



Sustainable Management for the Architectural Heritage in Intelligent Cities using MCDM methods

Hrudaya Kumar Tripathy¹, Sunday Adeola Ajagbe^{2*}, El-Sayed M. El-Kenawy³

¹School of Computer Engineering, Kalinga Institute of Industrial Technology, Deemed to be University, Bhubaneswar, Odisha, India.

²Department of Computer Engineering, Ladoke Akintola University of Technology Ogbomoso, Nigeria

³Department of Communications and Electronics, Delta Higher Institute of Engineering and Technology, Mansoura 35111, Egypt

Emails: hktripathyfcs@kiit.ac.in; saajagbe@pgschool.lautech.edu.ng; skenawy@ieee.org

Abstract

The success of sustainable management of the heritage building in an intelligent city is a difficult multi-criteria decision-making (MCDM) issue including the coexistence of conflicting elements. There is an issue with incomplete decision information utilization and information loss throughout the decision-making process, and the interaction difficulty in a fuzzy environment is easy to miss. This paper provides a hybrid MCDM framework that combines the spherical fuzzy analytical hierarchy process (SF-AHP). The SF-AHP is used to assess the significance levels of building heritage. To use the stage MCDM model, a thorough set of assessment criteria based on the notion of sustainable development has been identified via literature research and expert interviews. To assess the efficacy of the suggested strategy, an application is done in this paper. Using the decision framework, the building heritage in intelligent cities has been identified. The suggested technique may be utilized to achieve management of the building heritage in intelligent cities.

Keywords: AHP; Fuzzy; Smart Cities; MCDM; Heritage; Sustainable.

1. Introduction

Artificial surroundings are an essential part of city life in the twenty-first century. Numerous countries throughout the world have set themselves the goal of creating "intelligent cities," based on the premise that a self-sustaining metropolitan organisation may be created by utilising ICT (Information and Communications Technology) in a flexible, adaptable, and rational way. The idea of what constitutes an "intelligent city" is up for grabs. As a consequence of the fourth industrial revolution, there has grown a movement to promote the concept of the "smart city," which advocates for urban areas that are technologically dependent on one another. IoT infrastructure and technological integration in every facet of the urban environment has led to a rise in the creation of smart cities [66]. According to urban planning and urban development research, a "smart city" is defined as a sustainable lifestyle established by people who take responsibility for their actions. As a result, new solutions have the potential to significantly improve public health, reduce waste in the construction and support industries, transportation, and other sectors, as well as the management of resources such as water and electricity. Only one of many elements contributes to creating healthy and liveable surroundings, but they are an important one.

There has been a shift toward more intelligent cities throughout the world, as well as a rise in urban and residential circumstances as a result. Smart cities may deliver a wide range of benefits, including increased efficiency, better traffic flow, improved public safety, and a cleaner environment. It's possible that various smart city technologies will have an effect on almost every facet of daily urban life. As a result of all of the research, scientific endeavours, and seminars conducted so far, it has been possible to draw conclusions on

how to build an artificial city and transform existing urban areas into even more capable things. Prior research by the authors looked at smart cities from a variety of perspectives.

Some scholars [1], [2] have examined the intelligent city fundamentally, without delving further into its parts and working processes, but by examining the concept's relevance to contemporary urban ideas and sustainability concepts. In addition, one group of writers examined the evolution, changes, and features of its urban subsystems, including transportation, environment protection, livability, sustainable regions, design, institution building, and citizenship, in published research. Numerous articles examine the ecological aspect of an intelligent city through the framework of an intelligent grid location, focusing on the reprocessing of wild greenfield parts[3], [4], [68], the protection of natural resources and water[5], wastewater treatment[6], the use of alternative energy sources and the reduction of carbon dioxide[7], [8], and the construction of power and intelligent facilities[9]. Several studies examine the application of current technology in many facets of social life, including the improvement of the health systems[10], [11], [67], schooling[12], [13], living[14], art, and tourism [15], as well as the dissemination of information across boundaries. Some scholars have examined smart urban governance by focusing on the regulatory arrangements in spatial preparation, the collaboration of diverse investors, and implementing sustainable copies that integrate centrally specified legislation with movements and public engagement [16]–[20].

Several studies [21]–[23] examine the smart economy, which includes market expansion, self-service promotion, free enterprise, e-commerce, and planned stock. Numerous scientific works are devoted to urban infrastructure development through mobility systems[24]–[26], as well as creative energy system improvement[27]. Big data, gamification, IoT, 5G systems, as well as other intelligent skills have transformed the conventional picture of metropolises. Adapting to human demands, global issues, and technological advancements, cities endure multiple changes that modify their macro and microgeographic urban morphology. All of these issues may be seen in urban construction, disrupting urban individuality and calling its upcoming maintenance into doubt. The character and soundness of a region are dependent on its cultural legacy as an urban substructure and historical replication of social evolution. In dealing with the cultural aspect, national heritage also involves specific or gathered structures that are the portion of a region's architectural legacy. Visually, formally, and geographically, the area in which people live is primarily determined by their architectural legacy. It comprises many kinds of buildings and significant-cultural locations that are preserved as cultural resources or recognized as architecturally and culturally significant structures from diverse eras, counting modern activities [28]–[30].

To conserve the individuality and existing qualities of metropolitan areas, sustainable urban development efforts, such as the intelligent city drive, are centred on building heritage administration. The administration of built history is multidimensional and may be understood from various angles. In order to identify, define or affirm national identity, it is vital to use this method. UNESCO, for example, is committed to actively protecting cultural assets across the world. UNESCO puts a special focus on historical and heritage assets with outstanding characteristics. Many global heritage charters and conferences have been established and with them the values of heritage paperwork, like 1972, 2001, and 2003 UNESCO World Heritage Conferences, 1972, 1976, and 1978 UNESCO recommendations for protection, 2000 Council of Europe Constitutions and Conventions, and 1996 ICOMOS principles for capturing monuments, constructions, and cities[31]. The directives 2030 Agenda for Environmental Sustainability and the New Urban Agenda [32] emphasize that fostering awareness of the management of architectural and cultural heritage is vital to the idea of sustainability.

Many research on the placement of cultural assets in intelligent cities demonstrates scattered methods, notwithstanding the presence of heritage building concerns in smart city development initiatives. Using great decisions in heritage rebuilding and preservation with the assistance of many attribute assimilation. In recent decades, techniques of multi-criteria decision-making (MCDM) and their applications hip numerous domains of technical study have seen significant growth and popularity. MCDM is widely used when it is desired to reorganize an MCDM issue and decompose it hooked on distinct subunits, or when it is important to pick the best option. MCDM offers an official context for modelling multidimensional DM issues, particularly those that need systems examination, such as the study of choice complexity, the significance of repercussions, and the requirement for decision accountability. Regarding architectural legacy, several articles examine deserted historical, economic, commercial, political, and other sorts of buildings, as well as the issue of their regeneration prospects through reuse for new contents and functions. Consequently, MCDM approaches rank previously established redevelopment possibilities to choose the most sustainable and optimum choice[33]. In[34], decision-making techniques associated with heritage building and the restoration of historic structures are examined. Reform and restoration of historic structures may have a larger impact when they follow an AHP, an analytical hierarchical approach. [35], While AHP was used by others to identify which historical sites should be preserved, [36]. Contrarily, AHP

is widely used to assess key risks or indications pertaining to the execution of proactive measures, such as intervention. [37]. To evaluate criteria for intelligent cities or smart strategies, several publications have recognised the AHP as a helpful MCDM technique for determining the most important obstacles to their implementation [38].

This study investigates the subject of the built heritage associated with smart cities to determine the most important indicators for ensuring the protection, conservation, and repair of architectural structures in a sustainable manner. The study relates to all constructed structures with built heritage qualities, regardless of whether or not they are put under a protection system. The research examines the administration of heritage buildings in intelligent cities from the perspective of MCDM, using several AHP techniques to prioritize importance indicators. The objective is to compare the final decision of criteria, before set by specialists in the administration and conservation of heritage buildings and experts in the creation of smart cities, for various approaches. The spherical fuzzy set (SFS) was introduced by Kutlu Gündodu and Kahraman [39], [40] in 2018. It is a three-dimensional fuzzy set composed of Pythagorean fuzzy sets and neutrosophic fuzzy sets. SFS may also be used to implement criteria for dealing with uncertainty and vagueness in linguistic phrases, which is a novel approach to decision-making in a fuzzy context. The degree of indeterminacy of the decision-maker is specified regardless of the membership and non-membership degrees of these components. Decision-makers define the membership function in SFS on a spherical surface to infer additional fuzzy sets, with which they may permit the values of this membership function in a larger domain.

The structure of the paper consists of four parts. After a short introduction to the study, a theoretical background review of existing research in the area of heritage building management from the perspective of the intelligent city paradigm is presented. The third portion discusses the study approach to defining the spherical AHP algorithms, while the fourth section provides rankings produced by comparing the outcomes of various algorithms. In the fifth part, conclusion comments and future research objectives are offered.

2. Related Work

Numerous worldwide concerns and difficulties, such as a growing urban population, social requirements, economic and political development, and technological innovation, pose substantial obstacles to the protection of building history and individuality. As well as human, technical, organizational, and environmental resources, the architectural legacy is a reflection of the evolution of human civilization. In search of new patterns for the management of heritage buildings, the notion of an intelligent city has emerged as an outline for the incorporation of sustainable answers capable of meeting worldwide issues.

Urban landscapes are determined by architectural legacy, which reflects their past and shapes distinctive outlines and urban constructions. As a tangible proof of historical and national evolution, architectural legacy consists of a variety of architectural facilities that often reveal unique building principles of the era, as well as the shapes and characteristics of legitimate architectural movements. It is an indication of the past and an urban asset of the current that will serve as the basis for future endeavors. Managing architectural heritage may be an important catalyst for urban social and economic growth. Considering that building assets are part of the sustainability's cultural pillar[41], safeguarding, maintaining, and preserving heritage buildings is a component of sustainable urban regeneration. The administration of heritage buildings covers a vast array of activities and procedures that have been the subject of several studies. Until now, several scientific studies have focused on the various methodological measures for the overhaul of existing conveniences[42], as well as the numerous treatments for the restoration of the aesthetic values of buildings, archaeological ruins, and historical monuments in terms of the product functional and plastics[43]. There are several sorts of architectural heritage preservation concepts. Numerous articles examine the different facets of revitalization, which, in addition to the preservation of initial form and materials, often entails the adaptive reuse of abandoned facilities and the expansion of spatial capacity[44]. One set of writers examined vernacular architecture, focusing on traditional materials, culture, patterns, and building practices [45]. Several studies are devoted to the establishment of new artistic pathways or the incorporation of a facility into existing ones[46], while facilities and culture are promoted via tourist development[47]. Some scholars have examined the retrofitting of a heritage building in the concept of energy consumption[48]. Numerous revisions on the administration of heritage buildings have focused on case studies of historically important units, city centers, and structures of cultural relevance[49], [50].

As sustainability has become one of the essential prerequisites for the construction of smart cities, the management of heritage buildings in smart settings entails a variety of urban activities and instruments connected to the most important components of contemporary longitudinal sustainable development plans. Very tools for the organization of heritage building can be categorized using a system of appropriate groups of indicators that correspond to the imaginable aspects of the sustainability paradigm [51] financial,

ecologic, common (3 primary aspects), infrastructural[52], and based on culture [53], with the outline of the technological framework that conforms to smart development[54]. Assumed that heritage building is a subset of heritage and culture and the subject of this article, the national component of sustainable intelligent administration is acknowledged as an architectural element of influence. The economic side includes capital and its financial analysis in the protection and restoration of architectural heritage, in addition to monetary rewards. For this study, they are separated into 3 sub-criteria groups: income rate, asset expenses, and outside financing assistance.

The additional factor of sustainability, the communal element, refers to the societal effect on the perception of architectural heritage as well as desires for its preservation and protection. The greatest major social aspect is the establishment of employment possibilities for individuals via heritage management and the growth of heritage tourism, which has become a key sector in the economic plans of many nations[55]. The environmental component addresses whether current heritage building is harmful to the environment and the degree of pollution control during their restoration. In this way, urban recycling has been included in sustainable urban revitalization strategies and is strongly tied to the renovation and conversion of many forms of the heritage building. It increases the decrease of new materials used in building, effects directly the lessening of energy consumption, and reduces the emission of dangerous air [56]. The official component refers to the administration of heritage buildings at many hierarchical levels, including several investors and governmental, regulatory, and planning structures for implementing management processes. In this regard, the smart city idea often supports community engagement in decision-making and the creation of a collaborative approach as a means of enhancing urban governance[57]. A newly constructed heritage management practise illustrates the importance of community involvement and moves away from the traditional centralised governance model in favour of a more holistic one that takes into account community aspirations[58].

Existing historic buildings may be preserved and repaired using architectural indications. The originality, artistic worth, and preservation status of the structure are all taken into account, as are its multi-planet use, structural stability, and lifespan. It is becoming more common to see the application of new technologies in the regeneration, protection, and promotion of heritage buildings as a result of the smart city's expansion. With the internet and mobile connections, historic buildings may be digitally connected to a wide range of people and organisations. These urban history artefacts may be used using ICT tools like 3D reconstructions and virtual reality tours. With the aid of virtual reality (AR), it is essential to evaluate the characteristics of lengthy, damaged buildings designed that make it impossible to locate the past and authentic construction processes.[59]. The historic structures' heritage tourist experience has been enhanced by many layers of ICT integration. Heritage digitization makes it possible to virtually tour all of the world's museums, art galleries, and other public spaces, which has proven to be not only entertaining but also useful during the COVID pandemic when people's freedom of movement is restricted or outlawed. It also helps people learn more about architectural history and gives them new ways to become involved in a cold climate by expressing their thoughts in a survey and proposing rebuilding designs for buildings in response to many requests from across the globe. Apps in the heritage building industry will benefit from the use of IoT systems and technologies [60-66]. In order to improve analytical capabilities, GIS (geospatial information system) stations are needed [67], BIM (Building Information Model) is able to operate a system that allows the classification of heritage buildings completed modelling systems infrastructure, fully automated leaflets relating to heritage administrations, implementation of assets and intervention are some methods used to preserve historical buildings using electronic photogrammetry.

3. Spherical Fuzzy AHP

SF-AHP stands for Spherical fuzzy analytical hierarchy process. Kutlu Gündoudu and Kahraman [68] created spherical fuzzy sets (SFS) to manage uncertainty during the quantification of expert opinions. This study proposes a hybrid MCDM framework that combines the spherical fuzzy analytical hierarchy process (SF-AHP). The framework is presented in Figure 1, it consists of three stages, first determine the goal, criteria, and comparison matrix, then compute the weights of the criteria, and finally implement and rank of criteria. It was used to assess the significance levels of building heritage. To use the stage MCDM model, a thorough set of assessment criteria based on the notion of sustainable development has been identified via literature research and expert interviews

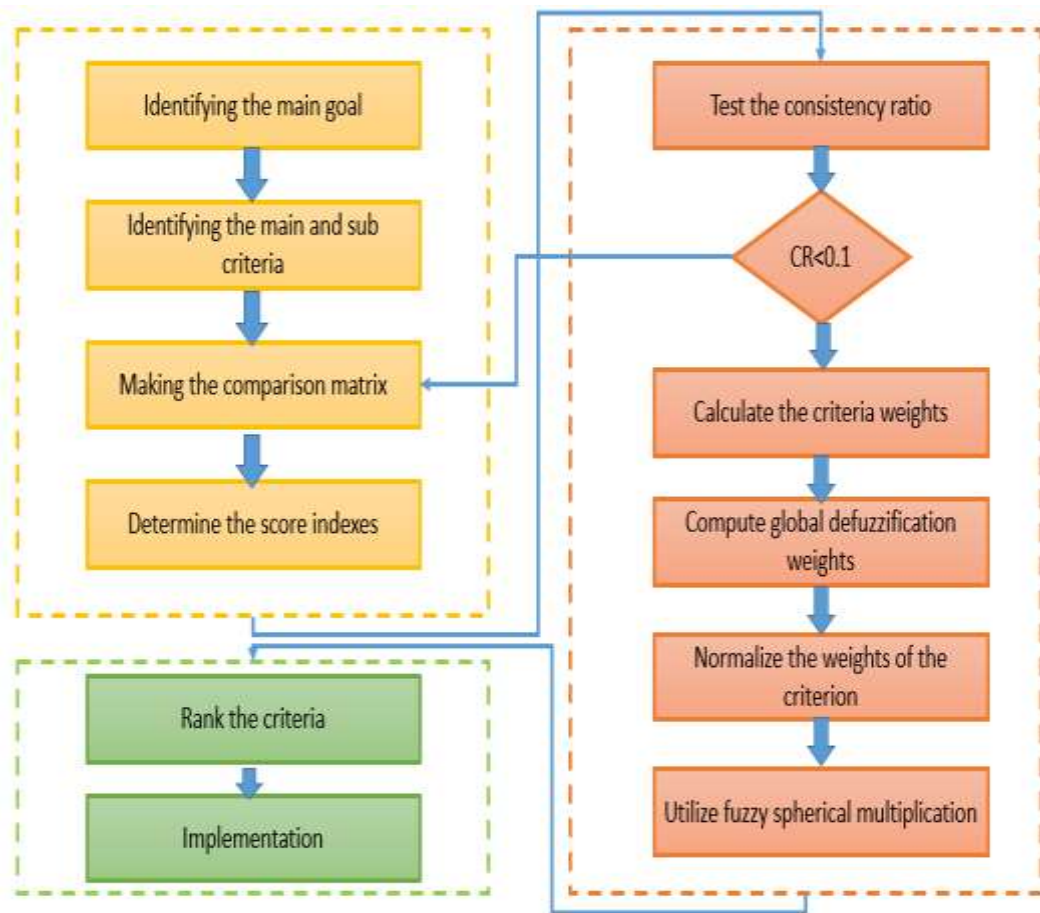


Figure 1: A hybrid MCDM framework based on SF-AHP.

Step 1: A Tree of hierarchical decisions has two levels: the study objective, a list of criteria, $SAC = \{SAC_1, SAC_2, \dots, SAC_x\}$ and options = $\{SAA_1, SAA_2, \dots, SAA_y\}$ $x = \{1, 2, 3, \dots, r\}$, $y = \{1, 2, 3, \dots, q\}$.

Step 2: Regarding linguistic concepts, comparison matrices based on pairwise comparisons are generated, as [62].

Step 3: Equations determine the score indexes (SIs) as:

$$SIs = \sqrt{|100 * (a - c)^2 - (b - c)^2|} \quad (1)$$

$$\frac{1}{SIs} = \frac{1}{\sqrt{|100 * (a - c)^2 - (b - c)^2|}}$$

(2)

Step 4: Pairwise comparison matrices should undergo a consistency test using the consistency ratio (CR), which must be below 10 %.

Step 5: Calculate the criteria as well as alternative fuzzy spherical weights. The SWAM operator is used to calculate the weight of every option.

$$SWAM = \left(\begin{array}{l} [1 - \prod_r^x (1 - a^2)^{w_r}]^{0.5}, \\ \prod_r^x (b^{w_r}), [\prod_r^x (1 - a^2)^{w_r} - \prod_r^x (1 - a^2 - c^2)^{w_r}]^{0.5} \end{array} \right) \quad (3)$$

Where $w = 1/x$.

Step 6: Global defuzzification weights

$$S(w) = \sqrt{|100 * (3 * a - \frac{c}{2})^2 - (\frac{b}{2} - c)^2|} \quad (4)$$

Step 7: Regulate the weights of the criterion

$$w = \frac{S(w)}{\sum_{i=1}^x S(w)}$$

(5)

Step 8: Utilize fuzzy spherical multiplication

$$w.A = \langle (1 - (1 - a^2)^w)^{0.5}, b^w, ((1 - a^2)^w - (1 - a^2 - c^2)^w)^{0.5} \rangle, \forall_x \tag{6}$$

Step 9: Spherical fuzzy arithmetic addition is used to compute the final SF-AHP score (D) for each option.

$$D = \sum_{q=1}^x SAA_{rq} = SAA_{r1} \oplus SAA_{r2} \dots \oplus SAA_{rx}, \forall_x \tag{7}$$

$$SAA_{11} \oplus SAA_{12} = \langle \begin{matrix} (a_{SAA_{11}}^2 + a_{SAA_{12}}^2 - a_{SAA_{11}}^2 a_{SAA_{12}}^2)^{0.5}, \\ b_{SAA_{11}} b_{SAA_{12}}, \\ ((1 - a_{SAA_{12}}^2)c_{SAA_{11}} + (1 - a_{SAA_{11}}^2)c_{SAA_{12}})^{0.5} \\ -c_{SAA_{11}}^2 c_{SAA_{12}}^2 \end{matrix} \rangle \tag{8}$$

Step 10: The other option is to keep on without defuzzification. Fuzzy spherical global choice weights are computed in this situation as:

$$\prod_{q=1}^x SAA_{rq} = SAA_{r1} \otimes SAA_{r2} \dots \dots \otimes SAA_{rx}, \forall_x \tag{9}$$

$$SAA_{11} \otimes SAA_{12} = \langle \begin{matrix} (a_{SAA_{11}} a_{SAA_{12}}, (b_{SAA_{11}}^2 + b_{SAA_{12}}^2 - b_{SAA_{11}}^2 b_{SAA_{12}}^2)^{0.5} \\ , \\ ((1 - a_{SAA_{12}}^2)c_{SAA_{11}} + (1 - a_{SAA_{11}}^2)c_{SAA_{12}})^{0.5} \\ -c_{SAA_{11}}^2 c_{SAA_{12}}^2 \end{matrix} \rangle \tag{10}$$

4. Results and Application

The algorithms described in the previous section were implemented. The judgment matrices are constructed with expert judgment in mind. There are three experts in this study. They have expertise in this field and thus kind of problems. The issue hierarchy is constructed based on the selected criteria and sub-criteria in Figure 2. In this study, there are six main criteria and twenty-two sub-criteria. The criterion comparison matrix provided by experts is shown in Tables 1-3. Table 4 shows the aggregated comparison matrix. Table 5 shows the normalized comparison matrix. Based on the calculated value CR being less than 0.1, it is possible to infer that the comparison matrix is consistent.

Figure 3. Show the weights of the criteria. from figure 3 the SAC_1 is the highest weights and SAC_6 is the lowest weight.



Figure 2: The main criteria and sub-criteria.

Table 1: Fuzzy judgment matrix for main criteria for the first expert.

| SAC_x | SAC_1 | SAC_2 | SAC_3 | SAC_4 | SAC_5 | SAC_6 |
|---------|----------|----------|----------|----------|----------|----------|
| SAC_1 | 1 | 5.491812 | 23.5 | 7.998594 | 5.491812 | 19.99994 |
| SAC_2 | 0.182089 | 1 | 10.5 | 7.998594 | 19.99994 | 23.5 |
| SAC_3 | 0.042553 | 0.095238 | 1 | 2.966058 | 5.491812 | 26.99995 |
| SAC_4 | 0.125022 | 0.125022 | 0.337148 | 1 | 7.998594 | 23.5 |
| SAC_5 | 0.182089 | 0.05 | 0.182089 | 0.125022 | 1 | 23.5 |
| SAC_6 | 0.05 | 0.042553 | 0.037037 | 0.042553 | 0.042553 | 1 |

Table 2. Fuzzy judgment matrix for main criteria for the second expert.

| SAC_x | SAC_1 | SAC_2 | SAC_3 | SAC_4 | SAC_5 | SAC_6 |
|---------|----------|----------|----------|----------|----------|----------|
| SAC_1 | 1 | 5.491812 | 5.491812 | 23.5 | 2.966058 | 1 |
| SAC_2 | 0.182089 | 1 | 23.5 | 5.491812 | 19.99994 | 0.182089 |
| SAC_3 | 0.182089 | 0.042553 | 1 | 23.5 | 23.5 | 0.182089 |
| SAC_4 | 0.042553 | 0.182089 | 0.042553 | 1 | 2.966058 | 0.042553 |
| SAC_5 | 0.337148 | 0.05 | 0.042553 | 0.337148 | 1 | 0.337148 |

| | | | | | | |
|---------|----------|----------|----------|----------|----------|----------|
| SAC_6 | 0.042553 | 0.037037 | 0.042553 | 0.037037 | 0.037037 | 0.042553 |
|---------|----------|----------|----------|----------|----------|----------|

Table 3. Fuzzy judgment matrix for main criteria for the third expert.

| SAC_x | SAC_1 | SAC_2 | SAC_3 | SAC_4 | SAC_5 | SAC_6 |
|---------|----------|----------|----------|----------|----------|----------|
| SAC_1 | 1 | 5.491812 | 23.5 | 7.998594 | 7.998594 | 26.99995 |
| SAC_2 | 0.182089 | 1 | 5.491812 | 5.491812 | 7.998594 | 7.998594 |
| SAC_3 | 0.042553 | 0.182089 | 1 | 2.966058 | 5.491812 | 26.99995 |
| SAC_4 | 0.125022 | 0.182089 | 0.337148 | 1 | 7.998594 | 19.99994 |
| SAC_5 | 0.125022 | 0.125022 | 0.182089 | 0.125022 | 1 | 23.5 |
| SAC_6 | 0.037037 | 0.125022 | 0.037037 | 0.05 | 0.042553 | 1 |

Table 4. Fuzzy aggregated judgment matrix for main criteria.

| SAC_x | SAC_1 | SAC_2 | SAC_3 | SAC_4 | SAC_5 | SAC_6 |
|---------|---------|---------|---------|---------|---------|---------|
| SAC_1 | 1.00 | 5.49 | 17.50 | 13.17 | 5.49 | 23.50 |
| SAC_2 | 0.06 | 1.00 | 13.16 | 6.33 | 16.00 | 19.50 |
| SAC_3 | 0.09 | 0.11 | 1.00 | 9.81 | 11.49 | 25.83 |
| SAC_4 | 0.10 | 0.16 | 0.24 | 1.00 | 6.32 | 23.50 |
| SAC_5 | 0.21 | 0.08 | 0.14 | 0.20 | 1.00 | 24.67 |
| SAC_6 | 0.04 | 0.07 | 0.04 | 0.04 | 0.04 | 1.00 |

Table 4. Fuzzy normalized judgment matrix for main criteria.

| SAC_x | SAC_1 | SAC_2 | SAC_3 | SAC_4 | SAC_5 | SAC_6 |
|---------|----------|----------|----------|----------|----------|----------|
| SAC_1 | 0.614765 | 0.795371 | 0.545518 | 0.431059 | 0.135977 | 0.199153 |
| SAC_2 | 0.111942 | 0.144829 | 0.410416 | 0.207165 | 0.396603 | 0.165251 |

| | | | | | | |
|------------------|----------|----------|----------|----------|----------|----------|
| SAC ₃ | 0.054754 | 0.015443 | 0.031177 | 0.321212 | 0.284932 | 0.218927 |
| SAC ₄ | 0.05996 | 0.023617 | 0.00745 | 0.032741 | 0.15669 | 0.199153 |
| SAC ₅ | 0.132023 | 0.010863 | 0.004227 | 0.006408 | 0.024788 | 0.20904 |
| SAC ₆ | 0.026556 | 0.009878 | 0.001212 | 0.001414 | 0.001009 | 0.008475 |

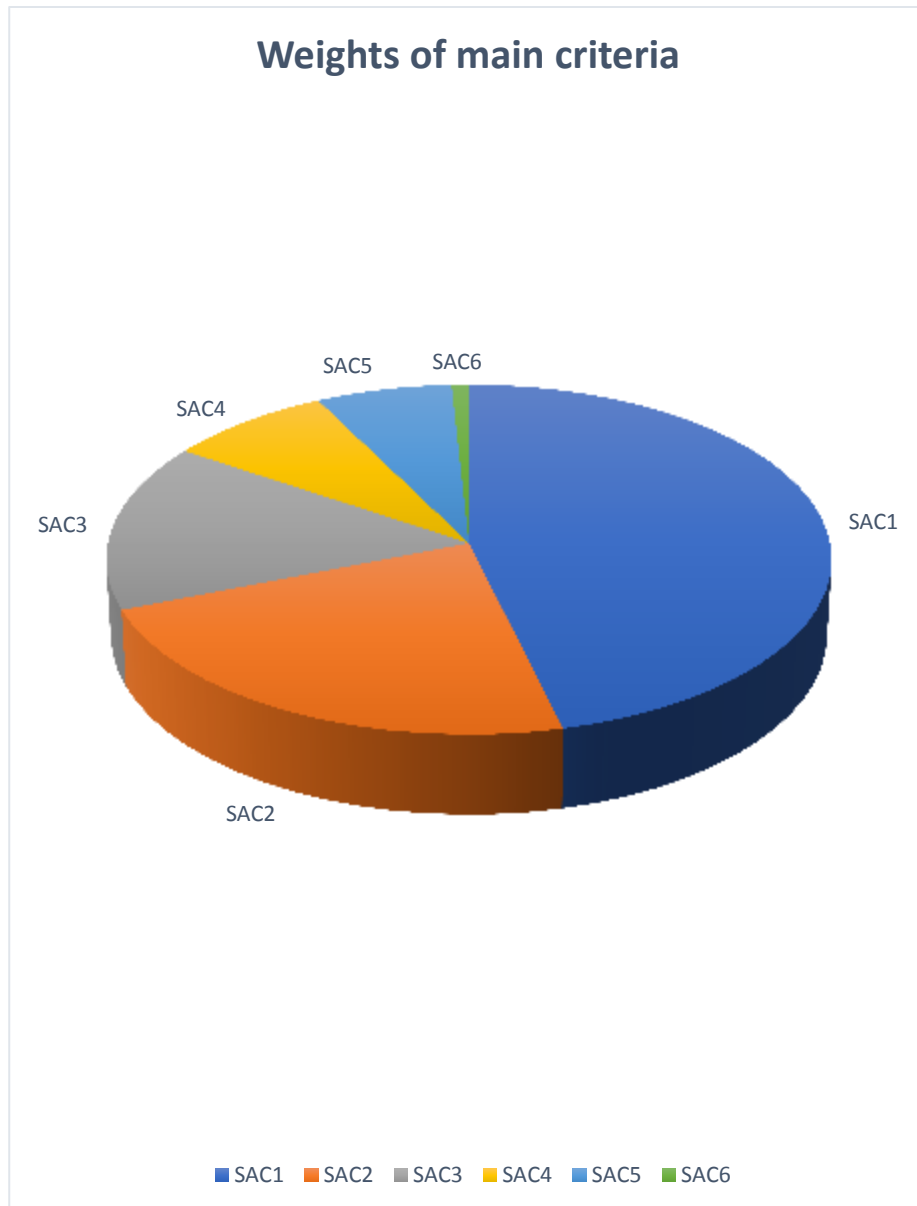


Figure 3. The weights of the main criteria

Table 6. show the comparison matrix of sub-criteria SAC_1 . Table 7 shows the normalization matrix. Figure 4. Show the weights of sub-criteria SAC_1 . From figure 1 the $SAC_{1,1}$ is the height weight and $SAC_{1,4}$ is the lowest weight.

Table 6. Fuzzy judgment matrix for sub-criteria SAC_1 .

| SAC_x | $SAC_{1,1}$ | $SAC_{1,2}$ | $SAC_{1,3}$ | $SAC_{1,4}$ |
|-------------|-------------|-------------|-------------|-------------|
| $SAC_{1,1}$ | 0.801736 | 0.812217 | 0.548501 | 0.434457 |
| $SAC_{1,2}$ | 0.048662 | 0.147896 | 0.412661 | 0.208799 |
| $SAC_{1,3}$ | 0.071407 | 0.01577 | 0.031348 | 0.323745 |
| $SAC_{1,4}$ | 0.078195 | 0.024117 | 0.007491 | 0.032999 |

Table 7. Fuzzy normalized judgment matrix for sub-criteria SAC_1 .

| SAC_x | $SAC_{1,1}$ | $SAC_{1,2}$ | $SAC_{1,3}$ | $SAC_{1,4}$ |
|-------------|-------------|-------------|-------------|-------------|
| $SAC_{1,1}$ | 0.801736 | 0.812217 | 0.548501 | 0.434457 |
| $SAC_{1,2}$ | 0.048662 | 0.147896 | 0.412661 | 0.208799 |
| $SAC_{1,3}$ | 0.071407 | 0.01577 | 0.031348 | 0.323745 |
| $SAC_{1,4}$ | 0.078195 | 0.024117 | 0.007491 | 0.032999 |

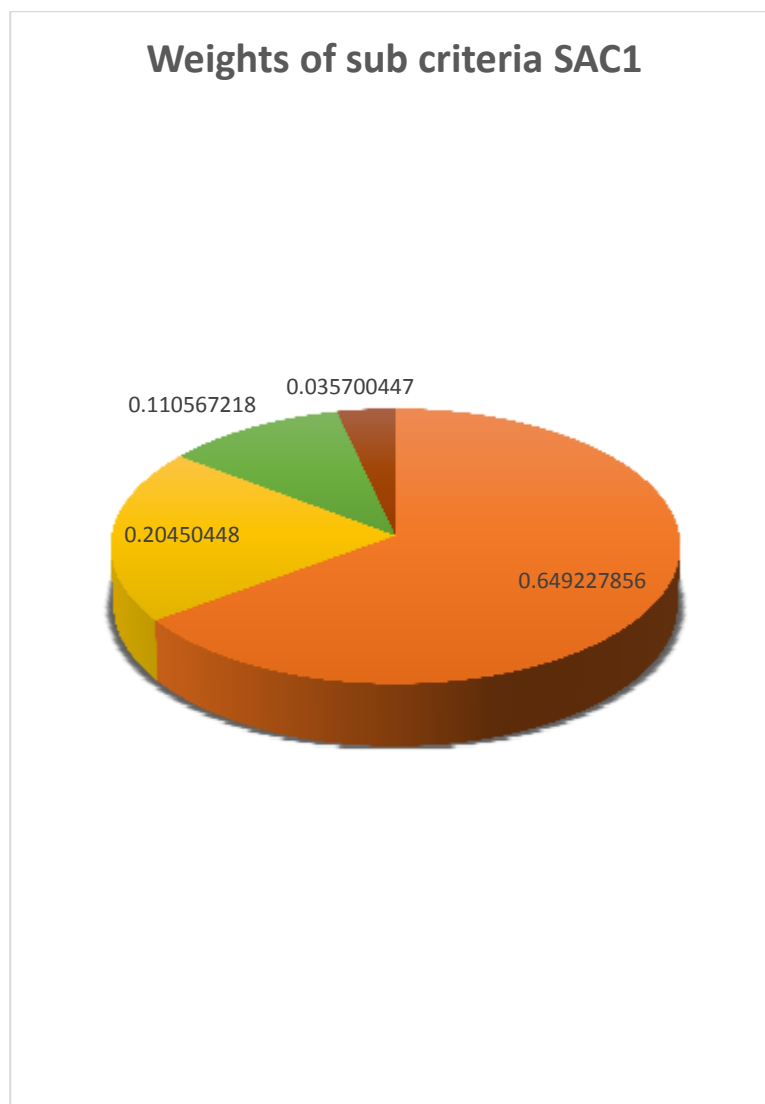


Figure 4: The weights of sub-criteria SAC_1

Table 8 shows the comparison matrix of sub-criteria SAC_1 . Table 9 shows the normalization matrix. Figure 5 shows the weights of sub-criteria SAC_2 . From Figure 5 the $SAC_{2,1}$ is the height weight and $SAC_{2,3}$ is the lowest weight.

Table 8. Fuzzy judgment matrix for sub-criteria SAC_2 .

| | | | |
|-------------|-------------|-------------|-------------|
| SAC_x | $SAC_{2,1}$ | $SAC_{2,2}$ | $SAC_{2,3}$ |
| $SAC_{2,1}$ | 1 | 11.49454 | 14.83333 |
| $SAC_{2,2}$ | 0.060696 | 1 | 19.16667 |
| $SAC_{2,3}$ | 0.077676 | 0.060115 | 1 |

Table 9. Fuzzy normalized judgment matrix for sub-criteria SAC_2 .

| | | | |
|-------------|-------------|-------------|-------------|
| SAC_x | $SAC_{2,1}$ | $SAC_{2,2}$ | $SAC_{2,3}$ |
| $SAC_{2,1}$ | 0.878447 | 0.91556 | 0.42381 |
| $SAC_{2,2}$ | 0.053319 | 0.079652 | 0.547619 |
| $SAC_{2,3}$ | 0.068235 | 0.004788 | 0.028571 |

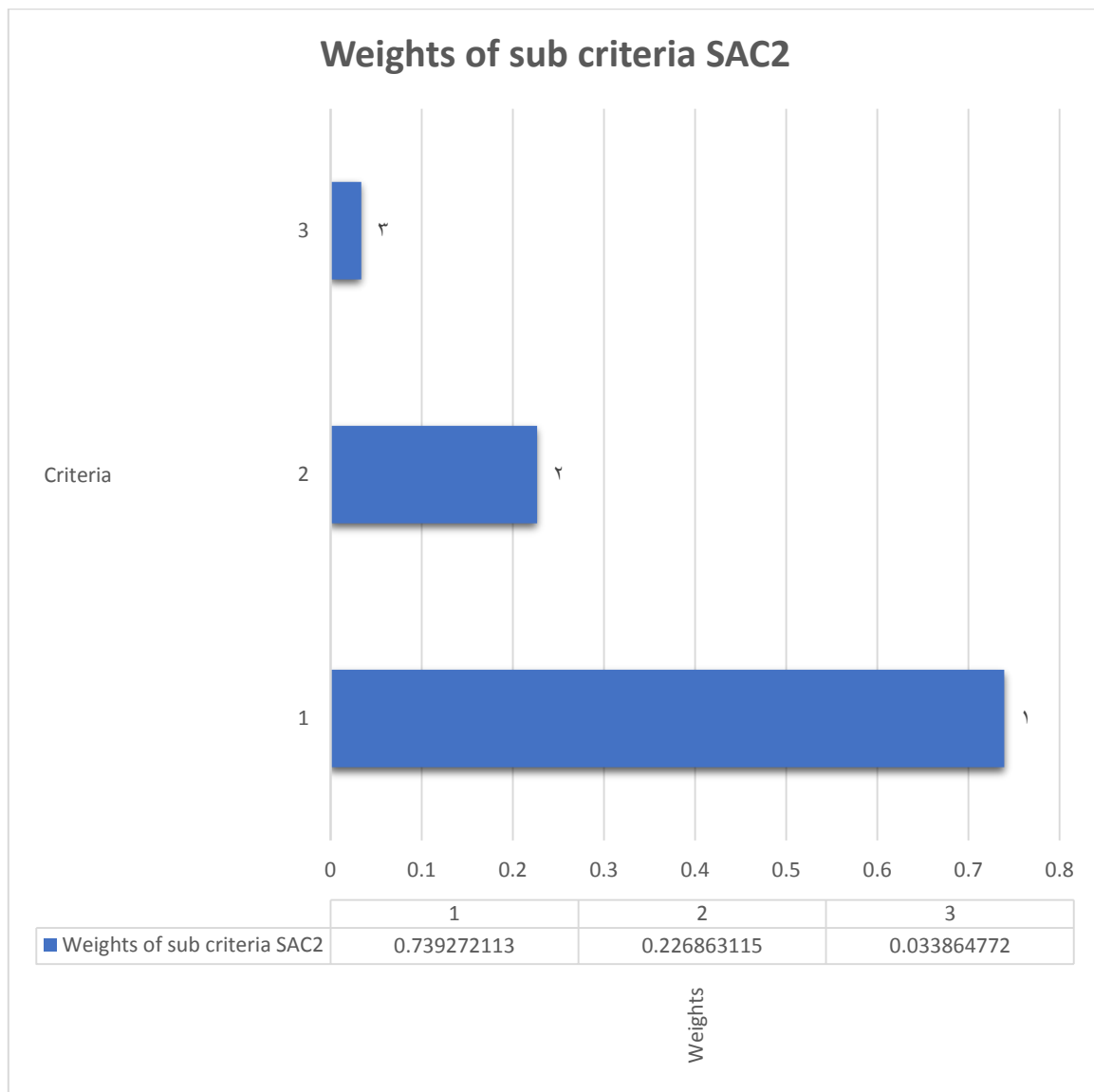


Figure 5: The weights of the key criteria

Table 10 displays the judgment matrix of sub-criteria SAC_3 . Table 11 shows the normalization comparison matrix. Figure 6. Show the weights of sub-criteria SAC_3 . From Figure 6 the $SAC_{3.1}$ is the height weight and $SAC_{3.3}$ is the lowest weight.

Table 10: Fuzzy judgment matrix for sub-criteria SAC_3 .

| SAC_x | $SAC_{3.1}$ | $SAC_{3.2}$ | $SAC_{3.3}$ |
|-------------|-------------|-------------|-------------|
| $SAC_{3.1}$ | 1 | 19.83057 | 13.16573 |
| $SAC_{3.2}$ | 0.012346 | 1 | 13.16394 |
| $SAC_{3.3}$ | 0.097532 | 0.106627 | 1 |

Table 11: Fuzzy normalized judgment matrix for sub-criteria SAC_3 .

| SAC_x | $SAC_{3.1}$ | $SAC_{3.2}$ | $SAC_{3.3}$ |
|-------------|-------------|-------------|-------------|
| $SAC_{3.1}$ | 0.901 | 0.947145 | 0.481738 |
| $SAC_{3.2}$ | 0.011123 | 0.047762 | 0.481672 |
| $SAC_{3.3}$ | 0.087877 | 0.005093 | 0.03659 |

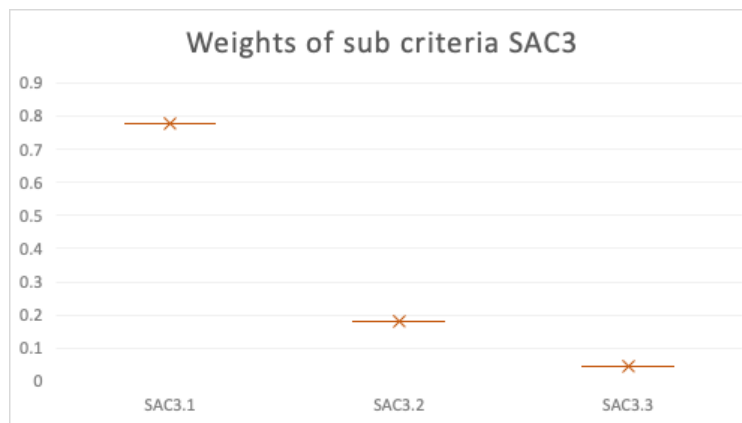
Figure 6: The weights of sub-criteria SAC_3

Table 12. show the comparison matrix of sub-criteria SAC_4 . Table 13 shows the normalization comparison matrix. Figure 7. Show the weights of sub-criteria SAC_4 . From Figure 7 the $SAC_{4.1}$ is the height weight and $SAC_{4.3}$ is the lowest weight.

Table 12: Fuzzy judgment matrix for sub-criteria SAC_4

| SAC_x | $SAC_{4.1}$ | $SAC_{4.2}$ | $SAC_{4.3}$ |
|-------------|-------------|-------------|-------------|
| $SAC_{4.1}$ | 1 | 11.49454 | 19.16667 |
| $SAC_{4.2}$ | 0.014184 | 1 | 7.161208 |
| $SAC_{4.3}$ | 0.060115 | 0.153139 | 1 |

Table 13: Fuzzy normalized judgment matrix for sub-criteria SAC_4

| SAC_x | $SAC_{4.1}$ | $SAC_{4.2}$ | $SAC_{4.3}$ |
|-------------|-------------|-------------|-------------|
| $SAC_{4.1}$ | 0.930839 | 0.908826 | 0.70136 |
| $SAC_{4.2}$ | 0.013203 | 0.079066 | 0.262048 |
| $SAC_{4.3}$ | 0.055957 | 0.012108 | 0.036593 |

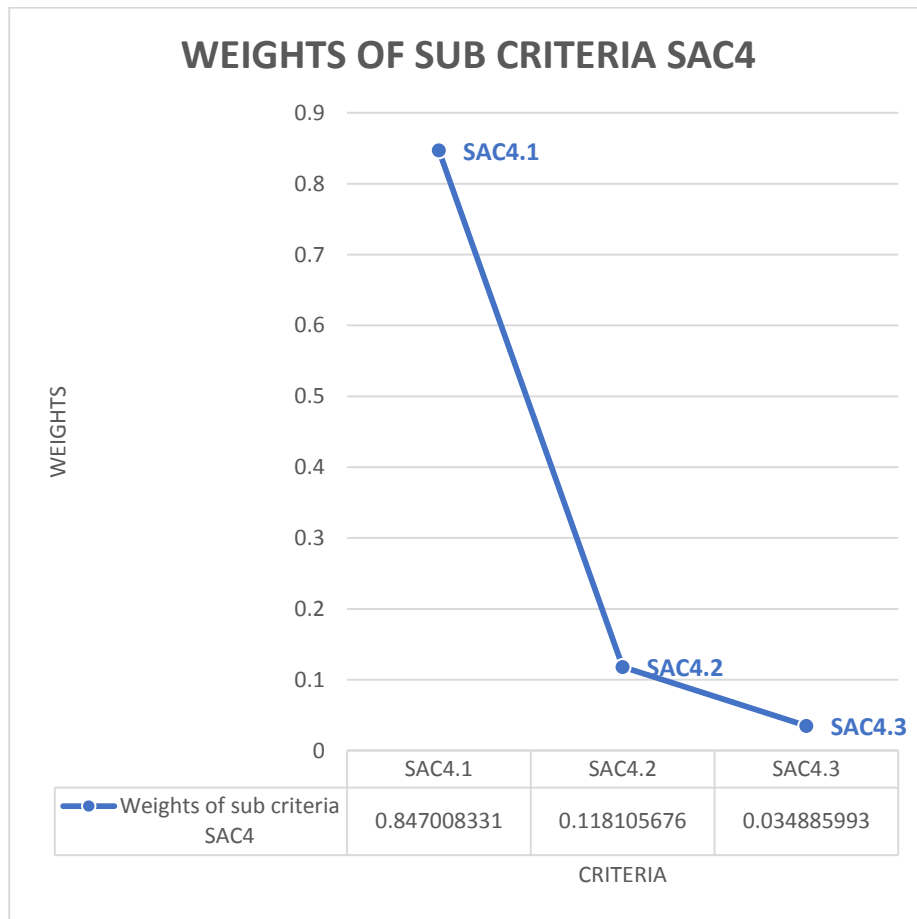


Figure 7: The weights of sub-criteria SAC_4

Table 14 shows the comparison matrix of sub-criteria SAC_5 . Table 15 shows the normalized comparison matrix. Figure 8. Show the weights of sub-criteria SAC_5 . From Figure 8 the $SAC_{5.1}$ is the height weight and $SAC_{5.4}$ is the lowest weight.

Table 14: Fuzzy judgment matrix for main criteria SAC_5 .

| SAC_x | $SAC_{5.1}$ | $SAC_{5.2}$ | $SAC_{5.3}$ | $SAC_{5.4}$ |
|-------------|-------------|-------------|-------------|-------------|
| $SAC_{5.1}$ | 1 | 6.31929 | 2.966058 | 13.99953 |
| $SAC_{5.2}$ | 0.031746 | 1 | 5.477372 | 5.485488 |
| $SAC_{5.3}$ | 0.337148 | 0.256511 | 1 | 9.810705 |
| $SAC_{5.4}$ | 0.087604 | 0.214753 | 0.23895 | 1 |

Table 15: Fuzzy normalized judgment matrix for main criteria SAC_5 .

| SAC_x | $SAC_{5.1}$ | $SAC_{5.2}$ | $SAC_{5.3}$ | $SAC_{5.4}$ |
|-------------|-------------|-------------|-------------|-------------|
| $SAC_{5.1}$ | 0.686578 | 0.811148 | 0.306336 | 0.462096 |
| $SAC_{5.2}$ | 0.021796 | 0.128361 | 0.565705 | 0.181065 |
| $SAC_{5.3}$ | 0.231478 | 0.032926 | 0.10328 | 0.323831 |
| $SAC_{5.4}$ | 0.060147 | 0.027566 | 0.024679 | 0.033008 |

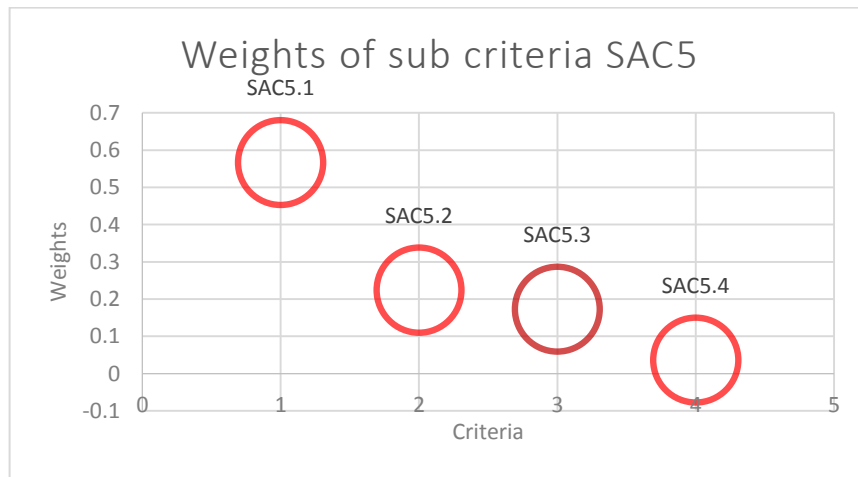


Figure 8: The weights of sub-criteria SAC₅

Table 16 shows the comparison matrix of sub-criteria SAC₆. Table 17 shows the normalization comparison matrix. Figure 9. Show the weights of sub-criteria SAC₆. From Figure 9 the SAC_{6,1} is the height weight and SAC_{6,5} is the lowest weight.

Table 16: Fuzzy judgment matrix for sub-criteria SAC₆.

| SAC _x | SAC _{6,1} | SAC _{6,2} | SAC _{6,3} | SAC _{6,4} | SAC _{6,5} |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| SAC _{6,1} | 1 | 15.99949 | 16.33058 | 11.48822 | 11.48822 |
| SAC _{6,2} | 0.016667 | 1 | 13.16394 | 13.16573 | 15.99949 |
| SAC _{6,3} | 0.091548 | 0.106627 | 1 | 9.810705 | 16.33058 |
| SAC _{6,4} | 0.168241 | 0.097532 | 0.23895 | 1 | 4.64357 |
| SAC _{6,5} | 0.168241 | 0.075007 | 0.091548 | 0.266439 | 1 |

Table 17: Fuzzy normalized judgment matrix for sub-criteria SAC₆.

| SAC _x | SAC _{6,1} | SAC _{6,2} | SAC _{6,3} | SAC _{6,4} | SAC _{6,5} |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| SAC _{6,1} | 0.692187 | 0.925968 | 0.529783 | 0.321519 | 0.232264 |
| SAC _{6,2} | 0.011536 | 0.057875 | 0.427054 | 0.368467 | 0.323471 |
| SAC _{6,3} | 0.063368 | 0.006171 | 0.032441 | 0.274571 | 0.330165 |
| SAC _{6,4} | 0.116454 | 0.005645 | 0.007752 | 0.027987 | 0.093882 |
| SAC _{6,5} | 0.116454 | 0.004341 | 0.00297 | 0.007457 | 0.020218 |

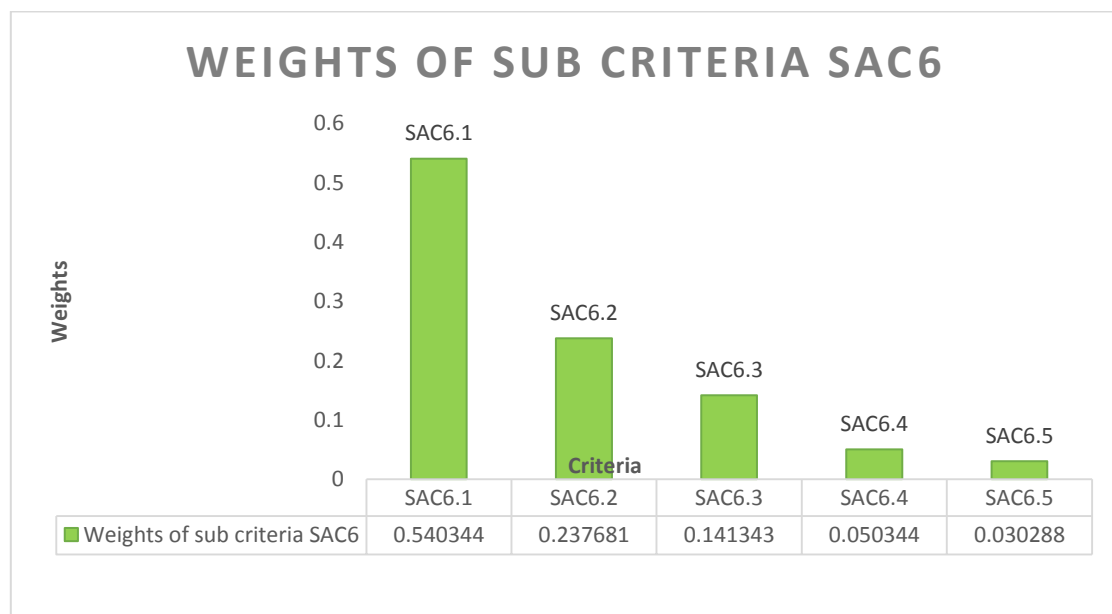


Figure 9: The weights of sub-criteria SAC₆

5. Conclusion

For a modern society based on the principles of sustainable development, the preservation of heritage structures is essential. The administration of heritage building is today an underused asset, despite the fact that there are multiple signs of such an approach, even if there are rising opportunities for inclusion inside the scope of intelligent cities. Taking use of urban diversity and interconnection, smart cities may significantly improve people's lives by lowering costs and increasing convenience. Integrating entire smart city solutions and opportunities for heritage preservation and enhancement is emerging right now. Urban areas throughout the world are benefiting from modern technologies in urban areas. Consequently, the use of IoT platforms and apps enhances the use of application areas in this field and the synchronization of management processes. Sustainability ideology recognised and improved from over idea of an IoT ecosystem, while enduringly defending familiar cityscapes and outlines, and also going to propose new ways of using degraded and dangerous urban resources in a financially sustainable way and custom them in humanising the native and wider general population about just the nationwide, communal, and economic highs, can meaningfully preserve honesty in building heritage for future competitors. The preservation of historic structures in an intelligent city's sustainable urban surroundings has been examined. There are six categories of indicators for the preservation of architectural legacy: organisational, financial and cultural; ecological; technological; and architectural. The final ranking results are influenced by the methodology used to analyse the signals, which involves the usage of fuzzier values and intervals. Spherical AHP was used to rate the importance of 22 key variables in the decision to maintain and conserve heritage buildings.

The acquired findings and conclusions paved the way for further study in the area of MCDM-based management of architectural heritage. Future research on fuzzy and AHP methods will be used in the area of heritage building administration under the data protection rules in terms of rehabilitation procedures for various degrees of historic preservation. Given the significance of the energy domain and power generation in intelligent cities, many forthcoming articles will seek to find the ideal strategies to boost energy efficiency by the degree of protection of architectural heritage structures.

References

- [1] P. Romero-Lankao, D. M. Gnatz, O. Wilhelmi, and M. Hayden, "Urban sustainability and resilience: From theory to practice," *Sustainability*, vol. 8, no. 12, p. 1224, 2016.
- [2] X. Zeng, Y. Yu, S. Yang, Y. Lv, and M. N. I. Sarker, "Urban resilience for urban sustainability: Concepts, dimensions, and perspectives," *Sustainability*, vol. 14, no. 5, p. 2481, 2022.
- [3] M. R. Milošević, D. M. Milošević, A. D. Stanojević, D. M. Stević, and D. J. Simjanović, "Fuzzy and interval AHP approaches in sustainable management for the architectural heritage in smart cities," *Mathematics*, vol. 9, no. 4, p. 304, 2021.
- [4] S. E. Bibri, *Advances in the leading paradigms of urbanism and their amalgamation: compact cities, eco-cities, and data-driven smart cities*. Springer, 2020.
- [5] W. A. Clark and J. C. Finley, "Determinants of water conservation intention in Blagoevgrad, Bulgaria," *Society and natural resources*, vol. 20, no. 7, pp. 613–627, 2007.
- [6] D. Hoornweg and P. Bhada-Tata, "What a waste: a global review of solid waste management," 2012.
- [7] V. Dimić, M. Milošević, D. Milošević, and D. Stević, "Adjustable model of renewable energy projects for sustainable development: a case study of the Nišava district in Serbia," *Sustainability*, vol. 10, no. 3, p. 775, 2018.
- [8] J. Z. Thellufsen *et al.*, "Smart energy cities in a 100% renewable energy context," *Renewable and Sustainable Energy Reviews*, vol. 129, p. 109922, 2020.
- [9] D. Gonçalves, Y. Sheikhejad, M. Oliveira, and N. Martins, "One step forward toward smart city Utopia: Smart building energy management based on adaptive surrogate modelling," *Energy and Buildings*, vol. 223, p. 110146, 2020.
- [10] M. Chen, W. Li, Y. Hao, Y. Qian, and I. Humar, "Edge cognitive computing based smart healthcare system," *Future Generation Computer Systems*, vol. 86, pp. 403–411, 2018.
- [11] G. Manogaran, R. Varatharajan, D. Lopez, P. M. Kumar, R. Sundarasekar, and C. Thota, "A new architecture of Internet of Things and big data ecosystem for secured smart healthcare monitoring and alerting system," *Future Generation Computer Systems*, vol. 82, pp. 375–387, 2018.
- [12] E. Aguaded-Ramírez, "Smart city and intercultural education," *Procedia-Social and Behavioral Sciences*, vol. 237, pp. 326–333, 2017.
- [13] R. Bajaj and V. Sharma, "Smart Education with artificial intelligence based determination of learning styles," *Procedia computer science*, vol. 132, pp. 834–842, 2018.
- [14] L. Buys, K. Barnett, E. Miller, and C. Hopkinson, "Smart housing and social sustainability: learning from the residents of Queensland's research house," *International Journal of Emerging Technologies and Society*, vol. 3, no. 1, pp. 44–57, 2005.
- [15] M. S. Khan, M. Woo, K. Nam, and P. K. Chathoth, "Smart city and smart tourism: A case of Dubai,"

- Sustainability*, vol. 9, no. 12, p. 2279, 2017.
- [16] E. C. Porse, "Stormwater governance and future cities," *Water*, vol. 5, no. 1, pp. 29–52, 2013.
- [17] V. Angeon and S. Lardon, "Participation and governance in territorial development projects: the 'territory game' as a local project leadership system," *International journal of sustainable development*, vol. 11, no. 2–4, pp. 262–281, 2008.
- [18] P. Repette, J. Sabatini-Marques, T. Yigitcanlar, D. Sell, and E. Costa, "The evolution of city-as-a-platform: Smart urban development governance with collective knowledge-based platform urbanism," *Land*, vol. 10, no. 1, p. 33, 2021.
- [19] S. Prahraj, J. H. Han, and S. Hawken, "Urban innovation through policy integration: Critical perspectives from 100 smart cities mission in India," *City, culture and society*, vol. 12, pp. 35–43, 2018.
- [20] S. Y. Tan and A. Taeiagh, "Smart city governance in developing countries: A systematic literature review," *Sustainability*, vol. 12, no. 3, p. 899, 2020.
- [21] V. Kumar and B. Dahiya, "Smart economy in smart cities," in *Smart economy in smart cities*, Springer, 2017, pp. 3–76.
- [22] C. Bolton, V. Machová, M. Kovacova, and K. Valaskova, "The power of human–machine collaboration: Artificial intelligence, business automation, and the smart economy," *Economics, Management, and Financial Markets*, vol. 13, no. 4, pp. 51–56, 2018.
- [23] L. P. Galperina, A. T. Girenko, and V. P. Mazurenko, "The concept of smart economy as the basis for sustainable development of Ukraine," *International Journal of Economics and Financial Issues*, vol. 6, no. 8S, pp. 307–314, 2016.
- [24] F. J. Huétink, A. van der Vooren, and F. Alkemade, "Initial infrastructure development strategies for the transition to sustainable mobility," *Technological forecasting and social change*, vol. 77, no. 8, pp. 1270–1281, 2010.
- [25] M. Attard, "Mobility justice in urban transport—the case of Malta," *Transportation research procedia*, vol. 45, pp. 352–359, 2020.
- [26] S. Smith, "Smart infrastructure for future urban mobility," *AI magazine*, vol. 41, no. 1, pp. 5–18, 2020.
- [27] E. E. Khalil, "Distributed energy in smart cities and the infrastructure," in *Solving Urban Infrastructure Problems Using Smart City Technologies*, Elsevier, 2021, pp. 249–268.
- [28] J. Szepesi, S. Harangi, Z. Ésik, T. J. Novák, R. Lukács, and I. Soós, "Volcanic geoheritage and geotourism perspectives in Hungary: a case of an UNESCO world heritage site, Tokaj wine region historic cultural landscape, Hungary," *Geoheritage*, vol. 9, no. 3, pp. 329–349, 2017.
- [29] P. Nijkamp, "Economic valuation of cultural heritage," *The economics of uniqueness: Investing in historic city cores and cultural heritage assets for sustainable development*, vol. 75, pp. 75–103, 2012.
- [30] K. Taylor and J. Lennon, "Cultural landscapes: a bridge between culture and nature?," *International journal of heritage studies*, vol. 17, no. 6, pp. 537–554, 2011.
- [31] L. Petti, C. Trillo, and B. C. N. Makore, "Towards a shared understanding of the concept of heritage in the European context," *Heritage*, vol. 2, no. 3, pp. 2531–2544, 2019.
- [32] J. Hosagrahar, J. Soule, L. F. Girard, and A. Potts, "Cultural heritage, the UN sustainable development goals, and the new urban agenda," *BDC. Bollettino Del Centro Calza Bini*, vol. 16, no. 1, pp. 37–54, 2016.
- [33] F. Ribera, A. Nesticò, P. Cucco, and G. Maselli, "A multicriteria approach to identify the Highest and Best Use for historical buildings," *Journal of cultural heritage*, vol. 41, pp. 166–177, 2020.
- [34] J. Zagorskas, E. K. Zavadskas, Z. Turskis, M. Burinskienė, A. Blumberga, and D. Blumberga, "Thermal insulation alternatives of historic brick buildings in Baltic Sea Region," *Energy and buildings*, vol. 78, pp. 35–42, 2014.
- [35] R. Uberman and A. Ostrega, "Applying the analytic hierarchy process in the revitalization of post-mining areas field," *Proceedings of the ISAHP*, vol. 5, 2005.
- [36] M. Dutta and Z. Husain, "An application of multicriteria decision making to built heritage. The case of Calcutta," *Journal of Cultural Heritage*, vol. 10, no. 2, pp. 237–243, 2009.
- [37] C. D'Alpaos and M. R. Valluzzi, "Protection of cultural heritage buildings and artistic assets from seismic hazard: A hierarchical approach," *Sustainability*, vol. 12, no. 4, p. 1608, 2020.
- [38] F. Du, L. Zhang, and F. Du, "Smart City Evaluation Index System: Based on AHP Method," in *International conference on Big Data Analytics for Cyber-Physical-Systems*, 2020, pp. 563–569.
- [39] F. Kutlu Gündoğdu and C. Kahraman, "Spherical fuzzy sets and spherical fuzzy TOPSIS method," *Journal of intelligent & fuzzy systems*, vol. 36, no. 1, pp. 337–352, 2019.
- [40] F. Kutlu Gündoğdu and C. Kahraman, "A novel VIKOR method using spherical fuzzy sets and its application to warehouse site selection," *Journal of Intelligent & Fuzzy Systems*, vol. 37, no. 1, pp. 1197–1211, 2019.
- [41] K. Soini and J. Dessein, "Culture-sustainability relation: Towards a conceptual framework," *Sustainability*, vol. 8, no. 2, p. 167, 2016.
- [42] A. Borri and M. Corradi, "Architectural heritage: A discussion on conservation and safety," *Heritage*, vol. 2, no. 1, pp. 631–647, 2019.

- [43] M. Anwar, "Practical techniques for restoration of architectural formation elements in historical buildings," *World Journal of Engineering and Technology*, vol. 7, no. 1, pp. 193–207, 2018.
- [44] H.-M. Tu, "The attractiveness of adaptive heritage reuse: A theoretical framework," *Sustainability*, vol. 12, no. 6, p. 2372, 2020.
- [45] A. Ćurčić, A. M. Petronijević, G. T. Ćurčić, and A. Keković, "An approach to building heritage and its preservation in Serbia and surrounding areas," *Facta Universitatis, Series: Architecture and Civil Engineering*, pp. 15–31, 2020.
- [46] E. Berti, "Cultural routes of the Council of Europe: new paradigms for the territorial project and landscape," *Almatourism-Journal of Tourism, Culture and Territorial Development*, vol. 4, no. 7, pp. 1–12, 2013.
- [47] S. Gholitabar, H. Alipour, and C. M. M. da Costa, "An empirical investigation of architectural heritage management implications for tourism: The case of Portugal," *Sustainability*, vol. 10, no. 1, p. 93, 2018.
- [48] S. Lidelöw, T. Örn, A. Luciani, and A. Rizzo, "Energy-efficiency measures for heritage buildings: A literature review," *Sustainable cities and society*, vol. 45, pp. 231–242, 2019.
- [49] E. Muminović, U. Radosavljević, and D. Beganović, "Strategic planning and management model for the regeneration of historic urban landscapes: the case of historic center of Novi Pazar in Serbia," *Sustainability*, vol. 12, no. 4, p. 1323, 2020.
- [50] A. Milojković, M. Brzaković, and M. Nikolić, "The Influences and Importance of the UNESCO World Heritage List: The Case of Plaošnik, Ohrid," *Space and Culture*, vol. 23, no. 2, pp. 164–180, 2020.
- [51] P. Guzman, A. R. Pereira Roders, and B. Colenbrander, "Impacts of common urban development factors on cultural conservation in world heritage cities: An indicators-based analysis," *Sustainability*, vol. 10, no. 3, p. 853, 2018.
- [52] J. H. Spangenberg, "Institutional sustainability indicators: an analysis of the institutions in Agenda 21 and a draft set of indicators for monitoring their effectivity," *Sustainable Development*, vol. 10, no. 2, pp. 103–115, 2002.
- [53] L. Petti, C. Trillo, and B. N. Makore, "Cultural heritage and sustainable development targets: a possible harmonisation? Insights from the European Perspective," *Sustainability*, vol. 12, no. 3, p. 926, 2020.
- [54] M. Adamczyk, A. Betlej, J. Gondek, and A. Ohotina, "Technology and sustainable development: towards the future?," *Entrepreneurship and Sustainability Issues*, vol. 6, no. 4, p. 2003, 2019.
- [55] R. Su, B. Bramwell, and P. A. Whalley, "Cultural political economy and urban heritage tourism," *Annals of Tourism Research*, vol. 68, pp. 30–40, 2018.
- [56] G. Foster and H. Kreinin, "A review of environmental impact indicators of cultural heritage buildings: A circular economy perspective," *Environmental Research Letters*, vol. 15, no. 4, p. 43003, 2020.
- [57] N. Čolić, B. Manić, A. Niković, and B. Brankov, "Grasping the framework for the urban governance of smart cities in Serbia. The case of interreg SMF project clever," *Spatium*, no. 43, pp. 26–34, 2020.
- [58] J. Li, S. Krishnamurthy, A. P. Roders, and P. Van Wesemael, "Community participation in cultural heritage management: A systematic literature review comparing Chinese and international practices," *Cities*, vol. 96, p. 102476, 2020.
- [59] U. Luna, P. Rivero, and N. Vicent, "Augmented reality in heritage apps: Current trends in Europe," *Applied Sciences*, vol. 9, no. 13, p. 2756, 2019.
- [60] A. Lerario, "The IoT as a key in the sensitive balance between development needs and sustainable conservation of cultural resources in Italian heritage cities," *Sustainability*, vol. 12, no. 17, p. 6952, 2020.
- [61] T. A. Kumar, R. Rajmohan, M. Pavithra, S. A. Ajagbe, H. Rania, and T. Gaber, T., "Automatic Face Mask Detection System in Public Transportation in Smart Cities Using IoT and Deep Learning" *Electronics*, vol. 11, no. 6: pp. 904, 2022.
- [62] T. W. Sung, P. W. Tsai, T. Gaber, C. Y. Lee, "Artificial Intelligence of Things (AIoT) technologies and applications", *Wireless Communications and Mobile Computing*, p. 2 2021
- [63] G. Saygi and F. Remondino, "Management of Architectural Heritage Information in BIM and GIS: State-of-the-art and Future Perspectives," *International Journal of Heritage in the Digital Era*, vol. 2, no. 4, pp. 695–713, 2013.
- [64] T. Gaber, A. El-Ghamry, A. E. Hassanien, "Injection attack detection using machine learning for smart IoT applications". *Physical Communication*. 2022 Jun 1;52:101685.
- [65] F. AlFayez, M. W. El-Soud, T. Gaber, "Thermogram Breast Cancer Detection: A comparative study of two machine learning techniques". *Applied Sciences*, 2020 Jan 11;10(2):551.
- [66] T. Gaber, A. Tharwat, V. Snasel, A. E. Hassanien, "Plant identification: Two dimensional-based vs. one dimensional-based feature extraction methods" *In10th international conference on soft computing models in industrial and environmental applications 2015* (pp. 375-385). Springer, Cham.
- [67] S. A. Ajagbe, J. B. Awotunde, A. O. Adesina, P. Achimugu, T. A. Kumar, "Internet of Medical Things (IoMT): Applications, Challenges, and Prospects in a Data-Driven Technology". In: C. Chakraborty, M. R. Khosravi, (eds) *Intelligent Healthcare*. pp 299–319, Springer, Singapore. 2022. https://doi.org/10.1007/978-981-16-8150-9_14
- [68] F. Kutlu Gündoğdu and C. Kahraman, "A novel spherical fuzzy analytic hierarchy process and its

renewable energy application,” *Soft Computing*, vol. 24, no. 6, pp. 4607–4621, 2020.