Original Article

# A hesitant fuzzy DANP for Identifying and prioritizing effects and challenges of green roof on mental health in developing countries

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**ABSTRACT**

Expanding the range of human civilization and industry sovereignty, based on new technology and a tendency towards machine life, in tandem with the destructive and destructive effects of natural resources and vegetation, the conversion of arable lands and gardens to building structures, along with the increasing population growth in cities And environmental pollution has not only disturbed the balance of the ecological system and the power of well-being, but it has also created difficult conditions for human life. This has given rise to the issue of urban green space in recent decades and the search for new ways to address this need. Designing green spaces for a city or a neighborhood is by no means an accident. On the other hand, land is scarce and very expensive to create green space in cities. In this case, unused surfaces such as roofs can be used. Green roofing is one of the environmental technologies that is formed under natural processes and has been attracted in many countries in recent years. This study seeks to identify the challenges of green roofing in developing countries and compare them with developed countries. To this end, the challenges and barriers to creating a green roof are first identified and then weighted and weighted to gauge the importance of each. The results showed that the investment dimension is the most important challenge for the development and construction of green roofs.

**Keywords:** of green roof, DANP, Hesitant fuzzy sets, environment, mental halth

## Introduction

Nowadays, urban green space is not only considered as one of the most important constituent components of a city, but also plays an important role in improving the living conditions and controlling the city's climate, and is one of the most functional green spaces that is of great interest to designers and urban planners today. Located, control and improvement of climatic conditions, creation of microclimate, prevention of thermal islands formation as well as restoration of living conditions [1].

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The physical expansion of cities has resulted in the destruction of the surrounding natural environments and arable lands. Flat roofs in high-rise urban buildings are designed to protect the building from rain, snow and mechanical maintenance. Flat roofs usually lack the aesthetic considerations of architectural design and therefore cannot play a role in capturing the aesthetic and architectural value of a building [2]. These rough, rough surfaces give the view of the city, or the area of the building, and need a rainwater disposal system. The creation and development of artificial green spaces has an important role in human life and is a substitute for the natural environment destroyed during construction [3]. Many new technologies and activities have emerged to reduce human impact on the earth, including: alternative energy, efficient use of natural resources, agriculture without the use of industrial materials, and green roofing. Green roofs are part of the effort of urban managers to stabilize urban space and are one of the modern solutions to solve urban environmental problems [4]. The modern-day apartment man is trying to restore the spirit and sense of humor to the rugged and sad residential blocks. He strives to combine the vibrant and green nature with the features of modern technology and to create beautiful and exquisite landscapes. On the other hand, land is scarce and very expensive to create green space in cities.

Since urban open spaces and green areas often lack direct economic value, the expansion of construction that in the short term will benefit the local governments and the public sector will increase land use [5]. The economic benefits have been short-lived and the expansion of urban green spaces is less financially supportive than other investments [6]. This problem exists in developed countries and in developing countries, especially in urban centers, but in developing countries due to his attention to economic benefits in the short term, urban leaders have a more pronounced presence. The purpose of this study is to identify barriers and challenges in developing countries and compare them with developed countries.

## Statement of the problem

The most important green space effect in cities is their environmental performance, which has made cities meaningful to the human community environment and has counteracted the detrimental effects of industry [7]. These functions mainly improve the ecological conditions and reduce the burden of environmental pollution, including gaseous, particulate, acoustic, radiation, unpleasant odors and other pollutants in air and water and soil and control the health of the environment [8]. Man provides. In general, from an environmental perspective, urban green space should provide the following ecological environmental benefits [9]:

- Improving bioclimatic conditions in the city
- Reduce air pollution

Have a positive impact on the water cycle in the urban environment and increase groundwater quality

- Increase soil permeability, reduce static levels
- Reduce noise pollution

## Vertical green space

The development of urban green space and its equitable distribution in neighborhoods, especially in urban centers, so that it is commensurate with urban clock and clock, is considered one of the strategies of sustainable urban development [10]. Urban human needs for nature, good visual prospects, and reduced environmental pollution on the one hand, and the need to rethink energy consumption and the need to optimize the use of energy carriers are important urban management issues. The development of vertical green space means the creation of green areas in urban buildings and includes green roofs and green walls [11]. Vertical green space has a variety of functions, including environmental beautification, environmental pollution reduction, energy storage, flood control, food provision and urban biodiversity conservation. Green roofs, as one of the most important vertical green spaces that play an important role in improving the environmental conditions of the city, have become particularly important in urban science [12].

Green roofs are one of the new approaches to architecture and urbanization and arise from the concepts of sustainable development that can be used to increase green space per capita, improve environmental quality and sustainable urban development. The mid-20th century can be seen as a turning point in the green roofing industry [13]. In the 1960s, considering the quality of the environment in urban contexts and the environmental challenges of major cities such as air pollution, scarcity of urban green space, especially in central areas, the emergence of urban heat island phenomena and the new wave energy crisis Green roofs have begun in their new and modern sense because of their environmental benefits and as an ecological solution from northern Europe. And it soon found its place in most European countries. Meanwhile, Germany, Switzerland, France and Austria were ahead of other European countries and began extensive work in this area [14].

## Green Roof Definition

A green roof is a roof that is covered in whole or in part by soil and vegetation, or by growing media. The term green roof is occasionally used for roofs that incorporate the concepts of "green architecture", such as solar panels or photovoltaic panels [3]. The green roof is actually the roof on which plants grow. The plant diversity of such a structure can range from roofing to artificial lawn to roofing, which is covered with plants used in landscape design. Roofing needs plants that can withstand the harsh, humid environment of the roof in conditions of dehydration, freezing, hurricanes, and so on. The type of plants selected varies depending on the climate and climatic conditions [1].

Most developed countries have taken the lead in using green roofs, some of which are more tangible [15]. For example, the most important goal of sustainable development in the United States has been to reduce dependence on petroleum products and to do all they can. In the green roof system, there are many potentials for use, and the application of this system in cities reduces the cost of energy consumption and increases the efficiency of the environment [1]. Green roofs also add to the usable area and provide new spaces for community gatherings and outdoor circulation. The continued encouragement and support of the mayors has made the building owners aware of the added value and benefits of such projects as the design, planting, allocation and construction of roof gardens, with the help of skilled professionals and architects [16].

In the meantime, various criteria are being considered for this system and the construction of different types of roof gardens requires planning decisions that are necessary to get the desired result, to be aware of how to use it. The green roof should be capable of maintaining and controlling the weight of rain and snow, the embedded pedestrian path, and more beyond the usual roofing engineering system [17].

**Figure 1:** Green roofs in North America

In North America, a number of city officials have begun extensively developing green roofs. Chicago has a major green roof program (including an outstanding one on the rooftop of America's greenest city.) The goal of creating a green space is to change the city from a completely industrialized past to a high-tech future that will lead to high technology [18]. Portland, Oregon, Seattle and Washington are also making extensive plans for green roofs, with heavy rainfall on the northwest coast and diversion not only flooding problems but also pollution of rivers and ditches [16]. Green roofs are deflected Water is scattered around buildings Toronto authorities are using green roofs as a tool to counter the city's heat island, which sometimes rises annoyingly in the center of the city, dramatically increasing the amount of heat used by green roofs. Reflects from the roofs and reduces the amount of heat lost to buildings [13].

**Figure 2 -** Green roofs in European countries

The most important boom centers and green roofs in Europe, Germany and Switzerland are currently. In these centers, especially in Germany, this phenomenon has become a legal requirement in many major cities [19]. Alongside this legal framework, there is a financial assistance system implemented by local authorities to give importance to the green space, which typically pays 50% of the associated costs, and of course, the main driver for the widespread adoption of the scheme is the laws. It was a government that dictated the need for green space as a result of industrial development [20]. But now green roofs are mainly used as part of concerted plans to prevent waste water from reducing the risk of urban flooding after heavy rainfall. The various types of green roofing initiative that has made a lot of noise in many countries has one thing in common [1]:

These projects, although strategically sponsored by the central government, operate at the city and regional level and focus on the specific needs of the area [21]. These projects, coupled with a high degree of interaction between local and city authorities, local research communities, the green roof industry and social and reconstruction institutions, provide solutions to meet regional needs. Sheffield University is a leading research institute in the field and has gained international fame in studies of green roofs [22]. The first national conference of green roofs that attracted more than 200 delegates was held in September 2003 in collaboration with the Sheffield City Council and the University of Sheffield. held. The conference strengthened the partnership between the University of Sheffield and the City Council and directly led to the implementation of green roof projects in the area [23]. For example, the Green Roofs project at the Morgets Craft Rotterdam Business Center was solely due to the designers present at the conference. The conference created the National Green Roof Institute. In 2004 The Green Roof Gathering was held in Sheffield with the City Council and the University of Sheffield aiming to create spaces to encourage building builders to green roofs. A considerable number of Green Roofing Institutions in south-east London have gained the trust of these mass builders, as a result of which the area has been a pioneer in the implementation of the Green Roofing Project in the UK[1].

**Figure 3 -** Examples of green roofs

Switzerland has one of the oldest green roofs in Europe. It is built in the city of Zurich. Its filtration tanks are 30,000 square meters of actual ceilings. To keep the interior cool and prevent bacteria from growing on the treatment floor, a drainage layer of sand and 15 cm of soil is placed on the roof and waterproofed with asphalt.

Earlier, the grass had grown there by shaving the seed, but now it has become a haven for many plants. The first rooftop vegetable garden in Augustonburg, a town on the outskirts of Mamloo, was built in 1999 by Mikat. Installed. The International Institute for the Green Roof (IGRI) was launched in 2001 as a research station and training facility. The green roof in Mamloo is very good [1].

English examples of green roofs are on display at the University of Nanningham and at the Henriemann Museum and Curry Museum in London. Atletide State near the River Thames in central London is the largest historic green roof in the English capital. Textiles in Liverpool is also one of the candidates for major green roof projects [1].

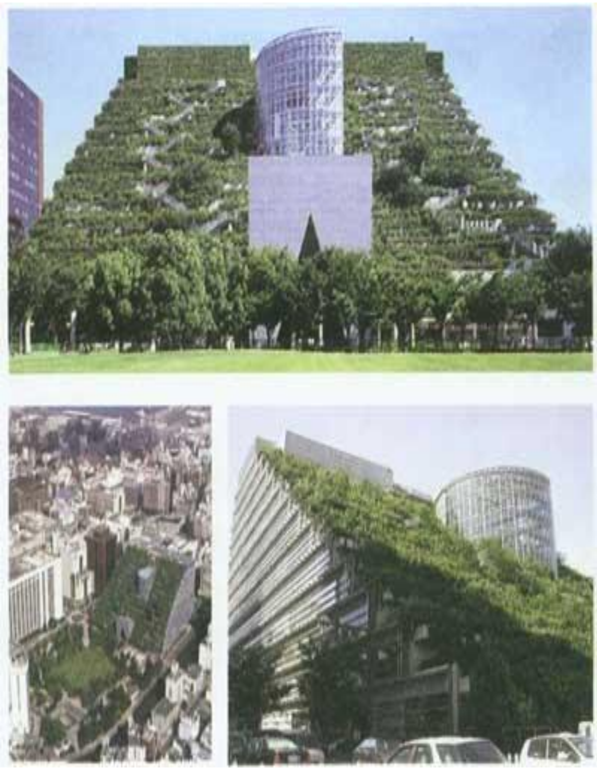

**Figure 4:** The Big Green Roof of the Rugged New Museum of El History El Lavender

In France, a large rough green roof (8,000 square meters) at the new L-Historial Museum in Delaware. Opened at Len Lus 3 Sur 2 Blogen.

The new building of the California Academy of Sciences, Golden Park Enancisco, has a 1-acre greenhouse that is home to indigenous plants. These new buildings consume 30 to 35 percent less energy, according to the Academy of Construction [1].

## The Benefits of Green Roofing

One of the solutions proposed to reduce energy consumption in large cities is the construction of green roofs that can be designed and implemented properly and with due regard to climate. In addition to its various benefits, it can greatly help reduce energy consumption, the efficiency of urban ecology, beautify the city, relieve urban pollution, and reduce urban tensions [24].

## Benefits of quantity and quality of green roofs compared to ordinary roofs

The difference between planted roofs and ordinary roofs can be classified into two categories of quantity and quality. The process of heat transfer in planted roofs is quite different.

Plants absorb a great deal of sunlight because of their biological function, such as photosynthesis, perspiration, respiration and evaporation. The rest of the sun's rays are converted into heat loads and affect the indoor air when passing through the roof of building elements [25].

Plants evaporate and return water to the atmosphere and are effective in regulating ambient temperatures [26].

## Quantitative Benefits of Creating a Green Roof

1. Soundproofing: Road noise is a major problem in urban areas. Although insulation of the facade helps to alleviate its sound load, that is, to reduce noise levels from outside to inside the building, its roof and its type also have an impact on the comfort of citizens. Green roofs increase sound insulation in the roof system. These roofs reduce noise by absorbing, reflecting and emitting sound waves. Soils and plants capture and trap acoustic frequencies and prevent their propagation [27].
2. Reduce heat effects: Large cities absorb the sun's radiant heat quickly and act as heat-emitting sources because of their high levels of hard impermeable and no vegetation. Such a condition is called the "heat island" phenomenon. In this case, there is a significant temperature difference between urban areas covered with asphalt and bitumen and areas covered with vegetation. Concrete and asphalt surfaces create "urban heat island" [28]. The ceilings and streets reflect light and heat and, at dusk, create a temperature dome above the cities. According to studies, the urban heat phenomenon affects the climate of the region, thus increasing the use of air conditioning and cooling devices, which in turn increases energy consumption and the greenhouse gas phenomenon, which The most important factors in the degradation of the ozone layer are the intensification [29]. A better understanding of the terrain and how the cover changes associated with urbanization over time can be very effective in the surface energy and climate characteristics of the area [30].
3. Reduce air pollution: In urban areas, trees have a significant contribution to reduce air pollutants. However, in many urban sites, there is little space for tree planting due to a variety of levels of penetration including street, parking, roofing and so on. Plants absorb air pollutants through their stomachs and remove particles with their leaves. In addition, indirectly by lowering the surface temperature by cooling and shedding, they reduce air pollution and reduce photochemical reactions of pollutants such as ozone in the

atmosphere. They absorb heavy elements and dust particles and reduce their displacement, and are one way to counteract the dust phenomenon in urban air [31].

4. Reduce carbon dioxide: The earth is warming due to the natural cycle and burning of fossil fuels. The burning of fossil fuels emits carbon dioxide as a by-product of combustion. Carbon dioxide, often because it is one of the atmospheric gases that impedes the transfer of heat energy near the surface to higher levels. As a circulating intervention agent, it increases the greenhouse effect and raises the ambient temperature. Green roofs not only reduce carbon dioxide through carbon decomposition, but also play a role in reducing insulation in buildings and reducing heat island [32].
5. Reduce the burden of sewage systems: Green roofs have the effect of reducing surface water flow, improving surface water flow quality and reducing wastewater overflow. In summer, green roofs can hold 80-70% and in winter between 25 and 40% water. Water retained in the soil will eventually evaporate or return to outer space. In addition, water flow is delayed due to soil saturation, which retains moisture and urban surface water, especially during seasonal rainfall, and by storing it prevents runoff and overflow. Green roof vegetation can absorb more than 95 percent of cadmium, copper, lead and 16 percent "zinc" from the rainwater and remove it from the water cycle and significantly reduce nitrogen levels [33].
6. Reduce Heat Transfer by Building Energy Storage: Green roofs help cool the roof space during summer and keep it warm in winter by reducing heat fluctuations on the roof's exterior and by increasing the roof's thermal capacity. Vegetation prevents freezing in the winter, increasing the insulation of the roof [17].

## Quality Benefits of Creating a Green Roof

1. Roof shell protection: The typical roofing life is about 20 years. If the life of the green roof is 45 years or more is met. The roof membrane is protected by ultraviolet radiation and severe temperature fluctuations between day and night by soil and vegetation [11].
2. Expansion of green space and habitat: Green roofs can offset the habitat of plants and plants that are being victimized by development, thereby reducing the amount of plant-free areas and limiting wildlife development. Was, expanded. Green roofs have a lot of environmental and wildlife benefits compared to conventional roofs, especially when they are adapted to the region's ecosystems and climates [18].
3. Food production: The green roof is an opportunity for agricultural development on the roof that expands food production. Green roofing products can have better quality and more natural production than marketed products due to their fertilizer and pesticides [19].
4. Beauty, wellbeing, and entertainment: Ordinary roofs often create an anomaly on the fifth facade of the building with ventilation equipment, chimneys, and bitumen and cobblestone layers. Also, the absorption of heat due to the dark color and the material of the roofing material, prevents the presence of roofing. Now, with a little bit of greenery, the functionality and role of these roofs can be changed. Green roofs with cooling and shading provide a pleasant environment and can be used by residents for recreation [12].
5. Promoting health and well-being: Studies often indicate the importance of direct human contact with natural and green spaces and their role in the physical and mental health of humans and show that access to green space directly reduces heart rate and blood pressure. And it generally helps to improve people's health. On the one hand, it provides interaction and co-operation between residents and enhances the spirit of co-operation and co-operation. Meanwhile it is a healthy place for children to grow [1].
6. Economical savings: reducing building materials consumption by increasing roof life and reducing roof repairs, energy conservation, surface water management, reducing greenhouse gas emissions, especially carbon dioxide, reducing fuel consumption and creating micro-roofs. Improves economic conditions. The social and environmental benefits of green roofs reduce health care costs, improve water quality, and reduce cooling and heating energy costs [5].

## barriers and challenges

**Table 1: barriers for green roof**

| Side barriers | code | The main barriers |
|---|---|---|
| Different Costs of Installing Green Roofs Based on Type, Materials and Environment than Common Roofs | C1 | investment |
| The cheapness of energy in Iran and the unwillingness of consumers to reduce energy carrier costs | | |
| Lack of government or non-state funding using existing forces | | |
| Different Costs of Maintaining Green Roofs During the Year for Developers Compared to Common Roofs | | |
| Failure to provide public and private developers with financial facilities | | |
| Lack of economically justified plans for public and private sector developers | | |
| Surplus costs of plant maintenance | | |
| Failure to inform the private sector about the benefits of investing in this sector and its propaganda | | |

| | | |
|---|---|---|
| Inclusion of green roofs as part of sustainable green space system, along with other urban green space planning and design policies | C2 | Managerial |
| Lack of information and awareness among officials and middle managers of municipalities on the benefits of green roofs | | |
| Failure to develop systems and solutions in municipalities and green space departments to address the needs and problems of the green roof | | |
| No public or private symbolic project on the green roof | | |
| Not using other countries' successful experiences in this field | | |
| Not encouraging consultants and contractors related to the activity, conducting research and research in this area | | |
| Lack of local standards and frameworks for its continuous evaluation to resolve problems and improve them over time | C3 | Legal |
| Lack of legal and legal framework to encourage investment in this sector | | |
| Lack of mandatory standards for green roofing (such as the green roof rules for high-rise buildings) | | |
| Easy construction and installation of ordinary roofs and easy access to its materials | C4 | Technical and infrastructure |
| Lack of experience, knowledge and communication with the green roofing industry | | |
| Lack of Native Green Roofing Industry | | |
| Lack of green roof equipment widely used for residential buildings, apartments and commercial centers with different technology | | |
| Lack of comprehensive software and hardware systems in introducing, consulting and quality access to information and equipment needed | | |
| The ability of ordinary roofs (common roofs) to cover any building form | | |
| Lack of applied research for metropolises to expand and justify green roofs and identify suitable plant species for different environments | | |
| Lack of applied research for small towns to expand and justify green roofs | | |
| Low level of scientific information for practical evaluation in different local situations | | |
| Normative compatibility of culturally appropriate roofs | C5 | Cultural |
| Lack of partnership and management space between people due to the creation and maintenance of green roofs in residential and commercial areas, etc. | | |
| Failure to train human resources and people to guide, standardize and maintain green roofs | | |
| Strong NGOs in the field of environmental protection and public participation | | |
| Failure to educate people about the sensitivity and importance of environmental, climatic and biomedical issues and the need for participation to improve the inadequate status of large cities and the positive impact of green roofs as a public action. | | |
| Lack of awareness about the green roof and its benefits | | |
| Geographical location dissatisfaction | C6 | Geographical |
| No green roofs in certain metropolises or specific geographical areas within the city, or urban areas | | |

## Analysis Method

The uncertainty of information in the decision-making process is very difficult due to the inherent complexity of natural objects and limited ability in humans. Fuzzy sets are introduced by Zadeh to deal with the uncertainty of real-life decision problems [34]. After Zadeh introduced fuzzy logic in 1965, fuzzy sets became one of the most appropriate decision-making techniques. Subsequently, various extensions of fuzzy sets were introduced as the gradual progress of decision science [35]. There is a new concept called the hesitant fuzzy sets introduced by Torra in 2011. hesitant fuzzy sets have more advantages than classic sets. The discovery of a marginal error that causes problems in membership values when using classical methods causes us to focus on fuzzy sets of doubt because this problem is solved by defining a set of possible values [34]. We have fixed this problem. It has been shown that allocating space for the response set may be less accurate than membership evidence, indicating that fuzzy decision making methods are more precise than other methods [36]. Some of functions is as follow [37]:

Definition 1: A fuzzy set is in a reference set, such as X, with membership function $m_F$ whose values are in range of [0,1] so that:

$$\mu_F : X \rightarrow [0,1]$$

After introducing the function of fuzzy sets, the concept of Intuitionistic Fuzzy set (IFS) was defined by Atanassov to express the decision makers' preferences more precisely in the decision-making process.

Definition 2: If the set $X=\{x_1,x_2,\ldots,x_n\}$ is a reference set, the intuitionistic fuzzy set A on the reference set X is defined as following:

$$A=\left\{\left\langle x_i,\mu\left(x_i\right),\nu\left(x_i\right)\right\rangle \middle| x_i \in X\right\} \quad (1)$$

$\mu(x_i)$ and $\nu(x_i)$ are the membership function and the non-membership function in the interval [0,1] and are true in the following condition for all values:

$$0 \le \mu(x_i) + \nu(x_i) \le 1 \tag{2}$$

Now we have $\pi_A(x_i) = 1 - \mu(x_i) - \nu(x_i)$ that $\pi_A(x_i)$ is the uncertainty value of $x_i$ in the reference set A.

Definition 3: A hesitant fuzzy element, such as H in A, is a function in HFS that is defined as a subset of h when the reference set is applied to the interval [0,1]. In fact, the hesitant fuzzy set is the generalization of intuitionistic fuzzy sets. This set is defined by Xu and Xia for convenience as follows:

$$H = \{\langle x_i, h(x_i)\rangle | x_i \in X\} \tag{3}$$

$h(x_i)$ is a set of different values in the interval [0,1]. $h(x_i)$ is called the hesitant fuzzy element (HFE) in the set H .

Definition 4: For a reference set X, if $h(x) = \{\gamma_1, \gamma_2, \ldots, \gamma_l\}$ is a hesitant fuzzy element with a set of possible values of with $\gamma_k$ (k=1,2,….,l) and 1 is a value of h(x) then the mean of h (x) in the HFE is defined by the following formula:

$$\bar{h}(x) = \frac{1}{l}\sum_{k=1}^{l}\gamma_k. \tag{4}$$

To compare the rules of hesitant fuzzy elements, a definition of the value operator and also variance operator is needed:

Definition 5: For per HFE the value operator is as follows:

$$s(h) = \frac{1}{l_h}\sum_{\gamma \in h}\gamma \tag{5}$$

It is clear that for two HF elements such as $h_1$ and $h_2$, if $s(h_1) > s(h_2)$ then $h_1 > h_2$ and if these two values are equal $s(h_1) = s(h_2)$ then $h_1 = h_2$ .

Note: obviously, due to the fact that the value operator of the two values is the same, there is no superiority between these two hesitant fuzzy element. Moreover, another concept called the variance operator is defined:

Definition 6: For each HFE, the variance operator formula is as follows:

$$\upsilon_1(h) = \frac{1}{l_h}\sqrt{\sum_{\gamma_i,\gamma_j \in h}(\gamma_i - \gamma_j)^2} \tag{6}$$

For both HFE elements such as h1 and h2, if $\upsilon_1(h_1) > \upsilon_1(h_2)$ then $h_1 < h_2$

New developments for hesitant fuzzy sets have been introduced. One of these constraints is that the interval-*valued hesitant fuzzy* (IVHF). This development shows the degree of membership of the components as possible intervals at [0, 1].

The coefficient of variation in 1 is as follows [35]:

$$CV = \frac{s}{\sigma + \varepsilon} \tag{8}$$

*3.1 IVHF-DANP*

The DANP method is one of the multi-criteria decision-making methods that computes an ANP super matrix using the DEMATAL communication link matrix and calculates the weight of criteria and sub-criteria. In fact, the DANP method is a combination of the DEMATAL based ANP (DANP) method [35]. In traditional and classical methods for solving the DEMATAL and ANP combination models, this was done using the DEMATAL method of the total communication matrix, then the threshold value was taken and based on the threshold value and the total communication matrix, the relationship between the criteria and The sub-criteria were extracted and subjected to the ANP method, and then the pairwise comparisons were performed and the weight of the criteria and sub-criteria were calculated. (One of the disadvantages of this approach is that, taking into account the threshold value, a large number of internal relationships are eliminated) [37].

But in the other DANP method, the total communication matrix does not take the threshold value (this makes it possible to maintain all internal relations), and with the same total effect numbers, the super matrix is formed, then it is balanced and reaches infinite power to the weight The final criteria and sub-criteria are calculated [35].

The steps in this algorithm are as follows [35]:

First, the direct impact matrix is calculated based on the experts' opinion based on IVHFE.

$$\tilde{G} = \begin{bmatrix} \tilde{g}^{11} & \cdots & \tilde{g}^{1j} & \cdots & \tilde{g}^{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{g}^{i1} & \cdots & \tilde{g}^{ij} & \cdots & \tilde{g}^{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{g}^{n1} & \cdots & \tilde{g}^{nj} & \cdots & \tilde{g}^{nn} \end{bmatrix} \tag{9}$$

Which $\tilde{g}^{ij} = (\tilde{\gamma}_1^{ij}, \ldots, \tilde{\gamma}_t^{ij}, \ldots, \tilde{\gamma}_s^{ij})$

Such a way that

$$\tilde{\gamma}_t^{ij} = [\tilde{\gamma}_t^{ijL}, \tilde{\gamma}_t^{ijR}]$$

In the next step, we normalize the direct impact matrix and then obtain the overall impact matrix using the following relation:

$$\tilde{T} = \tilde{D} + \tilde{D}^2 + \tilde{D}^3 + \ldots + \tilde{D}^m = \tilde{D}(\tilde{I} - \tilde{D})^{-1} \tag{10}$$

Where $\tilde{T}$ *and* $\tilde{D}$ represent the total impact matrix, and the direct impact matrix, respectively

$$(I-\tilde{D})=\begin{bmatrix} 1 & \cdots & 0 & \cdots & 0 \\ \vdots & 1 & \vdots & & \vdots \\ 0 & \cdots & 1 & \cdots & 0 \\ \vdots & & \vdots & 1 & \vdots \\ 0 & \cdots & 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} 0 & \cdots & \tilde{d}_{1j} & \cdots & \tilde{d}_{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{d}_{i1} & \cdots & \tilde{d}_{ij} & \cdots & \tilde{d}_{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{d}_{n1} & \cdots & \tilde{d}_{nj} & \cdots & \tilde{d}_{nn} \end{bmatrix} = \begin{bmatrix} 1 & \cdots & 0 & \cdots & 0 \\ \vdots & 1 & \vdots & & \vdots \\ 0 & \cdots & 1 & \cdots & 0 \\ \vdots & & \vdots & 1 & \vdots \\ 0 & \cdots & 0 & \cdots & 1 \end{bmatrix} \tag{11}$$

And also:

$$\tilde{D}(I-\tilde{D})^{-1}=\tilde{D}.I$$
$$=\begin{bmatrix} 0 & \cdots & \tilde{d}_{1j} & \cdots & \tilde{d}_{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{d}_{i1} & \cdots & \tilde{d}_{ij} & \cdots & \tilde{d}_{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{d}_{n1} & \cdots & \tilde{d}_{nj} & \cdots & \tilde{d}_{nn} \end{bmatrix} . \begin{bmatrix} 1 & \cdots & 0 & \cdots & 0 \\ \vdots & 1 & \vdots & & \vdots \\ 0 & \cdots & 1 & \cdots & 0 \\ \vdots & & \vdots & 1 & \vdots \\ 0 & \cdots & 0 & \cdots & 1 \end{bmatrix} = [\cdot]_{n\times n} \tag{12}$$

To calculate the matrix we use the following coefficient of variation operator. For this purpose, we first obtain the direct impact matrix using the coefficient of variation operator.

$$\Phi=\begin{bmatrix} \varphi_{11} & \cdots & \varphi_{1j} & \cdots & \varphi_{1n} \\ \vdots & & \vdots & & \vdots \\ \varphi_{i1} & \cdots & \varphi_{ij} & \cdots & \varphi_{in} \\ \vdots & & \vdots & & \vdots \\ \varphi_{n1} & \cdots & \varphi_{nj} & \cdots & \varphi_{nn} \end{bmatrix}$$

$$\varphi_{ij}=IVHFCV(\tilde{g}^{ij}) \tag{13}$$

Then we normalize the direct impact matrix using the following relation:

$$H=\frac{\Phi}{s} \tag{14}$$

$$s=\max\left(\max_{1\le i\le n}\sum_{j=1}^{n}\varphi_{ij},\max_{1\le j\le n}\sum_{i=1}^{n}\varphi_{ij}\right) \tag{15}$$

Finally, using the following relation matrix, the overall impact is calculated:

$$Z=H+H^2+H^3+\ldots+H^m+=H(I-H)^{-1} \tag{16}$$

Now we calculate r and c:

$$r=\left[\sum_{j=1}^{n}t_{ij}\right]_{n\times 1},\ c=\left[\sum_{j=1}^{n}t_{ij}\right]'_{n\times 1} \tag{17}$$

Then we calculate super matrix and weighted super matrix with combining methods DEMATEL and ANP:

$$T_c = \begin{matrix} D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{matrix} \begin{matrix} c_{11} \\ c_{12} \\ c_{1n_1} \\ \vdots \\ c_{i1} \\ c_{i2} \\ c_{in_i} \\ \vdots \\ c_{m1} \\ c_{m2} \\ c_{mn_m} \end{matrix} \overset{\begin{matrix} D_1 & \cdots & D_j & \cdots & D_m \\ c_{11}\cdots c_{1n_1} & \cdots & c_{j1}\cdots c_{jn_j} & \cdots & c_{m1}\cdots c_{mn_m} \end{matrix}}{\begin{bmatrix} g_c^{11} & \cdots & g_c^{1j} & \cdots & g_c^{1n} \\ \vdots & \vdots & \vdots & & \\ g_c^{i1} & \cdots & g_c^{ij} & \cdots & g_c^{in} \\ \vdots & \vdots & \vdots & & \\ g_c^{n1} & \cdots & g_c^{nj} & \cdots & g_c^{nn} \end{bmatrix}} \tag{18}$$

Then normalize the matrix $T_c$:

$$T_C^{nor}=\begin{bmatrix} T_C^{nor_{11}} & \cdots & T_C^{nor_{1j}} & \cdots & T_C^{nor_{1n}} \\ \vdots & & \vdots & & \vdots \\ T_C^{nor_{i1}} & \cdots & T_C^{nor_{ij}} & \cdots & T_C^{nor_{in}} \\ \vdots & & \vdots & & \vdots \\ T_C^{nor_{n1}} & \cdots & T_C^{nor_{nj}} & \cdots & T_C^{nor_{nn}} \end{bmatrix} \tag{19}$$

Then, the total influential matrix is normalized into a super-matrix according to the interdependence between the relations of the dimensions and related clusters to obtain an un-weighted super-matrix, *WC*,

$$W_c = (T_c^{nor})' = \begin{array}{c} \\ D_1 \begin{matrix} c_{11} \\ \vdots \\ c_{1n_1} \end{matrix} \\ \vdots \\ D_i \begin{matrix} c_{i1} \\ \vdots \\ c_{in_i} \end{matrix} \\ \vdots \\ D_m \begin{matrix} c_{m1} \\ \vdots \\ c_{mn_m} \end{matrix} \end{array} \overset{\begin{matrix} D_1 & \cdots & D_j & \cdots & D_m \\ c_{11} \cdots c_{1n_1} & \cdots & c_{m1} \cdots c_{mn_m} & \cdots & c_{j1} \cdots c_{jn_j} \end{matrix}}{\begin{bmatrix} W_c^{11} & \cdots & W_c^{i1} & \cdots & W_c^{m1} \\ \vdots & & \vdots & & \vdots \\ W_c^{1j} & \cdots & W_c^{ij} & \cdots & W_c^{mj} \\ \vdots & & \vdots & & \vdots \\ W_c^{1m} & \cdots & W_c^{im} & \cdots & W_c^{mm} \end{bmatrix}} \quad (20)$$

Calculate the weighted super-matrix *WC**

$$W_c^* = T_D^{nor} \times W_c = \begin{bmatrix} t_D^{nor11} \times W_c^{11} & \cdots & t_D^{norI1} \times W_c^{I1} & \cdots & t_D^{norm1} \times W_c^{m1} \\ \vdots & & \vdots & & \vdots \\ t_D^{nor1j} \times W_c^{1j} & \cdots & t_D^{norij} \times W_c^{ij} & \cdots & t_D^{normj} \times W_c^{mj} \\ \vdots & & \vdots & & \vdots \\ t_D^{nor1m} \times W_c^{1m} & \cdots & t_D^{norim} \times W_c^{im} & \cdots & t_D^{normm} \times W_c^{mm} \end{bmatrix} \quad (21)$$

Limit the weighted super-matrix by raising it to a sufficiently large power φ until it converges and become a long stable super-matrix term to obtain global priority vector, which defines the influential weights $w = (w1, \ldots, wj, \ldots, wn)$ from $lim\varphi \rightarrow \infty (W_c^*)^{\varphi}$ for the criteria.

## Finding:

First decision matrix and direct impact matrix **Φ** is calculated in table 2:

**Table 2. Direct impact matrix Φ**

| | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|
| C1 | 0/000 | 1/000 | 3/150 | 3/541 | 1/410 | 1/041 |
| C2 | 4/070 | 0/000 | 2/440 | 2/640 | 2/184 | 2/121 |
| C3 | 1/190 | 1/000 | 0/000 | 2/204 | 0/000 | 2/221 |
| C4 | 0/009 | 1/580 | 2/650 | 0/000 | 2/184 | 0/749 |
| C5 | 2/147 | 1/214 | 2/541 | 2/141 | 0/000 | 3/125 |
| C6 | 2/314 | 1/715 | 3/471 | 0/145 | 2/214 | 0/000 |

Then general matrix Z based on IVHFE calculated in table 3:

**Table 3. General matrix Z based on IVHFE**

| | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|
| C1 | 0/1016 | 0/1122 | 0/2147 | 0/2415 | 0/5124 | 0/2014 |
| C2 | 0/4912 | 0/1841 | 0/2408 | 0/2678 | 0/6102 | 0/2947 |
| C3 | 0/0832 | 0/1512 | 0/0578 | 0/1154 | 0/0741 | 0/3148 |
| C4 | 0/0512 | 0/0845 | 0/4115 | 0/0774 | 0/0198 | 0/1784 |
| C5 | 0/3114 | 0/3504 | 0/3211 | 0/2674 | 0/0188 | 0/2914 |
| C6 | 0/1314 | 0/1018 | 0/1547 | 0/1086 | 0/8401 | 0/1425 |

Now $r_i + c_i$ and $r_i - c_i$ are calculated in table 4:

**Table 4. $r_i + c_i$ and $r_i - c_i$**

| criteria | $r_i + c_i$ | $r_i - c_i$ |
|---|---|---|
| C1 | 3.497 | 0.312 |
| C2 | 2.210 | 1.312 |
| C3 | 1.909 | -0.745 |
| C4 | 2.238 | -0.902 |
| C5 | 2.714 | 1.0974 |
| C6 | 2.544 | -0.469 |

Based on data from Table 4, Fig. 5 is drawn and network relationship map (NRM) of influential relationships is created. Figure 5 shows the importance and effectiveness of the measures between the criteria. The horizontal axis of the graph shows the importance of the criteria and the vertical axis of the impact or influence of the criteria.

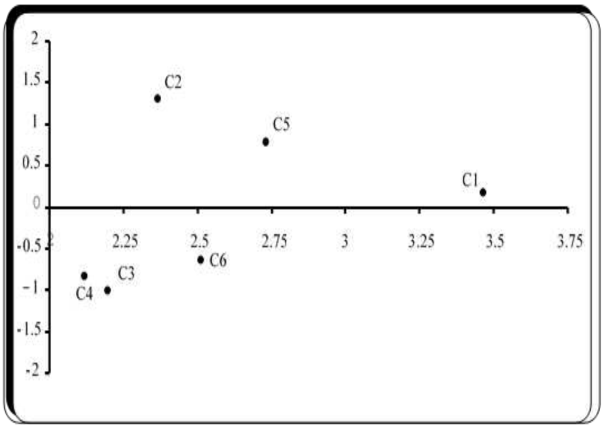


**Figure 5.** network relationship map

and then the weight of other component is as follow:

| | criteria | weight | rank |
|---|---|---|---|
| C1 | investment | 0/347826 | 1 |
| C2 | Managerial | 0/086957 | 4 |
| C3 | Legal | 0/043478 | 5 |
| C4 | Technical and infrastructure | 0/304348 | 2 |
| C5 | Cultural | 0/130435 | 3 |
| C6 | Geographical | 0/086957 | 4 |

| Sub-criteria | rank |
|---|---|
| Different Costs of Installing Green Roofs Based on Type, Materials and Environment than Common Roofs | 1 |
| The cheapness of energy in Iran and the unwillingness of consumers to reduce energy carrier costs | 23 |
| Lack of government or non-state funding using existing forces | 2 |
| Different Costs of Maintaining Green Roofs During the Year for Developers Compared to Common Roofs | 3 |
| Failure to provide public and private developers with financial facilities | 5 |
| Lack of economically justified plans for public and private sector developers | 24 |
| Surplus costs of plant maintenance | 4 |
| Failure to inform the private sector about the benefits of investing in this sector and its propaganda | 25 |
| Inclusion of green roofs as part of sustainable green space system, along with other urban green space planning and design policies | 6 |
| Lack of information and awareness among officials and middle managers of municipalities on the benefits of green roofs | 26 |
| Failure to develop systems and solutions in municipalities and green space departments to address the needs and problems of the green roof | 27 |
| No public or private symbolic project on the green roof | 28 |
| Not using other countries' successful experiences in this field | 7 |
| Not encouraging consultants and contractors related to the activity, conducting research and research in this area | 29 |
| Lack of local standards and frameworks for its continuous evaluation to resolve problems and improve them over time | 30 |
| Lack of legal and legal framework to encourage investment in this sector | 31 |
| Lack of mandatory standards for green roofing (such as the green roof rules for high-rise buildings) | 32 |
| Easy construction and installation of ordinary roofs and easy access to its materials | 33 |
| Lack of experience, knowledge and communication with the green roofing industry | 8 |
| Lack of Native Green Roofing Industry | 9 |
| Lack of green roof equipment widely used for residential buildings, apartments and commercial centers with different technology | 15 |
| Lack of comprehensive software and hardware systems in introducing, consulting and quality access to information and equipment needed | 16 |
| The ability of ordinary roofs (common roofs) to cover any building form | 17 |
| Lack of applied research for metropolises to expand and justify green roofs and identify suitable plant species for different environments | 19 |
| Lack of applied research for small towns to expand and justify green roofs | 13 |
| Low level of scientific information for practical evaluation in different local situations | 18 |
| Normative compatibility of culturally appropriate roofs | 14 |
| Lack of partnership and management space between people due to the creation and maintenance of green roofs in residential and commercial areas, etc. | 20 |
| Failure to train human resources and people to guide, standardize and maintain green roofs | 11 |
| Strong NGOs in the field of environmental protection and public participation | 10 |
| Failure to educate people about the sensitivity and importance of environmental, climatic and biomedical issues and the need for participation to improve the inadequate status of large cities and the positive impact of green roofs as a public action. | 21 |
| Lack of awareness about the green roof and its benefits | 22 |
| Geographical location dissatisfaction | 34 |
| No green roofs in certain metropolises or specific geographical areas within the city, or urban areas | 12 |

## Analysis of research findings:

Based on the results, it is clear that investing is the most important problem for creating a green roof. Measures should therefore be taken to support the foundations, such as developed countries, private sector lending and appropriate financial support, so that we can see progress in the use of green roofs. Also the technical and infrastructure component is very important. The best way to solve this problem is to combine knowledge, experience and skills. Therefore, it is necessary for the academic and industrial community to work together more. The next case is the cultural component, and the solution to this problem is to increase NGOs and culture by building training programs for green roofing benefits.

The next priority is given to the two managerial and geographical components. For the management component, the experience of successful and educated countries in these countries should be used to conduct training courses and launch green roofs. Geographic components also need to be set up in cities with higher rainfall and in hot and dry places to help protect the environment and reduce air pollution. The last priority is also legal, and it must be enacted to address the legal dilemma that high-rise apartments and high-rise hotels require green roofs.

Also, in the case of the sub-components, the most important ones are cost and most of these components are in the investment category. So, like developed countries, we need to increase green roof construction in the country by attracting investors and by enacting government incentive laws.

## Conclusion

As mentioned above, green roofs are one of the new ideas in architecture and urban development arising from the concepts of sustainable development that can be used in the field of green space, environmental quality improvement and sustainable development. Generally, the added value of land over land and the low land area in cities have made use of green roofs a good option because of improved urban environment quality.

In general, there are several obstacles to the development of green roofs that have been highlighted such as high cost of deployment, lack of attitude as an environmental solution, and the cheapness of energy carriers that are more at the macro level. According to the results of this study, the most important limitation of green roof is related to its costs, which must be included in the urban management component to reduce costs in order to achieve the final urban improvement. With the new emphasis and the development plans of governments, private bodies must also enter the arena.

The reality is that investing in green roof technology is the most important way that allows our cities to grow and develop with the assurance of protecting and preserving human life and the environment. Because these types of spaces provide the residents with a sense of beauty and relaxation and even reduce the heating and cooling load of the building. So paying attention to this will bring about a global upgrade that can also cover running costs.

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