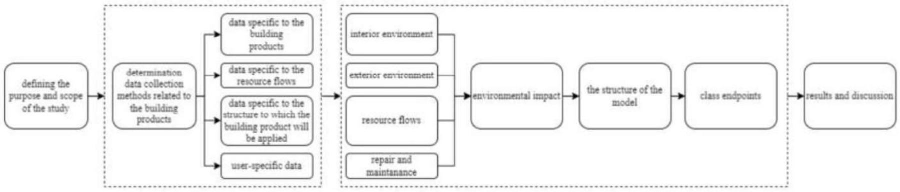


Figure 2. The Structure of the Gültekin Model (Gültekin, 2006).

3.2.2. The Taygun model

In this study, a model has been developed that aims to define the product during the selection stage and to examine and evaluate all life cycle processes. First of all, the relationship of building products with the environment was examined and models for life cycle assessment are described and evaluated. The first step of the model is to arrange the information sheets for the description of the building product. The second step is the determination of the inputs and outputs in each of the life cycle processes of the building product, the information obtained as a result, the outputs in the life cycle processes, and the preparation of the information cards of the affected environmental groups. The third step covers the environmental impact assessment of the outputs. The fourth and fifth steps are the stage in which the life cycle processes of the building product are evaluated (Figure 3). The model created is exemplified by polyvinyl chloride joinery (Taygun, 2005).

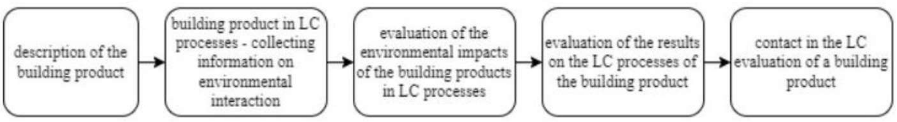


Figure 3. The Structure of the Taygun Model (Taygun, 2005)

3.2.3. The Alptekin model

This study proposes, a mixed material selection model, which compares alternatives and criteria for building products and ranks them with multi-criteria decision-making methods. First of all, the architect, who is in the decision-making position, determines the alternatives that constitute the decision-making problem. Then, the environmental impact class data of the determined alternatives are obtained from a database. After the material alternatives determined by the architect are entered into the program, the importance levels of the environmental impact data of the materials are determined by factor analysis according to their correlation with each other. Local conditions can be effective in determining the degree of importance. Then, each material alternative is evaluated with the degree of importance obtained by TOPSIS, which is one of the multi-criteria decision-making methods. As a result of the evaluation, an environmental impact score is given for each environmental impact class, and material alternatives are ranked from the highest performance to the lowest (Figure 4). In this way, the environmental impact performance of the building can be obtained in a way that is closest to the ideal. The proposed model can be used in all life cycle stages in the evaluation of the environmental impacts of materials. In a sample study carried out within the scope of the model, the environmental effects of the raw material extraction and production stage of the floor finishing materials were examined, and a material selection evaluation was made in line with the obtained environmental data (Alptekin, 2014).

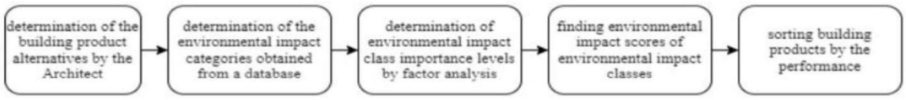


Figure 4. The Structure of the Alptekin Model (Alptekin, 2014)

3.2.4. The Bayraktar model

In this study, a model that evaluates the environmental effects of materials in line with the LCA method is proposed based on considering the current situation of Turkey on environmental issues, in line with the country's possibilities and limitations on environmental impacts. First of all, the properties and environmental effects of building materials were examined, the stages of LCA were defined and the studies on environmental impacts in the world and Turkey were presented. Within the scope of the proposed system, it is aimed to carry out a life cycle impact assessment by taking into account the lower and upper limit values specified in the reviewed regulations after the information regarding the life cycle stages of the product is determined in line with the designed leaflets. Evaluation can be made in three categories: mean value, a value close to the limit, and a value close to 0 (Figure 5). At the last stage of the study, the proposed system is exemplified by cement building material (Bayraktar, 2010).

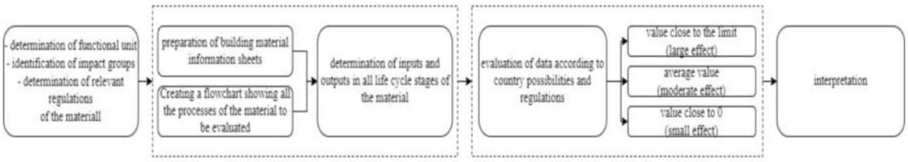


Figure 5. The Structure of the Bayraktar Model (Bayraktar, 2010)

3.2.5. The Paulsen model

One study focused on the link between the choice of a product and the effects that occur during the use phase of the product's service life. For the calculation of environmental loads in the usage process; (1) emissions from products to the indoor environment, (2) emissions from products to the external environment, (3) interference with resource flows in building systems, (4) consumption of auxiliary products and resources for maintenance and (1) LCI data for building products, (2) LCI data for flows in the usage process, (3) the necessity of knowing building-specific data are conveyed (Figure 6). In the study, first of all, the development of sustainability was mentioned, the stages of life cycle assessment were explained, and the problems in the calculation of environmental impacts in the use process were mentioned. In this context, it has been determined that the methodical analysis of the usage phase of floor coverings depends on creating a model for maintenance by making the following generalizations: (1) cleaning and maintenance methods, (2) products and machines used for maintenance, (3) amount of product and resource used for each maintenance method. Using a calculation tool, it is also shown how the environmental impacts of a product can be calculated based on its maintenance characteristics. Maintenance is grouped under 3 subheadings as; frequent maintenance, periodic maintenance and remedial maintenance. It has been mentioned that understanding the service life of the material depends on the economic, aesthetic, ecological service life and additional information. The study also addresses the total energy use of materials. At this point, 3 scenarios were constructed: (1) heat losses from external walls, (2) the effect of the building context, and (3) the importance of heat capacity. To calculate the energy loads of the building, the importance of the information in the usage process and the necessity of considering all information as a whole have been conveyed. In the conclusion, recommendations are made and it is mentioned that the use phase can have more environmental impact than maintenance and the impact on a building's energy use alone (Paulsen, 2001).

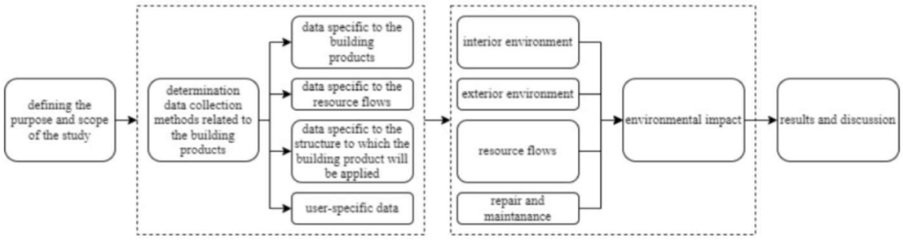


Figure 6. The Structure of the Paulsen Model (Paulsen, 2001).

3.2.6. Evaluation of the models created by using the LCA method

As indicated in the studies, each model can be used for each life cycle stage. The stages that are discussed in detail with the sample study in the models are indicated in Table 1.

Table 1. LC stages covered by the models

	Gültekin	Taygun	Alptekin	Bayraktar	Paulsen
Product stage		x	x	x	
Construction Process Stage		x		x	
Use Stage	x	x		x	x
End of life		x		x	

In Table 2, the environmental impact categories determined in the models are given. Since the Taygun model is for the Life Cycle Assessment process, environmental impact categories are not specified in the study. Instead, the inputs and outputs of the product are mentioned in each life cycle phase. In addition, since environmental impact categories were not determined in the Paulsen model, they are not given in the table. In this model, it is stated that the impact categories will be chosen according to the user's request.

Table 2. Environmental Impact Categories of the LCA models

	Gültekin	Alptekin	Bayraktar
Global warming	**x**	**x**	**x**
Depletion of the ozone layer	x	x	x
Acidification	x	x	x
Eutrophication	x	x	x
Photochemical fog formation	x	x	x
Indoor air quality		x	
Fossil fuel consumption		x	x
Resource consumption	x		x
Water consumption		x	
Human toxicity	x	x	x
Ecological toxicity	x	x	
Pollution (air, water, soil)	x		
Damage to biological diversity	x	x	
Air pollution		x	

When the models are evaluated in general, it is seen that there is no limitation on the product to be evaluated, and the models can be used optionally. Among the models, only Gültekin and Alptekin consider environmental impact importance weights. In addition, Alptekin model showed that multi-criteria decision making methods can be used in material life cycle evaluation. Studies have shown that the models produced at national and international level are only theoretical and unused. It is important to put these models into practice in order to reduce the environmental impact of materials.

3.3. Models That Assess The Environmental Impact

3.3.1. The Anderson model

The model, created by BRE based on life cycle assessments, presents the environmental impacts of materials in tables by grouping them according to their usage areas. Each effect has different relative importance. The life cycle evaluation headings are listed as follows, from the most important impact to the least important impact. Materials are evaluated under the headings of climate change, fossil waste consumption, ozone depletion, airborne toxins, waste management, water extraction, acid residue/accumulation, eutrophication, ecotoxicity, summer smoke/mist, and mineral extraction, toxins mixed with water. The value obtained as a result of the total evaluation and the effect levels for each title is expressed with the letters A, B, and C (Figure 7) (Anderson, et.al., 2009).

Loadbearing partitions

Element	Summary Rating	Climate Change	Fossil Fuel Depletion	Ozone Depletion	Human Toxicity to Air and Water	Waste Disposal	Water Extraction	Acid Deposition	Ecotoxicity	Eutrophication	Summer Smog	Minerals Extraction	Cost £/m^2	Typical Replacement Interval	Recycled Input	Recyclability	Recycled Currently	Energy Saved by Recycling
Aerated blockwork partition, plasterboard on dabs, paint	A	A	A	A	A	A	A	A	A	A	A	A	41-53	60	B	B	B	B
Brickwork, plaster, paint	B	A	A	A	A	B	A	A	A	A	A	A	45-60	60	C	A	A	A
Dense blockwork, plasterboard on dabs, paint	A	A	A	A	A	B	A	A	A	A	A	A	47-56	60	C	A	A	B
Fairfaced brickwork	A	A	A	A	A	B	A	A	A	A	A	A	26-36	60	C	A	A	A
Fairfaced reinforced concrete	C	A	A	A	B	C	B	A	A	A	A	C	80-95	60	C	A	A	A
Lightweight blockwork partition, plasterboard on dabs, paint	B	B	A	A	A	B	A	A	A	A	A	A	41-53	60	A	A	A	B

Figure 7. Sample Environmental Impact Assessment Charts of the Anderson Model (Anderson et.al., 2009).

3.3.2. The Wooley model

In this book, some evaluations reveal the environmental impact levels with life cycle analysis by classifying building materials on their usage areas. While making the life cycle assessment, the environmental effects of the materials over the headings in the "production" and "use" processes are compared with materials with similar functions and gain values between 0-4. Environmental impact assessment titles; Under the title of "production"; energy use, consumption of biological resources, consumption of non-biological resources, global warming, ozone depletion, toxins, acid rain, photochemical oxidants, under the title of "use"; energy use, strength/maintenance, recycling/reuse/waste, health. In the tables presenting the environmental impact assessments, visual expressions are used instead of numerical values, with larger dots meaning greater negative impact. At the same time, with written evaluations on each title, designers are provided with tips for choosing a material that will take into account its environmental impact (Figure 8) (Wooley et. al., 2005; Wooley & Kimmins, 2005).

	£	Production									Use					
	Unit Price Multiplier	Energy Use	Resource Depletion (bio)	Resource Depletion (non-bio)	Global Warming	Ozone Depletion	Toxics	Acid Rain	Photochemical Oxidants	Other	Energy Use	Durability/Maintenance	Recycling/Reuse/Disposal	Health	Other	
Insulation Materials																
Cellulose Fibres	n/a	·												?		
Compressed Straw Slabs	n/a	·	·										·			
Cork	7.2	·											·			
Foamed Glass	16.7	●		·			•	•	•	•						
Glass Wool	1.0	•		•			●	•	•	●			•	•		
Phenolic Foams	n/a	●		•	?	?	●	•	•	●				●		HFCS, HCFCS
Polystyrene - Expanded	3.1	●		•			●	•	•	●				·		
Polystyrene - Extruded	8.2	●		•	?	?	●	•	•	●				·		HFCS, HCFCS
Rigid Urethane Foam	4.9	●		•	?	?	●	•	•	●				●		HFCS, HCFCS
Rock Wool	1.0	•		•			●	•	•	●			•	•		
Softboard	9.5	·	·										·			
Softboard + Bitumen	8.7	•	·	·			·	·	·	·			·			
Urea-Formaldehyde Foam	n/a	●		•			●	•	•	●				●		
Vermiculite (Expanded)	n/a	•		•						●				?		
Wood-Wool Slabs	11.8	●	·	·	·		·	·	·	·			·			
Wool	10.4	·														

Figure 8. Sample Environmental Impact Assessment Charts of the Wooley Model (Wooley et. al., 2005; Wooley & Kimmins, 2005).

3.3.3. The Demkin model

The Environmental Resource Guide, prepared by the American Institute of Architects (AIA), provides assessments that reveal the environmental impact levels of building materials through life-cycle analysis. The life cycle assessment comparatively reveals the environmental impact levels on a 6-point scale under the headings of “environment and ecosystem”, “health and well-being”, “energy” and “building operation”. Visual expressions are used instead of numerical values in the tables. Environmental impact assessment titles are listed as; under the title of “environment and ecosystem”,air quality/ atmospheric effects, water quality/accessibility, land and soil quality/accessibility, raw material consumption, biodiversity / growing environment, under the title of “health and well-being”, the health of employees, the health of building users public health, under the title of “energy”, production, transportation, use and under the title of “building operation”, it can be listed as service life/durability, maintenance, and repair, reuse/recycling. In addition to the environmental impact assessment tables, the materials are handled under the headings of "supply and preparation of raw materials", "production and fabrication", "construction, use and maintenance" and "reuse, recycling, destruction" based on their origins and detailed evaluations are presented with written explanations and tips (Figure 9) (Demkin, 1998).

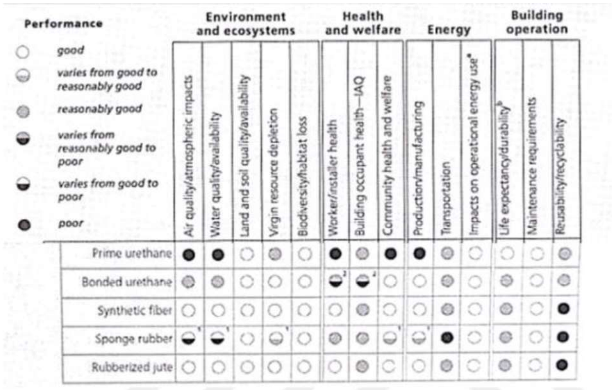


Figure 9. Sample Environmental Impact Assessment Charts for Carpet Cushions of the Demkin Model (Demkin, 1998).

3.3.4. The Curwell model

The model is designed to help designers choose the product that is least harmful to health but remains within the most adequate and logical limits in terms of technique and appearance, in the processes covering the design, construction, maintenance, and changes of the structure.

According to Curwell, the impact of the health risk arising from building products on users depends on the location of the building products in the building, the environmental factors inside the building, and the indoor ventilation. In the model; harmful effects on health caused by building products are determined on a numerical scale from 0 to 3 and in areas qualified as A/B/C (Figure 10). A defines the possible harmful effect of the position of the product in the structure on the health of the user, and B defines the possible harmful effect of the product on the health of the user as a result of maintenance, repair, change or fire and C defines the long-term potential environmental impact of maintenance, repair, replacement, fire and improper disposal

Life Cycle Stage	Resource Consumption	Score
Material Acquisition & Preparation	Betterment in resource use (10% from renewable source). Also, removes ash that is currently landfilled from waste stream for a beneficial use.	+1
Production & Distribution	An extra 2% water required in brick making process. However, this is not considered significant in terms of resource use. Lignosulphate is used, but this is a naturally derived product and assumed to be non-toxic.	0
Construction	No difference in the method of construction.	0
Use & Maintenance	No difference in durability or replacement cycles.	0
Demolition & Disposal	No difference in options for reuse/treatment.	0

Figure 11. Sample Environmental Impact Assessment Chart for Clay Bricks of the Urie Model (Urie & Dagg, 2004)

3.3.6. Evaluation of the models that assess the environmental impact

When the models are examined, it is seen that especially the Anderson, Woolley, Demkin and Curwell model has the characteristics of a material database and allows the comparison of different materials within the model (Table 3).

Table 3. Materials in the databases

	Materials in the database
Anderson	Materials over the area of use; are classified under the headings of exterior walls, roofs, floors and floor coverings, floor constructions, interior partition walls, suspended ceilings, and ceiling coverings, doors, paints, insulations, and landscaping elements.
Wooley	(1st book) thermal insulation materials, meshed systems, wood, composite panels, wood origin, joinery, paints, and stains on joinery, roofing materials, rainwater removal systems, plumbing systems, carpets, and floor coverings, (2nd book) interior decoration, connectors, electrical wiring, glass, flat roofs, ventilation, fences, straw/reed buildings.
Demkin	The materials are presented by classifying them under the following headings, based on their usage areas and origins; lightweight structures, insulations, coatings, wall finishes, elastic floor coverings, architectural finishes, glass, carpet, load-bearing system, metal, and plastic pipes, fabric and paper wall finishes.
Curwell	Building products that are harmful to health are listed as; asbestos and other natural materials, wood, cellulose fiber, calcium silicate board, mineral fiber, vermiculite, natural slate, phosphogypsum, mineral fibers originating from the building industry, metals, aluminum, zinc, iron, steel, copper, lead, chromium, plastics, and toxic chemicals.
Urie	No material database

It has been seen that the models are easy to use and their use is not mandatory. In particular, Anderson, Wooley, Demkin models have shown that environmental impact comparisons of several different materials can be made quickly. In addition, the Curwell model keeps the creation of information tables mandatory in material comparison. In the Urie model, which focuses on each of the material life cycle processes, a more complex selection system based on calculations has been created. The LC stages covered by the models is given in Table 4.

Table 4. LC stages covered by the models

	Anderson	Wooley	Demkin	Curwell	Urie
Product stage	x	x	x		x
Construction Process Stage	x		x		x
Use Stage	x	x	x	x	x
End of life	x		x	x	x

3.4. Life Cycle Impact Assessment (LCIA) Models

3.4.1. The Öztaş model

In this study, an LCIA model that deals with the entire life cycle of building materials produced in Turkey has been developed. Using the ISO 14040 standard, the midpoint approach model is adopted. Considering the environmental issues in Turkey, the EN 15804 standard, and the impact categories mostly used in the current LCIA models, 11 environmental impact categories caused by construction materials were selected. Identification models and category indicators were selected for seven impact categories based on the EN 15804 standard. For the remaining 4 impact categories, identification models and category indicators were determined based on Turkey-specific data. Weighting coefficients for these impact categories were determined using the panel method (Analytical Hierarchy Process). As a result of the weighting, 11 selected environmental impact categories are grouped as high risk, medium risk, and low-risk environmental problems for Turkey. The environmental impact caused by a Turkish citizen is proposed as the normalization reference value. During the model creation phase, many different difficulties were encountered and solution methods were explained. The model was tested on expanded polystyrene foam material and the results of the model were compared with other LCIA models using Simapro (Karaman Öztaş, 2014).

3.4.2. The ECOHESTIA model

The model evaluates the environmental impact of building materials and components. The system boundary of this model is cradle to gate. All the data it contains is specific to Cyprus. Materials used in the ECOHESTIA database are; aluminum, PVC, float flat glass, brick, plasterboard, tiles, cement, plaster, concrete (c10/ c15, c16, c20/ c25, c35) , thermal insulating materials (EPS, mineral wool), paint (exterior, interior), waterproofing, polyethylene film, plywood, steel. It employs CML 2001 methodology. Normalization and weighting are not possible with this method. (Kylili et. al., 2016).

3.4.3. The BRE (Building Research Establishment) environmental profiles model

This model created by UK BRE, allows for a 'cradle-to-grave' environmental impact assessment of materials using a midpoint approach. BRE LCIA model includes classification, definition, normalization, and weighting steps. It includes energy, mineral consumption, water consumption, waste, water emissions, and air emissions. The service life of the building material is taken as 60 years, and the functional unit is taken as 1 m^2. The model also includes normalization and weighting steps (BRE, 2008).

3.4.4. The BPIC-ICIP (Building Products Innovation Council-Industry Cooperative Innovation Programme) model

The BPIC/ICIP Construction Products Innovation Council and Industry Partnership Innovation Program aimed to establish a model of international construction industry LCA for Australia. The normalization value is based on the annual per capita environmental impact value in Australia (Bengtsson & Howard, 2010a). 11 workshops were conducted in major populated centers covering all climatic zones to calculate the weighting coefficients according to different climatic zones of Australia. The results are Australian averages and Australian demographically adjusted averages. As global effects, resource consumption, ecological impact, sea pollution, air pollution, and global warming are discussed; local effects, local resources, habitat loss, urbanization, water pollution, air pollution, land productivity, and poisoning are discussed. Comfort and health are handled as internal problems. Demographic weighting has been weighted according to age, gender, and income (Bengtsson & Howard, 2010b).

3.4.5. Evaluation of the LCIA models

The models are evaluated according to impact categories (Table 5), category indicators (Table 6), normalization values (Table 7), and weighting values (Table 8).

Table 5. Environmental Impact Categories of the LCIA models

	K. Öztaş	ECOHESTIA	BRE	BPIC-ICIP
Global warming	x	x	x	x
Depletion of the ozone layer	x	x	x	x
Acidification	x	x	x	x
Eutrophication	x	x	x	x
Photochemical fog formation	x	x	x	x
Indoor air quality	x			x
Fossil fuel consumption	x	x	x	x
Mineral resource consumption	x	x	x	x
Water consumption	x		x	x
Waste generation	x		x	
Land use	x			x
Human toxicity		x	x	x
Ecological toxicity			x	x
Ionizing radiation				x
Transport pollution				x

Table 6. Category Indicators of the Models

	K. Öztaş	ECOHESTIA	BRE	BPIC-ICIP
Global warming	kg CO_2 eq.	kg CO_2 eq.	kg CO_2 eq.	kg CO_2 eq.
Depletion of the ozone layer	CFC-11 eq.	kg R11	CFC-11 eq.	CFC-11 eq.
Acidification	kg /SO_2	kg/ SO_2	SO_2 eq.	SO_2 eq.
Eutrophication	kg/PO_4 eq.	kg/PO_4 eq.	PO_4 eq.	PO_4 eq.
Photochemical fog formation	kg/ C_2H_4	kg Ethene	kg.ethane	kg. NMVOC
Indoor air quality	VOC			-
Fossil fuel consumption	TEP	MJ	Toes	MJ
Mineral resource c.	Tonne	Kg Sb-Eq	Tonne	Kg
Water consumption	M^3		Litre	Kilo Litre
Waste generation	Tonne		Tonne	
Land use	m^2 x year			Hectare.year
Human toxicity		Kg DCB-Eq	Kg toxicity	1,4-D Beq. DALY'
Ecological toxicity			kg 1,4-DB	kg.1,4-DB
Ionizing radiation				Kg U235
Transport pollution				-

Table 7. Normalization Values of the Models

Model	Normalization value
K. Öztaş	Total environmental impact of a Turkish citizen
ECOHESTIA	-
BRE	Annual environmental impact created by a British citizen
BPIC-ICIP	The environmental impact per person per year in Australia

Table 8. Weighting Methods of the Models

Model	Weighting method
K. Öztaş	Panel method – Analytic Hierarchy Process
ECOHESTIA	-
BRE	Panel method--Eco-points system
BPIC-ICIP	Panel method--Delphi method

4. Conclusion and Suggestions

Today, building materials have been artificialized by using different techniques and components to meet the performance requirements expected from them. Materials that deviate from naturalness cause the world ecosystem to deteriorate and threaten human health. This situation brought with it the necessity of establishing a systematic model. Some institutions and organizations have started to take measures on the subject and aimed to reduce the environmental burden by developing various models for material selection. In addition, there are studies on the subject prepared on a country basis. Considering that material selection is a multi-criteria process that requires a lot of data, it has been observed that the models examined do not consider the material at every stage of the life cycle process or only consider some aspects. To maintain sustainability awareness and leave a better environment for future generations, models that deal with materials in detail and evaluate them based on country/region/city are needed. In this sense, institutions and organizations should work together, and laws, regulations, and standards should be established. In this study, some of the environmental impact assessment models created for material selection are discussed. The study revealed the importance of material selection at the design stage and emphasized the necessity of a comprehensive model in this regard.

Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

References

Alptekin, O. (2014). *Yapı Malzemesi Seçiminde Yöntem Araştırması ve Bir Model Önerisi*. (Publication No. 376145) [Doctoral dissertation, Gazi University]. Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Anderson, J., Shiers, D., Steele, K. (2009). *The Green Guide To Specification; An Environmental Profiling System For Building Materials And Components*, BRE Press.

Athena Sustainable Materials Institute. (n.d.) *Impact Estimator for Buildings*, Retrieved April 22, 2022, from http://www.athenasmi.org/our-software-data/impact-estimator/

Bayraktar, F. T. (2010). *Türkiye' de Yapı Malzemesi Yaşam Döngüsü Değerlendirmesi İçin Bir Sistem Önerisi*. (Publication No. 310403) [Master's thesis, istanbul Technical University]. Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Bengtsson, J. Howard, N. (2010a). *A Life Cycle Impact Assessment Method; Part I: Classification and Characterization*, Building Products Innovation Council and AusIndustry.

Bengtsson, J. Howard, N. (2010b). *A Life Cycle Impact Assessment Method; Part II: Normalization*, Building Products Innovation Council and AusIndustry

BRE (2008). *BREEAM Global Methodology for Environmental Profiles of Construction Products*. Retrieved April 21, 2022, *from* https:// www.bre.co.uk/filelibrary/greenguide/PDF/Methodology_for_Environmental_Profiles_2008_SD6050.pdf

Curwell, S. R., Fox, B., Greenberg, M., March, C. G. (1986). *Hazardous Building Materials*, E&F.N. Spon Ltd., London.

Demkin, J. A. (ed.) (1998). *Environmental Resource Guide*. AIA. New York: John Wiley & Sons, Inc.

Gültekin, A. B. (2006). *Yaşam Döngüsü Değerlendirme" Yöntemi Kapsamında Yapı Ürünlerinin Çevresel Etkilerinin Değerlendirilmesine Yönelik Bir Model Önerisi*. (Publication No. 184670) [Doctoral dissertation, Gazi University]. Ulusal Tez Merkezi, https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Kylili, A., Fokaides, P. A., Seduikyte, L. (2016). Sustainability Tools for the Assessment of Construction Materials and Buildings, Journal of Sustainable Architecture and Civil Engineering, Vol. 3:16, pp 61-69.

Karaman Öztaş, S., (2014). *Türk Yapı Malzemesi Sektörü İçin Yaşam Döngüsü Etki Değerlendirilmesine Yönelik Bir Model Önerisi*. (Publication No. 363841) [Doctoral dissertation, İstanbul Technical University]. Ulusal Tez Merkezi, https://tez.yok.gov.tr/UlusalTez Merkezi/tezSorguSonucYeni.jsp

Paulsen, J. (2001). *Life Cycle Assessment For Building Products: The Significance Of The Usage Phase*. KTH Royal Institute of Technology. [Doctoral dissertation, Kungl Tekniska Högskolan]. KTH, Superseded Departments (pre-2005), Building Sciences and Engineering. http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A8925&dswid=-8044

Spiegel, R. &. (2012). *Green Building Materials: A Guide To Product Selection And Specification*. Hoboken, N.J.: Wiley.

Taygun, T. G. (2005). *Yapı ürünlerinin Yaşam Döngüsü Değerlendirmesine Yönelik Bir Model Önerisi*. (Publication No.

198931) [Doctoral dissertation, Yıldız Technical University]. Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Urie, A., Dagg, S. (2004). Development Of A Life Cycle Assessment (LCA) Based Decision-Making Tool For The Assessment Of Building Products, *Journal of Environmental Assessment Policy and Management*, Vol. 6: 2 (June 2004) pp. 153–175.

Woolley, T. ve Kimmins, S. (2005). *Green Building Handbook Volume 2: A Guide To Building Products And Their Impact On The Environment.* E & FN Spon.

Woolley, T., Kimmins, S., Harrison, P., Harrison, R. (2005). *Green Building Handbook Volume 1: A Guide To Building Products And Their Impact On The Environment.* E & FN Spon, Thomson Science & Professional.

Lec. Nil KOKULU

E-mail: nil.kokulu@antalya.edu.tr
Educational Status: Ph.D. candidate, Istanbul Technical University
Licence: Bahçeşehir University
Degree: MSc in Architecture
Professional experience: Lecturer at Antalya Bilim University

Prof. Dr. Seden ACUN ÖZGÜNLER

E-mail: acunsed@itu.edu.tr
Educational Status: Doctorate, Istanbul Technical University
Licence: İstanbul Technical University
Degree: Ph.D. in Architecture
Doctorate: İstanbul Technical University
Professional experience: Prof. at İstanbul Technical University