Prioritizing The Indicators Responsible For Sustainable Municipal Solid Waste Management Using SF-AHP And SF-TOPSIS

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Abstract

Municipal corporations in small cities in India are struggling with the challenges that emerge from the unstructured solid waste management system. For successful implementation of the municipal solid waste management system, all the basic components of this system need to work effectively and efficiently. Identification of performance indicators is completed with the help of a literature review and expert information. Interviews were conducted with the experts working in the field of solid waste management, and three decision criteria, i.e., importance, performance, and understandability, were defined to evaluate the selected performance indicators. For uncertainties, criteria weights were established using the spherical fuzzy analytical hierarchy process approach, and the combined pairwise comparison matrix was aggregated by applying the spherical fuzzy TOPSIS method. Eventually, the indicators responsible for sustainable waste management were selected and ranked. An assessment of the conceptual framework of MSWM is also proposed for the practical implementation of the ranked indicators for the MSWM system in Dinanagar and other cities with similar situations.

Keywords: Waste Management, fuzzy logic, AHP, TOPSIS

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1. Introduction

Unscientific and unplanned waste management is increasingly becoming a major reason of environmental issues in the cities of developing countries. Municipal solid waste management (MSWM) is one of the major task creating many challenges for the Municipal Corporations, in Indian cities. The rise in population and urbanization also increases the waste generation quantity. As the life style of the population changes, the number of different kinds of discarded material also changes.

Waste management is one of the most important concerns in environmental protection and natural resource conservation. To manage solid waste, a variety of approaches can be used. MSWM is a complicated topic that is influenced by a number of specific aspects relating to the state of the country. For decision makers, choosing the optimal option for handling and managing MSW in terms of environmental quality and economic value is a critical priority. The use of Multi Criteria Decision Making (MCDM) under spherical fuzzy environment in MSWM is still limited. According to the findings of several research, this approach has the ability to handle dataset uncertainty, and decision makers can readily evaluate attributes using linguistic expressions. Human beings are the worlds largest source of garbage, everyone has the power and obligation to prevent it. Waste management has become a key issue to address on a priority basis as a result of negligence. Waste is treated as a resource rather than trash or garbage all over the world. Research and Development is

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becoming increasingly popular for resource management. Researchers in all disciplines are continuously focusing on recreating valuable resources from the trash. Nowadays, the 6 R's strategy (Refuse, Reduce, Repair, Reuse, Recover, Recycle) could be adopted in tandem with modern technological inventions. In general developing countries produce more waste than that of under development. The government of every country initiated various projects to alter the different type of waste to resources.

This research will lead to better waste management planning and decision-making. In addition, waste will be managed self-sustainably to some extent through effective application of the recommended methodology.

2. Literature review

All the extensions of ordinary fuzzy sets with three dimensional membership functions such as Intutionistic fuzzy sets (IFS), Intutionistic fuzzy sets of second type (IFS2), and neutron-sophic fuzzy sets (NFS) aim at defining the judgments of decision makers/experts with a more detailed description. The authors of Kutlu Gundo¨ gdu & Kahraman (2019(a) in-˘ troduced a generalized three dimensional spherical fuzzy sets (SFS) including some essential differences from the other fuzzy sets is presented in the paper. Chen (2018) proposed a remoteness index-based PFVIKOR methodology that considers uncertain information represented by PF values and conducted two types of problems; service quality and internet stock performance evaluation, and internet stock and R&D project investment problems. Cui et al. (2018) developed a PFVIKOR approach to solving the electric vehicle charging stations (EVCSs) site selection problems. Emec¸ & Akkaya (2018) developed a stochastic MCDM approach to solving the warehouse location problem in the stochastic environment which contains an uncertain condition. In this approach, the weights of the used criteria were calculated by using the stochastic AHP. The alternatives' ranking was evaluated by FVIKOR. Liu et al. (2018) presented an integrated ANP (analyti-cal network process) and FVIKOR method using IT2FSs to solve supplier selection problem in sustainable supply chain management. Zhou et al. (2018) developed an extended FVIKOR based model for

Table 1: Linguistic terms, SFN and score index for constructing PCM

Linguistic terms	Spherical fuzzy number	Score index
Absolutely strong important	[0.9,0.1,0.0]	9
Very strong important	[0.8,0.2,0.1]	7
Fairly strong important	[0.7,0.3,0.2]	5
Slightly strong important	[0.6,0.4,0.3]	3
equal important	[0.5,0.4,0.4]	1
Slightly low important	[0.4,0.6,0.3]	1/3
Fairly low important	[0.3,0.7,0.2]	1/5
Very low important	[0.2,0.8,0.1]	1/7
Absolutely low important	[0.1,0.9,0.0]	1/9

the construction of a robotic automation system in the healthcare industry. Khan et al. (2019) proposed a broad new extension of classical VIKOR method for decision-making problems with Pythagorean hesitant fuzzy information. Phochanikorn et al. (2020) also proposed a method based on AHP and VIKOR to help business analysis and supply chain managers formulate both short-term and long-term flexible decision strategies for successfully managing and implementing reverse logistics adoption in the supply chain scenarios. Kutlu Gundo¨ gdu et al. (2019(b) employed SFVIKOR to tackle a waste management prob-˘lem. In Kaur et al. (2022) an efficient algorithm is developed by the authors with the help of combination theory and combined fuzzy TOPSIS method to choose the best suitable alternative out of all possible single and hybrid energy resources in Turkey. In Dhara et al. (2021) the authors proposed an approach to determine the light business jet aircraft would provide long-range, less travel time, cozy seating arrangements, on-board lavatory facility, other aesthetic ambiance (audio systems, light systems and temperature-noise control) and appliances at reasonable flight cost.

3. Evaluation of selected methodology

This research is based on the article Mathew et al. (2020a), a novel framework is elaborated which combines AHP and TOPSIS with a spherical fuzzy set. Spherical fuzzy AHP is used to calculate the spherical fuzzy weights of the criteria, while spherical fuzzy TOPSIS is used to find the final rank of the multiple alternatives. A new spherical fuzzy geometric mean formula is proposed for calculating the spherical fuzzy criteria weights. A new eleven-point spherical fuzzy linguistic term scale is presented, which can be used by the experts to quantify the preference. The step by step procedure is as follows:

Table 2: Eleven point spherical fuzzy linguistic term scale.

Linguistic terms	Spherical fuzzy number
Extremely low	[0.045,0.955,0.045]
Very low	[0.135,0.865,0.135]
Low	[0.255,0.745,0.255]
Fair	[0.335,0.665,0.335]
Medium	[0.410,0.590,0.410]
Good	[0.500,0.500,0.500]
Very good	[0.590,0.410,0.410]
High	[0.665,0.335,0.335]
Very high	[0.745,0.255,0.255]
Exceptionally high	[0.865,0.135,0.135]
Excellent	[0.955,0.045,0.045]

Table 3: Random indices for consistency ratio Saaty & Vargas (1980)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3.1. Stage1: Spherical fuzzy analytical hierarchy process (SF-AHP)- To construct SF weights of criteria

This stage involves major three steps: Firstly, structure decision hierarchy by defining criteria for selected performance indicators through decision makers or experts. Secondly, construct the spherical fuzzy pairwise comparison matrix(SF-PCM) with the help of expert(s) to determine criteria weights on the basis of 9-pt linguistic scale given in table 1, using SF-AHP. In case of multiple experts the PCM has to be constructed by each expert and then the combined SF-PCM will be computed using spherical fuzzy geometric mean(SFGM). Let $\widetilde{S}_{GM_i}$ be the SFGM for criteria *i* is as follows:

$$\widetilde{S}_{GM_i} = (\widetilde{S}_{i1} \times \widetilde{S}_{i2} \times \ldots \times \widetilde{S}_{in})^{\frac{1}{n}}$$

$$= \left[\prod_{j=1}^{n} (\mu_{ij})^{\frac{1}{n}}, \sqrt{1 - \prod_{j=1}^{n} (1-\nu_{ij}^2)^{\frac{1}{n}}}, \sqrt{\prod_{j=1}^{n} (1-\nu_{ij}^2)^{\frac{1}{n}} - \prod_{j=1}^{n} (1-\nu_{ij}^2 - \pi_{ij}^2)^{\frac{1}{n}}} \right] \quad (1)$$

Let $[P_{eij}^1]_{n\times n}, [P_{eij}^2]_{n\times n}, \ldots, [P_{eij}^k]_{n\times n}$ be the SF-PCM for different $^0k^0$ number of experts.

So, the combined SF-PCM will be calculated as:

$$[\widetilde{P}_{ij}^C]_{n\times n} = ([\widetilde{P}_{ij}^1]_{n\times n} \otimes [\widetilde{P}_{ij}^2]_{n\times n} \otimes \ldots \otimes [\widetilde{P}_{ij}^k]_{n\times n})^{\frac{1}{k}}$$

where

$$[\widetilde{P}_{ij}^k]_{n\times n} = \begin{bmatrix} \widetilde{S}_{11} & \widetilde{S}_{12} & \ldots & \widetilde{S}_{1n} \\ \widetilde{S}_{21} & \widetilde{S}_{22} & \ldots & \widetilde{S}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{S}_{n1} & \widetilde{S}_{n2} & \ldots & \widetilde{S}_{nn} \end{bmatrix}$$

for all finite *k* and $S_{ij} = (\mu_{ij}, \nu_{ij}, \pi_{ij})$ for $i,j = 1,2,\ldots,n$.

Last and important step is to check the consistency ratio, $CR = \frac{CI}{RI}$ which should be less than 0.1 and is calculated by taking the corresponding score index number of values substituted in pairwise comparison matrix. Eventually, the second step is completed with the satisfying condition of consistency ratio. The score index is calculated by equation:

$$SI = (|100 \times ((\mu-\pi)^2 - (\nu-\pi)^2)|)^{\frac{1}{2}}.$$

Consider the same formula as $\frac{1}{SI}$ to find the inverse of score index corresponding to the spherical fuzzy number. Finalize, weights of criteria using formula (1) of SFGM, if the CR is satisfied otherwise reconstruct the SFPCM.

3.2. Stage2: Spherical fuzzy technique for order preference by Similarity to ideal solution (SFTOPSIS)- To select the best indicator/alternative

At this stage, we apply SF-TOPSIS method proposed in the article Kutlu Gundo¨ gdu˘ & Kahraman (2019(a) with 11-pt spherical fuzzy linguistic term scale shown in table 2. This stage includes six steps: 1. Initially, construct the spherical fuzzy evaluation matrix using eleven point SF linguistic term scale. 2. Construct the weighted SF evaluation matrix by multiplying the weights of criteria with the SF evaluation matrix. 3. Calculate the SF positive and negative ideal solutions of defuzzified weighted SF evaluation matrix. The formula (2) to defuzzify the SFN adopted from the article Kutlu Gundo¨ gdu & Kahraman˘ (2020). 4. Now, find the Euclidean distance from SF-PIS and SF-NIS for each alternatives using the formula (3) and (4.) 5. Calculate relative closeness to the SF positive and negative ideal solutions based on the formula (5). 6. Finally, based on the values of relative closeness assign the ranking to multiple alternatives such that the best one is ranked with higher value.

$$\sqrt{|100 \times [(3\mu - \frac{\pi}{2})^2 - (\frac{\nu}{2} - \pi)^2]|} \quad (2)$$

$$D^+ = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}((\mu_j - \mu_j^+)^2 + (\nu_j - \nu_j^+)^2 + (\pi_j - \pi_j^+)^2)} \quad (3)$$

$$D^- = \sqrt{\frac{1}{2n}\sum_{j=1}^{n}((\mu_j - \mu_j^-)^2 + (\nu_j - \nu_j^-)^2 + (\pi_j - \pi_j^-)^2)} \quad (4)$$

$$C = \frac{D}{\min D^-} - \frac{D}{\max D^+} \text{ or } C = \frac{D}{D^- + D^+} \quad (5)$$

4. Application to MSWM- A case study of Indian city, Dinanagar

4.1. Current situation in study area

Parameters	Numbers or %
Municipal Corporation Area:	14.36 km sq.
Total No. of wards:	15
Total Houses:	5637
Population in each ward:	376(approx.)
Total Population(2011):	23976
Present Population(2021):	25376(approx.)
Literacy rate:	88.66%
Male Literacy:	92.26%
Female Literacy:	84.73%
State avg. Literacy rate:	75.84%

The study area selected in this research is Dinanagar, which is a small city located in Punjab, India. The details of this area is shown in table 4. Waste management practices in Punjab is more challenging because of various reason such as human resources, financial and political constraints influencing the effective-eness of SWM process in the cities. The Municipal corporation, Dinanagar city of Punjab (India) is facing a lot of hindrances due to insufficient funds for maintaining the services related waste management, non-supportive behavior of urban local bodies, unawareness and lack of interest of inhabitants. It is observed via thorough literature review over Indian cities that the problems or challenges related to MSWM are different in different cities so there is need to monitor the WM practices at local level. Municipal solid waste management (MSWM) is one of the major task creating many challenges Malav et al. (2020) for the Municipal corporations, in India Joseph (2014). The rise in population and urbanization also increases trash generation. As the lifestyle of the population changes, the number of produced garbage kinds also increased. For MSWM, the collection of waste materials from primary, secondary or other source is the major problem. According to municipal corporations and in literature, it is clear that the expenditure over waste management is almost 70-80 percent of municipalities total budget. Instead of trash treatment, the major objective of this research is to concentrate on waste minimization by examining existing adapted strategies. This study will lead to better waste management planning and decision-making.The generators of MSW are broadly categorize into Residential and Non-residential waste. Further, the residential waste includes kitchen waste(left over food items), paper, cardboard, plastic, sanitary waste, inert and Non-residential waste includes bulk quantity of refused fruit, vegetables, packaging cardboard, plastic, construction & demolition waste, Industrial, restaurants & hotels waste etc. In Dinanagar, the average Municipal solid waste generation is about 6 metric tonnes (only of residential area, no record found for non-residential contribution in trash production), and typical physical composition of waste is mainly three types biodegradable, non-biodegradable, and hazardous. No any record is available for chemical composition of waste generated in city. The Indian government establishes new targets to minimize the quantity of biodegradable waste in landfill or dumping sites. To achieve this target, the composting is primarily solution in small municipality like Dinanagar. Using this technique the waste volume is reduced by 50-65%. Composting can be done either manually or mechanically. Presently,

33 number of manual compost- Table 4: Details of Study area-Dinanagar ing pits at different locations are Source:Census of India and MCD successfully maintained by Municipal Corporation of Dinanagar (MCD). There is need to improve the collection, treatment and disposal rate of generated waste. The population of Dinanagar is 25376 inhabitants and 15 square km land area which is further distributed in 15 wards with average of 376 inhabitants each. The MSW generated is only

about 0.20.25 kg/capita/day, of which 60% is wet waste, 40% is dry waste and only 50-60% of generated waste in the city is collected with the utilization of presently provided collection services. In particular, material recovery facility (MRF) is also adapted by the MCD to treat all metal, paper and plastic from the perspective of cost management. The need of effective and efficient MSWM is increasing as the poor management contributes adverse effects on economy, health, environment and one major threat is increase in Green House Gas (GHG) emissions which further responsible for global warming due to uncollected /untreated waste lying in open dump sites. The inefficient collection and treatment services are the reasons for unsuccessful practices of MCD.

4.2. Defining criteria and indicators

Three criteria were defined C1-importance, C2-performance and C3-understandability based on judgments by the experts. Furthermore, a communication considering present condition of MSWM was done with experts of waste management. It led to define different alternatives-performance indicators responsible for sustainable municipal solid waste management. Some performance indicators (PIs) were identified by thorough literature review and some were developed by the experts based on the actual situation of study area. Finally, the potential PIs were selected by the experts as per the limitations like data availability and other inadequacies (shown in table 5).

Table 5: Selected performance indicators for sustainable MSWM

Performance indicators (PIs)	
Operational	**Economic**
-waste minimization	-collection cost per ton of generated waste
-six Rs policy	-transportation cost
-composition of waste generated	-sorting cost
-waste collection & handling	-cost of operating & maintaining composting facilities
-segregation of waste at source level	-recycling cost
-composting facility	-disposal cost of rejected waste
-material recovery facility	-losses due to inefficient MSWM
-landfill & disposal sites	-operators revenue
Waste management staff	**Public service, participation and awareness**
-employees per ton of daily waste	-public satisfaction with waste management
-employees per 100 household served	-waste generation per capita per day
-employees for waste collection per 100 household served	-public participation in current practices
-employees working at MRF per ton of daily waste generated	-public acceptance for waste management plans & actions
-staff training & awareness	-performance of waste collection
-on duty accidents	-incentives for sorting at source level
-qualification of waste management staff	-recycling practices
-staff incentives	-public awareness about importance of MSWM
Technology & innovation	**Environmental**
-equipment/instrument relevance	-physicochemical quality parameters of Leachate
-equipment/instrument efficiency	-air quality parameters of leachate & landfill
-degree of innovation	-application of environment standards at disposal sites
-employees reluctance	-water saving
-technological capacity for adaptability	-visual and odor impact

As per the experts in the field of MSWM, the criteria matrix & PSPA evaluation matrix with their respective score indices are shown in appendix, table 13, 14, 15, 16.

4.3. Results and Discussions

The reason behind using the SF-AHP and SF-TOPSIS methods in prioritizing the indicators responsible for sustainable MSWM is the occurrence of uncertainty at various stages involved in waste management. Initially, spherical fuzzy evaluation matrix of PSPA (Public service participation & awareness) is constructed (shown in table 6). Now, the weighted SF PSPA evaluation matrix is constructed (shown in table 7) by multiplying the SF-PSPA with weights of criteria, calculated by SF-AHP (refer to table 10).

The SFP and SFN ideal solutions of defuzzified values (obtained in table 8) are also calculated and shown below the table 7. The relative closeness is calculated using the euclidean distances and finally the ranking of indicators PSPA is shown in table 9. From this table, it is clear that PU2 ranked 1, which means for effective implementation of MSWM the

Table 6: SF PSPA evaluation matrix

	C1			C2			C3		
	μ	v	π	μ	v	π	μ	v	π
PU1	0.865	0.135	0.135	0.5	0.5	0.5	0.745	0.255	0.255
PU2	0.745	0.255	0.255	0.955	0.045	0.045	0.865	0.135	0.135
PU3	0.865	0.135	0.135	0.41	0.59	0.41	0.5	0.5	0.5
PU4	0.59	0.41	0.41	0.335	0.665	0.335	0.5	0.5	0.5
PU5	0.745	0.255	0.255	0.865	0.135	0.135	0.665	0.335	0.335
PU6	0.5	0.5	0.5	0.59	0.41	0.41	0.255	0.745	0.255
PU7	0.41	0.59	0.41	0.355	0.665	0.335	0.5	0.5	0.5
PU8	0.745	0.255	0.255	0.5	0.5	0.5	0.59	0.41	0.41
SF wts	0.643	0.334	0.298	0.509	0.474	0.319	0.268	0.73	0.213

quantity of generated waste per capita per day has to be as accurate or certain as possible. After this, PU5 i.e., performance of waste collection is ranked at 2, which concludes that proper and in time collection of generated waste from sources led to maximize the expected revenue. The achievement of PU2 & PU5, the indicator PU1 i.e., public satisfaction is ranked with number 3. As per $\lambda_{max} = 3.2$ after consistency check (see table 11) the SF criteria weights are acceptable and the obtained $CI = 0.1$ and $CR = 0.089 < 0.1$.

5. Conclusion

The majority of multi-criteria decision-making procedures in the literature use scoring methods, which are quite basic. These strategies contain physical and intangible criteria in real-world challenges, which makes assigning a single numerical value difficult. For cases like this, fuzzy sets can be helpful. Although a wider range of linguistic scales introduces subjectivity into decision-making, the current article has applied the newly developed larger linguistic scale (moving from a five-point to a seven-point linguistic scale) that allows decision-makers to choose from a wider range of linguistic words. The framework is used to solve the problem of sustainable MSWM by prioritising the performance indicators, and it is discovered that the ranks generated from spherical fuzzy AHP-TOPSIS are the best. This approach can also be used in a variety of real-world problems involving uncertainty. In the future, the same method will be applied to the rest of the defined PIs to find the global ranking.

Data Availability

The author are thankful to Municipal Corporation Dinanagar to avail the data related to study area.

Table 7: Weighted SF PSPA evaluation matrix

Criteria	C1			C2			C3		
Indicators	μ	v	π	μ	v	π	μ	v	π
PU1	0.556	0.291	0.453	0.255	0.488	0.662	0.200	0.642	0.398
PU2	0.479	0.302	0.551	0.486	0.453	0.369	0.232	0.673	0.327
PU3	0.556	0.291	0.453	0.209	0.541	0.606	0.134	0.646	0.506
PU4	0.379	0.378	0.651	0.171	0.593	0.552	0.134	0.646	0.506
PU5	0.479	0.302	0.551	0.440	0.423	0.450	0.178	0.633	0.438
PU6	0.322	0.441	0.699	0.300	0.445	0.621	0.068	0.738	0.369
PU7	0.264	0.512	0.638	0.181	0.593	0.552	0.134	0.646	0.506
PU8	0.479	0.302	0.551	0.255	0.488	0.662	0.158	0.634	0.471
SFP	0.556	0.291	0.453	0.486	0.453	0.369	0.232	0.673	0.327
SFN	0.264	0.512	0.638	0.181	0.593	0.552	0.068	0.738	0.369

Table 8: Defuzzified values of table 7

Indicators	C1	C2	C3
PU1	14.087	1.088	3.923
PU2	10.905	12.657	5.320
PU3	14.087	0.892	1.063
PU4	6.690	1.002	1.063
PU5	10.905	10.694	2.915
PU6	3.864	4.361	0.204
PU7	2.770	0.726	1.063
PU8	10.905	1.088	1.828
Maximum	14.087	12.657	5.320
Minimum	2.770	0.726	0.204

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Table 9: Euclidean distances and rank of indicators

D+	D-	C	Rank
0.157	0.193	2.024	3
0.051	0.215	2.751	1
0.175	0.185	1.840	4
0.213	0.103	0.541	6
0.084	0.197	2.369	2
0.212	0.094	0.427	7
0.244	0.073	0.000	8
0.175	0.161	1.504	5
0.244	0.073		

Table 10: SF criteria weights using SFGM

	μ	v	π
C1	0.643	0.334	0.298
C2	0.509	0.474	0.319
C3	0.268	0.730	0.213

Table 11: Consistency check

	C1	C2	C3	Matrix weights	SFN weights	Ratios
C1	1.000	3.195	7.901	8.447	3.433	2.46
C2	0.319	1.000	4.742	3.107	1.087	2.858
C3	0.123	0.200	1.000	0.835	0.195	4.28
					λ_{max} =	3.2

Table 12: Ranking of indicators PSPA

Public service, participation and awareness	Short form	Ranking
Public satisfaction with waste management	PU1	3
Waste generation per capita per day	PU2	1
Public participation in current practices	PU3	4
Public acceptance for WM plans & actions	PU4	6
Performance of waste collection	PU5	2
Incentives for sorting at source level	PU6	7
Recycling practices	PU7	8
Public awareness about importance of MSWM	PU8	5

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Appendix

Table 13: Criteria matrix in linguistic terms by five experts using table 1

Experts	Criteria	C1	C2	C3
E1	C1	E	SS	AS
	C2	SL	E	FS
	C3	AL	FL	E
E2	C1	E	FS	VS
	C2	FL	E	VS
	C3	VL	VL	E
E3	C1	E	SS	AS
	C2	SL	E	FS
	C3	AL	FL	E
E4	C1	E	SS	AS
	C2	SL	E	SS
	C3	AL	SL	E
E5	C1	E	SS	AS
	C2	SL	E	FS
	C3	AL	FL	E

Table 14: PSPA evaluation matrix using 11 point scale given in table 2

Indicators	C1	C2	C3
PU1	EH	G	VH
PU2	VH	EX	EH
PU3	EH	M	G
PU4	VG	F	G
PU5	VH	EH	H
PU6	G	VG	L
PU7	M	F	G
PU8	VH	G	VG

Table 15: Score index of criteria for table 13

Experts	Criteria	C1	C2	C3
E1	C1	1.000	3.000	9.000
	C2	0.333	1.000	5.000
	C3	0.111	0.200	1.000
E2	C1	1.000	5.000	7.000
	C2	0.200	1.000	7.000
	C3	0.143	0.143	1.000
E3	C1	1.000	3.000	9.000
	C2	0.333	1.000	5.000
	C3	0.111	0.200	1.000
E4	C1	1.000	3.000	7.000
	C2	0.333	1.000	3.000
	C3	0.143	0.333	1.000
E5	C1	1.000	3.000	9.000
	C2	0.333	1.000	5.000
	C3	0.111	0.200	1.000

Table 16: SF-PCM from five experts

	C1			C2			C3		
Experts	μ	ν	π	μ	ν	π	μ	ν	π
	0.500	0.400	0.400	0.600	0.400	0.300	0.900	0.100	0.000
E1	0.400	0.600	0.300	0.500	0.400	0.400	0.700	0.300	0.200
	0.100	0.900	0.000	0.300	0.700	0.200	0.500	0.400	0.400
	0.500	0.400	0.400	0.700	0.300	0.200	0.800	0.200	0.100
E2	0.300	0.700	0.300	0.500	0.400	0.400	0.800	0.200	0.100
	0.200	0.800	0.100	0.200	0.800	0.100	0.500	0.400	0.400
	0.500	0.400	0.400	0.600	0.400	0.300	0.900	0.100	0.000
E3	0.400	0.600	0.300	0.500	0.400	0.400	0.700	0.300	0.200
	0.100	0.900	0.000	0.300	0.700	0.200	0.500	0.400	0.400
	0.500	0.400	0.400	0.600	0.400	0.300	0.800	0.200	0.100
E4	0.400	0.600	0.300	0.500	0.400	0.400	0.600	0.400	0.300
	0.200	0.800	0.100	0.400	0.600	0.300	0.500	0.400	0.400
	0.500	0.400	0.400	0.600	0.400	0.300	0.900	0.100	0.000
E5	0.400	0.600	0.300	0.500	0.400	0.400	0.700	0.300	0.200
	0.100	0.900	0.000	0.300	0.700	0.200	0.500	0.400	0.400

Table 17: Combined SF-PCM using SFGM for SF weight calculation

	C			C			C		
	μ	ν	π	μ	ν	π	μ	ν	π
C	0.50	0.40	0.40	0.61	0.38	0.28	0.85	0.14	0.06
C	0.37	0.62	0.30	0.50	0.40	0.40	0.69	0.30	0.21
C	0.13	0.86	0.05	0.29	0.70	0.20	0.50	0.40	0.40

Table 18: SFN of Combined SF-PCM to check the consistency

Criteria	C1	C2	C3
C1	1.000	3.195	7.901
C2	0.319	1.000	4.742
C3	0.123	0.200	1.000