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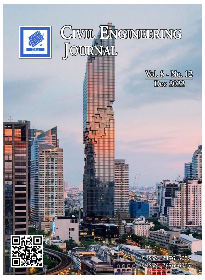

Integrated Framework for Inclusive Town Planning Using Fuzzy Analytic Hierarchy Method for a Semi Urban Town

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Abstract

Planning is a continuous process and must incorporate a regular evaluation of implementation and further revision for effective and efficient utility for the betterment of society through modification of the planning standards. Development plans for cities / towns are criticized for being rigid and static, having little regard for investment planning efforts, and taking a very long time in the process of formulation and approval. In depth analysis and review of the existing situation, covering the demographic, economic, financial, infrastructure, physical, environmental, and institutional aspects, is important so as to identify the strengths and weaknesses in the city overall development. In the present study, an attempt has been made to thoroughly review the existing planning standards adopted for the preparation and implementation of development plans in India, especially in Maharashtra. Since the development plan's objectives are not measurable, this study will use the Fuzzy Analytic Hierarchy Process (AHP) to assess their level of performance. For the purpose of identifying the various viewpoints of various stakeholders, field surveys and questionnaire surveys were conducted. This application can be used as an objective evaluation tool for planners and policy makers to improve planning practices and provide necessary knowledge for revising plans. The results indicated the importance of criteria from the pre-planning, preparation, and implementation stages of DP. These results were used for two semi-urban towns in Maharashtra regions and could also be used by planning engineers for further development of planning standards.

Keywords: Development Plan; MCDM; Fuzzy AHP; Hierarchy; Urban Planning; Land.

1. Introduction

Cities are the engine that drives economic productivity and prosperity for any country. The advancement of urbanization has benefits like global economic development, poverty decline, and social welfare. However, unplanned urbanization has also often led to pollution, congestion, segregation, sprawl, and other unintended consequences. Presently, the planning process has become very important and also significant considering various aspects like the collection of data, the preparation of land use plans and land reservations following the existing planning standards, the implementation of an approved development plan at ground level, and the monitoring and evaluation of the development plan. This helps to understand the critical components of actual implementation of proposed/approved land reservations in the development plan so as to identify the gaps or lacuna and formulate the remedial measures in the form of suggestions for modification in the approved development plan for optimization of reservations.

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Ultimately, this leads to the proper and efficient use of land resources and thereby increases flexibility to achieve maximum utilization of land reservations to serve the desired population and also it reflects the changes in thought process in planning proposals in Government Organization/Department, with professional way. Earlier, the decision makers and planners were thinking of the development plan as the final motto and not its implementation, which resulted in poor results from the development plan. However, there is a change in the planning process and also in the basic concepts and standards of planning that were followed without much thought, and nowadays pragmatic views are adopted to make the development plan more and more implementable and efficient from a utility perspective. Due to the increasing number of activities in the present age, the speed of urbanization has also increased tremendously, which has attracted more and newer activities to the urban area. This has subsequently resulted in these areas emerging as new and preferred destinations for becoming business, commercial, and industrial hotspots within such urban areas by attracting investment from all directions, including from national and international investors. To obtain such rising opportunities for the betterment of society and the country, it is necessary to make cities or urban places more liveable, socially and economically absorbent, sustainable, and accommodative. However, this is not easy task to adopt such challenges and become ready to welcome the major shift to attract global entities from the business and industrial world. But it is necessary to go for reforms in the planning process to make city or urban place more attractive to investors, accommodative to adopt classes of masses and obviously tremendous changes established norms, standards and processes in planning of the cities and urban places along with administrative, social and infrastructural point of views.

Town planning is the process of managing land resources, which involves the control of existing and new developments as well as strategy preparation to ensure the management of future requirements. It is a dynamic process that changes in response to policy, development proposals, and local needs. Various parameters need to be considered while making a development plan. This is the reason why the decision-making process is becoming increasingly complex, requiring taking into account more and more different criteria. One of the important and commonly used techniques that support decision making processes is Analytic Hierarchy Process (AHP) while for the purpose of supporting a more realistic way of decision making, fuzzy logic is used.

- To review the role and effect of the proposals of the development plans at the various stages of preparation of plans and sanction in the context of the existing Planning Standards.
- To identify the parameters that causes level of deficiencies during the various stages of the development proposals.
- To develop a ranking framework of development plan preparation and implementation which can be applied to any environment in an easy and efficient manner and with the sustainability.

2. Literature Review

Bhadane et al. (2020) discussed the urban land use planning/zoning for Maharashtra and Japan [1]. Through this critical comparative study, practices, which are adaptable from Japan model, are recommended in order to develop a multi-criteria framework for advance planning for Maharashtra.

De Balanzó & Rodríguez-Planas (2018) used adaptive cycle theory to improve the understanding of cycles of urban change in the city of Barcelona, Spain, from 1953 to 2016 [2]. More specifically, authors explored the vulnerabilities and windows of opportunity these cycles of change introduced in the release (Ω) and reorganization (α) phases. In the two recurring cycles of urban change analyzed (before and after 1979), two complementary loops are observed. During the front loop, financial and natural resources are efficiently exploited by homogenous dominant groups (private developers, the bourgeoisie, politicians, technocrats) with the objective of promoting capital accumulation based on private (or private-public partnership) investments. During the back loop, change is catalysed by heterogeneous urban social networks (neighborhood associations, activists, squatters, cooperatives, nongovernmental organizations) whose objectives are diverse but converge in their discontent with the status quo and their desire for a “common good” that includes social justice, social cohesion, participatory governance, and well-being for all. The heterogeneity of these social networks (shadow groups) fosters learning, experimentation, and social innovation and gives them the flexibility that the front loop’s dominant groups lack to trigger growing pressures for transformation, not only within, but also across spatial and temporal dimensions, promoting panarchy. At the end, the reorganization phase (α) becomes a competition or negotiation between potential directions and outcomes (including conservative leanings and intentional bottom-up change) to restore the former system.

Saha & Roy (2021) have used GIS-based multi-criteria analysis to identify suitable areas for built-up development in Siliguri Planning Area, India [3]. A total of nine criteria have been taken to locate best places for built-up development. Analytic hierarchy process or AHP has been used to calculate weights of each criterion by using pair wise comparison matrix. Final site suitability map has been prepared with four different classes: high suitable, moderate suitable, less suitable and restricted area and the percentage of land is high in moderate suitable category that is 52.33% which covers the intermediary portion, mainly wastelands and agricultural land of the study area with higher facility of accessibility. Results from this work would be helpful for the planners, stakeholders, policy makers by identifying best locations for the intensive developmental projects in near future.

Bargueñ et al. (2021) identified the state of the art of AHP applications to urban mobility [4]. With the support of graphical software, three clusters were identified, in the keywords network: AHP, Innovation & Public Management, and Urban Mobility. In the AHP cluster, research is driven by methodological subjects; on Innovation & Public Management, there is an open discussion on local versus national coordination; and the urban mobility cluster has hybrid or non-AHP applications of MCDM.

Parry et al. (2018) found out the urban land suitability for the provision of urban amenities [5]. Land use suitability assessment is a key determinant in any urban and suburban planning and decision-making process. The suitability assessment is carried out through AHP model using a set of criteria involving geo-physical and socioeconomic variables. The variables taken for the study are slope, altitude, land use/land cover and existing amenity status. The unit of study is a municipal ward. For better urban planning and suitable decision making, the study provided the information not only on the existing urban land use pattern and existing amenity status but also on suitability of land for the establishment of urban amenities in future.

Ganesh et al. (2020) carried out site suitability assessment for Neelambur, one of the peri-urban areas of Coimbatore city [6]. The factors considered for identifying the land parcels suitable for urban settlement included the land-use of the study area, proximity of sites to the nearest road, proximity of sites to the nearest facilities of importance and slope of the study area. The Analytical Hierarchy Process based Weighted Overlay Method was used in Geographic Information System to identify the land parcels suitable for urban settlements in order to ensure a sustainable development in the study area. The results indicated that 5.29 sq.km of the study area was classified as highly suitable for urban settlements. The results of the current study can be used by the local planning authorities in establishing development control norms for ensuring the sustainable growth of Neelambur.

Santosh et al. (2018) aimed the Geographic Information System (GIS) and Multicriteria Evaluation Technique (MCE) based site selection for urban development in Chikodi Taluk, Belagavi district, Karnataka (India) [7]. In the study six thematic layers were considered such as slope, land use/land cover, road proximity, land value, lineaments and aspect, the generated thematic maps of these criteria were standardized using pair wise comparison matrix known as Analytical Hierarchy Process (AHP). A weight for each criterion was given by comparing them with each other according to their importance and all the six maps were converted into raster. Finally with the help of these weights all the six maps were integrated and overlaid for the preparation of site suitability map for the urban development. The final site suitability map was divided into five different suitability categories. The area under very low, low, moderate, high and very high lands stand at 1.81 km^2, 12.71 km^2, 37.94 km^2, 66.88 km^2, and 22.44 km^2 respectively. The present study allows the local people as well as planners for the appropriate plans of land use planning in sustainable urban development.

Morales & Vries (2021) aimed at establishing the relevant and necessary evaluation criteria for Multi-criteria Evaluation (MCE) using the Analytic Hierarchy Process (AHP) for land use suitability analysis for residential, industrial, commercial, agricultural, and forest land uses [8]. The factors which were used as indicators in land suitability analysis were derived from both literature review and through experts' knowledge. Correspondingly, the relative importance (weights) of the criteria established were derived using pairwise comparisons through the AHP technique readily available for subsequent GIS analysis.

Mosadeghi et al. (2015) presented in his study how spatial decision-making can be used not only to rank the priority of options and performing scenario analysis, but also to provide insight into the spatial extent of the alternatives [9]. This is particularly helpful in situation where political transitions in regard to urban planning policies leave local decision-makers with considerable room for discretion. To achieve this, he has compared the results of two quantitative techniques (analytical hierarchy procedure (AHP) and (Fuzzy AHP) in defining the extent of land-use zones at a large-scale urban planning scenario. The presented approach also added a new dimension to the comparative analysis of applying these techniques in urban planning by considering the scale and purpose of the decision-making. The result demonstrated that in the early stage of the planning process, when identifying development options as a focal point is required, simplified methods can be sufficient. In this situation, selecting more sophisticated techniques will not necessarily generate different outcomes. However, when planning requires identifying the spatial extent of the preferred development area, considering the intersection area suggested by both methods will be ideal.

Srdjevic et al. (2013) has presented a two-phase algorithm based on the optimal clustering of decision makers (members of a group) into sub groups followed by consensus building both within sub groups and between sub groups [10]. Two dimensional Sammon's mapping is proposed as a tool for generating an approximate visualization of sub groups identified in multidimensional vector space, while the consensus convergence model is suggested for reaching agreement amongst individuals in and between sub groups. As a given, all decision makers evaluate the same decision elements within the AHP framework and produce individual scores of these decision elements. The consensual scores are obtained through the iterative procedure and the final scores are declared as the group decision. The results of two selected numerical examples are compared with two sets of results: the results obtained by the commonly used geometric mean aggregation method and also the results obtained if the consensus convergence model is applied directly without the prior clustering of the decision makers. The comparisons indicated the expected differences among the aggregation schemes and the final group scores. The matrices of respect values in the consensus convergence model, obtained for cases when the decision makers are optimally clustered and when they are not, show that in the latter case the decision makers receive lower weights of respect from other members in the group. Various tests showed that our approach is efficient in cases when no clusters can be visually and undoubtedly identified, especially if the number of group members is high.

Ansah et al. (2015) briefly discussed Multi Criteria Decision Making (MCDM) and AHP and suggested as one of the most popular MCDM methods for group decision making [11]. Also, steps, techniques and formulae used in AHP have been discussed to help handle the problems arising from choosing alternative(s). Finally, authors offered recommendations to researchers and professionals to apply AHP methodology techniques when analysing multiple, complicated and conflicting decision-making problems. Lee (2016) focused mainly on the comparison of two AHP approaches by examining weight vectors generated from a previous case study [12]. It was found that priority weights could be significantly different depending on the design of fuzzy membership functions and the way of aggregating experts' opinions. In general, error rates tended to increase as more factors were involved in an evaluation matrix. On the whole, APRH5 showed the best performance when compared with a traditional AHP method in terms of priority weights and root mean square errors. APRH2 also displayed a good performance in the evaluation process. But, APRH3 generated the worst performance since it showed higher error rates and too many zero weights. The main limitation of the study was to utilize one case study. The author made an effort to search a lot of previous studies, but could not obtain real case study data. Almost all previous studies attempted to develop a generic model and only showed an illustration example with fictitious numbers. Although one case study was analyzed in this article, it is a real case study where all numbers are real captured from surveys.

Görener (2012) proposed to enhance SWOT analysis with multi-criteria decision making techniques called Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) [13]. AHP approach achieves pairwise comparisons among factors or criteria in order to prioritize them at each level of the hierarchy using the eigenvalue calculation. In addition to AHP, ANP technique is a general form that allows interdependencies, outer dependencies and feedbacks among decision elements in the hierarchical or non-hierarchical structures. The main purpose of this paper is to explain how to use the AHP and ANP methods for prioritize of SWOT factors and compare them.

Awasthi et al. (2011) presented a multi-criteria decision-making approach for location planning for urban distribution centers under uncertainty [14]. The proposed approach involves identification of potential locations, selection of evaluation criteria, use of fuzzy theory to quantify criteria values under uncertainty and application of fuzzy TOPSIS to evaluate and select the best location for implementing an urban distribution center. Sensitivity analysis is performed to determine the influence of criteria weights on location planning decisions for urban distribution centers. The strength of the proposed work is the ability to deal with uncertainty arising due to a lack of real data in location planning for new urban distribution centers. The proposed approach can be practically applied by logistics operators in deciding on the location of new distribution centers considering the sustainable freight regulations proposed by municipal administrations. A numerical application is provided to illustrate the approach. Özdağoğlu & Özdağoğlu the comparison of classical AHP and fuzzy AHP on a case study that is constructed for the same hierarchy structure and criteria set [15].

3. Methodology

3.1. Research Methodology

This research aims to study the factors influencing the planning a development plan regime, identifying the variables in the planning process and also to formulate the modified planning standards for optimization of reservations in a development plan. To understand the issues related to the planning standards and planning process for any city or town and to develop a model in formulating strategies for significant and useful modification in planning standards; an approach with descriptive research and an exploratory Fuzzy AHP tool is adopted. In the primary stage of the work, the investigation of past attempts made by researchers for methods adopted for similar works, related to planning standards and planning process for preparation of development plan, was done and an analysis of these attempts was carried out for a better understanding of the planning process scenario. The flowchart of the research methodology that was used to achieve the study's aims is shown in Figure 1.

A detailed literature review and collection of secondary data related to the study area was done. Both are used to get the knowledge about the various settings of the study area and planning process for its development plan. These secondary data acquired from various Government Departments/Organizations are analyzed to acquire site-specific information in the format required for further analysis using Fuzzy AHP method. This acquired information is then coupled with the knowledge obtained through a thorough literature study and used in the analysis using Fuzzy AHP method, along with the field observations of locations of the reservations and their needs and necessities considered by the planners during planning process and then formulating the modifications to the planning standards and planning process for optimization of reservation so as to get efficient implementation of a development plan. Finally, modified planning standards for development plan, considered changing needs and requirements commensurate with the changing time, have been developed using the research methodology. This work uses a weightage and ranking based Fuzzy AHP analysis to identify the growth pattern being considered in planning process to select the most sustainable alternative.

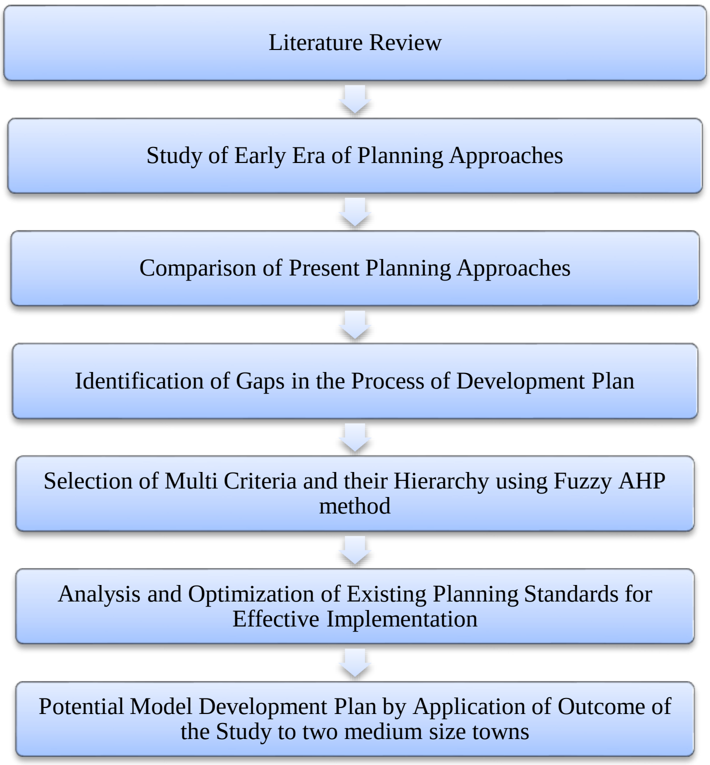

Figure 1. Flow Chart of Research Approach

3.2. Application of F-AHP Method

Analytical Hierarchy Process (AHP) is one of the best ways for deciding among the complex criteria structure in different levels. AHP is a method for ranking decision alternatives and selecting the best one when the decision maker has multiple criteria [16]. In AHP, preferences between alternatives are determined by making pairwise comparisons. In a pairwise comparison, the decision maker examines two alternatives by considering one criterion and indicates a preference. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference [17].

Since 1977, Saaty [18] proposed AHP as a decision aid to help solve unstructured problems in economics, social and management sciences. AHP has been applied in a variety of contexts: from the simple everyday problem of selecting a school to the complex problems of designing alternative future outcomes of a developing country, evaluating political candidacy, allocating energy resources, and so on. The AHP enables the decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environments in confliction. The application of the AHP to the complex problem usually involves four major steps [19]:

- Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form.
- Make a series of pair wise comparisons among the elements according to a ratio scale.
- Use the eigenvalue method to estimate the relative weights of the elements.
- Aggregate these relative weights and synthesize them for the final measurement of given decision alternatives.

If decision makers are provided with semantic descriptions and numerical intervals that are different from clear traditional dichotomy to integrate similar and ambiguous information, Fuzzy AHP proves to more advantageous as compared to other standard methods. Fuzzy AHP is a synthetic extension of classical AHP method when the fuzziness of the decision maker is considered. Regarding the application and handling of FMCDA, many studies have shown that FAHP is a fundamental and widely used method. This method presents a strong ability for tackling the qualitative multi-criteria evaluation problem by combining the concept of fuzzy theory with a hierarchical structure. This can effectively help decision makers to make more rational assessments under the hierarchical framework of specific issues through systematic mathematical operations.

Many fuzzy AHP methods are proposed to solve various types of problems. The EAFAHP was first introduced by Chang in (1992) [20]. For ascertaining the priorities of the evaluation criteria, the pairwise comparison of triangular fuzzy numbers is implemented, and the extent analysis for the synthetic extent value of the pairwise comparison is applied. The fuzziness of the data involved in determining preferences for the various evaluation criteria can be adequately solved through FAHP. This FAHP has been comprehensively applied to various fields' research [21].

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision-making problems based on decision maker's judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches. So, many researchers including Boender et al. (1989) [22]; Buckley (1985/a) [23], (1985/b) [24], Chang (2022) [25]; Coffey & Claudio (2021) [26]; Lootsma (1997) [27]; Martínez et al. (2022) [28] who have studied the fuzzy AHP which is the extension of Saaty's theory, have provided evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision-making processes compared to the traditional AHP methods.

3.3. Application of F-AHP on Selected Criteria's

Fuzzy Analytic Hierarchy Process is a method of Analytic Hierarchy Process (AHP) developed with fuzzy logic theory. Fuzzy AHP method is used similar to the method of AHP to calculate the weights of criteria. It is just that the fuzzy AHP method sets the AHP scale into the fuzzy triangle scale to be accessed in priority. Three main criteria and 21 sub-criteria were selected to arrive at a decision-making model and hierarchy [29, 30]. A questionnaire survey was conducted amongst the technical experts, academicians and industrialists. A total of 206 responses were obtained, which were then analyzed to make certain decisions. The following steps are followed to obtain the weights and ranks for the criteria.

Step 1: Pair-Wise Comparison Matrix obtained from the responses of questionnaire.

Step 2: Fuzzified Comparison Matrix developed from Crisp Numbers using fuzzy triangular scale.

Step 3: Calculation of Fuzzy Geometric Mean Value.

Step 4: Fuzzy Weight Matrix obtained from Geometric Mean Value.

Step 5: De-Fuzzification done to get crisp numeric values for further analysis and work.

Step 6: Normalized weights and ranks obtained.

Sample calculations for Criteria-I is given below and same is followed for all the criterions.

The first important step in FAHP is creating the Pair-Wise Comparison Matrix. This Pair-Wise Comparison Matrix is created with the help of Scale of Relative Importance. The Pair-Wise Comparison Matrix of Criteria-I from the responses obtained is as follows (Table 1).

Table 1. Pair-Wise Comparison Matrix of Criteria I

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1	3	$1/3$	4	3	$1/4$	$1/4$	3
2	$1/3$	1	4	$1/3$	4	4	$1/4$	4
3	3	$1/4$	1	4	4	3	4	2
4	$1/4$	3	$1/4$	1	$1/3$	$1/4$	$1/5$	$1/3$
5	$1/3$	$1/4$	$1/4$	3	1	$1/3$	$1/4$	3
6	4	$1/4$	$1/3$	4	3	1	$1/3$	4
7	4	4	$1/4$	5	4	3	1	5
8	$1/3$	$1/4$	$1/2$	3	$1/3$	$1/4$	$1/5$	1

On replacing the crisp numeric values with fuzzy numbers based on a fuzzy triangular scale, the fuzzy comparison matrix is obtained (Table 2).

Table 2. Fuzzified Comparison Matrix of Criteria I

	1	2	3	4	5	6	7	8
1	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)
2	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(3,4,5)
3	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(3,4,5)	(3,4,5)	(2,3,4)	(3,4,5)	(1,2,3)
4	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$
5	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)
6	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)
7	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(4,5,6)	(3,4,5)	(2,3,4)	(1,1,1)	(4,5,6)
8	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(2,3,4)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)

Geometric Mean Method which was proposed by Buckley in 1985 is used to calculate weights. Fuzzy Geometric Mean Value is calculated using following Equation (Table 3):

$$\widetilde{A_1}\otimes\widetilde{A_2} = (l_1, m_1, u_1)\otimes(l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \tag{1}$$

Sample Calculations:

$$r_i = [(1\times3\times\frac{1}{4}\times3\times2\times\frac{1}{5}\times\frac{1}{5}\times2)^{1/8}, (1\times4\times\frac{1}{3}\times4\times3\times\frac{1}{4}\times\frac{1}{4}\times3)^{1/8}, (1\times5\times\frac{1}{2}\times5\times4\times\frac{1}{3}\times\frac{1}{3}\times4)^{1/8}] \tag{2}$$

Table 3. Fuzzy Geometric Mean Values of Criteria I

	1	2	3	4	5	6	7	8	Fuzzy Geometric Mean Value r_i
1	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.836, 1.106, 1.432]
2	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(3,4,5)	[0.918, 1.277, 1.639]
3	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(3,4,5)	(3,4,5)	(2,3,4)	(3,4,5)	(1,2,3)	[1.468, 2.029, 2.586]
4	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	[0.337, 0.423, 0.556]
5	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.459, 0.594, 0.787]
6	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	[0.952, 1.232, 1.593]
7	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(4,5,6)	(3,4,5)	(2,3,4)	(1,1,1)	(4,5,6)	[1.904, 2.426, 2.996]
8	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(2,3,4)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)	[0.359, 0.462, 0.638]

The Fuzzy Weights for every sub-criterion is calculated using Equation 3:

$$W_i = r_i \times (r_1 + r_2 + \ldots\ldots + r_n)^{-1} \tag{3}$$

After multiplying each fuzzy geometric mean value with the reciprocals, following matrix is obtained (Table 4).

Table 4. Fuzzy Weight Matrix of Criteria I

	1	2	3	4	5	6	7	8	Fuzzy Geometric Mean Value r_i	Fuzzy Weights W_i
1	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.836, 1.106, 1.432]	(0.068, 0.115, 0.197)
2	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(3,4,5)	[0.918, 1.277, 1.639]	(0.075, 0.133, 0.226)
3	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(3,4,5)	(3,4,5)	(2,3,4)	(3,4,5)	(1,2,3)	[1.468, 2.029, 2.586]	(0.120, 0.212, 0.357)
4	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	[0.337, 0.423, 0.556]	(0.027, 0.442, 0.076)
5	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.459, 0.594, 0.787]	(0.037, 0.062, 0.108)
6	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	[0.952, 1.232, 1.593]	(0.078, 0.129, 0.220)
7	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(4,5,6)	(3,4,5)	(2,3,4)	(1,1,1)	(4,5,6)	[1.904, 2.426, 2.996]	(0.156, 0.254, 0.410)
8	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(2,3,4)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)	[0.359, 0.462, 0.638]	(0.029, 0.048, 0.088)

De-Fuzzification is done to get crisp numeric values for further analysis and work (Table 5).

$$COA = w_i = \left(\frac{l + m + u}{3}\right) \tag{4}$$

Table 5. De-Fuzzified Weights of Criteria I

	1	2	3	4	5	6	7	8	Fuzzy Geometric Mean Value $\tilde{r}_i$	Fuzzy Weights W_i	De-Fuzzified Weights
1	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.836, 1.106, 1.432]	(0.068, 0.115, 0.197)	0.126
2	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(3,4,5)	[0.918, 1.277, 1.639]	(0.075, 0.133, 0.226)	0.144
3	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(3,4,5)	(3,4,5)	(2,3,4)	(3,4,5)	(1,2,3)	[1.468, 2.029, 2.586]	(0.120, 0.212, 0.357)	0.229
4	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	[0.337, 0.423, 0.556]	(0.027, 0.442, 0.076)	0.181
5	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.459, 0.594, 0.787]	(0.037, 0.062, 0.108)	0.069
6	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	[0.952, 1.232, 1.593]	(0.078, 0.129, 0.220)	0.142
7	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(4,5,6)	(3,4,5)	(2,3,4)	(1,1,1)	(4,5,6)	[1.904, 2.426, 2.996]	(0.156, 0.254, 0.410)	0.273
8	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(2,3,4)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)	[0.359, 0.462, 0.638]	(0.029, 0.048, 0.088)	0.055
Sum											**1.219**

Since the sum of the defuzzified weights is greater than 1, it is required to find the normalized weighted matrix, which is found by simply dividing the weights by the total value, and then the ranking is given (Table 6).

Table 6. Normalized Weights and Ranks of Criteria I

	1	2	3	4	5	6	7	8	Fuzzy Geometric Mean Value r_i	Fuzzy Weights W_i	De-Fuzzified Weights	Normalized Weights	Rank
1	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.836, 1.106, 1.432]	(0.068, 0.115, 0.197)	0.126	0.103	VI
2	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(1,1,1)	(3,4,5)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(3,4,5)	[0.918, 1.277, 1.639]	(0.075, 0.133, 0.226)	0.144	0.118	IV
3	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	(3,4,5)	(3,4,5)	(2,3,4)	(3,4,5)	(1,2,3)	[1.468, 2.029, 2.586]	(0.120, 0.212, 0.357)	0.229	0.187	II
4	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	[0.337, 0.423, 0.556]	(0.027, 0.442, 0.076)	0.181	0.148	III
5	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(2,3,4)	[0.459, 0.594, 0.787]	(0.037, 0.062, 0.108)	0.069	0.056	VII
6	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	(2,3,4)	(1,1,1)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	(3,4,5)	[0.952, 1.232, 1.593]	(0.078, 0.129, 0.220)	0.142	0.116	V
7	(3,4,5)	(3,4,5)	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	(4,5,6)	(3,4,5)	(2,3,4)	(1,1,1)	(4,5,6)	[1.904, 2.426, 2.996]	(0.156, 0.254, 0.410)	0.273	0.223	I
8	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{3},\frac{1}{2},\frac{1}{1})$	(2,3,4)	$(\frac{1}{4},\frac{1}{3},\frac{1}{2})$	$(\frac{1}{5},\frac{1}{4},\frac{1}{3})$	$(\frac{1}{6},\frac{1}{5},\frac{1}{4})$	(1,1,1)	[0.359, 0.462, 0.638]	(0.029, 0.048, 0.088)	0.055	0.045	VIII
Sum											**1.219**		

The summarized table and ranking of all the 21 criterions is given Table 7.

Table 7. Ranking of all 21 Criterions

Sr. No.	Main Criteria	Sub-Criteria	Weights	Ranks
1.	Pre-Planning	Backlogs in the previous plan	0.103	VI
2.		Aim / vision of the Plan	0.118	IV
3.		Objectives to achieve the Plan	0.187	II
4.		3D or Satellite imagery ELU instead of 2D map	0.148	III
5.		City Character (Industrial, Tourism, Coastal, etc.)	0.056	VII
6.		Existing Growth Direction of the City (Sprawl)	0.116	V
7.		Accuracy in Population & Density forecasting for next 20years considering Opportunities available in city like Employment, Education, etc.	0.223	I
8.		Major reason for Revision	0.045	VIII
9.	Preparation of DP	Use of modified Tools and Practices (GIS, Geo Referencing, AutoCAD, etc.)	0.176	III
10.		Modification as per Class of Municipal Council and Corporation in Statutory Provisions of Planning Standards	0.072	V
11.		Decentralized allocation of amenities	0.048	VII
12.		Progressive FSI	0.224	II
13.		Combination Reservation	0.051	VI
14.		Involvement of Expert / Stakeholder in Planning Unit	0.086	IV
15.		Sustainability in Planning	0.340	I

16.		PPP / Stakeholder Promotion	0.040	VI
17.		Criteria's to be considered during Implementation of DP- Monitoring for Proposal outcomes	0.063	V
18.		Criteria's to be considered during Implementation of DP- Preparation of short term / 5 Years Plans for Infrastructure Development	0.164	III
19.	Implementation of DP	Criteria's to be considered during Implementation of DP- Preparation of Annual Plans for Financial Management	0.236	II
20.		Criteria's to be considered during Implementation of DP- Land as Resources for Town Planning Schemes, Townships, Major Specific Area Development Projects (Land Acquisition)	0.095	IV
21.		Criteria's to be considered during Implementation of DP- Pollution free, Zero Carbon Footprints by Promoting to Public Transports with Plans / Schemes like JNNURM	0.398	I

4. Conclusion

According to the literature survey, there was a need for major revisions in planning standards. The research has focused heavily on group decision-making through the AHP. As the opinions of all people, including public academicians, bureaucrats, engineers, officials, etc., were collected through a survey, this integrated framework is inclusive, and thus ranking through FAHP includes all stakeholders' opinions. From the study and analysis using F-AHP MCDM, we reached the proposed outcome with the assignment of weights to the selected criteria and the preparation and implementation of the development plan for the towns.

From the pre-planning criteria, it has been observed that sub-criteria: accuracy in population and density forecasting for the next 20 years considering opportunities available in cities like employment, education, etc., gained the highest weight, and sub-criteria: the major reason for revision was weighted the least. Sustainability in planning received the highest ranking in the development of DP criteria, while decentralized allocation of amenities received the lowest. From the implementation of DP criteria, sub-criteria: implementation of DP (pollution free, zero carbon footprints) by promoting public transport with plans and schemes like JNNURM gained the highest weight, and sub-criteria: PPP/stakeholder promotion got the least weight and rank. These results were used for two semi-urban towns in Maharashtra regions and could also be used by planning engineers for further development of planning standards. Future research focused on the effectiveness of coupling our two consensual AHP-group approaches could be very promising. The study can be augmented further based on the local area or town.

5. Declarations

5.1. Author Contributions

Conceptualization, R.K.J. and R.M.; methodology, P.B. and D.A.J.; software, A.R. and D.A.J.; validation, P.B. and A.R.; formal analysis, P.B., A.R., and R.M.; writing—original draft preparation, P.B. and A.R.; writing—review and editing, P.B. and A.R.; project administration, P.B. and D.A.J. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in the article.

5.3. Funding

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5.4. Conflicts of Interest

The authors declare no conflict of interest.

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