AN APPROACH TO ATTAINING SUSTAINABILITY BY ENHANCING THE ENVIRONMENTAL FACTORS THAT AFFECT THE QUALITY OF URBAN LIFE

S. Al-Ghamdi[1]*, M.R. Qureshi[1], N. Almakayeel[1], M. Mansour[1] & S.D. Abdul Khadar[1]

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Contact details
* Corresponding author
syalghamdi@kku.edu.sa

Author affiliations
1 Department of Industrial Engineering, King Khalid University, Saudi Arabia

ORCID® identifiers
S. Al-Ghamdi
https://orcid.org/0000-0002-7582-339X

M.R. Qureshi
https://orcid.org/0000-0002-9508-8724

N. Almakayeel
https://orcid.org/0000-0001-9461-5935

M. Mansour
https://orcid.org/0000-0002-4794-1399

S.D. Abdul Khadar
https://orcid.org/0000-0001-8902-2756

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ABSTRACT

Assessing the quality of present urban life was the main aim of this paper. This research concentrated mainly on four environmental sustainability indicators: physical, social, economic, and eco-friendly factors. An attempt was made to attain sustainability by identifying and comparing various assessment indicators and, finally, to rank the weights of the sustainable elements. It was essential to analyse the sustainable indicators to have a risk-free, safe, and tranquil life that is free from pollution hazards. The challenge lay in realising this by sharing knowledge and records, which is one of the main factors in successful approaches. The present study evaluated and prioritised the indicators and factors of sustainable urban life. The concept of sustainability has become significant in the need to improve the quality of urban life. A structured questionnaire survey was conducted with 510 expert delegates who participated in an open-ended interview to identify the sustainability indicators that are focused mainly on the quality of urban life. The data was analysed using an analytic hierarchy process (AHP) to prioritise the factors for urban life sustainability.

OPSOMMING

Die hoofdoel van hierdie artikel was om die kwaliteit van huidige stedelike lewe te bepaal. Hierdie navorsing het hoofsaaklik op vier omgewingsvolhoubaarheidsaanwysers gefokus: fisiese, sosiale, ekonomiese en ekovriendelik faktore. Daar is gepoog om volhoubaarheid te assesseer deur verskeie assesseringsaanwysers te identifiseer en te vergelyk en uiteindelik die gewigte van die volhoubare elemente te rangskik. Dit was noodsaaklik om die volhoubare aanwysers te ontleed om 'n risikovrye, veilige en rustige lewe te hê wat vry is van besoedelingsgevare. Die uitdaging was om dit te besef deur kennis en rekords te deel, wat een van die hooffaktore in suksesvolle benaderings is. Die huidige studie het die aanwysers en faktore van volhoubare stedelike lewe geëvalueer en geprioritiseer. Die konsep van volhoubaarheid het betekenisvol geword in die behoefte om die kwaliteit van stedelike lewe te verbeter. ’n Gestruktureerde vraelysopname is gedoen met 510 deskundige afgevaardigdes wat aan ’n oop-einde onderhoud deelgeneem het om die volhoubaarheidsaanwysers te identifiseer wat hoofsaaklik op die kwaliteit van stedelike lewe gefokus is. Die data is ontleed deur gebruik te maak van 'n analitiesehiërargieproses (AHP) om die faktore vir stedelike lewensvolhoubaarheid te prioritiseer.

1. INTRODUCTION

The growth of urban life has drastically increased in India with the effects of industrialisation. This growth reached its peak In the recent past and then began to decline steadily [1]. The key concern was the growth in population levels, the rise in pollution levels leading to global warming, and poorly designed old buildings. The critical issue was the shortage of jobs, while other concerns related to financial resources as a result of prevailing drought situations [2]. These all led to a significant decline in the quality of urban life. Although many measures were taken to solve these issues, they seemed to decline further. This study focused on environmentally sustainable growth in the physical, social, and economic sectors, and on eco-friendly factors. It then assessed and identified the impact of these factors as a dominant phenomenon in obtaining sustainable development through these indicators for an improved quality of life. But it was difficult to analyse and measure the results because of complications in adaptation systems. Thus urban life has a broad range of objective policies that enhance the renewal systems, improving social relationships through wide networks, rebuilding local economic policies with community-favoured rules and regulations [3]. However, there are no such options for assessing these outcomes of urban life projects when seeking to attain sustainability. So there is an urgent need to initiate and organise an assessment plan for improving urban life that focuses on sustainability.

This research has attempted to develop a hierarchical assessment model that mainly focuses on sustainable urban life [4]. This phase concentrated on identifying under-developed communities and enhancing their creativity through new job opportunities, using this sustainable method approach. Thus, the main objective of this paper was to achieve a quality urban life that combines physical conditions, a socially-oriented community, and economic improvements with adaptation for eco-friendly factors. Here, multi-criteria decision–making (MCDM) methods were applied to identify the chief differences between the indicators and the factors, and then their weights were calculated, leading to a clear path to attaining sustainability. This chain-linked, environmental factors, sustainability-oriented approach was a new attempt to raise a deprived community to levels of physical and social well-being and economic improvement with adaptation to eco-friendly factors [5]. India is not only dependent on natural resources, but also concentrates on new ways of creating employment opportunities for deprived communities through new business, loan offers, and building industrial sectors for young people. Thus, given these criteria, a literature review was conducted that provided broad knowledge about the future of urban life.

2. LITERATURE REVIEW

The sudden rise in population, development in standards of living, industrialisation, and improvements in hospital facilities led to the growth of urban life [5]. But urban problems were mainly from environmental issues such as air, water and soil pollution, leading to global warming. Other major hazards, such as the depletion of natural resources and the destruction of biodiversity, were at the top of the list. Then, other urban factors, such as many social inequity problems, led to quarrels among citizens. These problems were prevailing in cities as a result of poor planning. Previously, planners had always given priority to developing urban life at the cost of the destruction of natural resources, without considering the environmental aspects. No importance was given to the protection of society. Rather, some political leaders with a narrow-minded approach to rapid urban development made selfish plans to attract people with short-term business plans [6]. Hence, a need arises to attain sustainability. More importance needs to be given by government officials, experts, and decision-makers, in the name of sustainability, to concentrating on eco-friendly factors, with physical, social, and economic solutions to meet growing urban demands.

Urban life projects have realised the importance of attaining sustainability by enhancing the quality of urban life through developing physical environmental policies, meeting the needs of communities, and improving urban infrastructure; all of these can lead to sustainable goals. There are a few main points to be considered. First, the path towards sustainability goals is initially to create more employment opportunities and to provide a safe and peaceful environment. Second, it is to improve the physical capability of residents, to improve the cost of living, and to enhance the quality of urban life. Finally, it is to identify eco-friendly landscapes, and concentrate on welfare and cultural values [7]. Above all, owing to the changes in policies in industrial sectors, there are increased hazards for the population within city limit zones that should be controlled by strict rules before more disasters in these industries that might lead to catastrophic effects in maintenance [8]. Hence, the aim of this approach to enhancing urban life is to start with these key efforts at sustainability, because the physical factors mainly concentrate on enhancing the quality of urban life; social factors mainly highlight creating new opportunities for deprived communities; economic factors concentrate on improving economic stability; and eco-friendly factors focus on a green, pollution-free environment [9]. The analytical hierarchy process under group decision making (AHP-GDM) and fuzzy analytic hierarchy process (FAHP) methods are adopted to identify various factors leading to a better quality of urban life [10]. They lent weight to the sustainability indicators that relate to the selection and ranked them for an improved urban life, setting a steady path towards sustainability [11].

3. METHODOLOGY

In this present research, we identified key indicators for evaluating the sustainability of urban life projects in India. Thus, an attempt was made to balance urban life by eradicating the risk factors that threaten the peacefulness of urban life. This was related to developing a hierarchical evaluation model with an integrated index that was framed to evaluate the effects of the sustainability factors. First, from the literature it was decided to assess those urban life factors that concentrate on these sustainability criteria: mainly, physical, economic, social sustainability, and eco-friendly factors. In this first stage, quantitative goals were reviewed, and then a set of indicators that were based on objectivity, regularity, and that affect urban life [12]. Then, a questionnaire was used as a direct way to forecast the future [13]. The data that was collected was based on the opinions of various experts. This AHP-GDM and FAHP multi-criteria decision approach enabled us to identify and generate mutually least relevant and more exclusive related alternatives where many criteria factors are involved [14]. The main benefits of AHP-GDM are to establish a structure, evaluate the main relatively important factors, and analyse the effects of both qualitative and quantitative parameters [15]. The aim was to identify and verify various criteria with consistency in order to reach a conclusion about firm decision-making to prioritise the selected weights in the model. The research framework is shown in Figure 1.

3.1. Indicator selection

Based on a study of the literature, various indicators were revealed, which are shown in Table 1. The revealed indicators could evaluate sustainable urban life and a better quality of life, such as housing facilities, recreational activities, and safety in homes. Then economic factors emerged: growth in employment opportunities, the growth of business, and opportunities for the young. The social factors that emerged were social and community well-being, participation in communal gatherings, a real estate boom, and leasing options. The eco-friendly factors focused in developing the practice of using disposable waste bags, compostable utensils, recycled paper, stainless steel utensils, recycled aluminium foil, solar power, reusable bags, and rainwater harvesting.

Table 1: Indicators selected on the basis of the literature

Sustainability factors	Indicators
Physical factors *12 indicators*	Peaceful living, safety and security in homes, inbuilt cameras, parks for recreational activities, regular maintenance of infrastructure, repairs to roads, water pipes, drainage, street lights, cultural amenities, road facilities for pedestrians
Economic factors *10 indicators*	Enhancement of job opportunities, increased value of properties, benefits of population mobility, growth in business, rise in tourism, a balanced taxation and revenue system, growth of employment among young people, rise in sales growth, an increasingly healthy population
Social factors *8 indicators*	Participation programme for residents, cultural activities, creation of ample space for communities, rental facilities for public gatherings, fund generation, provision for leasing, improvements in real estate
Eco-friendly factors *10 indicators*	Disposable waste bags, compostable utensils, recycled paper, stainless steel utensils, recycled aluminium foil, solar power, reusable bags, rainwater harvesting

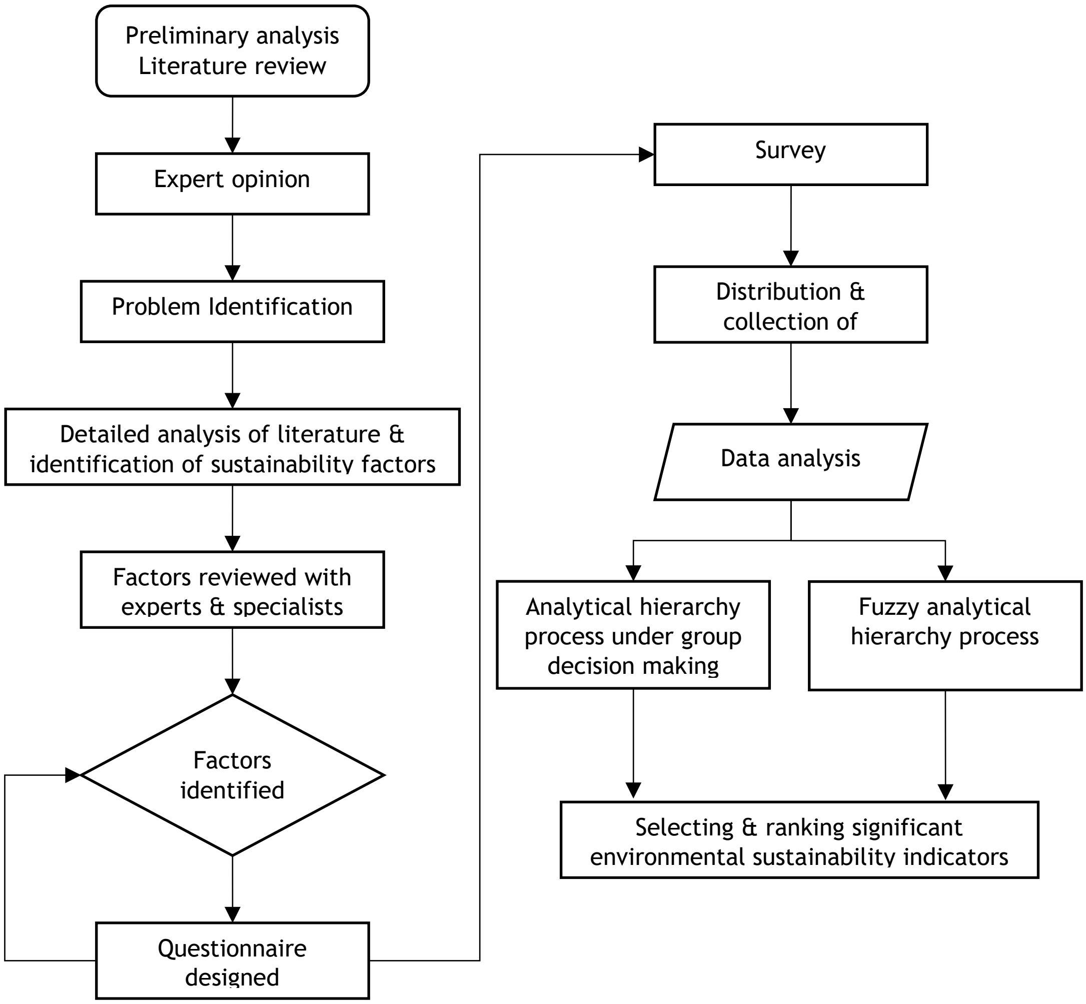

Figure 1: Research framework

A total of 38 indicators were identified through analysis of the expert panel. The final indicators were identified by using a questionnaire that was sent to 260 experts who included academics; officials from government sectors such as infrastructure, land, and transport; pollution control board members; and people from other public-oriented institutions. These organisations included national and local government bodies.

3.2. Outcome at the end of the first-round questionnaire survey

A questionnaire survey was administered to identify the sustainability factors. It consisted of open-ended questions put to a panel of 250 well-known experts. The findings are shown in Table 2.

Table 2: Findings of the first-round questionnaire survey

Sustainability factors	Indicators
Physical factors *Objective: better quality of living, such as housing facilities* *9 indicators*	Peaceful living, pedestrian road facilities, safety and security in homes, parks for recreational activities, improved infrastructure, water pipes and drainage facilities, parking facilities, hospital facilities
Economic factors *Objective: growth in employment opportunities* *8 indicators*	Enhanced job opportunities, growth in business, enhanced mobility of population, benefits of that mobility, growth in the tourism industry, increase in tax revenues, advancements in business start-ups
Social factors *Objective: social and community well-being* *6 indicators*	Fund generation, improvements in real estate, participation programmes for residents, win-win-based community, creation of ample space for communities, rental facilities for public gatherings
Eco-friendly factors *Objective: pollution-free zone and green environment* *8 indicators*	Recycled paper, stainless steel utensils, recycled aluminium foil, solar power, reusable bags, rainwater harvesting, organic food, microwave cooking

The outcome of the questionnaire survey helped to reveal the indicators to assess sustainable urban life. The questionnaire also helped to identify 31 factors and nine indicators among the physical factors, which mainly concentrated on peaceful life, and road facilities for pedestrians. Other important concerns were safety and security in homes, using technology to improve infrastructure, then water and drainage facilities, giving top priority to providing hospital facilities, and finally, good parking facilities. Then the economic factors had eight indicators that mainly pointed to enhanced job opportunities, followed by growth in business, and enhancements to and benefits from population mobility. Other important issues were a rise in tourism, increased tax revenue benefits, and finally, the advancement of business start-ups through proper planning. For the social factor, six indicators were identified: fund generation, improvements in real estate business, mutual participation programmes for residents, win-win-based community agreements, creation of ample space for communities, and finally, rental facilities for public gatherings. Finally, the ecofriendly factor had eight indicators whose main objective was a pollution-free and green environment, supported by factors such as using recycled paper, which does not harm the environment; stainless steel utensils, which are long-lasting and also do not harm the environment, unlike other harmful products; recycled aluminium foil for keeping food warm, which is easily disposed of; solar power, a pure form of energy; reusable bags to avoid the use of landfills; rainwater harvesting to energy and control flooding; organic food, which is free from chemicals; avoiding junk food in favour of healthy eating; and microwave cooking, which saves energy better than oven cooking.

The main aim of the AHP-GDM evaluation was to identify the factors of the quality of urban life that can create a sustainable environment. The factors of environmental sustainability could play a significant role in creating a sustainable urban life. Each stage is an important phenomenon; people always need peaceful living; a safe environment with the ability to earn an income; cooperative community relationships that result in win-win well-being; and a pollution-free environment with green surroundings. To achieve such a comfort zone, steps needed to be taken to analyse them in detail. The final survey indicators for the physical factors were a life of safety and security (C11), which has such specific objective features as advances in infrastructure, pedestrian road facilities, and good hospital facilities. The better quality-of-life facilities (C12) identified such specific objectives as water pipe and drainage facilities, ample parking facilities, and parks for recreational activities. The second main indicator, economic factors, started with growth in ways to earn a living (C21) with such objectives as growth in small and large businesses, enhanced job opportunities (C22), which has as its main objectives a growth in industries with an increase in tax revenues (only a rich country with a good payroll increases its tax revenue); enhancements from population mobility (C23) (they are usually produced by a floating population); and a tourism industry. The third main indicator, social, concentrated on social cooperation (C31) which mainly aims at participation programmes for residents, the creation of ample space for communities, and rental facilities for public gatherings. All of these factors create social relationships and cooperation among residents. A win-win-based community (C32) concentrates on generating funds mainly by improving the real estate business, and aims for a mutual understanding. Finally, the eco-friendly factor favours compostable paper (C41); it concentrates on creating a pollution-free zone, with fewer carbon emissions; it promotes nutrients for the fertility of the soil; Biodegradable/disposable bags (C42) reduce carbon emissions and are easier to recycle. Recycled paper (C43) helps to create a green environment, limits toxic gases, and eliminates landfills. Renewable energy (C44) helps to reduce greenhouse gas emissions, conserves natural resources with no toxic emissions, and prevents environmental degradation. Soil and water conservation (C45) improves the quality of air and water, which leads to reduced pollution, and saves aquatic life. Finally, rainwater harvesting (C46) reduces soil erosion, minimises energy use, and prevents flooding.

Table 3: Final survey indicators with related objectives

Environmental sustainability indicators	Final survey indicators	Related factors' objective elaboration
Physical factors	C11 - Safety and secure life	Advancement in infrastructure, pedestrian road facilities, hospital facilities
	C12 - Better quality of life facilities	Water pipe & drainage facilities, parking facilities, park for recreation activities
Economic factors	C21 - Growth in earning methods	Growth in small and large businesses
	C22 - Enhanced job opportunities	Growth in industries, increased tax revenues
	C23 - Enhanced population mobility	Benefits of a mobile population, tourism industry
Social factors	C31 - Social cooperation	Participation programme for residents, ample space for communities, rental facilities for public gatherings,
	C32 - Win-win-based community	Fund generation, improvements in real estate, mutual understanding in the community
Eco-friendly factors	C41 - Compostable products	Pollution-free zone, less carbon, promoting nutrients
	C42 - Biodegradable /disposable bags	Easier to recycle, minimise carbon emissions
	C43 - Recycled paper	A green environment reduces toxic gases, eliminates landfills
	C44 - Renewable energy	Reduce greenhouse gas emissions, conserve natural resources, no toxic pollution, prevent environmental degradation
	C45 - Soil and water conservation	Improved air and water quality, minimise pollution, save aquatic life
	C46- Rainwater harvesting	Reduce soil erosion, minimise energy usage, avoid flooding

4. DATA ANALYSIS AND VALIDATION

4.1. Conducting an item analysis for data validation

To assess the survey's validity and the reliability of its approach, an item test analysis was done on the collected data. This is an important confirmation technique for checking because the data was collected from experts, consultants, and panels, and then analysed independently; so there was a significant possibility of differences of opinion in their responses. Thus, for this item analysis, a Cronbach's alpha test was conducted using Minitab 19 software. This statistic approach displays the correlations with values between 0 and 1. Usually, a value above 0.7 is acceptable [16]. In the present survey, the Cronbach's alpha value was greater than 0.7, and so the collected data passed the test of reliability, as shown in Table 4.

Table 4: Reliability statistics

Cronbach's alpha	Cronbach's alpha based on standardised items	No. of items
0.721	0.703	13

4.2. MCDM-based research methodologies

The combined methodologies of AHP-GDM and FAHP were used in this research. Generally, AHP is carried out using pairwise comparisons using the expert knowledge of decision-makers (DMs). The AHP methodology is used in a crisp environment, whereas FAHP provides a pair-wise comparison in a fuzzy environment. Thus AHP-GDM and FAHP may combined to derive the weights of the indicators and factors of sustainable urban life.

4.2.1. Analytic hierarchy process under group decision making (AHP-GDM)

The AHP process (Saaty, 1988) has been widely used in solving simple to complex hierarchy-based problems in various areas [17,18]. The AHP process can easily solve complex problems with conflicting objectives.

The AHP uses the expert knowledge of DMs to form a pairwise matrix using Saaty's nine-point scale, as shown in Table 5. Generally, DMs have in-depth subject knowledge and sufficient expertise to solve a given problem. A pairwise matrix can be constructed using the judgement of a single DM or of more than one. More DMs are preferable in order to reach judgement of a decision that is free from vagueness and bias. Thus, in this research, we used group decision-making [19].

Table 5: Saaty's nine-point scale

Sr.No.	Decision preference	Relative importance
1	Equal preference	1
2	Moderate preference	3
3	Essential preference	5
4	Very strong preference	7
5	Extreme preference	9
6	In-between preference between two adjacent decisions	2-8

The detailed AHP-GDM process was structured into the following steps:

Step 1:

The sustainable urban life factors could be considered to generate a comparison matrix 'D'. The comparison matrix so construed could also be called a decision matrix. Generally, a nine-point scale is used to form a pairwise decision matrix. Thus the D matrix could be formed as shown in Equation 1.

$$D = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{12} & \dots & d_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix} \quad (1)$$

Step 2:

Using the feedback from the DMs, the decision matrix 'D' was generated. Subsequently, the pairwise decision could be used to derive the geometric means (GM). On using the GM, the priority vector (PV) of each decision matrix could be derived.

Step 3:

The decision matrix 'D', having pairwise comparison entries, could help to calculate the overall summation of the product of the sum of the column vectors for both the matrices with the PV values of each row. The principal eigenvalue (λ_{max}) was derived as follows:

$$\lambda_{max} = \sum_{i,j=1}^{k} C_j PV_i \tag{2}$$

where c_j is the sum of each column vector.

Step 4:

The consistency of DMs is an essential part of the AHP-GDM methodology [20]. The decision matrix is only acceptable if the consistency ratio is less than 10%. Thus the decision consistency had to be checked using a consistency index (C.I.), which could be calculated by using Equation (3):

$$\text{C.I.} = \frac{\lambda_{max} - n}{n-1} \tag{3}$$

where C.I. is the consistency index and n is the number of elements of each of the matrices.

Step 5:

The consistency ratio involves the ratio of consistency index and the random index; thus a random index could be derived using Equation 4. As a ready reckoner, an available random index table might also be used [21].

$$\text{R.I.} = \frac{1.98\ (n-2)}{n} \tag{4}$$

Step 6:

The consistency ratio (C.R.) provided an important result to accept or reject the decision matrix that was formed using the feedback from the DMs. The acceptable CR value of the decision matrix had to be less than 10%, otherwise the decision matrix would have to be repeated using the above procedure. The C.R. value was derived using Equation (5).

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \tag{5}$$

4.2.2. Fuzzy analytic hierarchy process (FAHP)

The FAHP method uses fuzzy set theory in representing two fuzzy numbers and the subsequent arithmetic operations. The extension principle is used in obtaining the intersection of two fuzzy numbers. The fuzzy-based methodology is useful in providing accurate decision making [21]. Triangular fuzzy numbers (TFN) and trapezoidal fuzzy numbers (TrFN) can be used to form the pairwise decision matrix. A brief description of carrying out fuzzy operations and extension principles is as follows:

The TFN or the TrFN may be used to carry out various arithmetic operations. The TFNs L_1 and L_2 might be (a_1, b_1, c_1) and (a_2, b_2, c_2) respectively. It can be used for various arithmetic operations such as addition and subtraction as ⊕ and Θ respectively.

$$\tilde{L}_1 \oplus \tilde{L}_2 = (a_1 + a_2,\ b_1 + b_2, c_1 + c_2) \tag{6}$$

$$\tilde{L}_1 \ominus \tilde{L}_2 = (a_1 - a_2, b_1 - b_2,\ c_1 - c_2) \tag{7}$$

$$\tilde{L}_1 \otimes \tilde{L}_2 = (a_1 a_2,\ b_1 b_2,\ c_1 c_2) \tag{8}$$

$$\lambda \otimes \tilde{L}_1 = (\lambda_1 a_1, \lambda_1 b_1, \lambda_1 c_1) \text{ where } \lambda > 0, \lambda \epsilon R \quad (9)$$

$$\tilde{L}_1^{-1} = \left(\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1}\right) \quad (10)$$

The two TFNs may be compared using the principles of extent analysis. Consider two sets as Y={y_1, y_2,........., y_n} and Z={z_1, z_2,........., z_3} respectively. Applying the extension principle, each object Y can be derived, and an extended analysis for each goal Z can be performed. As a result, m extent analysis values for each object can be derived as:

$$P_{gi}^1, P_{gi}^2 \ldots P_{gi}^m, i = 1,2, \ldots, n \quad (11)$$

where P_{gi}^j $(j = 1,2, \ldots m)$ are TFNs and are given as (m,n,o). The process described as Chang's extent analysis may be used, and is given below.

Step 1: Getting hierarchy structure to get a goal:

The factors of sustainable urban life could be ranked using the feedback of the DMs. A hierarchical structure helps in decision making; so a hierarchical structure that was framed earlier was used. The main goal is generally at the top, and the criteria and sub-criteria and alternatives are arranged at various subsequent levels.

Step 2: Pairwise comparison using TFNs for indicators and factors of sustainable urban life:

The DMs carried out the pairwise comparison in terms of TFN, and later these matrices were collected for comparison. First, the pairwise comparison between the indicators of sustainable urban life was carried out, while the factors of sustainable urban life were compared after that.

Step 3: Fuzzy synthetic extent value:

$$F_i = \sum_{j=1}^{m} P_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} P_{gi}^j\right]^{-1} \quad (12)$$

Using the fuzzy summation of the TFNs, m extent analysis values $\sum_{j=1}^{m} P_{gi}^j$, could be obtained as:

$$\sum_{j=1}^{m} P_{gi}^j = \left(\sum_{j=1}^{m} m_j, \sum_{j=1}^{m} n_j, \sum_{j=1}^{m} o_j\right) \quad (13)$$

and $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} P_{gi}^j\right]^{-1}$ gives the fuzzy summation of:

$P_{gi}^j (j = 1,2, \ldots, m)$ values are calculated as

$$\sum_{i=1}^{n} \sum_{j=1}^{m} N_{gi}^j = \left(\sum_{j=1}^{m} p_j, \sum_{j=1}^{m} q_j, \sum_{j=1}^{m} r_j\right) \quad (14)$$

The inverse of the vector could be obtained as:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} P_{gi}^j\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} r_i}, \frac{1}{\sum_{i=1}^{n} q_i}, \frac{1}{\sum_{i=1}^{n} p_i}\right) \quad (15)$$

Step 4: Degree of the possibility of supremacy for two TFNs i.e. $P_2 = (m_2, n_2, o_2) \geq P_1 = (m_1, n_1, o_1)$:

$$V(P_2 \geq P_1) = sup\left[min\left(\mu_{P_1}(x), \mu_{P_2}(y)\right)\right], \ y \geq x \quad (16)$$

and could be represented as:

$$V(P_2 \geq P_1) = hgt\ (P_1 \cap P_2) = \mu_{P_2}(d) \tag{17}$$

$$\mu_{P_2}(d) = \begin{cases} 0 & if\ n_2 \geq\ n_1 \\ 1 & if\ m_1 \geq\ o_2 \\ \frac{m_1 - o_2}{(n_2 - o_2) - (n_1 - m_1)} & otherwise \end{cases} \tag{18}$$

Generally, a group of DMs could be involved to obtain a precise judgement from carrying out the pairwise comparison. Considering K DMs, it yielded n elements in pairwise comparison. A set of K matrices, $\check{A}_k = \{\check{p}_{ijk}\}$, where $\check{A}_k = \check{p}_{ijk} = (m_{ijk}, m_{ijk}, o_{ijk})$, represented the relative importance of element i to j, as derived by DM k. Equation (19) was used for aggregation.

$$m_{ij} = min(m_{ijk}), k = 1,2, \dots k \tag{19}$$
$$n_{ij} = \sqrt[k]{\prod_{k=1}^{K} n_{ijk}}$$

$$o_{ij} = max(o_{ijk}), k = 1,2, \dots k$$

As shown in Figure 2, two TFNs – i.e. (m_1, n_1, o_1) and (m_2, n_2, o_2) – intersected at d. The ordinate d could be obtained from the highest intersection between two fuzzy numbers μP_1 and μP_2, denoted as Q. Thus P_1 and P_2, could be calculated through the values of V (P_1 ≥ P_2) and V (P_2 ≥ P_1).

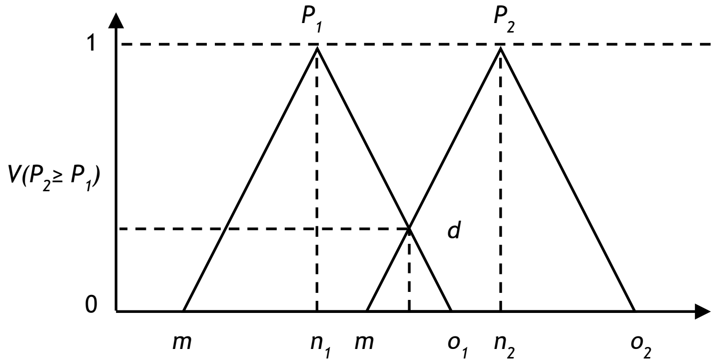

Figure 2: TFNs

Step 5: Possibility degree for a convex fuzzy number such that it is greater than k convex:

Fuzzy number $P_1(i = 1,2, \dots., k)$ could be derived as:

$$V\ (P \geq\ P_1, P_2 \dots . P_k) = V[(P \geq P_1)\ and\ (P \geq P_2\ and \dots \dots \dots and\ (P \geq P_k))] \\ = \min V\ (P \geq P_i),\ i = 1,2, \dots \dots \dots, k \tag{20}$$

Considering:

$$d'(B_i) = \min V(S_i \geq S_k)\ for\ k = 1,2, \dots \dots, m; k \neq i \tag{21}$$

The weight vector could be derived as $G' = (d'(B_1), d'(B_2), \dots \dots \dots, d'(B_n))^T$

Such that $B_i(i = 1,2, \dots \dots, n)$ has *n* elements.

Step 6: Normalised weight vectors:

The normalised weight vector was calculated using Eq. (22)

$$C = \left(d(B_1), d(B_2), \dots \dots \dots, d(B_n)\right)^T \quad (22)$$

where C denotes the crisp number.

Step 7: Overall score of each indicator and factors

The indicators and factors of sustainable life could be prioritised. The prioritisation was obtained by multiplying local weight and global weight. Subsequently, the obtained global weight could be arranged in descending order to decide the priority. Thus the overall rank could be decided.

4.3. MCDM methodologies for prioritising the indicators and factors of sustainable urban life

The MCDM-based AHP-GDM and FAHP methodology could be applied in prioritising and ranking sustainable urban life. The AHP method is based on pairwise calculations carried out by the expert DMs, who had sound knowledge and experience of the given problem area. In the present research, five DMs with more than six years' experience of working in the area of city planning, urban development, and municipal corporations were involved. They were briefed about the process of AHP-GDM and FAHP. A questionnaire containing the indicators and factors of sustainable urban life was provided for comparison. Later, the feedback from each DM was collected using AHP-GDM and FAHP processes. Figure 3 shows the framework for the indicators and factors of sustainable urban life that were obtained after a detailed review of the literature.

The next section briefly describes the steps, along with their output.

Step 1 – Define the goal of the problem

The goal of the problem had to be defined to collect all the relevant information about the prioritisation of the indicators and factors of sustainable urban life.

Step 2 – Frame the hierarchical structure

After the objective had been defined, the next step was to form the hierarchical structure by establishing the relationship among the indicators and factors of sustainable urban life. Figure 3 illustrates the hierarchical structure that was developed by arranging the indicators and factors of sustainable urban life.

Level I indicates the indicators of sustainable urban life, followed by the factors. The four indicators and 13 factors, as discussed earlier, were used to form the hierarchy.

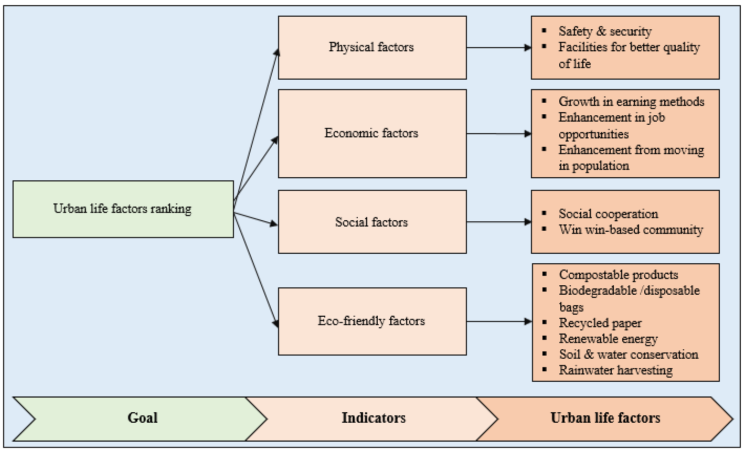

Figure 3: Hierarchical structure for AHP-GDM and FAHP

Step 3 – Pairwise comparison matrices

Once the hierarchical structure had been created, the relative influence of each indicator and factor of sustainable urban life was obtained through a pairwise comparison. Generally, in AHP-GDM, the DMs provide their final judgement using their experience and knowledge. As noted earlier, when there is a single DM, their decision might be biased, and so the judgement might not be accepted. To remove such ambiguity in the decision-making, we used group decision-making (GDM). We chose five DMs, each with more than six years of experience and knowledge in the relevant field. The DMs used Saaty's scale for building pairwise comparison, as shown in Table 1. Table 6 shows the pairwise comparison matrices for all of the DMs. Later, this matrix was combined to form the synthesised matrix using the geometric mean method.

Table 6: Urban life indicators pairwise comparison using AHP-GDM

	PF	EF	SF	EFF	Weight	Consistency checking
Indicators comparison by DM1						
Physical factors (PF)	1	3	2	1	0.3594	λ_{Max}=4.2343
Economic factors (EF)	1/3	1	3	1	0.2346	CI=0.0781
Social factors (SF)	1/2	1/3	1	1/3	0.1125	RI=0.9000
Eco-friendly factors (EFF)	1	1	3	1	0.2934	CR=0.0686
Indicators comparison by DM2						
Physical factors (PF)	1	2	2	1	0.3210	λ_{Max}=4.2349
Economic factors (EF)	1/2	1	5	1	0.2823	CI=0.0783
Social factors (SF)	1/2	1/5	1	1/4	0.0936	RI=0.9000
Eco-friendly factors (EFF)	1	1	4	1	0.3031	CR=0.0870
Indicators comparison by DM3						
Physical factors (PF)	1	2	2	1	0.3210	λ_{Max}=4.2349
Economic factors (EF)	1/2	1	5	1	0.2823	CI=0.0783
Social factors (SF)	1/2	1/5	1	1/4	0.0936	RI=0.9000
Eco-friendly factors (EFF)	1	1	4	1	0.3031	CR=0.0870
Indicators comparison by DM4						
Physical factors (PF)	1	3	2	1	0.3628	λ_{Max}=4.2356
Economic factors (EF)	1/3	1	3	1	0.2415	CI=0.0785
Social factors (SF)	1/2	1/3	1	1/2	0.1267	RI=0.9000
Eco-friendly factors (EFF)	1	1	2	1	0.2690	CR=0.08730
Indicators comparison by DM5						
Physical factors (PF)	1	3	2	1	0.3525	λ_{Max}=4.2402
Economic factors (EF)	1/3	1	3	1/2	0.2043	CI=0.0801
Social factors (SF)	1/2	1/3	1	1/2	0.1302	RI=0.9000
Eco-friendly factors (EFF)	1	2	2	1	0.3130	CR=0.0890

Step 4 – Synthesising of pairwise comparisons

The synthesis of all the pairwise matrices prepared by the DMs could be synthesised, as shown in Table 7. The final matrix thus obtained provided the relative influence of each indicator over the others in sustainable urban life.

Table 7: Result of synthesis of sustainable urban life dimensions using AHP-GDM

Dimensions	PF	EF	SF	EFF	Weight	Consistency checking
Physical factors (PF)	1	2 5/9	2	1	0.3448	λ_{Max}=4.2146
Economic factors (EF)	2/5	1	3 2/3	7/8	0.2482	CI=0.0715
Social factors (SF)	1/2	1/4	1	1/3	0.1102	RI=0.9000
Eco-friendly factors (EFF)	1	1 1/7	2 6/7	1	0.2968	CR=0.0795

Step 5 – Check consistency

Consistency checking is very important in AHP-GDM. The level of the consistency can be calculated using the relations shown in Equation 3. Consistency checking verifies whether or not the pairwise comparison is acceptable for further consideration.

Step 6 – Aggregation of judgements

Various pairwise decision matrices obtained by AHP-GDM could be aggregated to form a single matrix in order to arrive at a final decision. The geometric mean method can be used to calculate and arrive at the final matrix for each indicator and factor of sustainable urban life.

Step 7 – Ranking

The ranking of the indicators and factors reveals the importance of each indicator and factor, based on its global weight. The AHP-GDM pairwise matrix of indicators gives the local weights. Similar weights of all factors are derived. The product of these weights gives the global weightage that is used for the final ranking. The following formula provides the calculation of global weight for the indicators and factors of sustainable urban life:

Global weights=∑(Local weight for dimension *I* x local weight for factor *j* concerning dimension *i*)

On arranging the global weights in descending order, the final ranking of the factors of sustainable urban life could be obtained. The AHP-GDM method provided an evaluation and ranking of the indicators and factors of sustainable urban life. The synthesised weights of each of the indicators and factors were calculated through AHP-GDM, as shown in Table 8.

Table 8: Composite weightage table of the indicators and factors of sustainable urban life using AHP

Dimension	Criterion weight	Sustainable urban life factors	Local weights	Global weights	Rank
Physical factors	0.3448	Safety and security	0.5769	0.1989	1
		Facilities for better quality of life	0.4231	0.1459	2
Economic factors	0.2482	Growth in earning methods	0.5765	0.1431	3
		Enhancement of job opportunities	0.2743	0.0681	4
		Enhancement from mobile population	0.1492	0.0370	12
Social factors	0.1102	Social cooperation	0.4901	0.0540	10
		Win-win-based community	0.5099	0.0562	7

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Table 8: Composite weightage table of the indicators and factors of sustainable urban life using AHP (cont.)

Dimension	Criterion weight	Sustainable urban life factors	Local weights	Global weights	Rank
Eco-friendly factors	0.2968	Compostable products	0.1940	0.0576	5
		Biodegradable and disposable bags	0.1827	0.0542	9
		Recycled paper	0.1838	0.0546	8
		Renewable energy	0.1314	0.0390	11
		Soil and water conservation	0.1931	0.0573	6
		Rainwater harvesting	0.1151	0.0342	13

The FAHP could be used to calculate the priority weights of the indicators and factors of sustainable urban life, using TFN. The calculated weights of the indicators and factors of sustainable urban life using TFN are shown in Table 9. The research methodology discussed in section 3 was useful in calculating the local and global weights depicted in Table 10. The weights obtained by both methods were also compared, as shown in Table 11.

Table 9: Triangular fuzzy scale for FAHP

Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1,1,1)	(1,1,1)
Weakly more important	(1/2,1,3/2)	(2/3,1,2)
Moderately important	(1,3/2,2)	(1/2,2/3,1)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3.2/5)

Table 10: Composite AHP weights table of the indicators and factors of sustainable urban life using FAHP

Dimension	Criterion weight	Sustainable urban life factors	Local weights	Global weights	Rank
Physical factors	0.4424	Safety and security	0.6842	0.3027	1
		Facilities for better quality of life	0.3158	0.1397	2
Economic factors	0.2302	Growth in earning methods	0.5461	0.1257	3
		Enhancement in Job Opportunities	0.2929	0.0674	4
		Enhancement from mobility of population	0.1610	0.0371	11
Social factors	0.0915	Social cooperation	0.5000	0.0457	6
		Win-win-based community	0.5000	0.0457	7

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Table 10: Composite AHP weights table of the indicators and factors of sustainable urban life using FAHP (cont.)

Dimension	Criterion weight	Sustainable urban life factors	Local weights	Global weights	Rank
Eco-friendly factors	0.2359	Compostable products	0.2270	0.0535	5
		Biodegradable and disposable bags	0.1624	0.0383	9
		Recycled paper	0.1904	0.0449	8
		Renewable energy	0.1580	0.0373	10
		Soil and water conservation	0.1253	0.0296	13
		Rainwater harvesting	0.1369	0.0323	12

Table 11: Weight and rank comparison of indicators and factors of sustainable city using AHP and FAHP

Urban life indicators	Criterion weight by AHP	Criterion weight by FAHP	Urban life factors	Global weights by AHP	Rank	Global weights by FAHP	Rank
Physical factors	0.3448	0.4424	C11	0.1989	1	0.3027	1
			C12	0.1459	2	0.1397	2
Economic factors	0.2482	0.2302	C21	0.1431	3	0.1257	3
			C22	0.0681	4	0.0674	4
			C23	0.0370	12	0.0371	11
Social factors	0.1102	0.0915	C31	0.0540	10	0.0457	6
			C32	0.0562	7	0.0457	7
Eco-friendly factors	0.2968	0.2359	C41	0.0576	5	0.0535	5
			C42	0.0542	9	0.0383	9
			C43	0.0546	8	0.0449	8
			C44	0.0390	11	0.0373	10
			C45	0.0573	6	0.0296	13
			C46	0.0342	13	0.0323	12

5. RESULTS AND DISCUSSION

The indicators and factors of sustainable urban life play a significant role in creating sustainable urban life. To prioritise those indicators and factors, a systematic framework was required, and was been framed in the present study. The AHP-GDM-based methodologies were used to evaluate the indicators and factors of sustainable urban life. Instead of a single DM, a group of DMs was employed to enhance the accuracy of the decision-making. The prioritised indicators and factors provided good opportunities to ascertain what would lead to the conditions for successful and sustainable urban life. Generally, sustainable urban life involves various physical, economic, social, and eco-friendly factors. To create sustainable urban life, these indicators and the several factors that were identified would be essential. Both methods used – i.e., AHP-GDM and FAHP – were found to be useful, and provides detailed insight into the influence of the indicators and factors. Both methods were employed in different environments – i.e., crisp and fuzzy – which means that they could be employed to evaluate and to prioritise. City planners, urban development authorities, economists, and policymakers could find the evaluation and prioritisation of the indicators and factors of sustainable urban life useful. The weights that were derived from using two separate approaches could also help them to understand the importance of each indicator and factor.

The prioritisation of the indicators and factors of sustainable urban life obtained by using AHP-GDM and FAHP could be compared among the groups, and could be ranked in importance. Both methods derived the local weights and the global weights in both crisp and fuzzy environments. The global weights provided the importance of each indicator and factor on which they could be ranked.

On arranging the indicators in descending order, the relationships obtained in using AHP-GDM and FAHP were the same; that is, physical factors > eco-friendly factors > economic factors > social factors ('>' indicates a greater preference over the next factor). The corresponding weights were 0.3448 > 0.2968 > 0.2482 > 0.1102 in the case of GDM, and 0.4424 > 0.2359 > 0.2302 > 0.0915 in the case of FAHP. Similarly, the factors of sustainable urban life could be arranged in descending order; and the relationships so obtained in the case of AHP-GDM were: safety and security > facilities for better quality of life > growth in earning methods > enhancement of job opportunities > compostable products > soil and water conservation > win-win-based community > recycled paper > biodegradable and disposable bags > social cooperation > renewable energy > enhancement from mobility of population > rainwater harvesting, with the corresponding values of 0.1989 > 0.1459 > 0.1431 > 0.0681 > 0.0576 > 0.0573 > 0.0562 > 0.0546 > 0.0542 > 0.0540 > 0.0390 > 0.0370 > 0.0342.

Based on the FAHP method, the global weights of the factors provided the following relationships: safety and security > facilities for better quality of life > growth in earning methods > enhancement of job opportunities > compostable products > social cooperation > win-win-based community > recycled paper > biodegradable and disposable bags > renewable energy > enhancement from mobility of population > rainwater harvesting > soil and water conservation, with the corresponding values of 0.3027 > 0.1397 > 0.1257 > 0.0674 > 0.0535 > 0.0457 > 0.0457 > 0.0449 > 0.0383 > 0.0373 > 0.0371 > 0.0323 > 0.0296. Moreover, these factors are shown in Figures 4 and 5 to provide greater clarity and to facilitate comparison. Figure 4 shows the ranking and comparison of the weights of the urban life factors, and Figure 5 shows the comparison of the ranking factors for sustainable urban life using AHP-GDM and FAHP.

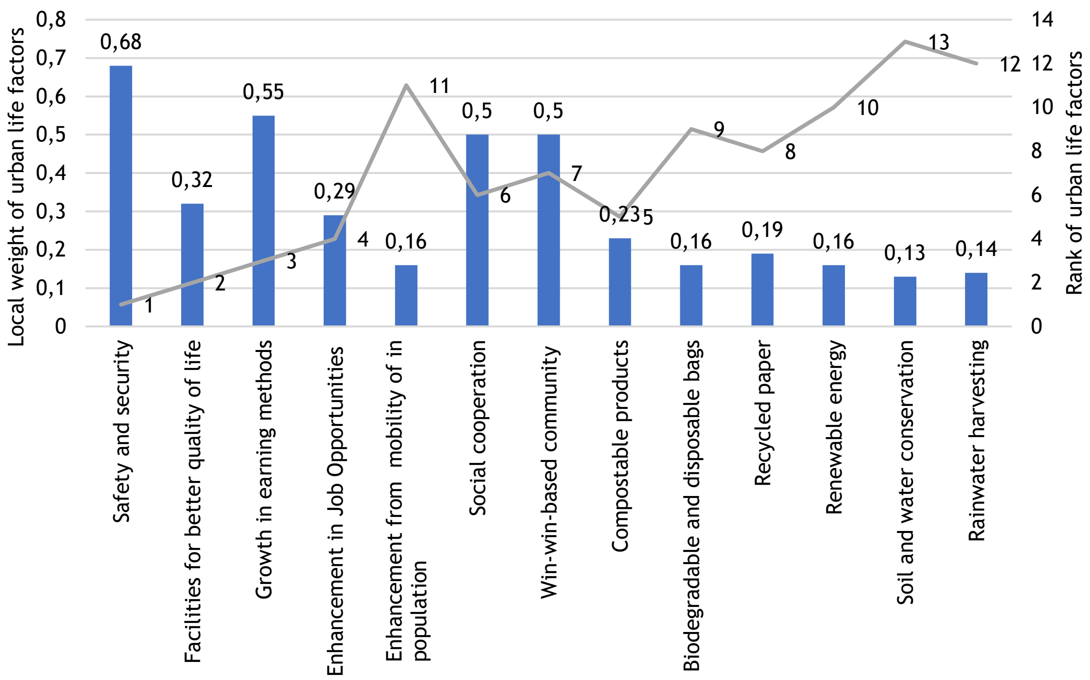

Figure 4: Comparison of sustainable urban life factors

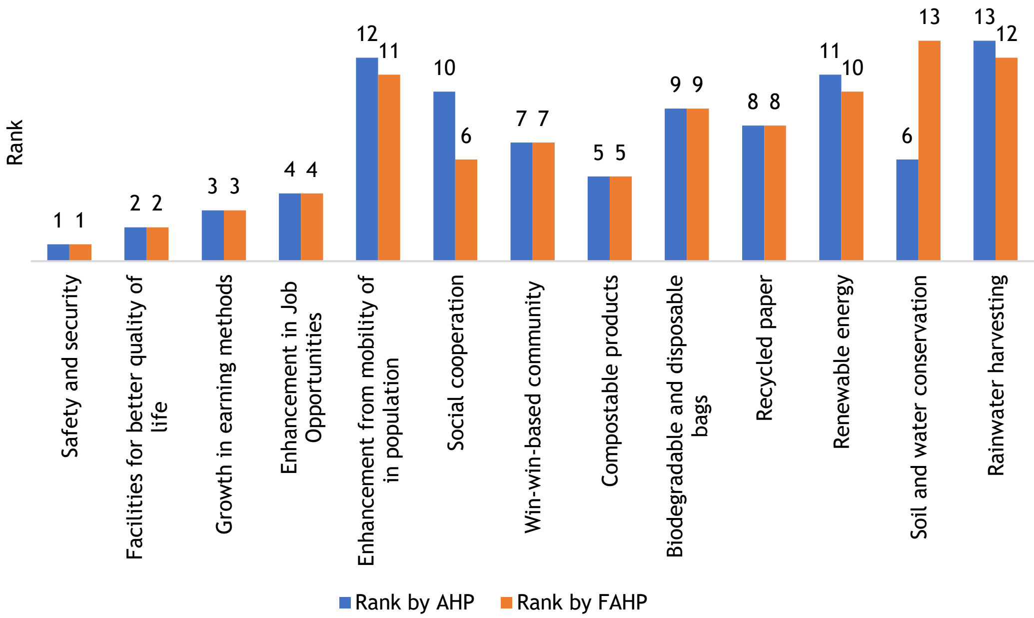

Figure 5: Comparison of factors for sustainable urban life using AHP-GDM and FAHP

6. LIMITATIONS, AND SCOPE OF FUTURE RESEARCH

This research assessed and prioritised the indicators and factors contributing toward successful and sustainable urban life. However, global financial, social, and regional conditions might influence the indicators and factors. Thus the indicators could change depending upon the nature of the country (underdeveloped, developing, or developed). The present study was based on the indicators and factors that were studied in India. The priorities obtained for the four indicators has an the thirteen factors were limited to this part of the world. However, this research has provided a robust methodology based on AHP-GDM and FAHP for assessing and ranking the indicators and factors of urban life. The AHP-GDM and FAHP both relied on the judgements of DMs, making it difficult to generalise the results. The use of GDM reduced judgemental bias to a great extent; thus more attention could be given to the physical and mental strength of the DMs. A more comprehensive study might yield accurate results; thus additional indicators and factors could be taken into consideration to provide a detailed evaluation and clarification. Depending on the type of study and the types of factors and indicators, other methodologies from the MCDM group could be used. Fuzzy-based techniques might also be useful to remove vagueness and biases in judgements, and might also be able to optimise the indicators and factors that influence sustainable urban life.

7. CONCLUSION

In this study, an attempt was made to create a hierarchical assessment model urban life, by comparing these indicators with weights from the AHP-GDM assessment of the sustainability indicators that relate to the urban lifestyle. The research identified that researchers mainly focus on the physical factors that emphasise the peaceful and happy lives of residents in deprived communities. However, this could be achieved by providing properly for their basic needs and care, and by increasing the provision of public-oriented facilities. The social factors could be greatly improved; for example, the findings highlight the importance of public gatherings for deprived communities, which could be achieved by creating strong social networks and providing more community space that people could access and so more easily enjoy their social relationships. Then, economic factors could develop urban life by creating more job opportunities for residents, thus increasing the growth of the business sector for a mobile population, leading in turn to greater access to tourism. The results also indicate that eco-friendly indicators need to be emphasized: they could have a highly sustainable impact on improvements when properly initiated. So the necessary steps mentioned in this paper should be taken, which could lead to more sustainable urban life.

The indicators and factors of sustainable urban life play a significant role in the standard of living and in creating prosperity. It is therefore essential to investigate the impact and influences of the indicators and factors of sustainable urban life. After assessing the impact of each indicator and factor, various stakeholders, such as policymakers, city planners, economists, and urban development authorities, should understand and control the influence of each of these factors and their indicators. The AHP-GDM and FAP approach could prove to be fruitful in categorising each dimension of sustainable urban life and its factors.

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