


EVALUATION OF VEGETATED ROOFS IN TERMS OF SUSTAINABLE  
PERFORMANCE



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EVALUATION OF VEGETATED ROOFS IN TERMS OF SUSTAINABLE  
PERFORMANCE

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## **ABSTRACT**

### **EVALUATION OF VEGETATED ROOFS IN TERMS OF SUSTAINABLE PERFORMANCE**

Vegetated roofs are an important component used in architectural design as part of the sustainability movement. However, difficulties arise over time in such roof arrangements and they cannot satisfy sustainable characteristics in our day.

For this reason, this thesis primarily discusses the topics of sustainability in architecture and sustainability in vegetated roofs, under the concept of sustainability. Later, it examines vegetated roofs typology and the advantages of their effective usage. As a result of all examinations, the vegetated roofs' sustainability performance is demonstrated.

Research is carried out regarding what qualifications under which factors are needed to ensure sustainability of vegetated roofs so as to achieve such performance. In conformity with the fact that vegetated roofs with these qualifications exhibit high performance, suitably selected examples are detailed. A detailed control list is created in relation to vegetated roofs, aiming to control aforementioned qualifications under certain variables.

With the purpose of examination using this control list, 11 buildings from İstanbul with vegetated roof characteristics are selected, examined and the results announced.

## ÖZET

### **BİTKİLENDİRİLMİŞ ÇATILARININ SÜRDÜREBİLİR PERFORMANS AÇISINDAN DEĞERLENDİRİLMESİ**

Bitkilendirilmiş çatılar, sürdürülebilirlik akımının mimari tasarımda kullanılan önemli bir bileşenidir. Ancak günümüzde söz konusu çatı düzenlemelerinde zaman içinde zorluklar ortaya çıkmakta ve sürdürülebilir niteliklerini sağlayamamaktadır.

Bu nedenle, tezde önce sürdürülebilirlik kavramı altında, mimaride sürdürülebilirlik ve bitkilendirilmiş çatılarda sürdürülebilirlik konuları açıklanmaktadır. Sonrasında bitkilendirilmiş çatıların tipleri ve etkin kullanım faydaları incelenmektedir. Tüm incelemeler sonucunda bitkilendirilmiş çatılarda sürdürülebilirlik performansı ortaya konmaktadır.

Bu performansa ulaşmada bitkilendirilmiş çatıların sürdürülebilirliğinin sağlanması için hangi etkenler altında hangi niteliklere sahip olması gerektiği araştırılmıştır. Bu niteliklere sahip bitkilendirilmiş çatıların yüksek performans göstermesine uygun olarak seçilmiş örnek detaylar ortaya konmuştur. Söz konusu niteliklerin hangi değişkenler altında kontrol edilebilmesini amaçlayan bitkilendirilmiş çatılara ait detaylı bir kontrol listesi oluşturulmuştur.

Bu kontrol listesi ile değerlendirilmek üzere bitkilendirilmiş çatı niteliğini kapsayan İstanbul'dan 11 adet bina seçilerek incelenmiş ve sonuçları açıklanmıştır.

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**LIST OF SYMBOLS/ABBREVIATIONS**

°	Degree
C O <sub>2</sub>	Carbon Dioxide
O <sub>2</sub>	Oxygen
%	Percentage
m <sup>2</sup>	Square meter
BREEAM	Building Research Establishment Environmental Assessment Method
BD	Building Based
CD	City Based
cm	Centimeter
dB	Decibel
DGNB	German Sustainable Building Council
GHG	Greenhouse Gases
FAO	Food and Agriculture Organization of the United Nations
g	Gram
IUCN	International Union for Conservation of Nature and Natural Resources
kg	Kilogram
LEED	Leadership in Energy and Environmental Design
lt	Litre
mm	Millimeter
PV	Photovoltaics
SD	Sustainable Development
UN	United Nations

UNCED	United Nations Conference on Environment and Development
UNESCO	United Nations Educational Scientific and Cultural Organization
UNEP	United Nations Environment Programme
WCS	The World Conservation Strategy
WSSD	The World Summit on Sustainable Development
WWF	World Wildlife Fund



## 1. INTRODUCTION

Increases in the population of big cities and the corresponding growth of towns, as well as day to day increases in the market values of land are among the reasons behind why high-rise structures are preferred. Increase in closely spaced urban settlements are the main reason for many environmental problems such as recreation, decrease in open areas, traffic and infrastructure issues. Due to similar reasons, habitants of such cities grow further apart from nature with the decrease in green spaces, places where one could take a short break to breathe. Issues frequently acknowledged in the world's agenda include the desire to provide more room for green areas in cities, to evaluate all opportunities of integration with nature and to preserve natural resources. Topics including the usage of natural resources and their sustainability, environmental issues, and the heat island effect in urban areas have resulted in increased sensitivity in city-dwellers and brought new order to efforts towards creating settlements with natural environment conditions. Therefore, cities resort to solving the problem of decreasing green areas in cities by carrying planting to the top of buildings, i.e. with the application of vegetated roofs.

As a concept, it is possible to think of the roof as an important factor in how a space is perceived, instead of just as one providing protection against outdoor weather conditions. The approach of using unexploited areas in existing buildings for different functions equips roofs with the potential to respond to such new functions.

The first known example of a vegetated roof in prehistoric times is the Hanging Gardens of Babylon, built by King Nebuchadnezzar II during the rebuilding of Babylon, approximately 6 centuries ago in Mesopotamia. Concealment of settlements with soil and plants or planting of roofs were designs seen in the Hanging Gardens of Babylon. The need to conceal as well as the need for aesthetic appearance are legacies passed down to the present day from prehistoric times. Unlike prehistoric times, the vegetated roof design is among the design methods applied in the big cities of our day because it provides many environmental and ecological benefits and with regard to approaches of re-integrating structural elements to nature. Structural architecture technologies, seeking solutions for both ecological and aesthetic purposes in our day, propose once more the usage of green roofs in living spaces. Consequently, green roofs gain importance not only for providing the urban dweller with an

easily accessible green area but also as a space capable of protecting people from the unfavorable conditions of the external environment [1].

Therefore, it is crucial if not a necessity to ensure the sustainability of vegetated roofs, alongside their design and application.

### **1.1. AIM OF THE RESEARCH**

The aim of this study is to determine criteria which will contribute to improving the performance of vegetated roof designs in new designs or existing buildings' renovation activities of individuals who play an active role in the construction process of building designs and ensure continuation of such performance. Furthermore, it aims to evaluate designs in terms of sustainability following the criteria. The main goal to be achieved in the study is to provide the contribution of vegetated roofs to the surroundings of the building and to the sustainability on a city scale. It can be said obviously that the importance of approaching nature on the basis of the buildings that forming the city is undeniable in making the city life sustainable with its ecological, social and economic aspects.

### **1.2. SCOPE OF THE RESEARCH**

In this thesis; General technical information, classifications and applications of vegetated roof systems are examined and an evaluation is made in terms of sustainability in architecture. By the concept of vegetated roof, it is meant to all types of vegetated roofs of the buildings that can be walked on or not. In this framework, the study; By addressing the topics of vegetated roofs, it covers the determinations, evaluations and controls in line with the criteria determined for the sustainability of the vegetated roofs on the building samples selected from Istanbul, and some samples selected from Europe are interpreted by observation and examination.

### **1.3. RESEARCH METHOD**

The thesis is initially approached by literature research as a method of data collection. Following the literature survey, the factors that are effective in the sustainability of vegetated roofs are analyzed and determined. Then, according to the determined factors, the qualities that ensure the sustainability of the vegetated roofs are determined and roof details appropriate to these qualities are determined through research and development. A table of control variables used in the control of the sustainability of the vegetated roof samples using the specified attributes and details is included in the study. Using the criteria in this table, a checklist is created to be used to evaluate the vegetated roof performances of the samples. At the last stage, based on the observation, interview and building examination of selected samples, the sustainability performances are evaluated through checklists.

Instead of “vegetated roof” , it is found in literature and practice in such variations as “roof garden”, “green roof”, and “eco roof”. However, since the purpose of the thesis was based on vegetation use on building roofs, it was deemed appropriate to use the phrase “vegetated roof”.

## **2. THE CONCEPT OF SUSTAINABILITY**

The concept of “sustainability” is a topic of agenda frequently discussed in recent times.

Sustainability can be explained as using natural resources to meet today's needs while still ensuring their preservation and leaving behind a healthy environment from which future generations can benefit for their needs.

Sustainable development and environmental issues were discussed for the first time in a panel of experts in Switzerland in 1971. In the report published after the meeting, it is mentioned that environmental problems arise from the production and consumption structure of industrialized countries, and these problems are also revealed as a result of poverty and underdevelopment [2].

**United Nations Stockholm Conference, 1972;**

The United Nations "Human and Environment" Conference (Stockholm Conference) was held in Stockholm, the capital of Sweden, between 5-16 June 1972. With the Stockholm Conference, environmental issues began to engage the international agenda.

At the end of the conference, the United Nations Environment Program (UNEP) was established and a declaration was published. The Declaration adopted and declared an approach linking economic and social development with environmental factors, taking into consideration future generations in the use of resources that form the basis of sustainable development. In addition, June 5, the date of the conference, has been accepted as World Environment Day [3].

**United Nations Conference on Human Settlements (Habitat I), 1976;**

Held in Vancouver 1976 and known as the first international UN conference to fully recognize the challenge of urbanization, Habitat I resulted in: the establishment of the precursors of UN-Habitat: the United Nations Commission on Human Settlements – an intergovernmental body – and the United Nations Centre for Human Settlements (commonly referred to as “Habitat”), which served as the executive secretariat of the Commission [4].

**The World Conservation Strategy, 1980;**

The concept of sustainability caught the attention of public opinion with the World Conservation Strategy (WCS), published in March of 1980. The World Conservation Strategy was developed by the International Union for Conservation of Nature and Natural Resources (IUCN) with the support of the United Nations Educational Scientific and Cultural Organization (UNESCO), the Food and Agriculture Organization of the United Nations (FAO), the World Wildlife Fund (WWF), and the United Nations Environment Program (UNEP) [5].

**Our Common Future (Brundtland Report), 1987;**

Following the 1983 World Commission on Environment and Development (WCED), chaired by Gro Harlem Brundtland, a 1987 report named 'Our Common Future' was published, defining Sustainable Development as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The report highlighted three fundamental components to sustainable development: environmental protection, economic growth and social equity. The concept of sustainable development focused attention on finding strategies to promote economic and social advancement in ways that avoid environmental degradation, over-exploitation or pollution, and sidelined less productive debates about whether to prioritize development or the environment [6].

**United Nations Conference on Environment and Development (Rio Conference), 1992;**

It was organized between 3-14 June 1992 in Rio de Janeiro, Brazil with the participation of 178 states. At the Rio Conference, it was accepted that "human beings are at the center of the SD phenomenon, and that every human being has a right to a healthy and productive life in harmony with nature". With the Rio conference, the scope of the concept of Sustainable Development has expanded considerably and the concept has gained its place in the field of study of many disciplines. In addition to the SD concept, The Agenda 21 document adopted at the conference focused in great detail on concepts and issues such as sustainable human settlement, Sustainable Mountain Development, Sustainable Agriculture and promoting rural development, and sustainable forest development. The new concepts introduced by the conference have an extremely close relationship with the SD concept; in order to achieve sustainable development, it is seen as pointing out the activities that need to be done in areas such as environment, economy, urbanization and Management [7].

**United Nations Conference on Human Settlements (Habitat II), 1996;**

The second United Nations Conference on Human Settlements (Habitat II) held in Istanbul in June 1996. In particular, the Meeting was in support of one of the two themes of the Habitat II Conference namely, 'Sustainable Human Settlements Development in an Urbanizing World', and specifically in response to paragraphs 125-127 and 163-169 of the Habitat Agenda which broadly call for enhancement of the quality of life through integrating development with population variables, and for a planning and management approach which integrates rural and urban human settlements, respectively [8].

**Rio + 5 Conference, 1997;**

The Rio + 5 Forum was held on 13-19 March 1997 in New York. The Forum focused on strategies and management systems that will implement Sustainable Development at local, national and global levels [7].

**The Kyoto Protocol, 1997;**

The Protocol was adopted in Kyoto, Japan in 1997, when greenhouse gases were rapidly threatening our climate, life on the earth, and the planet, itself.

The Kyoto Protocol is an international agreement that aimed to reduce carbon dioxide (CO<sub>2</sub>) emissions and the presence of greenhouse gases (GHG) in the atmosphere. The essential tenet of the Kyoto Protocol was that industrialized nations needed to lessen the amount of their CO<sub>2</sub> emissions [9].

**United Nations World Summit on Sustainable Development (Johannesburg Summit), 2002;**

The World Summit on Sustainable Development (WSSD) 2002 in Johannesburg, the follow-up summit to the Earth Summit in Rio 1992, raised great expectations. It was designated to define instruments to fight global poverty and to reach ecosystem security, and to set timeframes and specific targets for the implementation of Agenda 21, the programme of action negotiated in Rio [10].

**United Nations Conference on Sustainable Development (Rio+20 Conference), 2012;**

The United Nations Conference on Sustainable Development or Rio+20 took place in Rio de Janeiro, Brazil on 20-22 June 2012. It resulted in a focused political outcome document which contains clear and practical measures for implementing Sustainable Development [11].

**G20 Antalya Summit, 2015;**

The pulse of the global economy was held in Antalya at the G20 Summit. Presidents, prime ministers and relevant ministers from member and invited countries came together in Antalya, where the summit will be held on 15-16 November 2015, in order to determine common policies in the world economy, to work on the solution of current problems and to make new decisions. Considering the summit in general, increasing the quality of employment as well as stronger and inclusive growth are among the common goals of all representatives [12].

All over the World “sustainability concept” is gaining increasing importance in many sectors such as economy, commerce, agriculture, management, industry, urbanism and architecture. In this research on vegetated roofs, the issue of sustainability in architecture is mentioned firstly, and then the importance of sustainability in vegetated roofs is emphasized, since vegetated roofs concern architecture and reflect in the urbanism.

## **2.1. RELATION BETWEEN ECOLOGY AND THE SUSTAINABILITY CONCEPT IN ARCHITECTURE**

Sustainable architecture defines building designs developed in a manner more respectful of the environment thanks to minimal usage of energy resources, while also providing safe and comfortable living spaces. Architecture contributes to sustainable development by designing sustainable buildings, favoring nature conscious materials, allowing for recycling and reuse, and ensuring sustainability of this process even after usage.

Expansion of the sustainability movement to every sector in the world particularly affects the organization of settlement areas. New horizons such as “developing ecological settlements and green architecture in city planning”, “new urbanism”, “smart growth” and “subterranean settlements (landscrapers)” have lead to the development of new ecological urban design models. Such models have brought about the formation of typology like green city, eco city, slow city, compact city, digital city etc. and therefore also had an effect on architecture [13].

Addressing ecological structuring as a method of ensuring sustainability has set forth a sustainable and ecological architecture understanding, causing many architectural typology to be born under definitions of “green building”, “ecological building”, “eco friendly building” and “underground building”.

Common aspects of these typology are basic ecological design principles in architectural design, as explained below:

- Maximum utilization of the sun
- Reduction of heat loss

- Harmony with nature
- Optimization of infrastructure systems
- Utilization of planting
- Optimization of material usage [14].

Buildings with such ecological and sustainable qualifications are granted the BREEAM, LEED and DGNB vs. certificates.

Conformance to these principles and sustainable structures are defined as below.

These can be defined as structures which increase the quality of human subsistence, all the while causing no harm to the ecosystem neither on a macro or micro scale [15].

In sustainable architectural design, ecological and natural efficacy is based on planting, which has lead to the concept of “Use of Planting in Buildings.” With respect to this concept, building-level planting usage systems as can be seen in figure 2.1. pertaining to the usage, location and style of plants on buildings have been developed.

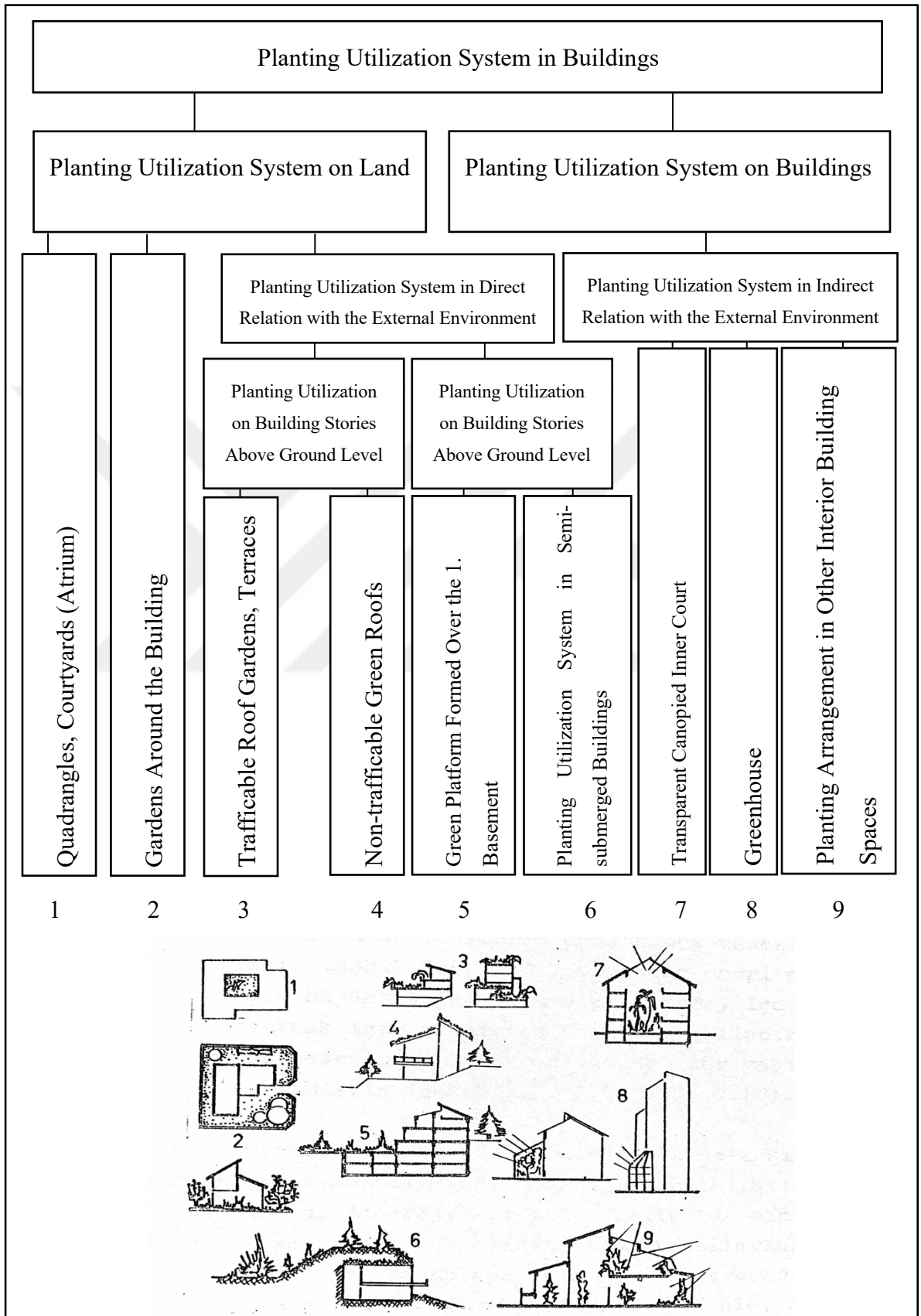


Figure 2.1. Building-level planting usage systems [16].

In figure 2.1., vegetated roofs are stated as trafficable “vegetated roofs and terraces” and “non-trafficable green roofs” under “vegetation utilization on building stories above ground level” in direct relation with the external environment.

## **2.2. SUSTAINABILITY IN VEGETATED ROOFS**

Utilization of roofs through planting is an architectural design which has popularized in densely populated cities, albeit variations across different countries. For this type of roofs to be sustainable, they need to exhibit characteristics which minimize the need for activities such as maintenance, repair, restoration etc. and which can conserve the efficiency of a livable environment for planting.

Benefits obtained through vegetated roofs play an active role in the sustainability of both buildings and cities. The contribution of each roof to architecture and sustainability of urban life, from reducing the heat loss of the building to providing the building with a common natural and socio-cultural environment and improving the urban ecology and climate, is becoming increasingly important. Therefore, in increasing this contribution, it is necessary to make the vegetated roofs sustainable. It is clear that the more sustainable the vegetated roofs perform, the more they will contribute to the increasingly urban sustainable qualities of the building and the environment.

In figure 2.2, there is a sample image from London regarding the vegetated roofs on urban sustainability.



Figure 2.2. An image created by vegetated roofs in London on a city basis [17].

In order to explain vegetated roofs as part of the concept of sustainability, it is necessary to examine the topics of “vegetated roof typology” and “advantages of effective usage in vegetated roof”.

### **3. VEGETATED ROOF TYPOLOGY**

Vegetated roof examples are defined with concepts such as eco-roof, living roof, roof garden and green roof. All these concepts are examined within the scope of vegetated roof systems.

Technical specifications like roof slope and roof load, as well as climatic conditions such as amount of precipitation, exposure and wind direction determine the types of roofs in green roof designs. These roof types are classified as intensive vegetated roofs, extensive vegetated roofs and semi-intensive vegetated roofs [18].

From these typology, the two types generally addressed in literature are densely intensive vegetated and extensive vegetated roofs. According to Seçkin, a third type semi-extensive vegetated roof can also be specified; however, since the usability of all three roof types together can be a matter of discussion, this topic will be further explained in section 3.3.

#### **3.1. INTENSIVE ROOFS**

Intensive roofs are, roofs with less than a 5% slope, allowing for people to walk on them. A variety of planting, such as trees, bushes and ornamental plants, which require a deep habitat and intensive root depth are the kinds of planting that can be used on intensive roofs. Additional loads which will weight down on the building due to the use of abundant amounts of soil for the vegetated gardens placed on building roofs to grow should be calculated both as wet and dry soil, and added to static calculations. For this reason, application on buildings to be newly-built would yield healthier results.

Intensive roof application, allowing for different functional usages, contributes to the improvement of the city's climate, add to the aesthetic and architectural features of a building and provides many more advantages to the inhabitants of the city. Furthermore, it creates spaces where building residents can spend a pleasant time eating, doing sports, having fun in an outdoor environment or cultivating. As these spaces are intended to be accessible for people, it is necessary to carry out regular maintenance for the sustainability of planting development in the designed spaces and outdoor equipment. Regular and frequent

maintenance will increase cost. Figure 3.1. The classical type of intensive roof detail is seen in. Figure 3.2 shows a sample of an intensive roof from New York.

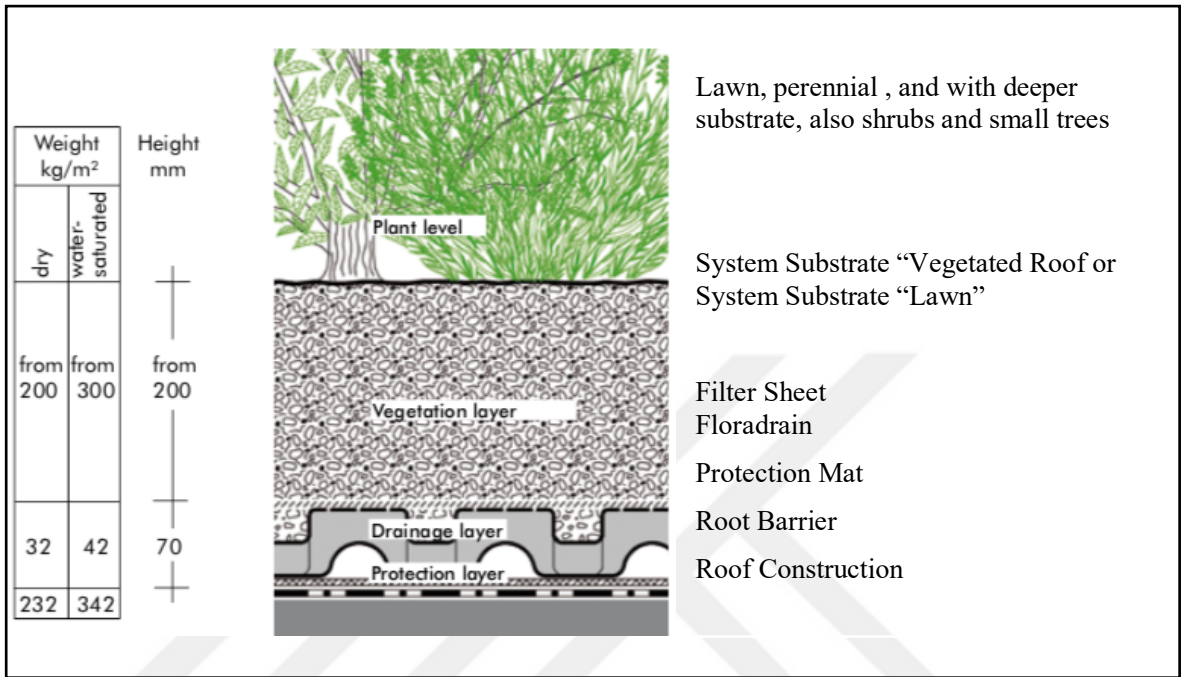


Figure 3.1. Intensive roof detail [19].



Figure 3.2. Intensive roof sample Eastwick Residence, New York [20].

### 3.2. EXTENSIVE ROOFS

Extensive Roofs are spaces located on the roofs of buildings which are generally inaccessible except for maintenance, are not suitable for spatial activities and ideally have at least a 1.5-2% slope to ensure drainage.

Extensive roofs can be set up as far as 30 degrees. Roofs exposed to strong winds and with more than a 15 degree slope must be protected with an erosion control net (in the form of jute or other natural biological fibers) during installation [21].

Planting that can be used on extensive roofs consist of planting such as sedum, moss, weeds and grass. Planting types used on the roof need to be selected with regard to the environmental and climatic conditions of the area in which it will be established. The roof does not carry too much load since planting used has low soil adhesion and sparse roots. This is thanks to the usage of low-cost planting which requires seldom irrigation and low maintenance.

Although low-intensity greening systems require very little maintenance, this does not mean they lack the need for maintenance altogether. For a healthy planting cover, wild weeds need to be regularly cleared and the cover (planting cover) might require fertilizer for nourishment. Even though such types of planting covers generally do not need irrigation, newly established systems should be irrigated during dry spells to support the planting [21].

Extensive roofs are also generally known as “layered systems” because they contain a number of layers. As general overview of the layered system, it can be established with the following arrangement from top to bottom: planting, substrate (growth medium), filter layer and drainage layer.

Green roof material vendors may change this order depending on material. Certain changes may need to be applied depending on the climatic conditions of the project’s location, but extensive (sparse) roofs are commonly established in this layout. As an exception, a system can also be formed by placing vegetated modular container units side by side [21].

Extensive roofs are typically designed to contribute to urban ecological balance and to increase visual comfort. Figure 3.3. The classical type of extensive roof detail is seen in. Figure 3.4. shows a sample of an extensive roof from Chicago.

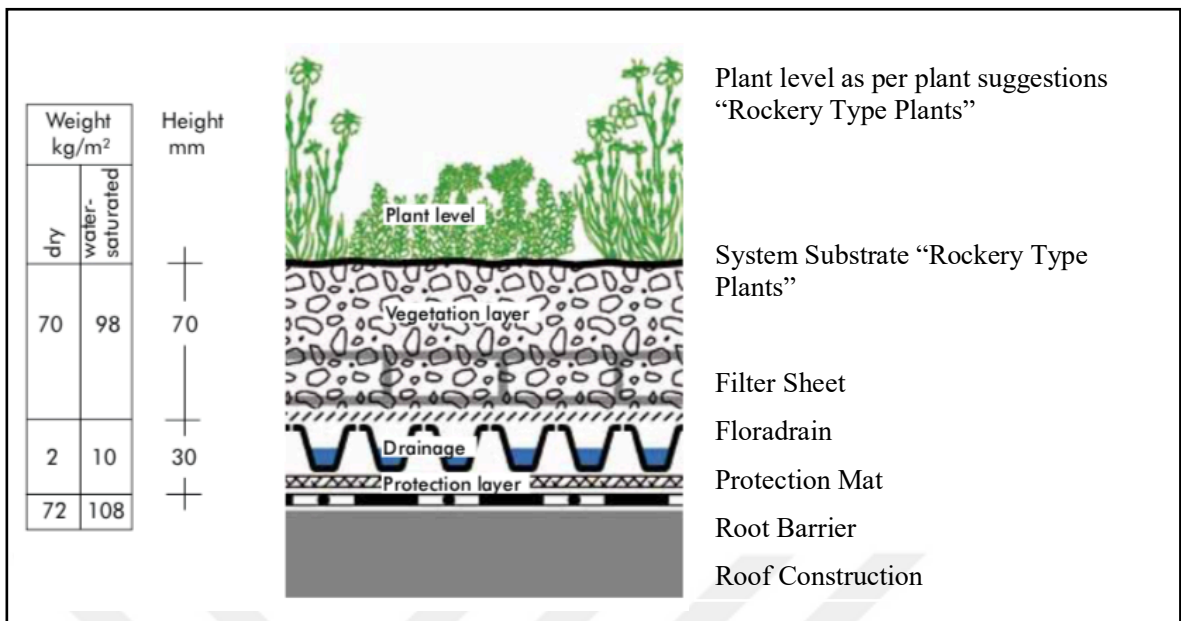


Figure 3.3. Extensive roof detail [19].



Figure 3.4. Extensive roof sample 111 South Wacker, Chicago [22].

### 3.3. SEMI-INTENSIVE ROOFS

Semi-Intensive Roofs, derive from a mixture of Intensive and Extensive roofs. They have greater surface depth than extensive (sparse) roofs. Although they contain a greater planting variety in comparison to extensive roofs, they are not suitable for planting requiring depth of soil such as trees and larger bushes. Similar to intensive roofs, they add extra load to the building. With no widespread application, the system has not been properly discussed and developed with sufficient amount of detail. Figure 3.5. the classical type semi-intensive roof detail is seen. Figure 3.6. shows a sample of a semi-intensive roof from California.

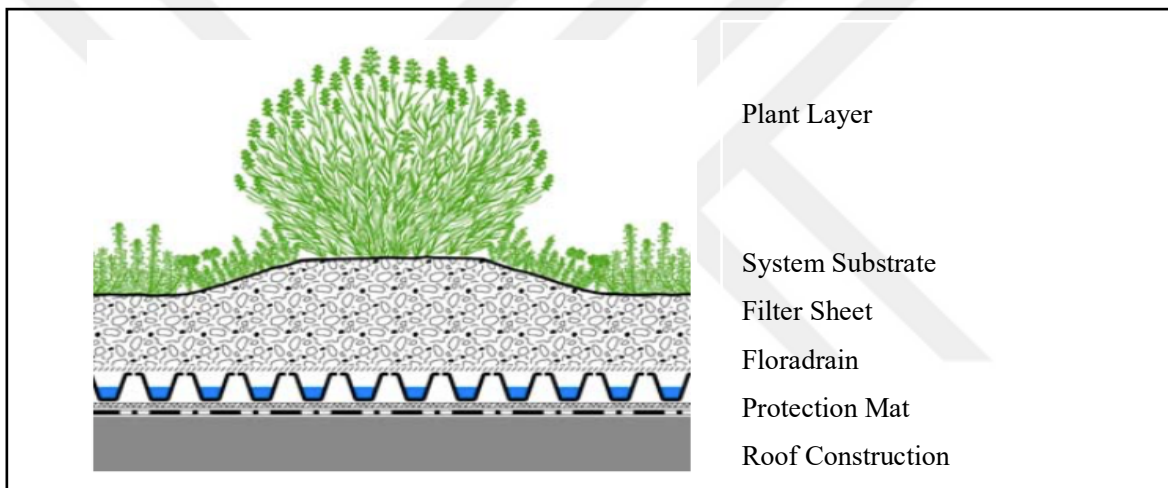


Figure 3.5. Semi-Intensive roof detail [19].

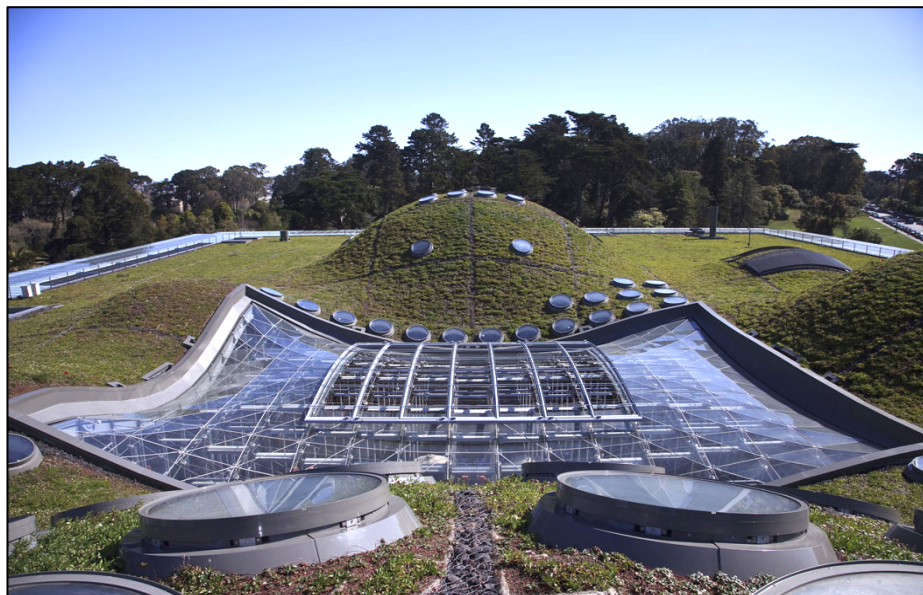


Figure 3.6. Semi-Intensive roof sample, California Academy, California [23].

### **3.4. THE POSITIVE AND NEGATIVE ASPECTS OF VEGETATED ROOF TYPOLOGY**

Research carried out in recent years shows that vegetated roofs are preferred due to their rehabilitative effects on the urban ecosystem. These roofs bring certain advantages to the buildings they are located on and to their environment in an ecological sense; these can be expressed as below.

All types of vegetated roofs bring certain disadvantages to the buildings they are located on and to their environment in an ecological sense; these can be expressed as below.

#### **Intensive Roof Specific Positive Aspects**

- It provides greater planting diversity
- It provides a good insulation option to the structure
- It creates significant visual and aesthetic appeal
- It enables the roof to be used for various purposes
- It has greater water retention properties than the extensive roof

#### **Extensive Roof Specific Positive Aspects**

- The roof does not need to be reinforced since the planting habitat is not deep and the roof does not carry much soil load
- Its application to large areas is convenient,
- It requires more than rare maintenance yet has lower maintenance costs than intensive roofs
- It does not require a frequent irrigation and drainage system
- Planting can grow independently
- It contributes in greater extent to urban ecology than the Intensive Roof

### **Intensive Roof Specific Negative Aspects**

- Adds extra load to the roof (soil, equipment, human load, technical systems)
- Requires additional structural support
- Requires regular maintenance, therefore has high maintenance and repair cost (may vary depending on the vegetated roof type)
- Requires an irrigation and drainage system,
- Presents implementation difficulty in existing buildings

### **Extensive Roof Specific Negative Aspects**

- Planting choices are more limited than the Intensive roof type
- It is not very suitable for recreational use

#### **3.4.1. Common Positive Aspects Observed in Vegetated Roof Typology**

- Lowers the drainage load and risk of sudden water overflow by retaining rain water, helps with the drainage system and lowers cost
- Helps in lowering the effect of heat fluctuations on the structure, thereby reducing thermal stress by providing isolation and heat insulation
- Prolongs the expected life of the roof by protecting it against ultraviolet rays
- Adorns the structure with aesthetic value
- Regulates the heat-humidity balance
- Decreases the heat island effect in cities
- Filters dust and toxic gases as well as pollution in air and water
- Absorbs carbon dioxide from the atmosphere and produces oxygen, improving the air quality of the city
- Creates a natural habitat for planting and small creatures
- Provides sound insulation

### **3.4.2. Common Negative Aspects Observed in Vegetated Roof Typology**

- Infestation
- Additional fire risks brought on by dried plants, plant soil absorbing extinguishing water and posing an obstacle to fire extinguishing
- Maintenance problems
- Climatic and weather related limitations

It is seen that the common positive aspects for each type of vegetated roofs are more than the common negative aspects. From this point, the importance of benefits from vegetated roofs becomes evident. Therefore, it has been deemed necessary to examine and reveal the effective benefits to be obtained by using vegetated roofs in order to eliminate the negative aspects mentioned in section 3.4.2.

## **3.5. ADVANTAGES OF EFFECTIVE USAGE IN VEGETATED ROOFS**

Taking into consideration the positive aspects of the concept of sustainability in architecture mentioned in section 3.4., it is possible to examine the effective benefits of the sustained roofs of vegetated roofs under three main headings: ecological, social and economic. These benefits are in section 3.5.1., 3.5.2. and 3.5.3. is also described.

### **3.5.1. Ecological Benefits**

Plants always play a positive and active role in the ecology of their environment. For this reason, vegetation of the roofs is important first of all in terms of creating a natural and ecological environment. Vegetated roofs have numerous benefits to structure, environment and ecology. The vegetated roofs have also multiple benefits from the positive contribution of the city to the improvement of the climate and natural conditions, to the improvement of

the building's bioclimatic climate conditions. These benefits can be explained under the following subheadings.

#### **3.5.1.1. Conservation of Habitat and Biological Diversity**

The natural habitat for living creatures diminishes by the day in big cities due to settlements. For this reason, vegetated roofs incorporated to structures help protect the habitat and biodiversity in the city. Gardens designed on roofs of structures could provide a safer living space for creatures capable of living in such a place, considering the risk factors on ground level.

#### **3.5.1.2. Heat Regulation Effect**

- Reduction of the urban heat islands effects
- Energy efficiency and cooling effect
- Cutback of cooling winds effect

These effects can be detailed as below. A significant increase in temperature has been observed in recent years in urban centers, places accommodating a big part of the human population. Increase in urban settlements diminishes green areas and damage the aforementioned heat balance.

In most big cities, artificial surfaces created by intense settlement lead to an increase in the absorption of sun rays and in heat capacity. Under normal conditions, heat absorbed by and accumulated on structures' surfaces can easily drift away from the urban center by way of convection. However, insufficient gaps between structures block ventilation. In this way, heat captured in the surfaces of structures during the day is released back to the environment at night. This causes temperature values to remain above normal, resulting in greater operation of air conditioning systems. Increase in the temperature values of the urban center as a result of this loop is called "heat island" [24].

The planting cover on Green Roofs, not only provides natural ventilation on the structure but also helps cool the air with its shadow effect and supports better air for the structure by moistening the air. The shadow effect provided by green roof planting facilitate the correction of heat islands' effect. What's more, the soil layer provides additional insulation for structures in the winter. Green roofs with thick-layered soil can reduces structures' heating needs and wind-related heat loss by 50%. Computer models created by the Lawrence Berkeley National Library in California have shown that hundreds of roof gardens together can reduce ambient temperature by up to 3° C [25].

### 3.5.1.3. Air Quality Improvement Effect

- Filtering airborne particles
- Oxygen production using carbon dioxide
- Elimination of harmful gases in the air

Nitrogen dioxide, sulfur oxide, hydrocarbon, carbon dioxide, carbon monoxide and dust particles mixed into the atmosphere by the influence of fossil fuels resulting from transportation, warming and industrial processes pollute the air, causing the natural balance to be deteriorated. It is recognized that chemically carbon dioxide can create problems due to its characteristic known as the greenhouse effect, which is the biggest global climate problem of our time and can cause the temperature rise on earth. Vegetated Roof plants use carbon dioxide for their respiration, thus helping to reduce the problems that will occur. In addition, Vegetated Roofs contribute to the Prevention of air pollution by reducing dust in cities. 1 m<sup>2</sup> grass area creates 100 m<sup>2</sup> leaf face. This means the ability to hold between 200 g and 2 kg of dust per m<sup>2</sup> per year depending on the wind. In the measurements made between the areas with and without green cover, 3 to 7 times more dust particles were found in 1 litre of air in areas without green [25].

#### **3.5.1.4. Noise Control Effect**

The noise from traffic and other sources in cities is reflected from structures and hard surfaces. The plant used in Vegetated roof arrangement helps to reduce the sound by showing the soil layer sound absorber feature. Thanks to this feature, it acts as a reduction of the noise level in the building or in the open spaces. In addition, year-round evergreen trees on the vegetated roof can reduce the noise level in the environment.

According to the intensity of noise, it is known that low frequencies are blocked by soil and high frequencies by planting. When the sound level is 50 dB in normal speech and the noise disturbance threshold is considered as 60 dB, it is seen that a green roof with a thickness of 12 cm reduces the sound of trucks and trains that are 90-100 dB below the noise threshold [26].

#### **3.5.1.5. Rainwater Utilization Effect**

The use of materials such as asphalt roads and concrete in urban environments restricts rainwater transmission, also, due to the effects of global warming, water shortages are increasing throughout the world. The effective and sustainable use of water is an important issue on water shortages. On vegetated roofs, a large amount of the water evaporates and returns to nature. Therefore, there is a decrease in the amount of water to be drained and the decrease in the amount of water relieves the burden of the city sewage system. It also reduces the use of mains water by storing rainwater. It enables the green areas to be used for irrigation, for general use of the house or for purification as drinking water.

#### **3.5.1.6. Electromagnetic Radiation Reducing Effect**

The production, transmission and distribution system of electrical energy occupies an important place in our lives. Energy transmission lines, substations, electrical cable networks, electric transport vehicles and electrical devices that we use in our daily lives constitute electromagnetic pollution. Electromagnetic fields have effects against the

environment and public health that should not be ignored. The planting and soil layer used in vegetated roofs have the effect of greatly reducing electromagnetic radiation.

Vegetated roofs absorb electromagnetic radiation. It has been proven that the green roof, which has a 10 cm soil layer, reduces the electromagnetic radiation by 99% [26].

### **3.5.1.7. Contribution to Protection of Settlements from Natural Catastrophes**

This contribution plays an important role in flooding caused by excessive rainfall. Vegetated roofs and terraces absorb rainwater by plants and soils, allowing slower and more balanced water transfer to the drainage. Therefore, vegetated roofs and terraces can reduce the effect of rain water flowing rapidly from buildings and gutters to the city in flood formation and protect the city from flooding.

It can also provide an opportunity as a gathering place for people trapped in buildings after earthquakes, floods and similar disasters to be rescued from the air by helicopters and similar vehicles.

### **3.5.2. Social Benefits**

The installation of vegetated roof systems provides significant social benefits to cities and people, especially in terms of creating visual comfort and recreation areas. These benefits are described as follows. Especially intensive roofs within vegetated roofs provide a social gathering area for the building, creating a highly effective common open space in structures with multiple independent sections. These social benefits, which can be stated as adding aesthetic value to the city, creating entertainment and functional outdoor space, positive impact on human health and comfort, and perception of space, can be explained as follows.

### **3.5.2.1. Aesthetic Value Addition**

Roofs are among the most idle areas in cities. The use of planting on the building provides an improvement in the visibility of both the building and the city in terms of aesthetics, and the development of social relations. Instead of the rooftop landscapes, which are unfavorable or filled with various technical equipment, which appear when looking at the entire city from the multi-storey high-rise buildings in dense city centers, the natural appearance created by green and various plants always adds aesthetic value to the human spirit.

### **3.5.2.2. Creating Entertainment and Functional Outdoor Space**

The vegetated roofs have an important role in providing various functional areas for the city and its surroundings, where green areas are limited. Many activities such as eating, sports, having fun outdoors, gathering and organizing events can be carried out in the recreation areas of vegetated roofs. In this context; Vegetated roofs can also contribute to the elimination of this deficiency in case of insufficient need of active green space per capita in cities.

### **3.5.2.3. Impact on Human Health and Comfort**

Being surrounded by trees, bushes, herbs and flowers found in gardens is beneficial for human health. Taking care of trees and plants or being in the same environment with them reduces stress, lowers blood pressure, helps breathe fresh air through the air it cleanses and helps relieve tension in muscles. The use of plant elements in urban areas where there is intense construction is one of the visual elements that relax people psychologically and increase positive emotions.

#### **3.5.2.4. Perception of Space**

For the purposes mentioned above, the softening and space limiting effects of planting in the roof space have a very positive effect on the perception and analysis of the space.

Because the design can be strengthened, if only the plants are seen as a green building elements [16].

Thanks to plants, an open space can be easily transformed into a natural space without using any structural elements.

#### **3.5.3 Economic Benefits**

The installation of a vegetated roof system is costly, but it is known that it pays investment costs due to its long-term contribution to the building. Considering that the most fundamental component of the concept of sustainability, as explained in section 2, is economic life, it is obvious that the ecological and social benefits of vegetated roofs described above will turn into economic gain by providing energy control and savings on both building and city basis. The economic benefits of vegetated roofs are examined in this section.

##### **3.5.3.1. Prolonging of Roof Life System**

Vegetated roofs protect the building from UV rays, heat from sunlight and cold winds, preventing the building from being exposed to high temperature differences throughout the year. In this way, the life of the roof system is prolonged. Therefore, the maintenance and repair cost of the roof is reduced.

##### **3.5.3.2. Saving on Insulation and Energy Control**

The soil, which forms the basis of the planting arrangement in vegetated roofs, contributes to the thermal insulation, thus reducing the heating and cooling energy costs. In addition, instead of a bare roof surface, vegetated roofs do not absorb the sun rays in summer and

transfer it to the interior, thanks to the vegetative texture on it, vegetated roofs contribute to energy control and thus the economy due to the fact that direct solar radiation warms the roof surface of the sun, with the help of deciduous plants in winter, in sunny weather, protects the roof environment of the plants from cold winds and acts as heat insulation of vegetative texture.

### 3.5.3.3. Urban Agriculture Opportunity

Being able to carry out agricultural activities on the roofs of the buildings will increase food production and help natural and organic food consumption, as well as benefit the economies of individuals. Thanks to the planting and agriculture on the roofs, it is possible to provide urban beekeeping, which contributes to the improvement of the urban ecology by making use of the flowering process of the plants. In figure 3.7; An example of urban agriculture can be seen on the roof of The Gary Comer Youth Center, which was established in 2009 in Chicago.



Figure 3.7. Urban agriculture sample, The Gary Comer Youth Center, Chicago [27].

In table 3.1. the effective benefits of the vegetated roofs in the building are mainly emphasized by the building and the city. When we look at the subject with explanations up to here; within these benefits, 'noise control', 'creating a social open space', 'perception of space', 'lengthening the roof life' can generally be considered as benefits to the building.

'' Conservation of habitat and biodiversity ''urban agriculture opportunity'' are generally benefits to the city; other " heat regulation effect ", " air quality improvement effect ", " rain water assessment ", " electromagnetic radiation reduction ", " contribution to protection from natural disasters ", " aesthetic value contribution ", "human health and comfort" and "savings in insulation and energy control " can be evaluated as benefits to both the building and the city.

Table 3.1. Vegetated roofs effective advantages

ECOLOGICAL BENEFITS	B. B.	C. B.	SOCIAL BENEFITS	B. B.	C. B.	ECONOMIC BENEFITS	B. B.	C. B.
Conservation of Habitat & Biological Diversity		X	Aesthetic Value Addition	X	X	Prolonging of Roof Life System	X	
Heat Regulation Effect	X	X	Creating Entertainment and Functional Outdoor Space	X		Saving on Insulation and Energy Control	X	X
Air Quality Improvement Effect	X	X	Impact on Human Health and Comfort	X	X	Urban Agriculture Opportunity	X	X
Noise Control Effect	X		Perception of Space	X				
Rainwater Utilization Effect	X	X						
Electromagnetic Radiation Reducing Effect	X	X						
Contribution to Protection of Settlements from Natural Catastrophes	X	X						

B.B: Building Based

C.B: City Based

#### 4. SUSTAINABLE PERFORMANCE OF VEGETATED ROOFS

For the validity of the benefits described above, it is important to make vegetated roofs long-lasting and permanent. Because of this importance, sustainable performance evaluation of vegetated roofs is required. Effective Usage Advantages are only achievable if vegetated roofs demonstrate high performance. As shown in figure 4.1.; the performance evaluation depends on the determination of the qualifications that the vegetated roofs should acquire. These characteristics can be demonstrated through the factors mentioned in section 4.1.

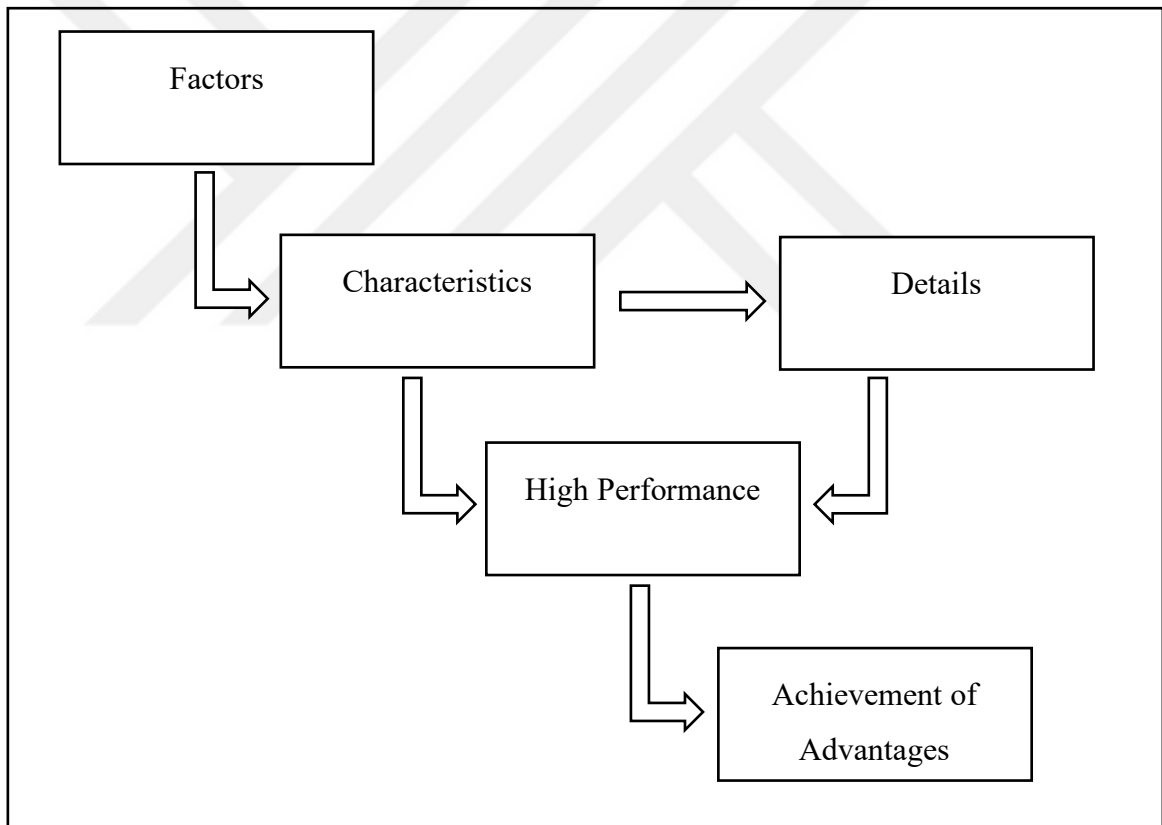


Figure 4.1. Sustainable performance flow of vegetated roofs

## **4.1. FACTORS AFFECTING SUSTAINABILITY OF VEGETATED ROOFS**

Whether or not to ensure the sustainability of vegetated roofs depends on certain factors. Taking into account the expected benefits from the vegetated roofs identified in section 3.5, these factors can be listed as follows,

- Maintenance and repair
- Planting
- Security
- Material Selection
- Hardware
- Access

### **4.1.1. Maintenance and Repair**

Maintenance and repair is the most important factor affecting the sustainability of vegetated roofs. Because all problems in maintenance and repair negatively affect the sustainability of the roof. Therefore, the convenience to be provided in this regard is important.

#### **Ease of Maintenance**

In order for planting to be successful in vegetated roofs, adequate and appropriate water supply, adequate drainage, adequate environment for plant development, periodically feeding and spray application to reduce evaporation should be provided. These practices help the plant to need care less often, while making it easier for the caregiver to work. Choosing the flooring material so as not to interfere with the roof cleaning is one of the factors that will facilitate its maintenance. The selection of evergreen plants, require minimal maintenance helps to reduce the frequency of maintenance and help to reduce repair and maintenance costs.

### **Ease of Repair**

When the need for repair is required, it is necessary to create an assembly that can be provided with ease in terms of material selection and proper detailing. Equipment such as railing, bench, lightings, pools, fountains, children's play parks in vegetated roofs require constant maintenance from a safety and visual point of view. In addition, in order to make the repair of factors such as water leakage fast, easy and less costly, the application of removable layer design may be preferred.

### **4.1.2. Planting**

It is clear that the sustainability of vegetated roofs can be assessed by appropriate selection and correct application in terms of factors such as plant types, arrangement type, amount, seasonality, purpose of planting. Therefore, errors or improprieties to be applied in planting can be stated as the main factor that cannot be given up in the sustainability of vegetated roofs. In planting, climate and purpose, suitability for roof construction and visual satisfaction and richness of plant equipment are explained separately below.

#### **Suitability to Climate and Purpose**

In planting design, besides creating a place with high visual quality, plant selection for climate and purpose is very important. Plants that are not selected according to different season types and climates will start to deteriorate in a short time, will be a visual obstacle and will require extra care. In addition, the lack of selection of plants according to the function and usefulness such as providing fresh air of the place, preventing noise pollution, wind breaking, sun breaking may cause disruption or negatively affect the operation in the area.

#### **Compliance with Roof Construction**

In the vegetated roofs at high altitudes, the plants need to be protected against the wind as the wind has a stronger and turbulent effect and the winds are the meteorological factors that

accelerate evaporation. The strong wind makes the leaves of the plants darker and causes the thin and long plants to fall over as well as excessive moisture loss [28].

In this case, the choice of wind-resistant plants is also important in terms of suitability for roof construction, under the condition that the position of the roof is appropriate.

It is recommended to choose less water retention and lighter soil in order not to load the roof slab on vegetated roofs. But due to loose soil, the plant that interacts with the wind is at risk of overturning. Special details are needed to be developed, such as fixing large plants with steel ropes at risk of overturning.

The choice of plants that do not take root too deep is very important, the plants that are suitable for rooting too much can not fit into the area where they are located, and they have risk of drilling the waterproofing membrane.

### **Suitability for Visual Satisfaction**

As a result of concrete in cities, green areas such as parks near houses and offices are often not easily accessible. In addition to air purification, noise insulation, sun and wind breaking effects, planting equipment should be used frequently due to its healing effect and concentration increasing effects. Especially in the settlements where the construction is high, the landscape consisting of upper floors is improved with vegetated roofs and thus, visual satisfaction can be created by removing inappropriate technical and structural images.

### **Abundance of Plant Equipment**

With the creation of a deep growing environment, a more complex ecosystem can be created where many different kinds of animals can be found, as plant diversity will include trees, flowers and shrubs. They can also enable the cultivation of herbal products. In other words, in terms of planting, dense green roof systems allow vegetative food production, trees, flowers and shrubs with high maintenance needs can take place in these roofs depending on the carrier substrate elements of the system [29].

In this sense, in the world; There are many examples such as the Gary Comer Youth Center in Chicago, which contains a very rich vegetative richness of up to 70% (6000 square feet / 8600 square feet) of the total vegetated area within the total roof surface area [30].

### 4.1.3. Security

As with all issues related to design, the issue of security is the main factor in ensuring sustainability. Other factors affecting the sustainability of vegetated roofs are important in the condition of ensuring the safety. Below; for the investigation of the safety factor, it is necessary to explain the dangers in the use of water and electrical insulation, the dangers in the use of roof, the negativity in fire extinguishment and the dangers that roof - terrace loads will pose to the statics of the building.

#### **Water & Electrical Insulation Removal of Danger in Use**

Since the interaction with water is intense in the vegetated roofs and electricity is required according to the usage function, it is important to isolate the water and electricity materials from each other. If water and electricity lines interact with each other, they cause hazards such as fire. Since the water and power lines interact with each other will cause fire and similar hazards, it should be foreseen that the safety of the vegetated roofs will be ensured first by the separation of the water and power lines and by the construction and insulation.

#### **Ensuring Safety Against Danger**

One of the important sub-factors related to the safety factor to be considered in the vegetated roof design is the subject of safety against danger during use. Safety measures should be taken for the team that initially builds on walkable roofs, and then for the persons who will use the space and the persons who will make maintenance and repair, the material that serves as guardrail against the danger of falling. The height of the railing should be designed to be at least 80cm. Suicide or approaching the edge of the roof terrace for any reason should be prevented by preventive vegetative arrangement. In addition, protected plugs should be used, maintenance tools and chemicals should be stored in protected areas.

### **Troubleshooting in Case of Fire**

As mentioned in indoor planting, additional fire load of dried plants in vegetated roofs is valid. Especially in coniferous plants, when the plant starts to dry, the possibility of deflagration is very high. In such vegetated roofs, the fire zone levels within the building should be paid attention and this zone should be maintained on the roof. Green roof landscaping should not be such as to complicate fire fighting intervention. It should be noted that the soil used for planting can absorb the extinguishing water during the extinguishing process on the roof. This will increase the amount of extinguishing water to be used [31].

When the use and production of electricity is considered, outbreaking of fire becomes easier. The fire is caused by electricity and reaches the generator motor, batteries are at great risk. As a result of all these critical situations, the class of the photovoltaic panels should be known. Toxic gas extraction and dripping in case of fire should be investigated and used as a result of certain decisions at the design stage [32].

As mentioned above, photovoltaic panels used in vegetated roofs are also known to be an obstacle to fire extinguishment. As a result of the PV sparking, the panels burn and release toxic gases.

### **Effects of Roof Loads on Building Statics**

One of the most important conditions of roof planting is the creation of a solid roof construction for the loads it will undertake. It is necessary to calculate the fixed and moving loads and to select the carrier equipment to be used as a result of the static results. Choosing solutions that require constant plant and soil loads to be mitigated on the roof / terraces will facilitate convenience in building statics. In vegetated roofs, it is important to transfer the loads of plants to the building carrier system.

#### **4.1.4. Material Preference**

The use of natural materials is very important because the roofs and terraces are habitats for living things, because they are intertwined with nature and in terms of human health. The

choice of natural materials that are minimally affected or unaffected by the outdoor conditions can save both in terms of easy maintenance and maintenance and repair costs.

All phases of the construction and production process need to be taken into account to ensure that environmental impacts of buildings are minimal and environmental and structural sustainability is taken into account. Considering that approximately one of the environmental impacts of a building is caused by the building materials used, the importance of building material selection becomes apparent [33].

The type of material used in building design can be called as ; natural materials, artificial materials, local materials, special materials produced for the project and recycled materials.

The building material used in the design of the building continues its association with the environment throughout the life of the building. Starting from the raw material state, production, usage, demolition and recycling phases, building materials interact with the environment. In order for the material to be sustainable throughout its life cycle, it needs to meet conditions such as energy efficiency , indoor comfort conditions, selection of materials that do not create environmental waste that adapt to environmental conditions. The use of environmentally sensitive materials is a very important issue to be considered by architects in terms of not harming the ecological balance.

When we look at the common aspects of the most preferred building materials compared to their counterparts in terms of their environmental impact, we find the following characteristics.

1. Effective use of Resources

- Give priority to the use of renewable raw materials
- They contain recyclable components derived from waste
- Easy to use, assemble and disassemble
- Recyclable

2. Protect the health of people working in construction and users;

- Chemical emissions are very low or none, so they do not adversely affect indoor air quality
- They do not contain high amounts of toxic components
- They are durable and require little maintenance and repair

3. They are beneficial for the ecological environment and society;
  - There are no gas emissions that harm the ozone layer
  - Obtained from renewable sources
  - Obtained from local sources and producers
  - Buried energy value is low
  - Resoluble in nature after service life [34].

As described above, the materials to be used in sustainable and ecologically vegetated roofs must have the same qualities.

#### **4.1.5. Hardware**

It is an important factor in terms of sustainability to arrange all kinds of hardware to be placed in vegetated roofs in accordance with the conditions. In this regard, compliance with the usage function of the roof and the unobstructed placement of all kinds of energy equipment such as solar panels that can be used on the roof can be stated as sub factors.

#### **Hardware Suitable for Purpose**

Since the roof loads will be determined according to the type of use, it should be clarified which function the space will be used for when designing the planted roof. When the functions are uncertain, the equipment to be added later, fixed load of the roof and moving loads (snow, rain) carrying capacity should be calculated and manufactured in accordance with the data obtained from the calculations. After manufacturing, the user should not add additional equipment to the roof other than those required to be on the roof

#### **Installation of Energy Equipment That Does Not Obstruct**

Recently, in line with the needs of people, energy use has increased and the need for energy has become a subject of increasing consumption. As a result of the energy crises, renewable energy sources are needed. One of the most important sources of energy, the use of the sun

in energy production, photovoltaic panels (PV) is achieved through the conversion of solar energy into electrical energy. The use of PV in facades and roofs of the building is becoming widespread, but these panels can cause fire to occur and spread the fire quickly.

In photovoltaic panels, two different types of fire occur. The first is that the fire arises from the panels. High voltage, short circuit, strong current etc. causes this. The second is the fires that reach the panels due to the external environment [32].

As Yaman stated, the use of PV can cause fire. At the time of many fires, panels without a closing mechanism continued to generate electricity, resulting in injuries to firefighters. Since most of the materials that make up the panels contain flammable components, the roof fire load is increasing. The possibility of waterproofing membrane damage during PV installation on vegetated roofs is another factor to be considered. In addition, precautions should be taken to ensure that plants are not exposed to PV reflected sun or that panels do not create shade for plants.

#### **4.1.6. Access**

Vegetated roofs will lose their sustainability when they are difficult to access by building users and builders, and if a permanent use is not achieved after access. In this case, it would not make sense to evaluate other factors positively. Therefore, both the ease of access to the vegetated roof and the presence of sheltered areas on the roof, which can be used temporarily in different weather conditions, are briefly explained below as the sub-factors of the access.

##### **Ease of Access to the Roof**

Access to the area should be easy, starting with the vegetated roof construction team, and the users and maintenance personnel of the site should have easy access to the vegetated roof. This is primarily due to the fact that the transportation of the building team and the transport of materials are easily handled without any obstacles. Then, in general use and during the emergency, users' entrance and exit to the building, circulation should be easy and quick. Narrow, winding stairs should not be used.

It is a wise solution to plant in areas that are in danger of falling, such as roof edges where the space should not be reached by users. However, it is necessary to provide access to maintenance personnel to these areas. The catwalk, which can only be reached and used by staff, can facilitate access.

### **Protected Areas for Adverse Weather Conditions**

These areas, which are suitable for use on the roofs of buildings or in the form of terrace, may be areas that may be exposed to adverse weather conditions such as heavy wind, rainfall, tornado, Sun. For this type of weather conditions, isolated, sheltered spaces need to be created. The reason is that sheltered storage areas are constructed so that furniture and other equipment that is not fixed in bad weather can be thrown away or damaged. Since this is important for the safety of the people who use the place, the creation of areas where people can be protected from outside weather is also an important issue.

These factors are considered as the main factors, each of the main factors in accordance with the benefits of vegetated roofs sub-factors were identified and grouped at table 4.1.

Table 4.1. Classification of Factors

MAIN FACTORS	SUB FACTORS
MAINTENANCE and REPAIR	Ease of Maintenance Ease of Repair
PLANTING	Suitability to Climate and Purpose Compliance with Roof Construction Suitability for Visual Satisfaction Abundance of Plant Equipment
SECURITY	Water & Electrical Insulation Removal of Danger in Use Ensuring Safety Against Danger Troubleshooting in Case of Fire Effects of Roof Loads on Building Statics
MATERIAL PREFERENCE	Environment Friendly Material Preference
HARDWARE	Hardware Suitable for Purpose Installation of Energy Equipment That Does Not Obstruct
ACCESS	Ease of Access to the Roof Protected Areas for Adverse Weather Conditions

## **4.2. CHARACTERISTICS OF VEGETATED ROOFS BASED ON SUSTAINABLE FACTORS**

The factors described in section 4.1. enable the determination of the sustainable characteristics of vegetated roofs. By associating factors, these sustainable qualities in vegetated roofs can be listed as follows.

- Easy to clean
- Rare and easy maintenance
- Rare and easy to repair
- To be equipped with plants that can live in climate and dominant season type
- Equipped with plants suitable for its intended use; For example, wind-cutting, sun-shading, noise-canceling, air-purifying
- Equipped with plants that will not disturb the roof construction
- Equipped with plants with high visual quality
- To have intensive plant equipment
- Have a safe water and electrical insulation
- Ensuring security
- To have plant species that prevent the formation and reproduction of fire
- Reduced plant retention layer of constant load weight
- Selected materials compatible with nature
- Free of unnecessary hardware
- Keeping energy equipment separate from planting
- Easily accessible from within the building
- Sheltered areas

### 4.3. DETAILS OF SUSTAINABLE VEGETATED ROOF

The characteristics of the vegetated roofs to ensure their sustainable performance, as stated in section 4.2., can be created by the construction of the appropriate details with these qualities. These details, which are referred to as "sustainably vegetated roof details", may be given weight to one or more of the attributes set out in section 4.2. figure below 4.2., 4.3., 4.4., 4.5., 4.6., 4.7., 4.8. and 4.9. also contains detail examples that may be suitable for specific sustainable vegetated roof characteristics.

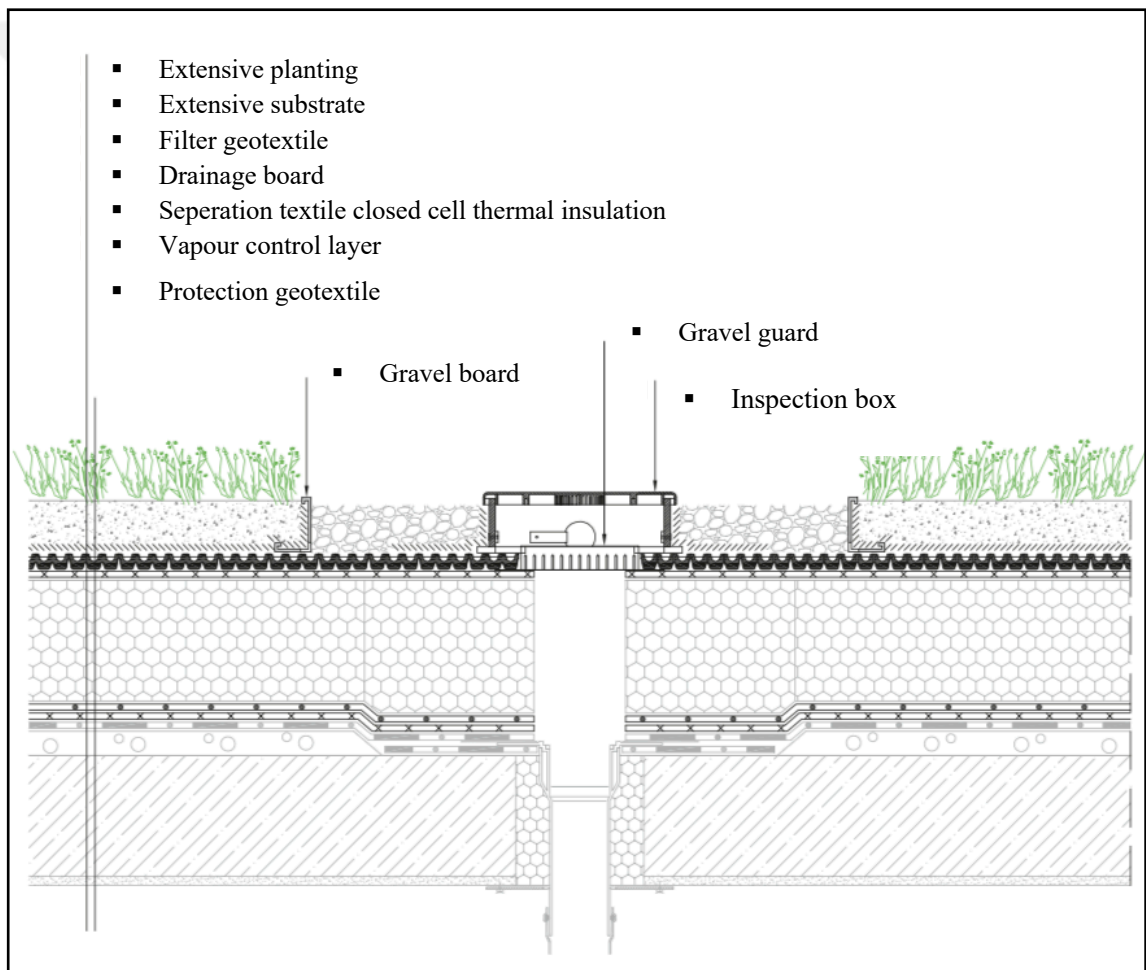


Figure 4.2. Outlet on extensive vegetated roof detail [35].

The detail of the outlet that can be used for the discharge of water that can accumulate from rainwater or automatic irrigation systems in extensive vegetated roofs, which generally have a slope of 1.5-2%.

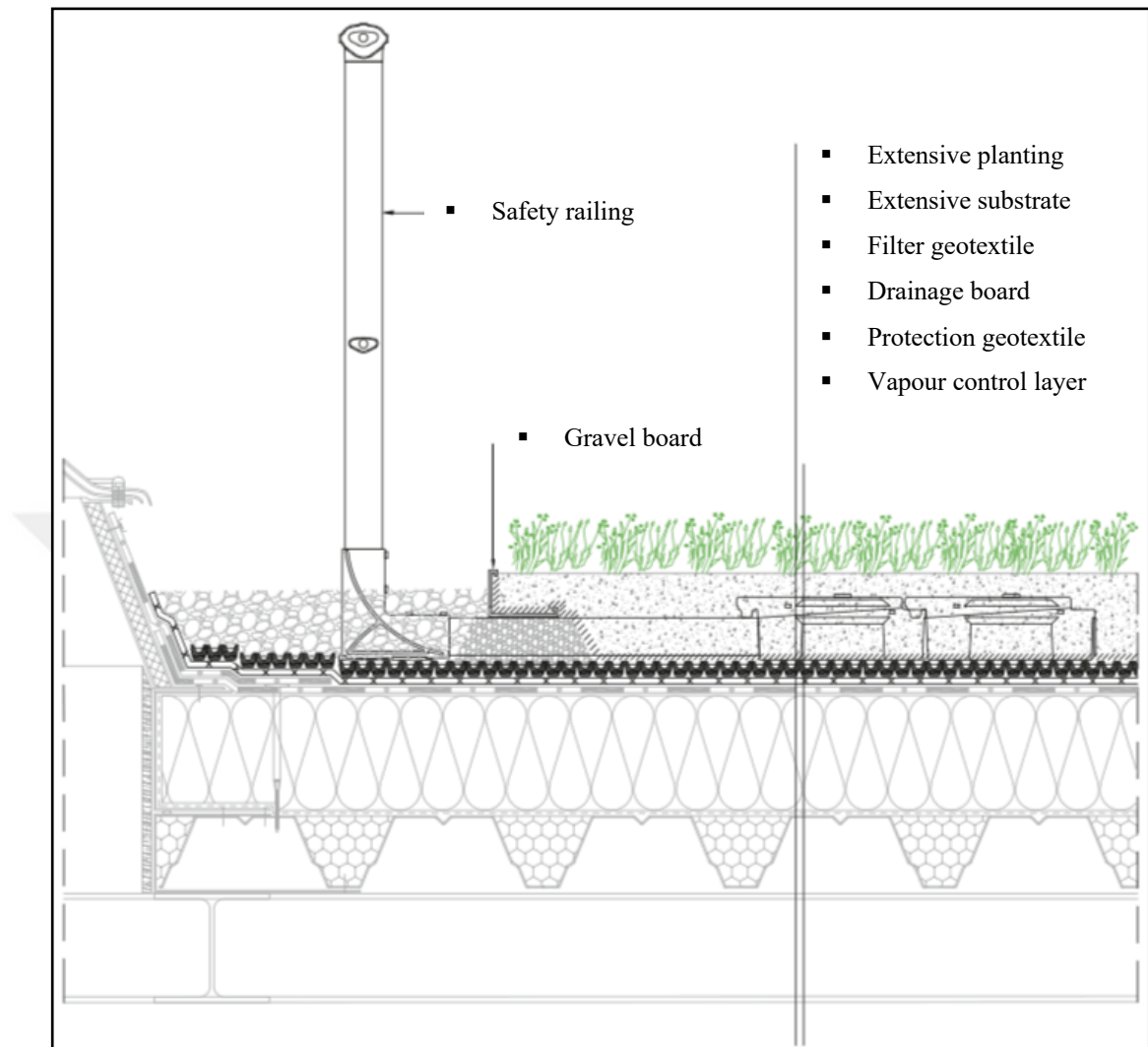


Figure 4.3. Railing detail on extensive vegetated roof [35].

Extensive vegetated roof railing detail that provides the necessary safety during maintenance due to all kinds of maintenance requirements, although it is not navigable.

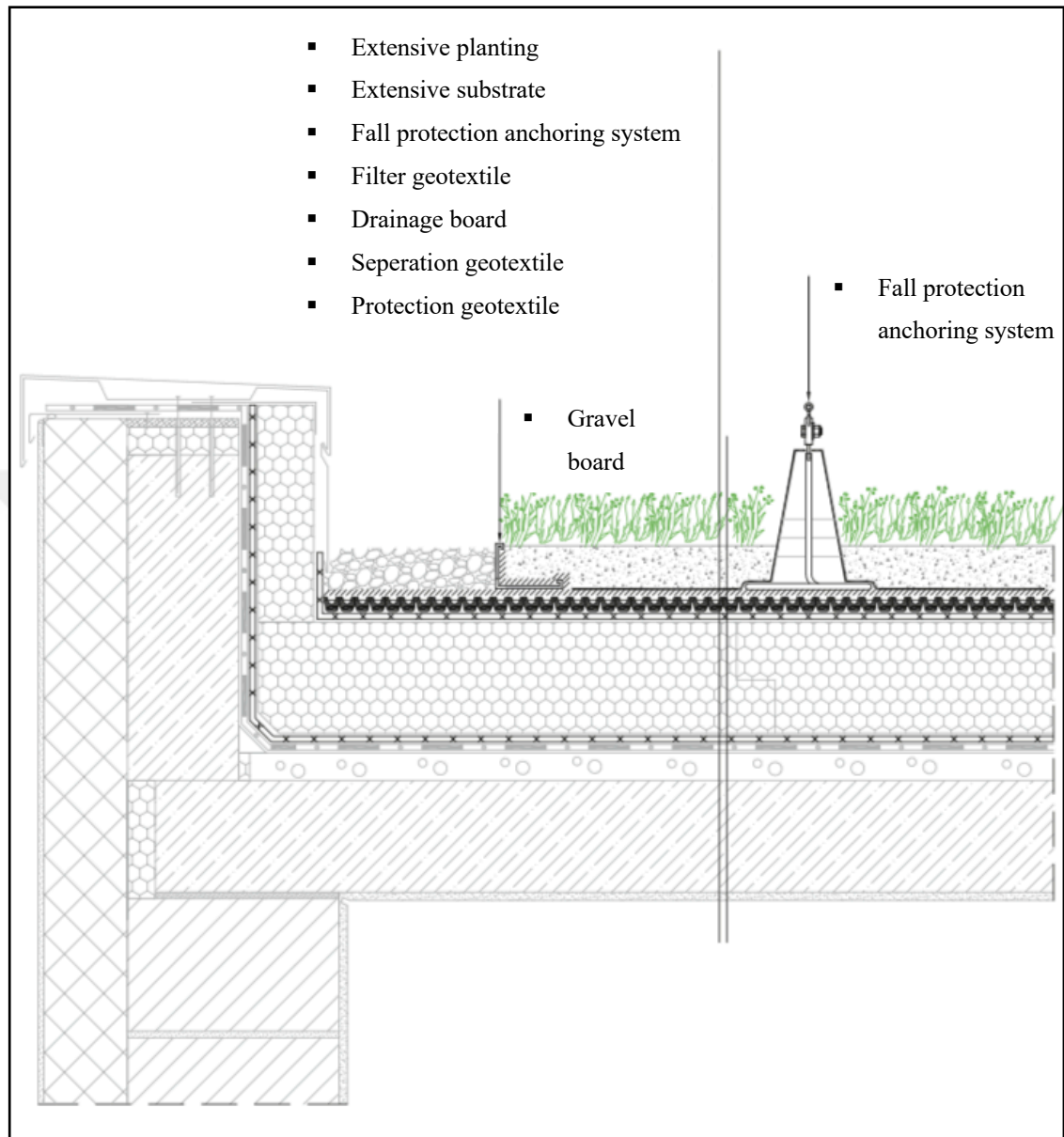


Figure 4.4. Fall protection anchoring system detail on extensive vegetated roof [35].

Extensive vegetated roof railing detail with anchorage system that provides the necessary safety during maintenance due to all kinds of maintenance requirements, although it is not navigable.

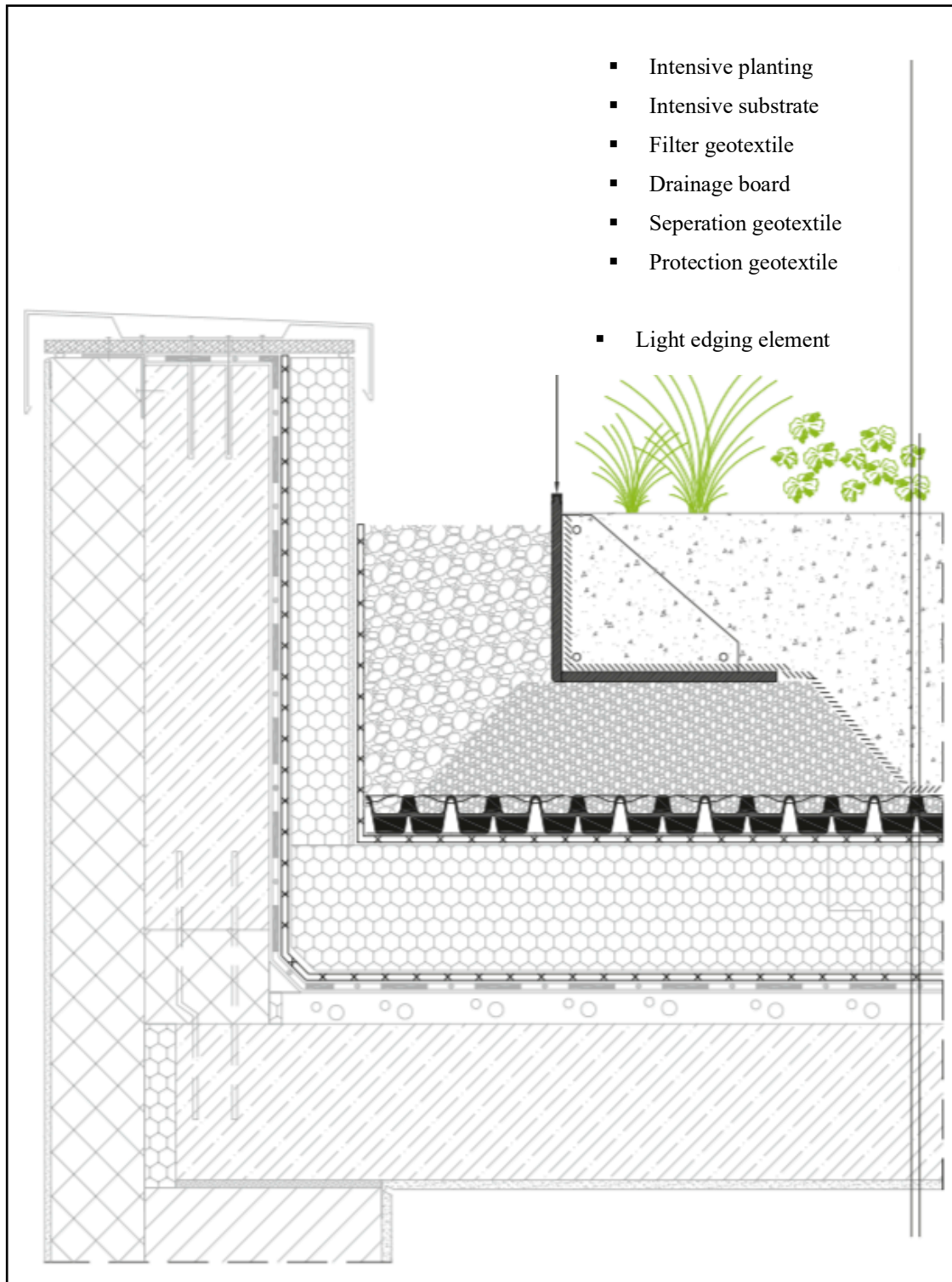


Figure 4.5. Parapet wall connection detail on intensive vegetated roof [35].

On intensive vegetated roofs, security can be provided with parapet walls, except for railing, on roofs that are not high-rise, in order to prevent passing from other areas or that do not provide access.

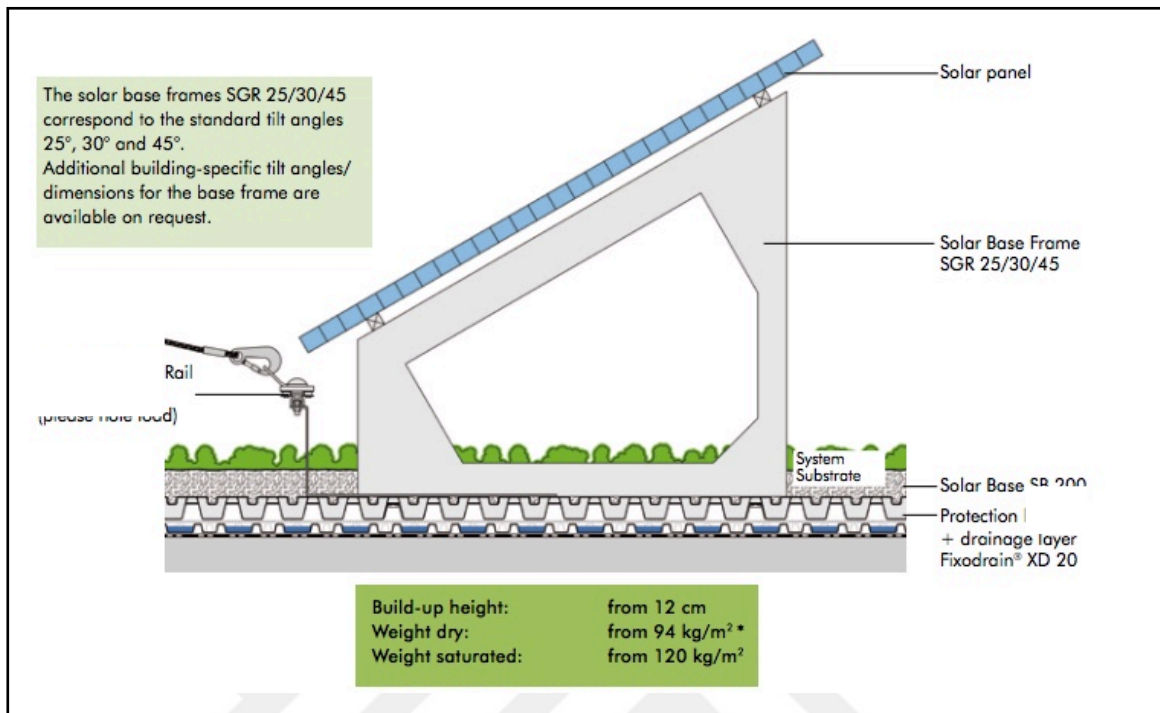


Figure 4.6. Solar panel detail on vegetated roof [19].

It is important to keep the solar panel and the vegetation separate from each other, since the use of plants that are water-retaining and the plant that does not grow too long does not pose a risk of fire, the detail of use with the plant and solar panel.

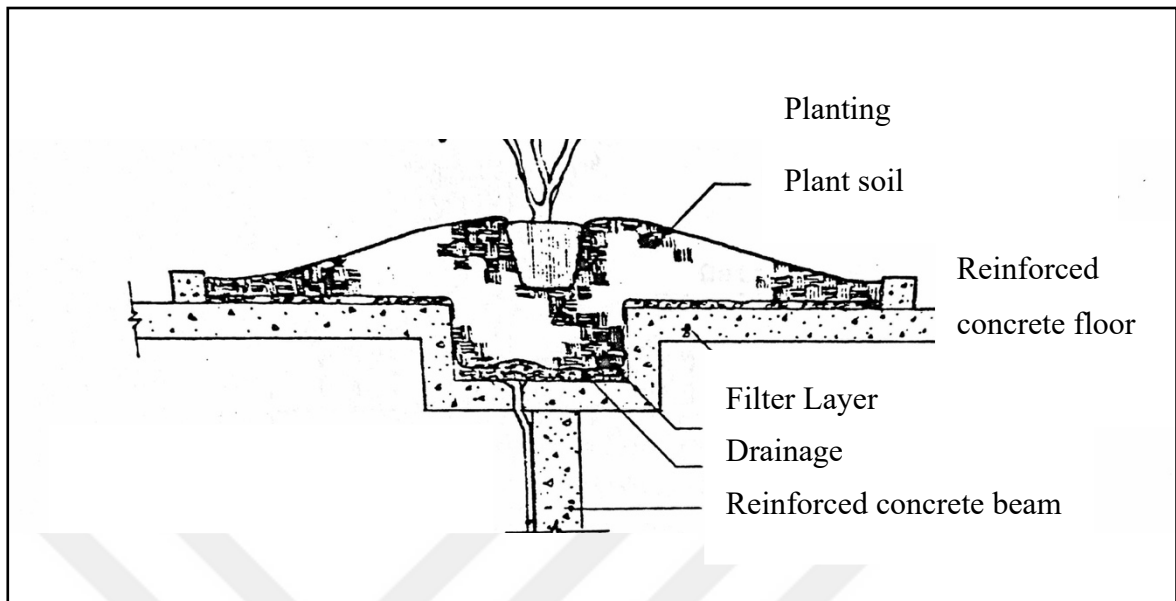


Figure 4.7. Detail of tree transport to column on intensive vegetated roof [16].

On intensive vegetated roofs, the detail of carrying heavy loads, such as trees, by the column, one of the bearing systems of the buildings.

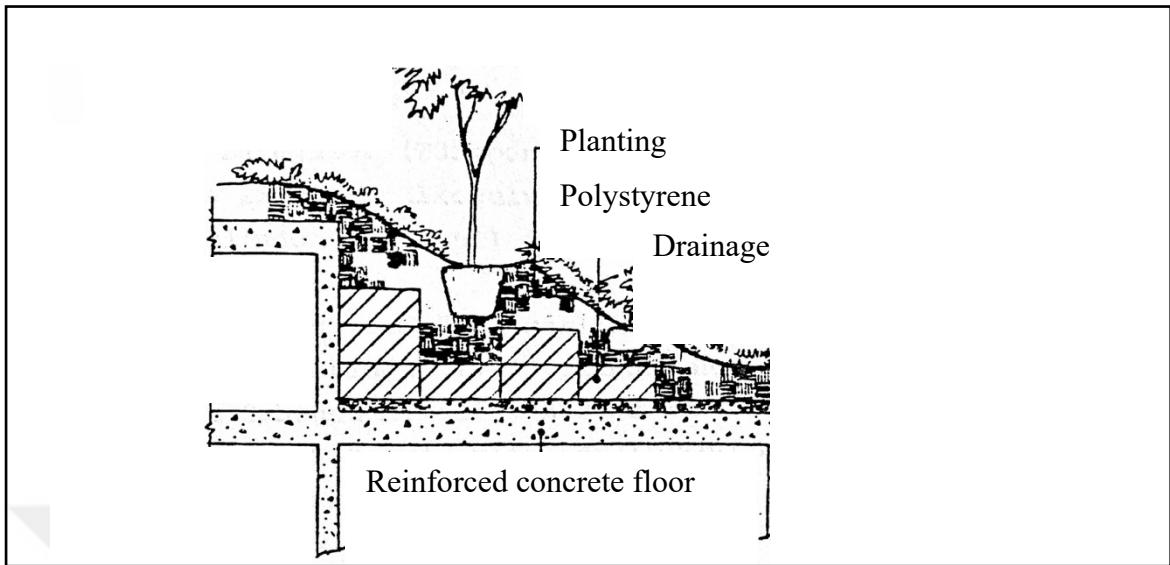


Figure 4.8. Detail of hollow structure of plant soil on intensive vegetated roof [16].

Detail of hollow plant soil formed by polystyrene or light concrete blocks which are intended to relieve roof load on intensive vegetated roofs.

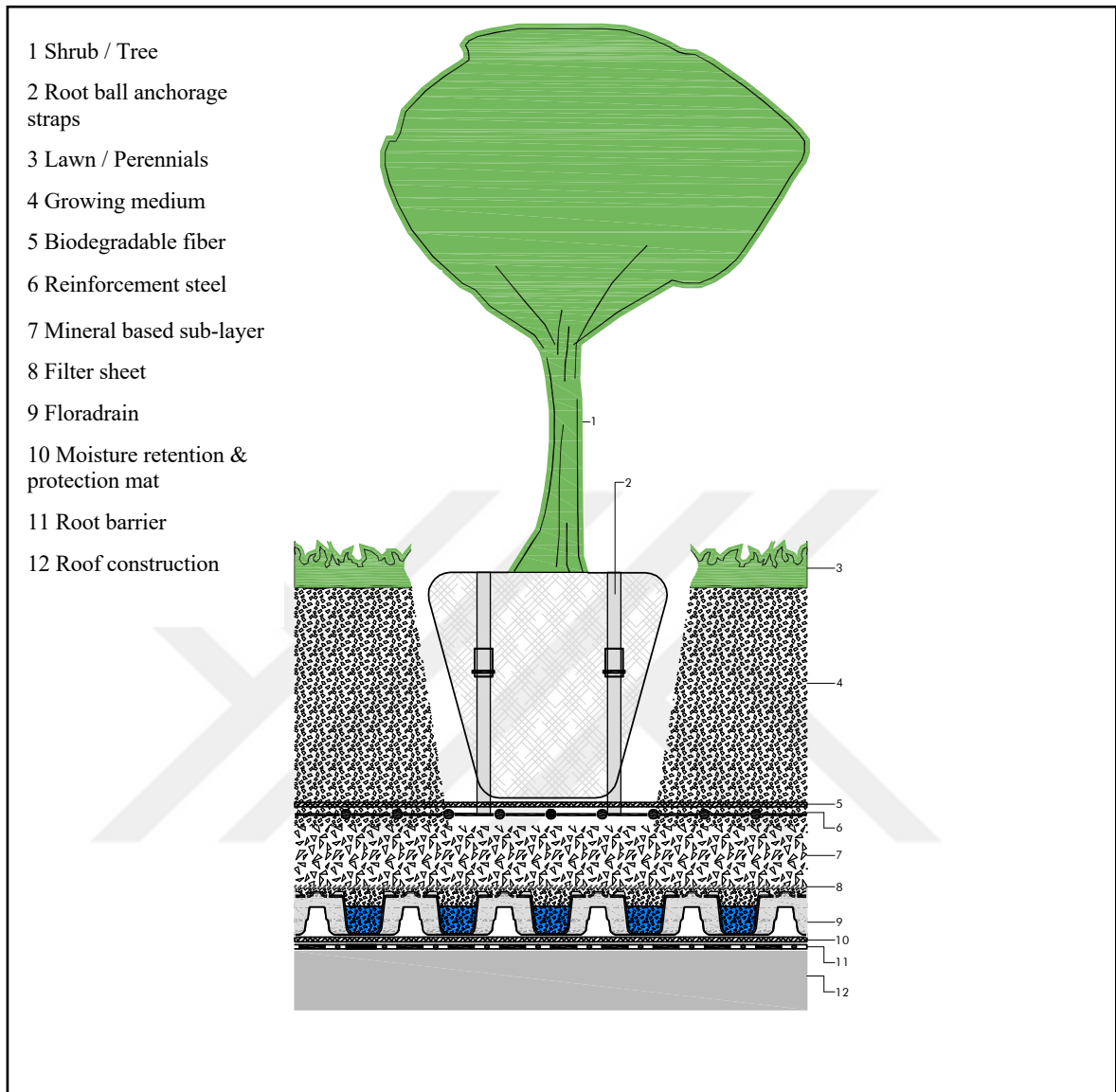


Figure 4.9. Tree anchor detail on intensive vegetated roof [19].

On intensive vegetated roofs, high plants such as trees need to be fixed against the risk of overturning. It can usually be made by connecting to the carrier with an anchoring system with steel ropes.

## 5. EVALUATION OF SUSTAINABLE PERFORMANCE IN VEGETATED ROOFS

Providing the effective benefits expected from vegetated roofs depends on the high performance of the roofs within the framework of the qualifications and appropriate details described so far. Therefore, it is important to evaluate this performance in line with the sustainable performance flow of vegetated roofs in figure 4.1. The evaluation in question includes a control, and it is necessary to determine which variables can be made according to this control. Therefore, which control variables may be valid for the control of the sustainable qualities of vegetated roofs and the unit, criterion and scale of these variables should be specified. Thanks to the “checklists” created through the Control variables specified on a table, vegetated roofs can be examined and evaluated for sustainable performance.

Figure 5.1. shows the performance evaluation system of vegetated roofs.

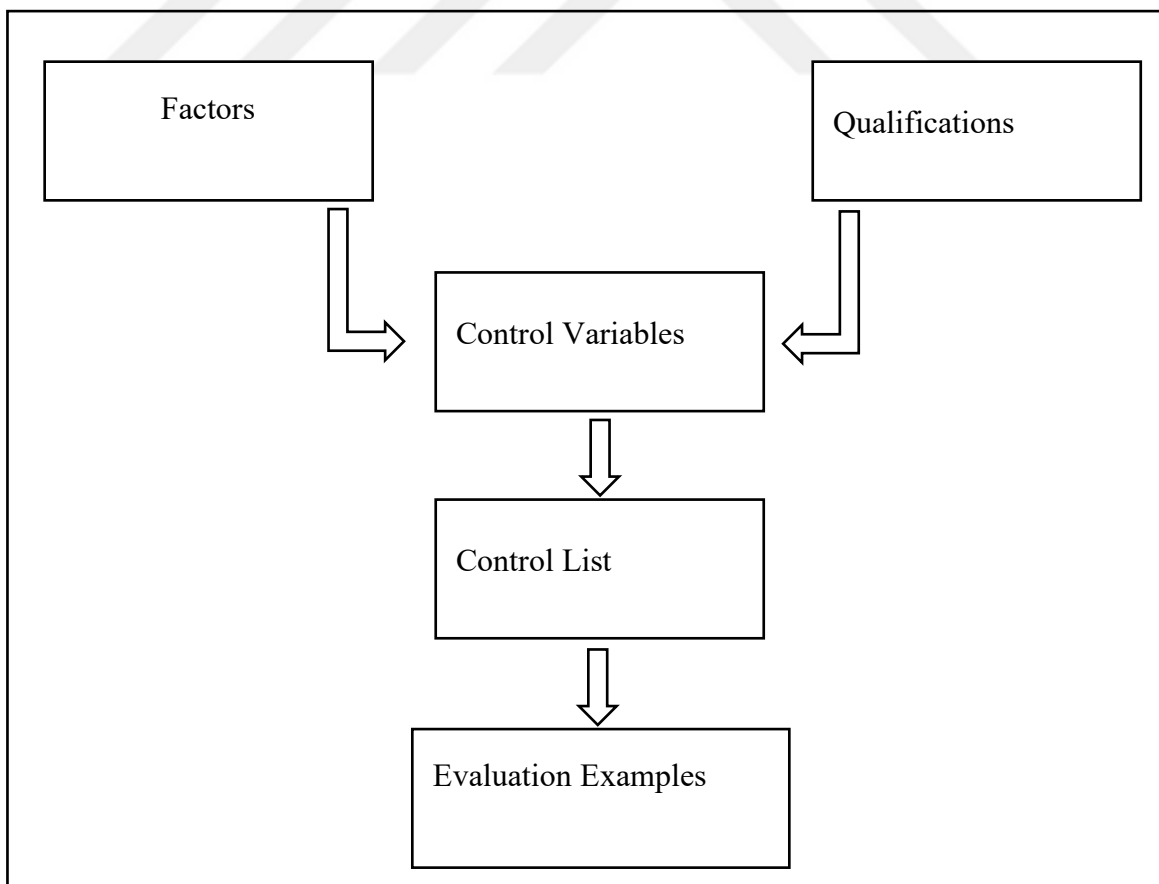


Figure 5.1. Performance evaluation system of vegetated roofs

## **5.1. DETERMINATION OF CONTROL VARIABLES**

There is need for number of variables that set the criteria for the control of the sustainability of the vegetated roofs. For this reason, the factors and possible control variables are determined based on the factors and characteristics shown in table 5.1. Nominal scales in the form of available/not available, yes/no were used for the non-numeric criteria of the control variable.



Table 5.1. “Control Variables” used in sustainable performance evaluation of vegetated roofs

FACTORS	SUB-FACTORS	QUALIFICATIONS OF VEGETATED ROOF	CONTROL VARIABLES				
			VARIABLE NAME	VARIABLE UNIT	CRITERION	SCALE	
M A I N D T R E N P A N C I E	Ease of maintenance	Easy to clean	Plant pollution	Quantity of deciduous flower shedding plants / Quantity of total plants	Unpolluted plant rate $\geq 1/2$	Rational	
			Cleanability of the material	Use of dirt-free materials	Yes / No	Nominal	
		Requires rare and easy maintenance	Irrigation frequency of plants	Daily irrigation amount	Quantity of daily irrigation $\leq 2$ / Day*	Rational	
			Irrigation way of plants	Automatic irrigation system	Available / Not Available	Nominal	
	Ease of repair	Requires rare and easy repair	Annual repair frequency	Annual repair quantity	Annual repair quantity $\leq 4$ / Year**	Rational	
			Installation laying suitable for easy repair	Removable layer design	Yes / No	Nominal	
P L A N T I N G	Suitability to climate and purpose	Arranged with plants that can live in prevailing climate and season type	Hot dry climate: plant arrangement that do not require frequent irrigation	Quantity of plants that do not require frequent irrigation / Quantity of total plants	Quantity of plants that do not require frequent irrigation / Quantity of total plants $\geq 1/2$	Rational	
			Hot humid climate: plant arrangement that require frequent irrigation	Quantity of plants that require frequent irrigation / Quantity of total plants	Quantity of plants that require frequent irrigation / Quantity of total plants $\geq 1/2$	Rational	
			Mild climate: Summer: evergreen Winter: deciduous	Quantity of Deciduous Plants / Evergreen Plants	Quantity of deciduous plants / Evergreen plants = 1***	Rational	
			Cold climate: deciduous plant arrangement	Quantity of Deciduous Plants / Quantity of Total Plants	Quantity of deciduous plants = Quantity of Total Plants	Rational	
		By purpose					
		Vegetated roof arranged with purpose plants: windbreaker, sun breaker, noise preventive, Air cleaner (Oxygen producing, dust absorbent)	Wind breaker plant weighted arrangement	Quantity of wind permeability low plants / Quantity of total plants	Quantity of wind permeability low plants / Quantity of total plants $\geq 1/2$	Rational	
			Solar shade plant weighted arrangement	Quantity of wide and thick leafed plant / Quantity of total plants	Quantity of wide and thick leafed plant / Quantity of total plants $\geq 1/2$	Rational	
			Noise-cancelling plant-weighted arrangement	Quantity of noise-cancelling plants / Quantity of total plants	Quantity of noise-cancelling plants / Quantity of total plants $\geq 1/2$	Rational	
			Air cleaner	Plant arrangement with high oxygen production	Plant arrangement with high oxygen production / Total plant arrangement	Plant arrangement with high oxygen production / Total plant arrangement = 1/2 ****	Rational
				Plant arrangement with high dust absorber	Plant arrangement with high dust absorber / Quantity of total plants	Plant arrangement with high dust absorber / Quantity of total plants = 1/2 ****	Rational
	Compliance with roof construction	Arranged with plants of qualities that will not disrupt roof construction	Plants do not root much	Quantity of plants do not root much / Quantity of total plants	Quantity of plants do not root much / Quantity of total plants = 1	Rational	
			Wind resistance of plants	Thin and long plant quantity	Thin and long plant quantity = 0	Rational	
			Non-blocking drainage	Sheltered drainage system	Available / Not Available	Rational	
	Suitability for visual satisfaction	Arranged with high visual quality plants	Season-appropriate and long-term flower-giving plant arrangement	Flowering period of plants / Year	Flowering period of plants $\geq 3$ months	Rational	
			Long-lasting plant arrangement	Permanency of plants during the year	Permanency of plants $\geq 6$ months	Rational	
	Abundance of plant arrangement	Intensive plant arrangement	Plant arrangement rate	Plant arrangement rate = Total planted area / Total roof area	Plant arrangement $\geq 1/2$	Rational	
	S E C U R I T Y	Water and electrical insulation	Has a safe water and electrical insulation	Prevention of water and electrical lines contact	Right systematic detail	Yes / No	Nominal
Ensuring safety against danger		Secured	Anti-fall railing	Railing height	H $\geq 80$ cm	Rational	
			Terrace edges to deter suicide	Plant arrangement on terrace sides	Aside $\geq 100$ cm plant leaning	Rational	
Troubleshooting in case of fire		Plant species that prevent the hazard and increment of fire	Water-retaining plant	Quantity of water-retaining plant / Quantity of total plants	Quantity of water-retaining plant / Quantity of total plants $\geq 1/2$	Rational	
			Covering the soil with non-water absorbing material	Low flammable material quantity / Total material quantity	Low flammable material quantity / Total material quantity = 1		
Effects of loads on building states		Low fixed load weight	Light material hardware	Heavy material quantity	Heavy material quantity = 0	Rational	
		Lighting of plant holding layer	Hollow structure of plant soil kayer	Usage of hollow soil	Yes / No		
MATERIAL PREFERENCE	Environment friendly material preference	Selection of material compatible with nature	Use of natural material	Used natural material / Total material rate	Used natural material / Total material rate = 1	Rational	
HARDWARE	Hardware suitable for purpose	Free from unnecessary hardware	Constant hardware usage	Constant hardware usage / Total hardware usage	Constant hardware usage / Total hardware usage $\geq 1/2$	Rational	
	Accessible hardware of energy equipments	Energy equipment separated from plantation	Sheltering of energy equipment	Majority of sheltered energy equipment	Available / Not Available	Nominal	
A C C E S S	Access to vegetated roof	Easy accessibility from building to vegetated roof	Access to the vegetated garden from the building along with stairs and elevators	Access to the vegetated garden with elevators	Available / Not Available	Nominal	
	Protected areas for adverse weather conditions	Sheltered areas have been placed in the vegetated roof	Sheltered area arrangement	Sheltered area	Available / Not Available	Nominal	

\* Criterion of this variable; As a result of examining the existing vegetated roofs and discussing with the users, it was accepted according to a stated generalization considering the comfort of the roofs.

\*\* The criterion of this variable for annual repair, which is defined as  $< 4/\text{year}$  (maximum 4 times a year), is based on the acceptance of a maximum of 1 time in each season.

\*\*\* The criterion of this variable requires both deciduous and evergreen plants, summer and winter, throughout the year. Therefore, it is foreseen that the amount of these different plants should be equal in planting on the roof.

\*\*\*\* The value of the value of this variable's criterion is chosen because the plants with strong oxygen production and dust absorption are required at the same time.

Note: In this table, with the expression " $< 1/2$ " in general, meaning half or less; The expression " $> 1/2$ " meaning half or more is used. These expressions are used to convert the criterion acceptance in the sense of more or less of the nominal scale into a rational value.

## 5.2. CONTROL LIST

The control list shown in table 5.2. was created to be used in the performance evaluation of the samples selected in accordance with the control variables table.

Table 5.2. Control List

MAINTENANCE AND REPAIR	
1	What is the ratio of the amount of deciduous plants to the total amount of plants?
2	Has the dirt-free material been used?
3	What is the number of irrigation per day?
4	Is there an automatic irrigation system?
5	How many times maintenance is made annually?
6	Has the removable layer design been applied?
PLANTING	
1	What is the quantity of deciduous plants?
2	What is the ratio of low wind permeable plants to total plant quantity?
3	What is the ratio of large and thick-leaved plants to total plant quantity?
4	What is the ratio of noise blocker plants to total plant quantity?
5	What is the ratio of dust holding plants to the total plant quantity?
6	What is the ratio of non-rooted plants to total plant quantity?
7	What is the number of tall plants?
8	Has the sheltered drainage system been applied?
9	How many times a year do plants bloom?
10	What is the period of persistence of plants in a year?
11	What is the ratio of vegetated equipment to the vegetated roof?
SECURITY	
1	Has the water and electricity lines been detailed separately?
2	Is the railing height minimum 80 cm?
3	Is there a vegetative arrangement on the side of the terrace?
4	What is the ratio of water retention plant amount to total plant quantity?
5	What is the ratio of low flammable material to total material quantity?
6	What is the amount of heavy material?(fixed load)
7	Has hollow soil been used?
MATERIAL	
1	What is the ratio of natural material to the total material?
EQUIPMENT	
1	What is the ratio of fixed equipment usage to total equipment usage?
2	Is there a sheltered energy equipment or not?
ACCESS	
1	Is there an elevator to the roof garden?
2	Is there a sheltered area or not?

### 5.3. EVALUATION ON SAMPLES

In the study so far, 11 vegetated roof samples from Istanbul were evaluated on the basis of sustainability benefits, factors, qualifications and checklist; on-site observations and interviews were conducted. In the following section, the characteristics of each selected sample in terms of the vegetated roof are presented as an illustrated presentation table. A sustainable performance rubric has been added to the back of the illustrated presentation table of each selected building sample in accordance with the checklist.




<b>ZORLU CENTER</b>

<b>BUILDING INFORMATION</b>
<b>CITY, DATES OF CONSTRUCTION:</b> Istanbul, 2013
<b>USAGE:</b> Residence, Office, Hotel, Shopping Mall, Performance Hall
<b>ROOF TYPE:</b> Intensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.2. Zorlu Center vegetated roof introductory information

In the Zorlu Center project, the anchorage system glass railings details, as shown in figure 4.4, were applied along with the tree anchorage connection details, which are given in figure 4.9.

Table 5.3. Zorlu Center evaluation of sustainable performance

<b>ZORLU CENTER</b>			
<b>MAINTENANCE AND REPAIR</b>			<b>ANSWER</b>
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
<b>PLANTING</b>			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	<50 %	-
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	>0	-
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	>3 Months	+
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
<b>SECURITY</b>			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	Yes	+
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
<b>MATERIAL</b>			
1	What is the ratio of natural material to the total material?	<1	-
<b>EQUIPMENT</b>			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
<b>ACCESS</b>			
1	Is there an elevator to the roof garden?	Available	+
2	Is there a sheltered area or not?	Available	+

## ÖZDİLEK PARK SHOPPING MALL



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Istanbul, 2014

**USAGE:** Shopping Mall

**ROOF TYPE:** Intensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.3. Özdilek Park Shopping Mall vegetated roof introductory information

In Özdilek Park Shopping Center project, the intensive roof parapet-wall connection details, which are given in figure 4.5, were applied.

Table 5.4. Özdilek Park Shopping Mall evaluation of sustainable performance

ÖZDİLEK PARK SHOPPING MALL			
MAINTENANCE AND REPAIR		ANSWER	
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	No	-
PLANTING			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	<50 %	-
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	>3 Months	+
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	<50 %	-
SECURITY			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	Yes	+
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
MATERIAL			
1	What is the ratio of natural material to the total material?	<1	-
EQUIPMENT			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
ACCESS			
1	Is there an elevator to the roof garden?	Available	+
2	Is there a sheltered area or not?	Available	+


<b>MEYDAN SHOPPING MALL</b>

<b>BUILDING INFORMATION</b>
<b>CITY, DATES OF CONSTRUCTION:</b> Istanbul, 2007 <b>USAGE:</b> Shopping Mall
<b>ROOF TYPE:</b> Extensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.4. Meydan Shopping Mall vegetated roof introductory information

Table 5.5. Meydan Shopping Mall evaluation of sustainable performance

<b>MEYDAN SHOPPING MALL</b>			
<b>MAINTENANCE AND REPAIR</b>			<b>ANSWER</b>
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	>1	-
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	No	-
<b>PLANTING</b>			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	<50 %	-
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	-	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
<b>SECURITY</b>			
1	Has the water and electricity lines been detailed separately?	No	-
2	Is the railing height minimum 80 cm?	-	-
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
<b>MATERIAL</b>			
1	What is the ratio of natural material to the total material?	<1	-
<b>EQUIPMENT</b>			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
<b>ACCESS</b>			
1	Is there an elevator to the roof garden?	Not Available	-
2	Is there a sheltered area or not?	Available	+

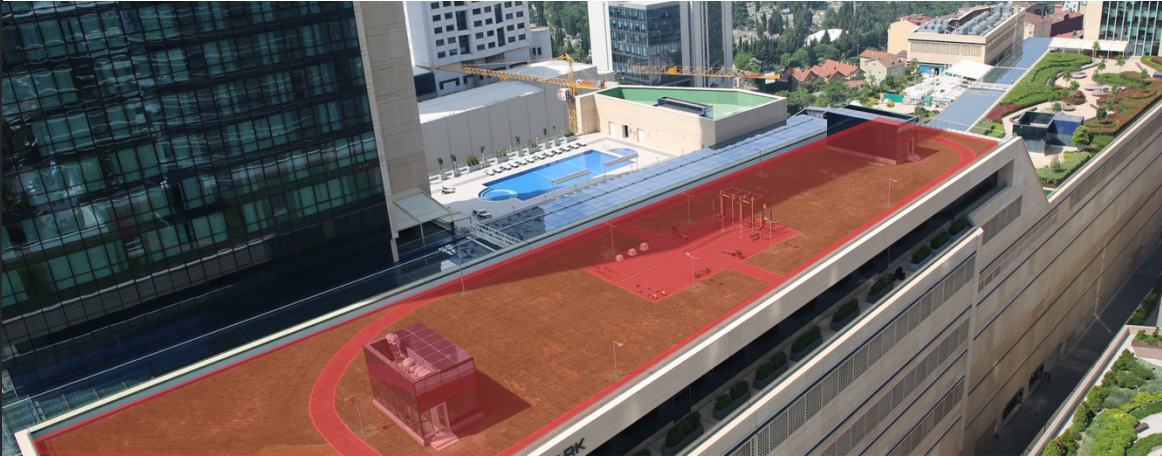
<b>WYNDHAM GRAND LEVENT</b>

<b>BUILDING INFORMATION</b>
<p><b>CITY, DATES OF CONSTRUCTION :</b> Istanbul, 2014</p> <p><b>USAGE:</b> Hotel</p>
<p><b>ROOF TYPE:</b> Intensive Roof</p>
<p><b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.</p>

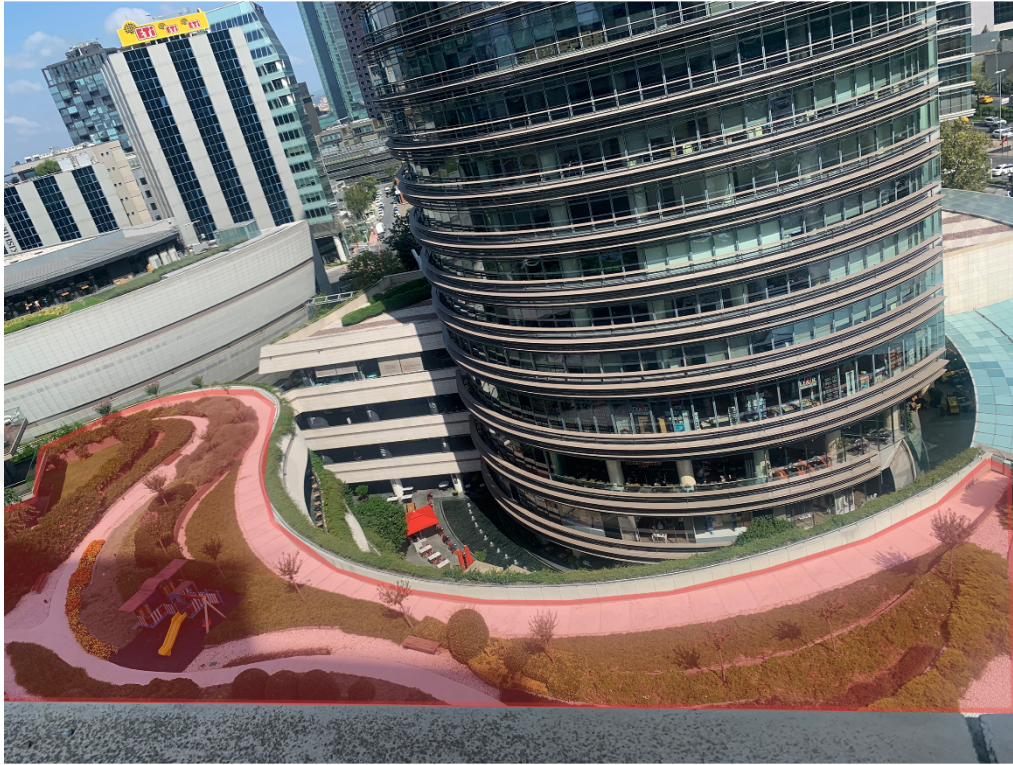
Figure 5.5. Wyndham Grand Levent vegetated roof introductory information

In the Wyndham Grand Levent project, the Intensive roof parapet-wall connection details, which is given in figure 4.5, were applied.

Table 5.6. Wyndham Grand Levent evaluation of sustainable performance

<b>WYNDHAM GRAND LEVENT</b>			
<b>MAINTENANCE AND REPAIR</b>			<b>ANSWER</b>
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	>1	-
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
<b>PLANTING</b>			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	<50 %	-
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	-	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
<b>SECURITY</b>			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
<b>MATERIAL</b>			
1	What is the ratio of natural material to the total material?	1	+
<b>EQUIPMENT</b>			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
<b>ACCESS</b>			
1	Is there an elevator to the roof garden?	Not Available	-
2	Is there a sheltered area or not?	Not Available	-

## KANYON



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Istanbul, 2006

**USAGE:** Residence, Office, Shopping Mall

**ROOF TYPE:** Intensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.6. Kanyon vegetated roof introductory information

In the Kanyon project, the intensive roof parapet-wall connection details, as indicated in figure 4.5, were applied.

Table 5.7. Kanyon evaluation of sustainable performance

KANYON			
MAINTENANCE AND REPAIR			ANSWER
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	No	-
PLANTING			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	>50 %	+
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	>3 Months	+
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
SECURITY			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	Yes	+
4	What is the ratio of water retention plant amount to total plant quantity?	<50	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
MATERIAL			
1	What is the ratio of natural material to the total material?	1	+
EQUIPMENT			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
ACCESS			
1	Is there an elevator to the roof garden?	Available	+
2	Is there a sheltered area or not?	Not Available	-

## ISTANBLOOM RESIDENCES AND OFFICES



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Istanbul, 2015

**USAGE:** Residence, Office

**ROOF TYPE:** Intensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.7. Istanbul Bloom Residences and Offices vegetated roof introductory information

In the Istanbul Bloom Residences and Offices project, anchorage system glass railing details, as shown in figure 4.4, were applied.

Table 5.8. Istanbul Residences and Offices evaluation of sustainable performance

ISTANBLOOM RESIDENCES AND OFFICES			
MAINTENANCE AND REPAIR			ANSWER
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
PLANTING			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	>50 %	+
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	<3 Months	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	<50 %	-
SECURITY			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	>0	-
7	Has hollow soil been used?	Yes	+
MATERIAL			
1	What is the ratio of natural material to the total material?	1	+
EQUIPMENT			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
ACCESS			
1	Is there an elevator to the roof garden?	Available	+
2	Is there a sheltered area or not?	Available	+


<b>TORUN CENTER</b>

<b>BUILDING INFORMATION</b>
<p><b>CITY, DATES OF CONSTRUCTION :</b> Istanbul, 2016</p> <p><b>USAGE:</b> Residence, Office</p>
<b>ROOF TYPE:</b> Intensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.8. Torun Center vegetated roof introductory information

In the Torun Center project, the roof railing details specified in figure 4.3 were applied.

Table 5.9. Torun Center evaluation of sustainable performance

TORUN CENTER			
MAINTENANCE AND REPAIR			ANSWER
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	No	-
PLANTING			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	>50 %	+
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	>3 Months	+
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
SECURITY			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
MATERIAL			
1	What is the ratio of natural material to the total material?	<1	-
EQUIPMENT			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
ACCESS			
1	Is there an elevator to the roof garden?	Available	+
2	Is there a sheltered area or not?	Available	+


<b>NARLIFE</b>

<b>BUILDING INFORMATION</b>
<p><b>CITY, DATES OF CONSTRUCTION:</b> Istanbul, 2015</p> <p><b>USAGE:</b> Residence</p>
<b>ROOFTOP INFORMATION</b>
<b>ROOF TYPE:</b> Extensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.9. Narlife vegetated roof introductory information

In the Narlife project, the extensive roof railing detail specified in figure 4.3 was applied.

Table 5.10. Narlife evaluation of sustainable performance

NARLIFE			
MAINTENANCE AND REPAIR			ANSWER
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	>1	-
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
PLANTING			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	>50 %	+
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	-	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
SECURITY			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
MATERIAL			
1	What is the ratio of natural material to the total material?	<1	-
EQUIPMENT			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
ACCESS			
1	Is there an elevator to the roof garden?	Not Available	-
2	Is there a sheltered area or not?	Not Available	-


<b>UNIQ ISTANBUL</b>

<b>BUILDING INFORMATION</b>
<b>CITY, DATES OF CONSTRUCTION:</b> Istanbul, 2014
<b>USAGE:</b> Office, Shopping Mall, Performance Hall
<b>ROOF TYPE:</b> Extensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.10. Uniq Istanbul vegetated roof introductory information

In the Uniq Istanbul project, the Extensive roof outlet details specified in figure 4.2 were applied.

Table 5.11. Uniq Istanbul evaluation of sustainable performance

<b>UNIQU CENTER</b>			
<b>MAINTENANCE AND REPAIR</b>			<b>ANSWER</b>
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	-	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
<b>PLANTING</b>			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	<50 %	-
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	-	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
<b>SECURITY</b>			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	No	-
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
<b>MATERIAL</b>			
1	What is the ratio of natural material to the total material?	1	+
<b>EQUIPMENT</b>			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
<b>ACCESS</b>			
1	Is there an elevator to the roof garden?	Not Available	-
2	Is there a sheltered area or not?	Not Available	0

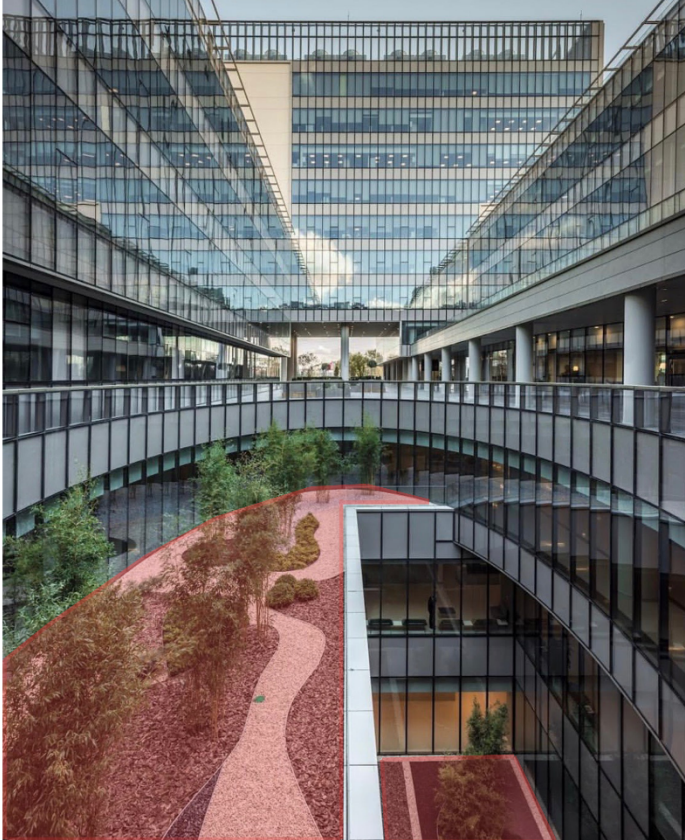
<b>KOÇ UNIVERSITY HOSPITAL</b>

<b>BUILDING INFORMATION</b>
<b>CITY, DATES OF CONSTRUCTION:</b> Istanbul, 2014
<b>USAGE:</b> Hospital
<b>ROOF TYPE :</b> Intensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.11. Koç University Hospital vegetated roof introductory information

In the Koç University Hospital project, anchorage system glass railing details, as shown in figure 4.4, were applied.

Table 5.12. Koç University Hospital evaluation of sustainable performance

<b>KOÇ UNIVERSITY HOSPITAL</b>			
<b>MAINTENANCE AND REPAIR</b>			<b>ANSWER</b>
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	1	+
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
<b>PLANTING</b>			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	>50 %	+
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	>50 %	+
5	What is the ratio of dust holding plants to the total plant quantity?	>50 %	+
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	>0	-
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	-	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
<b>SECURITY</b>			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	Yes	+
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	>0	-
7	Has hollow soil been used?	Yes	+
<b>MATERIAL</b>			
1	What is the ratio of natural material to the total material?	1	+
<b>EQUIPMENT</b>			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
<b>ACCESS</b>			
1	Is there an elevator to the roof garden?	Available	+
2	Is there a sheltered area or not?	Available	+

## ISTANBUL TECHNICAL UNIVERSITY'S ENTRANCE DOOR BUILDING TO THE SUBWAY



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Istanbul

**USAGE:** University

**ROOF TYPE :** Intensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.12. Istanbul Technical University's entrance door building to the subway vegetated roof introductory information

In the project of the building of the entrance gate of the Istanbul Technical University, the intensive roof parapet-wall connection details, which are given in figure 4.5, were applied.

Table 5.13. Istanbul Technical University's entrance door building to the subway evaluation of sustainable performance

<b>ISTANBUL TECHNICAL UNIVERSITY'S ENTRANCE DOOR BUILDING TO THE SUBWAY</b>			
<b>MAINTENANCE AND REPAIR</b>			<b>ANSWER</b>
1	What is the ratio of the amount of deciduous plants to the total amount of plants?	<50 %	+
2	Has the dirt-free material been used?	Yes	+
3	What is the number of irrigation per day?	>1	-
4	Is there an automatic irrigation system?	Available	+
5	How many times maintenance is made annually?	1	+
6	Has the removable layer design been applied?	Yes	+
<b>PLANTING</b>			
1	What is the quantity of deciduous plants?	<50 %	+
2	What is the ratio of low wind permeable plants to total plant quantity?	<50 %	-
3	What is the ratio of large and thick-leaved plants to total plant quantity?	<50 %	-
4	What is the ratio of noise blocker plants to total plant quantity?	<50 %	-
5	What is the ratio of dust holding plants to the total plant quantity?	<50 %	-
6	What is the ratio of non-rooted plants to total plant quantity?	>50 %	+
7	What is the number of tall plants?	0	+
8	Has the sheltered drainage system been applied?	Yes	+
9	How many times a year do plants bloom?	-	-
10	What is the period of persistence of plants in a year?	>6 Months	+
11	What is the ratio of vegetated equipment to the vegetated roof?	>50 %	+
<b>SECURITY</b>			
1	Has the water and electricity lines been detailed separately?	Yes	+
2	Is the railing height minimum 80 cm?	No	-
3	Is there a vegetative arrangement on the side of the terrace?	No	-
4	What is the ratio of water retention plant amount to total plant quantity?	<50 %	-
5	What is the ratio of low flammable material to total material quantity?	1	+
6	What is the amount of heavy material?(fixed load)	0	+
7	Has hollow soil been used?	Yes	+
<b>MATERIAL</b>			
1	What is the ratio of natural material to the total material?	1	+
<b>EQUIPMENT</b>			
1	What is the ratio of fixed equipment usage to total equipment usage?	>1/2	+
2	Is there a sheltered energy equipment or not?	Not Available	+
<b>ACCESS</b>			
1	Is there an elevator to the roof garden?	Not Available	-
2	Is there a sheltered area or not?	Not Available	-

## JOSEPH PSCHORR HAUS



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Munich, Germany, 2013

**USAGE:** Office, Shopping Mall, Residence

**ROOF TYPE :** Extensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.13. Joseph Pschorr Haus vegetated roof introductory information

## BMW MUSEUM



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Munich, Germany

**USAGE:** Museum

**ROOF TYPE :** Extensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.14. Bmw Museum vegetated roof introductory information

## EVANGELISCHER KINDERGARTEN SCHWANTHALERHÖHE



### BUILDING INFORMATION

**CITY, DATES OF CONSTRUCTION:** Munich, Germany, 2014

**USAGE:** Kindergarten

**ROOF TYPE :** Extensive Roof

**EVALUATED AREA:** The vegetated roof area selected with red color was evaluated.

Figure 5.15. Evangelischer Kindergarten Schwanthalerhöhe vegetated roof introductory information


<b>SHERIDAN CENTER</b>

<b>BUILDING INFORMATION</b>
<p><b>CITY, DATES OF CONSTRUCTION:</b> Augsburg, Germany, 2016</p> <p><b>USAGE:</b> Office</p>
<b>ROOF TYPE :</b> Extensive Roof
<b>EVALUATED AREA:</b> The vegetated roof area selected with red color was evaluated.

Figure 5.16. Sheridan Center vegetated roof introductory information

In many of the examples selected from Europe, plant arrangement was added to existing building roofs and it was observed that these plant applications were preferred as an extensive vegetated roof application at minimum cost. It has been observed that extensive roofing is more preferred than intensive roofing application in these cities for the purpose of providing city-based benefits, not building-based, due to the minimum access to the roof, or lack of access, and since the vegetative applications on the roofs are left in their own state, Because they are typical examples of the large extensively vegetated roofs on the building, which can be observed in selected locations from Europe, the figure in the thesis is 5.13, 5.14, 5.15 and 5.16 also provided roof information for the buildings of Joseph Pschorr Haus in Munich, BMV Museum, Evangelischer Kindergarten Schwanthalerhöhe and Sheridan Center in Augsburg.

For these examples, like other examination examples selected from Istanbul, sustainable performance evaluation has not been made using “checklists” since one-to-one interviews could not be made with the construction and its users. However, due to the ecological benefits of extensively roofs especially to the environment and the city, these roof samples are predicted to perform positively in terms of sustainability.

The selected vegetated roof samples are examined according to the control list values and arranged in figure 5.17. and table 5.14.

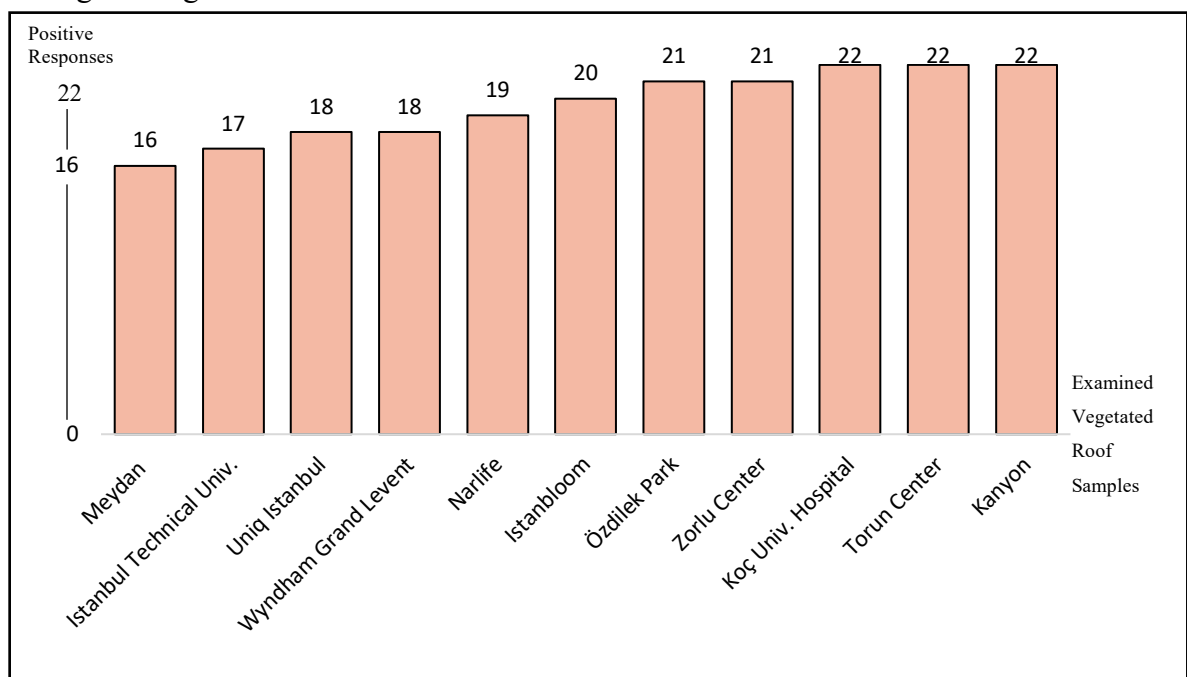


Figure 5.17. Selected vegetated roof samples; positive response numbers given to control list questions.

When the figure 5.17. is interpreted, it is observed that the number of positive responses in the control list of the examined vegetated roof samples varies between 16 and 22. If this is evaluated over a total of 29 questions of the control list, it can be said that the sustainability ratings of the vegetated roofs of the observed structures vary by 55% to 76%.

Table 5.14. Number of positive responses determined according to control lists for sustainability factors of examined planted roof samples

TOTAL NUMBER OF QUESTION	6	11	7	1	2	2
FACTORS						
EVALUATED BUILDINGS	MAINTENANCE AND REPAIR	PLANTING	SECURITY	MATERIAL	EQUIPMENT	ACCESS
ZORLU CENTER	5/6	6/11	6/7	-	2/2	2/2
ÖZDİLEK PARK SHOPPING MALL	5/6	6/11	6/7	-	2/2	2/2
MEYDAN SHOPPING MALL	4/6	6/11	3/7	-	2/2	1/2
WYNDHAM GRAND LEVENT	5/6	6/11	5/7	+	2/2	0/2
KANYON	5/6	8/11	6/7	+	2/2	1/2
İSTANBLOOM	6/6	6/11	4/7	+	2/2	2/2
TORUN CENTER	5/6	8/11	5/7	-	2/2	2/2
NARLIFE	5/6	7/11	5/7	-	2/2	0/2
UNIQ CENTER	6/6	6/11	4/7	+	2/2	0/2
KOÇ UNIVERSITY HOSPITAL	6/6	8/11	4/7	+	2/2	2/2
İSTANBUL TECHNICAL UNIVERSITY	5/6	6/11	4/7	+	2/2	0/2

When the table 5.14. is interpreted, the following evaluations can be made:

- The number of positive answers within the total number of questions obtained by the checklists can be considered as a “degree of sustainability”.
- The number of positive answers in terms of maintenance and repair in the control list of the vegetated roofs examined varies between 4 and 6 out of a total of 6 questions

and the sustainability ratings are between 67% and 100%. Therefore, the sustainability of these vegetated roofs in terms of maintenance and repair can be considered very positive.

- The number of positive responses to planting in the control list of the surveyed vegetated roofs varies between 6 and 8 out of a total of 11 questions, with sustainability ratings between 55% and 73%. Therefore, the sustainability ratings of these planted roofs in terms of planting can generally be considered close to positive.
- The number of positive answers in terms of safety of these roofs varies between 3 and 6 out of a total of 7 questions, and sustainability ratings can be said to vary between 43 and 86%. Therefore, the safety-oriented sustainability ratings of these roof samples are partially positive and generally positive.
- The number of positive responses in terms of material of 11 vegetated roofs examined is 6. Therefore, 55% of the roofs can be considered close to positive.
- For all roof samples examined, two of the total 2 questions asked in terms of hardware suitability in the control lists are answered positively, and all vegetated roof samples can be evaluated as sustainable in terms of hardware.
- Among the 11 buildings examined, the total number of buildings that have answered both of the 2 questions asked in terms of access for the vegetated roofs in the control list is 5. The number of structures that do not respond positively to any of them is 4. The remaining 2 structures also answered one question positively from the 2 questions asked. In this case, close to 50% of the structure's vegetated roof can be considered as sustainable in terms of access, while the other 50% can be considered as weak in sustainability.
- In general, the sustainability values determined according to the control list of the vegetated roof samples examined do not fall below 55%, but do not exceed 76%. Therefore, this value can approach 100% when a conscious performance is achieved.
- In the examined planted roof samples, maintenance and repair, planting, equipment and safety sustainability seems to be positive or near positive, but it seems to be moderately or weakly sustainable in terms of material selection and access.

## 6. CONCLUSIONS

Apart from the conclusions from the evaluation of the examples in section 5.3, the general results presented on the thesis basis can be listed as follows;

- Proper benefits from vegetated roofs are directly proportional to its sustainable performance.
- Sustainable performance of vegetated roofs is ensured by the characteristics of the vegetated roofs, which are based on the factors affecting this performance.
- The ecological, social and economic benefits that can be obtained when planted roofs display sustainable performance are effective not only for the building but also for the entire city.
- Intensive roofs that walkable are much more effective in terms of the benefits to life in the building than extensible roofs that are not walkable. However, despite the negative aspects of intensive roofs, the negative aspects of extensive roofs are less.
- For good performance, plants placed on vegetated roofs should be selected according to the climate and intended use.
- In the selection of the plants placed in the vegetated roof, the dust absorber, oxygen producer, windbreaker, noise cancelling etc. In cases where the qualities suitable for the purposes are not in parallel with the qualities suitable for the climate and season type, the performance evaluation should be made by taking the control variable criteria related to the climate and seasonal suitability in the checklist.
- The degree of sustainability of vegetated roofs can be determined by the number of positive answers in the checklists.
- The maintenance and repair frequency of the roof should be low and it should have the qualities and details that provide convenience in terms of construction and installation.
- Since the plant is at the basis of all benefits, in particular the improvement of urban climate and ecology, supporting urban agriculture, increasing visual attraction and satisfaction, the greater the amount of plants in the vegetated roofs, the better. Therefore, it is important that the vegetation area in the vegetated roofs is not less than half the area of the roof. In this regard, it is important to make sure that the equipment other than the vegetation on the roof does not prevent planting.

- While the vegetated roofs are sustainable in terms of compliance with all factors, if they are negative in terms of access; frequency of use, perception of space, the possibility of recovery in disasters and so on. will keep the building away from many important benefits. Therefore, the ease of access to the vegetated roof of the building horizontally and vertically should be considered as an important feature.
- In this study, plant qualities are mentioned. However, the need to coordinate with botanists in the selection of plant species with these qualities is also an important issue.
- In practice, the evaluation of the performance of vegetated roofs can be done by using the control lists that will be created by determining the factors, attributes and control variables that measure the sustainability of vegetated roofs, based on the benefits of vegetated roofs.
- The examples in Europe among the vegetated roof samples examined in this study indicate the importance of ecology in the city and its contribution to the improvement of the climate, as the wide-area extensively vegetated roof types it covers on the building roof.
- The performance evaluation results of the examined samples are presented as an example of the use of the checklist revealed in the research. As the number of samples examined increases, it can be said that the results obtained can be gradually evaluated towards generalization.
- Vegetated roofs, developed as a contribution to sustainable and ecological life can also be accepted as a positive design for the pandemic that is emerged today. After the spread of Covid-19 virus worldwide, isolation from communities and need to stay home within curfew days emphasized the importance of using balconies and terraces during the quarantine process. Providing outdoor environment conditions, these spaces make the duration of staying home longer and more comfortable. In addition to aforementioned contributions; residents can engage in social activities that are essential for mental health, through plant arrangements on the roofs and terraces while maintaining social distance.

## 7. REFERENCES

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