# ANALYTIC HIERARCHY PROCESS (AHP) BASED APPROACH TO IDENTIFY THE BEST FIT GREEN BUILDING CERTIFICATION SYSTEM FOR TURKEY

**FATMA S. SAID**

**NOVEMBER 2017**

# ANALYTIC HIERARCHY PROCESS (AHP) BASED APPROACH TO IDENTIFY THE BEST FIT GREEN BUILDING CERTIFICATION SYSTEM FOR TURKEY

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Submitted by **FATMA S. SAID**

Approval of the Graduate School of Natural and Applied Sciences, Çankaya University

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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## ABSTRACT

**ANALYTIC HIERARCHY PROCESS (AHP) BASED APPROACH TO IDENTIFY THE BEST FIT GREEN BUILDING CERTIFICATION SYSTEM FOR TURKEY**



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As one of the most important global issues, the sustainable development goal has been legislated by many countries in order to ensure the compliance of the projects. Thus, ensuring the compliance of projects with the sustainability requirements is considered important for development. In this research, a methodology is introduced based on a strategy to find out the most influential criteria and sub-criteria that shall be considered for the development of a green building certification system for Turkey. The research adopts the Analytic Hierarchy Process (AHP) method by identifying the criteria and sub-criteria from the literature, as well as interviewing experts from different background; academicians, consultants and government decision makers. Using criteria and sub-criteria that are considered important according to the green building and sustainability studies, the questionnaire developed by the AHP software (Expert choice 11.5 academic version) is filled by the experts. The final results show that economy (cost) and efficiency are considered the most important criteria for the green building certification system in Turkey, while overall assessment success, registration and certification costs, and adaptability and reliability are the most important sub-criteria. The hypotheses testing show that the current certification systems are unsufficient for Turkey; and also the AHP method is thought to be successful for the assessment of Turkey's green building certification system.



**Keywords:** Sustainability, Green Buildings, Green Building Certification System Analytic Hierarchy Process (AHP).

# ÖZ

# TÜRKİYE İÇİN EN UYGUN YEŞİL BİNALAR SERTİFİKASYON SİSTEMİNİ BELİRLEMEYE YÖNELİK ANALİTİK HİYERARŞİ SÜRECİ (AHP) TABANLI YAKLAŞIM

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KASIM 2017

En önemli küresel konulardan biri olan sürdürülebilir kalkınma hedefi, projelerin uyumluluğunu sağlamak için birçok ülke tarafından yasalaştırılmıştır. Dolayısıyla, projelerin sürdürülebilirlik gerekliliklerine uygunluğunun sağlanması kalkınma için önemlidir. Bu araştırmada, Türkiye için yeşil bina sertifikasyon sisteminin geliştirilmesi için dikkate alınacak en etkili kriterleri ve alt kriterleri bulmak için bir strateji temelinde bir yöntem getirilmiştir. Araştırma, literatürden kriterleri ve alt kriterleri belirleyerek ve farklı alanlardan uzmanlarla (akademik araştırmacılar, danışmanlık uzmanları ve hükümet karar mercileri) röportaj yaparak Analitik Hiyerarşi Süreci (AHP) yöntemini uyarlamaktadır. Yeşil bina ve sürdürülebilirlik çalışmalarına göre önemli kabul edilen kriterleri ve alt kriterleri kullanarak, AHP yazılımı (Expert choice 11.5 akademik sürüm) tarafından geliştirilen soru formu uzmanlar tarafından dolduruldu. Nihai sonuca göre, yeşil bina maliyet ve verimlilik yeşil bina sertifikasyonu için en önemli ölçüt olarak görülürken, genel değerlendirme başarısı, kayıt ve belgelendirme maliyetleri ve uyum ve güvenilirlik en önemli alt kriterlerdir. Hipotez testleri, mevcut değerlendirme araçlarının Türkiye için yeterli olmadığını göstermektedir. Bununla birlikte, AHP yönteminin Türkiye'nin yeşil bina değerlendirme aracının değerlendirilmesi için başarılı olduğu düşünülmektedir.

**Anahtar Kelimeler:** Sürdürülebilirlik, Yeşil Bina, Yeşil Bina Sertifikasyon Sistemi, Analitik Hiyerarşi Süreci (AHP)

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| | |
|---|---|
| **AHP** | Analytical Hierarchy Process |
| **BREEAM** | Building Research Establishment's Environmental Assessment Method |
| **CP** | Comparison Programming |
| **CASBEE** | Comprehensive Assessment System for Built Environment Efficiency |
| **CED** | Cumulative Energy Demand |
| **ÇEDBİK** | Çevre Dostu Yeşil Binalar Derneği |
| **DGNB** | Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council) |
| **ELECTRE** | Elimination and choice translating reality |
| **HQE** | High Quality of Environment |
| **IBC** | International Building Code |
| **LCA** | Life Cycle Assessment |
| **LCC** | Life Cycle Cost |
| **LEED** | Leadership in Energy and Environmental Design |
| **MAUT** | Multi-Attribute Utility Theory |
| **MCDM** | Multi-Criteria Decision-Making |
| **OECD** | Organization for Economic Cooperation and Development |
| **PROMETHEE** | Preference Ranking Organization Method for Enrichment Evaluation |
| **OPSIS** | Technique for Order Preference by Similarity to Ideal Solutions |
| **TQA** | Total Quality Assessment |
| **USGBC** | United States Green Building Council |
| **WSM** | Weighted Sum Method |
| **WPM** | Weighted Product Method |
| **WCED** | World Commission of Environment and Development |

# 1. INTRODUCTION

The price of energy has increased as a result of the reduction of fossil fuel supplies all around the world. In response, countries around the world have developed sustainable strategies through the creation of policy instruments. Almost all the sectors including business, manufacturing, construction, transportation have included sustainable strategies into their existing business plans to insure environmental safety (Kibert, 2016). According to researchers and scientists, one of the ways to reduce the harm to the environment is to make buildings more sustainable and more energy effective. When it comes to the design stage, the architect designs the building through advanced certification systems which predicts, calculates and estimates the environmental performance characteristics of a building (Morledge & Jackson, 2001). The environmental certification system as for buildings have been developed to provide an objective evaluation of indoor environmental quality, resource use, and ecological loadings, etc. (Cole, 2005). These certification system present various methods to define criteria of green buildings. They connect large number of environmental issues and combine them into overall judgments. Those issues addressed by the certification systems may influence environmental policies, designs and building practices. The methodologies of assessment play several roles; they facilitate understanding the effect of buildings on natural systems, marketing green buildings, as well as addressing sustainability (Cole, 2005). They also help politicians and decision makers in environmental management, primarily in architectural projects (Gluch & Stenberg, 2006). Accordingly, construction sector becomes the potential contributor to the achievement of sustainable development at a great level.

Buildings achieve people’s needs in terms of working, living and playing. However, they strongly affect the environment (Zuo & Zhao, 2014). The effects are linked to the building-related elements as its design, construction, location, and demolition activities. The consumption of electricity, natural gas and other fuels by the common household is the major reason for greenhouse gas emission. Therefore, the role of buildings in causing environmental degradation has been studied at a universal level, in the areas of climate change (Darko & Chan, 2016; Kim, Hwang & Oh, 2014). Furthermore, the concept of green building is considered as a marketing area that includes several opportunities in the long run. The report of World Green Building Trends in 2013 stated that:

> 28% of engineering firms reported that more than 60% of their work is involving green buildings criteria in 2012 which is an increase from the 13% of firms in 2009 and with an expectation for this number to raise to 51% in the future (Bernstein, 2013, p. 9).

Thus, the certification systems for green buildings are important subjects in the field of construction. For that reason, it is necessary to investigate the most widely used green certification systems like Leadership in Energy and Environmental Design' (LEED), 'Building Research Establishment's Environmental Assessment Method' (BREEAM), 'Comprehensive Assessment System for Built Environment Efficiency'(CASBEE), 'High Quality of Environment'(HQE), 'Deutsche Gesellschaft für Nachhaltiges Bauen'(DGNB) and Turkish system Çevre Dostu Yeşil Binalar Derneği (ÇEDBİK) in this research. In addition, each system is compared based on the criteria included in it. Moreover, the case study of the research uses the Analytic Hierarchy Process (AHP) method to understand the best strategy to choose the green building certification system that could satisfy Turkey's needs and requirements. Although the concept of green buildings is not new, it is important to use the best appropriate certification system for Turkey to be aligned with the world's vision and concerns.

### 1.1. Problem Statement

Due to the global movement for implementing green building strategies in design, construction and facility management, Turkey has been one of the countries that several projects and designers are adopting a similar approach. Consequently, to achieve sustainable development best outcomes, the sector of construction must recognize and understand the strategies of application and the related techniques and certification systems. The increasing consumption of natural resources has been directing the world towards concerned situations of the scarce resources that our environment has.

Therefore, Turkey also needs to implement the green building strategies and method as most of its resources have been consumed within the construction sector (Kaplan, Özturk & Kalyoncu, 2011). There is scarcity in resources in our environment nowadays and that is mainly due to the increment of natural resources consumption. Most of Turkey's resources are consumed in the sector of construction, for that reason Turkey must apply the methods and strategies of green building ( Kaplan et al , 2011). Despite the extensive researches that have been conducted on the efficiency of the green buildings and the certification systems, there has been minimal effort towards defining the criteria and certification systems that should be considered for local requirements.

### 1.2. Purpose of the Research

The purpose of the research is to develop the best strategy and approach for a green building certification system for Turkey based on the best fit judgment criteria that are used by the worldwide green building certification systems. In order to achieve this purpose, an AHP methodology is used in comparison between different green building certification systems ; LEED, BREEAM, CASBEE, DGNB and HQE, as there is no specific certification system from the afore-mentioned suitable for Turkey. For this purpose interviews with 9 experts in the sustainability and the green buildings domain, who come from three backgrounds; academicians, governmental decision makers and consultants. The nine people chosen for AHP methodology since it is believed that they represent the set of main decision makers.

Moreover, the research seeks methodology and implementation strategies through a case study that includes experts in the Turkish green building industry from different professional background. Therefore, the aim of this research is also to conclude the most important criteria and sub-criteria that influence the choice of a green building certification system for Turkey and the most compatible certification system for these criteria. The AHP method and Expert Choice software (11.5 academic version) were used as it is utilized in the projects of complex decision making with several criteria, as well as its easiness for use and its ability to arrange the priorities among the set criteria.

This research offers a comprehensive comparison between 5 international Green Building certification systems, in addition to the available green building certification system in Turkey (ÇEDBİK). Therefore, the purpose of the comparison is to investigate the green building certification systems that are adopted in the developed countries worldwide, understand its judgement criteria that are used in the assessment process and investigate the best fit green building assessment criteria that shall be used for Turkey.

However, it is important to understand that there is no specific international certification system that is used or adapted in Turkey. Thus, this research works also on providing the necessary data to create a new certification system for Turkey through understanding the most important criteria and sub-criteria that shall be considered in the development process and establishing a benchmark from the international certification systems for comparison and reference. Because with the thesis it is argued that Turkey needs to develop its own green building certification systems according to its strategic priorities.

Furthermore, the research does not imply that one of the compared green building certification systems shall be adopted completely for Turkey. However, the comparison is based on a methodology that compiles the most important criteria and sub-criteria, then involving experts from different fields into indicating the importance of each item in building an implementation strategy that would eventually highlight the priority items that shall be considered during the development of the green building certification system for Turkey.

### 1.3. Aims and Objectives

This study aims at defining and examining a general framework as well as a methodology used to analysis and compare between various systems in order to define the advantages and disadvantages of every system to develop the best strategy for a certification system for green buildings certification system for Turkey. The objectives of this research are:

• Defining concepts of the sustainability and green buildings.
• Comparing several certification systems in terms of their assessment and analysis criteria (Pros and cons comparison and analysis).
• Understanding the certification systems and their correspondent assessment criteria and the weights assigned to them.
• Finding the evaluation criteria for green buildings certification system.
• Determining the advantages and disadvantages of various certification systems; BREEAM, LEED, DGNB, CASBEE, HQE and ÇEDBİK.
• Utilizing the AHP method as a strategy to choose the most important criteria in choosing a green building certification system as well as setting priorities among them.
• Checking the adaptability of the current certification systems in projects and frameworks for the Turkish system.

### 1.4. Research Questions and Hypotheses

This research attempts to answer the research questions below.

Q1: What are the strength and weaknesses of different certification systems (LEED, BREEAM, DGNB, HAQ, CASBEE, ÇEDBİK) and the relationship between them?

Q2: What are the identical or contrasting features of the certification systems of green building?

Q3: Which is the best fit among the selected certification systems for meeting the needs of Turkey?

Q4: What are the most relevant and important criteria that shall be taken into consideration when developing a green building certification system for Turkey?

Based on the aforementioned research questions, two hypotheses are developed and subsequently tested, as follows:

H1: The current certification system is unsufficient for the Turkey assessment of green building.

H2: AHP can be used as a methodology to assess certification system for Turkey.

### 1.5. Thesis Structure:

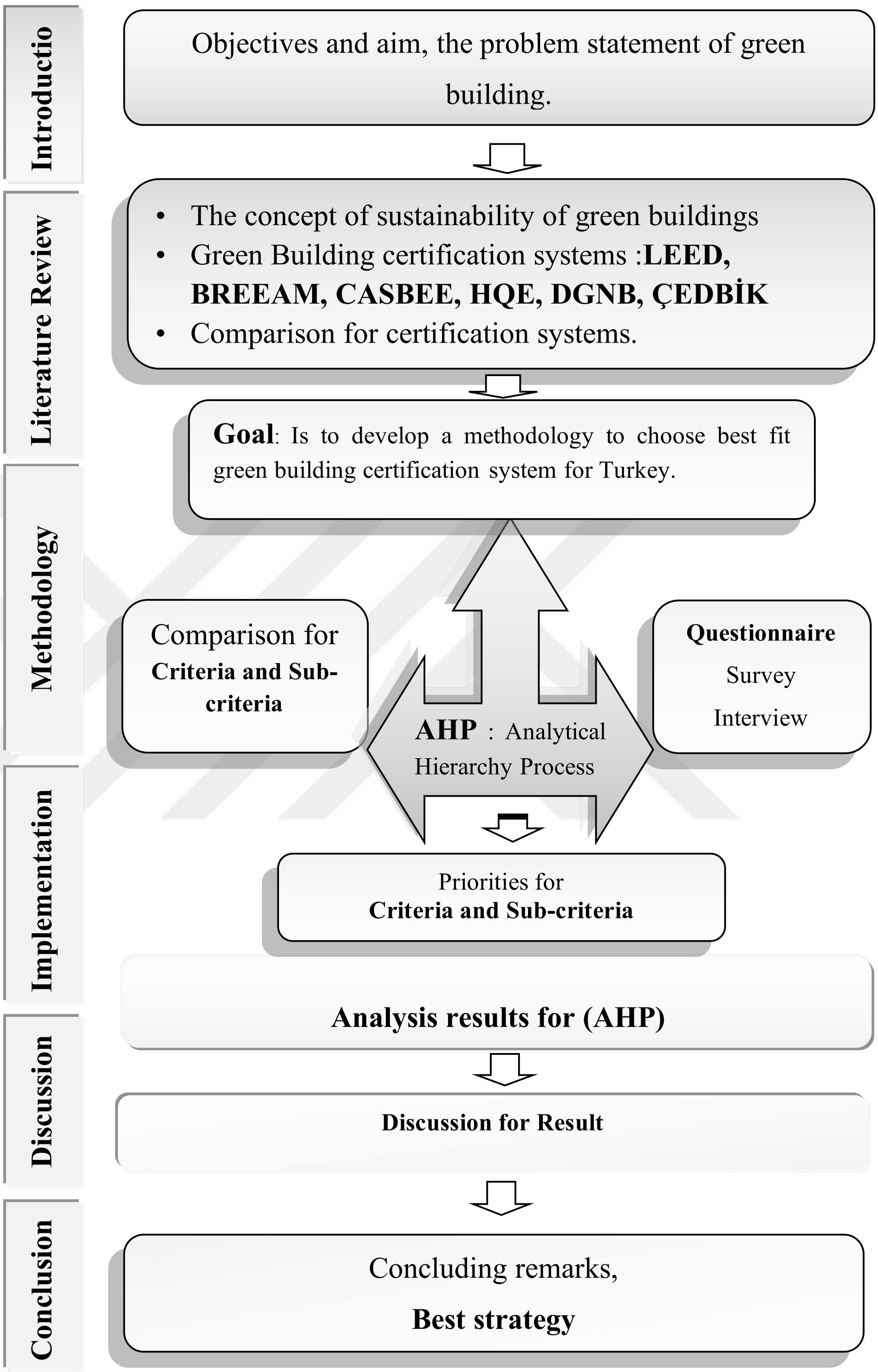



**Figure 1.1:** Research Structure.

The thesis commences by providing an introductory overview about the subject. Moreover, the first chapter provides the problem statement that is addressed in the research, research purpose and aim, research questions and hypotheses that are tested through the study.

The second chapter discusses the related literature, which focuses on the strategies of green buildings that protect the environment. Furthermore, the sustainability concepts of green buildings and sustainable development are discussed. This part compares the green building certification systems in order to highlight their advantage and disadvantages for an adoptive investigation for Turkey.

The third chapter addresses the methodology selected for this research, which starts by discussing the Multi-Criteria Decision-Making (MCDM) methods and specifically the AHP method used in this study. Moreover, the chapter provides the selection of the criteria and sub-criteria that are used in the AHP method through a literature survey, as well as the experts' selection process and details. The methodology chapter provides an application to the preparatory stages of the AHP method by developing the hierarchy diagram and understanding the procedures of the AHP method.

The fourth chapter provides the findings of the research as a result of the interviews with the experts by comparing each criterion to another and each sub-criterion with its counterparts within the same criterion. Furthermore, the fifth chapter discusses the results of the AHP analysis, provides the final results and discusses them. The sixth chapter provides a conclusion for the research by answering the study questions and testing the hypotheses established in the study.

# 2. LITERATURE REVIEW

## 2.1. Sustainability

The concept of sustainability can be defined by several methods; the most common definition was by the World Commission of Environment and Development (WCED) in 1987; “sustainability is addressing the needs of the present without undermining the needs of the future” ( Brundtland,1987). Since the productivity of the universal ecosystem is limited, this lead to a decrease in the activities of daily living, and damaging the availability of fossil fuels and minerals. Boundaries of Growth published in 1972, contributed to this field by showing two-time frames, presenting economic changes on a universal scale through simulation done by computer. The situation of the universal economy was first analyzed between 1900 and 1970, involving the population, agricultural production, industrial production, natural resources, and pollution (Bartlett, 2012). In this regard, the book faced criticism, because it focuses on the earth being finite, and that leads to a misinterpretation which would result in the crashing of infinite limits. Nevertheless, researchers were obliged to investigate the main parts of the book again, because of the current environmental conditions along with the increased level of global warming (Turner & Alexander, 2014).

As there is a commitment from all participants in the construction sector towards the sustainability and environmental issues, there are several trials from all of them to ensure that all engineering disciplines empowers the sustainability concept. However, the current sustainability standards do not provide enough support for the goal, as each country is facing different challenges that makes its environmental case unique. Moreover, the current green building certification systems  are not designed to be used in different countries, rather than being a local certification system for the developing authority for its region (Erten, Henderson & Kobas, 2009).

## 2.2. Sustainable Development

In the field of real state, sustainability has been considerably implemented. Based on the possible impact of different factors, the importance of employing sustainability as a prime priority has been recognized by developers, owners, investors and the public sector. The sustainability is considered as a continuous process of sustainable development to achieve a stable state among the environmental, economic and social aspects, as can be seen in Figure 2.1.

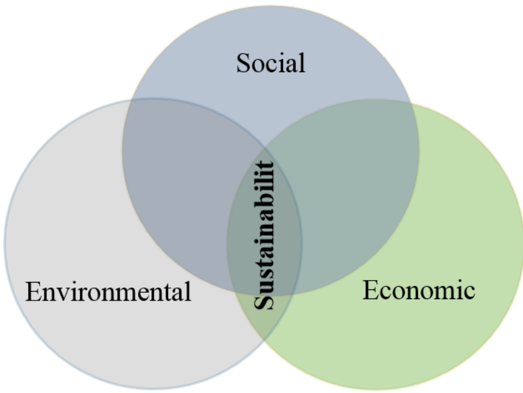



**Figure 2.1:** Sustainable development elements (Younan, 2011).

There are studies that have proven that built structures, throughout the different life cycle stages, affect the environment by producing emissions and pollutants that have an adverse effect on the elements of the ecology (Belarus, 2005).

The carbon dioxide ($CO_2$) emission, energy and raw material consumption, water usage, and solid wastes have negative impacts on the climate change. In this context, the Organization for Economic Cooperation and Development (OECD) report of 2011 stated that the construction sector contributes significantly to the sustainable development. Therefore, it is known as the keystone of sustainability. Moreover, not taking sufficient actions would cost more than the cost of taking action (Fankhauser, 2013).

The concept of sustainable development was defined as “an attempt to combine growing concerns about a range of environmental issues with socio-economic issues” (Hopwood, Mellor & O'Brien, 2005, p. 4). However, this concept cannot be generalized as it involves responsibility towards securing the future of the current generation. Therefore, the approach of sustainable development is based on the collaborative impacts of ecology and economic development (Chichilnisky, 2011).

### 2.3. Green Buildings and Sustainability

The green building concept is not a recent concept and the techniques related to this concept have developed with time (Emmit & Gorse, 2006). A green building is designed to be more efficient than the traditional building, regarding the building construction, use of construction materials, functionality of building system, performance, energy and water efficiency, indoor quality; which involves air quality, thermal comfort, lighting, site disturbance, waste management, air emissions, water management, and adaptability in terms of change in user needs and options for occupant’s transportation (Paumgartten, 2003). The use of green building principles give a possibility to decrease environmental damage (Eno, 2005). Currently, there is a widespread acknowledgement of environmental engineers and energy economist of the importance of reducing carbon emissions while maintaining economic growth of companies (Sioshansi, 2011)

There are several advantages that are offered by the implementation of green buildings including the empowerment of a healthy environment and ecological systems. Moreover, the preservation of natural resources is an added advantage that does not only include mineral resources, but also biological and ecological resources. Implementing green building strategies are proven to enhance the building performance, the occupants’ productivity, and the economic values of the assets. Green buildings are also proven for their provided comfort for the occupants, as well as the minimized usage of energy and resources (Kuhlman & Farringtom, 2010; Reed, Bilos, Wilkinson & Schulte, 2009). The impacts of green building implementation are illustrated in Figure 2.2.

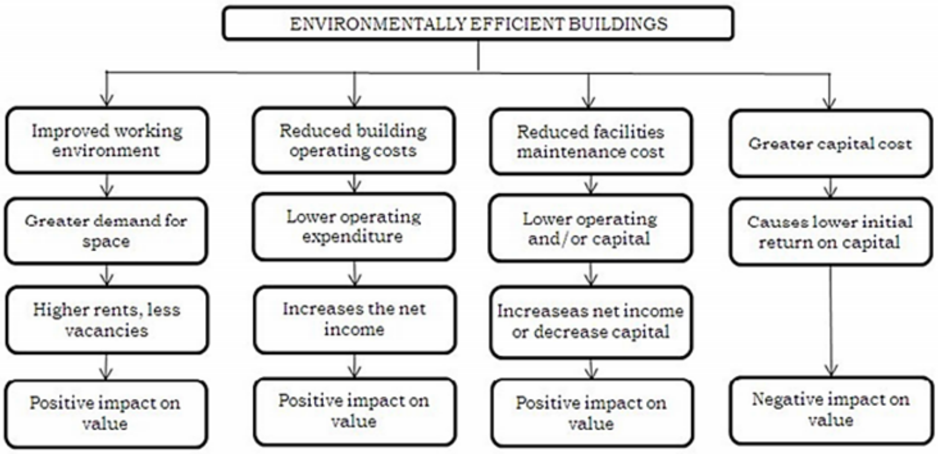



**Figure 2.2:** The value impact of energy efficient buildings (Gündoğan, 2012).

Furthermore, green building and sustainability have been proven to reduce construction and operational costs on owners, as it encourages recycling, using local building material and reducing energy consumption through renewable sources. Moreover, the sustainability concept has faced an approval from authorities worldwide, which eases the access of the development into the market and increases its business opportunities. The concept also encourages other positive practices, such as innovation. Finally, adopting a sustainable development strategy increases the acceptance of the development among people and corporations, which subsequently increases its access to investment capital (Freidman, 2012).

## 2.4. The Need for Green Buildings in Turkey

The green buildings were immediately accepted worldwide. With the aggravation of the energy crisis and the efforts to protect the environment, the necessity of implementing green strategy became obvious. According to the research conducted by Manioğlu and Yılmaz, Turkey employs this green strategy and acknowledges its historical presence and architectural importance. 'The House of Mardin' contains one of the first green building projects in Turkey, which is more energy-efficient compared to traditional houses. It also reflects the concept of

modern construction in terms of area selection, orientation, distance and the form of the building. The Turkish Green Building Association, ÇEDBİK, was founded in 2007, for the impacts of green strategy and sustainability principles. Training programs have been implemented with pilot projects in order to encourage green buildings and raise awareness (Manioğlu & Yılmaz, 2006 ; ÇEDBİK, 2012).
Turkey has used the innovations of modern technologies to make important changes related to the future impacts of globalization; where several actions have been taken to employ the energy resources to achieve economic improvements through modern solutions adaptation. According to the United States Green Building Council (USGBC) yearly report, Turkey is ranked ninth in the application of green building certification systems (Roberts, 2015)

## 2.5. Green Building Certification Systems

Engineers have a significant role in enhancing the commercial, industrial, and institutional buildings designs, so that the residents, owners and other users are supported in decreasing the use of resources and offered an improved indoor environment (Cheng & Venkataraman, 2013; Kuhlman& Farrington, 2010). Architects efforts in improving buildings designs are as important as engineers. The fundamental aspects that require expertise in design include making the buildings more energy-efficient, using existing infrastructures instead of the open space development, decreasing the dependency on vehicles, promoting a sense of community, employing the materials effectively and improving the design, protecting the ecosystem and the biodiversity as well as guaranteeing the characteristics of durability and adaptability in the design (Simnett, Vanstraelen, & Chua, 2009). Figure 2.3 demonstrates the sustainable approaches impact on all levels and it can be seen that all levels are connected together.

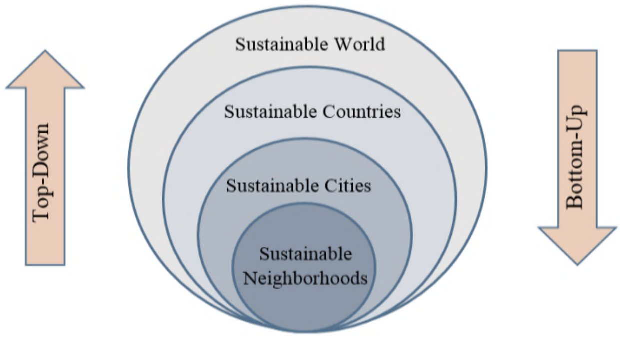



**Figure 2.3:** Sustainable approaches impacts (Borhani & Hamedani, 2011).

There are two approaches according to the variation in the process of evaluating; Top-Down and Bottom-Up. The Top-Down approach is used when there is a need for further investigation of the green strategies deployment as sustainable development in terms of general aims at the national and global level (Kuhlman & Farrington, 2010). Whereas the Bottom-Up approach is used to define functional strategies and examine executive level projects at a local level, with observing operation is executed on national and international levels. From the perception of national and global levels, the research aims of these specific certification systems must be examined at a regional level. That being said, it is claimed that the success of a certification system used in sustainable development, would require a suitable certification system result. Certification systems support measurable standards for defining the sustainable development approach, while its convenience remains constant on diverse strategies, aims, and processes.

Figure 2.4 illustrates the worldwide certification systems. Many rating systems for green buildings have been established recently, promoting higher performance and lower energy buildings (Arkesteijn &Van, 2010), as can be seen in Figure 2.5. It is generally accepted that: “Life Cycle Assessment in the Sustainability Assessment (LCA) is a conceptually preferred method for determining the environmental impacts of materials” (Bragança & Mateus, 2008, p. 23). There are some well-known Life Cycle Assessment (LCA) certification systems worldwide. The LCA has been recognized as a globally efficient approach to evaluate the environmental effects of products or operations throughout their life cycle. Figure 2.5 demonstrates the worldwide rating certification system.

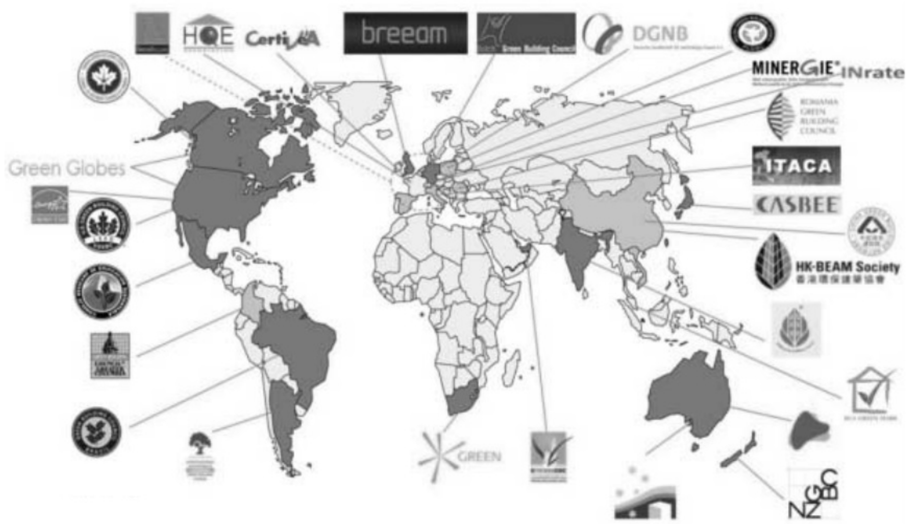



**Figure 2.4:** International rating certification system (Reed, Wilkinson, Bilos & Schulte, 2011)

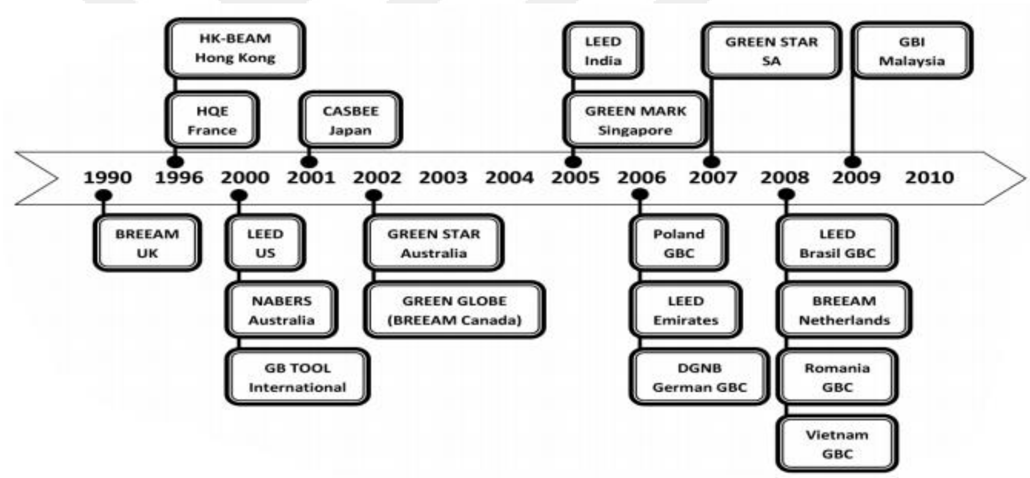



**Figure 2.5**: Rating tools development timeline (Yusoff & Wen, 2014)

Certification systems are significantly suitable for various projects needs for sustainable development in various places. In addition, there are differences between the certification systems and the policies and procedures of buildings (Simnett et al., 2009).The building and advancement of practical applications has not got many requirements. Furthermore, the certification system is based on the given criteria with relation to the building quality, and that in turn supports and reinforces sustainable development. Table 2.1 shows several certification systems all over the world.

**Table 2.1:** Worldwide certification system (Reed, et al, 2011)

| Continent | Labelling | Country | Web Page |
|---|---|---|---|
| **America** | LEED | USA | http://www.usgbc.org |
| | Green Globes | USA | http://www.greenglobes.com |
| | LEED Canada | Canada | http://www.cagbc.org |
| | Green Globes | Canada | http://www.greenglobes.com |
| | LEDD Mexico/Sices | Mexico | http://www.mexicogbc.org |
| | LEED Brazil | Brazil | http://www.gbcbrasil.org.br/pt/ |
| | AQUA | Brazil | http://www.vanzolini.org.br |
| | - | Colombia | - |
| | - | Argentina | http://www.agrentinagbc.org.ar |
| **Europe** | Green Building | Europe | http://www.eu-greenbuilding.org |
| | DGNB | Germany | http://www.dgnb.de |
| | BREEAM | UK | http://www.breeam.org |
| | HQE | France | http://www.assohqe.org |
| | Certivea | France | http://www.certiva.fr |
| | Prommis E | Finland | http://www.vtt.fi |
| | Lider A | Portugal | - |
| | BREEAM | Netherlands | http://www.dgbc.nl |
| | ProtocolloItaca | Italy | http://www.itaca.org |
| | - | Italy | http://www.gbcitalia.org |
| | SPIN | Swiss | http://www.inrate.ch/index.php?id=47 |
| | Minenergie | Swiss | http://www.minergie.ch/ |
| | - | Poland | http://www.plgbc.org/ |
| | - | Romania | http://www.rogbc.org/romania-green-building-council/ |
| | VERDE | Spain | - |
| **Asia** | LEED Emirates | VAE | http://www.esoul.gohspher.com/default.aspx |
| | LEED India | India | http://www.cagbc.org |
| | TGBRS India | India | http://www.teriin.org |
| | Green Mark | Singapore | http://www.bca.gov.sg/greenmark/green_mark_building |
| | SGP 2012 | Singapore | http://www.mewe.gov.sg/sgp2012/ |
| | ABRI | Taiwan | http://www.abri.gov.tw/utcPageBox/ENGMAIN.aspx?ddsp |
| | GBAS | China | - |
| | - | Vietnam | http://www.vsccan.org/vgbc/green-building-tools/ |
| | HK-BEAM | Hong Kong | http://www.hk-beamorghk/general/home.php |
| | CASBEE | Japan | http://www.ibec.or.jp/CASBEE/ |
| **Africa** | Green Star SA | South Africa | - |
| **Australia** | Green Star | Australia | http://www.gbcsa.org.za |
| | Nabers | Australia | http://www.gbca.org.au |
| | Green Star NZ | New Zealand | http://www.nzgbc.org.nz |

As mentioned previously, this research contains a range of certification systems for green building, both local and global versions. Based on the requirements and aims of the research data, the following certification systems have been chosen and examined:

1. LEED: ‘Leadership in Energy and Environmental Design’.
2. BREEAM: ‘Building Research Establishment's Environmental Assessment Method’.
3. CASBEE: ‘Comprehensive Assessment System for Built Environment Efficiency’.
4. DGNB: ‘German Sustainable Building Council’.
5. HQE: ‘High Quality of Environment’.
6. ÇEDBİK: Çevre Dostu Yeşil Binalar Derneği.

Although there has been a considerable effort that has been put into developing the Turkish certification system ÇEDBİK, the comparison with the other five international systems is only performed in the theoretical comparison from the literature within this chapter. Therefore, the Turkish certification system is not included in the case study comparison using the AHP methodology due to comprehensively issues, as ÇEDBİK is currently developed for new residential buildings only.

The role of green building certification systems has been simplifying the objective analysis of indoor quality, resource use, and ecological loadings (Bernardi, 2015). On this matter, engineers were determined to enhance the reliability of the certification systems towards the aims of expecting, calculating and evaluating the environmental performance characters of a building (Sundkvist et al., 2006). Therefore, different certification systems have diverse criteria defining the conception and level of green for a building, as several environmental issues are considered to provide efficient and effective solutions. However, it is also declared that these certification systems approach might have effects on the policies and strategies of building and designing. It is also noted that the success of the certification systems is determined by various aspects. These certification systems offer a basic understanding of the impacts of building approaches on the environment based on the sustainability concept (Borowitzka, 1998). Moreover, the process of decision-making is assisted and that in fact is considered as the most significant feature of these certification systems.

## 2.6. Features of Selected Certification Systems

To determine the built environment reliability, several certification systems approaches have been studied and investigated (Zuo& Zhao, 2014).Various local and global certification systems have been established to contribute to the green buildings development. Those certification systems were established to work voluntarily and not compulsory. The Council of Green buildings has established these certification systems in several countries and regions. However, the evaluation process for the quality of building is done by the engineers or experts allocated by the Council of Green buildings in that particular regions (Wangel, Wallhagen, Malmqvist & Finnveden, 2016). The chosen certification systems are investigated for the following qualities:

The key role for the criteria is to accomplish the aim of an environmental building assessment approach which "provides a comprehensive assessment of the environmental characteristics of a building" (Ding, 2008, p. 7). System construction and metrics have an important effect on performance evaluation of an assessment process (Cole, 2005). This is also supported by Ali and Nsairat who recommend determining the exterior borders of a tool which vary from one area to another (Ali & Nsairat, 2009). Moreover, several assessment methods, such as weighing systems and flexibility, have a strong connection to system criteria (Ding, 2008). Therefore, ignoring a weighing system and complexity are major problems in accepting an assessment method (Ding, 2008).

The indicators reflect the numerical and measurable description of every particular criteria of the assessment systems. Several indicators could be used for evaluating particular criteria.

Rating system is the boundaries of classification. It includes the qualitative and quantitative analysis technique considerations for indicators measurement, as well as the lowest-level of requirements and the importance factor criteria. Therefore, the rating system requires an exact representation of the assessment outcomes (Reed, et al., 2009).

The certification process depends on the requirements of certification. It happens at several stages for the assessment and rating of building quality. Some of these stages are the planning, design and construction of the building in addition to other stages (Lee & Burnett, 2008). Originally, the certification systems are to merge between sustainability and the buildings infrastructure. However, currently there is a significant emphasis on assessments in sustainable areas (Zuo & Zhao, 2014). The negative impacts of the economic crisis, demographic changes, and climate change are some of the reasons for the focus on towns and city's sustainable development, particularly in Turkey. Thus, the aims of the sustainable society development are toward achieving higher success at the highest level. Furthermore, the stakeholders of the community are assisted by the outcomes of these certification systems (Giama & Papadopoulos, 2012; Watkiss, 2007)

## 2.7. Comparison of Green Building Certification Systems

The chosen certification systems are capable of meeting the requirements of sustainability efficiently, in a way that facilitates the spread of ‘Green Buildings’ all over Turkey. In this section, a comprehensive comparison will be made between the key characteristics of these certification systems. Furthermore, certain features such as the international recognition, notion of seniority, and other features make some certification systems desirable over the others (Bowd, McKay & Shaw, 2015 ; Hamedani & Huber, 2012). Diverse certification systems have been examined and further explored with taking in consideration the effects of their particular countries (Nguyen & Altan, 2011; Wangel et al., 2016). Thus, the chosen certification systems take into consideration the economic, social and environmental aspects.

Five fundamental certification systems were selected for this research. Table 2.2 illustrates the origin and year of establishment for those certification systems.

**Table 2.2:** Fundamental certification systems and their origin (Younan, 2011; Abedmousa, & Arafat, 2017)

| Certification Tool/System | Year | Country |
|---|---|---|
| LEED ‘Leadership in Energy and Environmental Design’ | 1998 | USA |
| BREEAM ‘Building Research Establishment's Environmental Assessment Method’ | 1990 | UK |
| CASBEE ‘Comprehensive Assessment System for Built Environment Efficiency’ | 2001 | Japan |
| DGNB ‘German Sustainable Building Council’ | 2009 | Germany |
| HQE ‘High quality of environment’ | 1994 | France |

This section discusses and compares the five selected certification systems, examining them one by one as following:

### 2.7.1. LEED certification system:

The LEED certification system gives different weighing, represented by percentages, for different categories as shown in Table 2.3.

**Table 2.3:** LEED Categories and weighing (LEED, 2016; 2017)

| LEED Criteria new building for houses | Percentage (%) |
|---|---|
| Location and Transport | 15 |
| Sustainable Sites | 7 |
| Water Efficiency | 12 |
| Energy and Atmosphere | 38 |
| Material and Resources | 10 |
| Indoor Environmental Quality | 16 |
| Innovation | 6 |
| Regional Priority | 4 |

The certification of in LEED assessment system starts with a certified degree with a range of 40 to 49 points. Thereafter, LEED awards projects that achieve 50 to 59 points with a silver certificate, 60 to 79 points with a gold certificate, and projects with 80 points and over with a platinum certificate (Mattoni, et al,2018)

The assessment process of LEED certification system has six main steps as described in Figure 2.6. Firstly, the design team starts with building registration. After that, the team presents the data at two steps, design submittal and construction submittal. After each submittal the USGBC makes a review. Finally, LEED certification is issued to the building after the final submission (Say & Wood, 2008 ; LEED, 2017)

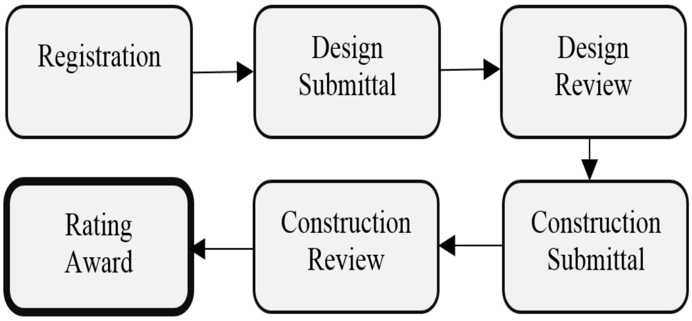



**Figure 2.6:** LEED certification process (Say & Wood, 2008 ; LEED, 2017)

Due to the different objectives awaited from the different types of buildings, LEED provides different certifications and assessment systems according to the building type. The LEED assessment and certification process covers the lifecycle of the project starting from the design phase, throughout the construction and reaching to the operation stage (Borhani & Hamedani, 2011). Therefore, LEED provides different certifications as follows (LEED, 2017)

- LEED BD+C: Types are; New Construction, Core and shell, Schools, Retail, Healthcare, Data Centers, Hospitality, Water houses and Distribution Centers, Homes, and Multifamily Midrise.
- LEED ID+C: Types are; Commercial Interiors, Retail, and Hospitality
- LEED O+M: Types are; Existing Building, Schools, Retail, Data Centers, Hospitality, Water houses and Distribution Centers, and Multifamily
- LEED ND: Types are; Plan, and Built Project.
- Homes (H).

### 2.7.2. BREEAM Certification System:

The BREEAM certification system gives different weighing, represented by percentages, for different categories as shown in Table 2.4.

**Table 2.4:** BREEAM categories and weighing (Fauzi & Malek, 2013 ; BREEAM 2017; Parker, 2012)

| BREEAM Criteria new building for houses | Percentage (%) |
|---|---|
| Management | 12 |
| Health & Wellbeing | 15 |
| Energy | 19 |
| Transport | 8 |
| Innovation (Added-value) | 10 |
| Water | 6 |
| Materials | 12.5 |
| Pollution | 10 |
| Waste | 7.5 |
| Land Use and Ecology | 10 |

The BREEAM certification system offers levels: Unclassified, Pass, Good, Very Good, Excellent, and outstanding, depending on the points earned through complying with the system requirements. BREEAM starts awarding with a “pass” degree if the project achieves 30 to 44 points on the certification system. Following that the projects are awarded with a “good” certificate for 45 to 54 points, “very good” certificate with 55 to 69 points, “Excellent” certificate with 70 to 84 points, and “outstanding” certificate with 85 points and above (Mattoni, et al,2018)

The assessment process of BREEAM certification system has five main steps, as described in Figure 2.7. Firstly, the design team starts with registration. After that, BREEAM assessor review the project and fill the assessment report, and then a member of the BREEAM team will review this report. Finally, BREEAM certification is issued to the building (Say& Wood, 2008 ; BREEAM , 2017).

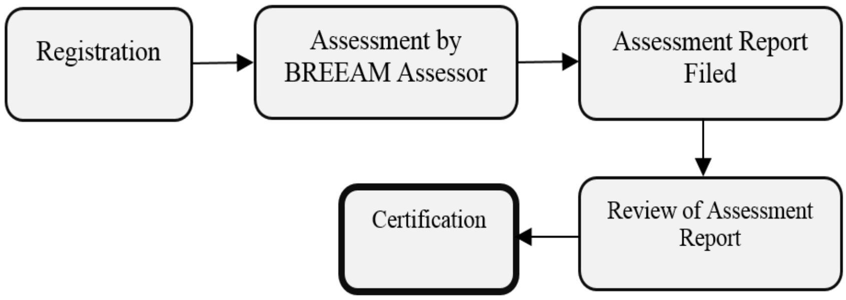



**Figure 2.7:** BREEAM certification process (Say & Wood, 2008 ; BREEAM , 2017)

The types of BREEAM certification system are based on buildings general types. Furthermore, the regulations in this system are created for sustainable buildings. BREEAM is an international certification system that is applied to all countries apart from England. Non-residential building types also can hold licenses (Parker, 2012). There are different types of BREEAM certification systems which are; Residential, Education & Healthcare, Industrial, Mixed Use & Other, Retail (New), Retail (In Use), Offices (In-Use), Offices (New), Offices (Refurb and Fit-Out) (BREEAM ,2017)

2.7.3. DGNB Certification System:

The DGNB certification system gives different weighing, represented by percentages, for different categories as shown in Table 2.5.

**Table 2.5:** DGNB categories and weighing (Miranda, 2013;Bernardi, et al, 2017)

| **DGNB Criteria new building for houses** | **Weighting Factor %** |
|---|---|
| Environmental quality | 22.5 |
| Economic quality | 22.5 |
| Socio-cultural and functional quality (SOC) | 22.5 |
| Process quality | 10.0 |
| Technical quality | 12.5 |
| Quality of the location | Rated independently |

The DGNB certification system has three different types: Existing buildings, new buildings, urban areas as seen in Table 2.6.

**Table 2.6:** DGNB certificate types (Borhani & Hamedani, 2011 ; DGNB, 2017)

| **DGNB Certification System Types** | |
|---|---|
| Existing Buildings | • Industrial buildings.<br>• Commercial buildings.<br>• Office and administrative buildings.<br>• Residential buildings. |
| New Buildings | • Educational buildings.<br>• Meeting buildings.<br>• Health care centers.<br>• Industrial buildings.<br>• Residential buildings.<br>• Mixed use.<br>• Laboratories.<br>• Office and administrative buildings.<br>• Office and administrative buildings (the modernization measures).<br>• Small residential buildings. |
| Urban Areas | • Business areas and Industrial settlements. |

The DGNB certification system offers three levels: Bronze, Silver, Gold, and platinum certificates for 35 points, 35 to 50 points, 50 to 65 points, and 65 to 80 points, respectively, as earned by the project compliance with the DGNB requirements. (Giama& Papadopoulos, 2012; Bernardi, et al, 2017)

The assessment process of DGNB certification system has five main steps as described in Table 2.7.

**Table 2.7:** DGNB certification process (DGNB, 2017)

| **DGNB Certification Process** | | |
|---|---|---|
| Step 1 | Selection | • Connecting the project owner with the investigators of DGNB.<br>• Checking the compatibility between certification system and the project. |
| Step 2 | Registration | • An online registration to the system.<br>• DGNB investigators make the decision for suitable classification of green building after the application. |
| Step 3 | Notification | • An investigation for the building suitability according to the DGNB standards done by a specialist. |
| Step 4 | Investigation | • Approval on the compatibleness by DGNB investigators |
| Step 5 | Verification | • Final approval on the certification |

### 2.7.4. CASBEE Certification System:

The CASBEE certification system gives different weighing, represented by percentages, for different categories as shown in Table 2.8.

**Table 2.8:** CASBEE categories and weighing (Bernardi, et al, 2017)

| CASBEE Criteria new building for houses |
|---|
| **Scoring for Q** |
| Q1: Indoor environment |
| Q2: Quality of Service |
| Q3: Outdoor environment (On-site) |
| **Scoring for LR** |
| LR1:Energy |
| LR2: Resources and Material |
| LR3: Off-site Environment |

The CASBEE certification system of for five levels: Excellent, Very Good, Good, Fairly Poor, and Poor, as described in Table 2.9. The assessment in the CASBEE system starts with a C mark for projects complying poorly with the system, and range to S mark indicating an excellent compliance with the requirements.

**Table 2.9.** CASBEE certification levels (Fauzi & Malek, 2013; Mattoni, et al,2018)

| System Levels | | | | | |
|---|---|---|---|---|---|
| **Point** | **S** | **A** | **B+** | **B** | **C** |
| | Excellent | Very good | Good | Fairy Poor | Poor |

The CASBEE certification system has four different types: pre-design, existing buildings, new buildings, and restoration (CASBEE, 2014; Bernardi, et al, 2017).
The assessment process of CASBEE certification system has three fundamental steps as described in Figure 2.8. It starts with the pre-design stage, it is established for the processes of architectural design combined with the pre- and after-processes. Excel charts taken from CASBEE website are used to automatically determine the result, as the input is entered by the user, the system immediately displays the result in comparison with other systems. In the following level, the values of environmental

activity are presented as charts and the building sustainability level of is specified by these charts (Sev & Canbay, 2009)

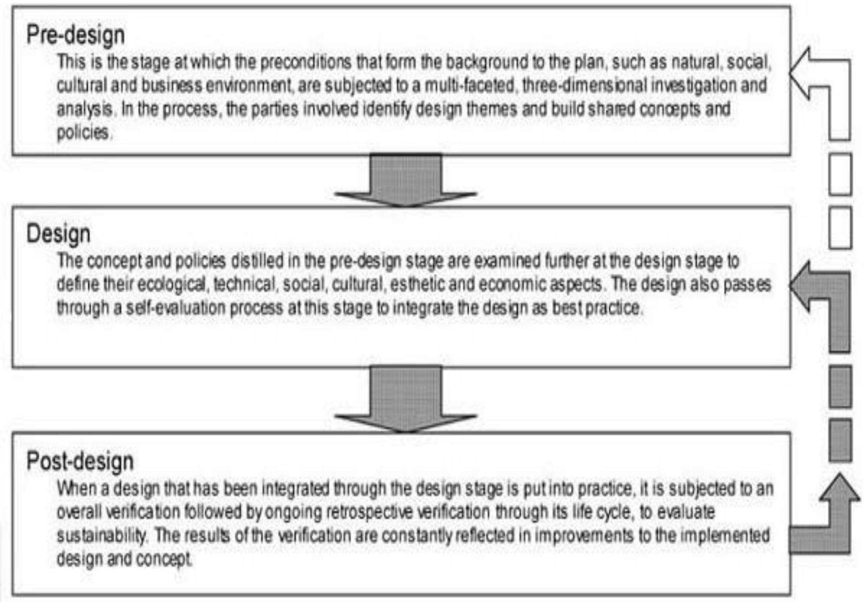



**Figure 2.8:** CASBEE certification process (IBEC, n, d)

2.7.5. HQE Certification system:

The HQE certification system has four main criteria: Environment, energy and savings , comfort, and health and safety, as described in Table 2.10.

**Table 2.10:** HQE certification criteria (Schmidt, 2012; Bernardi, et al, 2017)

| **HQE Criteria new building for houses** | |
|---|---|
| **Environment** | Target 1: Building’s relationship with its immediate environment |
| | Target 2: Quality of components |
| | Target 3: Sustainable worksite |
| | Target 4: Waste management |
| **Energy and Savings** | Target 5: Energy management |
| | Target 6: Water management |
| | Target 7: Maintenance management |
| **Comfort** | Target 8: Hygrothermal comfort |
| | Target 9: Acoustic comfort |
| | Target 10: Visual comfort |
| | Target 11: Olfactory comfort |
| **Health and Safety** | Target 12: Quality of spaces |
| | Target 13: Air quality and health |
| | Target 14: Water quality and health |

The HQE certification system offers five levels: Good, Very Good, Excellent and Exceptional, as described in Table 2.11.

**Table 2.11:** HQE certification levels (Giama & Papadopoulos, 2012; HQE, 2017)

| **Levels of HQE** | |
|---|---|
| Good | (1–4 stars) |
| Very good | (5–8 stars) |
| Excellent | (9 –11 stars) |
| Exceptional | (12 stars and higher) |

The developer determines the level of certification based on the following principles (Hoyez, 2016).

- An independent body assess the performance.
- In order to accomplish the aims, the management system is applied.
- Controlling environmental effects and at the same time creating a comfortable and healthy interior environment.
- Technical solutions and design are not required; the selection is suitable to the context.

The HQE certification system has several different types which are: Tertiary Buildings, Tertiary Buildings, Logistic and Trade Platform, Education, Offices, Residential, and Homes (Gazzeh & Mahfoudh, 2010).

### 2.7.6. ÇEDBİK Certification System:

Until recent years, Turkey did not develop its own green building certification system. However, Turkish Green Building Association (TGBA; or ÇEDBİK in Turkish) has worked with global organizations such as LEED, BREEAM and DGNB in order to certify buildings in Turkey (Chergia, 2012). Furthermore, the TGBA has coordinated with BREEAM in order to establish a Turkish subsidiary for it in Turkey, which is attributed to the closeness between the British and Turkish standards and regulations. A second reason for the effort put towards BREEAM is the Turkish application to join the European Union as a requirement to adopt similar regulations to the current members (Ilter & Ilter, 2011)

In 2013, the TGBA established its own green building certification system under the name ÇEDBİK-KONUT certification. The program covers the following categories (CEDBİK, 2016):

1. ÇEDBİK certification criteria:

**Table 2.12:** ÇEDBİK criteria weights (ÇEDBİK, 2016)

| Criteria | Percentage (%) |
|---|---|
| Green project management practices | 6 |
| Land use | 13 |
| Water use | 12 |
| Energy use | 25 |
| Health and comfort | 10 |
| Material and Installations | 14 |
| Living Standards | 13 |
| Operations and maintenance | 5 |
| Innovation | 2 |

The certification types are a four-scale system that starts with approval with the minimum of 45% compliance, and continues over the four scales in 10% to 15% intervals. Table 2.12 shows the certification assessment scales for the ÇEDBİK-KONUT Certification. The Turkish certification system covers some of the projects or building types (Housing) through assessment in the design, construction and operation phases (ÇEDBİK, 2016).

2. ÇEDBİK certification levels:

**Table 2.13:** CEDBİK certification levels (CEDBİK, 2016)

| Total Points | Degrees | Certificate |
|---|---|---|
| 45% to 65% | Approved | Çedbik |
| 65% to 80% | Good | Çedbik |
| 80% to 90% | Very Good | Çedbik |
| 90% to 100% | Excellent | Çedbik |

## 2.8. Comparison of the certification system

Several researchers have investigated the efficiency of the green building certification systems, and found that some certification system is effective in specific aspects. However, the use of the certification system is more widespread outside their region. In this context, the PWC report stated that the adoption of LEED is larger outside its region (PWC, 2013). As can be seen in Figure 2.9.

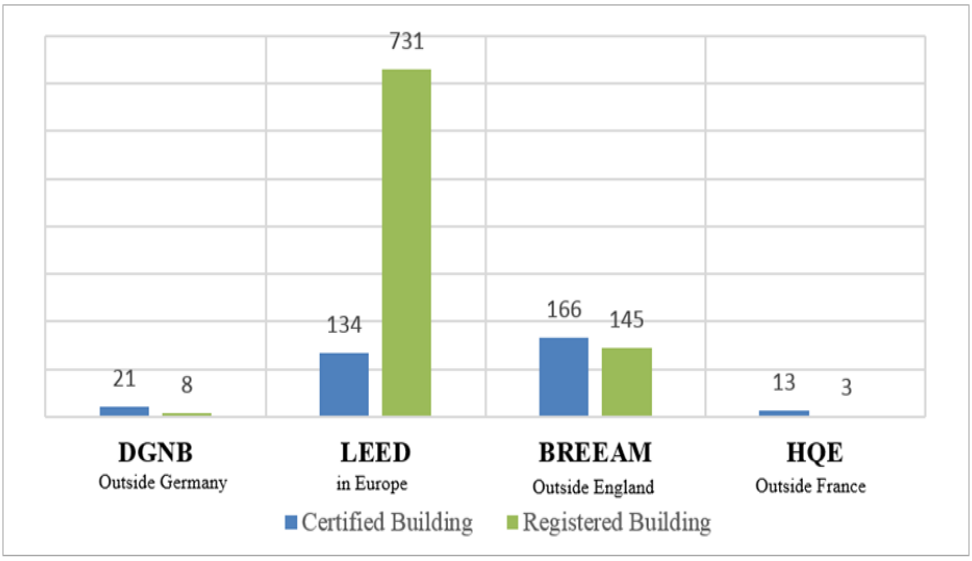



**Figure 2.9:** Overall comparison of the certification systems (PWC, 2013).

In this section, the rating systems are compared against several assessment criteria as illustrated in Tables 2.13 and 2.14. The comparison shows that the different tools address the several sustainability domains in a different manner; either inclusion, exclusion or weighing. The BREEAM system includes all the mentioned aspects in the Table as main criteria, while includes the environmental impacts in the pollution, land use and ecology criteria. LEED includes the transport domain as a sustainable sites domain. Both LEED and BREEAM systems do not include any points for socio-economic aspects. HQE does not include the management and transport domains in its system; however, a partial inclusion is present in the assessment targets.

DGNB includes the transport domain as sustainable sites and functional quality, similar to the indoor environmental quality domain. Moreover, the environmental impacts are included in the ecological quality of the DGNB system. While the majority of the domains are included in the CASBEE certification system, there are no points offered for innovation, similar to HQE and DGNB. Finally, the ÇEDBİK certification system in Turkey includes most of the domains except for transport and environmental impacts as main domain. Nonetheless, these aspects are considered within other domains within the assessment system (Giama,& Papadopoulos, 2012; ÇEDBİK, 2016).

Table 2.14: The rating systems comparison (Giama,& Papadopoulos, 2012; ÇEDBIK, 2016;  Mattoni, et al, 2018)

| **Environmental aspects** | **BREEAM** | **LEED** | **HQE** | **DGNB** | **CASBEE** | **ÇEDBIK** |
|---|---|---|---|---|---|---|
| Management | ✓ | ✓ | Not as a separate aspect, but included in the assessment targets | ✓ | ✓ | ✓ |
| Energy efficiency | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Transport | ✓ | Included in the environmental aspect 'sustainable sites' | Not as a separate aspect, but included in the assessment targets | Included in the environmental aspect 'sustainable sites and functional quality ' | ✓ | - |
| Sustainable | ✓ | ✓ | ✓ | ✓ | ✓ | - |
| Indoor environmental quality | ✓ | ✓ | ✓ | Not as a separate aspect, but included in the aspect 'sustainable sites and functional quality ' | ✓ | ✓ |
| Water efficiency | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Materials | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Socio-economic aspects | - | - | ✓ | ✓ | ✓ | ✓ |
| Innovation | ✓ | ✓ | - | - | - | ✓ |
| Environmental impacts | Not as a separate aspect, but included in the assessment criteria (pollution, land use and ecology) | ✓ | ✓ | Included in the environmental aspect 'ecological quality' | ✓ | - |

**Table 2.15:** A Broad comparison of the certification system (Giama & Papadopoulos, 2012; Yusoff & Wen, 2014 ; Bernardi,et al, 2017)

| Criteria | BREEAM | LEED | HQE | DGNB | CASBEE | ÇEDBİK |
|---|---|---|---|---|---|---|
| **Country** | UK | USA | France | Germany | Japan | Turkey |
| **Certification Body, year** | BRE<br>1990 | USGBC<br>1998 | HQE Association<br>1994 | DGNB auditors<br>2007 | JSBC<br>2001 | TGBA<br>2007 |
| **Main type of examined buildings** | New/existing<br>Renewed<br>Commercial<br>Retail<br>Education Homes<br>Hospitals | New/existing<br>Renewed<br>Commercial<br>Retail<br>Education Homes<br>Hospitals | New/existing<br>Offices<br>Logistics, Hospitals<br>Education<br>Hospitality Buildings<br>Commercial | New/existing<br>Offices , Retail<br>Shopping Buildings<br>Laboratories<br>Schools, Industrial<br>Homes<br>Mixed Use, Hospitals | New/Existing<br>Renewed<br>Urban development<br>Cities<br>Residential Property appraisal | Residential |
| **Certification** | Pass. Good.<br>Very Good.<br>Excellent<br>Outstanding | Certified. Silver.<br>Gold.<br>Platinum | Good (1 to 4 stars). Very good (5-8 stars).Excellent (9-11 stars).Exceptional (12 stars and higher) | Bronze (35%)<br>Sliver (50%)<br>Gold (at least 65%) | S, A, B+, B and C. | Approved, Good, Very Good, Excellent |
| **Building Phases** | Design<br>Maintenance<br>Construction<br>Operation<br>Renewal | Design<br>Maintenance<br>Construction<br>Operation<br>Renewal | Design<br>Maintenance<br>Construction<br>Operation<br>Renewal | Maintenance<br>Construction<br>De-construction<br>Operation<br>Renewal | Design Operation<br>De-construction<br>Construction | Design, construction maintenance and operation |
| **Assessment types** | Design & procurement<br>Operation & Management<br>Post-construction | Construction review<br>Design Review<br>Combined design & construction review | Construction review<br>Design Review<br>Combined design & construction review | Maintenance<br>Construction<br>De-construction<br>Operation<br>Renewal | Planning<br>Pre-design design<br>Renewal | Construction review Design Review Combined design & construction review |

Continuation of Table 2.15.

| Criteria | BREEAM | LEED | HQE | DGNB | CASBEE | ÇEDBİK |
|---|---|---|---|---|---|---|
| **Categories** | Health &Comfort Management Transportation Energy, Water Pollution Land Use & Ecology Resources Waste Innovation(extra) | Sustainable Sites Energy Atmosphere Water, Efficiency Material, Interior Environment Quality Design Innovation Resources Local Priority | Eco-construction Health Well-being Management | Location Quality Environmental Quality Socio-cultural Quality Economical Quality Technical Quality Process Quality | Environmental, Quality (Q). Environmental Load (L). Indoor Environment Quality of Service, Outdoor Environment., BEE (Building Environmental Efficiency) = Q/L. Energy, Resources and Materials, Off-site Environment | Integrated Green Project Management, Land use, Water use, Energy use, Health and comfort, Material usage, Living in the residence, Operation and maintenance, Innovation |
| **International Versions and National Adaptations** | **International** versions: Nondomestic refurbishment, In-use **New construction**: buildings National adaptations: United Kingdom, USA, Germany, Netherlands Norway, Spain, Sweden, Austria | **International versions:** LEED v3.0 for new construction and major renovations LEED for homes LEED for core and shell, LEED for existing buildings: operations, retail , maintenance LEED for commercial interiors LEED for schools, **National adaptations:** Argentina, Brazil, Italy | **International versions:** Non-residential building in operation 2015 Infrastructures 2015, Habitat and environment Nonresidential building under construction 2015 Residential building under construction 2015 Management system for urban planning projects 2016 | **International version** Core 14 **National adaptation:** Austria, Bulgaria China, Denmark Germany Switzerland Thailand | N/A | - |

Table 2.15 shows the different green building certification systems compared in this research in terms of their establishing country, system establishment date and certification body. Furthermore, the table shows the different types of buildings covered under each system, where DGNB has the most types of classification. The assessment scale domains are also shown, which varies in its inclusions and complexity. Further information is shown such as the certification types, building phases covered under each system, and the assessment strategy types.

Based on a comparison between the included alternatives in this research, there are general comparison points between the certification systems as the following (European Urban Knowledge Network, 2014 ; Erten, 2009; Bernardi, et al ,2017)

1. The whole rating systems which are used in order to evaluate the environmental effect of buildings are appropriate for both the new and present buildings .

2. All types of building can be evaluated by the use of BREEAM, CASBEE, DGNB, and HQE whereas LEED does not protect the industrial .All the life cycle stages of the building are covered by BREEAM, CASBEE, DGNB, and HQETM.

3. In terms of the classifications which can be evaluated by the schemes, the most considered classifications include solid waste management, material, energy performance and water.

4. The most resistance categories against the natural disasters and prevention of earthquake are the classifications which are considered less.

5. None of the certification systems have an expiry date, except for CASBEE which its certification expires after five years and can be renewed at the end of the period for an additional five years .

6. Some of the green building certification systems offer over-scale-points for innovation such as BREEAM and LEED .

7. LEED provides the designers with a high level of standardization, which presents LEED as an easy tool to use.

8. BREEAM provides online resources for assessment. However, the agents are more used in the design process.

9. All green building assessment and certification system have prerequisites except HQE. Certifications such as LEED and BREEAM have twelve prerequisites.

In summary, it must be mentioned that these schemes are basically accepted and commonly used in the building sector. The desirable features of these schemes in the future can be explained as follow :

• Completeness which refers to the analysis in a suitable method the whole factors which characterize the building and its life cycle.

• They can be represented in clear method the system of weighting and supporting the counting system with complete evidence.

Furthermore, certification systems such as DGNB has several advantages with an early stage assessment that helps the project to stay on track within the required completion time. Moreover, the detailed definition of the processes eliminates any risking during the implementation of the requirements from the designer and owner perspective. DGNB is considered one of the mature systems that covers not only the environmental aspects of the projects, but also the economic, social, cultural, and functional aspects. For the designers, DGNB is always updated and shared with the relevant parties, while the structure of the guidelines is easy to understand for smooth implementation (Miranda, 2013)

Energy and recycling are one of the most important topics in all of the certification system; however, the approach may vary from one system to another. For instance, while BREEAM works mainly on the energy efficiency and lessening the $CO_2$ emission, LEED focuses on lessening the cost of energy which affects subsequently the emissions (Banani & Elmualim, 2011). Another factor that is different between the different certification systems is the ease of international adaption. certification system such as DGNB are highly flexible for international use from climatic, regulatory, and cultural perspectives, where its indicators are balanced to reflect the importance of all the input factors (Reith & Orova, 2015). Based BREEAM is considered one of the international standards which can be adopted, operated and applied by a set of the international professionals. The operation of BREEAM by the clients work on decreasing the environmental impacts of the buildings. BREEAM has been applied in more than 70 countries in order to certify more than 530,000 building evaluations over the life cycle of building (Global, 2016).

There are other certification systems which have their own unique way of assessment, such as CASBEE, which was developed from scratch without depending on any other certification systems. The weighing system used in CASBEE is relatively different from other systems, which forces the designers and implementors to account for all the green building requirements in its manual (Fauzi & Malek, 2013). Other aspects are absent from other certification systems such as LEED, which lacks economic and acoustic assessment criteria that are available in BREEAM and DGNB (Yuce, 2012) There are criteria that are better enforced in some certification systems better than other such as material local supply, which is strongly required by BREEAM while it is less addressed in LEED and CASBEE (Banani, R , Vahdati , & Elmualim, 2011)

The certification process does not imply any apparent difference between the different tools, which requires the projects' owners or designers to register their projects and submit the relevant documentations. Some certification systems require a third party that reviews the compliance of the project against the set criteria and issues a report to the certifying body for review and issuance (Hamedani & Huber, 2012).

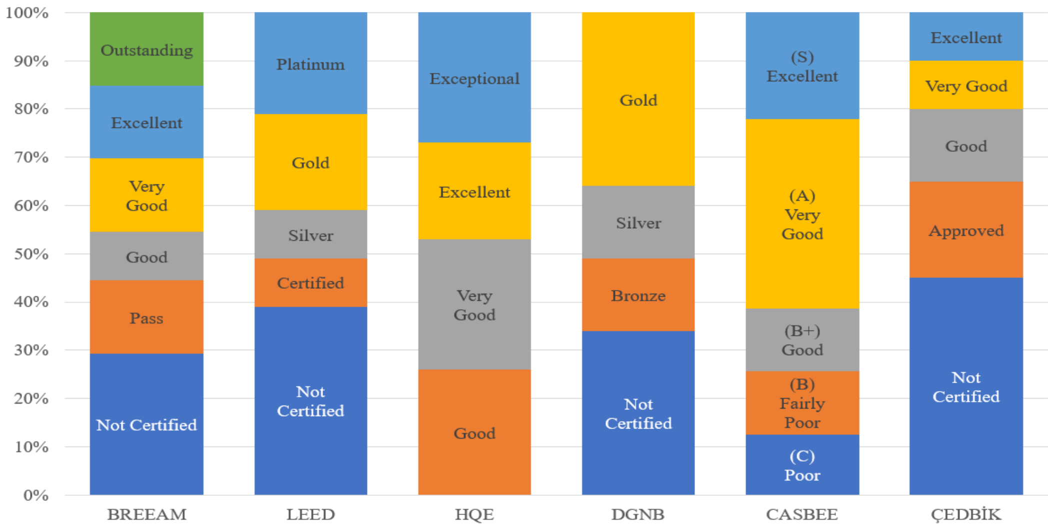



**Figure 2.10:** Comparison between green building certification systems according to scoring scale.

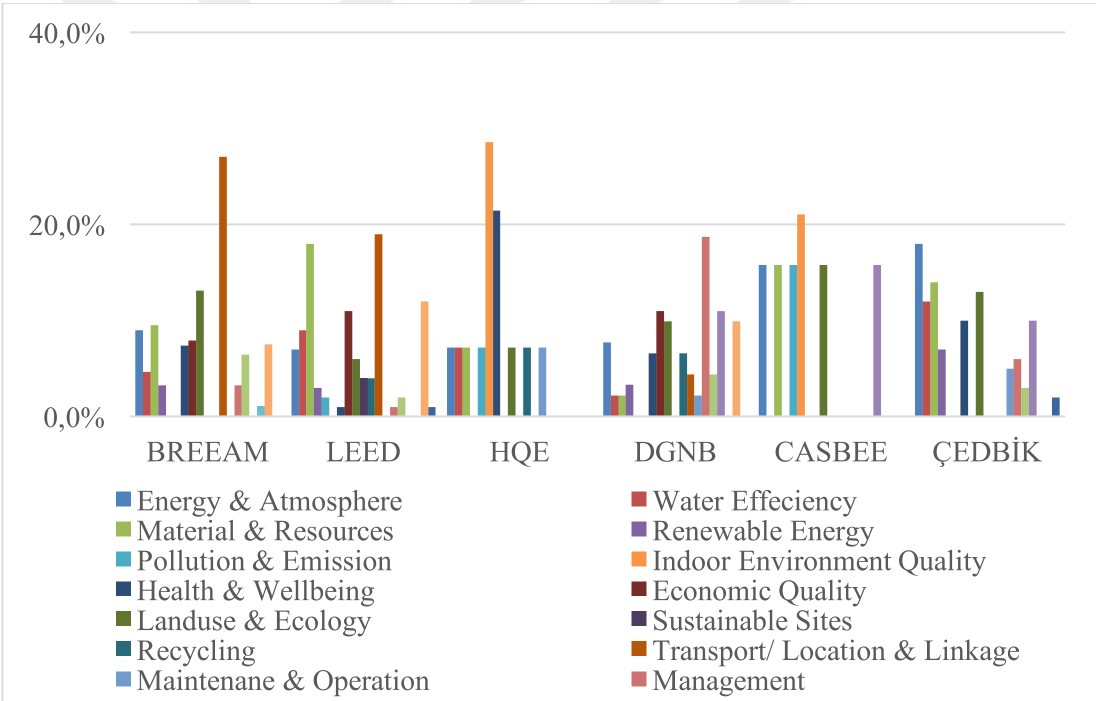



**Figure 2.11:** Comparison between green building certification systems criteria and weights.

Figures 2.11 and 2.12 show the criteria weights comparison between the different green building certification systems and the certification scoring scale, respectively. It is shown through the graph that the BREEAM system gives the highest weight for the transportation criteria, while LEED gives the highest weight for material and sources. HQE, however, focuses on indoor environmental quality similar to CASBEE, and DGNB gives the highest weight for management. The Turkish certification system ÇEDBİK gives the highest weight to the energy and atmosphere criterion.

On the scoring system, the certifications start with a buffer where projects that do not achieve the minimum points are not certified or labelled as poor ranging between 12% to 45% depending on the system. The scoring scale divisions also vary between the different systems. While DGNB and HQE has three certification scoring categories, BREEAM has five scoring categories as the largest division among the compared systems. Each of LEED, CASBEE and ÇEDBİK have four scoring categories.

## 2.9. Criteria Affecting the Choice of Green Buildings Certification System

There are several criteria affecting the choice of certification systems for green buildings. One of those criteria is that the development economic aspect hardly contributes to accountability. This shortage does not allow for evaluating the economic consequences of the sustainable choice and therefore creates a key restriction for the certification systems of sustainability. Without doubt, by ignoring the economic aspects evaluation, the certification systems of sustainability conflict with one of the development aspects and allow further logical concept for sustainable selections and that is highly criticized. This method is interesting in the field of construction as the analysis of life cycle cost (LCC) gives a familiar example for the stakeholders of construction (Ding, 2008). Furthermore, the certification systems vary from one to another in terms of economic, artistic, cultural, social, and functional aspects. However, there is a vital need for a progressive comprehensive method that does not take into account external effects, life cycle effects as well as social and economic aspects (Berardi, 2012)

The social and economic assessments have been developed lately; as it is now obvious that the life-cycle cannot be the only assessment category due to the economic and social equality (Gibberd, 2005). Moreover, the green building certification systems assessment is indeed challenging because every system has its particular collection of criteria. Because of this, a complete collection of sustainability measures need to be gathered to evaluate the level of a certification system and in turn evaluating the certification systems. There is no doubt that every criterion is significant for achieving sustainability. Yet, particular criteria have more effect than the others (Berardi, 2012). Furthermore, every criterion has a specific number of points on the entire assessment, where the overall assessment of sustainability happens by gathering the outcomes of the assessed criteria (Hahn, 2008). Thus, the entire criteria will be ordered into three groups of importance: very important, important, and less important, as illustrated in Tables 2.16, 2.17 and 2.18 (Yuce, 2012).

**Table 2.16:** The very important group of criteria (Yuce, 2012)

| Group of Importance | Criteria Group |
|---|---|
| **Very Important** | Energy |
| | Materials |
| | Climate Change |
| | Land Use and Ecology |
| | Water |
| | Waste |
| | Life Cycle Costs |
| | Building Adaptability |
| | Comfort and health |
| | Accessibility of the Building and Access to Transport |
| | Safety and Security |

**Table 2.17:** The important group of criteria (Yuce, 2012)

| Group of Importance | Criteria Group |
|---|---|
| **Important** | Site Selection |
| | Aspects during Construction |
| | Management and Maintenance |
| | Process Quality |
| | Innovation |
| | Usability |

**Table 2.18:** The less important group of criteria (Yuce, 2012)

| Group of Importance | Criteria Group |
|---|---|
| Less Important | Further Environmental Criteria |
| | Further Indoor Environment Criteria |
| | Architectural and Cultural Considerations |
| | Externalities |
| | Planning and Implementation |

One of the challenges suggested by Rogers in the theory of innovation diffusion is the complexity, and if the sustainability and rating systems of sustainability are considered too complex, then the stakeholders of building would slowly accept the practices of sustainability. Therefore, the evaluation systems of buildings need a balance between the complete coverage and the ease of use at the same time (Berardi, 2012).The selection of material takes into consideration few concerns such as the quality, process, performance, cost, and aesthetics. And this procedure in general determine the criteria for material performance. Nowadays, the importance of materials choice has significantly increased for the development process of sustainable performance criteria (Khoshnava, Rostami, Valipour, Ismail & Rahmat, 2016). Furthermore, the buildings and their materials are very durable and therefore have a long-lasting effect on the environment and community (European Union, 2002).

Several studies support this concept and recommend taking the social, environmental, and economical criteria as well as the technical indicators into account (Alwaer & Clements, 2011). Evaluating the buildings technical performance does not mean that the buildings should only be sustainable, but they also need to be smart at the same time (Dirlich, 2011). These international standards must be valid to all regions with their particular socio-cultural, economic, and legal conditions, as well as their specific climate. Therefore, it is impossible to use the same certification system in all the countries (Reed, et al, 2009)

## 2.10. Criteria and Sub-Criteria Selections for Choose Green Building Certification System.

Several criteria were selected according to their use in several research and technical reports for further evaluation certification systems of sustainability. They are significantly important and would impact on the selection of the suitable certification systems. Furthermore, this main criteria and sub-criteria support concept of sustainability for aspects social, environmental and economical. Table 2.19 shows the selected criteria and the sub-criteria which will be applied to the evaluation. The criteria that are presented in the table below shall not be interpreted with the same importance or value. Efficiency mostly addresses the ability and the extent of which the certification system can achieve the green building objectives. The economy criterion assesses the certification systems impact on the project's budget. The usage criterion addresses the easiness of usage and adaptability of the certification system . The time criterion is concerned with the time spent by the stakeholders in order to achieve the certification systems objectives. Finally, the accordance with legislations criterion ensures the alignment of goals between the current legislations and the green building certification system.

**Table 2.19:** Selected Criteria and sub-criteria for AHP analysis.

| Criteria | Sub-Criteria | Reference |
|---|---|---|
| **Efficiency** | Coverage of variety of building types | (Driedger, 2009 ; Portalatin, Shouse, & Roskoski, 2015; Kleist, 2010; Dorßt, 2010; Markelj et al 2014; BREEAM, 2011). |
| | Coverage of Building process (Pre-design to in use) | |
| | Overall success for assessment (success for reducing wastes& increasing energy efficiency) | |
| **Economy** | Cost for registration & certification | (Driedger, 2009; Nicolow, 2008; Ding, 2008; Birgisdottir & Hansen, 2011). |
| | Cost for Implementation added costs | |
| | Cost for consultancy | |
| **Usage** | Ease of use<br>i. Ease of Calculations<br>ii. Ease of labelling | (Driedger, 2009; Portalatin, Shouse, & Roskoski, 2015; Berardi, 2012; Driedger, 2009; Wang, Fowler, & Sullivan, 2012) |
| | Adaptability & Reliability | |
| | Clarity of Criteria &Sub-criteria | |
| **Time** | Certification time | (Markelj, et al, 2014). |
| | Labelling time | |
| | Effects on design & construction | |
| **Accordance with Turkish Legislation** | Accordance with Turkish Legislation | (Seinre, Kurnitski, & Voll, 2014; Markelj, et al, 2014) |
| | Accordance with legislations | |
| | Accordance with procedures | |

The criteria and their sub-criteria were chosen based on their usage in previous studies and technical reports for other sustainability certification system. These criteria are considered important and could affect choosing the appropriate evaluation certification system.

### 2.10.1. Accordance with Turkish Legislation:

This criterion indicates the alignment extent between the requirements and assessment criteria of the green building certification system and the aims of the environmental and urban Turkish legislation in terms of laws building and development standards, and governmental procedures. Moreover, it also indicates the alignment with the current Turkish green building policy (Seinre, Kurnitski, & Voll, 2014; Markelj, et al, 2014)

- Accordance with legislations

This sub-criterion tests the alignment between the five green building tools that are evaluated under this study with the laws and legislations of the Turkish development. Furthermore, it shows the convenience of the usage of the green building tools with the Turkish green building development.

- Accordance with standards

The Turkish developments apply International Building Code (IBC) and the Eurocode taking into consideration the special conditions of the country. Therefore, this sub-criterion takes indicates the convenience of using the six green building tools with the current standards implemented in Turkey.

- Accordance with procedures

Every country has a certain nature of development and construction procedures. Thus, this sub-criterion shows the alignment between the currently implemented procedures in the construction and urban development industry and the procedures required by each green building certification system.

### 2.10.2. Economy (Cost):

This criterion evaluates the economic aspect of the green building certification system in terms of costs and financial feasibility to the Turkish projects. Therefore, three sub-criteria are assessed under this category which are the registration and certification costs, implementation added costs and the cost required for consultancy fees. (Driedger, 2009; Nicolow, 2008; Ding, 2008; Birgisdottir & Hansen, 2011).

- Cost for registration & certification

This sub-criterion evaluates the projects registration and certification costs required by each green building certification system. The cost is compared between each tool and the total cost imposed on the projects.

- Cost for Implementation added costs

There are costs imposed on the projects depending on the requirements of the green building certification system, which effectively impact the material and the assemblies used in the design and the construction phases of the project. Therefore, during the project budget estimation process, the designer and the cost estimator need to take into consideration the amount added by implementing the green building policy required for certification.

- Cost for consultancy

Additional manpower that includes Engineers, consultants and managers is required in order to plan, implement and monitor the execution of the project in accordance with the chosen green building certification system. Hence, imposing additional overheads on the project's budget. Moreover, the complexity and the familiarity with the tool may require the owner of the project to employ a consultancy firm which has the expertise in planning and monitoring the green building requirements.

### 2.10.3. Time (Duration):

Since time imposes additional costs on the project, this criterion is essential to understand the implications of adopting a green building assessment tool on the timeline of the project. Furthermore, the time needed to implement a green building assessment tool requires studying the time required for certification in order to obtain the completion certificate from the authorities, the labelling time, and the additional time required to incorporate the tool's requirements into the project design and construction phases ( Markelj, et al. 2014)

- Certification time

This sub-criterion evaluates the time required to obtain the certification from inception to completion, which could have a direct relation with the complexity of the green building assessment tool's requirements and procedures. Moreover, since the green building policy is set by the concerned authority, this sub-criterion may impact the final completion date of the project based on the final completion certificate.

- Labelling time

The time needed to identify the elements affected by the green building certification system and implement the requirements into the project. Therefore, this sub-criterion evaluates the complexity of the requirements and the time added due to the availability of the necessary resources according to the assessment tool.

- Effects on design & construction

Since the green building certification system becomes an essential part of the project, it is evident that there is an added time that affects the overall design and construction schedule of the project. Therefore, based on the tool's requirements, this time could be estimated and incorporated into the master schedule through extending the affected activities.

#### 2.10.4. Implementation (Usage):

This criterion evaluates the easiness in using the assessed green building tools through the complexity of their procedures, requirements and legislations. Moreover, the criterion evaluates the clarity of the tool's requirements and procedure that need to be comprehended by the local market (Driedger, 2009; Portalatin, Shouse, & Roskoski, 2015; Berardi, 2012; Driedger, 2009; Wang, Fowler, & Sullivan, 2012)

- Ease of use
    - Ease of Calculations
    - Ease of labelling

This sub-criterion tests the green building certification system through the easiness to calculate the possible and earned points through the aspects of the projects in order to have a clear understanding of the project goals. Furthermore, the labelling easiness, which emerges from the nature of the procedures and policy adopted by the tool, plays a major role in increasing or decreasing the usability of the green building certification system.

- Clarity of Criteria &Sub-criteria

Since the green building certification systems are based on different standards and requirement in the country of origin, the language used in narrating the requirement needs to be evaluated in order to avoid any miscommunication with the certifying body. This sub-criterion is one of the reasons consultancy might be needed for the project, which subsequently impact the cost of the projects.

- Adaptability & Reliability

This sub-criterion measures the acceptance of the tool by the local Turkish market and easiness to adaptation of its requirements by the projects. Furthermore, the criterion evaluates the reliability of the green building assessment tool to acquire an international recognition for the projects, in addition to achieving the green building aims of the country.

### 2.10.5. Competence (Efficiency):

This criterion assesses the efficiency of the green building certification system in covering the several building and project types that are implemented in Turkey, in additional to providing the needed regulation to guide the project throughout its lifecycle. Moreover, the evaluation includes the efficiency of the tool in reducing the waste and increasing the energy efficiency (Driedger, 2009 ; Portalatin, Shouse, & Roskoski, 2015; Kleist, 2010; Dorßt, 2010; Markelj et al 2014; BREEAM, 2011).

- Coverage of a variety of building types

This sub-criterion examines the coverage of the green building certification system to the different building types in terms of policy, procedures and requirements. Furthermore, the evaluation includes the tool taking into consideration the impact of the different building types on the environment, therefore, adopting different strategies for the different types.

- Coverage of Building process (Pre-design to in use)

This sub-criterion evaluates the coverage of the green build certification systems procedures to the lifecycle of the project from the pre-design stage to the operation stage.

- Overall success for assessment (success for reducing wastes& increasing energy efficiency)

This sub-criterion assesses the efficiency of the green building certification system in achieving the green development aims and the country's specific green development objectives by reducing waste and increasing the energy efficiency of the project.

# 3. METHODOLOGY

## 3.1. Multi-Criteria Decision Making (MCDM)

In order to be able to handle decision making for complex technical issues, the experts in the field have always preferred the multi-criteria decision-making tools as way to technically maximize benefits and minimize costs (Pohekar & Ramachandran, 2004). The process involves several steps as shown in figure 3.1. The process starts with setting the criteria that comparison is based on, as well as the options that are compared through the MCDM method. Thereafter, the MCDM process is selected and the performance evaluation is carried out and the parameters that awaited from the process. Based on those steps the shortlisted options are revised. The method is carried out and the results are obtained with the final decision targeted from the process.

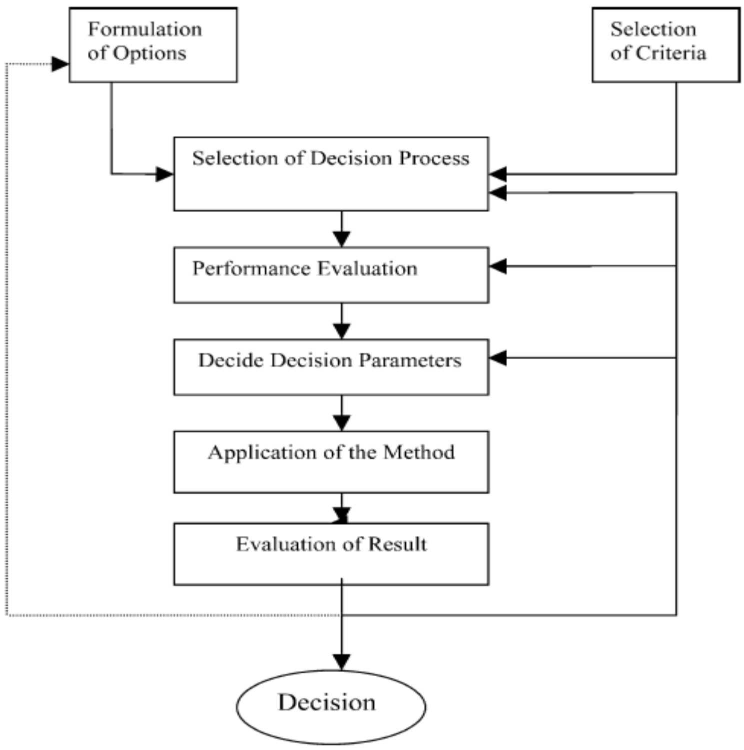



**Figure 3.1:** Multi-criteria decision-making process (Pohekar & Ramachandran, 2004)

Therefore, several multi-criteria decision-making techniques have been deployed, such as (Pohekar & Ramachandran, 2004):

- Weighted Sum Method (WSM): considered the simplest MCDM method.
- Weighted Product Method (WPM): similar to WSM but uses a different mathematical model.
- Analytical Hierarchy Process (AHP): used for complex decision making where several criteria and sub-criteria are provided.
- Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE): using geometrical analysis that takes into consideration the preference and priorities of the decision makers.
- Elimination and Choice Translating Reality (ELECTRE): using binary outranking relations to determine preferences.
- Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS): which compares the alternatives to ideal solutions available in the process.
- Comparison Programming (CP).
- Multi-Attribute Utility Theory (MAUT): focuses on the objectives of the comparison process.

There are specific steps for multi-criteria decision making that shall be followed in the following order (Majumder, 2015):

1. Setting the aim and the objectives of using the decision-making process.
2. Choosing the criteria and sub-criteria that are used for assessment.
3. Choosing the subjects that needs to be compared.
4. Choosing the specific MCDM method in order to represent importance.
5. Aggregation method
6. Making the decision based on the results of the aggregation.

Moreover, in order to ensure the working according to accurate guidelines and working principles as the following (Majumder, 2015):

1. The used criteria shall be selected in coherence with the decision, not dependent on each other, represented through the same scale, can be measured, and related to the subjects to be assessed.
2. The subjects (alternatives) shall be available for assessment, can be compared, used in reality and feasible to decide for if selected.
3. The researcher shall be aware of the type of MCDM method and its type, i.e. compensatory using scoring or out-ranking using elimination.
4. The aggregation method shall be suitable to be a product, an average and a function.

For the benefit of this research and based on its type and required outcomes, the AHP method is selected in order to carry out the process of decision making between the green building certification systems. The AHP method is selected in order to make a conclusion of the best fit green building certification system based on certain criteria and its importance for the Turkish context. Such a method would take into consideration the different aspects covered by the certification systems and all the pros and cons that are associated with each one.

The AHP method is chosen amongst the MCDM methods as it can be used for individuals and groups by creating hierarchical structure and pairwise comparison matrices in support of complex decision making. Moreover, the AHP method is known for its flexibility, ease of use and adaptability. The AHP method requires consistency measurement, as it uses a pair wise comparison of tangible and intangible criteria. The AHP method gives consistent results for every decision making process; however, the evaluation is carried out linearly. A comparison with other MCDM methods is shown in Table 3.1.

**Table 3.1:** Comparison between MCDM different methods (Harputlugil, et al., 2011)

| | **AHP** | **ANP** | **PROMETHEE** | **SAW** | **TOPSIS** |
|---|---|---|---|---|---|
| **Decision Making** | Individual and Group | Individual and Group | Individual and Group | Individual & Group | Individual and Group |
| **Methodology** | Creating hierarchical structure and pairwise comparison matrices | Creating hierarchical structure and pairwise comparison matrices | Creating matrix structure and comparing pairs of alternatives to form an outranking relation | Creating matrix structure and calculating a global (total) score foreach alternative by adding contributions of alternative with respect to each attribute | Creating matrix structure and calculating distance to positive and negative ideal poin |
| **Areas of Usage** | To support decision making for complexity | To support decision making for complexity | To support decision making for complexity | To support decision making for complexity | To support decision making for complexity |
| **Adaptability/ Flexibility** | + easy to adapt case specific | + easy to adapt case specific | - not easy to adapt | - not easy to adapt | - not easy to adapt |
| **Consistency Measurement** | + | + | No need | No need | No need |
| **Weighting System** | Pair Wise comparison | Pair Wise comparisons | No specific method. | No specific method. | No specific method. Linear or vector normalization |
| **Criteria Evaluation** | Tangible and intangible criteria | Tangible and intangible criteria | Tangible criteria | Tangible criteria | Tangible criteria |

Continuation of Table 3.1.

| | AHP | ANP | PROMETHEE | SAW | TOPSIS |
|---|---|---|---|---|---|
| **Pros** | Can give consistent results for every decision making process | Easy to implement, expressive power of modeling | Low level of interaction with decision maker (It may be defined as a negative issue for integrated design teams for assessment of design quality) | Low level of interaction with decision maker (It may be defined as a negative issue for integrated design teams for assessment of design quality) | Low level of interaction with decision maker (It may be defined as a negative issue for integrated design teams for assessment of design quality) |
| **Cons** | Linear evaluation | Several pairwise comparison questions. Complex survey process for non-expert participants | Identifying thresholds, incomparable results | Very easy, can give unreliable results | Easy, can give unreliable results |

### 3.2.AHP Method

AHP was first introduced by Thomas Saaty in 1980 in order to be used in taking complex decisions that are based on a defined criteria and sub-criteria. The methodology mainly depends on comparing the importance of the criteria against each other in pairs, which leads into weighing the options and giving the most relevant result. The main advantage of using the AHP method is ensuring the consistency between the results given by the experts (Saaty, 1980). The AHP method is used in different domains and industries, in addition to its usage by leading corporations and governmental institutes, which proves its reliability in complex decision making (Bhushan & Rai, 2007).

The AHP method simplifies the steps and questions of the main problem for the study and the decision makers through a step by step analysis. There are six main steps in implementing the AHP method, which are as the following (Bhushan & Rai, 2007):

Step 1: assigning the main aim of the decision-making problem and defining the criteria and their sub-criteria of which the decision must be evaluated. The inventor of the method advices that the best way to structure the method is by using a tree structure that narrates the main goal down to the sub-criteria, then the options that are included in the decision making, as shown in the Figure 3.2. At each level of criteria, the factors are compared in a pairwise manner.

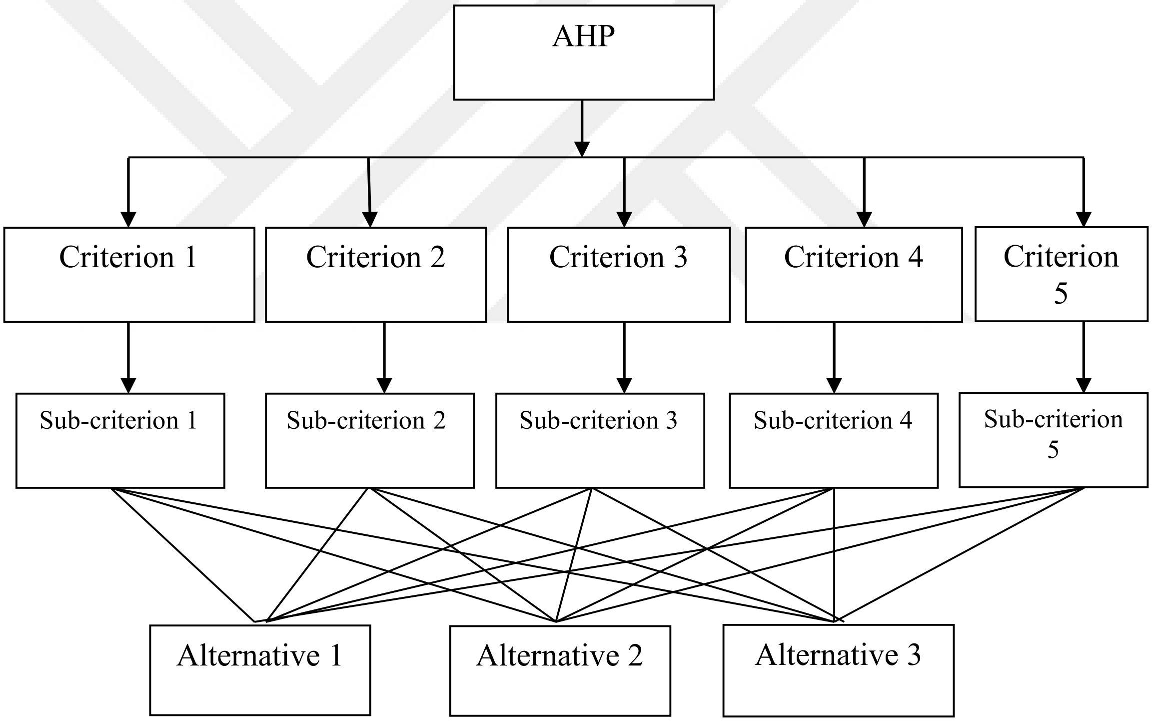



**Figure 3.2:** AHP Hierarchy (Saaty, 1980)

Step 2: collecting the data from the experts based on the pairs that are produced from the AHP structure at each level. The experts assign the strength of the relationship between each pair on a 9-degree scale, According to Saaty (2008), by defining the criteria and the sub-criteria that are influential in the decision making, the relation between each two criteria is assigned to an importance, intensity score from 1 to 9, which reflect the contribution comparison between each two criteria with respect to the main aim of the study, and each two sub-criteria with respect to their main criteria. Table 3.3 shows the AHP scoring.

**Table 3.2**: AHP importance intensity (Saaty, 2008)

| Importance Intensity | Classification | Description |
|---|---|---|
| 1 | Equal importance | Two criteria that are exactly equal in contributing to the aim |
| 2 | Weak | |
| 3 | Moderate importance | There is a slight favor to one of the criteria from experience and judgement |
| 4 | Moderate plus | |
| 5 | Strong importance | There is a strong favor to one of the criteria from experience and judgement |
| 6 | Strong plus | |
| 7 | Very strong | From practical results, one of the activities is very strongly favored over the other |
| 8 | Very, Very strong | |
| 9 | Extreme importance | When there is no doubt of one activity dominance over the other one |

Step 3: constructing a matrix that assign the relation between the different pairs on (i, j) manner, as shown in the Figure 3.3. If the value is bigger than 1, this means that the criteria in row (i) is better than the criteria in column (j), and vice versa.

$$
\begin{pmatrix}
W1\backslash W1 & W1\backslash W2 & W1\backslash 3W & \ldots\ldots & W\backslash Wn \\
W2\backslash W1 & W2\backslash W2 & W2\backslash W3 & \ldots\ldots & W2\backslash Wn \\
W3\backslash W1 & W3\backslash W2 & W3\backslash W3 & \ldots\ldots & W3\backslash Wn \\
\ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \\
Wn\backslash W1 & Wn\backslash W2 & Wn\backslash W3 & & Wn\backslash Wn
\end{pmatrix} = A
$$

**Figure 3.3:** Scale of importance intensities (Saaty, 1980)

Step 4: the relative importance of the criteria compared in the matrix is given by the principal and normalized right eigenvalues, which the last represents the weights between the different criteria and the alternatives.

Step 5: the evaluation of matrix consistency is performed; however, the evaluation and acceptability of the consistency is subjective in accordance with the redundancy of the method. This is indicated through the consistency index (CI), which is calculated from the equation:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

The consistency index is required to reach a certain level in order to accept the results of the study. In the above equation, the λ_max-n represents the maximum eigenvalue. Another indicator is calculated, which is the random consistency index (RI) given by Saaty through the below table based on n value.

**Table 3.3:** For calculate the random consistency index (RI) (Saaty, 1980)

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

Thereafter, the consistency ratio is calculated by dividing the consistency index (CI) on the random consistency index (RI), where the recommended value by the AHP inventor is 0.1 or less.

Step 6: the initial rating of the different decisions and the weights of the sub-criteria are multiplied together in order to produce a rating that is then multiplied by the weights of the criteria. This final step produces a final score for each decision based on the importance of the criteria and sub-criteria that are given by the experts.
In a study that examined the AHP methodology in quality aspects judgement in architectural design, the authors developed a step by step method in order to carry out the process (Harputlugil, Gultekin, Prins, & Topcu, 2014). The second step was developing the AHP structure as shown in Figure 3.4.

The third step of this process is deploying a software in order to set priorities based on the importance of the chosen criteria. In any AHP process, following the modelling of the problem which has been done through the previous steps, a researcher needs to then perform weights valuation, weights aggregation and sensitivity analysis (Ishizaka & Labib, 2009). Each criterion is assigned to a score based on a pairwise comparison with another criterion. Therefore, each main criterion is compared to another main criterion, and each sub-criterion is compared to another sub-criterion under the same main criterion, which fills the comparison matrices (Ishizaka & Labib, 2009).

Furthermore, the priorities need to be derived based on the scoring that was developed in the previous step and all matrices are checked for consistency. Thereafter, the aggregations of the scores produces the final decision-making tool. Finally, a sensitivity test is performed by slightly altering the scoring of few criteria in order to understand their impact on the final decision making (Ishizaka & Labib, 2009).

The hierarchy structure explained for the AHP method is established in this study, as shown in Figure 3.4 developed by the researcher. The main goal of the study is to develop a methodology to establish identify a green building certification system for Turkey, and choosing the most influential criteria and sub-criteria that would affect this process. Identified as finding the best fit green building certification system for

Turkey through establishing a methodology to develop a system. The method takes into consideration the criteria and sub-criteria that shall be taking into account in the development process. The second step was identifying the type of experts that are included in the study, which are academicians, consultants and government Decision Makers . Furthermore, the criteria and sub-criteria tested through the AHP method are compiled from the literature as shown in Table 2.18 by identifying the criteria that were used in previous studies in the analysis and judgement of the green building certification systems. Finally, the alternatives that are intended to be studied as a benchmark for the future Turkey's certification systems are chosen as BREEAM, LEED, DGNB, CASBEE and HQE. These systems are chosen based on their popularity internationally and the level of maturity. Those nine experts were chosen from three backgrounds; 3 academicians, 3 government decision makers and 3 consultants, as shown in Table 3.4. The experts were selected based on their experience in the sustainability and green building certification domains in Turkey. Moreover, the different types of experts are involved in order to provide a feedback that is based on all stakeholders that are involved in the assessment and certification process.

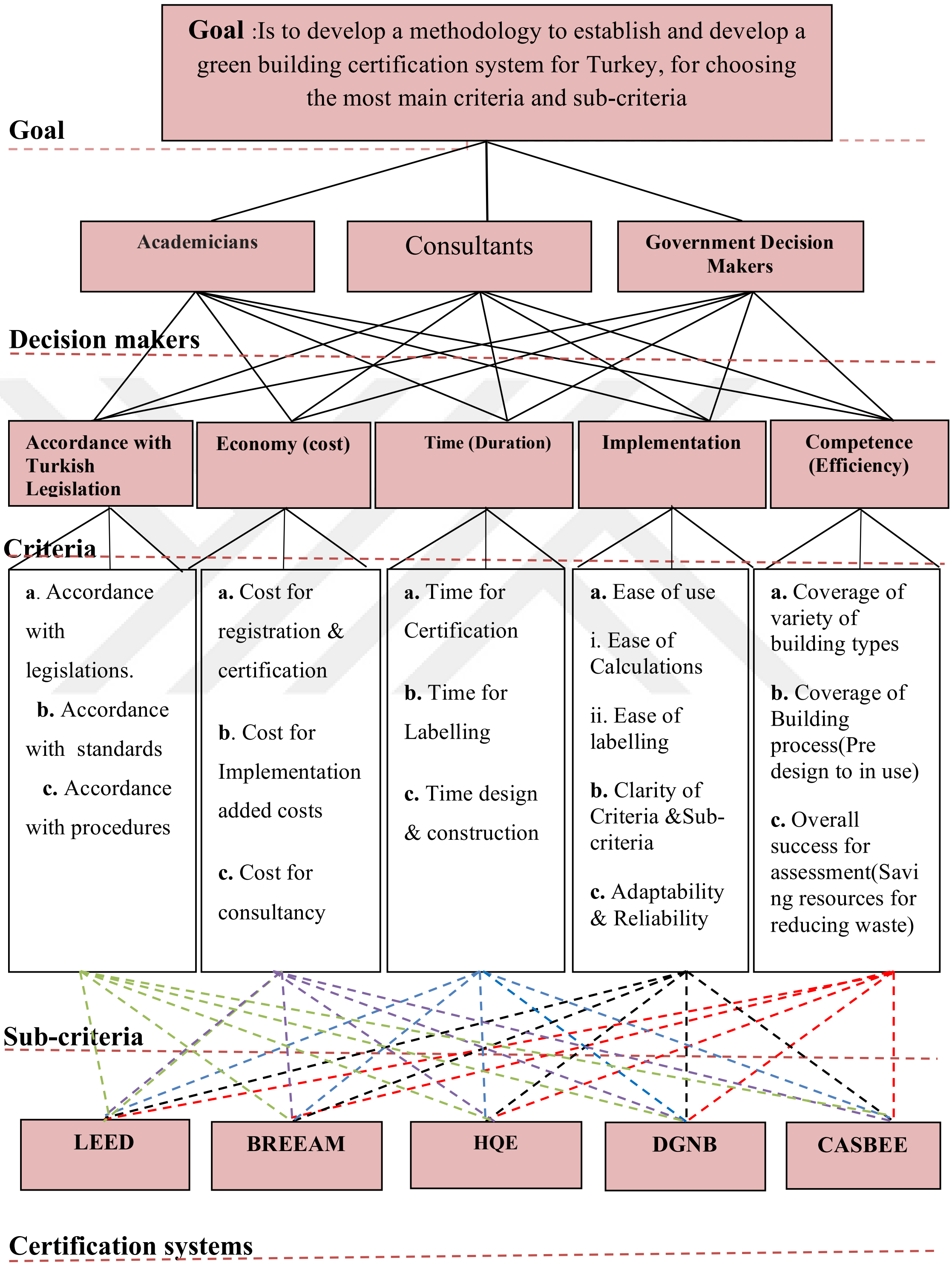



**Figure 3.4:** Analytic Hierarchy Process Method (AHP)

**Table 3.4:** Experts participating in the study.

| Expert Background | Names |
|---|---|
| Academicians Experts/ Scholars | Prof. Dr. Gülser ÇELEBİ |
| | Assoc. Prof. Dr. Idıl AYCAM |
| | Assoc. Prof. Dr. Arzuhan BURCU GÜLTEKİN |
| Consultants | Tolga UZUNHASANOĞLU |
| | Müge EMEN |
| | İsmail ENGİN SEKER |
| Government Decision Makers | Samet YİLANCİ |
| | Yildiz AGAYA |
| | Esra TOMBAK |

# 4. IMPLEMENTATION

There are several green building certification systems around the world, which differ in characteristic, strengths, and weakness. The criteria of certification systems can influence the identification of the best certification system.

The research has been made through the following steps:

1. Studying five green building certification systems and comparing them based on the criteria used in each one of them.
2. Through the literature review, the most important criteria for certification systems have been compiled.
3. Choosing the AHP method
4. Choosing the experts that can participate in the study.
5. Conducting interviews in order to compare the set of criteria and the five assessment tools.
6. Using the AHP software (Expert choice 11.5 academic version) in order to reach to the purpose of the research.

Thus, this research aims to choose the most important criteria that affect the choice of the best green building certification system for Turkey. Furthermore, five green building certification systems will be compared to determine the strengths and weakness of each certification system.

The five certification systems that have been chosen are BREEAM, LEED, DGNB, CASBEE, HQE . In addition to the current Turkish certification system CEDBİK.

- These certification systems were chosen due to**:**
- They are the most common tools.
- Most widely used around the world.

- They provide a comprehensive, comparison that covers a wide group of global criteria.
- In addition to providing a clarification of the most important criteria for choosing the best certification system.
- Creating a higher opportunity for the spread of green buildings in Turkey.
- Encouraging the adopting of suitable certification systems for future sustainable development in Turkey.

A comprehensive research was conducted on the most relevant specialists in both the private and public sectors in Turkey. Nine experts were chosen from different institutions: Government decision makers, consultants, academicians. As they considered are to represent the set of experts as the main decision makers and users for the green building certification systems in Turkey. Those participants represent comprehensive views of the evaluation process for buildings in Turkey. In addition to that, those institutions are effective, and they reflect the three pillars of sustainable development**,** environmental, economic, social.

Those participants were chosen based on their extensive experience in the sustainability and green buildings' development in Turkey. Furthermore, the selection of the experts' panel was based on several criteria according to their experience, specialty in green building and sustainability, and the several research efforts that have been made by them in the domain. The criteria are shown in the Table 4.1 and explained as the following:

- Their specialties: Green building assessment, auditing and certifications. The specialist needs to be aware of the current regulations and standards in Turkey and internationally in the green development domain.
- Years of experience: the amount of years shall reflect an extensive knowledge in the domain of green buildings and sustainability. Moreover, the number of years shall reflect seniority and a managerial level.

- Publications: which are results of research in the domain. The specialists were selected based on their contribution to the scientific domain with publications, journals and researchers.

**Table 4.1:** Description of participants.

| | Specialty | Years of Experience | Specialty |
|---|---|---|---|
| Academicians | Sustainability and green buildings | + 10 years | Publications Related with the green building |
| Consultants | Green building assessment | + 10 years | Project involved in Green building certification system |
| Government Decision Makers | Environmental legislations | + 10 years | Participating in the control group of national certification system |

They were classified participants into three categories**:**

- Government decision makers
- Academicians
- Consultants

From Ministry of Environment and Urbanization, Consultancy Company, and different universities this variety in the institutions and participants provides satisfactory results for their experience each in their fields.

The interviews were arranged**:**

• The interviews were arranged with the participating experts through email communication, then direct interviews with each one of them (face to face), which approximately took 45 minutes on average. Table 4.2 presents more details about the participants.

The questionnaire form used in the study is based on the compiled information through the literature, which is related to the subject, as well as building a set of criteria and sub-criteria for the different alternatives. The hierarchy diagram was built as shown in the third chapter, and building the questionnaire form based on a pairwise comparison between the different criteria and sub-criteria. Further to conducting the interviews with the experts and academic, the results are evaluated software (Expert Choice version 11.5), where the consistency ratio was tested to be below 10% according to AHP methodology.

Given the interview process discussed earlier, there are pros and cons for the interview process as it can be used for more than one purpose, although the process of organizing each expert according to their time schedule and travelling to different cities in order to conduct the interviews can be considered a minor disadvantage. Furthermore, a good understanding of the AHP methodology is needed in order to achieve the most accurate and reliable results.

A pilot study was conducted with three students prior the interview process in order to assess the questions in terms of quality, acceptability and period taken to complete answering all the questions. The pilot study also aimed to ensure that the questions are practical, understood and reasonable, and test the validation of the survey.

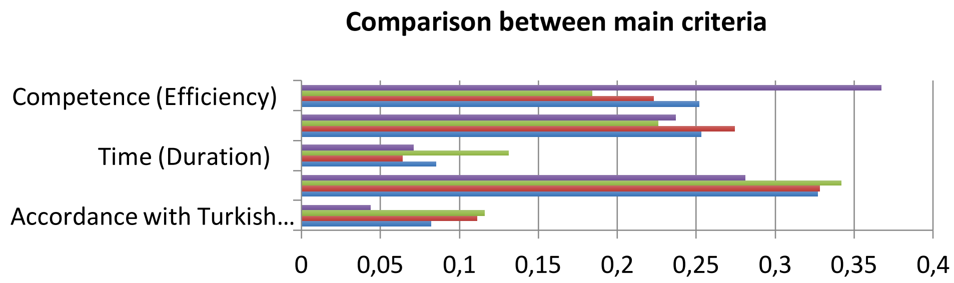
In Table 4.2: The names are assigned to numbers for objectivity and privacy reasons.

**Table 4.2:** Participant Details.

| ID | Classification | Sector | Study % |
|---|---|---|---|
| A | Government Decision Makers | Public | 33.3% |
| B | Government Decision Makers | Public | |
| C | Government Decision Makers | Public | |
| D | Consultants | Private | 33.3% |
| E | Consultants | Private | |
| F | Consultants | Private | |
| G | Academicians | Private | 33.3% |
| H | Academicians | Public | |
| I | Academicians | Private | |

## 4.1. Assessment of Government Decision Makers

As shown in Figure 4.1. the main criterion is most important for each variable, and these standards are competence (efficiency), implementation (usage), time (duration), economy (cost) and according to with Turkey legislation. As in Figure 4.1. shows that the main criterion is most important for each variable.

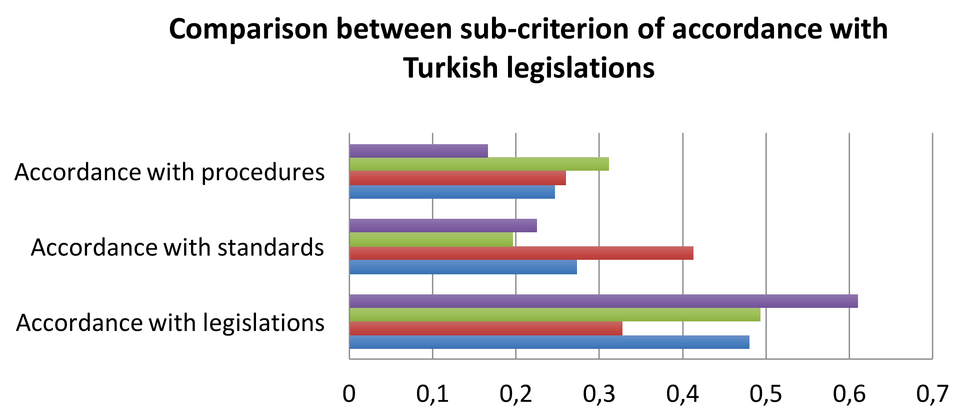



| | Accordance with Turkish Legislation | Economy(Cost) | Time (Duration) | Implementation (Usage) | Competence (Efficiency) |
|---|---|---|---|---|---|
| A | 0,044 | 0,281 | 0,071 | 0,237 | 0,367 |
| B | 0,116 | 0,342 | 0,131 | 0,226 | 0,184 |
| C | 0,111 | 0,328 | 0,064 | 0,274 | 0,223 |
| TOTAL AVERAGE | 0,082 | 0,327 | 0,085 | 0,253 | 0,252 |

**Figure 4.1:** Comparison between main criteria

According to criteria comparison shown in Figure 4.1, Specialist A classified efficiency as the most important criteria with 36.7%, followed by Economy (28.1%), implementation (23.7%), time (7.1%), and finally Turkish legislations (4.4%). Moreover, Specialist B classified the economy factor as the most important criteria with 34.2%, followed by implementation (22.6%), efficiency (18.4%), time (13.1%), and Turkish legislations (11.6%). Specialist, given the identification code C classified economy as the most important criteria with 32.8%, while implementation (27.4%), efficiency (22.3%), Turkish legislations (11.1%), and time (6.4%) have followed respectively.

Therefore, the resultant of the classification of the main criteria by the government decision makers of the Ministry of Environment of Urbanization show that the economy criterion have taken the first place with 32.7%, where the rest of the criteria have been ordered as follows; implementation (25.3%), efficiency (25.2%), time (8.5%), and Turkish legislation (8.2%).

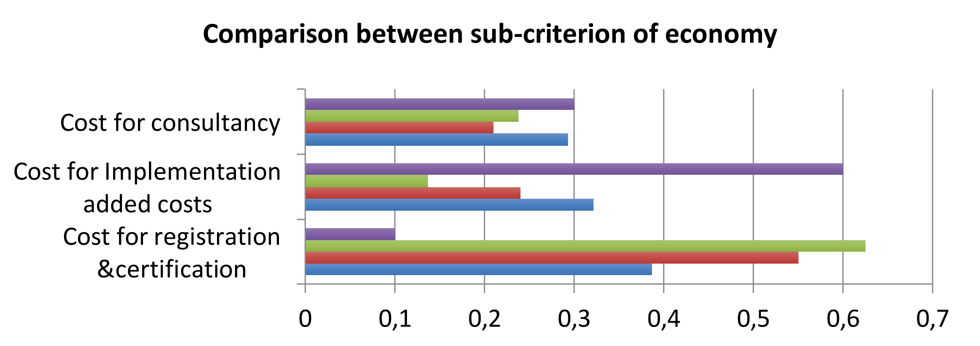



| | Accordance with legislations | Accordance with standards | Accordance with procedures |
|---|---|---|---|
| A | 0,61 | 0,225 | 0,166 |
| B | 0,493 | 0,196 | 0,311 |
| C | 0,327 | 0,413 | 0,26 |
| TOTAL AVERAGE | 0,48 | 0,273 | 0,247 |

Figure 4.2: Comparison between sub-criterion of accordance with Turkish legislations.

Furthermore, the sub-criteria of the different criteria were compared by the government decision makers. Figure 4.2 shows the sub-criteria comparison under the Turkish legislations criteria by the government decision makers. Specialist A classified the accordance with legislations as the most important sub-criteria under this category with 61%, while accordance with standards and accordance with procedures were given 22.5% and 16.6%, respectively. Specialist B has given accordance with legislations 49.3%, while accordance with procedures and accordance with standards were given 31.1% and 19.6%, respectively. Finally, Specialist C has given accordance with standards 41.3%, and the other two sub-criteria followed with accordance with legislation (32.7%) and accordance with procedures (26%).

The resultant of the comparison shown that the accordance with legislations have taken the highest score with 48%, and the second and third rank were averaged as accordance with standards (27.3%) and accordance with procedures (24.7%), respectively.

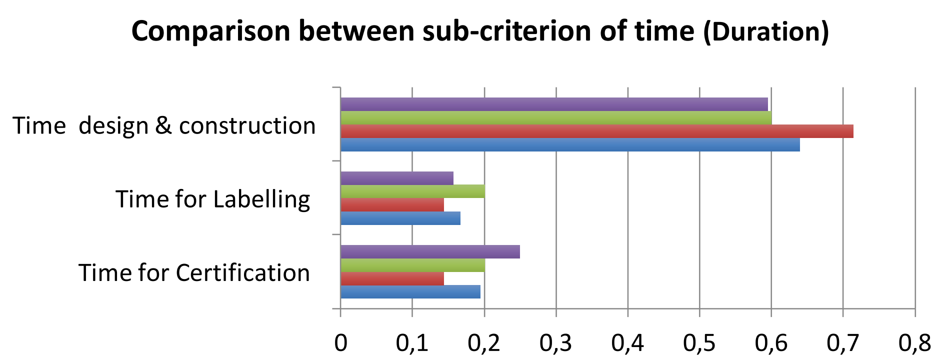



| | Cost for registration &certification | Cost for Implementation added costs | Cost for consultancy |
|---|---|---|---|
| A | 0,1 | 0,6 | 0,3 |
| B | 0,625 | 0,136 | 0,238 |
| C | 0,55 | 0,24 | 0,21 |
| TOTAL AVERAGE | 0,386 | 0,321 | 0,293 |

**Figure 4.3:** Comparison between sub-criterion of economy (cost)

For the economy criteria, Figure 4.3, a group of sub-criteria were also compared by the government decision makers, where Specialist A has given 60% to implementation added cost followed by cost for consultancy (30%) and cost for registration and certification (10%). Moreover, Specialist B has indicated that the cost for registration and certification is the most important economy sub-criterion with 62.5%, followed by the cost for consultancy (23.8%) and implementation added cost (13.6%). Specialist C has indicated that the registration and certification with (55%, followed by the cost for implementation added cost with (24%) and the cost for consultancy (21%). Thus, the overall scoring for the three specialists from the ministry of environment and urbanization is summed as the following:

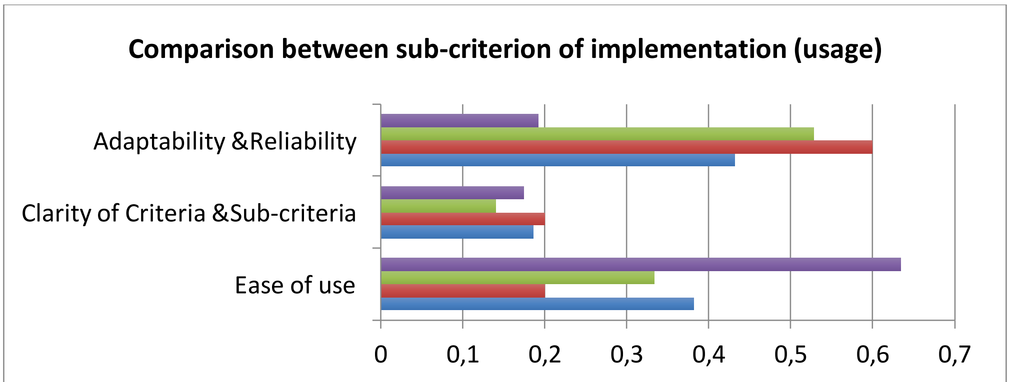
- First rank: cost for registration and certification (38.6%)
- Second rank: Implementation added costs (32.1%)
- Third rank: cost for consultancy (29.3%)




| | Time for Certification | Time for Labelling | Time design & construction |
|---|---|---|---|
| A | 0,249 | 0,157 | 0,594 |
| B | 0,2 | 0,2 | 0,6 |
| C | 0,143 | 0,143 | 0,714 |
| TOTAL AVERAGE | 0,194 | 0,166 | 0,639 |

**Figure 4.4:** Comparison between sub-criterion of time (Duration)

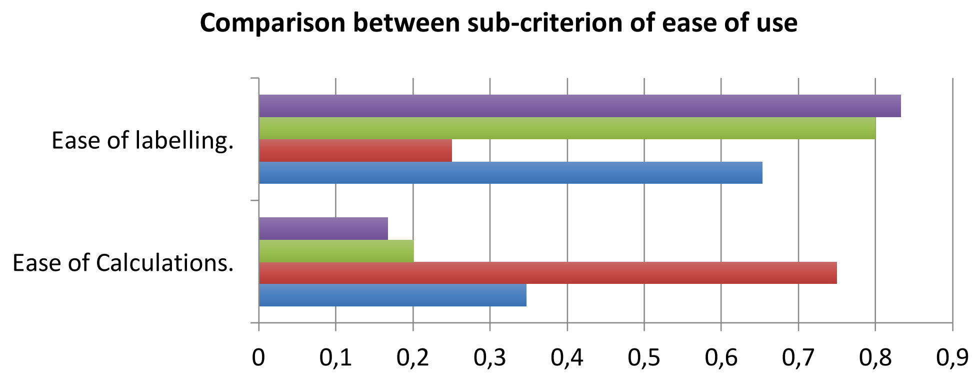
The next set of sub-criteria were compared under the time criterion by the government decision makers, Figure 4.4. All specialists have classified the time for design and construction as the most important sub-criterion under this category with 59.4%, 60% and 71.4% for specialists A, B, and C, respectively. However, Specialists B and C have ranked the time of certification and time for labeling equally as 20% for specialist B and 14.3% for specialist C. Therefore, the final ranking for the sub-criteria under this category is time for design and construction (63.9%), time for certification (19.4%), and time for labelling (16.6%).




| | Ease of use | Clarity of Criteria &Sub-criteria | Adaptability &Reliability |
|---|---|---|---|
| A | 0,634 | 0,174 | 0,192 |
| B | 0,333 | 0,14 | 0,528 |
| C | 0,2 | 0,2 | 0,6 |
| TOTAL AVERAGE | 0,382 | 0,186 | 0,432 |

**Figure 4.5:** Comparison between sub-criterion of implementation (usage)

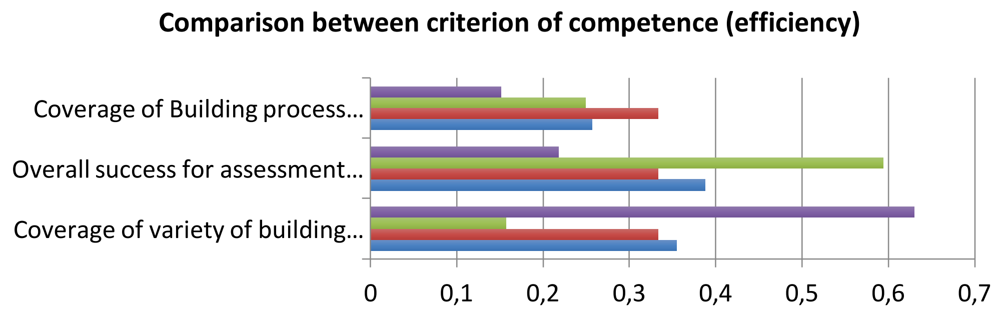
As shown in Figure 4.5, the sub-criteria for the implementation criterion is compared by the government decision makers. Specialist A has ranked the ease of use as the most important sub-criterion with 63.4%, with adaptability and reliability, and clarity of criteria and cub-criteria have been given 19.2% and 17.4%, respectively. Nonetheless, adaptability and reliability have been ranked as the most important sub-criterion with 52.8% by Specialist B. The second and third ranked sub-criteria were ranked as ease of use (33.3%) and clarity of criteria and sub-criteria (14%). Specialist C has ranked adaptability and reliability first with 60%, where ease of use and clarity of criteria and sub-criteria equally with 20% for each. Thus, the overall ranking under this category is adaptability and reliability (43.2%), ease of use (38.2%) and clarity of criteria and sub-criteria (18.6%).




| | Ease of Calculations. | Ease of labelling. |
|---|---|---|
| A | 0,167 | 0,833 |
| B | 0,2 | 0,8 |
| C | 0,75 | 0,25 |
| TOTAL AVERAGE | 0,347 | 0,653 |

**Figure 4.6:** Comparison between sub-criterion of ease of use

Under the ease of use sub-criterion, further sub-criteria are established as shown in Figure 4.6. Specialists A and B has indicated that the ease of labelling has more priority with 83.3% and 80%, respectively, where the ease of calculation have taken 16.7% and 20% for the same specialists, respectively. Nevertheless, Specialist C has ranked the ease of calculation at the first place with 75%, while the ease of labelling was assigned with 25%. The average ranking has shown that ease of labelling has an average score of 65.3% and ease of calculation has an average score of 34.7%.

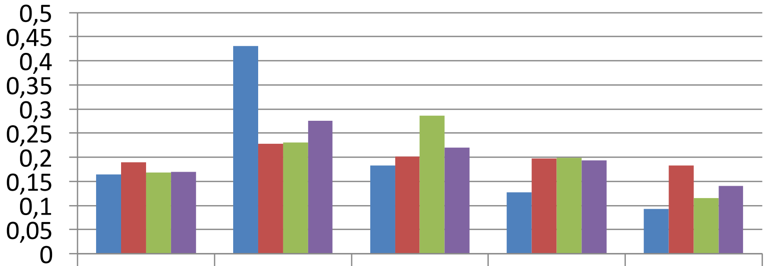



| | Coverage of variety of building types | Overall success for assessment (saving resources, reducing waste) | Coverage of Building process (Pre design to in use). |
|---|---|---|---|
| A | 0,63 | 0,218 | 0,151 |
| B | 0,157 | 0,594 | 0,249 |
| C | 0,333 | 0,333 | 0,333 |
| TOTAL AVERAGE | 0,355 | 0,388 | 0,257 |

**Figure 4.7:** Comparison between sub-criterion of competence (efficiency)

Under the criterion of efficiency, the government decision makers assessed the set of sub-criteria, Figure 4.7, where specialist C indicated an equal importance for all the items with 33.3%. Nonetheless, specialist B indicated that the first priority is for the overall success for assessment with 59.4%, which is followed by coverage of the building process (24.9%) and coverage of variety of building types (15.7%). Specialist A gave the highest priority to the coverage of variety of building types with 63%, followed by overall success for assessment (21.8%) and coverage of the building process (15.1%). The overall average for this category showed that the first importance is for the overall success for assessment (38.8%), then coverage of variety of building types (35.5%) and coverage of the building process (25.7%).

Furthermore, the government decision makers assessed the alternatives provided in the study, where specialists A and B have chosen certification system 2 as the most suitable green building a certification system with 0.05 and 0.06, respectively, which does not exceed the 0.10 acceptable limit by the AHP method. However, specialist C has chosen certification system 3 as the most suitable tool with 0.05. Therefore, the overall assessment show that the government decision makers prefer certification system 2 with 0.03, as acquired from the AHP software and shown in Figure 4.8.




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A | 0,164 | 0,431 | 0,183 | 0,128 | 0,093 |
| B | 0,189 | 0,228 | 0,202 | 0,198 | 0,183 |
| C | 0,168 | 0,231 | 0,286 | 0,199 | 0,116 |
| TOTAL AVERAGE | 0,17 | 0,276 | 0,22 | 0,193 | 0,14 |

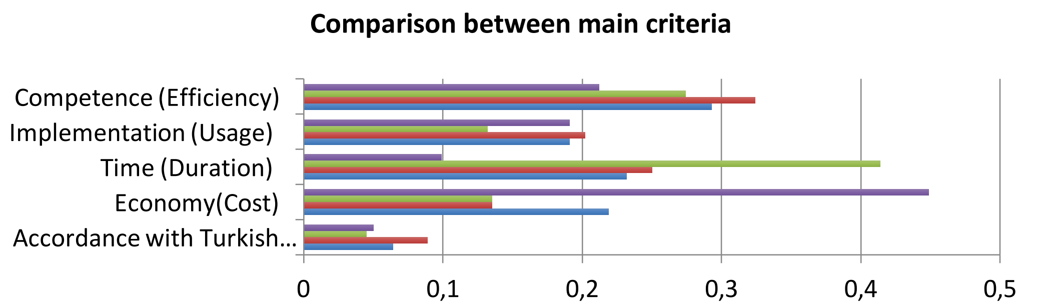
**A= 0.05 , B= 0.06 , C= 0.05**
**Overall inconsistency = 0.03**

**Figure 4.8:** Comparison criteria with certification systems

## 4.2. Assessment of Consultants

The consultants have also provided their assessment for the criteria and sub-criteria that were compiled for the research. In comparing the main criteria, Figure 4.9, specialist F gave the highest importance for efficiency with 32.4%, followed by time (25%), implementation (20.2%), economy (13.5%) and accordance with Turkish legislations (8.9%). Moreover, specialist E assigned the highest importance for the time criterion with 41.4%, followed by efficiency (27.4%), economy (13.5%), implementation (13.2%), and accordance with Turkish legislation (4.5%). The last consultant specialist, assigned to code D, assessed the economy criterion to the highest importance with 44.9%, which is followed by efficiency (21.2%), implementation (19.1%), time (9.9%), and accordance with Turkish legislations (5%). The average score for the main criteria was compiled as the following:

- First rank: efficiency (29.3%)
- Second rank: time (23.2%)
- Third rank: economy (21.9%)
- Fourth rank: implementation (19.1%)
- Fifth rank: accordance with Turkish legislations (6.4%)



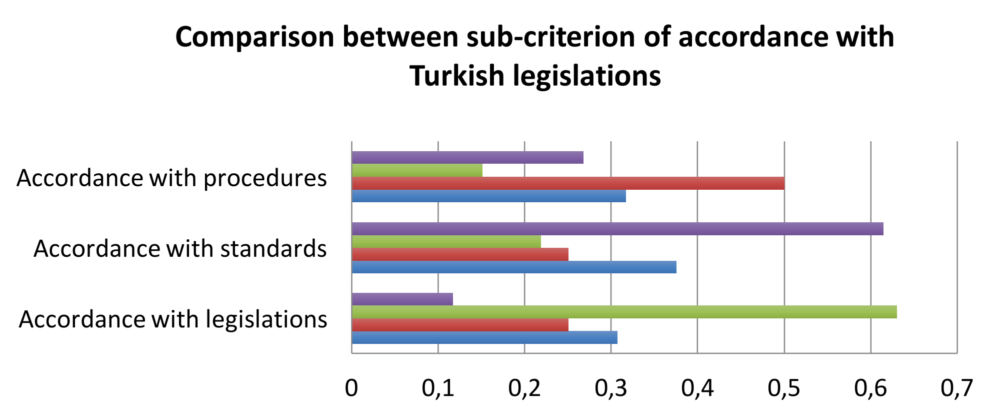

| | Accordance with Turkish Legislation | Economy(Cost) | Time (Duration) | Implementation (Usage) | Competence (Efficiency) |
|---|---|---|---|---|---|
| D | 0,05 | 0,449 | 0,099 | 0,191 | 0,212 |
| E | 0,045 | 0,135 | 0,414 | 0,132 | 0,274 |
| F | 0,089 | 0,135 | 0,25 | 0,202 | 0,324 |
| TOTAL AVERAGE | 0,064 | 0,219 | 0,232 | 0,191 | 0,293 |

**Figure 4.9:** Comparison between main criteria

In evaluating the sub-criteria under the accordance with Turkish legislation main criterion, Figure 4.10, Specialist F indicated that the first priority shall be given to the accordance with procedures (50%), where accordance with legislations and accordance with standards were rated equally with 25%. However, Specialist E rated the accordance with legislations as the most importance sub-criterion under this category with 63%, followed with accordance with standards (21.8%) and accordance with procedures (15.1%). The last consultant specialist, assigned to code D, provided that the most important sub-criterion under this category is the accordance with standards with 61.4%, followed by accordance with procedures

(26.8%) and accordance with legislations (11.7%). The average scores for the sub-criteria under the accordance with Turkish legislations are as the following:

- First rank: accordance with standards (37.5%)
- Second rank: accordance with procedures (31.7%)
- Third rank: accordance with legislations (30.7%)

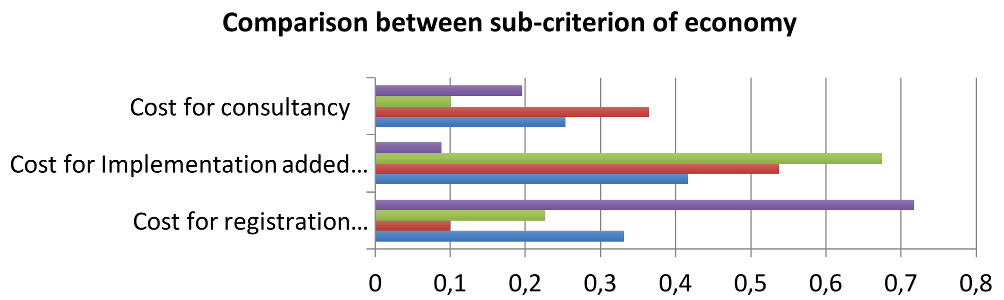



| | Accordance with legislations | Accordance with standards | Accordance with procedures |
|---|---|---|---|
| D | 0,117 | 0,614 | 0,268 |
| E | 0,63 | 0,218 | 0,151 |
| F | 0,25 | 0,25 | 0,5 |
| TOTAL AVERAGE | 0,307 | 0,375 | 0,317 |

**Figure 4.10:** Comparison between sub-criterion of accordance with Turkish legislations

The consultants have also assessed the sub-criteria under the economy main criterion, as shown in Figure 4.11, where specialist F assigned the highest priority to implementation added costs (53.7%), and the second and third ranks were given to cost for consultancy (36.4%) and cost for registration and certification (9.9%), respectively. Furthermore, the same first priority was indicated by specialist E for implementation added costs with 67.4%, followed by cost for registration and certification (22.6%) and cost for consultancy (10.1%). Specialist D have assigned the cost for registration and certification to the highest importance with 71.7%, followed by cost for consultancy (19.5%) and implementation added costs (8.8%). The average scores were then as the following:

- First rank: implementation added costs (41.6%)
- Second rank: cost for registration and certification (33.1%)
- Third rank: cost for consultancy (25.3%)

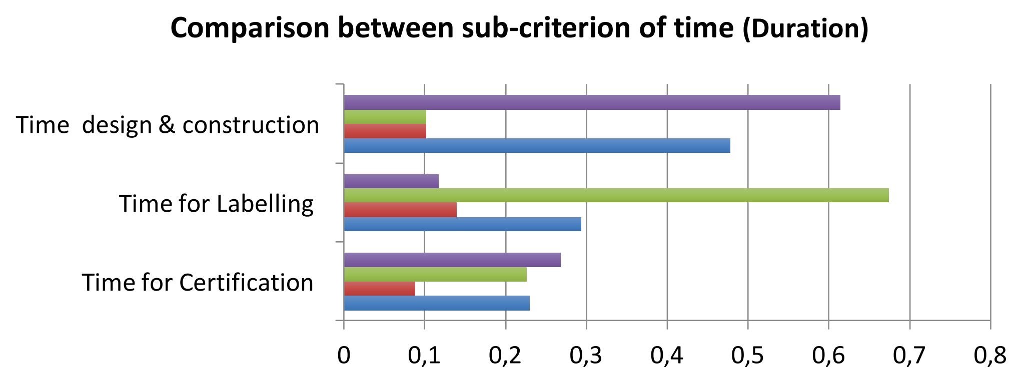



| | Cost for registration &certification | Cost for Implementation added costs | Cost for consultancy |
|---|---|---|---|
| D | 0,717 | 0,088 | 0,195 |
| E | 0,226 | 0,674 | 0,101 |
| F | 0,099 | 0,537 | 0,364 |
| TOTAL AVERAGE | 0,331 | 0,416 | 0,253 |

**Figure 4.11:** Comparison between sub-criterion of economy(cost)

Under the time main criterion, the compiled sub-criteria were evaluated by the Consultants as shown in Figure 4.12. Specialists F and D have indicated that time for design and construction is the most important sub-criterion under this category with 77.3% and 61.4%, respectively, which contributed into being the most important sub-criterion under the time main criterion with 47.8%. Moreover, specialist F have chosen time for labelling for the second rank with 13.9% and time for certification for the third rank with 8.8 %. Nonetheless, specialist D has chosen different second and third ranks with time for certification (26.8%) and time for labelling (11.7%). Specialist E has given the first priority to time for labelling with 67.4%, followed by time for certification (22.6%) and time for design and construction (10.1%). The overall second and third ranks were affected accordingly to have time for labelling (29.3%) and time for certification (23%), respectively. The final averages for these sub-criteria under the time main criterion by the consultancy specialists are as the following:

- First rank: time for design and construction (47.8%).
- Second rank: time for labelling (29.3%)
- Third rank:  time for certification (23%)

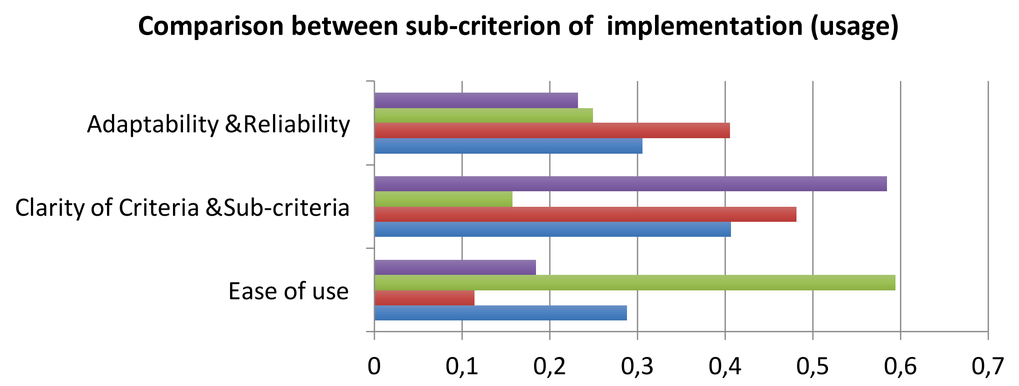



| | Time for Certification | Time for Labelling | Time  design & construction |
|---|---|---|---|
| D | 0,268 | 0,117 | 0,614 |
| E | 0,226 | 0,674 | 0,101 |
| F | 0,088 | 0,139 | 0,101 |
| TOTAL AVERAGE | 0,23 | 0,293 | 0,478 |

**Figure 4.12:** Comparison between sub-criterion of time (Duration)

Furthermore, the sub-criteria under the implementation main criterion were evaluated as shown in Figure 4.13. Specialist F have given the highest importance to the clarity of criteria and sub-criteria with 48.1%, followed by adaptability and reliability (40.5%) and ease of use (11.4%). Specialist E has given the highest importance to the ease of use with 59.4%, followed with adaptability and reliability (24.9%) and clarity of criteria and sub-criteria (15.7%) in the second and third ranks. Specialist D have indicated the clarity of the criteria and sub-criteria as the most important factor within this category with 58.4%, while adaptability and reliability (23.2%) and ease of use (18.4%) were ranked second and third accordingly. The final averages for the sub-criteria under the implementation main criterion by the consultancy specialists are as the following:

- First rank: clarity of criteria and sub-criteria (40.7%)
- Second rank: adaptability and reliability (30.5%)
- Third rank: ease of use (28.8%)



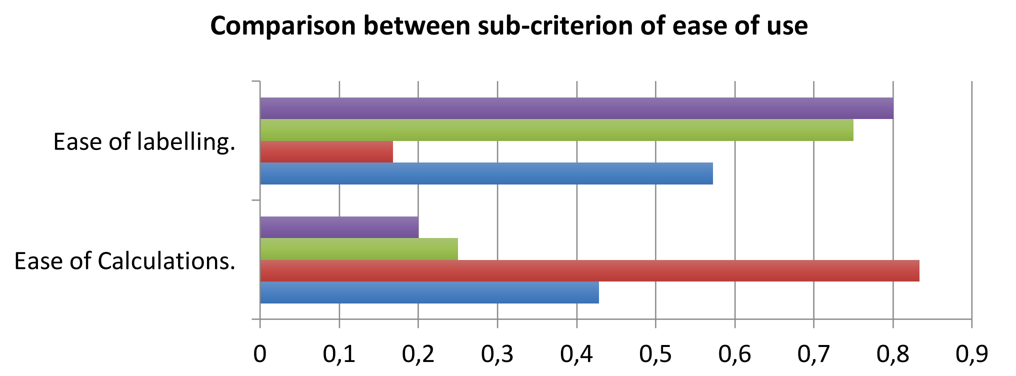

| | Ease of use | Clarity of Criteria &Sub-criteria | Adaptability &Reliability |
|---|---|---|---|
| D | 0,184 | 0,584 | 0,232 |
| E | 0,594 | 0,157 | 0,249 |
| F | 0,114 | 0,481 | 0,405 |
| TOTAL AVERAGE | 0,288 | 0,407 | 0,305 |

**Figure 4.13:** Comparison between sub-criterion implementation (usage)

Under the ease of use sub-criterion, other two sub-criteria were evaluated by the consultants specialists, as shown in Figure 4.14. Specialists F has rated the ease of calculation as the most important factor with 83.3% and ease of labelling as the second factor with 16.7%. Nevertheless, specialists E and D has given the first priority to ease of labelling with 75% and 80%, respectively. The second rank was given to ease of calculation by the two specialists with 25% for specialist E and 20%

for specialist D. Therefore, the final averages were as the following:

- First rank: ease of labelling (57.2%)
- Second rank: ease of calculations (42.8%)

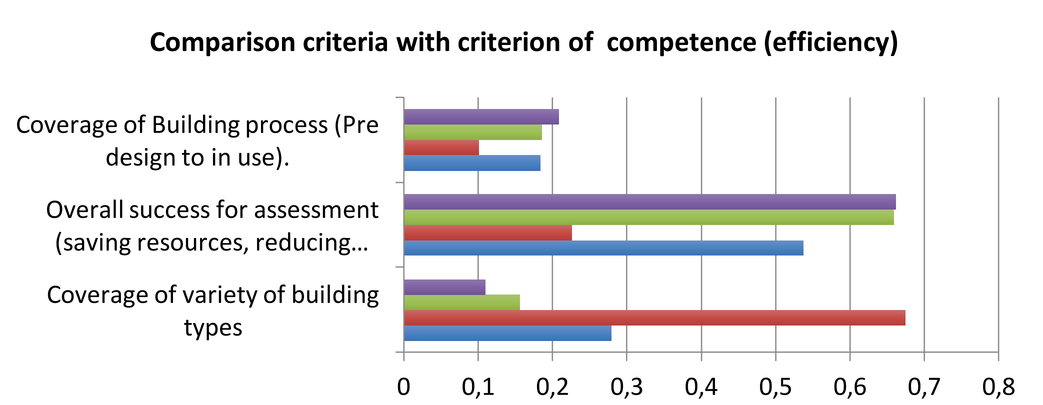



| | Ease of Calculations. | Ease of labelling. |
|---|---|---|
| D | 0,2 | 0,8 |
| E | 0,25 | 0,75 |
| F | 0,833 | 0,167 |
| TOTAL AVERAGE | 0,428 | 0,572 |

**Figure 4.14:** Comparison between sub-criterion of ease of use

The last set of sub-criteria evaluated by the consultants specialists was under the efficiency main criterion, as shown in Figure 4.15. Specialist F had assigned the highest priority to the coverage of variety of building types with 67.4 %, while overall success for assessment and coverage of building process have been assigned to 22.6% and 10.1%, respectively. Specialists E and D have ranked the sub-criteria similarly with overall success for assessment given 65.9% and 66.1 %, respectively, by the two specialists. Moreover, coverage of the building process was given 18.5% by specialist E and 20.8% by specialist D, and coverage of variety of building types was given 15.6% by specialist E and 13.1% by specialist D. The overall results for the efficiency criterion by the consultants is as the following:

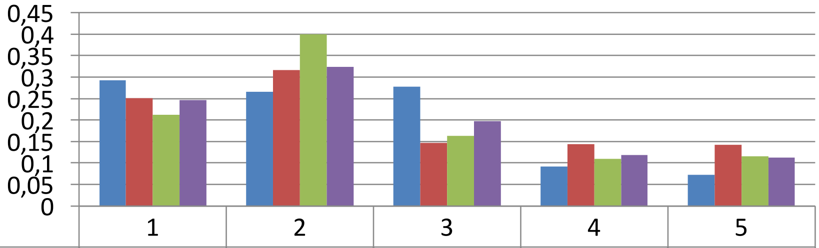
- First rank: overall success for assessment (53.7%)
- Second rank: coverage of variety of building types (27.9%)
- Third rank: coverage of building process (18.3%)




| | Coverage of variety of building types | Overall success for assessment (saving resources, reducing waste) | Coverage of Building process (Pre design to in use). |
|---|---|---|---|
| D | 0,109 | 0,661 | 0,208 |
| E | 0,156 | 0,659 | 0,185 |
| F | 0,674 | 0,226 | 0,101 |
| TOTAL AVERAGE | 0,279 | 0,537 | 0,183 |

**Figure 4.15:** Comparison criterion of competence (efficiency)

For the alternatives, specialists E and F have chosen certification system 2 as the best fit green building certification system with 0.07, while specialist D has chosen certification system 1 with the rate 0.07. All rates are below the 0.10 acceptable limit by AHP. The overall assessment shows that certification system 2 is the chosen tool by the consultants with a rate of 0.02 as shown in Figure 4.16.




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| D | 0,293 | 0,266 | 0,278 | 0,092 | 0,072 |
| E | 0,251 | 0,316 | 0,147 | 0,144 | 0,142 |
| F | 0,212 | 0,4 | 0,163 | 0,109 | 0,115 |
| TOTAL AVERAGE | 0,247 | 0,323 | 0,198 | 0,119 | 0,113 |

**D= 0.07 , E= 0.07 , F= 0.07**
**Overall inconsistency = 0.02**

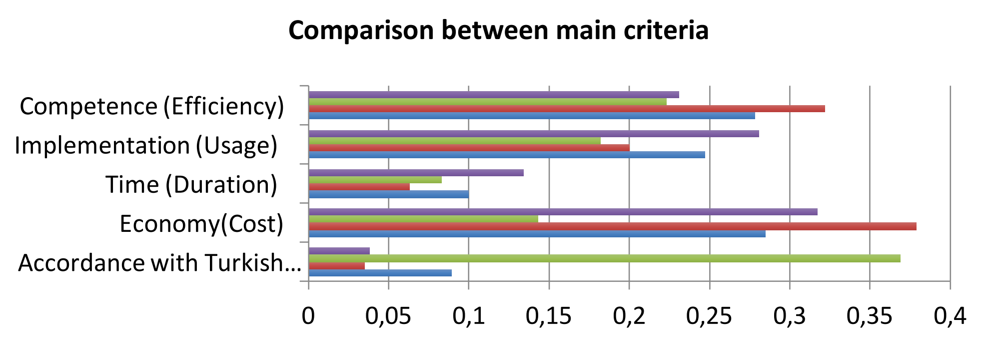
**Figure 4.16:** Comparison criteria with certification systems

### 4.3. Assessment by Academicians

The third evaluation group is formed by academicians who have extensive experience in the sustainability and green building assessment studies in Turkey. The first assessment is made for the main criteria of the study, as shown in Figure 4.17. Specialist I indicated that economy is the most important criteria with 37.9%, followed by efficiency (32.2%), implementation (20%), time (6.3%) and accordance with Turkish legislations (3.5%). Specialist H indicated that accordance with Turkish regulations is the most important main criterion with 36.9%, followed by efficiency (22.3%), implementation (18.2%), economy (14.3%), and time (8.3%). Moreover, specialist G have stated that the economy is the most important factor with 31.7%, closely followed by implementation (28.1%), then efficiency (23.1%), time (13.4%), and accordance with Turkish legislations (3.8%). Thus, the overall assessment for academics of the main criteria is as the following:

- First rank: economy (28.5%)
- Second rank: efficiency (27.8%)
- Third rank: implementation (24.7%)

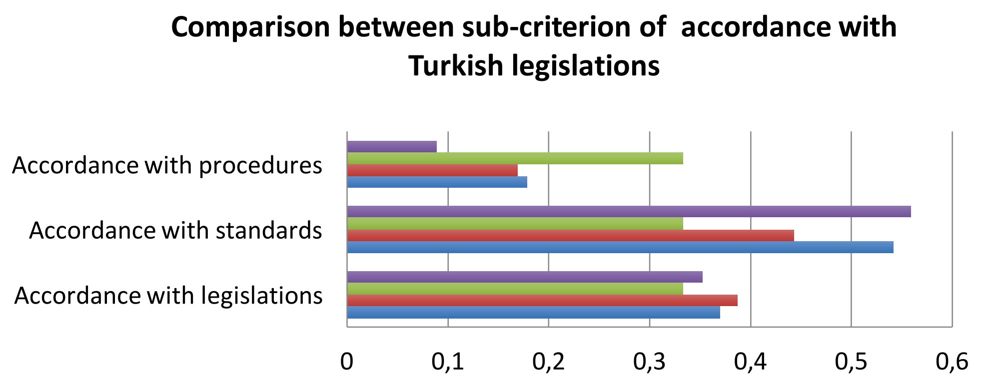
- Forth rank: time (10%)
- Fifth rank: accordance with Turkish legislations (8.9%)




| | Accordance with Turkish Legislation | Economy(Cost) | Time (Duration) | Implementation (Usage) | Competence (Efficiency) |
|---|---|---|---|---|---|
| G | 0,038 | 0,317 | 0,134 | 0,281 | 0,231 |
| H | 0,369 | 0,143 | 0,083 | 0,182 | 0,223 |
| I | 0,035 | 0,379 | 0,063 | 0,2 | 0,322 |
| TOTAL AVERAGE | 0,089 | 0,285 | 0,1 | 0,247 | 0,278 |

**Figure 4.17:** Comparison between main criteria

In evaluating the sub-criteria under the main criterion accordance with Turkish legislations, specialist I have indicated that accordance with standards is the most important criteria with 44.3%, while accordance with legislations and accordance with procedures fell in the second and third places with 38.7% and 16.9%, respectively .Specialist H indicated that all three sub-criteria are equally important with 33.3%, while specialist G gave the most importance for the accordance with standards criterion with 55.9%, followed by accordance with legislations (35.2%) and accordance with procedures (8.9%). The results are shown in Figure 4.18, where the final average show that accordance with standards comes in the first rank with 54.2%, accordance with legislations in the second rank with 37%, and accordance with procedures is in the third rank with 17.8%.

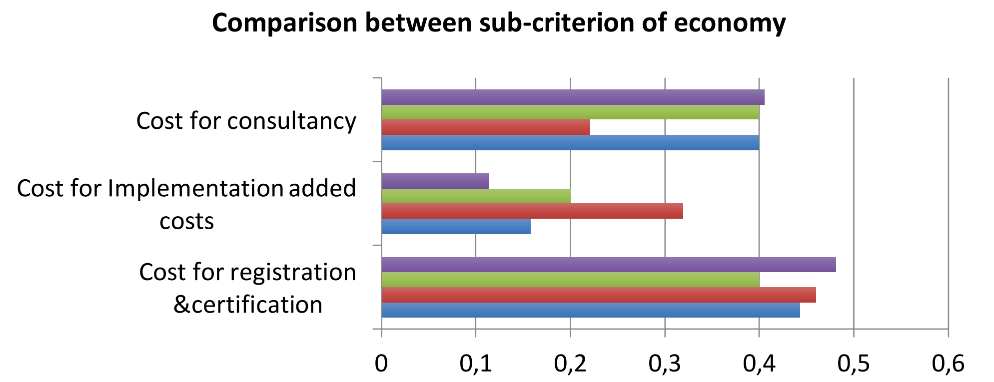



| | Accordance with legislations | Accordance with standards | Accordance with procedures |
|---|---|---|---|
| G | 0,352 | 0,559 | 0,089 |
| H | 0,333 | 0,333 | 0,333 |
| I | 0,387 | 0,443 | 0,169 |
| TOTAL AVERAGE | 0,37 | 0,542 | 0,178 |

**Figure 4.18:** Comparison between sub-criterion of accordance with Turkish legislations

Under the economy main criterion, the academicians assessed the compiled sub-criteria accordingly, as shown in Figure 4.19 While specialist H rated sub-criterion cost for registration and certification and cost for consultancy cost equally with 40%, and implementation added costs 20% .Specialist G indicated that cost of registration and certification is the most important with 48.1%, followed by cost for consultancy (40.5%), and implementation added costs (11.4%). Specialist I rated the cost for registration and certification as the most important by 44.3%, followed by consultancy cost (38.7%) and implementation added costs (16.9%). Therefore, the final results are as the following:

- First rank: cost for registration and certification (44.3%)
- Second rank: cost for consultancy (40%)
- Third rank: implementation added costs (15.8%)

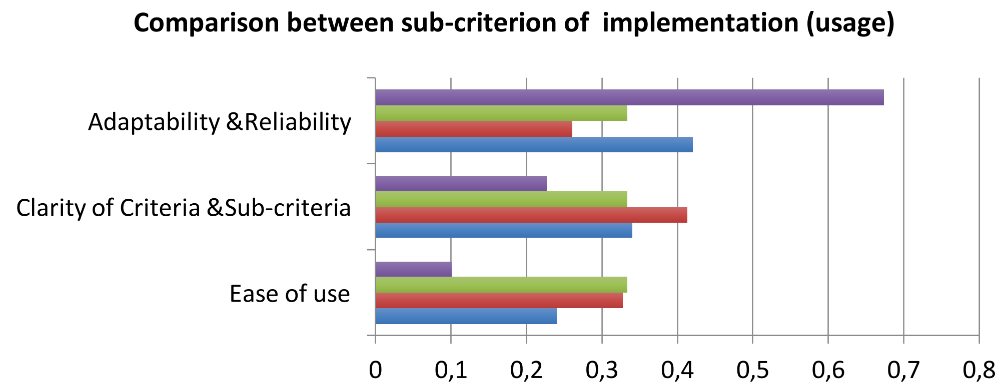



| | Cost for registration &certification | Cost for Implementation added costs | Cost for consultancy |
|---|---|---|---|
| G | 0,481 | 0,114 | 0,405 |
| H | 0,4 | 0,2 | 0,4 |
| I | 0,46 | 0,319 | 0,221 |
| TOTAL AVERAGE | 0,443 | 0,158 | 0,4 |

**Figure 4.19:** Comparison between sub-criterion of economy (Cost)

Furthermore, the implementation sub-criteria were assessed in pairwise comparison by academicians, Figure 4.20, where specialist H indicated that all factors are equal in importance with 33.3%. Nonetheless, specialist G indicated that adaptability and reliability is the most important factor within this criterion with 67.4%, while clarity of criteria and sub-criteria, and ease of use fell in the second and third places with 22.6% and 10.1%, respectively. Specialist I ranked clarity of criteria and sub-criteria as the most important with 41.3%, followed by ease of use 32.7% and adaptability and reliability (26%). Therefore, the overall assessment of this category by the academics is as the following:

- First rank: adaptability and reliability (42%)
- Second rank: clarity of criteria and sub-criteria (34%)
- Third rank: ease of use (24%)

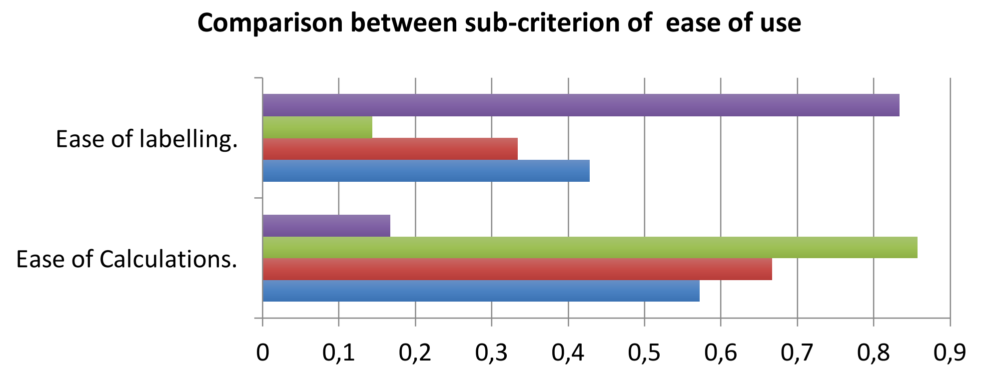



| | Ease of use | Clarity of Criteria &Sub-criteria | Adaptability &Reliability |
|---|---|---|---|
| G | 0,101 | 0,226 | 0,674 |
| H | 0,333 | 0,333 | 0,333 |
| I | 0,327 | 0,413 | 0,26 |
| TOTAL AVERAGE | 0,24 | 0,34 | 0,42 |

**Figure 4.20:** Comparison between sub-criterion of implementation

Under the sub-criterion ease of use, two other sub-criteria were evaluated by academicians as shown in Figure 4.21. Specialist H indicated that the ease of calculation is the most important factor with 85.7%, while ease of labelling is in the second rank with 14.3%. Nevertheless, the opposite was indicated by specialist G, where ease of labelling was marked with 83.3% and ease of calculation was marked with 16.7%. Specialist I gave the highest importance to the ease of calculation with 66.7%, followed by ease of labelling (33.3%) Therefore, the final averages were calculated as the following:

- First rank: ease of calculation (57.2%)
- Second rank: ease of labelling (42.8%)

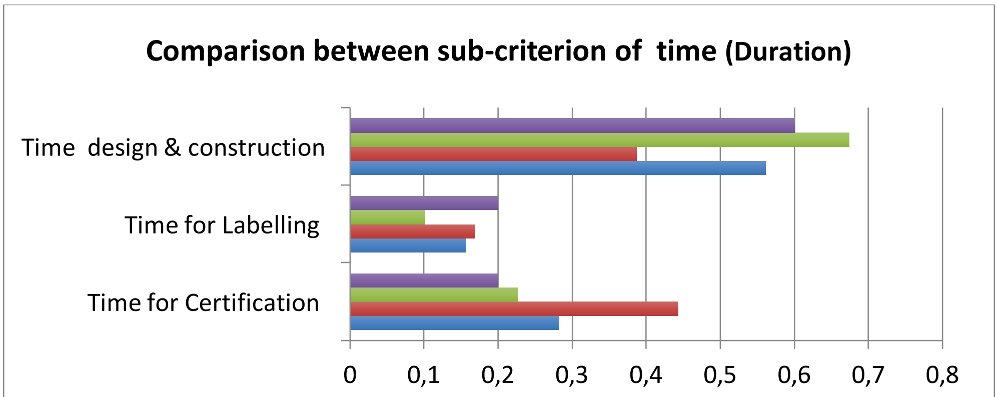



| | Ease of Calculations. | Ease of labelling. |
|---|---|---|
| G | 0,167 | 0,833 |
| H | 0,857 | 0,143 |
| I | 0,667 | 0,333 |
| TOTAL AVERAGE | 0,572 | 0,428 |

**Figure 4.21:** Comparison between sub-criterion of ease of use

Moreover, a pairwise comparison was carried out for the sub-criteria under the time main criterion, where specialist H assigned the highest importance to the design and construction time with 67.4%, followed by time for certification (22.6%) and time for labelling (10.1%), as shown in Figure 4.22 Similarly, the time of design and construction was given the highest importance by specialist G with 60%, followed by an equal ranking of time for certification and time for labelling with 20%. Specialist I indicated that time of certification in the first rank with 44.3%, followed by design and construction time (38.7%) and time for labelling (16.9%). Therefore, the final ranking of the sub-criteria is as the following:

- First rank: time for design and construction (56.1%)
- Second rank: time for certification (28.2%)
- Third rank: time for labelling (15.7%)



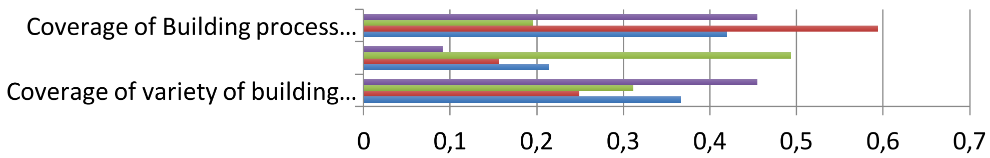

| | Time for Certification | Time for Labelling | Time design & construction |
|---|---|---|---|
| G | 0,2 | 0,2 | 0,6 |
| H | 0,226 | 0,101 | 0,674 |
| I | 0,443 | 0,169 | 0,387 |
| TOTAL AVERAGE | 0,282 | 0,157 | 0,561 |

**Figure 4.22:** Comparison between sub-criterion of time (Duration)

The last set of sub-criteria evaluated by the academicians were under the efficiency main criterion, as shown in Figure 4.23 Specialist H have indicated that overall success for assessment is the most important factor with 49.3%, while coverage of variety of building types and coverage of building process fell in the second and third places with 31.1% and 19.6 %, respectively. Furthermore, specialist G indicated two factors as the most and equally important, which are coverage of variety of building types and coverage of building process, with 45.5%. Subsequently, overall success for assessment fell in the third place with 9.1%. Specialist I gave the highest importance coverage of the building process with 59.4%, followed by coverage of variety of building types (24.9%) and overall success for assessment (15.7%). Therefore, the overall ranking for this category by the academics is:

- First rank: coverage of variety of building types (41.9%)
- Second rank: coverage of  building types (36.6%)
- Third rank: overall success for assessment (21.4%)

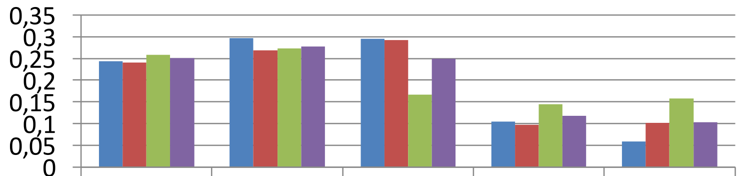
**Comparison between criterion of competence (efficiency)**




| | Coverage of variety of building types | Overall success for assessment (saving resources, reducing waste) | Coverage of Building process (Pre design to in use). |
|---|---|---|---|
| G | 0,455 | 0,091 | 0,455 |
| H | 0,311 | 0,493 | 0,196 |
| I | 0,249 | 0,157 | 0,594 |
| TOTAL AVERAGE | 0,366 | 0,214 | 0,419 |

**Figure 4.23:** Comparison between criterion competence (efficiency).

Furthermore, academicians G, I have chosen certification system 2 as the preferred green building certification system with an equal rate of 0.06 and 0.04, while specialist H has chosen certification system 3 with the rate 0.05, where the overall assessment show that certification system 2 is the most preferred certification system by academics with a rate of 0.02 as shown in Figure 4.24. All rates are within the acceptable 0.10 limit of AHP method.




| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| G | 0,243 | 0,297 | 0,295 | 0,105 | 0,059 |
| H | 0,24 | 0,268 | 0,292 | 0,098 | 0,102 |
| I | 0,258 | 0,273 | 0,166 | 0,145 | 0,158 |
| TOTAL AVERAGE | 0,251 | 0,278 | 0,25 | 0,118 | 0,103 |

**G= 0.06 , H= 0.05 , I= 0.04**
**Overall inconsistency = 0.02**

**Figure 4.24:** Comparison criteria with certification systems

# 5. DISCUSSION

This study aims to develop a methodology to establish and develop a green building certification system for Turkey, and choosing the most influential criteria and sub-criteria that would affect this process by using the AHP method, the research has yielded important results that are discussed in this chapter, followed by the conclusion and the recommendations in the following chapter.

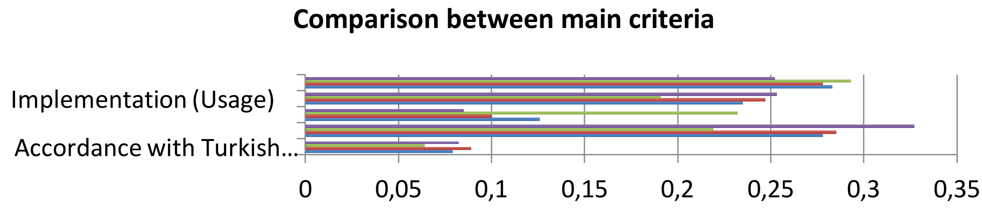
As a type of multi-criteria decision-making (MCDM) methodology, the AHP method is chosen for this research as it can be used for individual and group participants, which makes the interpretation of the results possible in both cases. The AHP method uses a hierarchical structure in building the case and depends on comparing each criterion with its counterpart individually on a scale that decides the importance of each criterion in comparison with another criterion. The AHP method breaks the complex decision-making problem into simpler decisions to be taken on a criterion per criterion basis. Therefore, this method is used for complex decision making, where several criteria contribute into the final decision.

One of the most important advantages of using the AHP methodology is its flexibility, ease of use and adaptability to different problem types. The AHP method has simple steps that builds the comparison case, which develops into matrices for the different criteria. In developing the criteria, the types of criteria used can be tangible and intangible, which makes its use more possible for more problems in comparison with other MCDM methods that have constraints on the types of criteria. One of the most important advantages of the AHP method is having the consistency measurement, which ensures that the results from different participants are consistent with each other, as well as using linear mathematical model for ease of interpretation.

According to the main criteria pairwise comparison by the study groups, the most important and influential criteria in choosing the best fit green building certification system are as the following:

1. The government decision makers from the ministry of environment and urbanization have indicated that the economy main criterion is the most influential factor with 32.7%, which indicates the impact of this factor on achieving sustainable development.
2. The consultants have indicated that the efficiency factor is the most influential main criterion with 29.3%.
3. The academicians have indicated that the economy factor is the most influential main criterion with 28.5%.

Therefore, the overall assessment of the study groups results shows that efficiency is the most influential main criterion in choosing the best fit green building assessment tool for Turkey with 28.3%, followed by economy (27.8%), implementation (23.5%), time (12.6%), and accordance with Turkish legislations (7.9%). The overall results of the main criteria are shown in Figure 5.1.




| | Accordance with Turkish Legislation | Economy(Cost) | Time (Duration) | Implementation (Usage) | Competence (Efficiency) |
|---|---|---|---|---|---|
| Government decision makers | 0,082 | 0,327 | 0,085 | 0,253 | 0,252 |
| Consultants | 0,064 | 0,219 | 0,232 | 0,191 | 0,293 |
| Academicians | 0,089 | 0,285 | 0,1 | 0,247 | 0,278 |
| TOTAL AVERAGE | 0,079 | 0,278 | 0,126 | 0,235 | 0,283 |

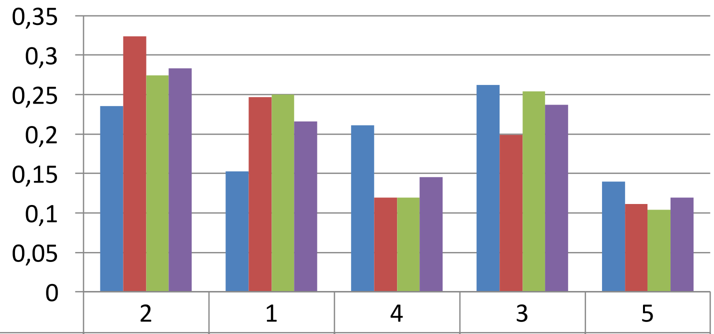
**Figure 5.1:** Overall comparison for government decision makers, consultants, and academicians for main criteria.

Furthermore, the most influential sub-criteria according to the study groups are summarized as the following:

- Government decision makers.
    - Efficiency: Overall assessment success (39%)
    - Economy: Registration and certification costs (38.6%)
    - Implementation: Adaptability and reliability (43.2%)
    - Time: Design and construction (63.9%)
    - Accordance with Turkish legislations: accordance with legislations (48%)
- Consultants.
    - Efficiency: overall assessment success (53.7%)
    - Economy: implementation added costs (41.6%)
    - Implementation: clarity of criteria and sub-criteria (40.7%)
    - Time: Design and construction (47.8%)
    - Accordance with Turkish legislations: accordance with standards (37.5%).
- Academicians.
    - Efficiency: Coverage of Building process (Pre-design to in use) (41.9%)
    - Economy: Registration and certification costs (44.3%)
    - Implementation: Adaptability and reliability (42%)
    - Time: Design and construction (56.1%)
    - Accordance with Turkish legislations: accordance with standards (45.2%).

Furthermore, the alternatives assessment shows that the government decision makers indicated certification no. 2 as the most fit green building certification system with an overall consistency ratio of 0.03, which does not exceed the 0.1 acceptable limit by the AHP method. The academicians group and consultants results showed a choice of certification system no. 2 as the most fit green building certification system with an overall consistency ratio of 0.02, which does not exceed the 0.1 acceptable limit by the AHP method.

Figure 5.2 shows the final rating of the experts for the different alternatives. Therefore, the final ranking for the alternatives are 2, 1, 3, 4 and 5, respectively, with an overall consistency ratio of 0.01.




| | 2 | 1 | 4 | 3 | 5 |
|---|---|---|---|---|---|
| Government decision makers | 0,235 | 0,153 | 0,211 | 0,262 | 0,14 |
| Consultants | 0,324 | 0,247 | 0,119 | 0,199 | 0,111 |
| Academicians | 0,274 | 0,25 | 0,119 | 0,254 | 0,104 |
| TOTAL AVERAGE | 0,283 | 0,216 | 0,145 | 0,237 | 0,119 |

**Figure 5.2:** Comparison for decision makers, consultant, academicians for all certification systems.

Figure 5.3 below show the overall results of the study of criteria, sub-criteria and alternatives with respect to each study group. From the results, it can be noticed that the highest rating was given to the ease of labelling from the sub-criteria by the government decision makers, as it is important to be able to use the certification system effectively and clearly for the most accurate results. The academicians and the government decision makers also indicated that the impact of the certification system on the time of design and construction is one of the most important sub-criteria due to its direct relation to increasing the costs of the projects. Therefore, understanding the certification system requirements in detail requires understanding this type of impact. Moreover, the academicians also indicated that the certification system shall work in conjunction with the standards that are used in Turkey, and minimize any conflicts in the requirements.

The consultants have given a high rating for the overall success of the certification system to assess the green building strategy of any project in Turkey, as well as understanding the costs added to the projects by implementing each certification system's requirements. Finding a successful assessment and minimizing the impact of the projects' budgets is a goal that could satisfy the goals of both government decision makers and developers. Furthermore, the academicians also showed that the ease of points calculation in the certification system makes it easier for the developers to follow the requirements, as well as setting their green development goals and monitoring them from the beginning to the end of the process.

Moreover, other factors were found influential in the strategy of developing a green building certification system for Turkey. The government decision makers showed that the certification system shall not conflict with the legislations of the country, and it shall be easy to adapt with and reliable to achieve the sustainability goals of the country. The academicians also indicated that the consultancy costs are an important criterion to consider, as it would be affected directly by the complexity of requirements and process of the certification system. The academicians also indicated that the system shall cover different building types and shall be applied to the candidate projects throughout their different phases.

In figure 5.3, the alternatives are assigned to numbers as none of them is considered suitable for use in Turkey. Nonetheless, the titles of the alternatives were not used in order not to promote a certain certification system as it would not be possible to apply any of the certification systems perfectly for Turkey. Therefore, the suggestion of it is required to develop a unique certification system for Turkey dependent on the criteria that are concluded in this study.

Furthermore, using the AHP method in order to differentiate between the different criteria and sub-criteria according to their priority and importance to Turkey through the incorporation of the opinion of different specialist, ensures that all the factors are taken into consideration for the certification system development process. The method itself is considered reliable for this type of research and provides consistent results.

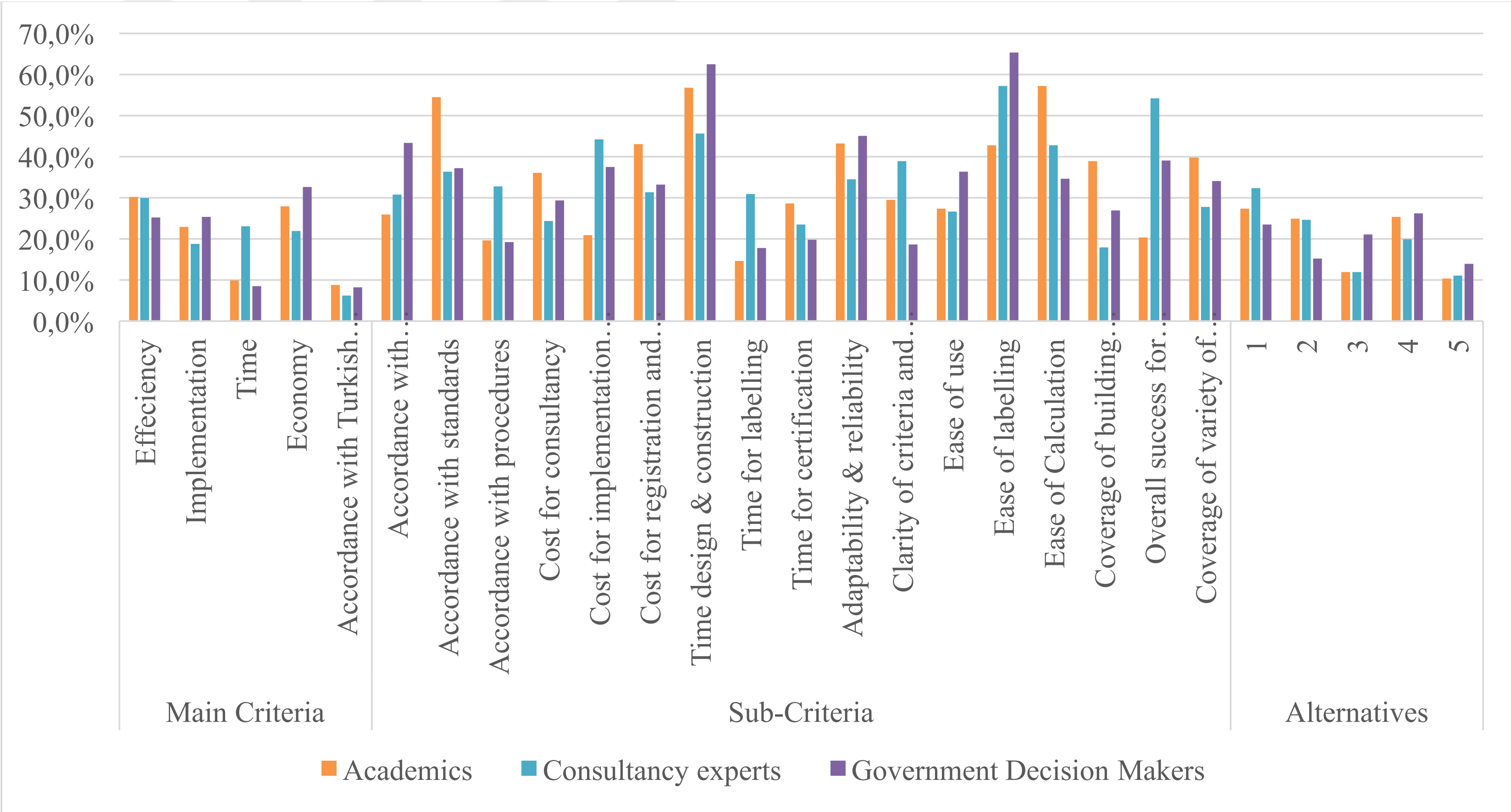



**Figure 5.3:** Overall results of the study

# 6. CONCLUSION

In this chapter, the outcomes of the research are summarized and concluded through an overall summary of the findings of the literature review and the methodology used in the study. Moreover, the research questions are answered and explained based on the literature and the case study performed. Thereafter, the hypotheses of the research are tested. Finally, the chapter is concluded with the final outcomes of the study.

It is evident in the construction and development industries that sustainable development is one of the hot topics within the sector due to awakened awareness towards energy consumption and the ecological impacts that the development has imposed. Therefore, over the past two decades, many green building assessment tools have been developed around the world in order to ensure that existing and future developments are executed in accordance with sustainable standards. Although ÇEDBİK is considered a start for sustainable and green development in Turkey, there has been minimal efforts made in developing an extensive green building certification system for the country. Therefore, all the projects certified in Turkey adopted one of the global certification systems such as LEED and BREEAM. The main aim of this research was to develop a strategy in identifying the most important criteria that shall be considered when developing a green building certification system for Turkey. The research commenced with an exhaustive review of five green building certification systems that are developed and adopted worldwide, which are:

1. BREEAM: Developed in the UK in 1990 and one of the most used green building certification systems worldwide.
2. LEED: Developed in the USA in 1998 and used mainly in countries that use the American standards in construction and development, in addition to many countries worldwide.
3. HQE: Developed in France in 1994 and mainly used in French speaking countries.

4. DGNB: Developed in Germany in 2007
5. CASBEE: Developed in Japan in 2001
6. ÇEDBİK: Developed in Turkey in 2007

The literature review included a comparison between the different certification systems in terms of their judgement criteria, assigned weights and the certification scale provided with each green building certification system. While most of the certification systems share the core criteria such as energy, material and efficiency, they differ in adopting additional criteria that impact the sustainable development, as well as adopting a different approach to the same criterion. Nonetheless, the current green building certification system in Turkey (ÇEDBİK) is considered non-exhaustive and currently only used for residential developments. Therefore, this research mainly focused on studying the advantages of the global certification systems and providing the necessary development points that shall be considered for building a complete green building certification system for Turkey.

It is important to understand that there is no specific international certification system that perfectly fits to Turkey. Thus, this research works also on providing the necessary data to create a new certification system for Turkey through understanding the most important criteria and sub-criteria that shall be considered in the development process and establishing a benchmark from the international certification systems for comparison and reference.

In making a decision regarding such an issue, a strong multi-criteria decision-making methodology shall be adopted. Therefore, the AHP method is chosen due to its high reliability in complex decision-making studies. Moreover, a set of criteria and sub-criteria is developed based on the previous studies in the same domain, as well as a list of experts in Turkey that were distributed on three main categories:

1. Government decision makers: specialists from the ministry of environment and urbanization are selected based on their experience in the sustainability and green development sector.
2. Consultants: specialists from the top green building consultancy firms in Turkey are chosen.

3. Academicians scholars: professors and scholars are chosen based on their contribution to green buildings and sustainable development research in Turkey.

There are four main research questions that were answered through this study, as the following:

Q1: What are the strength and weaknesses of different certification systems and the relationship between them?

Through the comparison of the five-international green building certification systems, several advantages and advantages were found. An extensive comparison was performed in Table 2.16 and Table 2.17, as well as a criterion by criterion comparison through Figures 2.14 and 2.15 in the second chapter. It is noted that each of these certification systems mainly consider the environmental and strategic criteria for their countries. For instance, it can be seen that BREEAM have given an absolute importance to the transportation, location and linkage criteria. Similarity, the same criteria has the majority points by LEED, but it is more balanced with the socio-cultural aspects. HEQ gives an absolute weight for indoor environment quality like CASBEE, while DGNB focuses on management, and ÇEDBİK focuses its weight on energy and atmosphere impacts.

Q2: What are the identical or contrasting features of the certification systems of green building?

The different green building certification systems are identical in their aims of implementing sustainable developments into their countries. Moreover, all green building certification systems adopt a weighted sum assigned to certain criteria that are considered strategically important for their aims and goals for green development. However, the weights of each criteria differ completely from one system to another, as well as the marking system, which can be very stringent for higher certification levels and easier for the lower ranks. Furthermore, all the certification systems were developed separately, in different time periods, and using different methods that suite the domestic interests. The certification systems always aim to have a mature system that can be easily adopted by the local developers, in addition to achieving the sustainability goals of the country.

Q3: Which is the best fit among the selected certification systems for meeting the needs of Turkey?

None of the international certification systems are considered perfectly fitting perfectly for Turkey, and it has been noted through this research that the research of the five certification systems is only for comparison and reference. The different

systems are developed according to the strategic needs of their original countries. Therefore, any green building certification system that is going to be used in Turkey shall be developed according to the specific needs and strategic goals of the country.

Q4: What are the most relevant and important criteria that shall be taken into consideration when developing a green building certification system for Turkey?

Based on the analysis results, it was concluded that government decision makers and academic scholars gave the highest importance to the economy main criterion, while consultancy experts have assigned the highest importance to the efficiency main criterion. Furthermore, the most important sub-criteria were chosen as the following:

- Overall assessment success: this sub-criterion assesses the efficiency of the green building certification system in achieving the green development aims and the country's specific green development objectives by reducing waste and increasing the energy efficiency of the project.
- Registration and certification costs: there are costs registration and certification imposed on the projects depending on the requirements of the green building certification system, which effectively impact the material and the assemblies used in the design and the construction phases of the project. Therefore, during the project budget estimation process, the designer and the cost estimator need to take into consideration the amount added by implementing the green building policy required for certification.
- Adaptability and reliability: this sub-criterion measures the acceptance of the tool by the local Turkish market and easiness to adaptation of its requirements by the projects. Furthermore, the criterion evaluates the reliability of the green

building certification system to acquire an international recognition for the projects, in addition to achieving the green building aims of the country.

- Design and construction timing: since the green building certification system becomes an essential part of the project, it is evident that there is an added time that affects the overall design and construction schedule of the project. Therefore, based on the certification systems requirements, this time could be estimated and incorporated into the master schedule through extending the affected activities.

- Accordance with Turkish legislation and standards: this sub-criterion concerns the alignment between the if green building tools that are evaluated under this study with the laws and legislations of the Turkish development. Furthermore, it shows the convenience of the usage of the green building tools with the Turkish green building development. Moreover, The Turkish developments apply International building code (IBC) and the Eurocode taking into consideration the special conditions of the country. Therefore, this sub-criterion takes indicates the convenience of using the six green building tools with the current standards implemented in Turkey.
- Clarity of criteria and sub-criteria: since the green building certification systems are based on different standards and requirement in the country of origin, the language used in narrating the requirement needs to be evaluated in order to avoid any miscommunication with the certifying body. This sub-criterion is one of the reasons consultancy might be needed for the project, which subsequently impact the cost of the projects.

It is important to understand that there is no specific international certification system that perfectly fits for Turkey. Thus, this research works also on providing the necessary data to create a new certification system for Turkey through understanding the most important criteria and sub-criteria. It is also understood that Turkey needs to develop its own green building certification system according to its strategic priorities.

Therefore, and based on the abovementioned factors, the following recommendations are provided:

- The government decision makers and academic scholars shall study the current green building certification system in Turkey (ÇEDBİK), and work on bridging the gap between its current status the most recommended certification systems in this study, which are LEED, BREEAM, HQE,CASBEE and DGNB.
- Adopting a development approach for green building and sustainable tools that are based mainly on the efficiency in covering a variety of building types, processes and reducing waste and increasing energy efficiency.

- Taking the sub-criteria identified in this research as of high priority in developing a green building certification system for Turkey.
- Enforcing laws that support the compliance with green building certification systems in Turkey, as well as providing motivational advantages for complying projects.
- Carrying out an awareness campaign that includes construction professionals, designers, developers, academic scholars, and government professionals in order to reinforce the knowledge about the developing tool and the expected outcomes from the strategy.
- The AHP method can be used for a future study of the subject with a bigger expert sample in order to confirm results and establish a base for developing the green building certification system.

On testing the hypothesis of the study, the first hypothesis states "The current certification system are unsufficient for Turkey assessment of green building.". It is evident that all the certification system that are developed internationally cannot perfectly fit for the strategic needs of Turkey. An exhaustive comparison between five of the most mature, successful and used certification systems are compared in the study, along with a current Turkish system that covers residential developments only. The study results show that the criteria considered in the international certification systems are designed to fit the needs of the original countries of the certification, as well as adopting a scoring system that is different from one tool to another. Therefore, the international certification systems, are not considered sufficient and further development shall be made based on the recommendations of this research. Therefore, this null hypothesis is accepted.

The second hypothesis state “AHP can be used as a methodology to assess certification system for Turkey”. It is shown from the case study and its discussion that the criteria and sub-criteria were rated differently among the three study groups using the AHP methodology. The AHP methodology is highly useful in the process of complex decision making. Subsequently, several criteria and sub-criteria were developed and tested through the experts' panel, academic scholars, governmental

decision makers, and consultancy experts, in order to set priorities for the most important criteria and sub-criteria for Turkey. The AHP methodology successfully was able to filter out the most important criteria and sub-criteria, which were reviewed as the results of the study. Therefore, the null hypothesis is accepted, and development of the Turkish green building certification system shall be based on the priority of the items. Items such as efficiency and cost were highly prioritized by the study groups, where other items such as accordance with Turkish legislations were not given similar importance.

According to the main criteria pairwise comparison by the study groups, the most important and influential criteria in choosing the best fit green building certification system are as the following:

The first efficiency mostly addresses the ability and the extent of which the tool can achieve the green building objectives. Three sub-criteria are assessed under this category which are the coverage of a variety of building types, in additional to coverage of Building process (Pre-design to in use). Moreover, overall success for assessment (success for reducing wastes& increasing energy efficiency)

The second the economic criterion assesses the certification system impact on the project's budget. Therefore, three sub-criteria are assessed under this category which are the registration and certification costs, implementation added costs and the cost required for consultancy fees.

Therefore, Turkey needs to develop a new certification system considering the criteria efficiency, economy. Furthermore, the AHP method has proven its success in achieving the research objectives in finding a methodology of development for a green building certification system for Turkey. Therefore, this method can be further applied with a bigger experts’ sample for results conformity.

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