ANALYSING AND DETERMINING OF WALL ELEMENTS FOR BUILDING CONSTRUCTION PROJECTS USING MULTI-CRITERIA DECISION-MAKING METHODS

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“I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles, and I have, according to the requirements of these regulations and principles, cited all those which do not originate in this work.”

Harez Kanabi ABDULRAHMAN

ABSTRACT

M.Sc. Thesis

ANALYSING AND DETERMINING OF WALL ELEMENTS FOR BUILDING CONSTRUCTION PROJECTS USING MULTI-CRITERIA DECISION-MAKING METHODS

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Wall element selection is challenging due to the different categories of construction materials with various properties, performances, and characteristics available today; the designers and decision-makers frequently consider many factors. These combinations of variables or factors frequently provide trade-offs. As a result, they were adding to the complexity of the decision-making process. This study presents a three-phase Multi-Criteria Decision Making (MCDM) framework for evaluating and selecting the most suitable exterior and interior wall material for residential buildings. In the first step, five main criteria, including performance, economic, management, environmental, and social criteria, and 27 sub-criteria have been collected from literature and wall materials such as clay brick, autoclaved aerated concrete block, pumice block, and glass brick are determined. In the second step, the

Best-Worst method is applied to find the weights and ranking of the criteria and sub-criteria. The last step is evaluating and ranking materials using four multi-criteria decision-making techniques WASPAS, TOPSIS, EDAS, and MOORA. In conclusion, as a result of the data analysis, the most important criteria are performance criteria C1 and economic criteria C2 in selecting exterior and interior wall materials. Based on the proposed model for exterior walls, isolation brick was chosen as the most suitable material. For interior walls, however, clay brick 2 (19x10x19) cm was ranked as the best alternative for residential buildings.

Key Words : Building system**,** Wall element evaluation, and selection, Exterior wall, Interior wall, MCDM, BWM, WASPAS, EDAS, TOPSIS, MOORA method.

Science Code : 91129

ÖZET

Yüksek Lisans Tezi

YAPI PROJELERİ İÇİN DUVAR ELEMANLARININ ÇOK KRİTERLİ KARAR VERME YÖNTEMLERİYLE ANALİZİ VE BELİRLENMESİ

Harez Kanabi ABDULRAHMAN

Karabük Üniversitesi
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Günümüzde çeşitli özellik, performans ve özelliklere sahip farklı yapı malzemeleri kategorilerinin mevcut olması nedeniyle duvar elemanına ait malzeme seçimi zorlu bir iştir. Tasarımcılar ve karar vericiler sıklıkla birçok farklı faktörü göz önünde bulundururlar. Değişkenler veya parametrelere ait bu kombinasyonlar karar verme sürecinin karmaşıklığına sebep olmaktadır. Bu çalışmada, konut binaları için en uygun dış ve iç duvar malzemesinin değerlendirilmesinde ve seçiminde üç aşamalı Çok Kriterli Karar Verme (ÇKKV) yöntemi sunulmaktadır. İlk aşamada literatüre bağlı olarak performans, ekonomik, yönetim, çevresel ve sosyal kriterler olmak üzere 5 ana kriter ve 27 alt kriter derlenmiş olup, ayrıca kil tuğla, gazbeton blok, bims blok ve cam tuğla gibi duvar malzemeleri de incelenmiştir. İkinci adımda, kriterlerin ve alt kriterlerin ağırlıklarını ve sıralamasını bulmak için En İyi-En Kötü yöntemi uygulanmıştır. Son adımda, çok kriterli karar verme tekniği WASPAS, TOPSIS, EDAS ve MOORA kullanılarak malzemelerin değerlendirilmiş ve sıralanmıştır. Verilerin analizinden, dış ve iç duvar malzemesi seçiminde en önemli kriterin performans kriteri (C1) ve ekonomik kriter (C2) olduğu sonucuna varılmıştır. Önerilen modele göre dış duvar için en uygun malzeme olarak izolasyon tuğlası ve iç duvar için 19x10x19 cm boyutlu kil tuğla konut binaları için en iyi alternatif olarak sıralanmıştır.

Anahtar Kelimeler: Bina sistemi, Duvar elemanı değerlendirmesi ve seçimi, dış duvar, İç duvar, MCDM, BWM, WASPAS, EDAS, TOPSIS, MOORA

Bilim Kodu : 91129

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SYMBOLS AND ABBREVIATIONS INDEX

SYMBOLS

% : Percent Sign
M : Meter
cm : Centimeter
Mm : Millimeter
µm : Micrometer
Min : Minute
S : Seconds
Kg : Kilogram
oC : Degrees Celsius
DB : Decibels
CO2 : Carbon Dioxide

ABBREVIATIONS

HVAC : Heating, Ventilation, and Air conditioning
2SiO2. 2H2O : Hydrated silicate of alumina
Al2O3 : Alumina
AAC : Autoclaved Aerated Concrete
ALC : Autoclaved Light Weight Concrete
CaOH : Calcium hydroxide
MCDM : Multi-criteria decision-making methods
BWM : Best- Worst method
WASPAS : Weighted Aggregated Sum Product Assessment
TOPSIS : Technique for order preference by similarity to an ideal solution
EDAS : Evaluation based on the Distance from Average Solution
MOORA : Multi-Objective Optimization by Ratio Analysis

AHP	: Analytical hierarchy process
ESP	: Expanded polystyrene
LCA	: Life cycle analysis
AEAS	: Additive Ratio Assessment
WSM	: Weighted Sum Model
WPM	: Weighted Product Model
PDA	: positive distance from average
NDA	: Negative distance from average
ASi	: Evaluation appraisal score

PART 1

INTRODUCTION

1.1. GENERAL INTRODUCTION

Buildings are constructed to resist loads, serve a specific objective, and meet the clients' requirements per the building type. There are different types of buildings according to their practical use, including residential, educational, business, hospital, institutional, industrial, storage, military buildings, etc. Every building has its requirements and specification that differ from the others. Buildings serve as shelter protection against weather, rain, and the snow wind and provide a comfortable and safe indoor environment for occupants, particularly are called residential buildings [1]. Residential buildings should be designed and planned based on several principles such as structural stability, acoustic, heat and moisture resistance, durability, environmentally friendly, resistance against fire and risk reduction, costly effective, daylight and ventilation of buildings, and low energy consumption [2]. Generally, residential buildings are among the most critical aspects of a society's social and economic growth in every country. In recent decades, there has been an increasing demand for energy efficiency in buildings and high comfort levels of internal areas in the overall building principles, significantly since the number of high-rise buildings has increased together with population growth [3].

A building consists of many elements such as floors, walls, roofs, windows, doors, columns, beams, and some architectural detailing parts, interacting together and working as a system . Each of the elements has a different function in the system and plays a vital role in meeting the performance requirements of the building. Each element influences the performance of the other elements.

For example, wall elements are one of the critical components of the building, which either provide an interface between the internal and external environment as exterior walls or divide buildings into separate rooms as interior walls [2]. The performance of wall elements involves various factors such as energy efficiency, structural behavior, thermal comfort, acoustic comfort, durability, etc. Wall elements are critical in achieving occupant satisfaction, building performance, energy efficiency, and cost-effective construction strategies [4].

Choosing a material for wall elements is a difficult task that requires time, effort, and consideration due to the several materials available in construction in recent decades; many parameters and criteria are taken into account, including economic, performance, environmental, and architecture. Moreover, many Stakeholders are involved, such as designers, owners of the project, project managers, and subcontractors [5]. Among other reasons, materials account for a significant portion of a building's cost, accounting for 64 percent to 67 percent of the total cost of a building. As a result, an increase in material’s price leads to an increase in the total cost of the building [6]. Additionally, one of the main components of global energy consumption and environmental pollution is the use of construction materials. Tremendous amount of energy is used in every stage of building materials, for instance, extraction of raw materials, manufacturing, transportation, building construction in every phase CO_2 emits into the environment and cause of climate change and global warming [7]. Types of wall material will significantly impact the indoor air quality of the building, Comfort ability, and residents' health, such as thermal and acoustic comfort [8]. Moreover, building materials provide safety structures that can resist external and internal loads [9]. Wrong and improper wall material selection in the design stage leads to severe issues with the economy because it might cause time overrun, higher costs, more manpower requirements for a construction process, higher amount of material waste in the construction stage, and a longer duration of the construction process, that affect in the later stages of the project. It is believed that material selection affects the success of any project. Therefore, the decision-maker must have a good understanding and information about the material's properties, mechanical properties, chemical properties, and the effect of materials on the environment. Conversely, the impact of poor decisions and choices of materials made during the design phase of construction projects manifests itself later in the project's life cycle, resulting in a significant increase in energy consumption and environmental impacts such as CO_2 emissions and global warming [10,11].

Selection of the best wall element among various alternatives is a multi-criteria decision-making problem and a fundamental problem in the design phase of every project. Since various materials with varying compositions and characteristics are employed to construct a wall. Thus, different materials with different quality, prices, and performance are available in the markets. Choosing a single one to meet all requirements has become a trial-and-error procedure [12]. In this study, wall materials such as, clay brick, Autoclaved Aerated Concrete (AAC) block , pumice block, and glass brick are involved in the evaluation and selection process of exterior and interior walls .Clay brick is one of the oldest and most extensively used building materials in the history of construction applications. clay bricks have become popular building material, due to durability, affordability, economical and accessibility, with compressive strength, ease of handling and workability, and fire and weathering resistance [13]. Autoclaved Aerated Concrete (AAC) block is a certified green building material that is eco-friendly, non-toxic, porous, reusable, recyclable, and lightweight because 70% to 80% of AAC consists of air in various sizes and thicknesses [14]. Pumice block is produced from the lightweight, spongy, and porous pumice aggregate used as external and internal wall material [15]. Pumice block has a low compressive strength between 2.5 to 3 MPa. As a result, it is more suitable for non-load-bearing structures [16]. Glass brick is a very sustainable building material that can be made from recycled materials and is reusable, available in a variety of sizes, colors, textures, and shapes. It is uded more for beauty perpusoe and architectural applications [17].

As a result of an extensive literature review on the field of building material selection , it was observed that the material selection for exterior and interior wall together had not been studied widely yet. In terms of criteria, previous investigations mainly focused on environmental consideration and just a few criteria have been considered. Moreever, This study focuses in particular to study the decision making in the selection of the appropriate wall materials in order to obtain affordable quality wall element and buildings .

1.2. RESEARCH PROBLEM STATEMENT

Depending on the designer's expertise, the type of architectural design, the client's desire, the cost of construction, and the availability of materials on the local market, various kinds of wall materials have been considered in the selection process of wall elements. In selecting and optimizing wall elements, just a few factors have been examined; in most instances, efficient and accurate thought is not given to which kind of wall components is the best option for each type of building projects. This seems to indicate the requirement for developing a systematic wall material selection system that will allow designers and engineers to identify and prioritize the relevant criteria to assess the trade-offs efficiently and precisely between technical, environmental, economic, and performance issues during the material evaluation and selection processes.

1.3. RESEARCH QUESTIONS

The main question of this research is “Which material is the most appropriate choice for exterior and interior wall elements in residential building projects in terms of clay brick, autoclaved aerated concrete AAC, pumice block, and glass brick?

1.4. RESEARCH AIMS AND OBJECTIVES

This research aims to formulate a multi-criteria decision-making model to evaluate and select the best alternative wall elements for a building project's external and internal walls using multiple considerations, including performance, economic, management, environmental, and social criteria.

In this study, karabuk and its surrounded region has been chosen as the case study and suitable for our MCDM model. The Black Sea climate is a type of climate in the Black Sea Region. the winter is very cold and the summer is not too hot. The annual average temperature is 13.0 °C, the July average is 22.1 °C, and the January average is 4.2 °C. The annual relative humidity average is 71%. Generally is a rainy region[18]. Location of the building project has great influence on the overall selection process of building materials in particular wall materials. Different location has different climate conditions even in a country, for instance in turkey, there areb more than 4 different climate conditions according to places. The wall material that can be used for a very cold weather like Arzrum in turkey it is not suitable for a hot weather like Diyarbakr or hot country like Iraq, as well as a seaplace with high humidity (Antalya, Izmir). This MCDM model and criteria list created in this research study can be used for every location but the final selection of the suitable material is change according to climate condition of the place.

The main objectives of the research are to:

1. Identify a list of main and sub-criteria essential in selecting wall elements for building projects.
2. Evaluate the alternatives.
3. Find the most suitable wall material for exterior and interior walls.
4. Formulate a framework based on multi-criteria decision-making methods after data analyzing. .

1.5. RESEARCH ORGANIZATION

This thesis consists of five chapters

Chapter 1: contains the general introduction of the research study, determining the problem statement, primary questions, Aim& objectives, and research organization.

Chapter 2: Background of the widely used wall materials ,decision criteria, and will review the related literature in MCDM methods ,wall material selection and related topics.

Chapter 3: Research methodology.

Describes the MCDM methods applied to find the criteria weights and rank the alternatives.

Chapter 4: MCDM Method application& results and discussion.
Shows the calculation results of every MCDM method used and discusses the results.

Chapter 5: presents the summary and conclusion of this research study.

PART 2

LITERATURE REVIEW

2.1. BUILDING SYSTEMS

A building can be defined as a physical expression consisting of various systems and subsystems interacting and coordinating with different functions in the system. Building system deals with different components, interactions, and relationships. Each component's performance influences the performance of other components and the overall system [1]. Buildings are enclosed for privacy protection against weather, rain, snow, and wind, and they provide a safe and comfortable indoor environment by controlling air temperature and humidity. Especially nowadays, because of the widespread use of modern construction and using technology in the manufacturing processes, as well as novel materials, buildings are developed and more complicated than in the past, using more building systems. As a result, they must be able to fulfill more functions, more durable buildings , and keep the construction and maintenance costs as low as possible to satisfy clients' and occupant’s requirements [19]. The building is classified into structural and non-structural systems. The structural system is the primary and most important system in the building; it supports and holds the other building systems. Subsystems of the structural system include (the foundation, floors, columns, beams, walls, and roof system) Figure 2.1 show the major elements of the building. In the building's design stage, a specialist structural engineer design and investigate the structure system's stability, strength, and rigidity, Either load-bearing or non-load-bearing system, and create a structure that can withstand all the live load and dead load without failure [2]. On the other hand, non-structural systems such as mechanical, finishes, plumbing, electrical, lighting, and HVAC systems.

They are also called service systems, which are more responsible for the comfortability of the indoor climate of the building [19].

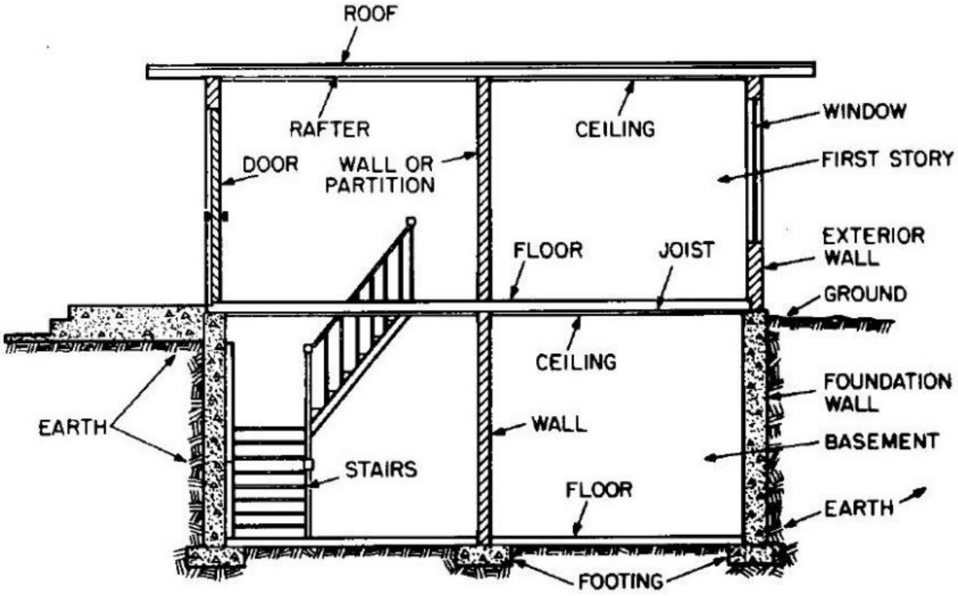

Figure 2.1. Major elements of the building [1].

2.1.1. Building Types

Buildings are construced for different purposes and objectives. Buildings can be categorized based on functions, uses, sizes, construction techniques, and designs . According to functions, buildings are divided into various types: residential, educational, institutional, assembly, business, industrial, storage, religious (mosque, church), sports, hazardous, military buildings, etc. Each of these types of buildings has its properties and requirements as well as different materials with different performances (quality, strength, price). For instance, military buildings require different wall materials than residential buildings [1,2].

2.1.1.1. Residential Buildings

The construction sector was one of the earliest economic sectors, contributing to the country's development by spending trillions of dollars on various projects. The residential building takes first place compared to the other building types accounting for 30-50 percent of all construction costs [20,21].

The residential building is one of the most famous building types that provides basic requirements for human requirements. The simplest type of residential building includes sleeping, living, and cooking room, where human activities can occur [22].

People are always looking for a better place to live in a more comfortable environment. As a result, buildings are becoming more complicated. Developers and investors have always been trying to benefit from adopting new technology, materials, tools, techniques, and approaches to improve the building by meeting the occupant's requirements, including increasing occupant comfort, swiftly resolving operational issues, improving building performance, assuring occupant safety, lowering energy and water use, and making effective use of maintenance workers . In addition, there is a continuous demand for residential buildings as the population increases [23].

In the design of the residential building, some principles and standards should be considered as well as the designer follow the building codes that provide information about the minimum size of windows and doors, the thickness of the exterior and interior walls, the height of the roof, size of staircases, etc. The main principles required in every residential building are structural stability, acoustic and heat resistance, durability, environmentally friendly, resistance against fire and risk reduction, costly effectiveness, daylight, ventilation, and low energy consumption [4]. Environmental and climatic factors play a vital role in building design. For example, a building with prolonged and severe rains requires heavy rain protection, such as a watertight roof. In windy solid regions, the buildings' walls, especially exterior walls, require an adequate thickness. The requirements for building in hot and dry climates; are proper ventilation and air conditioning are essential in these regions [24].

2.2. WALL ELEMENTS IN BUILDINGS

A wall element is one of the physical elements of a building system[25]. Generally,Walls are classified into two types load-bearing and non-load-bearing walls, and both have different characteristics in functions and different design criteria. Load-bearing walls carry the loads from the other structural elements, such as floors,roofs, beams,its weight and side forces from wind and other environmental factors are transferred to the foundation. Thus, the load-bearing wall is an essential structural element integrated with the roof and floor. While non-load-bearing walls carry just their weight, resisting environmental factors (wind and seismic load) does not support any structure loads. Thus, this type of wall is constructed onto the structural frame of steel or reinforced concrete to support and carry the weight of the floor, roof, and non-load-bearing wall [2, 25, and 26]. This study only focus on non-load bearing wall.

2.2.1. Types of Wall Elements

Exterior and interior walls are two types of wall elements in every building [1], which are described in the following.

2.2.1.1. Exterior Walls

The exterior wall is a sub-system that separates the interior and exterior environments. Exterior walls are a barrier due to direct exposure to environmental factors such as rain, heat, wind, moisture, solar, fire, and sound. However, due to the primary function of the exterior wall, which is essential in providing a comfortable and safe interior environment for residents, the exterior wall should be designed to withstand and respond to changing environmental conditions [4]. However, to achieve durability and the ability to remain for an extended period of service life, exterior walls should have such a good performance criterion. Any exterior walls should meet some fundamental requirements, including (moisture, heat, air, light and solar radiation controls, acoustical resistance, providing adequate strength and stability, responding to weather tightness, fire resistance, be cost-effective) all these requirements should be obtained as far as possible at a reasonable cost initial and maintenance cost [2,4].

2.2.1.2. Interior Walls

Interior walls can be either non-load-bearing or load-bearing but are usually constructed as non-load-bearing walls. In practice, interior walls are called partition walls; the primary function of a interior wall is to divide an enclosed space [25]. The height of the interior wall is not always up to the full floor, sometimes up to 2.5 m height or lesser to provide privacy facilitates, spatial division and developed acoustical resistance. The interior wall requirements differ from exterior walls because interior walls are not subjected to the same harsh environments (rain, snow, or solar rays) as exterior walls. An internal wall should meet some basic requirements, including (good acoustical resistance, giving satisfactory privacy, fire resistance, and lightweight. They are usually thin walls not to take up so much space from the floor [27].

Masonry Wall

Masonry wall assemblage pieces of materials such as bricks, concrete blocks, stone, glass blocks, tiles, marbles, and gypsum blocks that are boned and held together with a binding material such as mortar, the mortar is a mixture of sand, lime, sand, and water [28].

Masonry can be used as load-bearing(structural wall) and non- load bearing wall. Masonary has been used widely as a structural wall. Recently, load-bearing masonry has been hardly used because it is weak in earthquake resistance and more costly due to material and labor use. Currently, most modern multi-story buildings have structural frames and non-load-bearing walls, which are more resistant to earthquakes because structural frameworks keep their integrity. Masonry walls often improve the wall system's fire resistance. Masonry is set on a sturdy rigid foundation, A concrete foundation, structural steel, or concrete beam system is usually used. The masonry units are set in a mortar bed. The horizontal joints between units are referred to as bed joints, whereas the vertical joints are referred to as head joints. Clay brick masonry should have solid (complete) head and bed joints. [26]. Figure 2.2 shows masonary wal.

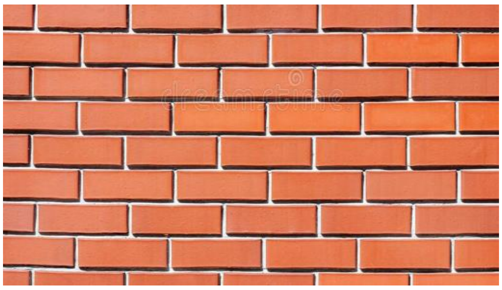

Figure 2.2. Masonry wall [29].

2.2.2. Wall Materials

A wall is constructed using various materials with varying compositions and qualities. The wall's functions or responsibilities, either load bearing or non-load bearing, play a crucial role in determining the most appropriate material [5]. Sverre Fern says, “Each material has its characteristics, such as weight, strength, durability, cost, voice, and tells its own story that make it suited for specific applications [30]. Today, many materials are available, each with its qualities, applications, benefits, and drawbacks. We must comprehensively understand the functional requirements for each element when selecting materials for engineering designs. The technological concerns of material features and factors are significant when selecting materials for an application, physical qualities, electrical, magnetic, mechanical, chemical, and manufacturing properties, cost of materials, product shape, the environmental impact of materials, performance qualities, supply, cultural elements, aesthetics, recycling, target group, are some of these factors [31]. Any company or individual planning to construct a building first should determine the type of the building ; it can be of any sort, whether industrial, commercial, or residential, depending on the desire or needs of the situation. Environmental conditions of the surrounding area also need to be considered [32]. clay brick, Autoclaved Aerated concrete block (AAC), pumice block, and glass brick are some of the most common wall materials nowadays; each material's composition, properties, and manufacturing are presented in this study.

2.2.2.1. Clay Brick

Brick is one of the oldest and most widely used building materials in construction history. Brick can be made from various materials, but the most popular type is made from ordinary clay soil. Due to their resilience, affordability, availability, strength under compression, ease of handling and usage, fire and weather resistance, thermal and sound insulation, and natural material composition, clay bricks have gained popularity as a construction material [33]. Since ancient times, bricks have been manufactured; they were a vital construction material during the Mesopotamian, Egyptian, and Roman periods in both sun-dried and burnt forms [13,34]. Brick is a building material used to construct walls, pavements, and other elements. Since it is produced, it has a special place among wall elements.

Figure 2.3. Various sizes of clay brick [35].

Composition of Fired Clay Brick

The main components of clay-based brick are silica (sand), alumina (clay), and silt; these ingredients greatly influence the properties of clay brick. Thus, the properties of these raw materials must be known and investigated before using in the production of brick. clay, which is described as a hydrated silicate of alumina ($Al2O3.\ 2SiO2.\ 2H2O$). Various types of clay can be used, including kaolinite, illite, montmorillonites, and others (chlorite, muscovite, and so on but Illite and Kaolinite clays are the most preferred in brick production [13]. Silica, as the significant ingredient of clay brick (50% - 60%), prevents raw bricks from cracking, shrinking, and warping; the right proportion of silica is vital in bricks because it dramatically affects the durability and properties of brick. Another main component is alumina

(Al2O3) in arranging between (20%-30%), which provides plasticity to the brick and makes the brick be molded easily. Iron oxide contributes to a small quantity (≤7%), giving the brick a red color during the phase process. Also, the presence of iron developed the durability and impermeability of the brick [36].

Production of Clay Brick

Brick manufacturing is vital in any country's construction industry and national economy [37]. Producing clay brick includes various stages like preparation, mining, and grinding of Raw materials, Forming, Drying, burning, Packaging and dispatch. In the first stage, The raw materials, clay or shale, are transferred to a primary crusher, which will first reduce large chunks of rock to a manageable size (100-200mm), then fed into a secondary crusher.in this stage, Water is added to a ‘wet pan' [13]. Preparing clay is shaped into rectangular bricks during the molding process.

Before firing, the produced bricks gained strength and must be dried to avoid deformation (shrinkage). The drying process is performed naturally under normal atmospheric conditions, and the final process is burning. When the temperature inside the klin reaches 300 °C, the brick undergoes physical and chemical changes and then transforms into a new artificial material; during the burning process in the tunnel Kilns, the temperature is gradually increased to 900 - 1250°C. The ceramic bond formed during the sintering phase of the silica and alumina makes the clay brick homogeneous, more complex, and more robust [38].

2.2.2.2. Autoclaved Aerated Concrete Block (AAC)

Autoclaved Aerated Concrete (AAC) block is a certified green building material that is eco-friendly, factory-made, non-toxic, porous, reusable, renewable, and recyclable. AAC, also defined as Aerated concrete, or Autoclaved Light Weight Concrete (ALC) [39]. The rapid growth of AAC usage in the building industry began in Europe in the 1940s and rapidly expanded in several countries worldwide. Nowadays, it has been used all over the world. AAC has several excellent physical properties [14,40]. Such as (AAC) blocks are lightweight, an excellent insulator resulting in an easier-to-maintain interior environment, sufficient compressive strength, easy to construct, and economical to transport, Also, fireproof, heat retention, sound insulation, and good anchoring ,that comes in various sizes and strengths, as shown in Figure2.4. [41]

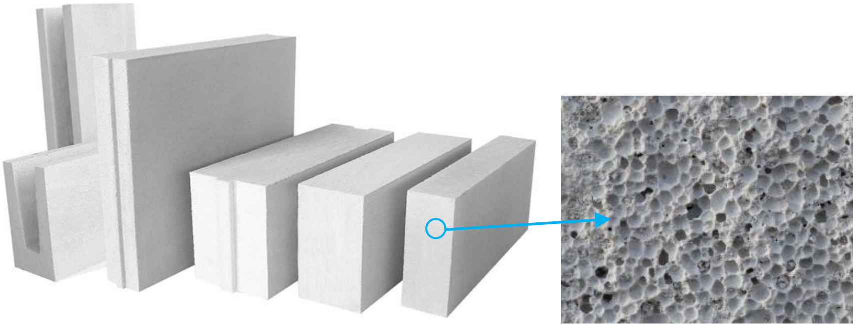

Figure 2.4. Different sizes of AAC block [35].

Composition of AAC

The AAC block is made of inorganic materials, including sand, cement, lime, fly ash, gypsum, water, and, most importantly, aluminum powder makes the mixture to expand considerably. Silica sands are used in the greatest volume in AAC. approximately ACC has an air content of 70% to 80% (depending on the required strength and density) and is up to five times than the volume of the raw materials see Figure (2.5) [41].

Production of ACC

The manufacturing process of AAC contains many phases and steps in the factory [42]. The process begins by mixing raw materials in a considerable container, silica sand or fly ash as the main raw material, lime and cement are mixed, then water is added, and the reaction starts. After mixing raw materials, aluminum powder is added to the mixture as an expansion agent, and aluminum reacts with calcium hydroxide ($Ca(OH)_2$), which is produced as the reaction between cement and water [41]. Hydrogen will be released into the atmosphere and creates lots of bubbles in the concrete. The hydrogen gas and bubbles make concrete expand and increase its volume.Concrete swells and acquires a hollow structure, then placed in different molds as per requirement, then wire-cutting into blocks. In order to reach the ultimate mechanical characteristics, AAC is subjected to steam pressure hardening for 10-12 hours at 12 bar pressure, and the temperature reaches 190 °C [43, 44]. The production scheme of aerated concrete is shown in Figure 2.5.

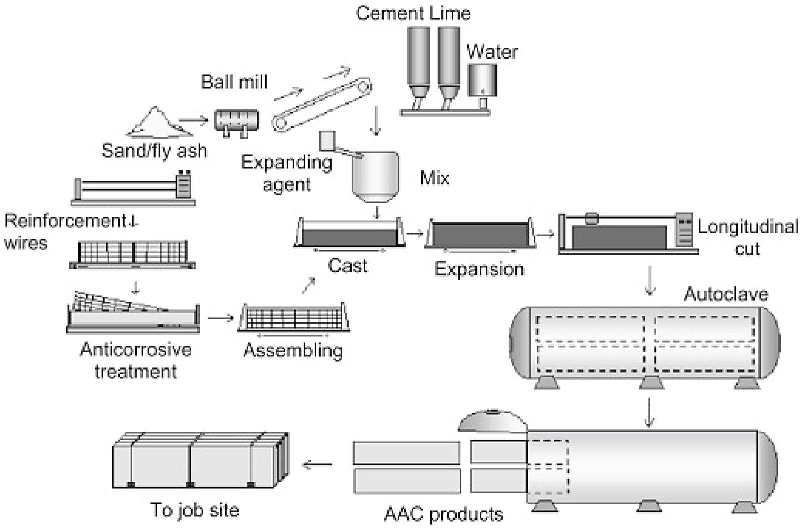

Figure 2.5. Overall steps in manufacture of autoclaved aerated concrete [45].

Auto claved aerated concrete has an alkaline structure consisting of silica hydrates. PH value varies between 9.5 - 11. In this respect, it is adversely affected by acidic environments sulfuric acid, hydrochloric acid, chlorides, and nitrates damage the equipment, thus, Autoclaved aerated concrete AAC should be protected against seawater in case of intense and continuous chemical aggressive substances in the environment [46].

2.2.2.3. Pumice Block

Pumice is an extrusive volcanic rock. It has been used as aggregate in the production of Light Weight Concrete. Pumice aggregate is formed as a result of volcanism process [47], which is very porous and light rock material filled with tiny gas bubbles. Gas bubbles and voids in the pumice provide excellent insulating properties against heat, cold, and sound [15]. physical and chemical properties of pumice are significantly influenced by its aggregate size [48]. According to another definition, pumice is a porous and glassy rock with a unit volume weight of less than400 to 800 kg/ cm^3, and its porosity ranges from 70–85 vol.%. The glassy composition makes it resistant to fire for up to 6 hours [49,50].

The best examples of the materials obtained from pumice stone are pumice blocks, different types of hollow masonry units are made in different sizes, as shown in Figure (2.6) [17]. Pumice block is widely regarded as unsuitable for load-bearing applications. Because pumice has low compressive strength ranging between 2.5 to 3 MPa, it has been mainly used for the production of partitions and panel walls [51].

Figure 2.6. Different sizes of pumice block [35].

In the construction industry, pumice is a building material that is considered to have started with the use of the Greeks and later the Romans in the construction of walls, water channels, amphitheaters, temples, and water arches were widely used in baths, cellars and residential construction**.** The most prominent examples are the Roman Pantheon and the Hagia Sophia Museum, as shown in Figure 2.7 [17].

Figure 2.7. Roman Pantheon and the Hagia Sophia Museum [35].

Manufacturing Process of Pumice Block

Pumice stones are collected from the pumice quarry Crushing, screening, and sizing are applied to the pumice stone by digging with a rubber loader, then loaded on trucks and transferred to the factory. It is classified by reducing the size in suitable crushing and screening systems in the factory and converted into pumice aggregate. The aggregate is first measured into the mixer for homogeneous mixing with the necessary amount of cement and water. The mixture formed is removed from the mixer and pressed into molds under high pressure and vibration for a few seconds. The wet blocks are removed from the molds and stacked for 24 to 36 hours. After the pumice blocks have reached the desired strength, Then, it is shipped to the stock area by the transporter and used for building [15].

2.2.2.4. Glass Brick

Glass bricks are are square shaped double glazing units available in a variety of sizes, colors, textures, and shapes and are used in construction applications [52]. The surface of glass bricks is smooth and not permeable compared to other building materials. Glass brick is a sustainable building material produced from recycled materials and can be used again. The modern glass brick evolved from prism lighting principles to provide natural light. Moreever, glass bricks are extremely energy efficient. Therefore, the cost of heating is decreased by the strong insulating characteristics of glass brick. Furthermore, advancements in acoustic and, fire resistance are another quality of glass brick [17].

Glass bricks are utilized in various architectural applications. When it comes to interior design for residential and commercial buildings , they may be used in various ways, including skylights and translucent coverings, while allowing natural light to reach the inner part of the room. In addition to inside walls, glass brick may also be utilized outside [52]. Figure 2.8 shows the application of glass brick in interior design.

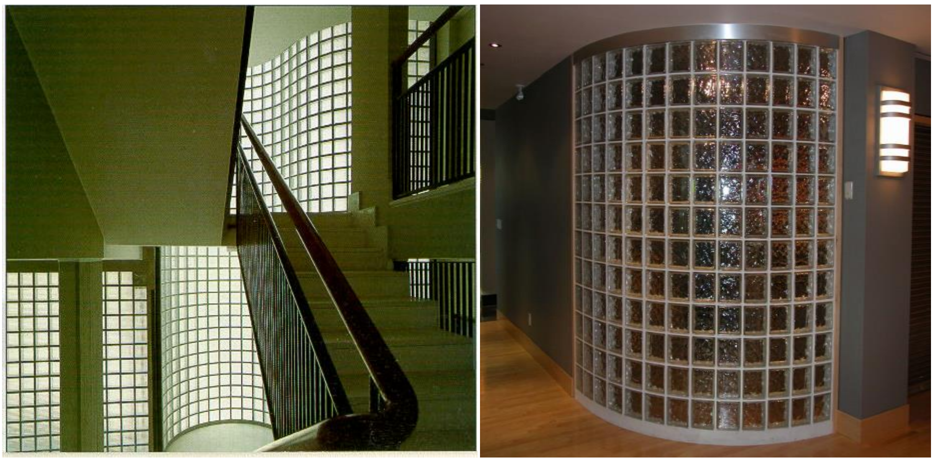

Figure 2.8. Application of glass brick in arc [52].

Installation of Glass Brick

Glass brick walls are reasonably simple to install and may be fastened with mortar, tile adhesives, silicone, or a mortar-less grid system that integrates perfectly with any wall.

The masonry with the Portland cement-based mortar with reinforcing rods of steel. is the most common and traditional way to install glass brick. Installation may be made easier with plastic spacers see Figure 2.9, this application is not particularly sensitive to environmental factors like moisture, dust, and temperature. A greater quantity of mortar helps prevent fractures caused by the temperature-induced expansion of bricks. Joint thicknesses around 10 mm are generally handled by mortar, while those of 5 mm or less are often handled by tile adhesives In addition, mortar is less expensive than adhesives [53].

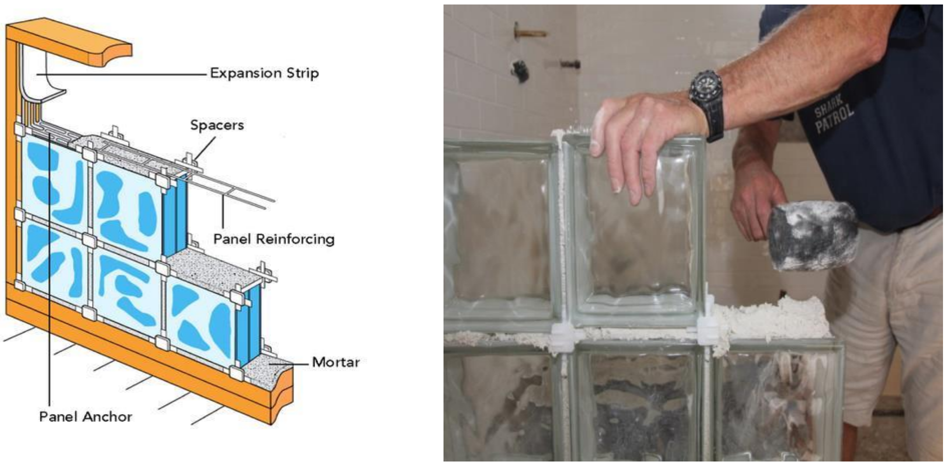

Figure 2.9. Installation of glass brick by using mortar [54].

Another method of glass brick installation using silicone and spacers is the drywall Installation System. Spacers are used to hold and keep the blocks in place, while silicone is used to join the spacers and the blocks together. Finishing the seams with a unique tile grout gives the completed product a clean and professional appearance. Additionally, the adhesive layer's possible thickness is very thin [53].

2.3. BUILDING PERFORMANCE

Buildings are inextricably linked with the natural environment and must therefore be designed to meet the criteria imposed on them. The performance of a building includes, but is not limited to, energy efficiency, indoor air quality, lighting comfort, thermal comfort, and acoustic comfort.

2.3.1. Wall Element Selection Criteria

As mentioned earlier in this study, to create a wall selection model five main criteria performance, economic, environmental, management, and social criteria have been considered. Each of them is divided into several sub-criteria can be seen in the description below.

2.3.1.1. Performance Criteria of Wall Elements

The exterior wall system works as a protective layer between outdor and indoor spaces since it is directly exposed to environmental factors including heat, water, moisture, solar, sound, etc. It should adapt to changing environmental circumstances to give inhabitants a comfortable and safety indoor environment.Depending on the characteristics of the building and its surrounding environment , building wall materials have different performances . In this research, nine performance criteria, namely, thermal resistance, acoustic and sound insulation, fire resistance, earthquake resistance, compressive strength, durability (freeze-thaw resistance), durability (life cycle), and weight, were selected and assessed for their suitability to the case project [4].

Thermal Resistance

Thermal resistance of wall elements is one of the most important performance criteria In terms of occupant health and comfort, In the summer, wall materials should withstand overheating and heat loss in winter. Condensation is also a result of temperature variation. The danger of condensation is reduced if the wall element has a good thermal performance. on the other hand, Condensation may damage the walls and cause health issues for occupants [55]. Increasing building energy efficiency and decreasing building energy consumption have become significant issues for the construction industry in recent years [56]. Furthermore, the thermal properties of wall materials can considerably impact the total energy utilized throughout the operation stage of a building. Finally, the selection of an appropriate material for the construction of buildings, walls as the predominant component of buildings, can significantly decrease the energy consumption of AC [57].

Acoustics and Sound Insulation

The acoustic performance of wall materials may significantly impact the levels of noise pollution inside a building. Noise pollution reduces interior comfort and negatively impacts the health of the occupants [58]. According to [58], outdoor noise may negatively affect human health. The continuous noise is detrimental to our overall physical health and immunity. In addition, bodily responses might result in headaches, excessive irritability, and tiredness, even at deficient levels. Therefore, the wall system must be planned and built to isolate the inside of the building from outside noises. However, the extent of the noise reduction depends on how much external noise may be endured. For example, the most prevalent airborne noise in apartments is neighbors' conversations and traffic noise. Nevertheless, the human ear can detect frequencies as low as 50 Hz, lower than the frequencies used for calculating the STC of building material or system. The mass law is the typical guideline for minimizing airborne sound propagation. This says that the heavier the structure, the less sound it will transmit (i.e., the greater attenuation for airborne sound and low-frequency sound) [59].

Weight

It is very important for the wall system (exterior and interior) to be constructed of lightweight materials to avoid any overload bearing on structural elements, particularly in high rise buildings or when the exterior walls are loaded on the cantilever. Accordingly, the volume of structural elements can be reduced [60]. Another advantages of light weight wall materials are easier to transport and more comfortable in execution and maintenance. In addition, these materials are transported quickly, resulting in less storage space and reduction of the duration time of the work [61].

Durability (Life Cycle)

One of the most critical considerations in selecting building materials and components is their long service life and durability . Material selection for wall elements are based on specific climatic conditions. Aside from the climatic conditions, long-term building projects need careful consideration of environmental changes and the effects from the use of these materials are very important [62].

Durability (Freeze-Thaw Resistance)

The resistance to decay of exterior wall systems considerably influences their serviceability throughout their planned service life. Specially, in regions where the air temperature often drops below freezing. When water seeps into the materials and freezes it then expands, after that ,the ice will melt when the temperature rises above freezing. Over time the repeated freeze-thaw action of water can damage the wall material and cause deterioration [63].

Fire Resistance

Residential building fires claim the lives of almost 4,000 people annually Only in the United States. In addition, the majority of fatal fires happen while residents are sleeping. Because it relates to life safety, fire resistance is one of the most critical performance criteria for wall systems. Wall materials should resist the effect of fire, which may include smoke, the propagation of flames, toxic gases and burn through. While no building materials are completely fireproof, it must be contained temporarily using detail-oriented measures. A wall system fire protection and smoke control properties are crucial for preventive measures of fire protection and thus for human life and property protection [64].

Compressive Strength

Walls provide an additional complexity since they may interact with the structural framework to contribute to its strength and stiffness. Self weight and wind load are the principal sources of loads in non load-bearing wall structures, Sometimes, hurricanes and tornadoes bring winds exceeding the designed tolerance capacity. whereas earthquake load, Thermal load, window washing load, and snow/ice are minor causes. These loads, along with the dead load of the wall, must be transferred to the structural frame via suitable structural connections, thus, it is important to select a wall material with a sufficient compressive strength to resist all these loads [65].

Earthquake Resistance

Earthquake-resistant typically incorporate ductility (the ability of a building to bend, sway, and deform without collapsing. Different construction materials react differently to the shaking induced by seismic waves. the mortar that typically binds the components together shakes away, it is the weak point in wall eleemnts because of lacks strength. Earthquake damage depends on several aspects, such as duration, frequency, and intensity of ground motion), geology, and soil conditions), buildingcharacteristic, and construction quality, etc. The design of a structure has to be such that it has adequate strength and excellent ductility and remains integral unit even when exposed to intense ground motion [66].

Moisture Control (Water Vapor Permeability)

Moisture control is among the most significant factors in building performance, compromising durability, especially in countries with cold climates. Comprehending and anticipating moisture movement throughout the structure and enclosure is essential for its control and avoiding moisture-related disorders.

Controlling moisture is a crucial part of designing an integrated building enclosure. In practice, it is almost difficult to eliminate all sources of moisture, construct walls without flaws, and eliminate all forces that drive moisture migration. Also, it is inefficient and uneconomical to utilize just materials impervious to moisture harm. In practice, it is sometimes desirable to address two or more of these conditions to reduce the probability of having of a problem. For example, deterioration may result if a material's safe storage capacity is surpassed for an extended period. materials having a porous internal structure may store considerable amounts of moisture, whether in the form of vapor, adsorbed, liquid, or frozen, inside this porous structure this will lead to thermal load in the future of the structure. In addition, non-porous materials can store moisture in cracks or fissures, which are absorbed and retained by capillary forces [67]. Figure 2.10 shows damage of bricks is caused by the migration of soluble salt through them

Figure 2.10. Damage of bricks is caused by the migration of soluble salt through them [68].

2.3.1.2. Economic Criteria

Decisions are frequently made based on project economic assessments. Materials are crucial for building projects and can significantly affect how cost-effective a project is, because building materials constitute the major elements in the buildings costs, accounting for 64% to 67% of the total cost of any structure [69]. In this study, economic factors include initial, maintenance, transport, and mortar costs.

Initial Cost and Maintenance Cost

Building construction cost can be broken down in to two categories including , cost of construction material and labor costs. First, the cost of construction materials may be decreased in low-cost buildings by using readily accessible resources and managing resource allocation effectively [70]. It is possible to minimize initial costs by selecting lower-quality materials at the expense of more maintenance or reduce service life or by compromising in other ways. As a result ,the initial cost should not be the primary consideration when evaluating and selecting wall materials. Maintenatce cost must also be considered. Thus, architects and decision makers should evaluate and select wall materials based on their total life cycle cost (Merritt, 1982) [71] . As part of an economical construction system, materials and maintenance play a key role in keeping a structure in good condition. These expenditures include painting, repair, remodeling, insulation, and other upkeep that have a negative impact on the environment. Such strategies result in high economic implementation productivity [72].

Transportation Cost

The longer the distance a material must be transported, the more significant on the financial and environmental consequences. For example, transporting heavy or bulky materials is more expensive than transporting lightweight ones. Because of the direct influence of local supply on lowering transportation expenses, Therefore, consideration must be given to the origin source of materials to reduce transport expenses and emissions to the lowest. [73].

Mortar Cost

Mortar is produced by mixing a binding material (cement or lime) with fine aggregate (sand,) and with water. There are three major types of mortars used in buildings for coating. Including cement mortar (cement, sand, and water), lime mortar (lime, sand, and water), and Gauged Mortar(cement, lime, sand, and water) [74]. The main cost of each type of mortar depends on the ingredient quantity and thickness of the mortar used for wall construction.

2.3.1.3. Environmental Criteria

The quality of the building would be enhanced by the usage of materials that releases fewer CFCs into the environment. Recently, environmental impact has been an important selection criterion used to reduce carbon emissions and to ensure sustainable development aspects [75]. This study's environmental factors are waste during production, construction, and carbon footprint.

Waste During Production

This comprises all production trash and stone refuse from mining and quarrying. The construction and building materials industries are engaged in both processes: the construction business is the most significant consumer of natural resources, and the destruction of structures generates a substantial quantity of garbage. However, due to air pollution (dust and extremely small particles that travel throughout the atmosphere) and harmful chemical leakage, wastes pose a significant threat to the environment . For example, the cement sector is responsible for 5 to 7 percent of global CO2 emissions (equating to 1,6 billion tons of carbon dioxide released into the atmosphere) [76].

Waste During Construction

Construction waste defines by SEPA as “materials resulting from building construction, remodeling, maintenance, or demolition, ". the energy, materials, and labor consumption adds no value to the construction process. There are many factors affect construction waste quantity in every building projects such as structure type, structure size, types of materials, geographical location, and activity being performed [77].

Carbon Footprint

The extraction of raw materials, their processing, and the manufacture of final products and services. In other words, the production of building materials and commodities and the structure's construction and surrounding environment contribute considerably to greenhouse gas emissions (CO2). Thirty percent of the world's CO2 emissions and 40 percent of the loss of natural resources are attributable to construction materials. Therefore, it is feasible to restrict CO2 emissions at the start of the construction process [76]. During the planning phase, the designer may make crucial decisions that will assist the bioclimatic design and provide the framework for future low-impact building material choices [78].

2.3.1.4. Management Criteria

This study chose seven sub-criteria as the most influential factors under management criteria in Wall element selection including difficulties of the Construction Process, availability, construction Speed, Need for Specialized skills, Dimensional Flexibility, Cladding Techniques, and plaster type.

Difficulties of the Construction Process

A problematic installation with precise tolerances may need additional waste or possibly rework. For example, detail applications on particular joints, beams-walls interact edges, roof ceilings, different materials interactions, etc., can hardly be constructed .

Availability

Availability of the material in the local market affects the material selection decision, material delivery delay leads to time overruns and cost overruns in every project [61].

Construction Speed

The shorter investment payback time is made possible by the haste with which high-rise buildings are constructed. If a project is finished more quickly, the company will have to pay an incentive fee. Project delays are known to lead to cost overruns, and time overruns are thought to be a direct cause of both. In both cases, speed comes at a price. In order to complete a project quickly, one must spend more money on supplies, labor, or technology. If there is a substantial disparity between the supply and demand of commodities, this cost will continue to rise. Therefore, selecting building materials and processes is crucial for decision-making when estimating project duration [79].

Needs For Specialized Skill

Construction expertise is a crucial consideration when choosing construction materials and techniques. It is associated with the selection of labor-saving construction equipment or technologies, labor-efficient materials, designs with preassembled pieces in accordance with labor availability and skill levels, and appropriate local practices [80].

Dimensional Flexibility

Load-induced strains and deformations in building components are widely understood and routinely addressed in structural design. However, other factors than stress may also induce minor dimensional changes in materials. These may cause deformations, loads, and strains that are not usually effectively considered. Changes in the moisture content of some materials and the effects of age and deterioration caused by the environment may also result in dimensional alterations. When these expansions or contractions are unrestrained, the constituent changes its dimensions. This may be a frequent source of the difficulty. After the formation of cracks, the wall will often get severely soaked. This is a consequence of the direct penetration of rain and the condensation of water vapor transported by air escaping through the crevices [81].

Cladding Techniques

Ceramics applications and their effects on construction management like labor works and arrangements of surface screening (interior walls). Heat isolation techniques and their details on walls, curtainwalls with stones or glass-like materials, and their application problems.

Plaster Type Using in Construction

Several plaster types are used in buildings for coating, depending upon the materials used for mortar mixture preparation, including (cement, sand, and water), lime mortar (lime, sand, and water), and Gauged Mortar(cement, lime, sand, and water) [74]. The problem of mortar can depend on the substances and application process (labor works)

2.3.1.5. Social Criteria

A building is normally constructed within the context of an existing community. As a result, a building can have a significant impact not just on its residents but also on the surrounding community [82]. In this study, Suitability to climate, safety during construction, and health have been chosen as the most influential social criteria.

Suitability to Location

This section focused on the influence of climate on the material's selection. Long-term exposure to specific climatic circumstances may develop unsightly stains, efflorescence, and fissures. For instance, materials with high porosity result in significant danger of attack, and the choice of paint finish for this facade system results in a high probability of stain appearance and high stain visibility. Squeezing through the crevices [82].

Safety During and after Construction:

It is related to the risks of lethal and nonlethal occupational injuries that result from the construction activities, materials that generate dust and other airborne pollutants, may be dangerous to people during installation. It also associated with the safety of occupants, which results from selecting materials that provide security to occupants and do not contain any hazardous [83].

Health

Labor health is essential in the construction of building systems, especially dusting and contaminants of materials must be prevented during the installation of the wall structure. These are the most critical factors on labor health both during the installation process and after construction, so consider them before deciding on wall materials. However, some requirements cannot be considered in developing countries because of the lack of education and finance. Hence, especially, dusting like problems on the wall element materials cause some health problems or diseases after finishing the construction. In addition, some materials can cause more dust, which should be considered before the project starts.

2.4. DECISION MAKING

The concept of decision-making is one of the most significant management concepts that has gained popularity in recent years. According to Harris (2009) [84], decision-making is "the study of evaluating and selecting alternatives according to the values and preferences of the decision maker". Decision making is so linked with human life that People are faced circumstances in their daily lives where they need to make critical decisions. However, decisions that are made without any planning have a risk of leading to failure. Making well-organized decisions is crucial to prevent such issues [85]. When problems in everyday life cannot be solved quickly, models are created to tackle them, and this model is used to solve decision-making challenges [86].

Decision making is challenging due to the uncertainty of the future. All alternatives are evaluated in all aspects before a decision is made. In today's world, where competition is expanding, communication and information technology tools are highly developed and diverse, decision making has become more complex. The best option for decision makers is to achieve the goal in the most efficient way by evaluating numerous interactive elements. The decision's effectiveness is demonstrated by achieving the desired results [87].

2.4.1. Types of Decision

According to Harris (2009) [84], there are several basic types of decisions. These are:

- "Whether" decisions This is the yes/no, either/or option that must be made before proceeding with the alternative selection.nsince we frequently assume that decision making begins with the discovery of options, assuming that the decision to select one has already been made.

- Decisions on "which" These decisions include selecting one or more alternatives from a range of options, with the selection dependent on how well each alternative meets a set of preset criteria.
- Decisions that are contingent. These are decisions that have already been made but have been put on hold until a certain condition is met.

2.4.2. Decision-Making Process Stages

Decision-making process requires a specific time because the process of deciding is a multi-stage procedure [85]. The process of decision making follow a common working principles [87].

- Identifying the problem
- Criteria selection
- Identifying alternatives
- Determine the criteria weight
- Evaluation and comparison of alternatives
- Making the decision
- implementation of the decision

2.4.2.1. Multi-Criteria Decision-Making (MCDM)

Multi-criteria decision-making (MCDM) problems related to determining the best alternative in the presence of multiple criteria that would typically conflict and affect the decision-making process [88]. MCDM methods have a long history, dating back over 240 years. It has been widely acknowledged as a distinct scientific discipline since the mid-twentieth century. It was created in the 1960s after that it was realized that several decision-making approaches were lacking. The goal of using MCDM methods is to regulate the decision-making process when there are many options and criteria to consider and to make the optimal decision more easily and quickly [89].

MCDM methods can be classified under three main issues, selection, classification, and ranking problems. In Selection Issues: The goal of selection problems is to find the best option or make a proper decision from many options that are hard to compare or have equal weight. A manager's choice of staff for a particular project can illustrate such issues. The purpose of classification problems is to rank the alternatives according to the criteria. In ranking problems, alternatives or criteria are ranked measurably from best to worst. MCDM methods use the criteria weights to solve complex problems with multiple conflicting objectives; for example, in the classification stage, Alternatives are categorized based on specific criteria or preferences. The primary goal is to reassemble options with comparable traits and behaviors. In the ranking part, alternatives are ranked from best to worst in a quantitative or definite way [90]. In addition, MCDM problems are used in many fields, such as the engineering field, which is identified as a field that has used mostly MCDM methodologies and approaches, management and business field, Science and technology field, political, commercial, and financial [91].

Multi-Criteria Decision-Making Techniques

Even though there are numerous ways for solving multi-criteria decision-making problems today, computer programs developed to apply these techniques, with helping technology, provide considerable ease to researchers, managers, and decision-makers**.** Because the nature of MCDM problems varies, various strategies have been presented as solutions. Some of them are listed below [91]; the methods to be used in the study will be described in detail.

- AHP
- ANP
- TOPSIS
- VIKOR
- SWARA
- MOORA
- MULTIMOORA
- BWM

- ARAS
- WASPAS
- COPRAS
- SMART

In this study, Five Multiple Criteria Decision Making (MCDM) methodologies are used as powerful tools to calculate decision-makers data. The first best worst method is performed to calculate the weight of the criteria. Then, WASPAS, TOPSIS, EDAS, and MOORA methods are used to evaluate alternatives,

2.5. LITERATURE REVIEW

Nikkhou s et al. (2021) [92] studied a sustainable multi-criteria decision-making framework for selecting the appropriate interior walls in Tehran, Iran's high-rise residential constructions. Twenty-three sub-criteria were discovered, and the analytic hierarchy approach was used to determine the weight of each criterion. According to the acquired data, the financial criterion has the most weight among the primary criteria, followed by the technical, environmental, and social elements. Similar weights are assigned to financial and technical factors.

Mathiyazhagan et al. (2018) [93] focused on selecting the best and most appropriate brick material for every form of structure in the Indian construction sector. To this end, a three-phase model was established for selecting the most appropriate construction material based on the TBL's three primary criteria (environmental, economic, and social) and 23 sub-criteria. Four alternative brick materials were discovered. Burned clay bricks, burned clay fly ash bricks, hollow concrete blocks, and autoclaved aerated concrete blocks. In their investigation, two MCDM techniques were used to determine the weights and rankings of criteria and sub-criteria for material selection based on expert opinion and to prioritize the discovered materials using Fuzzy TOPSIS from the standpoint of the building industry. Based on this research's findings, fly ash from burned clay emerged as the best alternative material among the four types of bricks analyzed.

B.kiani (2018) [94] presented a repair material selection. A preliminary performance criterion for choosing repair materials by VIKOR technique for structural concrete. The suggested material selection process is simple and aims to reduce overall costs by minimizing the likelihood of costly errors, ensuring the long-term performance of restored concrete buildings, and preventing early failure.

S. Mahmoudkelaye et al. (2018) [95] utilized the ANP method to separate the selection criteria into four divisions based on maintainable values: technical, environmental concerns, economic and socio-cultural. Environmentally, the criteria are categorized into three sections: environmental consequences, energy, resource use, and human comfort and health. Three substitutes were assessed for the outdoor enclosure of housings. Brick and mortar walls, aluminum siding, and cedar siding were used in this model because these materials are commonly used in Iran. The term "life cycle assessment" refers to determining the overall environmental effect of materials by considering all stages of the product's existence. Finally, a computer model was developed to choose eco-friendly materials. According to the data, aluminum siding is the most sustainable choice, whereas cedar siding is the least sustainable. This model established the significance of the criteria and sub-criteria for selecting sustainable materials.

Govindan et al. (2016) [96] focused on construction in UAE. The study primarily aimed to create a model to assess the best building material (wool brick, AAC block, clay brick) based on sustainable factors using a hybrid MCDM technique that combines DANP and TOPSIS. The study gathered 25 sub-criteria under the three pillars of sustainability from the literature, and a case study was used to verify the suggested framework. Regarding sustainability, the research indicates that wool brick is the most influential alternative material, followed by AAC brick and clay brick. Compared to the other two types of bricks, clay bricks needed more energy and materials throughout their life cycle.

Mesároš and Mandičák (2015) [97] studied decision-making integrated with determining the factors that influence the usage of innovative materials in construction. The political environment, building techniques, construction quality, cost, and duration of construction are identified as the most critical factors in using modern materials and methods in construction as increased need for environmentally friendly development initiatives in future applications.

Martabid and Álvarez, (2015) [98] focused on a case study establishing the standards for choosing envelope wall systems in Chile. In their study, a set of criteria were examined, including cost, the complexity of construction, safety and environmental impact, durability, and aesthetics. Thermal, acoustic, and structural characteristics are also included. The structural behavior requirement is the most crucial, whereas complexity is the least crucial.

Balali et al. (2014) [99] utilized the multi-criteria decision-making approach known as PROMETHEE to choose the best structural system for multi-housing projects. Different economic and technical standards have been considered, representing the accessibility of skilled engineers and technicians and the required equipment and building supplies used in this procedure. The country and region where the project will be built are essential factors that should be considered in the decision-making process, as are the economic life cycle, environmental protection-related issues, site safety, and vulnerability to natural catastrophes like earthquakes.

Ruzgys et al. (2014) [100] Analysis of the effectiveness of modernizing residential buildings focusing on external wall thermal insulation selection. Estimating factors like the total cost of modernizing the exterior walls, the simple payback period, the implementation time of the project, and other factors relating to the properties of thermal insulation systems are among the most crucial for the implementation of apartment building modernization. SWARA-TODIM MCDM method was used to determine the weights of the criteria and rank the alternatives

Al-Hammad et al. (2014) [101] offered a methodical approach to the assessment and choosing the right curtain wall system among various common types for medium-high rise structures, analyzed several performance criteria, as well as the financial and non-financial factors influencing the assessment, and choosing curtain wall systems. The precast concrete curtain wall system is thought to be the best option, according to the analysis of the data gathered. The prefabricated brick panel curtain is the second option.

Zavadskas et al. (2013) [102] used a set of twelve criteria to assess four building facade choices for public or commercial structures. Cellular concrete masonry enclosed with Rockwool plates and ornamental plaster surface (a1), "sandwich" facade panels (a2), gas silicate masonry coated with Rockwool and "Minerit" facade plates (a3), and aluminum-glazing facade (a4) (a4), Installation cost, labor intensity, user-friendliness, durability, warranty, environmental friendliness, recovery (utilization), aesthetic, the weight of the structure, structure thickness, sound isolation, and fire resistance are considered as criteria. The WASPAS and MOORA were used as ranking options. According to the WASPAS approach outcomes, Alternative a4 (aluminum-glazing façade) was selected as the top option, while Alternative a2 (sandwich facade panels) stayed in the second position. However, MORA determined that "sandwich" facade panels (a2) placed highest.

P.O. Akadiri et al. (2013) [103] proposed a model for selecting a sustainable roofing element in the United Kingdom using Fuzzy extended AHP approaches. An integrated MCDM technique combining sophisticated proportional assessment and evaluation of mixed data was used to identify the ideal material option. The team of decision-makers examined three roofing components based on six primary criteria: environmental effect, life cycle cost, resource efficiency, waste reduction, performance capacity, and social benefit, considering three roofing materials as selection options.

Do and Kim (2012) [104] proposed an optimum concrete repair material selection model; they studied the performance criteria of the repair material that influence the selection, which split into two categories: the necessary chemical performance and the necessary physical performance. The first comprises electrical resistivity, chloride permeability, and alkali resistance. The second comprises elastic properties, thermal expansion, drying shrinkage, adhesive strength, compressive strength, and tensile strength. Among MCDM methods, AHP was used to evaluate six repair materials for a chloride-deteriorated concrete

Ogunkah and j.Yang (2012) [105] established a multi-factorial analytical decision support toolbox to help architects evaluate and select environmentally friendly local building materials. As well as the effects of their material choices on whether or not they are likely to advance sustainability goals. The Analytic Hierarchy Process (AHP) model was used to apply the quantitative evaluation criteria and choose the best option for building material

Susinskas et al. (2011) [106] proposed the Additive Ratio Assessment (ARAS) method to choose the most appropriate and effective pile-columns installment alternative, a technique for making decisions that use pairwise comparisons of different criteria including Mass, labor costs, installment expense, machinery costs, amount of earthwork, and tolerance for installments. The weights of the criteria were calculated using the entropy approach. The suggested method could also support the choice of efficient alternatives for structures, technology, investments, etc.

Reza et al. (2011) [107] examined three kinds of block-jointed flooring systems (concrete block, clay, and expanded polystyrene (EPS) blocks) in Tehran using life cycle analysis (LCA). In accordance with the concept of triple-bottom-line sustainability, the primary criteria were separated into environmental, economic, and sociopolitical concerns and subdivided into thirteen more criteria. First, the analytical hierarchy process (AHP) was utilized as a multi-criteria decision-making approach. Comprehensive research demonstrates that the EPS block is the most sustainable option for Tehran's block-jointed flooring system.

Zheng et al. (2010) [108] suggested an enhanced grey relational projection approach for selecting China's optimal building envelope option. Various parameters were used to assess the roof, exterior wall, floor, door, and window possibilities for the building envelope, such as thermal properties, architectural form, cost, innovation, dependability, and environmental implications. A technique combining subjective and objective weights is used to determine the weights of the components and sub-factors. Calculating the relative projection values of the options as well as the optimal solution is achieved.

Zavadskas et al. (2010) [109] exhibited the procedure for selecting the most suitable and secure foundation installation option for a structure that lies on auriferous soil. The choice is based on a set of factors, including installment prices, length of installment, decision complexity, decision benefits, and drawbacks, transferability and maintainability of the installed foundation system, and previous implementation experience with the authorized decision. The issue was solved using the Additive Ratio Assessment (ARAS) approach.

Abeysundara et al. (2009) [110] advanced a quantitative model for selecting sustainable construction materials in Sri Lanka, grounded on environmental factors like embodied energy, financial factors such as market value and expenses, and social factors like thermal comfort, aesthetics, speed of construction, and resistance. The materials used for the foundations, roofs, ceilings, doors, windows, and floors of five building components were evaluated. It has been discovered that structures with a tile roof, rubble base, etc. function better than those with an asbestos roof and a brick foundation. According to their research findings, environmental elements are preferred in decision-making.

Florez et al. (2009) [111] Framed dimensions that impact the assessment of a product's or material's sustainability are subjective elements or variables such as the product's appeal, resourcefulness, and functionality. Without mentioning whether it may be beneficial for assessing the performance metrics of other materials, the proposed material selection tool, in particular, includes essential information on the technical features of brick materials. However, their study did not outline how prospective customers might distinguish between environmentally friendly materials or products.

Zavadskas et al. (2008) [112] studied selecting the most appropriate dwelling house wall according to thermal transmittance, price, durability, weight, and human labor input. In this model, the grey relational grade was applied to determine the characteristics of the alternatives, which are expressed as intervals. The practicality and efficiency of the suggested approach were demonstrated using a case study of the evaluation of external walls of four possibilities

Rahman et al. (2008) [113] created the multi-criteria decision-making model (MCDM), which allows architects, designers, quantity surveyors, and decision-makers to handle combinational issues related to the material selection process for roof elements by considering the performance criteria of new technologies or materials. The system objective, however, focused more intently on creating a knowledge-based cost model that considers the lifecycle of materials and technologies while being as economical as possible.

Giudice et al**.** (2005) [114] proposed a systematic method by using multi-objective analysis techniques and incorporating environmental factors into the materials used in components, achieving mechanical and performance criteria while minimizing the environmental effect associated with the product's complete life-cycle.

Van Kesteren et al. (2005) [115] give a model of the designer's factors when choosing materials. These factors include the product's personality, application, purpose, material properties, shape, and production procedures.

Ermolaeva et al. (2002) [116] researched the choice of materials in conjunction with structural optimization. Using the developed methods is confined to choosing from a small selection of particular materials. It is used to determine whether composites of natural fibers can replace some conventional (steel, aluminum alloy) and non-conventional (metallic and synthetic fiber composites) materials for a specific structural component.

Smith et al. (1997) [117] formed a behavioral decision-making model for selecting bridge materials for highway officials across several states and decision-making levels. Maintenance needs, lifecycle costs, and material longevity were the most crucial factors; local highway officials favor timber more frequently than other highway officials. Most of the time, prestressed concrete was used as the most appropriate construction material. Reinforced concrete, steel, and wood came next.

PART 3

METHODOLOGY

3.1. TECHNICAL SPECIFICATION OF MATERIALS

In this thesis, the common problem in the buildings in evaluating to choose wall material is solved by using the multi-criteria decision-making methods. The most common wall materials in buildings are clay brick, pumice block, auto claved aerated concrete block, and glass brick. These wall materials' initial properties are collected from the technical sheets and industry to evaluate the materials in the decision-making process. Some technical properties and information about clay brick, autoclaved aerated concrete block , pumice block, and glass brick for exterior and interior wall elements are given in Table 3.1. and Table 3.2.

Table 3.1. Technical properties of different types of Exterior wall materials according to Turkish standards.

Properties	**Horizontal Perforated Clay brick TS EN 771-1**		**Vertical Perforated (Insulation) Brick -W class[118]**	**Autoclaved aerated concrete AAC TS EN 771-4**	**Pumice block (Gündüz, 1998)**
Dimension (cm)	19x19x19	23.5x18.5x25	24x19x23.5	60x20x25	39x19x18.5
Consumption (m^2/Piece)	25	16	16.5	7	12.5
Weight volume (kg/piece)	4	6	6	2.5	7
Compressive strength (N/mm2)	2.0	2.0	3.5	2.7	1.82
Water vapor permeability (kg/m2 spa)	5.5-8.5	5.5-8.5	5.5 -8.5	10	6.67
Thermal conductivity (W/mK)	0.32	0.32	0.10	0.11	0.198
Sound insulation (db)	43	43	46	41	44
Fire resistance	A1	A1	A1	A1	A1

Table 3.2. Technical properties of interior wall materials according to turkish standards.

Properties	**Horizontal Perforated Clay brick TS EN 771-1**		**Autoclaved aerated concrete AAC TS EN 771-4**	**pumice block (Gündüz, 1998)**	**Glass brick [129]**
Dimension (cm)	19x13.5x19cm	19x10x19cm	60x10x25	39X15X18.5	19x8x19
Consumption (m^2/Piece)	25	25	7	12.5	25
Weight volume (kg/piece)	3	2.3	2.7	6.5	2.5
Compressive strength (N/mm^2)	2.0	2.0	2.5	2.3	13.9
Water vapor permeability (kg/m^2 spa)	5.5-8.5	5.5- 8.5	10	7.42	0.01
Thermal conductivity (W/mK)	0.32	0.32	0.11	0.156	2.8 W/m^{2}K
Sound insulation (db)	31.5	30	30	35	38
Fire resistance	A1	A1	A1	A1	G- class

3.2. RESEARCH METHODOLOGY

The methodology used in this research to choose the most appropriate material for exterior and interior walls consists of several stages; in the first stage, an extensive literature review was undertaken to identify and collect a comprehensive set of decision criteria, and sub-criteria are essential in wall material selection. Thus, five main criteria and 27 sub-criteria were obtained through previous research studies on material selection issues. The second stage involves comparing and ranking the criteria through expert questioning; for this purpose, the Best-Worst Method, a weighting method, is used to identify essential criteria levels. Finally, after collecting all the criteria weights, in Stage 3, a multi-criteria evaluation framework is suggested by using the WASPAS, TOPSIS, MOORA, and EDAS methods for selecting the optimal Exterior and interior wall material for building projects. The flowchart representing the process steps related to the solution is shown in Figure 3.1

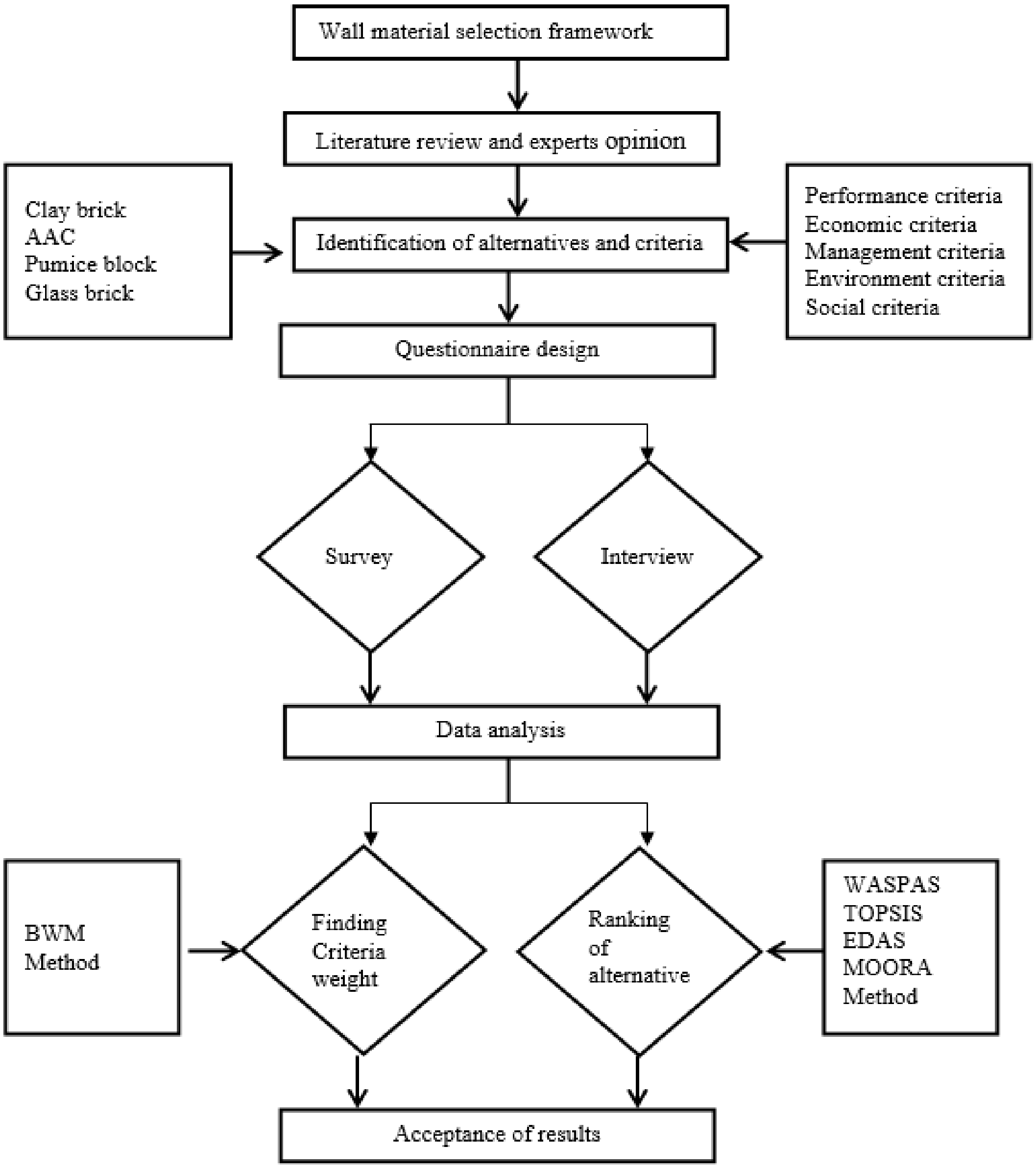

Figure 3.1. Flowchart of thesis methodology.

3.2.1. Weighting Criteria With Best&Worst Method

The best-worst method was introduced by Rezaei (2015); BWM is a modified AHP approach used to solve multi-criteria decision-making problems. BWM method has recently gained popularity due to its ease of use, involves fewer pairwise comparisons, reduces comparison times, and generates more consistent and accurate findings, Compared to the conventional AHP method.

In the BWM method, the exprts determine the most important and least important criteria. Then Pairwise comparisons are performed between best criteria to others and worst criteria to others. Then weights of various criteria are calculated by formulating and solving a maximin problem [119].

Some of the previous studies which used this method are as follows

- Gupta and Barua (2016) utilized this method to examine the enablers of technological \ innovation for Indian Micro-small and Medium Enterprises
- Annema et al. (2015) used the BWM method to investigate politicians' views on transportation policy evaluation
- Nispeling (2015), the BW approach was applied for supplier selection in the Oil Industry.
- Ren, J., Liang, H., & Chan, F. T. (2017) identify the proportional importance of the criteria for assessing the sustainability of the technologies for treating urban sewage sludge.

This study uses the Best-Worst method to assess the relative weight of the criteria and sub-criteria for exterior and interior wall element selection Furthermore, determine the relative performances of the wall materials considering the attributes.

BMW consists of four steps (Rezaei, 2015; Rezaei, 2016) [120,121]

Step 1: All the criteria {c1; c2; …; cn} are determined.

Step 2: The most important and worst (least critical) criteria are determined among the criteria.

Step 3. In this step, the pairwise comparison is made, and the importance degree of the essential criterion compared to the other criteria is obtained using a scale between 1 to 9 (1: equally important; 9: extremely important. Then, Another Comparison is made using the Significance of the other criteria concerning the least important criterion, which is selected from a scale of 1-9. As shown in Eq. (3.1) and (3.2), respectively.

$$AB = (a_{B1,}\ a_{B2}, \ldots, a_{Bn)} \qquad (3.1)$$

Where aBj denotes the relative preference of the best criterion (B’s) over criterion j.

$$AW = (\ a_1w,\ \ a_2w\ ,\ \ \ldots;\ a_nw) \qquad (3.2)$$

Here, a denotes the preference of criterion j over W, which is the least important criterion

Step4: calculating optimal weights of the criteria ($W_1{}^*$, $W_2{}^*$, … $W_n{}^*$)

If the indicator is close to “0”, it indicates high consistency

$$\text{minimax}\ \ \{\left|\frac{Wb}{Wj} - abj\right|,\ \left|\frac{Wj}{Ww} - \mathrm{aJW}\right|\} \qquad (3.3)$$

$$\textstyle\sum_j W_j = 1$$

$$W_j \geq 0,\ \forall j$$

$$\begin{aligned} \mathrm{Min}\mathcal{E} \quad & \{\left|\frac{Wb}{Wj} - abj\right|\ \ ,\ \leq \mathcal{E},\ \forall j \qquad (3.4) \\ & \left|\frac{Wj}{Ww} - \mathrm{aJW}\right| \quad \leq \mathcal{E},\ \forall j \\ & \textstyle\sum_j W_j = 1 \\ & W_j \geq 0,\ \forall j \end{aligned}$$

Step5: consistency check

At the last stage of the method, the consistency of the evaluations is tested, and the values of the consistency ratio are calculated by using equation (3.5),

$$\text{Consistency Rate}=\frac{\xi}{\text{consistency index}} \qquad (3.4)$$

As seen from Eq. (3.5), the value of the consistency index should be known to find the consistency ratio. Thus, Table 3.1 is used to obtain the values of the consistency index.

Table 3.3 Consistency index (CI).

a	1	2	3	4	5	6	7	8	9
Consistency Index (max ξ)	0	0.44	1.0	1.63	2.30	3.00	3.73	4.47	5.23

The closer the consistency ratio is to 0, the more consistent the assessment is, and the closer it is to 1, whereas it shows less consistency

3.2.1.1. Weighted Aggregated Sum Produced Assessment Methods (WASPAS)

The WASPAS (Weighted Aggregated Sum Product Assessment) approach is a hybrid of the commonly utilized Weighted Sum Model (WSM) and Weighted Product Model (WPM) methods in MCDM. Zavadskas developed the method, Turskis, Antucheviciene, and Zakarevicius (2012) [122]. It is now commonly regarded as an effective decision-making tool due to its mathematical simplicity and capacity to offer more relevant results than WSM, and WPM approaches. The WASPAS method uses the alternatives' criteria-based performance values and criterion weights to solve multi-criteria decision-making problems.

The steps used in solving problems with the WASPAS method can be summarized as follows [122, 123].

Step 1: Creation of decision-making matrix, which is presented as Equation (3.6)

$$X=\left[x_{ij}\right]_{mxn}=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{ln} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (i=1, 2\ldots, m \text{ and } j=1, 2\ldots n) \qquad (3.5)$$

Step2: Normalization of the decision matrix; the maximization and minimization type of criteria are normalized by Equation (3.7) and Equation (3.8), respectively.

$$\mathrm{x}_{\mathrm{ij}}^{*}=\frac{\mathrm{x}_{\mathrm{ij}}}{\underset{\mathrm{i}}{max}(\mathrm{x}_{\mathrm{ij}})} \qquad \text{i=1, 2, m and j=1, 2, n} \qquad (3.6)$$

$$\mathrm{x}_{\mathrm{ij}}^{*}=\frac{min\mathrm{x}_{\mathrm{ij}}}{\mathrm{x}_{\mathrm{ij}}} \qquad \text{i=1, 2, m and j=1, 2, n} \qquad (3.7)$$

Step 3: In this stage, the total relative importance of the alternatives is calculated According to Weighted Sum Model WSM and Weighted Product Model WPM sequentially. The total relative importance of an alternative according to WSM (Qi (1)) and the total relative importance of an alternative according to WPM (Qi (2)) are computed using Equation (3.9) and Equation (3.10), respectively.

$$Q_i^{(1)}=\sum_{j=1}^{n} r_{ij}w_j \qquad (3.8)$$

$$Q_i^{(2)}=\prod_{j=1}^{n} r_{ij}^{w_j} \qquad (3.9)$$

Step 4: Determination of overall relative importance; Equation (3.11) is applied to generalize the total relative importance of the alternatives computed using the WSM and WPM procedures in step 3.

$$\mathrm{Q}_{\mathrm{i}}=\lambda\mathrm{Q}_{\mathrm{i}}^{(1)}+(1-\lambda)\mathrm{Q}_{\mathrm{i}}^{(2)}$$
$$Q_i=0.5Q_i^{(1)}+0.5Q_i^{(2)}=0.5\sum_{j=1}^{n} r_{ij}w_j+0.5\prod_{j=1}^{n} r_{ij}^{w_j} \qquad (3.10)$$

According to the WASPAS technique, Qi. Reflects the alternative's overall relative importance, a parameter of the WASPAS method that accepts a value between 0 and 1. When these values are set to 0, the WASPAS technique becomes WPM and when set to 1 WASPAS method acts as WSM, and the decision maker determines the value to be used. The WASPAS technique ranks the alternatives based on their Qi ratings. The best alternative is chosen with the highest Qi value.

3.2.1.2. TOPSIS Method

TOPSIS (a technique for order preference by similarity to an ideal solution) is a multi-criteria decision-making method that uses numerous criteria to select the best option from a limited number of choices. The simplicity, logic, comprehensibility, good processing efficiency, and capacity to quantify the relative performance of each choice in a straightforward mathematical form are some of the benefits of TOPSIS approaches. The primary concept is that the optimal solution should be the closest to the positive ideal solution while being the furthest away from the negative ideal solution. The ideal solution is a fictitious solution for which all criteria values match the highest ones found in the database of acceptable alternatives. Conversely, the theoretical solution where all criteria values match the minimum ones in the database mentioned above is known as the negative-ideal solution. TOPSIS is a concept that can be stated in several steps: [124, 125]

Step 1: Making a Decision Matrix (A)

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \tag{3.11}$$

Step 2: Normalization decision matrix: The normalized Decision Matrix is calculated using matrix A elements and the following formula.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \tag{3.12}$$

Step 3: Creating weighted normalization matrix: After determining the weight values (wi) of the evaluation factors $\sum_{i=1}^{n} w_i = 1$ then, the elements in each column of the R matrix are multiplied by the corresponding wi value to form the V matrix. V matrix is shown below:

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \qquad (3.13)$$

Step 4: Determine the positive ideal and negative ideal solution: The positive ideal solution set is created according to the criteria type; the maximum of the weighted evaluation factor is selected in each column if the criteria are beneficial, and the minimum if the relevant criteria are non- beneficial. Finding the ideal solution set is shown in the formula below.

$$A^* = \left\{ (\underset{i}{max} v_{ij} \left| j \in J), (\underset{i}{min} v_{ij} \right| j \in J' \right\} \qquad (3.14)$$

The negative ideal solution set is formed by choosing the minor weighted evaluation factors in the V matrix if the criteria type is minimum. Moreover, (the largest if the relevant evaluation factor is in the maximization direction), finding the negative ideal solution set is shown in the formula below.

$$A^- = \left\{ (\underset{i}{min} v_{ij} \left| j \in J), (\underset{i}{max} v_{ij} \right| j \in J' \right\} \qquad (3.15)$$

Step 5: Separation Measures Calculation: It is expressed as the distance between each alternative to the optimum solution. For positive ideal solution can be calculated as

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \qquad (3.16)$$

Similarly, the distance between each alternative to the negative ideal solution is given as

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \qquad (3.17)$$

Step 6: Calculating Relative Closeness to the Ideal Solution

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \qquad (3.18)$$

Here, the value of C_i^* is in the range of $0 \leq C_i^* \leq 1$. If $C_i^* = 1$ indicates the absolute closeness of the relevant decision point to the positive ideal solution, and $C_i^* = 0$ the relative closeness of the relevant decision point to the negative ideal solution.

3.2.1.3. MOORA Method

MOORA (Multi-Objective Optimization by Ratio Analysis) method; It was initially introduced in 2006 by Willem Karel M. BRAUERS and Edmundas Kazimieras ZAVADSKAS in their work called 'Control and Cybernetics. Advantages of this method include considering and evaluating all criteria simultaneously and using non-subjective, unbiased values instead of subjectively weighted normalization.

The steps of the MOORA method are shown below [126].

Step1: starts with making the decision matrix

$$\mathrm{X} = \left[\mathrm{x_{ij}}\right]_{\mathrm{mxn}} = \begin{bmatrix} \mathrm{x_{11}} & \mathrm{x_{12}} & \cdots & \mathrm{x_{ln}} \\ \mathrm{x_{21}} & \mathrm{x_{22}} & \cdots & \mathrm{x_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{x_{m1}} & \mathrm{x_{m2}} & \cdots & \mathrm{x_{mn}} \end{bmatrix} \qquad \text{(i=1, 2…, m and j=1, 2, n)}$$

Step 2: Normalization of decision matrix: In the ratio method, normalization is done by dividing the criteria by the square root of the sum of the squares of each alternative. Normalization is performed because the data are not in the same unit, and there is no direct comparison of different units. So, the data is normalized by various methods. This process is shown in equation (3.20)

$$\mathrm{X_{ij}}^* = \frac{Xij}{\sqrt{\sum_{k=1}^{m} Xij^2}} \qquad \text{(j= 1, 2, .n)} \qquad (3.19)$$

Step3: weighted normalization matrix

The weighted normalized value vij is calculated as

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \dots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \dots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \dots & w_n r_{mn} \end{bmatrix} \qquad (3.20)$$

Step4: Reference point approach: Overall variance for all the maximum and minimum criteria for i alternative is measured by the performance index (Pi), shown in equation (3.22).

$$Pi = \ Min_{j} \{ max_{i} | r_{j} - X_{ij}^{*} | \} \qquad (3.21)$$

Step5: Significance coefficient approach: In the reference point approach, the importance coefficients are calculated with the following equation (3.23).

$$|S_J r_j - S_j x_j^{*}| \qquad (3.22)$$

3.2.1.4. EDAS Method

Evaluation based on the Distance from Average Solution (EDAS) one recently presented method was introduced in 2015 by Keshavarz Ghorabaee Zavadskas, Olfat, and Turskis (2015), whose computational approach can be distinguished as novel and based on tried-and-true methodologies. EDAS method uses the distance from average solution (AV) to select the optimal option; in other words, this method considers the PDA (positive distance from average) and NDA measurements (negative distance from average). With this approach, all potential solutions to a decision-making problem can be assessed in accordance with numerous criteria, many of which are incompatible when greater PDA and lower NDA values are present [127,128]. Here are the EDAS method's steps.

Step1: Creating a decision-making matrix

$$X = \left[x_{ij}\right]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{ln} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{1n} & x_{2n} & \cdots & x_{mn} \end{bmatrix} \tag{3.23}$$

Step2: The average solution is determined according to all criteria. Equations (3.25) and (3.26) are used for this operation.

$$AVj = \frac{\sum_{j}^{m} x_{ij}}{m} \tag{3.24}$$

$$AV = [AV_j]_{1xn} \tag{3.25}$$

Step3: Calculating positive and negative distance from average: PDA and NDA are the two primary necessary measures for the suitability of the alternatives. Find the positive distance from the average PDA ij and the negative distance from the average NDAij for each type of criterion (benefit and non-benefit) shown as follow:

If the jth criterion is beneficial

$$PDAij = \frac{\max(0,(X_{ij}-AV_j))}{AV_j} \tag{3.26}$$

$$NDAij = \frac{\max(0,(AV_j-X_{ij}))}{AVj} \tag{3.27}$$

If the jth criterion is non-beneficial

$$PDAij = \frac{\max(0,(AV_j-X_{ij}))}{AV_j} \tag{3.28}$$

$$NDAij = \frac{\max(0,(X_{ij}-AV_j))}{AV_j} \tag{3.29}$$

Step4: The weighted sum of PDA and NDA are calculated for all options. Presented as follow

$$SPi = \sum_{j=1}^{n} wj\, PDA_{ij} \tag{3.30}$$

$$SNi \ = \ \sum_{j=1}^{n} wj \ NDA_{ij} \tag{3.31}$$

Wj Indicates the weight of the criteria.

Step5: For each option, the SP and SN values are normalized using Equations (3.33) and (3.34).

$$NSPi \ = \frac{SP_i}{max_i(SP)_i} \tag{3.32}$$

$$\text{NSNi} \ = 1 - \frac{SN_i}{max_i(SN)_i} \tag{3.33}$$

Step6: Evaluation appraisal score (ASi) is calculated with Equation (3.35) for all alternatives.

$$\text{AS}_{\text{i}} = \frac{1}{2}(NSP_i + NSN_i) \tag{3.34}$$

ASi value $0 \leq \text{AS}_{\text{i}} \leq 1$

Step7: The options are ranked in descending order of evaluation appraisal score (ASi value). The option with the highest value is considered the best alternative. The average initial relationship matrix for criteria and dimensions was created using respondents' responses (academic experts, designers, architects, constructors, construction managers), and it takes the form of Eq. (3.12).

PART 4

RESULTS AND DISCUSSIONS

4.1. APPLICATION OF METHODS

4.1.1. Identification of Experts

In the problem of material selection for exterior and interior walls for residential buildings in Turkey, the first and the most critical stage is to select some appropriate experts that have experience in the field of construction materials and are familiar with decision making to evaluate the decision criteria as well as evaluate the alternatives. For this purpose, 11 experts who are academic staffs from Civil Engineering, site civil engineers, contractors, and architects were chosen. Four are female, and the others are male; most are academicians in scientific studies and work in university. Their academic titles are Professor, Assoc. Professor and Assist. Professor at Karabük University. Table 4.1 shows some general information about the experts.

In the first survey, six experts were used to determine the importance degree of the criteria. Before starting the survey, a detailed form was prepared to include the problem of the study, main aim and objectives, main criteria and sub-criteria, and all alternatives of exterior and interior walls, and a pairwise comparison between 1-to-9-point scale has been explaned, 9 is the best, 1 is the worst, in terms of price,9 is cheapest, and 1 is the most expensive value . Moreover, the MCDM methods used to solve the problem of wall element selection were formed in the questionnaire survey to help the decision maker understand each aspect of the questionnaire and obtain an efficient result. The formed questionnaire survey was sent to experts through email and by conducting a face-to-face meeting with them. In the first part of the survey, only academicians were selected to evaluate and find the importance of criteria and sub-criteria. In the second part of the survey, the number of experts were increased to 11 and covered all the aspects of the project that can influence and involve in the material selection for wall elements, such as architects and designers, project managers, and contractors.

Table 4.1. Some general information about experts.

Participant No.	Field of working	Position	Years of experience
Expert-1	Building& Structure	Professor	20-25
Expert-2	Construction materials	Assoc. Professor	15-20
Expert-3	Architect& designer	Assist. Professor	10-15
Expert-4	Architect& designer	Designer	20-25
Expert-5	Architect& designer	Assist. Professor	5-10
Expert-6	Building& Structure	Assist. Professor	5-10
Expert-7	Construction materials	Assist. Professor	5-10
Expert-8	Building Construction	Contractor	10-15
Expert-9	Construction material	Assist. Professor	5-10
Expert-10	Building Construction	Project manager	5-10
Expert-11	Hydraulic structure	Assist. Professor	5-10

4.1.2. Determination Of Criteria

To determine a set of appropriate criteria for this decision problem, a comprehensive literature review has been carried out in the field of material selection. In addition, the evaluating team and experts added some criteria during interviews . A total of five main criteria and twenty-seven sub-criteria have been determined to evaluate alternatives for exterior walls; considering the interior walls, sub-criteria have been eliminated to 26 sub-criteria. Therefore, the following are the main criteria that will be considered in the implementation study.

- Performance criteria
- Economic criteria
- Management criteria
- Environmental criteria
- Social criteria

4.1.2.1. Evaluation of Main Criteria

Abbreviations used for the main criteria are as follows: C1: performance criteria, C2: Economic criteria, C3: Management criteria, C4: Environmental criteria, and C5: Social criteria. In the study, an abbreviation of the main criteria is considered as C1. Then, increasing the sub-criteria according to the main criteria will be C11. For instance, the abbreviation of performance criteria is C1, and its sub-criteria ranked as C11, C12, and C13..etc respectively. Exterior wall main criteria and evaluation sub-criteria were used in this study and are given in Table 4.2.

Table 4.2. Main criteria and sub-criteria for exterior wall.

Main Criteria		**Sub-Criteria**	
Performance criteria	C1	Sound insulation	C11
		Compressive strength	C12
		Fire resistance	C13
		Durability (freeze-thaw resistance)	C14
		Durability(life cycle)	C15
		Earthquake resistance	C16
		Thermal resistance	C17
		Moisture resistance	C18
		Material weight	C19
Economic criteria	C2	Initial cost	C21
		Mortar cost	C22
		Transport cost	C23
		Maintenance cost	C24
Management criteria	C3	Availability	C31
		Needs for specialized skill	C32
		Construction speed	C33
		The difficulty of the construction process	C34
		Cover techniques	C35
		The plaster used in construction	C36
		Dimensional flexibility	C37
Environmental criteria	C4	Waste during production	C41
		Waste during construction	C42
		Carbon emission	C43
Social criteria	C5	Raw material reserve	C51
		Health	C52
		Safety during and after construction	C53
		Suitability to location	C54

Table 4.3. Interior wall main criteria and sub-criteria.

Main Criteria		**Sub-Criteria**	
Performance criteria	C1	Sound insulation	C11
		Compressive strength	C12
		Fire resistance	C13
		Durability(life cycle)	C14
		Earthquake resistance	C15
		Thermal resistance	C16
		Moisture resistance	C17
		Material weight	C18
Economic criteria	C2	Initial cost	C21
		Mortar cost	C22
		Transport cost	C23
		Maintenance cost	C24
Management criteria	C3	Availability	C31
		Needs for specialized skill	C32
		Construction speed	C33
		The difficulty of the construction process	C34
		Cover techniques	C35
		The plaster used in construction	C36
		Dimensional flexibility	C37
Environmental criteria	C4	Waste during production	C41
		Waste during construction	C42
		Carbon emission	C43
Social criteria	C5	Raw material reserve	C51
		Health	C52
		Safety during and after construction	C53
		Suitability to location	C54

4.1.3. Determination Of Criteria and Sub-Criteria Weights with Best-Worst Method

BWM approach was used to determine the priority of each criterion and sub-criteria in the generated model. The main criteria and sub-criteria are summarized in Table 4.2. A questionnaire with pairwise comparisons was created in the Microsoft Office Excel program, in which the BWM was formulated. and sent to 6 experts. They received the questionare surveye lectronically, and after that, a face to face meeting was conducted with them to explain all the requirments and answer any question they have.

Firsty, Experts are requested to choose the most important and least important criteria among the five main criteria. After determining the most important and least important criteria, the next step is to give the significance of one criterion over another using a scale that ranges from 1 to 9 in this stage. (1: equally important, 2: between equal and balanced, 3: moderately more critical than, 4: between moderate and strongly important, 5: greatly more important than, 6: between strong, 7: very strongly significant than, 8: between very strong and definitely strong, 9: extremely important). Similar to how main criteria are compared in pairs, all sub-criteria for each main criterion are also compared in pairs on the same scale (1-9). . The main criteria evaluations of first and second experts are presented in Table 4.4

As mentioned earlier, the main aim of this thesis is to design an MCDM framework for exterior and interior wall element selection for building projects, the same process to find the criteria weights and evaluate alternatives have been applied in terms of exterior and interior wall, certainly with different results of the criteria weight as can be seen in the following steps. Therefore, only exterior wall calculation steps have been explained in detail. For interior wall only the final results is beening presented.

4.1.3.1. Determination of Main Criteria Weights

After receiving the results of the pairwise comparisons from each experts see Table 4.5, The next step is to calculate the weights of the main and sub-criteria. All the best-worst steps were applied in the linear programming model, which is as optimization software solves the mathematical model to analyze the data and attain the criteria weights, then geometric mean was performed to take the average of the main criteria weights of all the experts and attain the final main criteria weight as shown in Table 4.6

Table 4.4. The first and second expert's evaluation of the main criteria for the exterior wall.

First expert's evaluation					
The most important criteria: **C1**	The least essential criteria: **C3**				
Pairwise comparison vector (ABvector) of the most critical criterion concerning other criteria					
	C1	**C2**	**C3**	**C4**	**C5**
The preference rate of the most critical criterion (C1) for the other criteria	1	3	6	5	4
Pairwise comparison vector of the other criteria according to the least important criterion					
	C1	**C2**	**C3**	**C4**	**C5**
Preference rate of other criteria according to the least essential criterion **(C3)**	6	3	1	2	3
Second expert's evaluation					
The most important criteria: **C1**	The least essential criteria: **C5**				
Pairwise comparison of the most critical criterion concerning other criteria					
	C1	**C2**	**C3**	**C4**	**C5**
The preference rate of the most critical criterion **(C1)** for the other criteria	1	3	4	4	7
Pairwise comparison of the other criteria according to the least important criterion					
	C1	**C2**	**C3**	**C4**	**C5**
Preference rate of other criteria according to the least essential criterion **(C5)**	7	4	3	3	1

Table 4.5. Main criteria weights and average criteria weight of each experts.

Evaluators	**C1**	**C2**	**C3**	**C4**	**C5**
Expert 1	0.491	0.187	0.070	0.112	0.140
Expert 2	0.485	0.182	0.136	0.136	0.061
Expert 3	0.531	0.124	0.049	0.207	0.089
Expert 4	0.476	0.143	0.143	0.190	0.048
Expert 5	0.508	0.198	0.148	0.099	0.047
Expert 6	0.632	0.100	0.117	0.088	0.062
Average	0.518	0.151	0.103	0.132	0.069

In this step, by applying BWM, the weights of the main criteria and sub-criteria are established. Calculated weight values were used as the degree of importance of the main criteria are shown in Table 4.6. Among the five perspectives, it was concluded that the importance of performance criteria was more significant than the other four criteria : it ranks first with the highest priority criterion (0.518). However, due to being directly exposed to environmental factors, the exterior wall's principal purpose, which is to play a crucial part in ensuring occupants' internal comfort and safety, all performance sub-criteria such as thermal conductivity, moisture resistance, durability- freeze-thaw resistance, material weight fire resistance and has played an essential role in determining and ranking the performance criteria as most important criteria. These results show that performance factors are more highly considered than other factors. For example, the economic dimension (C2) is the second-ranking criterion among the significant criteria reaching the value of 0.151. Third is environmental criteria (C4) has a weight value of 0.132; finding the right balance between economic and environmental concerns is challenging since they frequently disagree. After that is management criteria (C3), with a weight of 0.103, and social criteria (C5), with (0.069) weight value, became the last one in the primary criteria list.

Table 4.6. Priority values of main criteria for exterior wall.

Ranking	Main criteria	Main criteria weight
1	Performance criteria	0.518
2	Economic criteria	0.151
4	Management criteria	0.103
3	Environmental criteria	0.132
5	Social criteria	0.069

4.1.3.2. Determination Of Sub-Criteria Weight

After the experts evaluated the main criteria, each sub-criterion was also assessed.. Criteria weights were calculated using equations (3.3) and (3.4) and solved with the Microsoft Office Excel solver add-on. The final weights were calculated by taking the average of the criteria weights by using geometric mean. Then combined weights are obtained by multiplying the weights of the main criteria by the weights of each of its sub-criteria. Calculated criteria weights and combined weights According to the Best–Worst Method for exterior wall show in table 4.13.

Performance Criteria

Performance criteria are essential in selecting wall materials for residential buildings to determine the importance of their sub-criteria weight. Table 4.7 shows all experts' evaluation of performance sub-criteria. The final criterion weights were obtained by taking the average of the weights of the decision-makers; after that, to find the global weight, each sub-criteria weight is multiplied by the main criteria weight.

Table 4.7. Expert’s performance sub- criteria weight, and average weight.

	C11	C12	C13	C14	C15	C16	C17	C18	C19
Expert 1	0.026	0.097	0.055	0.077	0.064	0.310	0.129	0.048	0.193
Expert 2	0.041	0.082	0.109	0.025	0.264	0.164	0.041	0.109	0.164
Expert 3	0.192	0.027	0.064	0.077	0.128	0.048	0.315	0.055	0.096
Expert 4	0.074	0.099	0.059	0.099	0.149	0.287	0.099	0.099	0.035
Expert 5	0.067	0.067	0.134	0.134	0.089	0.134	0.211	0.134	0.031
Expert 6	0.047	0.086	0.059	0.129	0.129	0.086	0.247	0.129	0.086
Average Weight	0.060	0.071	0.075	0.080	0.124	0.142	0.143	0.089	0.081

Nine additional sub-criteria for this performance criterion have been graded under the global weights. Thermal conductivity C17 among nine sub- criteria examined under main performance criteria carries more weight. It has reached the most important criteria with a value of 0.143 because this is directly related to the occupant’s health and comfort inside the home; wall materials with resistance to overheating in summertime and heat loss in winter (energy efficient) will have an impact on the performance of the whole building by reducing the energy consumption of the structure and reducing the electricity cost. Second is C16 Earthquake resistance with priority value 0.142, C15 Durability (life cycle) of material is in the third place with value 0.124 which has been influenced by climate condition and environmental changes of the place, fourth is C18 Moisture resistance with value 0.089 moisture resistance of exterior wall has significantly affect the quality and performance of the building specially in cold climate, C19 material Weight with a value of 0.081 is in the fifth place in the group of performance particular in high rise buildings material weight has a significant impact to reduce the dead load of the structure, C14 Durability (freeze-thaw resistance) with a value of 0.080 ranked as sixth in the list, after that C13 Fire resistance with a value of 0.075

became seventh, then C12 Compressive strength with a value of 0.071 is in the eighth, and the last one in the list of performance criteria for exterior wall is C11 Sound insulation with criteria weight of 0.060 from this results can be concluded that sound insulation is not very important for exterior wall as its essential in terms of interior wall. performance sub-criteria weights are shown in Table 4.8.

Table 4. 8. sub-criteria weight of performance criteria.

Ranking	Sub-criteria	Code	Sub-criteria weight
9	Sound insulation	C11	0.060
8	Compressive strength	C12	0.071
7	Fire resistance	C13	0.075
6	Durability (freeze-thaw resistance)	C14	0.080
3	Durability(life cycle)	C15	0.124
2	Earthquake resistance	C16	0.142
1	Thermal conductivity	C17	0.143
4	Moisture resistance	C18	0.089
5	Material weight	C19	0.081

Economic Criteria

This outcome is expected because any industry has a primary focus on profit. The time required and cost will decrease if the proper materials are used. As given in Table 4.9, C21 initial cost has reached the most important criteria with a priority value of 0.326 among the 4 Sub-criteria evaluated under the main Economic criterion. The second important attribute is C22 mortar cost with a value of 0.193, and maintenance cost C24 was evaluated and ranked as the 3rd in the group of economic criteria with a value of 0.192, as can be seen with a slight difference value between mortar cost and maintenance cost. People frequently favor purchasing inexpensive goods, but the quality is not paid much attention to. Selecting the appropriate building wall materials for a place is an investment strategy because these materials do not require upkeep throughout the material's life cycle and building. Finally, it is Transport cost C23 with a value of 0.192.

Table 4.9. Sub-criteria priority value of economic criteria.

Ranking	Sub-criteria	Codes	Sub-criteria weight
1	Initial cost	C21	0.326
2	Mortar cost	C22	0.193
4	Transport cost	C23	0.121
3	Maintenance cost	C24	0.192

Management Criteria

According to the main criterion of management criteria, experts evaluated 7 Sub-criteria, C31 availability with a value of 0.022 is the most critical criterion among all the seven sub-criteria because if the material is unavailable in the local market, purchasing and ordering form another country will be more costly, then it can be rejected. C32 needs the specialized skill with a value of 0.020 ranked as the second in the list, after that is construction speed C33 with weight the value of 0.017 because, in high-rise buildings, construction speed is a critical factor of success that shortens the financial payback time. Fourth is difficulty of construction process C34 with a criteria weight is 0.015 because the difficulty of installation of wall materials leads to time overrun and cost overrun, cladding technique C35 with a value of 0.013 ranked as the fifth in the group of management criteria, sixth is C36 plaster using in construction with a criteria weight of 0.010, Dimensional flexibility C37 with a value of 0.010 became the seventh in the group of management criteria as can be seen in Table 4.10

Table 4.10. Priority of the sub-criteria of the main criterion of management criteria.

Ranking	Sub-criteria	Codes	Sub-criteria weight
1	Availability	C31	0.022
2	needs for specialized skill	C32	0.020
3	Construction speed	C33	0.017
4	The difficulty of the construction process	C34	0.015
5	Cladding techniques	C35	0.013
6	the plaster used in construction	C36	0.010
7	Dimensional flexibility	C37	0.010

Environmental Criteria

Under the Environmental factors, three sub- criteria were evaluated by experts; the result of the evaluation and ranking are given in Table 4.11, as seen carbon emission C43 receives the most points and has the most influence, with a value of 0.293 is the first, and most important criteria between the other two criteria. The resean is Recently, sustainable construction has been more focused on it in all the world, and trying to use materials release fewer CFCs in to the environment.[85] Second is waste during construction C43 with a weight value of 0.197, and the last one is waste during production C41 with a priority value of 0.266.

Table 4.11. Sub-Criteria weights of Environmental criteria

Ranking	Sub-criteria	Codes	Sub-criteria weight
3	Waste during production	C41	0.266
2	Waste during construction	C42	0.197
1	Carbon emission	C43	0.293

Social Criteria

There are four sub-criteria under the main social criteria criterion: raw material reserve, health, safety during and after construction, and suitability to location. The results of the evaluation are given in Table 4.12. Suitability to location C54 was determined as the most significant with a value of 0.241, and the second most important is Safety during construction C53 with a value of 0.22 since the building construction process faces more incidents and safety-related problems. For example, health with the value C52 is in third place and has a weight value of 0.198. The fact is related to human life; at the end and fourth is natural material reserve C51 with a priority value of 0.120.

Table 4.12. Sub-criteria priority value of social criteria.

Ranking	Sub-criteria	Codes	Sub-criteria weight
4	Raw material reserve	C51	0.120
3	Health	C52	0.198
2	Safety during and after construction	C53	0.229
1	Suitability to location	C54	0.241

Table 4.13. Calculated criteria weights and combined weights According to the Best–Worst Method for exterior wall.

Main Criteria	**Main criteria weight**	**Sub-Criteria**	**Sub-criteria weight**	**Final combined weight**
C1	0.518	C11	0.060	0.038
		C12	0.071	0.045
		C13	0.075	0.048
		C14	0.080	0.051
		C15	0.124	0.079
		C16	0.142	0.090
		C17	0.143	0.091
		C18	0.089	0.057
		C19	0.081	0.052
C2	0.151	C21	0.326	0.061
		C22	0.193	0.036
		C23	0.121	0.023
		C24	0.192	0.036
C3	0.103	C31	0.171	0.022
		C32	0.159	0.020
		C33	0.132	0.017
		C34	0.119	0.015
		C35	0.100	0.013
		C36	0.083	0.010
		C37	0.075	0.010
C4	0.132	C41	0.266	0.043
		C42	0.197	0.032
		C43	0.293	0.047
C5	0.069	C51	0.120	0.010
		C52	0.198	0.017
		C53	0.229	0.019
		C54	0.241	0.020

Interior Wall Application

Table 4.14. Evaluation of the first and second expert regarding the main criteria for interior wall.

<table>
<tr><th colspan="6">First expert’s evaluation</th></tr>
<tr><td>The most important criteria: C1</td><td colspan="5">The least essential criteria: C5</td></tr>
<tr><td colspan="6">Pairwise comparison vector (ABvector) of the most critical criterion concerning other criteria</td></tr>
<tr><td></td><td>C1</td><td>C2</td><td>C3</td><td>C4</td><td>C5</td></tr>
<tr><td>The preference rate of the most critical criterion (C1) for the other criteria</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td colspan="6">Pairwise comparison vector of the other criteria according to the least important criterion</td></tr>
<tr><td></td><td>C1</td><td>C2</td><td>C3</td><td>C4</td><td>C5</td></tr>
<tr><td>Preference rate of other criteria according to the least essential criterion (C5)</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td></tr>
<tr><th colspan="6">Second expert’s evaluation</th></tr>
<tr><td>The most important criteria: C2</td><td colspan="5">The least essential criteria: C4</td></tr>
<tr><td colspan="6">Pairwise comparison of the most critical criterion concerning other criteria</td></tr>
<tr><td></td><td>C1</td><td>C2</td><td>C3</td><td>C4</td><td>C5</td></tr>
<tr><td>The preference rate of the most critical criterion (C2) for the other criteria</td><td>2</td><td>1</td><td>5</td><td>8</td><td>3</td></tr>
<tr><td colspan="6">Pairwise comparison of the other criteria according to the least important criterion</td></tr>
<tr><td></td><td>C1</td><td>C2</td><td>C3</td><td>C4</td><td>C5</td></tr>
<tr><td>Preference rate of other criteria according to the least essential criterion (C4)</td><td>6</td><td>8</td><td>4</td><td>1</td><td>5</td></tr>
</table>

Table 4.15. Priority values of main criteria for interior wall.

Ranking	Main criteria	Main criteria weight
1	Performance criteria	0.395
2	Economic criteria	0.192
5	Management criteria	0.090
3	Environmental criteria	0.128
4	Social criteria	0.090

Table 4.16. Calculated criteria weights and global weights According to the Best–Worst Method for interior wall.

Main Criteria	Main criteria weight	Sub-Criteria	Sub-criteria weight	Final global weight
Performance criteria	0.395	C11	0.207	0.108
		C12	0.087	0.046
		C13	0.114	0.060
		C14	0.118	0.062
		C15	0.089	0.046
		C16	0.058	0.031
		C17	0.074	0.039
		C18	0.097	0.051
Economic criteria		C21	0.316	0.081
		C22	0.180	0.046
		C23	0.126	0.032
		C24	0.191	0.049
Management criteria		C31	0.192	0.023
		C32	0.167	0.020
		C33	0.132	0.016
		C34	0.100	0.012
		C35	0.095	0.011
		C36	0.084	0.010
		C37	0.076	0.009
Environmental criteria		C41	0.297	0.050
		C42	0.145	0.025
		C43	0.367	0.062
Social criteria		C51	0.106	0.013
		C52	0.543	0.065
		C53	0.177	0.021
		C54	0.124	0.015

4.1.4. Evaluation of Alternatives According to Criteria

In this study, a susceptible measurement is used to evaluate material. Experts evaluate five exterior wall material alternatives (clay brick size 19x19x19 cm), clay brick-2 size (23.5x18.5x25 cm), clay brick-3 (isolation brick), autoclaved aerated concrete block (60x20x25 cm), pumice block (39x19x18.5 cm), five other materials were evaluated for interior wall including, clay brick (19x13.5x19 cm), clay brick (19x10x19 cm), AAC (60x10x25 cm), pumice block (39x15x18.5 cm) and glass brick (19x8x19 cm). The first 27 criteria were determined to examine wall materials, and then the criteria were classified into value and expert’s opinions; among these 27 criteria, as meansioned in part three of this thesis, nine criteria are values collected from industry technical specification of materials and literature , and 18 criteria are expert’s opinions. As a result, alternatives have been evaluated according to 18 criteria. For example, this study's evaluation preferred a 1-9 interval rating scale; one indicates the lowest or worst, and 9 denotes the best value. 11 experts in the relevant field participated in this study. They consisted of academicians in the civil and architecture department at Karabuk university, constructors, and designers. Then, Data collected from each expert was compiled into a single data by taking the geometric mean. First exper’s evaluation of exterior and interior wall alternatives is given in table 4.17.

Table 4.17. Evaluation of all alternatives by Expert1.

		Exterior wall alternatives					Interior wall alternatives				
	criteria	A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
1	Durability (Life Cycle)	7	8	9	7	6	8	7	5	4	9
2	Earthquick Resistance	7	8	9	6	6	9	8	5	6	4
3	Health	8	9	8	6	6	8	7	5	4	9
4	Availability	8	9	8	6	5	9	8	7	6	4
5	Construction Speed	8	9	9	8	7	8	6	9	7	5
6	Raw materıal reserve	9	9	9	8	5	9	8	6	5	4
7	Dimensional Flexibility	8	8	7	9	6	9	8	8	5	1
8	Suitability To Location (climate)	9	9	8	8	7	9	8	6	5	1
9	Mortar cost	8	9	7	8	6	9	7	8	7	1
10	Safety During Construction	7	7	9	8	6	8	7	7	6	1
11	Transport Cost	9	9	9	8	6	9	8	7	6	1
12	maintenance cost	6	6	6	6	6	6	6	6	6	9
13	Waste During Production	7	7	7	8	6	8	7	6	6	5
14	Waste During Construction	7	6	5	8	4	7	6	6	5	8
15	Needs For Specialized Skill	8	8	7	8	7	9	8	8	7	1
16	Cover Techniques	6	6	6	6	6	6	6	6	6	9
17	Plaster Using In Construction	6	6	6	6	6	6	6	6	6	9
18	Difficulty Of The Construction Process	9	8	7	7	7	8	8	7	6	1

4.1.5. Application Of WASPAS Method

The alternatives are evaluated with the WASPAS method, which is one of the multi-criteria decision-making methods,The following steps are performed to rank alternatives.

4.1.5.1. Creation Decision Matrix for Exterior Wall

The decision matrix was obtained with the data taken from the expert's evaluation of wall material and the value gathered from the literature. The alternatives are in the column of the matrix and criteria in the rows. The decision matrix shows the performance of the staff according to the criteria. The type and weight values of the criteria are given in Table 4.18.

Table 4.18.Creation of decision-making matrix for exterior wall.

Criteria	Type	Weight	A1	A2	A3	A4	A5
C11	Max	0.038	43.000	43.000	46.000	41.000	44.000
C12	Max	0.045	2.000	2.000	3.500	2.500	1.820
C13	Max	0.048	9.000	9.000	9.000	5.000	7.000
C14	Max	0.051	55.000	55.000	75.000	25.000	100.000
C15	Max	0.079	6.080	5.707	7.430	5.323	4.070
C16	Max	0.090	4.963	4.682	6.269	6.084	4.468
C31	Max	0.022	7.866	8.075	7.621	5.484	6.107
C33	Max	0.017	5.040	6.289	5.980	8.162	6.889
C37	Max	0.010	5.283	5.534	4.335	7.343	4.497
C51	Max	0.010	7.828	7.745	7.454	6.329	5.391
C52	Max	0.017	6.33	6.011	6.487	4.471	5.189
C53	Max	0.019	5.130	4.412	4.386	8.506	6.125
C54	Max	0.020	6.637	6.630	6.991	6.828	5.563
C17	Min	0.091	0.320	0.320	0.100	0.110	0.198
C18	Min	0.057	6.000	6.000	6.000	10.000	6.670
C19	Min	0.052	4.000	6.000	6.000	2.700	7.000
C21	Min	0.061	62.500	49.500	99.000	191.400	75.000
C22	Min	0.036	4.995	5.049	5.478	5.237	7.121
C23	Min	0.023	5.923	5.778	5.738	6.887	4.634
C24	Min	0.036	5.573	5.320	4.815	7.142	5.101
C32	Min	0.020	6.576	6.768	6.854	6.686	6.973
C34	Min	0.015	4.850	5.320	4.935	6.874	5.279
C35	Min	0.013	4.957	4.857	5.425	6.571	5.520
C36	Min	0.010	3.598	3.869	3.183	4.963	4.120
C41	Min	0.043	5.886	5.823	5.072	5.619	5.619
C42	Min	0.032	5.040	5.085	4.336	6.336	4.292
C43	Min	0.047	0.270	0.270	0.270	0.230	0.300

Table 4.19.Creation decision matrix for interior wall.

Criteria	Type	Weight	A1	A2	A3	A4	A5
C11	Max.	0.108	31.500	30.000	30.000	35.000	38.000
C12	Max.	0.046	2.000	2.000	2.500	2.300	13.900
C13	Max.	0.060	9.000	9.000	5.000	7.000	3.000
C14	Max.	0.062	6.564	6.200	5.758	4.003	7.230
C15	Max.	0.046	5.537	5.707	7.025	5.153	4.215
C31	Max.	0.023	8.506	8.138	6.732	5.864	3.595
C33	Max.	0.016	4.700	5.531	8.388	7.049	5.728
C37	Max.	0.009	5.482	5.535	7.818	5.486	2.298
C51	Max.	0.013	7.939	7.855	5.978	5.031	5.410
C52	Max.	0.065	6.716	6.464	4.440	5.344	6.869
C53	Max.	0.021	5.210	5.128	8.100	5.109	3.221
C54	Max.	0.015	7.146	7.111	6.841	6.699	3.092
C16	Min.	0.031	0.320	0.320	0.110	0.156	0.250
C17	Min.	0.039	6.500	6.500	10.000	7.420	0.010
C18	Min.	0.051	3.000	2.300	2.700	6.500	2.500
C21	Min	0.081	52.000	49.400	99.000	68.750	1218.750
C22	Min.	0.046	5.206	5.121	5.941	6.533	6.533
C23	Min.	0.032	5.871	5.906	6.844	5.386	2.965
C24	Min.	0.049	5.713	5.454	6.884	5.164	5.337
C32	Min.	0.020	6.447	6.457	6.191	6.614	2.683
C34	Min	0.012	4.663	4.867	8.122	5.422	3.537
C35	Min	0.011	5.869	6.251	6.191	5.347	2.454
C36	Min	0.010	3.008	3.356	4.769	4.154	4.580
C41	Min.	0.050	5.943	5.871	6.951	5.024	6.928
C42	Min.	0.025	5.513	5.296	7.368	5.257	6.062
C43	Min.	0.062	0.270	0.270	0.230	0.300	1.090

4.1.5.2. Normalization Decision Matrix

The resulting decision matrix was normalized based on the type of the criteria, benefit or non-benefit criteria. Equation (3.7) was used for beneficial criteria, and Equation (3.8) was used for non-beneficial criteria. WASPAS normalization matrix is shown in Table 4.20.

Table 4.20. WASPAS- normalization decision matrix.

Criteria	**A1**	**A2**	**A3**	**A4**	**A5**
C11	0.935	0.935	1.000	0.891	0.957
C12	0.571	0.571	1.000	0.714	0.520
C13	1.000	1.000	1.000	0.556	0.778
C14	0.550	0.550	0.750	0.250	1.000
C15	0.818	0.768	1.000	0.716	0.548
C16	0.792	0.747	1.000	0.970	0.713
C31	0.974	1.000	0.944	0.679	0.756
C33	0.617	0.771	0.733	1.000	0.844
C37	0.719	0.754	0.590	1.000	0.612
C51	1.000	0.989	0.952	0.809	0.689
C52	0.976	0.927	1.000	0.689	0.800
C53	0.603	0.519	0.516	1.000	0.720
C54	0.949	0.948	1.000	0.977	0.796
C17	0.313	0.313	1.000	0.909	0.505
C18	1.000	1.000	1.000	0.600	0.900
C19	0.675	0.450	0.450	1.000	0.386
C21	0.792	1.000	0.500	0.259	0.660
C22	1.000	0.989	0.912	0.954	0.701
C23	0.782	0.802	0.808	0.673	1.000
C24	0.864	0.905	1.000	0.674	0.944
C32	1.000	0.972	0.959	0.984	0.943
C34	1.000	0.912	0.983	0.706	0.919
C35	0.980	1.000	0.895	0.739	0.880
C36	0.885	0.823	1.000	0.641	0.773
C41	0.862	0.871	1.000	0.903	0.903
C42	0.852	0.844	0.990	0.677	1.000
C 43	0.852	0.852	0.852	1.000	0.767

4.1.5.3. Performance Calculation Based on WSM And WPM Method

The relative importance of alternatives is calculated based on the weighted sum model of the criteria (WSM) using Eq. (3.9). calculated values are shown in Table 4. 21.

Table 4.21. Calculated Total Relative Significance of Alternatives with the Weighted Sum Model (WSM).

Criteria	**Weight**	**A1**	**A2**	**A3**	**A4**	**A5**
C11	0.038	0.036	0.036	0.038	0.034	0.037
C12	0.045	0.026	0.026	0.045	0.032	0.023
C13	0.048	0.048	0.048	0.048	0.027	0.037
C14	0.051	0.028	0.028	0.038	0.013	0.051
C15	0.079	0.065	0.061	0.079	0.057	0.043
C16	0.090	0.071	0.067	0.090	0.087	0.064
C31	0.022	0.021	0.022	0.020	0.015	0.016
C33	0.017	0.010	0.013	0.012	0.017	0.014
C37	0.010	0.007	0.007	0.006	0.010	0.006
C51	0.010	0.010	0.010	0.010	0.008	0.007
C52	0.017	0.016	0.015	0.017	0.012	0.013
C53	0.019	0.012	0.010	0.010	0.019	0.014
C54	0.020	0.019	0.019	0.020	0.020	0.016
C17	0.091	0.028	0.028	0.091	0.083	0.046
C18	0.057	0.057	0.057	0.057	0.034	0.051
C19	0.052	0.035	0.023	0.023	0.052	0.020
C21	0.061	0.048	0.061	0.030	0.016	0.040
C22	0.036	0.036	0.035	0.033	0.034	0.025
C23	0.023	0.018	0.018	0.018	0.015	0.023
C24	0.036	0.031	0.032	0.036	0.024	0.034
C32	0.020	0.020	0.020	0.019	0.020	0.019
C34	0.015	0.015	0.014	0.015	0.011	0.014
C35	0.013	0.012	0.013	0.011	0.009	0.011
C36	0.010	0.009	0.009	0.010	0.007	0.008
C41	0.043	0.037	0.037	0.043	0.039	0.039
C42	0.032	0.027	0.027	0.032	0.022	0.032
C 43	0.047	0.040	0.040	0.040	0.047	0.036

Then According to WPM, the total relative importance of the alternatives (Qi (2)) was calculated with Eq. (3.10). Calculated values are presented in Table 4.22

Table 4.22. Total Relative Significance of Alternatives with Weighted Product Model (WPM).

Criteria	**Weight**	**A1**	**A2**	**A3**	**A4**	**A5**
C11	0.038	0.997	0.997	1.000	0.996	0.998
C12	0.045	0.975	0.975	1.000	0.985	0.971
C13	0.048	1.000	1.000	1.000	0.972	0.988
C14	0.051	0.970	0.970	0.986	0.932	1.000
C15	0.079	0.984	0.979	1.000	0.974	0.953
C16	0.090	0.979	0.974	1.000	0.997	0.970
C31	0.022	0.999	1.000	0.999	0.992	0.994
C33	0.017	0.992	0.996	0.995	1.000	0.997
C37	0.010	0.997	0.997	0.995	1.000	0.995
C51	0.010	1.000	1.000	1.000	0.998	0.996
C52	0.017	1.000	0.999	1.000	0.994	0.996
C53	0.019	0.990	0.987	0.987	1.000	0.994
C54	0.020	0.999	0.999	1.000	1.000	0.995
C17	0.091	0.899	0.899	1.000	0.991	0.940
C18	0.057	1.000	1.000	1.000	0.971	0.994
C19	0.052	0.980	0.960	0.960	1.000	0.952
C21	0.061	0.986	1.000	0.959	0.921	0.975
C22	0.036	1.000	1.000	0.997	0.998	0.987
C23	0.023	0.994	0.995	0.995	0.991	1.000
C24	0.036	0.995	0.996	1.000	0.986	0.998
C32	0.020	1.000	0.999	0.999	1.000	0.999
C34	0.015	1.000	0.999	1.000	0.995	0.999
C35	0.013	1.000	1.000	0.999	0.996	0.998
C36	0.010	0.999	0.998	1.000	0.995	0.997
C41	0.043	0.994	0.994	1.000	0.996	0.996
C42	0.032	0.995	0.995	1.000	0.988	1.000
C43	0.047	0.992	0.992	0.992	1.000	0.987

4.1.5.4. Determining and Ranking the Ultimate Performance of Options

The final performance weights of the personnel were calculated and ranked using Eq. (3.8). as show in table 4.23.

Table 4.23. Determination and Ranking of Final Performance options for exterior wall.

	A1	**A2**	**A3**	**A4**	**A5**
preference WSM	0.783	0.776	0.892	0.761	0.740
preference WPM	0.748	0.736	0.868	0.712	0.716
preference WASPAS	0.766	0.756	0.880	0.737	0.728

Table 4.24. Ranking of exterior wall alternatives

	A1	A2	A3	A4	A5
WSM Rank	2	3	1	4	5
WPM Rank	2	3	1	5	4
WASPAS Rank	2	3	1	4	5

Ranking results of the evaluation of five wall materials with the WASPAS method are determined as A3>A1 >A5. According to the results of this method, It has been seen that A3, which represents isolation brick, took the first place in the ranking and was determined as the best solution for exterior walls. The second material is A1 clay brick with a dimension size 19x19x19 cm, clay brick with dimension (23.5x18.5x 25) cm which symbolized by A2 chosen as the third, AAC block witch is A4 ranked as the fourth, the last one in ranking list is A5 means pumice block.

Table 4.25. Ranking of alternatives for interior wall.

	A1	A2	A3	A4	A5
WSM Rank	2	1	4	5	3
WPM Rank	2	1	5	4	3
WASPAS Rank	2	1	4	5	3

From WASPAS ranking results, it is observed that clay brick 2(19x10x19), symbolized by alternative 2, topped the first position among the five materials considered. In fact (19x10x19) cm clay brick is the most popular material used for the interior wall in turkey due to its extensive production cost and easy availability with its properties. Clay brick 2, which A2 symbolizes, is followed by A1 (19x13.5x19) cm clay brick, A5 glass brick, A3 AAC (60x10x25) cm, and alternative four pumice block in the last position of the ranking.

4.1.6. Application Of TOPSIS Method

The alternatives are evaluated With the TOPSIS method, which is one of the multi-criteria decision-making methods, the following steps are carried out in order to rank the alternatives.

4.1.6.1. Creating the Decision Matrix

The average initial relationship matrix for criteria and dimensions was created using respondents' responses. The type and weight values of the criteria are given in Table 4.26.

Table 4.26. Integrated Decision Matrix for exterior wall.

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Criteria	Type	Weight	A1	A2	A3	A4	A5	Sum of Squares	Square root
C11	Max	0.038	43.00	43.00	46.00	41.000	44.000	9431	97.113
C12	Max	0.045	2.000	2.000	3.500	2.500	1.820	29.812	5.460
C13	Max	0.048	9.000	9.000	9.000	5.000	7.000	317	17.804
C14	Max	0.051	55.00	55.00	75.00	25.000	100.00	22300	149.332
C15	Max	0.079	6.080	5.707	7.430	5.323	4.070	169.646	13.025
C16	Max	0.090	4.963	4.682	6.269	6.084	4.468	142.831	11.951
C31	Max	0.022	7.866	8.075	7.621	5.484	6.107	252.529	15.891
C33	Max	0.017	5.040	6.289	5.980	8.162	6.889	214.790	14.656
C37	Max	0.010	5.283	5.534	4.335	7.343	4.497	151.470	12.307
C51	Max	0.010	7.828	7.745	7.454	6.329	5.391	245.944	15.683
C52	Max	0.017	6.33	6.011	6.487	4.471	5.189	165.198	12.853
C53	Max	0.019	5.130	4.412	4.386	8.506	6.125	174.887	13.224
C54	Max	0.020	6.637	6.630	6.991	6.828	5.563	214.449	14.644
C17	Min	0.091	0.320	0.320	0.100	0.110	0.198	0.266	0.516
C18	Min	0.057	6.000	6.000	6.000	10.000	6.670	252.489	15.890
C19	Min	0.052	4.000	6.000	6.000	2.700	7.000	144.290	12.012
C21	Min	0.061	62.50	49.500	99.000	191.400	75.000	58416.460	241.695
C22	Min	0.036	4.995	5.049	5.478	5.237	7.121	158.586	12.593
C23	Min	0.023	5.923	5.778	5.738	6.887	4.634	170.297	13.050
C24	Min	0.036	5.573	5.320	4.815	7.142	5.101	159.573	12.632
C32	Min	0.020	6.576	6.768	6.854	6.686	6.973	229.352	15.144
C34	Min	0.015	4.850	5.320	4.935	6.874	5.279	151.299	12.300
C35	Min	0.013	4.957	4.857	5.425	6.571	5.520	151.241	12.298
C36	Min	0.010	3.598	3.869	3.183	4.963	4.120	79.652	8.925
C41	Min	0.043	5.886	5.823	5.072	5.619	5.619	157.424	12.547
C42	Min	0.032	5.040	5.085	4.336	6.336	4.292	128.626	11.341
C 43	Min	0.047	0.270	0.270	0.270	0.230	0.300	0.362	0.601

Table 4.27.Creation decision matrix for interior wall.

Criteria	**Type**	**Weight**	**A1**	**A2**	**A3**	**A4**	**A5**	**Sum of Squares**	**Square root**
C11	Max	0.108	31.50	30.00	30.00	35.00	38.000	5461.250	73.900
C12	Max	0.046	2.000	2.000	2.500	2.300	13.900	212.750	14.586
C13	Max	0.060	9.000	9.000	5.000	7.000	3.000	245.000	15.652
C14	Max	0.062	6.564	6.200	5.758	4.003	7.230	182.980	13.527
C15	Max	0.046	5.537	5.707	7.025	5.153	4.215	156.904	12.526
C31	Max	0.023	8.506	8.138	6.732	5.864	3.595	231.221	15.206
C33	Max	0.016	4.700	5.531	8.388	7.049	5.728	205.528	14.336
C37	Max	0.009	5.482	5.535	7.818	5.486	2.298	157.181	12.537
C51	Max	0.013	7.939	7.855	5.978	5.031	5.410	215.044	14.664
C52	Max	0.065	6.716	6.464	4.440	5.344	6.869	182.355	13.504
C53	Max	0.021	5.210	5.128	8.100	5.109	3.221	155.532	12.471
C54	Max	0.015	7.146	7.111	6.841	6.699	3.092	202.868	14.243
C16	Min	0.031	0.320	0.320	0.110	0.156	0.250	0.304	0.551
C17	Min	0.039	6.500	6.500	10.00	7.420	0.010	239.557	15.478
C18	Min	0.051	3.000	2.300	2.700	6.500	2.500	70.080	8.371
C21	Min	0.081	52.0	49.4	99.0	68.75	1218.750	1505023.485	1226.794
C22	Min	0.046	5.206	5.121	5.941	6.533	6.533	173.992	13.191
C23	Min	0.032	5.871	5.906	6.844	5.386	2.965	153.988	12.409
C24	Min	0.049	5.713	5.454	6.884	5.164	5.337	164.930	12.843
C32	Min	0.020	6.447	6.457	6.191	6.614	2.683	172.521	13.135
C34	Min	0.012	4.663	4.867	8.122	5.422	3.537	153.315	12.382
C35	Min	0.011	5.869	6.251	6.191	5.347	2.454	146.450	12.102
C36	Min	0.010	3.008	3.356	4.769	4.154	4.580	81.282	9.016
C41	Min	0.050	5.943	5.871	6.951	5.024	6.928	191.329	13.832
C42	Min	0.025	5.513	5.296	7.368	5.257	6.062	177.098	13.308
C43	Min	0.062	0.270	0.270	0.230	0.300	1.090	1.477	1.215

4.1.6.2. Normalization Decision Matrix

The normalization process was performed for the decision matrix created in Step 1 (see Table 4.28). With helping Equation (3.13), normalization was done by dividing each value in each column by the square root of the sum of the squares of the values in the column, and it is ensured that each matrix element is between 0 and 1.

Table 4.28. TOPSIS – normalization process.

Criteria codes	A1	A2	A3	A4	A5
C11	0.443	0.443	0.474	0.422	0.453
C12	0.366	0.366	0.641	0.458	0.333
C13	0.505	0.505	0.505	0.281	0.393
C14	0.368	0.368	0.502	0.167	0.670
C15	0.467	0.438	0.570	0.409	0.313
C31	0.415	0.392	0.525	0.509	0.374
C33	0.495	0.508	0.480	0.345	0.384
C37	0.344	0.429	0.408	0.557	0.470
C51	0.429	0.450	0.352	0.597	0.365
C52	0.499	0.494	0.475	0.404	0.344
C53	0.492	0.468	0.505	0.348	0.404
C54	0.388	0.334	0.332	0.643	0.463
C16	0.453	0.453	0.477	0.466	0.380
C17	0.620	0.620	0.194	0.213	0.384
C18	0.378	0.378	0.378	0.629	0.420
C21	0.333	0.499	0.499	0.225	0.583
C22	0.259	0.205	0.410	0.792	0.310
C23	0.397	0.401	0.435	0.416	0.565
C24	0.454	0.443	0.440	0.528	0.355
C32	0.441	0.421	0.381	0.565	0.404
C34	0.434	0.447	0.453	0.441	0.460
C35	0.394	0.433	0.401	0.559	0.429
C36	0.403	0.395	0.441	0.534	0.449
C41	0.403	0.434	0.357	0.556	0.462
C42	0.469	0.464	0.404	0.448	0.448
C43	0.444	0.448	0.382	0.559	0.378
Abs	0.449	0.449	0.449	0.382	0.499

4.1.6.3. Step3: Weighted Normalization Matrix

Eq. (3.14) generates the weighted, normalized decision matrix in this step. The weight of each criterion was obtained by the best-worst method multiplied by the matrix's relevant value. Obtained values are given in Table (4.29).

Table 4.29. TOPSIS weighted normalization decision matrix.

Criteria	Weight	A1	A2	A3	A4	A5
C11	0.038	0.017	0.017	0.018	0.016	0.017
C12	0.045	0.016	0.016	0.029	0.021	0.015
C13	0.048	0.024	0.024	0.024	0.013	0.019
C14	0.051	0.019	0.019	0.025	0.008	0.034
C15	0.079	0.037	0.035	0.045	0.032	0.025
C16	0.090	0.037	0.035	0.047	0.046	0.034
C31	0.022	0.011	0.011	0.010	0.007	0.008
C33	0.017	0.006	0.007	0.007	0.009	0.008
C37	0.010	0.004	0.004	0.003	0.006	0.003
C51	0.010	0.005	0.005	0.005	0.004	0.003
C52	0.017	0.008	0.008	0.008	0.006	0.007
C53	0.019	0.008	0.006	0.006	0.012	0.009
C54	0.020	0.009	0.009	0.010	0.009	0.008
C17	0.091	0.057	0.057	0.018	0.019	0.035
C18	0.057	0.021	0.021	0.021	0.036	0.024
C19	0.052	0.017	0.026	0.026	0.012	0.030
C21	0.061	0.016	0.012	0.025	0.048	0.019
C22	0.036	0.014	0.014	0.016	0.015	0.020
C23	0.023	0.010	0.010	0.010	0.012	0.008
C24	0.036	0.016	0.015	0.014	0.020	0.014
C32	0.020	0.009	0.009	0.009	0.009	0.009
C34	0.015	0.006	0.007	0.006	0.008	0.006
C35	0.013	0.005	0.005	0.006	0.007	0.006
C36	0.010	0.004	0.005	0.004	0.006	0.005
C41	0.043	0.020	0.020	0.017	0.019	0.019
C42	0.032	0.014	0.014	0.012	0.018	0.012
C 43	0.047	0.021	0.021	0.021	0.018	0.024

4.1.6.4. Step4: Positive Ideal and Negative Ideal Solution

Positive and negative ideal solutions were determined in this step, utilizing Eq. (3.15) for the positive ideal solution and Eq. (3.16) for the negative ideal solution. As shown in Table 4.30, A+ represents ideal values, and A- represents negative ideal values.

Table 4.30. TOPSIS - ideal and negative ideal solutions.

A+	A-
0.018	0.016
0.029	0.015
0.024	0.013
0.034	0.008
0.045	0.025
0.047	0.034
0.011	0.007
0.009	0.006
0.006	0.003
0.005	0.003
0.008	0.006
0.012	0.006
0.010	0.008
0.018	0.057
0.021	0.036
0.012	0.030
0.012	0.048
0.014	0.020
0.008	0.012
0.014	0.020
0.009	0.009
0.006	0.008
0.005	0.007
0.004	0.006
0.017	0.020
0.012	0.018
0.018	0.024

4.1.6.5. Step 5: Calculation of Separation Measures

Negative and positive ideal distance measures were calculated (see Table 4.31). Si+ shows the distance of the relevant alternatives from the positive ideal solution, calculated using Eq. (3.17), while Si- shows the distance of the relevant alternatives from the negative ideal distance calculated by Eq. (3.18). However, an option may be further ahead in the ranking by being further away from the negative ideal and closer to the positive ideal.

Table 4.31. Negative ideal and positive ideal distance measure.

	A1	A2	A3	A4	A5
Si+	0.047	0.049	0.022	0.051	0.040
Si-	0.044	0.044	0.060	0.046	0.047

4.1.6.6. Step 6: Finding Relative Closeness to the Ideal Solution

As a final step, the closeness (Ci*) values to the ideal solution were calculated by Eq. (3.19) (see Table 4.32). The Ci* value was obtained by dividing the negative ideal distance by the sum of the positive ideal distance and the negative ideal distance for the appropriate option. The more considerable Ci* value indicates that it is farther from the negative and closer to the positive ideal solution.

Table 4.32. TOPSIS – Ci* Values and ranking alternatives for exterior wall.

	A1	A2	A3	A4	A5
Ci*	0.484	0.471	0.731	0.472	0.540
Ranking	3	5	1	4	2

As a result of the evaluation of five wall materials using the TOPSIS method, the obtained ranking was A3>A5 >A1>A4>A2; depending on this method, it was proved that the most suitable alternative is A3 (isolation clay brick) among the other alternatives and A5 (pumice block) was ranked as the second one, the third-ranking is A1 (clay brick 19X19X19 cm) for exterior wall, A4 remained in the fourth place of ranking, the last ranking alternative according to TIOPSIS method is A2 (clay brick (23.5x18.5x 25).

Table 4.33. TOPSIS-Ci* values and ranking of alternatives for interior wall.

	A1	A2	A3	A4	A5
Ci*	0.677	0.677	0.636	0.624	0.380
Ranking	2	1	3	4	5

According to the calculation results of the TOPSIS method, the ranking of materials is determined as A2>A1>A3>A4>A5; it is observed that alternative 2, which represents (19x10x19) cm clay brick holds the first position in our material evaluation selection framework for interior wall, then alternative 1which is also clay brick with different dimension (19x13.5x19) cm is the second most suitable interior material, AAC holds the third position and AAC is followed by pumice block and glass brick.

4.1.7. Application Of MOORA Method

MOORA method is another multi- criteria decision making method, which is used to choose the most suitable alternatives among the five alternatives. The following steps are performed to rank the alternatives.

4.1.7.1. Reference point Approach

There are more than one type of MOORA method in this study , 4.1.7.1. Reference point Approach is uded as the best choice among the different competing methods.

Step1: Decision-Making Matrix

Decision options, criteria, criterion weights, and the value of the alternatives according to the criteria, as well as the data that emerged after the evaluation was made, are given in Table 4.33, and the square root of the sum of the squares of each alternative was found by to steps as shown at the end of Table 4.34. In the 1st step sum of the squares of the corresponding column, values were calculated, and then the root of the initial values in the next row was found.

Table 4.34. Decision matrix.

Criteria	**Type**	**Weight**	**A1**	**A2**	**A3**	**A4**	**A5**	Sum of Squares	square root
C11	max	0.038	43.000	43.000	46.000	41.000	44.000	9431	97.113
C12	max	0.045	2.000	2.000	3.500	2.500	1.820	29.8124	5.460
C13	max	0.048	9.000	9.000	9.000	5.000	7.000	317	17.804
C14	max	0.051	55.00	55.00	75.00	25.00	100.0	22300	149.33
C15	max	0.079	6.080	5.707	7.430	5.323	4.070	169.646	13.025
C16	max	0.090	4.963	4.682	6.269	6.084	4.468	142.831	11.951
C31	max	0.022	7.866	8.075	7.621	5.484	6.107	252.529	15.891
C33	max	0.017	5.040	6.289	5.980	8.162	6.889	214.790	14.656
C37	max	0.010	5.283	5.534	4.335	7.343	4.497	151.470	12.307
C51	max	0.010	7.828	7.745	7.454	6.329	5.391	245.944	15.683
C52	max	0.017	6.33	6.011	6.487	4.471	5.189	165.198	12.853
C53	max	0.019	5.130	4.412	4.386	8.506	6.125	174.887	13.224
C54	max	0.020	6.637	6.630	6.991	6.828	5.563	214.449	14.644
C17	min	0.091	0.320	0.320	0.100	0.110	0.198	0.266	0.516
C18	min	0.057	6.000	6.000	6.000	10.00	6.670	252.489	15.890
C19	min	0.052	4.000	6.000	6.000	2.700	7.000	144.290	12.012
C21	min	0.061	62.50	49.50	99.00	191.4	75.00	58416.5	241.70
C22	min	0.036	4.995	5.049	5.478	5.237	7.121	158.586	12.593
C23	min	0.023	5.923	5.778	5.738	6.887	4.634	170.297	13.050
C24	min	0.036	5.573	5.320	4.815	7.142	5.101	159.573	12.632
C32	min	0.020	6.576	6.768	6.854	6.686	6.973	229.352	15.144
C34	min	0.015	4.850	5.320	4.935	6.874	5.279	151.299	12.300
C35	min	0.013	4.957	4.857	5.425	6.571	5.520	151.241	12.298
C36	min	0.010	3.598	3.869	3.183	4.963	4.120	79.652	8.925
C41	min	0.043	5.886	5.823	5.072	5.619	5.619	157.424	12.547
C42	min	0.032	5.040	5.085	4.336	6.336	4.292	128.626	11.341
C 43	min	0.047	0.270	0.270	0.270	0.230	0.300	0.362	0.601

Table 4.35.Creation decision matrix for interior wall.

Criteria	**Type**	**Weight**	**A1**	**A2**	**A3**	**A4**	**A5**	Sum of Squares	square root
C11	max	0.108	31.50	30.000	30.000	35.000	38.000	5461.250	73.900
C12	max	0.046	2.000	2.000	2.500	2.300	13.900	212.750	14.586
C13	max	0.060	9.000	9.000	5.000	7.000	3.000	245.000	15.652
C14	max	0.062	6.564	6.200	5.758	4.003	7.230	182.980	13.527
C15	max	0.046	5.537	5.707	7.025	5.153	4.215	156.904	12.526
C31	max	0.023	8.506	8.138	6.732	5.864	3.595	231.221	15.206
C33	max	0.016	4.700	5.531	8.388	7.049	5.728	205.528	14.336
C37	max	0.009	5.482	5.535	7.818	5.486	2.298	157.181	12.537
C51	max	0.013	7.939	7.855	5.978	5.031	5.410	215.044	14.664
C52	max	0.065	6.716	6.464	4.440	5.344	6.869	182.355	13.504
C53	max	0.021	5.210	5.128	8.100	5.109	3.221	155.532	12.471
C54	max	0.015	7.146	7.111	6.841	6.699	3.092	202.868	14.243
C16	min	0.031	0.320	0.320	0.110	0.156	0.250	0.304	0.551
C17	min	0.039	6.500	6.500	10.00	7.420	0.010	239.557	15.478
C18	min	0.051	3.000	2.300	2.700	6.500	2.500	70.080	8.371
C21	min	0.081	52.00	49.40	99.00	68.75	1218.75	1505023.5	1226.794
C22	min	0.046	5.206	5.121	5.941	6.533	6.533	173.992	13.191
C23	min	0.032	5.871	5.906	6.844	5.386	2.965	153.988	12.409
C24	min	0.049	5.713	5.454	6.884	5.164	5.337	164.930	12.843
C32	min	0.020	6.447	6.457	6.191	6.614	2.683	172.521	13.135
C34	min	0.012	4.663	4.867	8.122	5.422	3.537	153.315	12.382
C35	min	0.011	5.869	6.251	6.191	5.347	2.454	146.450	12.102
C36	min	0.010	3.008	3.356	4.769	4.154	4.580	81.282	9.016
C41	min	0.050	5.943	5.871	6.951	5.024	6.928	191.329	13.832
C42	min	0.025	5.513	5.296	7.368	5.257	6.062	177.098	13.308
C43	min	0.062	0.270	0.270	0.230	0.300	1.090	1.477	1.215

Step2: Normalization of Decision Matrix

The normalization of the decision matrix was obtained by dividing each criterion by the square root of the sum of the squares of each alternative. As can be seen in Eq. (3. 20). The calculation values of the normalization are given in Table 4. 36

Table 4.36. MOORA- normalization decision matrix.

Criteria codes	**A1**	**A2**	**A3**	**A4**	**A5**
C11	0.443	0.443	0.474	0.422	0.453
C12	0.366	0.366	0.641	0.458	0.333
C13	0.505	0.505	0.505	0.281	0.393
C14	0.368	0.368	0.502	0.167	0.670
C15	0.467	0.438	0.570	0.409	0.313
C31	0.415	0.392	0.525	0.509	0.374
C33	0.495	0.508	0.480	0.345	0.384
C37	0.344	0.429	0.408	0.557	0.470
C51	0.429	0.450	0.352	0.597	0.365
C52	0.499	0.494	0.475	0.404	0.344
C53	0.492	0.468	0.505	0.348	0.404
C54	0.388	0.334	0.332	0.643	0.463
C16	0.453	0.453	0.477	0.466	0.380
C17	0.620	0.620	0.194	0.213	0.384
C18	0.378	0.378	0.378	0.629	0.420
C21	0.333	0.499	0.499	0.225	0.583
C22	0.259	0.205	0.410	0.792	0.310
C23	0.397	0.401	0.435	0.416	0.565
C24	0.454	0.443	0.440	0.528	0.355
C32	0.441	0.421	0.381	0.565	0.404
C34	0.434	0.447	0.453	0.441	0.460
C35	0.394	0.433	0.401	0.559	0.429
C36	0.403	0.395	0.441	0.534	0.449
C41	0.403	0.434	0.357	0.556	0.462
C42	0.469	0.464	0.404	0.448	0.448
C43	0.444	0.448	0.382	0.559	0.378
	0.449	0.449	0.449	0.382	0.499

Step3: Weighted Normalization Matrix

Eq. (3.21) was applied to get a weighted normalization matrix. The values given in Table 4.36 were multiplied by the coefficient of the relevant criterion. The Formed matrix containing the weighted new values is given in Table 4.37..

Table 4.37. Weighted matrix with significance factor.

Criteria	Weight	A1	A2	A3	A4	A5
C11	0.038	0.017	0.017	0.018	0.016	0.017
C12	0.045	0.016	0.016	0.029	0.021	0.015
C13	0.048	0.024	0.024	0.024	0.013	0.019
C14	0.051	0.019	0.019	0.025	0.008	0.034
C15	0.079	0.037	0.035	0.045	0.032	0.025
C16	0.090	0.037	0.035	0.047	0.046	0.034
C31	0.022	0.011	0.011	0.010	0.007	0.008
C33	0.017	0.006	0.007	0.007	0.009	0.008
C37	0.010	0.004	0.004	0.003	0.006	0.003
C51	0.010	0.005	0.005	0.005	0.004	0.003
C52	0.017	0.008	0.008	0.008	0.006	0.007
C53	0.019	0.008	0.006	0.006	0.012	0.009
C54	0.020	0.009	0.009	0.010	0.009	0.008
C17	0.091	0.057	0.057	0.018	0.019	0.035
C18	0.057	0.021	0.021	0.021	0.036	0.024
C19	0.052	0.017	0.026	0.026	0.012	0.030
C21	0.061	0.016	0.012	0.025	0.048	0.019
C22	0.036	0.014	0.014	0.016	0.015	0.020
C23	0.023	0.010	0.010	0.010	0.012	0.008
C24	0.036	0.016	0.015	0.014	0.020	0.014
C32	0.020	0.009	0.009	0.009	0.009	0.009
C34	0.015	0.006	0.007	0.006	0.008	0.006
C35	0.013	0.005	0.005	0.006	0.007	0.006
C36	0.010	0.004	0.005	0.004	0.006	0.005
C41	0.043	0.020	0.020	0.017	0.019	0.019
C42	0.032	0.014	0.014	0.012	0.018	0.012
C 43	0.047	0.021	0.021	0.021	0.018	0.024

Step4: Reference Point Approach

The performance index was measured by Eq. (3. 22), considering all the maximum and minimum criteria for every alternative. Table 4.38 shows the performance index of each alternative.

Table 4.38. Performance index.

	A1	A2	A3	A4	A5
MAX sum	0.201	0.197	0.239	0.191	0.190
MIN sum	0.231	0.236	0.204	0.247	0.232

Step5: Significance Coefficient Approach

Table 4.39. Significance Coefficient Approach and ranking for exterior wall.

Alternatives	A1	A2	A3	A4	A5
Yi*	-0.029	-0.039	0.035	-0.056	-0.042
Rank	2	3	1	5	4

According to calculation ranking results, when the MOORA method was applied, the ranking of alternatives can be expressed as A3>A1>A2>A5>A4. A3 (isolation brick) appeared as the best wall material alternative among all the five materials taken up for analysis. After that is A1 (clay brick 19X19X19) in the second place of the ranking, the third wall element according to MOORA method is A2 (clay brick 23.5x18.5x 25, A5 pumice block is fourth in ranking and finally is A4 (AAC).

Table 4.40. Significance Coefficient Approach and ranking for interior wall.

Alternatives	A1	A2	A3	A4	A5
Yi*	0.035	0.036	-0.002	-0.007	-0.048
Rank	2	1	3	4	5

As can be seen from Table (4.40), according to the MOORA method the ranking of alternatives for exterior wall can be expressed as A2>A1>A3>A4>A5. A2 appeared as the best wall material alternative among all the five materials taken up for analysis.

4.1.8. Application Of EDAS Method

4.1.8.1. The Application Procedure of the EDAS Method

EDAS method is also used to rank the alternatives and chose the most suitable alternatives. The calculation results of all the applied steps are shown below.

Step1: constructing decision-making matrix

In the first step, the initial decision-making matrix was created by equation (3.24),

Step2: Determination of average value

After creating the decision matrix, the next step was taking the average value for all the criteria, helping Eq. (3. 25) and Eq. (3.26). as shown in Table 4. 41.

Table 4.41. EDAS- Decision-making matrix.

Criteria	Type	Weight	A1	A2	A3	A4	A5	Criteria average
C11	max	0.038	43.000	43.000	46.000	41.000	44.000	43.400
C12	max	0.045	2.000	2.000	3.500	2.500	1.820	2.364
C13	max	0.048	9.000	9.000	9.000	5.000	7.000	7.800
C14	max	0.051	55.000	55.000	75.000	25.000	100.000	62.000
C15	max	0.079	6.080	5.707	7.430	5.323	4.070	5.722
C16	max	0.090	4.963	4.682	6.269	6.084	4.468	5.293
C31	max	0.022	7.866	8.075	7.621	5.484	6.107	7.031
C33	max	0.017	5.040	6.289	5.980	8.162	6.889	6.472
C37	max	0.010	5.283	5.534	4.335	7.343	4.497	5.398
C51	max	0.010	7.828	7.745	7.454	6.329	5.391	6.949
C52	max	0.017	6.33	6.011	6.487	4.471	5.189	5.698
C53	max	0.019	5.130	4.412	4.386	8.506	6.125	5.712
C54	max	0.020	6.637	6.630	6.991	6.828	5.563	6.530
C17	min	0.091	0.320	0.320	0.100	0.110	0.198	0.210
C18	min	0.057	6.000	6.000	6.000	10.000	6.670	6.934
C19	min	0.052	4.000	6.000	6.000	2.700	7.000	5.140
C21	min	0.061	62.500	49.500	99.000	191.400	75.000	95.480
C22	min	0.036	4.995	5.049	5.478	5.237	7.121	5.576
C23	min	0.023	5.923	5.778	5.738	6.887	4.634	5.792
C24	min	0.036	5.573	5.320	4.815	7.142	5.101	5.590
C32	min	0.020	6.576	6.768	6.854	6.686	6.973	6.771
C34	min	0.015	4.850	5.320	4.935	6.874	5.279	5.452
C35	min	0.013	4.957	4.857	5.425	6.571	5.520	5.466
C36	min	0.010	3.598	3.869	3.183	4.963	4.120	3.947
C41	min	0.043	5.886	5.823	5.072	5.619	5.619	5.604
C42	min	0.032	5.040	5.085	4.336	6.336	4.292	5.018
C 43	min	0.047	0.270	0.270	0.270	0.230	0.300	0.268

Table 4.42. Creation decision matrix for interior wall.

Criteria	Type	Weight	A1	A2	A3	A4	A5	Criteria average
C11	Max	0.108	31.500	30.000	30.000	35.000	38.000	32.900
C12	Max	0.046	2.000	2.000	2.500	2.300	13.900	4.540
C13	Max	0.060	9.000	9.000	5.000	7.000	3.000	6.600
C14	Max	0.062	6.564	6.200	5.758	4.003	7.230	5.951
C15	Max	0.046	5.537	5.707	7.025	5.153	4.215	5.528
C31	Max	0.023	8.506	8.138	6.732	5.864	3.595	6.567
C33	Max	0.016	4.700	5.531	8.388	7.049	5.728	6.279
C37	Max	0.009	5.482	5.535	7.818	5.486	2.298	5.324
C51	Max	0.013	7.939	7.855	5.978	5.031	5.410	6.443
C52	Max	0.065	6.716	6.464	4.440	5.344	6.869	5.967
C53	Max	0.021	5.210	5.128	8.100	5.109	3.221	5.354
C54	Max	0.015	7.146	7.111	6.841	6.699	3.092	6.178
C16	Min	0.031	0.320	0.320	0.110	0.156	0.250	0.231
C17	Min	0.039	6.500	6.500	10.000	7.420	0.010	6.086
C18	Min	0.051	3.000	2.300	2.700	6.500	2.500	3.400
C21	Min	0.081	52.000	49.400	99.000	68.750	1218.750	297.580
C22	Min	0.046	5.206	5.121	5.941	6.533	6.533	5.867
C23	Min	0.032	5.871	5.906	6.844	5.386	2.965	5.394
C24	Min	0.049	5.713	5.454	6.884	5.164	5.337	5.710
C32	Min	0.020	6.447	6.457	6.191	6.614	2.683	5.678
C34	Min	0.012	4.663	4.867	8.122	5.422	3.537	5.322
C35	Min	0.011	5.869	6.251	6.191	5.347	2.454	5.222
C36	Min	0.010	3.008	3.356	4.769	4.154	4.580	3.973
C41	Min	0.050	5.943	5.871	6.951	5.024	6.928	6.143
C42	Min	0.025	5.513	5.296	7.368	5.257	6.062	5.899
C43	Min	0.062	0.270	0.270	0.230	0.300	1.090	0.432

Step3: Calculating Positive and Negative Distance From Average

Positive distance from average and negative distance from average was calculated based on the type of the criteria (beneficial and non-beneficial criteria). To determine PDA ij for beneficial criteria, Eq. (3.27) was used, and non-beneficial criteria Eq. (3.29) was used. The calculation values are given in Table 4.43.

Table 4.43. Positive distance from average (PADij) values.

Criteria	A1	A2	A3	A4	A5
C11	0.000	0.000	0.060	0.000	0.014
C12	0.000	0.000	0.481	0.058	0.000
C13	0.154	0.154	0.154	0.000	0.000
C14	0.000	0.000	0.210	0.000	0.613
C15	0.063	0.000	0.298	0.000	0.000
C16	0.000	0.000	0.184	0.149	0.000
C31	0.119	0.149	0.084	0.000	0.000
C33	0.000	0.000	0.000	0.261	0.064
C37	0.000	0.025	0.000	0.360	0.000
C51	0.126	0.114	0.073	0.000	0.000
C52	0.111	0.055	0.139	0.000	0.000
C53	0.000	0.000	0.000	0.489	0.072
C54	0.016	0.015	0.071	0.046	0.000
C17	0.000	0.000	0.523	0.475	0.055
C18	0.135	0.135	0.135	0.000	0.038
C19	0.222	0.000	0.000	0.475	0.000
C21	0.345	0.482	0.000	0.000	0.214
C22	0.104	0.095	0.018	0.061	0.000
C23	0.000	0.002	0.009	0.000	0.200
C24	0.003	0.048	0.139	0.000	0.088
C32	0.029	0.001	0.000	0.013	0.000
C34	0.110	0.024	0.095	0.000	0.032
C35	0.093	0.111	0.008	0.000	0.000
C36	0.088	0.020	0.193	0.000	0.000
C41	0.000	0.000	0.095	0.000	0.000
C42	0.000	0.000	0.136	0.000	0.145
C 43	0.000	0.000	0.000	0.142	0.000

After determining the positive distance from the average, later (NDAij) was calculated considering the type of criteria; for beneficial criteria, Eq. (3. 28) was applied, and for cost criteria, Eq. (3.30) was applied. The calculation values are shown in Table 4. 44.

Table 4.44 Negative distances from average (NADij) values.

Criteria	**A1**	**A2**	**A3**	**A4**	**A5**
C11	0.009	0.009	0.000	0.055	0.000
C12	0.154	0.154	0.000	0.000	0.230
C13	0.000	0.000	0.000	0.359	0.103
C14	0.113	0.113	0.000	0.597	0.000
C15	0.000	0.003	0.000	0.070	0.289
C16	0.062	0.115	0.000	0.000	0.156
C31	0.000	0.000	0.000	0.220	0.131
C33	0.221	0.028	0.076	0.000	0.000
C37	0.021	0.000	0.197	0.000	0.167
C51	0.000	0.000	0.000	0.089	0.224
C52	0.000	0.000	0.000	0.215	0.089
C53	0.102	0.228	0.232	0.000	0.000
C54	0.000	0.000	0.000	0.000	0.148
C17	0.527	0.527	0.000	0.000	0.000
C18	0.000	0.000	0.000	0.442	0.000
C19	0.000	0.167	0.167	0.000	0.362
C21	0.000	0.000	0.037	1.005	0.000
C22	0.000	0.000	0.000	0.000	0.277
C23	0.023	0.000	0.000	0.189	0.000
C24	0.000	0.000	0.000	0.278	0.000
C32	0.000	0.000	0.012	0.000	0.030
C34	0.000	0.000	0.000	0.261	0.000
C35	0.000	0.000	0.000	0.202	0.010
C36	0.000	0.000	0.000	0.258	0.044
C41	0.050	0.039	0.000	0.003	0.003
C42	0.004	0.013	0.000	0.263	0.000
C 43	0.007	0.007	0.007	0.000	0.119

Step 4: Weighted Sum of Positive Distance from Average and Negative Distance from Average

In this stage, the weighted sum of the positive distance from an average and the negative distance from the average was calculated. Equation (3.31) shows the positive distance from the average in Table 43. Multiplied by the weights of the criterion thus weighted sum of positive distance was created, as presented in Table 4.45.

Table 4.45. (PDAij × *wj*) values.

Criteria	Weight	A1	A2	A3	A4	A5
C11	0.038	0.000	0.000	0.002	0.000	0.001
C12	0.045	0.000	0.000	0.022	0.003	0.000
C13	0.048	0.007	0.007	0.007	0.000	0.000
C14	0.051	0.000	0.000	0.011	0.000	0.031
C15	0.079	0.005	0.000	0.024	0.000	0.000
C16	0.090	0.000	0.000	0.017	0.013	0.000
C31	0.022	0.003	0.003	0.002	0.000	0.000
C33	0.017	0.000	0.000	0.000	0.004	0.001
C37	0.010	0.000	0.000	0.000	0.003	0.000
C51	0.010	0.001	0.001	0.001	0.000	0.000
C52	0.017	0.002	0.001	0.002	0.000	0.000
C53	0.019	0.000	0.000	0.000	0.009	0.001
C54	0.020	0.000	0.000	0.001	0.001	0.000
C17	0.091	0.000	0.000	0.048	0.043	0.005
C18	0.057	0.008	0.008	0.008	0.000	0.002
C19	0.052	0.011	0.000	0.000	0.024	0.000
C21	0.061	0.021	0.029	0.000	0.000	0.013
C22	0.036	0.004	0.003	0.001	0.002	0.000
C23	0.023	0.000	0.000	0.000	0.000	0.005
C24	0.036	0.000	0.002	0.005	0.000	0.003
C32	0.020	0.001	0.000	0.000	0.000	0.000
C34	0.015	0.002	0.000	0.001	0.000	0.000
C35	0.013	0.001	0.001	0.000	0.000	0.000
C36	0.010	0.001	0.000	0.002	0.000	0.000
C41	0.043	0.000	0.000	0.004	0.000	0.000
C42	0.032	0.000	0.000	0.004	0.000	0.005
C 43	0.047	0.000	0.000	0.000	0.007	0.000
SUM (SPi)		0.067	0.057	0.161	0.111	0.067

The process was repeated for (NDAij) Equation (3.32) was applied to obtain the weighted sum of the negative distance from the average. The calculation values are shown in Table 4.46

Table 4.46. (NDAij × *wj*) values.

Criteria	**Weight**	**A1**	**A2**	**A3**	**A4**	**A5**
C11	0.038	0.000	0.000	0.002	0.000	0.001
C12	0.045	0.000	0.000	0.022	0.003	0.000
C13	0.048	0.007	0.007	0.007	0.000	0.000
C14	0.051	0.000	0.000	0.011	0.000	0.031
C15	0.079	0.005	0.000	0.024	0.000	0.000
C16	0.090	0.000	0.000	0.017	0.013	0.000
C31	0.022	0.003	0.003	0.002	0.000	0.000
C33	0.017	0.000	0.000	0.000	0.004	0.001
C37	0.010	0.000	0.000	0.000	0.003	0.000
C51	0.010	0.001	0.001	0.001	0.000	0.000
C52	0.017	0.002	0.001	0.002	0.000	0.000
C53	0.019	0.000	0.000	0.000	0.009	0.001
C54	0.020	0.000	0.000	0.001	0.001	0.000
C17	0.091	0.000	0.000	0.048	0.043	0.005
C18	0.057	0.008	0.008	0.008	0.000	0.002
C19	0.052	0.011	0.000	0.000	0.024	0.000
C21	0.061	0.021	0.029	0.000	0.000	0.013
C22	0.036	0.004	0.003	0.001	0.002	0.000
C23	0.023	0.000	0.000	0.000	0.000	0.005
C24	0.036	0.000	0.002	0.005	0.000	0.003
C32	0.020	0.001	0.000	0.000	0.000	0.000
C34	0.015	0.002	0.000	0.001	0.000	0.000
C35	0.013	0.001	0.001	0.000	0.000	0.000
C36	0.010	0.001	0.000	0.002	0.000	0.000
C41	0.043	0.000	0.000	0.004	0.000	0.000
C42	0.032	0.000	0.000	0.004	0.000	0.005
C 43	0.047	0.000	0.000	0.000	0.007	0.000
SUM (SPi)		0.067	0.057	0.161	0.111	0.067

Step 5: Normalization of SPI and SNI

The summed positive distance from average (spi) and summed negative distance from average were normalized for all alternatives by using equations (3.33) and (3.34) subsequently. The calculation results are given in Table 4. 47.

Table 4.47. NSPi and NSNi values.

Criteria	Weight	A1	A2	A3	A4	A5
C11	0.038	0.000	0.000	0.000	0.002	0.000
C12	0.045	0.007	0.007	0.000	0.000	0.010
C13	0.048	0.000	0.000	0.000	0.017	0.005
C14	0.051	0.006	0.006	0.000	0.030	0.000
C15	0.079	0.000	0.000	0.000	0.006	0.023
C16	0.090	0.006	0.010	0.000	0.000	0.014
C31	0.022	0.000	0.000	0.000	0.005	0.003
C33	0.017	0.004	0.000	0.001	0.000	0.000
C37	0.010	0.000	0.000	0.002	0.000	0.002
C51	0.010	0.000	0.000	0.000	0.001	0.002
C52	0.017	0.000	0.000	0.000	0.004	0.001
C53	0.019	0.002	0.004	0.004	0.000	0.000
C54	0.020	0.000	0.000	0.000	0.000	0.003
C17	0.091	0.048	0.048	0.000	0.000	0.000
C18	0.057	0.000	0.000	0.000	0.025	0.000
C19	0.052	0.000	0.009	0.009	0.000	0.019
C21	0.061	0.000	0.000	0.002	0.061	0.000
C22	0.036	0.000	0.000	0.000	0.000	0.010
C23	0.023	0.001	0.000	0.000	0.004	0.000
C24	0.036	0.000	0.000	0.000	0.010	0.000
C32	0.020	0.000	0.000	0.000	0.000	0.001
C34	0.015	0.000	0.000	0.000	0.004	0.000
C35	0.013	0.000	0.000	0.000	0.003	0.000
C36	0.010	0.000	0.000	0.000	0.003	0.000
C41	0.043	0.002	0.002	0.000	0.000	0.000
C42	0.032	0.000	0.000	0.000	0.008	0.000
C 43	0.047	0.000	0.000	0.000	0.000	0.006
SUM (SNi)		0.076	0.088	0.019	0.182	0.099

Step 6: Calculation of Appraisal Score (ASi)

Appraisal scores were calculated for each alternative with benefit Equation (3.35), which took an average of NSPi and NSNi and then multiplied by 0.5. the results of the calculation are shown in Table 4. 48

Step 7: the final step is ranking the alternatives, which is based on the (ASi) value

Table 4.48. Calculation of appraisal Score and ranking of Alternatives for exterior wall.

	A1	A2	A3	A4	A5
SPI	0.067	0.057	0.161	0.111	0.067
SNI	0.076	0.088	0.019	0.182	0.099
NSPI	0.412	0.354	1.000	0.688	0.415
NSNI	0.584	0.519	0.895	0.000	0.457
ASI	0.498	0.436	0.948	0.344	0.436
Ranking	2	3	1	5	4

Obtained values were analyzed with the EDAS method, and the most suitable wall material for residential building projects and ranking was obtained, according to the ranking results of this method, A3>A1>A2>A5>A4. It has been determined that the A3 (isolation brick) kept the first place in the ranking, A1 Clay brick (19x19x19) was ranked as the second option, and the third alternative was A2 (clay brick 23.5x18.5x 25). A5 (pumice block) appeared as the fourth and the last ranked AAC obtained alternative.

Table 4.49. Calculation of appraisal Score and ranking of Alternatives for interior wall.

	A1	A2	A3	A4	A5
SPI	0.157	0.164	0.144	0.121	0.224
SNI	0.056	0.060	0.133	0.123	0.439
NSPI	0.700	0.734	0.645	0.542	1.000
NSNI	0.873	0.863	0.697	0.720	0.000
ASI	0.786	0.798	0.671	0.631	0.500
Ranking	2	1	3	4	5

Evaluation ranking results of five interior wall materials by EDAS method is expressed as A2>A2>A3>A4>A5. From the ranking results it was concluded that ,clay brick 2(19x10x19), symbolized by alternative 2, topped the first position among the five materials considered.

4.2. COMPARISON OF THE RESULTS- EXTERIOR WALL

In this study, WASPAS, TOPSIS, MOORA, and EDAS methods were applied to determine the most suitable wall materials for Exterior and Interior walls; the evaluation and ranking of exterior materials for each method are given in Table 4.50. and show in figure 4.1.

Table 4.50. Comparison of ranking results of methods.

Alternatives	**WASPAS ranking**	**TOPSIS ranking**	**MOORA Ranking**	**EDAS Ranking**
A1	2	3	2	2
A2	3	5	3	3
A3	1	1	1	1
A4	4	4	5	5
A5	5	2	4	4

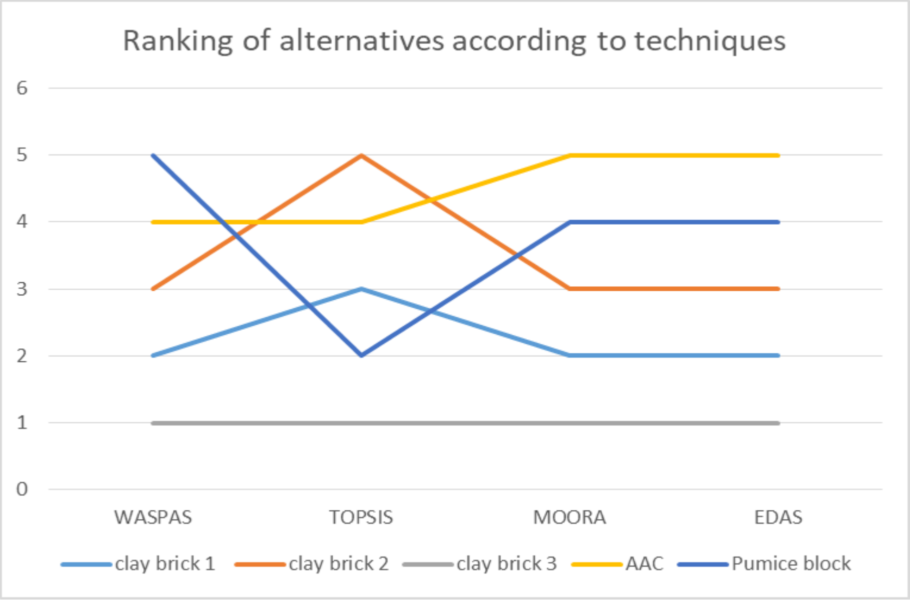

Figure 4.1.Comparison of Ranking Results of Methods - Exterior wall.

As can be seen in Table 4.50 and Figure 4.1.

When the results are compared according to all four methods, as shown in Table 4.50 And Figure 4. 1 Alternative A3 (isolation bricks) is in the first place in every applied method, including WASPAS, TOPSIS, MOORA, and EDAS. According to these results, it is considered the best suitable material for the exterior wall in residential buildings. From the ranking results of the WASPAS, MOORA, and EDAS methods, it was found that the first three alternatives have not changed their ranking and are in the same ranking in every applied method, although each method takes different values as a result of the solution. Expect the ranking of the TOPSIS method to be a little different. For example, A1 ranks third based on the TOPSIS method, while WASPAS, MOORA, and EDAS are second. A2 took the last ranking according to the TOPSIS method, while A2 was ranked as the third alternative by WASPAS, MOORA, and EDAS. A4 is in the fourth row of ranking using the WASPAS and TOPSIS method, while it was ranked as the last alternative using MOORA and EDAS method. A5 was ranked as the last option of exterior wall material when the WASPAS method was applied. On the other hand, A5 is in second place, according to the TOPSIS method. A5 remained in the fourth place ranking by using MOORA and EDAS method.

4.3. COMPARISON OF THE RESULTS- INTERIOR WALLS

Table 4.51.Comparison of Ranking Results of different Methods for interior wall.

Alternatives	**WASPAS ranking**	**TOPSIS ranking**	**MOORA Ranking**	**EDAS Ranking**
A1	2	2	2	2
A2	1	1	1	1
A3	4	3	3	3
A4	5	4	4	4
A5	3	5	5	5

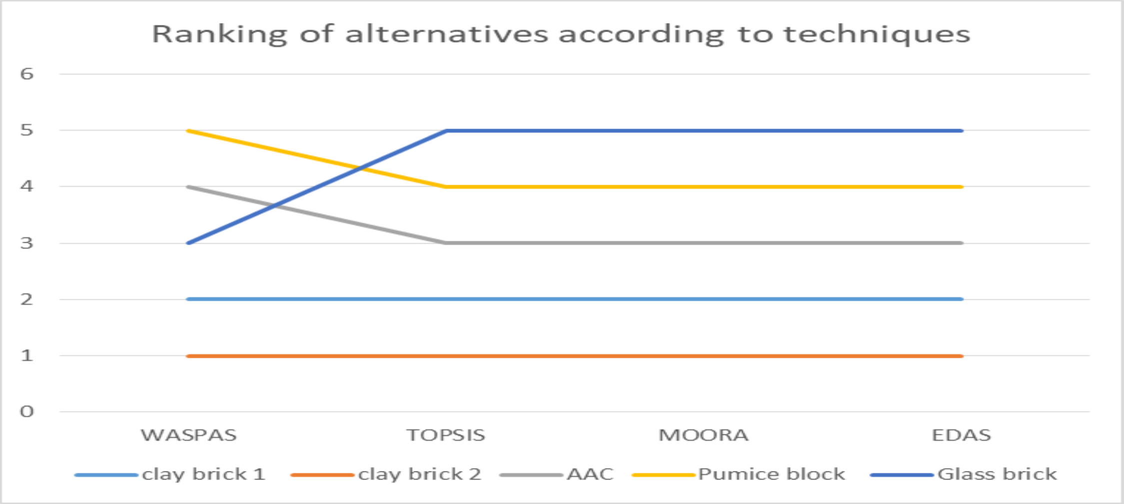

Figure 4.2. compare ranking results by different methods for interior wall.

The results of Table 4-51 and Figure 4-2 are discussed below:

To achieve the main objective of this study, a multi-criteria decision-making model is created to evaluate and select the most desirable exterior and interior wall elements considering a set of criteria. Exterior and interior main criteria and sub-criteria are obtained by using BWM. The exterior wall material alternatives are ranked by using four MCDM methods. Moreover, the comparison of results has been discussed. The ranking results of interior wall materials are compared, and the MCDM methods were used to evaluate and rank interior wall materials, although different materials and dimensions were evaluated. In addition, materials were taken into consideration as interior elements, including two different dimensions of clay brick (19x10x19) cm and 19x13.5x19 cm clay brick, pumice block (39X15X18.5) cm, AAC(60x10x25) cm, the last one is glass brick (19x8x19) cm.

Evaluation and ranking results of alternatives of four applied approaches are provided in Table 4.49 and Figure 4.2. When the ranking results of each method are compared to another, it is concluded that alternative two clay brick (19x10x19) holds the first ranking when WASPAS, TOPSIS, MOORA, and EDAS methods are applied. Depending on these results, alternative two can be chosen as the most reliable interior wall material for residential buildings in Turkey. Alternative one clay brick (19x13.5x19) achieved the second-ranking according to TOPSIS, EDAS, WASPAS, and MOORA method results. Also, it was found that ranking results of MOORA, EDAS, and WASPAS are the same for all alternatives. . Although each method has different steps of evaluation and calculation with different values.

The ranking results of TOPSIS, EDAS, and MOORA can be expressed as A2>A1>A3>A4>A5. Excluding the TOPSIS results is slightly different compared to other methods. in terms of (alternative 3, alternative 4, and alternative 5). For example, alternative three is ranked fourth with the TOPSIS method, while the other methods are in the third position. With the TOPSIS method, alternative 4 holds the fifth row of ranking but when other methods are tried is in the 4th of ranking. The last alternative in our material selection model is glass brick. When TOPSIS is applied is in the third position of ranking, while with TOPSIS, EDAS and MOORA hold the last position of the ranking.

PART 5

CONCLUSION

Due to the enormous variety of diverse materials that are readily available, material selection is a challenging and subtle undertaking. However, there is often more than one clear criterion when selecting the ideal material. Therefore, designers and engineers should consider a more significant number of essential factors in material selection. For example, a poor choice of material can frequently result in high costs and ultimately hasten component or product failure. Therefore, one of the most challenging aspects of the design phase and development is choosing suitable materials for various components. Therefore, to achieve the required outcome with minimal cost involvement and specialized applicability, the designers and engineers should identify and choose appropriate materials with specific capabilities. Furthermore, the success and competitiveness of the projects greatly depend on making the best choice of the available material.

This study proposed a multi-criteria decision-making model to select the preferable wall material for exterior and interior walls. The proposed solution approach consists of three primary stages. The first stage was identifying and evaluating the main criteria and sub-criteria; for this purpose, a literature review was conducted in this study's field and took experts' opinions. As a result, five main criteria were determined, including performance, economic, management, environmental, and social factors, and 27 sub-criteria under these main criteria. The criteria included quantitative and qualitative criteria, and criteria values were obtained from the conducted survey and applied Best- Worst Method. According to the results of data analysis in terms of exterior walls in this thesis study, it was found that the most important criteria were performance criteria C1, and the second criteria which are essential in the selection of wall material are economic criteria C2. Management criteria C3, Environmental criteria C4, and Social Criteria C5 have been determined as the third, fourth, and most minor essential criteria. Primary criteria for the interior wall have different values and different ranking, performance criteria remained as the essential criteria, economic criteria were the second most important, the third vital criteria was an environmental factor, social criteria were in the fourth importance level, and the least important criteria for the interior wall was management criteria.

In the next step, five wall materials were determined to be evaluated, including clay brick 1 (19x19x19) cm, clay brick 2 (23.5x18.5x 25) cm, clay brick3 (isolation brick), AAC (60 X20X 25) cm, pumice block (39X19X18.5)cm for exterior wall, and materials for the interior wall were clay brick1 with dimension size (19x13.5x19) cm, clay brick 2 (19x10x19) cm, AAC (60x10x25) cm, pumice block(39X15X18.5) cm, Glass brick (19x8x19) cm. 11 decision-makers evaluated these alternatives. The data were analyzed using four multi-criteria decision-making methods, including WASPAS, TOPSIS, MOORA, and EDAS, to select the best exterior and interior wall alternatives. According to the model proposed within the scope of the thesis, it was discovered that by integrated WASPAS, TOPSIS, MOORA, and EDAS methods, isolation brick was chosen as the most suitable material for exterior walls. Furthermore, clay brick 2 (19x10x19) cm for interior walls was ranked as the best alternative for residential buildings.

Multi-criteria decision-making methods are practical, time and cost-saving. It is frequently used in the literature regarding reliability and satisfaction; for this purpose, this study will be carried out in the future evaluation study by increasing the number of evaluators and making decision groups or by increasing the number of alternatives that can be observed how to affect the results. Also, this method can be used as a computerized decision support system in every different country that helps designers and managers to select the best alternatives for each type of building considering the criteria and importance level of the criteria changes according to the project type and location of the project as well as.

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APPENDIX A.

SAMPLE OF QUESTIONNAIRE

Dear participant:

You have been asked to voluntarily participate in this research study, which is a part of an MS study conducted under Assoc's supervision. Prof. Dr. İlker TEKIN in the department of civil engineering and co-supervision of Assoc. Prof. Dr. Fuat ŞİMŞİR in the department of industrial engineering at Karabuk University.

The study aims to formulate a multi-criteria decision-making model for evaluating and selecting the best alternative wall elements for a building project's external and internal walls using multiple considerations.

In the study, an evaluation will be made on the most appropriate selection of exterior and interior wall elements in residential-type buildings under different criteria. In this context, in line with the essential criteria, it is necessary to determine which criterion is the best and worst for the interior and exterior wall elements. For this reason, the first survey will be carried out under the criteria below. At this stage, the materials used in the exterior and interior walls will be evaluated in terms of which criterion is the most suitable and the most appropriate, and expert opinion will be gathered in the survey.

If you agree to participate in this study, you will be asked to fill in a questionnaire specially designed to collect data for this study. Your responses to the questionnaire will be kept confidential and used for academic issues only.

Thank you very much for your participation.
Researcher: Harez kanabi Abdulrahman

Table Appendix A.1 main criteria and sub-criteria for exterior wall.

Main Criteria		**Sub-Criteria**	
Performance criteria	C1	Sound insulation	C11
		Compressive strength	C12
		Fire resistance	C13
		Durability (freeze-thaw resistance)	C14
		Durability(life cycle)	C15
		Earthquake resistance	C16
		Thermal resistance	C17
		Moisture resistance	C18
		Material weight	C19
Economic criteria	C2	Initial cost	C21
		Mortar cost	C22
		Transport cost	C23
		Maintenance cost	C24
Management criteria	C3	Availability	C31
		Needs for specialized skill	C32
		Construction speed	C33
		The difficulty of the construction process	C34
		Cover techniques	C35
		The plaster used in construction	C36
		Dimensional flexibility	C37
Environmental criteria	C4	Waste during production	C41
		Waste during construction	C42
		Carbon emission	C43
Social criteria	C5	Raw material reserve	C51
		Health	C52
		Safety during and after construction	C53
		Suitability to location	C54

AppendixA.2. Applied questionnaire to evaluate the criteria

Table Appendix A.2. Sample of questionnaire requested to experts to evaluate the criteria.

*Expert'sevaluation					
The most important criteria: C*	The least essential criteria: C*				
Pairwise comparison vector (ABvector) of the essential criterion for other criteria.					
	C*	C*	C*	C*	C*
The essential criterion (C*) preference rate to the other standards.					
Pairwise comparison vector of the other criteria according to the least essential bar.					
	C*	C*	C*	C*	C*
Preference rate of other criteria according to the least essential criterion (C*).					

Appendix A.3: Main criteria evaluation

Table Appendix A.3 evaluation of main criteria according to 6 experts.

First expert's evaluation					
The most important criteria: **C1**	The least essential criteria: **C3**				
Pairwise comparison vector (ABvector) of the essential criterion for other criteria					
	C1	C2	C3	C4	C5
The preference rate of the essential criterion (C1) for the other criteria	1	3	6	5	4
Pairwise comparison vector of the other criteria according to the least important criterion					
	C1	C2	C3	C4	C5
Preference rate of other criteria according to the least essential criterion (C3)	6	3	1	2	3
Second expert's evaluation					
The most important criteria: **C1**	The least essential criteria: **C5**				
Pairwise comparison of the essential criterion for other criteria					
	C1	C2	C3	C4	C5
The preference rate of the essential criterion (C1) for the other criteria	1	7	6	8	9
Pairwise comparison of the other criteria according to the least important criterion					
	C1	C2	C3	C4	C5
Preference rate of other criteria according to the least essential criterion (C5)	9	2	3	2	1
Third expert's evaluation					
The most important criteria: **C1**	The least essential criteria: **C3**				
Pairwise comparison of the essential criterion for other criteria					
	C1	C2	C3	C4	C5
The preference rate of the most critical criterion (C1) for the other criteria	1	3	4	6	9
Pairwise comparison of the other criteria according to the least important criterion					
	C1	C2	C3	C4	C5
Preference rate of other criteria according to the least important criterion (C3)	9	6	5	3	1
Fourth expert's evaluation					
The most important criteria: **C1**	The least essential criteria: **C3**				
Pairwise comparison of the most important criterion concerning other criteria					
	C1	C2	C3	C4	C5
The preference rate of the most important criterion (C1) for the other criteria	1	5	9	3	7
Pairwise comparison of the other criteria according to the least important criterion					
	C1	C2	C3	C4	C5
Preference rate of other criteria according to the least essential criterion (C3)	9	4	1	6	2

Fifth expert’s evaluation					
The most important criteria: **C1**	The least essential criteria: **C5**				
Pairwise comparison of the essential criterion for other criteria					
	C1	C2	C3	C4	C5
The preference rate of the essential criterion (C1) for the other criteria	1	4	4	3	8
Pairwise comparison of the other criteria according to the least important criterion					
	C1	C2	C3	C4	C5
Preference rate of other criteria according to the least essential criterion (C5)	8	4	5	6	1
Sixth expert’s evaluation					
The most important criteria: **C1**	The least essential criteria: **C5**				
Pairwise comparison of the essential criterion concerning other criteria					
	C1	C2	C3	C4	C5
The preference rate of the essential criterion (C1) for the other criteria	1	3	4	4	7
Pairwise comparison of the other criteria according to the least important criterion					
	C1	C2	C3	C4	C5
Preference rate of other criteria according to the least essential criterion (C5)	4	7	3	3	1

Appendix A.4 Evaluations of the sub-criteria

Table Appendix A.4. Evaluation of performance criteria.

First expert's evaluation									
The most important criteria: **C16**		The least important criteria: **C11**							
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
The preference rate of the most important criterion (C16) to the other criteria.	9	4	7	5	6	1	3	8	2
Pairwise comparison vector of the other criteria according to the least important criterion.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
Preference rate of other criteria according to the least essential criterion (C11).	1	6	7	5	4	9	8	2	7
Second expert's evaluation									
The most important criteria: **C17**		The least important criteria: **C19**							
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
The preference rate of the most important criterion (C17) to the other criteria.	4	4	2	2	3	2	1	2	5
Pairwise comparison vector of the other criteria according to the least important criterion.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
Preference rate of other criteria according to the least essential criterion (C19).	4	2	3	3	4	4	5	3	1
Third expert's evaluation									
The most important criteria: **C17**		The least important criteria: **C12**							
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
The preference rate of the most important criterion (C17) to the other criteria.	2	9	6	5	3	8	1	7	4
Pairwise comparison vector of the other criteria according to the least important criterion.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
Preference rate of other criteria according to the least essential criterion (C12).	8	1	4	5	7	2	9	3	6
Fourth expert's evaluation									
The most important criteria: **C15**		The least important criteria: **C19**							
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
The preference rate of the most important criterion (C15) to the other criteria.	8	2	3	3	1	2	8	4	8
Pairwise comparison vector of the other criteria according to the least important criterion.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
Preference rate of other criteria according to the least essential criterion (C19).	2	6	2	7	8	6	2	4	1
Fifth expert's evaluation									
The most important criteria: **C16**		The least important criteria: **C19**							
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
The preference rate of the most important criterion (C16) to the other criteria.	4	3	5	3	2	1	3	3	8
Pairwise comparison vector of the other criteria according to the least important criterion.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
Preference rate of other criteria according to the least essential criterion (C19).	2	3	2	3	4	8	3	3	1

Sixth expert's evaluation									
The most important criteria: **C17**				The least important criteria: **C11**					
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
The preference rate of the most important criterion (C17) to the other criteria.	5	3	4	2	2	3	1	2	3
Pairwise comparison vector of the other criteria according to the least important criterion.									
	C11	C12	C13	C14	C15	C16	C17	C18	C19
Preference rate of other criteria according to the least essential criterion (C11).	1	2	2	3	3	2	5	3	2

Table Appendix A.4.2. evaluation of Economic criteria.

First expert's evaluation				
The most important criteria: **C24**	The least essential criteria: **C21**			
Pairwise comparison vector (*AB*vector) of the essential criterion concerning other criteria				
	C21	C22	C23	C24
The preference rate of the essential criterion (C24) for the other criteria	6	2	3	1
Pairwise comparison vector of the other criteria according to the least important criterion				
	C21	C22	C23	C24
Preference rate of other criteria according to the least essential criterion (C21)	1	3	4	6
Second expert'sevaluation				
The most important criteria: **C24**	The least essential criteria: **C23**			
Pairwise comparison of the essential criterion concerning other criteria				
	C21	C22	C23	C24
The preference rate of the essential criterion (C24) for the other criteria	2	3	4	1
Pairwise comparison of the other criteria according to the least important criterion				
	C21	C22	C23	C24
Preference rate of other criteria according to the least essential criterion (C23)	3	2	1	4
Third expert's evaluation				
The most important criteria: **C21**	The least essential criteria: **C24**			
Pairwise comparison vector (*AB*vector) of the most important criterion for other criteria				
	C21	C22	C23	C24
The preference rate of the essential criterion (C21) for the other criteria	1	3	2	6
Pairwise comparison vector of the other criteria according to the least important criterion				
	C21	C22	C23	C24
Preference rate of other criteria according to the least essential criterion (C24)	6	4	4	1
Fourth expert's evaluation				
The most important criteria: **C21**	The least essential criteria: **C23**			
Pairwise comparison vector (*AB*vector) of the essential criterion concerning other criteria				
	C21	C22	C23	C24
The preference rate of the essential criterion (C21) for the other criteria	1	3	9	2
Pairwise comparison vector of the other criteria according to the least important criterion				
	C21	C22	C23	C24
Preference rate of other criteria according to the least essential criterion (C23)	9	5	1	5
Fifth expert's evaluation				
The most important criteria: **C21**	The least essential criteria: **C23**			
Pairwise comparison vector (*AB*vector) of the essential criterion concerning other criteria				
	C21	C22	C23	C24
The preference rate of the most important criterion (C21) for the other criteria	1	5	8	3
Pairwise comparison vector of the other criteria according to the least important criterion				
	C21	C22	C23	C24
Preference rate of other criteria according to the least essential criterion (C23)	8	2	1	3

Sixth expert's evaluation				
The most important criteria: **C21**	The least essential criteria: **C24**			
Pairwise comparison vector (*AB*vector) of the essential criterion concerning other criteria				
	C21	C22	C23	C24
The preference rate of the essential criterion (C21) for the other criteria	1	2	3	8
Pairwise comparison vector of the other criteria according to the least important criterion				
	C21	C22	C23	C24
Preference rate of other criteria according to the least important criterion (C24)	8	4	3	1

Table Appendix A.4.3 Evaluation of management criteria.

First expert's evaluation							
The most important criteria: **C32**			The least important criteria: **C37**				
Pairwise comparison vector (*AB*vector) of the most important criterion concerning other criteria.							
	C31	C32	C33	C34	C35	C36	C37
The preference rate of the most important criterion (C32) to the other criteria.	5	1	2	7	4	3	9
Pairwise comparison vector of the other criteria according to the least important criterion.							
	C31	C32	C33	C34	C35	C36	C37
Preference rate of other criteria according to the least essential criterion (C37).	5	9	8	3	6	7	1
Second expert's evaluation							
The most important criteria: **C37**			The least important criteria: **C33**				
Pairwise comparison vector (*AB*vector) of the most important criterion concerning other criteria.							
	C31	C32	C33	C34	C35	C36	C37
The preference rate of the most important criterion (C37) to the other criteria.	2	3	5	6	2	3	1
Pairwise comparison vector of the other criteria according to the least important criterion.							
	C31	C32	C33	C34	C35	C36	C37
Preference rate of other criteria according to the least essential criterion (C33).	6	3	1	2	4	7	8
Third expert's evaluation							
The most important criteria: **C33**			The least important criteria: **C32**				
Pairwise comparison vector (*AB*vector) of the most important criterion concerning other criteria.							
	C31	C32	C33	C34	C35	C36	C37
The preference rate of the most important criterion (C33) to the other criteria.	2	7	1	4	6	5	3
Pairwise comparison vector of the other criteria according to the least important criterion.							
	C31	C32	C33	C34	C35	C36	C37
Preference rate of other criteria according to the least essential criterion (C32).	6	1	7	4	2	3	5
Fourth expert's evaluation							
The most important criteria: **C31**			The least important criteria: **C37**				
Pairwise comparison vector (*AB*vector) of the most important criterion concerning other criteria.							
	C31	C32	C33	C34	C35	C36	C37
The preference rate of the most important criterion (C31) to the other criteria.	1	3	3	2	5	5	8
Pairwise comparison vector of the other criteria according to the least important criterion.							
	C31	C32	C33	C34	C35	C36	C37
Preference rate of other criteria according to the least essential criterion (C37).	8	5	6	5	2	2	1
Fifth expert's evaluation							
The most important criteria: **C32**			The least important criteria: **C36**				
Pairwise comparison vector (*AB*vector) of the most important criterion concerning other criteria.							
	C31	C32	C33	C34	C35	C36	C37
The preference rate of the most important criterion (C32) to the other criteria.	6	1	3	2	4	8	5
Pairwise comparison vector of the other criteria according to the least important criterion.							
	C31	C32	C33	C34	C35	C36	C37
Preference rate of other criteria according to the least essential criterion (C36).	2	8	3	4	2	1	2
Sixth expert's evaluation							
The most important criteria: C31			The least important criteria: C37				
Pairwise comparison vector (*AB*vector) of the most important criterion concerning other criteria.							
	C31	C32	C33	C34	C35	C36	C37
The preference rate of the most important criterion (C31) to the other criteria.	1	2	3	2	4	5	6
Pairwise comparison vector of the other criteria according to the least important criterion.							
	C31	C32	C33	C34	C35	C36	C37
Preference rate of other criteria according to the least essential criterion (C37).	6	3	2	3	2	2	1

Table Appendix A.4.4 Evaluation of environmental criteria

First expert's evaluation

The most important criteria: **C42**	The least essential criteria: **C41**		
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria			
	C41	C42	C43
The preference rate of the most important criterion (C42) for the other criteria	9	1	3
Pairwise comparison vector of the other criteria according to the least important criterion			
	C41	C42	C43
Preference rate of other criteria according to the least essential criterion (C41)	1	9	5
Second expert's evaluation			
The most important criteria: **C43**	The least essential criteria: **C42**		
Pairwise comparison of the most important criterion to other criteria			
	C41	C42	C43
The preference rate of an essential criterion (C43) for the other criteria	3	8	1
Pairwise comparison of the other criteria according to the least important criterion			
	C41	C42	C43
Preference rate of other criteria according to the least essential criterion (C42)	4	1	8
Third expert's evaluation			
The most important criteria: **C41**	The least essential criteria: **C42**		
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria			
	C41	C42	C43
The preference rate of the most critical criterion (C41) for the other criteria	1	5	3
Pairwise comparison vector of the other criteria according to the least important criterion			
	C41	C42	C43
Preference rate of other criteria according to the least essential criterion (C42)	5	1	3
Fourth expert's evaluation			
The most important criteria: **C43**	The least essential criteria: **C42**		
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria			
	C41	C42	C43
The preference rate of the most critical criterion (C43) for the other criteria	2	5	1
Pairwise comparison vector of the other criteria according to the least important criterion			
	C41	C42	C43
Preference rate of other criteria according to the least essential criterion (C42)	3	1	5
Fifth expert's evaluation			
The most important criteria: **C42**	The least essential criteria: **C43**		
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria			
	C41	C42	C43
The preference rate of the most critical criterion (C42) for the other criteria	4	1	8
Pairwise comparison vector of the other criteria according to the least important criterion			
	C41	C42	C43
Preference rate of other criteria according to the least essential criterion (C43)	3	8	1
Sixth expert's evaluation			
The most important criteria: **C41**	The least essential criteria: **C42**		
Pairwise comparison vector (ABvector) of the most important criterion concerning other criteria			
	C41	C42	C43
The preference rate of the most critical criterion (C41) for the other criteria	1	4	2
Pairwise comparison vector of the other criteria according to the least important criterion			
	C41	C42	C43
Preference rate of other criteria according to the least essential criterion (C42)	4	1	3

Table Appendix A.4.5 Social criteria’s evaluation

First expert’s evaluation				
The most important criteria: **C53**	The least essential criteria: **C51**			
Pairwise comparison vector (ABvector) of the most critical criterion concerning other criteria.				
	C51	C52	C53	C54
The preference rate of the most critical criterion (C53) to the other criteria.	8	3	1	2
Pairwise comparison vector of the other criteria according to the least important criterion				
	C51	C52	C53	C54
Preference rate of other criteria according to the least essential criterion (C51)	1	4	8	6
Second expert’sevaluation				
The most important criteria: **C53**	The least essential criteria: **C51**			
Pairwise comparison of the most critical criterion for other criteria				
	C51	C52	C53	C54
The preference rate of the essential criterion (C53) for the other criteria	3	2	1	2
Pairwise comparison of the other criteria according to the least important criterion				
	C51	C52	C53	C54
Preference rate of other criteria according to the least essential criterion (C51)	1	2	3	3
Third expert’s evaluation				
The most important criteria: **C52**	The least essential criteria: **C51**			
Pairwise comparison vector (ABvector) of the most critical criterion concerning other criteria				
	C51	C52	C53	C54
The preference rate of an essential criterion (C52) for the other criteria	7	1	3	5
Pairwise comparison vector of the other criteria according to the least important criterion				
	C51	C52	C53	C54
Preference rate of other criteria according to the least essential criterion (C51)	1	7	5	3
Fourth expert’s evaluation				
The most important criteria: **C51**	The least essential criteria: **C54**			
Pairwise comparison vector (ABvector) of the most critical criterion concerning other criteria				
	C51	C52	C53	C54
The preference rate of an essential criterion (C51) for the other criteria	1	2	4	7
Pairwise comparison vector of the other criteria according to the least important criterion				
	C51	C52	C53	C54
Preference rate of other criteria according to the least essential criterion (C54)	7	5	4	1
Fifth expert’s evaluation				
The most important criteria: **C54**	The least essential criteria: **C51**			
Pairwise comparison vector (ABvector) of the essential criterion concerning other criteria				
	C51	C52	C53	C54
The preference rate of the most critical criterion (C54) for the other criteria	8	5	3	1
Pairwise comparison vector of the other criteria according to the least important criterion				
	C51	C52	C53	C54
Preference rate of other criteria according to the least essential criterion (C51)	1	2	3	8
Sixth expert’s evaluation				
The most important criteria: **C54**	The least essential criteria: **C52**			
Pairwise comparison vector (ABvector) of the most critical criterion concerning other criteria				
	C51	C52	C53	C54
The preference rate of the most critical criterion (C54) for the other criteria	3	9	6	1
Pairwise comparison vector of the other criteria according to the least important criterion				
	C51	C52	C53	C54
Preference rate of other criteria according to the least essential criterion (C52)	3	1	2	9

Appendix A.5. Evaluation of alternatives

A questionnaire was administered to experts to evaluate the alternatives.

Table Appendix A.5.is a prepared questionnaire for experts to evaluate alternatives

	Nine is the best, 1 is the worst value, in terms of price, one is the most expensive, and nine is the cheapest.										
		Exterior wall alternatives					**Interior wall alternatives**				
	criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)										
2	Earthquake Resistance										
3	Health										
4	Availability										
5	Construction Speed										
6	Raw materıal reserve										
7	Dimensional Flexibility										
8	Suitability To Location (climate)										
9	Mortar cost										
10	Safety During Construction										
11	Transport Cost										
12	maintenance cost										
13	Waste During Production										
14	Waste During Construction										
15	Needs For Specialized Skill										
16	Cover Techniques										
17	Plaster Using In Construction										
18	Difficulty Of The Construction Process										

Table Appendix A.5.1 first expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	7	8	9	7	6	8	7	5	4	9
2	Earthquake Resistance	7	8	9	6	6	9	8	5	6	4
3	Health	8	9	8	6	6	8	7	5	4	9
4	Availability	8	9	8	6	5	9	8	7	6	4
5	Construction Speed	8	9	9	8	7	8	6	9	7	5
6	Raw materıal reserve	9	9	9	8	5	9	8	6	5	4
7	Dimensional Flexibility	8	8	7	9	6	9	8	8	5	1
8	Suitability To Location (climate)	9	9	8	8	7	9	8	6	5	1
9	Mortar cost	8	9	7	8	6	9	7	8	7	1
10	Safety During Construction	7	7	9	8	6	8	7	7	6	1
11	Transport Cost	9	9	9	8	6	9	8	7	6	1
12	maintenance cost	6	6	6	6	6	6	6	6	6	9
13	Waste During Production	7	7	7	8	6	8	7	6	6	5
14	Waste During Construction	7	6	5	8	4	7	6	6	5	8
15	Needs For Specialized Skill	8	8	7	8	7	9	8	8	7	1
16	Cover Techniques	6	6	6	6	6	6	6	6	6	9
17	Plaster Using In Construction	6	6	6	6	6	6	6	6	6	9
18	Difficulty Of The Construction Process	9	8	7	7	7	8	8	7	6	1

Table Appendix A.5.2 Second expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	9	9	9	5	3	8	8	5	3	9
2	Earthquake Resistance	1	2	3	9	5	1	2	7	5	9
3	Health	9	9	9	2	4	8	8	2	4	9
4	Availability	6	9	9	9	9	9	7	9	9	8
5	Construction Speed	2	4	4	9	5	2	4	9	5	4
6	Raw materıal reserve	7	7	7	9	6	7	7	8	6	9
7	Dimensional Flexibility	5	5	5	9	4	5	5	9	4	1
8	Suitability To Location (climate)	9	9	9	4	5	9	9	4	5	2
9	Mortar cost	4	5	6	1	9	4	5	7	9	1
10	Safety During Construction	5	4	3	9	8	5	4	9	8	2
11	Transport Cost	2	2	2	5	7	2	2	5	7	1
12	maintenance cost	5	3	2	9	6	5	3	9	6	2
13	Waste During Production	6	6	6	9	3	6	6	8	3	9
14	Waste During Construction	4	3	2	9	5	4	3	9	5	2
15	Needs For Specialized Skill	7	8	9	6	7	7	8	6	7	2
16	Cover Techniques	9	9	9	6	5	9	9	6	5	1
17	Plaster Using In Construction	3	5	6	9	7	3	5	8	7	9
18	Difficulty Of The Construction Process	1	2	2	7	5	1	2	7	5	9

Table Appendix A.5.3 Third expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	7	8	9	6	5	8	8	6	7	9
2	Earthquake Resistance	6	7	9	8	5	5	5	6	6	9
3	Health	7	7	7	9	5	8	8	6	5	9
4	Availability	9	8	7	5	6	9	9	7	8	6
5	Construction Speed	6	5	7	9	8	5	5	9	8	7
6	Raw materıal reserve	9	8	7	5	6	9	9	8	7	6
7	Dimensional Flexibility	9	8	7	5	6	9	9	7	8	9
8	Suitability To Location (climate)	5	6	8	9	7	5	6	9	8	7
9	Mortar cost	5	6	7	9	8	6	6	8	9	7
10	Safety During Construction	6	5	5	9	8	8	8	9	5	4
11	Transport Cost	9	8	7	6	5	9	9	8	7	6
12	maintenance cost	6	5	4	9	7	7	7	6	8	9
13	Waste During Production	9	8	7	6	5	7	7	8	9	6
14	Waste During Construction	7	8	6	9	8	6	6	9	8	7
15	Needs For Specialized Skill	5	6	7	9	8	6	6	8	7	9
16	Cover Techniques	5	6	9	7	8	8	8	7	9	5
17	Plaster Using In Construction	9	8	7	5	6	9	9	8	7	0
18	Difficulty Of The Construction Process	9	8	7	5	6	6	6	8	9	7

Table Appendix A.5.4 Fourth expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	6	6	8	3	6	6	6	2	3	8
2	Earthquake Resistance	3	3	4	9	9	4	4	9	9	2
3	Health	6	6	6	5	5	6	6	5	5	9
4	Availability	9	9	9	7	6	9	9	7	6	3
5	Construction Speed	4	4	3	9	8	4	4	9	8	3
6	Raw materıal reserve	8	8	8	6	6	8	8	6	6	4
7	Dimensional Flexibility	3	3	2	9	7	2	2	9	7	1
8	Suitability To Location (climate)	5	5	5	9	8	5	5	9	8	3
9	Mortar cost	2	2	2	8	6	2	2	8	6	2
10	Safety During Construction	2	2	1	9	7	1	1	9	7	1
11	Transport Cost	7	7	8	5	4	8	8	5	4	4
12	maintenance cost	4	4	4	8	6	4	4	8	6	4
13	Waste During Production	6	6	6	9	9	6	6	9	9	8
14	Waste During Construction	6	6	6	9	9	6	6	9	9	8
15	Needs For Specialized Skill	7	7	7	7	7	7	7	7	7	1
16	Cover Techniques	8	8	9	3	3	8	8	3	3	1
17	Plaster Using In Construction	1	1	1	1	1	1	1	1	1	9
18	Difficulty Of The Construction Process	5	5	4	9	8	4	4	9	8	4

Table Appendix A.5.5 Fifth expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	6	6	8	5	4	6	6	8	5	3
2	Earthquake Resistance	7	7	9	6	5	7	7	9	6	4
3	Health	4	4	5	5	9	4	4	5	4	9
4	Availability	9	9	7	6	6	9	9	7	6	5
5	Construction Speed	9	9	9	9	7	9	9	9	9	9
6	Raw materıal reserve	6	6	6	6	6	8	8	6	6	6
7	Dimensional Flexibility	3	3	6	4	3	3	3	6	4	3
8	Suitability To Location (climate)	6	5	6	6	8	5	5	4	7	3
9	Mortar cost	4	4	8	5	7	4	4	6	3	6
10	Safety During Construction	6	6	7	7	7	7	7	6	4	3
11	Transport Cost	6	6	5	5	5	4	4	4	4	4
12	maintenance cost	8	8	6	7	7	6	6	7	7	7
13	Waste During Production	8	8	4	3	3	8	8	6	6	6
14	Waste During Construction	6	6	5	5	5	5	5	5	5	5
15	Needs For Specialized Skill	7	7	7	7	7	4	4	3	5	6
16	Cover Techniques	7	7	7	9	9	7	7	6	5	8
17	Plaster Using In Construction	9	9	3	3	2	9	9	2	3	1
18	Difficulty Of The Construction Process	9	9	9	9	9	9	9	9	9	9

Table AppendixA.5.6 Sixth expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	7	7	7	7	7	7	7	7	7	8
2	Earthquake Resistance	6	6	8	7	5	6	6	7	5	8
3	Health	9	9	9	7	8	9	9	7	8	9
4	Availability	8	8	8	7	7	8	8	7	7	6
5	Construction Speed	7	7	7	9	8	7	7	9	8	8
6	Raw materıal reserve	8	8	8	8	8	8	8	8	8	8
7	Dimensional Flexibility	6	6	6	9	5	6	6	9	5	2
8	Suitability To Location (climate)	8	8	8	8	8	8	8	8	8	8
9	Mortar cost	6	6	6	8	7	6	6	8	7	6
10	Safety During Construction	7	7	7	9	8	7	7	9	8	6
11	Transport Cost	7	7	7	9	8	7	7	9	8	6
12	maintenance cost	8	8	8	8	8	8	8	8	8	9
13	Waste During Production	6	6	6	8	7	6	6	8	7	9
14	Waste During Construction	7	7	7	9	7	7	7	9	7	5
15	Needs For Specialized Skill	7	7	7	8	7	7	7	8	7	8
16	Cover Techniques	7	7	7	7	8	7	7	7	8	1
17	Plaster Using In Construction	5	5	5	7	8	5	5	7	8	9
18	Difficulty Of The Construction Process	5	5	5	9	7	5	5	9	7	8

Table Appendix A.5.7 Seventh expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	2	1	3	3	2	6	6	8	4	8
2	Earthquake Resistance	3	1	5	2	2	7	6	8	4	3
3	Health	4	3	4	3	1	5	5	2	2	8
4	Availability	5	5	5	3	3	7	7	3	1	1
5	Construction Speed	9	8	7	5	6	7	7	6	6	5
6	Raw materıal reserve	8	8	6	4	5	7	7	2	2	5
7	Dimensional Flexibility	6	9	3	5	1	8	8	6	2	1
8	Suitability To Location (climate)	4	4	4	8	5	6	6	8	8	1
9	Mortar cost	5	5	5	8	8	5	5	5	5	9
10	Safety During Construction	3	1	2	9	7	7	7	7	3	4
11	Transport Cost	9	9	9	6	3	9	9	6	3	3
12	maintenance cost	5	6	5	4	3	6	6	4	3	2
13	Waste During Production	6	6	3	1	2	9	9	7	7	6
14	Waste During Construction	6	6	3	1	2	9	9	7	7	6
15	Needs For Specialized Skill	8	8	8	2	4	5	5	2	5	1
16	Cover Techniques	4	4	4	6	2	6	6	8	3	1
17	Plaster Using In Construction	6	6	6	6	6	5	5	5	5	1
18	Difficulty Of The Construction Process	8	8	8	2	3	7	7	6	5	3

Table Appendix A.5.8 Eighth expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	7	6	6	5	4	7	6	5	4	5
2	Earthquake Resistance	7	6	6	6	5	7	6	6	5	4
3	Health	7	7	7	7	7	7	7	7	7	7
4	Availability	7	7	7	7	6	7	7	7	6	3
5	Construction Speed	5	5	5	7	5	5	5	7	5	6
6	Raw materıal reserve	6	6	6	5	6	6	6	5	6	5
7	Dimensional Flexibility	6	6	6	7	6	6	6	7	6	5
8	Suitability To Location (climate)	7	7	7	7	7	7	7	7	7	5
9	Mortar cost	5	5	5	7	6	5	5	7	6	4
10	Safety During Construction	5	5	5	7	6	5	5	7	6	4
11	Transport Cost	5	5	5	7	5	5	5	7	5	3
12	maintenance cost	5	5	5	7	6	5	5	7	6	5
13	Waste During Production	3	3	3	5	4	3	3	5	4	7
14	Waste During Construction	2	3	3	5	4	3	3	5	4	7
15	Needs For Specialized Skill	6	6	6	7	7	6	6	7	7	3
16	Cover Techniques	5	5	5	6	5	5	5	6	5	1
17	Plaster Using In Construction	5	5	5	7	3	1	1	5	3	7
18	Difficulty Of The Construction Process	3	3	3	7	5	3	3	7	5	1

Table Appendix A.5.9 Ninth expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	6	6	9	7	1	5	4	7	1	9
2	Earthquake Resistance	5	5	7	9	1	5	6	9	2	1
3	Health	3	4	5	1	9	4	3	2	9	1
4	Availability	9	8	7	1	5	9	8	5	6	1
5	Construction Speed	1	6	5	9	7	1	4	9	7	6
6	Raw materıal reserve	9	9	9	5	1	9	9	5	1	4
7	Dimensional Flexibility	4	5	1	9	7	4	5	9	7	1
8	Suitability To Location (climate)	9	9	7	8	1	9	9	7	3	1
9	Mortar cost	6	4	9	1	7	7	6	1	9	5
10	Safety During Construction	7	6	5	9	1	5	6	9	1	4
11	Transport Cost	7	6	5	9	1	5	6	9	4	1
12	maintenance cost	4	4	4	9	1	5	5	9	1	7
13	Waste During Production	5	5	5	9	1	5	5	9	1	8
14	Waste During Construction	6	6	6	9	1	6	6	9	1	8
15	Needs For Specialized Skill	9	9	9	7	8	9	9	7	8	1
16	Cover Techniques	3	2	1	9	5	1	2	7	5	9
17	Plaster Using In Construction	2	3	1	9	5	1	2	8	6	9
18	Difficulty Of The Construction Process	4	7	5	9	1	5	4	9	1	3

Table Appendix A.5.10 Tenth expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	9	8	8	**7**	6	9	8	7	6	7
2	Earthquake Resistance	9	8	8	8	7	9	8	8	7	6
3	Health	9	9	9	9	9	9	9	9	9	9
4	Availability	9	9	9	9	8	9	9	9	8	5
5	Construction Speed	7	7	7	9	7	7	7	9	7	8
6	Raw materıal reserve	8	8	8	7	8	8	8	7	8	7
7	Dimensional Flexibility	8	8	8	9	8	8	8	9	8	7
8	Suitability To Location (climate)	9	9	9	9	9	9	9	9	9	7
9	Mortar cost	7	7	7	9	8	7	7	9	8	6
10	Safety During Construction	7	7	7	9	8	7	7	9	8	6
11	Transport Cost	7	7	7	9	7	7	7	9	7	5
12	maintenance cost	7	7	7	9	8	7	7	9	8	7
13	Waste During Production	5	5	5	7	6	5	5	7	6	9
14	Waste During Construction	5	5	5	7	6	5	5	7	6	9
15	Needs For Specialized Skill	8	8	8	9	9	8	8	9	9	5
16	Cover Techniques	7	7	7	8	7	7	7	8	7	1
17	Plaster Using In Construction	1	1	1	3	2	1	1	3	2	9
18	Difficulty Of The Construction Process	5	5	5	9	7	5	5	9	7	3

Table Appendix A.5.11 Eleventh expert’s evaluation of alternatives

		Exterior wall alternatives					**Interior wall alternatives**				
	Criteria	**A1**	**A2**	**A3**	**A4**	**A5**	**A1**	**A2**	**A3**	**A4**	**A5**
1	Durability (Life Cycle)	5	5	9	6	7	4	4	7	5	8
2	Earthquake Resistance	9	7	5	3	6	9	9	5	5	5
3	Health	8	4	5	4	3	9	9	5	7	6
4	Availability	9	9	9	9	9	9	9	9	9	5
5	Construction Speed	7	8	6	8	9	5	5	8	9	5
6	Raw materıal reserve	9	9	9	9	9	9	9	9	9	4
7	Dimensional Flexibility	4	4	4	9	3	6	6	8	9	5
8	Suitability To Location (climate)	5	5	8	3	4	9	8	7	9	7
9	Mortar cost	6	6	3	7	7	6	6	6	6	6
10	Safety During Construction	5	5	5	9	9	4	4	9	8	7
11	Transport Cost	3	3	4	9	6	5	5	9	7	6
12	maintenance cost	5	5	5	5	5	5	5	5	5	5
13	Waste During Production	6	6	6	6	6	5	5	5	5	5
14	Waste During Construction	3	3	3	8	7	5	5	8	8	6
15	Needs For Specialized Skill	3	3	3	8	7	5	5	9	5	4
16	Cover Techniques	1	1	4	8	8	8	8	6	6	6
17	Plaster Using In Construction	3	3	3	7	8	5	5	9	5	5
18	Difficulty Of The Construction Process	4	4	4	8	8	5	5	9	5	5

RESUME

Harez kanabi ABDULRAHMAN completed her primary, secondary, and high school education in Koya city. After that, she started undergraduate program in Koya University Department of Civil Engineering in 2012 and graduated in 2017. After graduation, Harez worked as a volunteer for 5 months in enginnering department of Koya University, and then she worked for one year in Erbil as site civil engineer in a residential project. Then in 2020, she moved to turkey and stared her Civil Engineering master’s degree program at Karabuk University.