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THE APPLICATION OF ANALYTIC HIERARCHY PROCESS (AHP) FOR SELECTING COMMUNITY PROBLEMS: MULTICRITERIA DECISION-MAKING APPROACH ON ENVIRONMENTAL HEALTH ASPECTS

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Abstract: Addressing environmental health problems within communities necessitates an approach that considers multiple factors. A multicriteria method can identify useful decisions for carrying out alternative aspects of environmental health. This cross-sectional study illustrates the utility of the analytic hierarchy process (AHP) technique, which is suitable for combining qualitative and quantitative factors across a wide area. This study aims to apply a multicriteria decision-making approach. Stakeholder opinions were collected and the Expert Choice software was utilised. The results showed that solid waste management was the most suitable alternative in addressing problems in the community, with a significance level of 34.3% (Consistency Ratio; C.R.≤ 0.1). Other alternatives were wastewater management (26.8%), air pollution management (25.3%), water consumption and quality (8.1%), and food safety and sanitation (5.6%). This study recommends the use of AHP as a crucial tool for prioritising environmental management plans to allocate resources necessary to mitigate adverse environmental health aspects within the community.

Keywords: Community problem, environmental health aspect, analytic hierarchy process, multicriteria decision-making approach.

Introduction

Pathum Thani province, located in central Thailand, presents a unique blend of rural and urban landscapes. However, the region faces several environmental health problems, specifically in its rural areas. The region lacks adequate management of its water consumption and water quality, solid waste, food safety and sanitation, air pollution, and wastewater. These five key environmental health elements play a vital role in preventing deaths and illnesses in the region (Takeuchi & Boonprab, 2006; Chiemchaisri *et al.,* 2008; Tsuzuki *et al.,* 2010; Vichit-Vadakan & Vajanapoom, 2011; Soticha *et al.,* 2014).

In 2020, a research team conducted a survey focusing on the five key environmental health elements within the community, involving 1,024,709 households. They found that 15.1% (154,731 households) do not have access to clean drinking water, an indicator of potential health risks. Furthermore, approximately 55% of households were discharging sewage and solid waste into public water sources. The increase in solid waste, the majority of which were organic (56.5%), and the practice of open dumping (25.3%) are common in several areas in Pathum Thani. Regarding sanitation and food safety, the survey indicated a high level of knowledge of food safety and sanitation (94.0%) among villagers, a moderate perception of food safety and sanitation (64.2%), and a moderate level of food safety and sanitation practice (53.0%). Regarding air pollution, enormous industrial estates are located in the area as the source of air pollution. Moreover, open burning prior to seasonal sowing is commonly practised in the area, the main source of air pollution in the community. Furthermore, both factories and households were found to release wastewater into the main river. These five key elements were included in the analytic hierarchy process (AHP). Making decisions for the public is a complex endeavour as it involves several stakeholders with different priorities with certain types of problems, particularly in aspects of environmental health. The application of AHP in this problem-solving process ensures the preservation of important information and guarantees the inclusion of controversial issues and unpredicted elements.

Multicriteria decision analysis (MCDA) plays a major role in decision analysis in the aspects of environmental health. (Achillas *et al.,* 2011; Diana *et al.,* 2021). MCDA has been used to assess alternative projects (Figueira *et al.,* 2005). It has also been used to assess the value judgements of individual decisions among multiple stakeholders.

This study combines MCDA and stakeholder analysis to resolve conflicts within the community, with the objective of addressing environmental health aspects in community problem-solving using the MCDA method.

This study addresses problems through the integration of AHP, MCDA, stakeholder's analysis, and the interest matrix (Saaty, 1980). The combination of AHP and stakeholder analysis is a well-documented approach in several studies, including in waste management (Contreras *et al.,* 2008; Geneletti, 2010; Shen *et al.,* 2012; Diana *et al.,*2021), environmental deterioration (Achillas *et al.,* 2011), project management selection (Bottero *et al.,* 2011), and disaster response (Hoscan & Cetinyokus, 2021). However, its application in determining environmental health aspects for community problem-solving planning remains relatively underexplored.

The application of AHP offers several advantages, including its stability and flexibility regarding changes within and addition to the hierarchy of structure. Additionally, AHP's capacity to rank criteria according to the needs of policymakers allows for more precise decision-making processes. However, AHP does come with some weaknesses. One such drawback is its complexity, which may be inconvenient to implement. The complexity is further exacerbated when multiple opinions exist regarding the weighting of criteria. Moreover, AHP relies on inputs from various decision makers, each drawing from their experience, knowledge and judgement. An associated disadvantage is the limited incorporation of risks and uncertainties associated with environmental health aspects in the community.

The study started with a community survey to identify environmental health aspects, and then was used to described all the importance factors. Subsequently, stakeholder analysis was performed to reduce any potential conflicts within the community. This approach can support collaboration and the exchange of opinions among various community stakeholders, including scientific researchers, municipal authorities, and private companies. The engagement of these stakeholders ensures that issues are addressed through community-wide participation, fostering sustainability in future solutions.

Materials and Methods

This study considered environmental health aspects as community concerns, employing MCDA with the AHP technique for decision-making. The process involved three essential steps: identifying environmental health aspects through a community survey using questionnaires, determining the main criteria for participatory decision-making, and computing their relative weights using the AHP technique. Following this, the AHP technique was employed to rank environmental health aspects within the group through pairwise comparisons, assessing two alternatives at a time.

Study area and participants

A cross-sectional study was conducted encompassing residents from all district in Pathum Thani province, which included stakeholders responsible for determining environmental health aspects within the community, as shown in Figure 1.

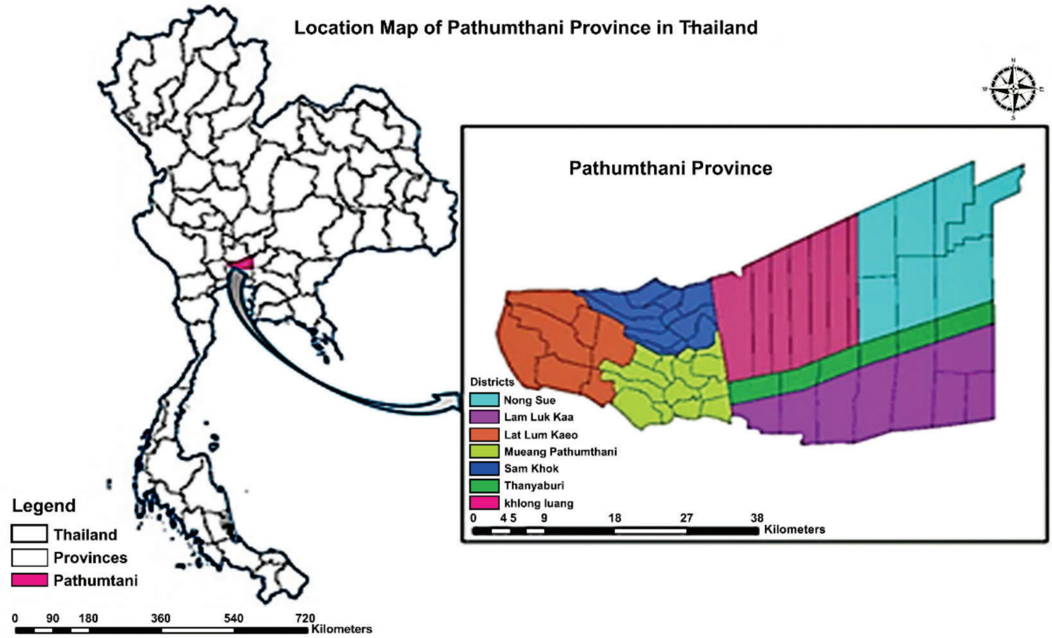

Figure 1: A map of Pathum Thani province, Thailand

The study population consisted of 1,024,427 households in Pathum Thani (Department of Provincial Administration, Ministry of Interior, 2019). The specific breakdown of households in each district is provided in Table 1. A sample of 384 households was selected using stratified random sampling, and these samples were proportionally allocated to each district. The determination of the sample size, considering a proportional representation and the need for a confidence interval (1-α), was calculated using Equation (1).

$$n = \frac{p(1-p)}{\frac{e^2}{z^2}+\frac{p(1-p)}{N}} \quad (1)$$

where
n = sample size
N = population
p = the portion of the population to which the researcher had reasonable access (p = 0.5)
e = tolerance interval or a specified proportion of the population for a given confidence level (e = 0.05, Z =1.96)

Table 1: The number of households in each district in Pathum Thani province (n=384)

Districts	Number of Households	Sample Size
Nong Sua	50,322	19
Lam Luk Kaa	240,178	90
Lat Lum Kaco	58,624	22
Muaeng Pathum Thani	179,876	67
Sam Khok	52,563	20
Thanyaburi	203,692	76
Klong Luang	239,172	90
Total	1,024,427	384

Data Collection and Instruments

Face-to-face interviews were conducted with participants using a standardised questionnaire to gather basic information on the community's environmental health aspects. The questionnaires were adapted from previous studies and were revised by the researchers. Before data collection, the study obtained the approval for the content of the questionnaire from three experts (IOC: 0.70-1.00). There were five alternative groups in the community: water consumption and quality management, solid waste management, food safety and sanitation management, air pollution management, and wastewater management (Figure 2).

The questionnaire consisted of a wide range of variables, including socioeconomic factors, household characteristics, outdoor water characteristics, indoor water appliances, attitudes towards water use, solid waste management characteristics, attitudes towards solid waste management, general attitudes on solid waste management, outdoor food safety and sanitation characteristics, indoor food safety and sanitation applications, attitudes towards indoor food safety and sanitation practices, attitudes regarding outdoor food safety and sanitation practices, general attitudes towards food safety and sanitation, air pollution management characteristics, attitudes towards air pollution management, general attitudes towards air pollution management wastewater management characteristics, attitudes towards wastewater management, and general attitudes towards wastewater management .

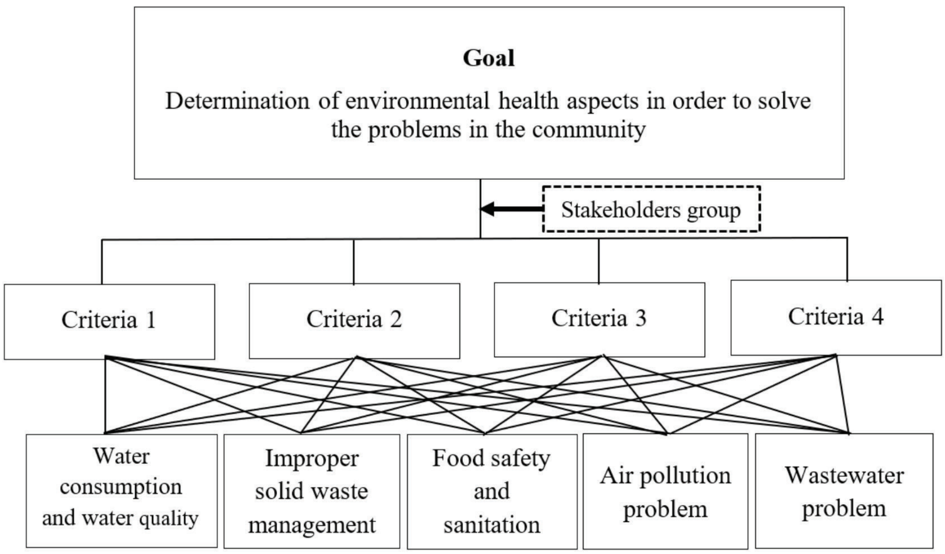

Figure 2: The hierarchical structure of the AHP model

Remarks:

Goal	=	The determination of environmental health aspects to solve community problems.
Stakeholders group	=	Provincial public health officer (2 persons), provincial pollution control officer (2 persons), provincial hospital officer (2 persons), provincial administrative organisation officer (2 persons), and community leaders in each district of Pathum Thani province (7 persons).
Criteria	=	The criteria consisted of four elements: The difficulty in solving the problem, the available budget, the community's need to resolve the problem, and the time period for resolution.
Alternative	=	There are five community environmental health aspect alternatives: water consumption and quality, solid waste management, food safety and sanitation management, air pollution management, and wastewater management. These aspects were identified through a community problem survey.

Data Analysis

The AHP principle, aided by the Expert Choice software, was used to analyse the data. Four decision criteria were defined, with environmental health aspects considered as decision alternatives within the community. The AHP principle was introduced, featuring a hierarchical structure for decision problems and a systematic calculation of the relative weight for each criterion, as described by Mert et al. (2010). The procedures for implementing the AHP were as follows:

Step 1: Decision-making identification

The decision goal that the stakeholder group wants to reach must be defined. Five environmental health aspects were compared to obtain the relative weight according to the AHP principle. The relative weight of each environmental health aspect was multiplied by the relative weight of each main criterion to achieve the goal. Both the main and alternative criteria were based on the AHP technique, and the relative weights were calculated using the Expert Choice software.

Step 2: Constructing a pairwise comparison matrix

A pairwise comparison matrix was constructed to determine the relative weights of the criteria, as represented by Equation (2). The level of importance from the pairwise comparisons of the main criteria and alternatives was logged into the Expert Choice software, as shown in Table 2, The values in matrix diagonals were designated as “1”. The stakeholders were asked for their opinions on the importance of alternative decisions. The matrix decision process involved conducting m×m pairwise comparisons, taking into accont the values of importance. In this context, C_1, …C_m represent the decision criteria, while W_1, …, W_m are the normalised relative weight vector.

$$A = \left(a_{ij}\right)_{mxm} = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_m \end{matrix} \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \vdots & \vdots & \dots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mm} \end{bmatrix} \quad (2)$$

a_{ij} represented quantified judgement of w_i/w_j with a_{ii} =1 and a_{ij} =1/a_{ji} for i,j=1, …, m.

Step 3: The eigenvector (l) calculation

The first normalised eigenvector of the matrix was employed to establish the ratio scale or weighting, while the largest eigenvalue was utilised to determine the consistency ratio. This calculation of the eigenvector was performed to determine the percentage distribution, and it was computed according to Equation (3), resulting in the generation of the B column vector.

$$\text{vector}.b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (3)$$

Matrix C was obtained as shown in Equation (4).

$$C = \begin{bmatrix} c_{11} & c_{12} & \dots & c_{1m} \\ c_{21} & c_{22} & \dots & c_{2m} \\ \vdots & \vdots & \dots & \vdots \\ c_{m1} & c_{m2} & \dots & c_{mm} \end{bmatrix} \quad (4)$$

Table 2: The values of importance

Quantitative Number	Meaning	Description
1	Similar importance	Two criteria are equally importancte
3	Less important	Judgement makes one criterion slightly better than the other
5	More important	Judgement makes one criterion much better than the other
7	Greatly important	Judgement makes one criterion very much better than the other
9	Excessively important	Judgement makes one criterion extremely very much better than the other
2,4,6,8	Intermediate values	This is the value used when choosing a compromise

Furthermore, the vector W was computed using Equation (5).

$$w_i = \frac{\sum_{j=1}^{n} c_{ij}}{n} \quad (5)$$

Step 4: consistency ratio (C.R.) calculation

It is deemed acceptable when C.R. ≤0.1 (Hoscan & Cetinyokus, 2021). If this condition is not met, revisions are necessary. To calculate the eigenvector, column D was computed using Equation (6) by multiplying matrix A and vector W.

$$D = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \vdots & \vdots & \dots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mm} \end{bmatrix} x \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (6)$$

The eigenvector was obtained by dividing the reverse components of the column vector D by the column vector W, as shown in Equation (7). Equation (8) shows the calculation of the maximum eigenvector (λ_{max}) by determining the values of the arithmetic mean.

$$\lambda = \frac{d_i}{w_i} (i = 1,2, \dots \text{n}) \quad (7)$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \lambda}{n} \quad (8)$$

After the maximum eigenvector (λ_{max}) was derived, the consistency index (CI) was calculated using Equation (9).

$$\text{CI} = \frac{\lambda_{max} - n}{n-1} \quad (9)$$

$$\text{C.R.} = \frac{CI}{RI} \quad (10)$$

The calculation of *CI* was performed according to Equation (9). Table 3 presents the Random Index *(RI)* values, which were utilised to compute C.R. as shown in Equation (10).

Step 5: Vector calculation

The relative weights of the decision criteria were obtained using pairwise comparisons. The overall weights were generated using the additive weighing method as shown in Equation (11).

$$w_{ai} = \sum_{j=1}^{m} w_{ij} w_j , i = 1, \dots, \text{n} \quad (11)$$

The alternative decisions and the overall weights were systematically calculated as illustrated in Table 4. The Expert Choice software was used at this stage.

Table 3: Random Index *(*RI*)* for pairwise comparison matrix

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

Table 4: Overall weight calculation

Decision Alternative	Decision Criteria (Main Criteria)					Overall Weights
	C_1	…	C_j	…	C_m	
	W_i	…	W_j	…	W_m	
A_1	W_{11}	…	W_{1j}	…	W_{1m}	$w_{a1} = \sum_{j=1}^{m} w_{1j} w_j$
A_i	W_{i1}	…	W_{ij}	…	W_{im}	$w_{ai} = \sum_{j=1}^{m} w_{ij} w_j$
A_n	W_{n1}	…	W_{nj}	…	W_{nm}	$w_{an} = \sum_{j=1}^{m} w_{aj} w_j$

Ethical Approval

This project was approved by the Human Research Ethics Committee of Thammasat University (COA 064/2562).

Results and Discussion

Criteria assessment and the construction of a hierarchical structure regarding environmental health aspects are essential steps in identifying the most significant aspect for resolving community issues. According to Kiker *et al*. (2005), the establishment of a generalised framework for decision analysis forms a fundamental cornerstone for a more structured and tractable environmental decision-making process. This aligns with other studies that employed MCDA methods for selecting environmental aspect (Baby *et al.,* 2013; Algarín *et al.,* 2017; Ren & Lützen*,* 2017; Chauvy *et al.,* 2020).

The criteria were categorised into four elements: difficulty in solving the problem, the budget allocated, the community's need to solve the problem, and the time frame for problem resolution. This categorization was the result of a collaborative brainstorming effort within the stakeholder group.

A pairwise comparison matrix was created for the four decision criteria, and this matrix was generated through the Delphi MAH technique, which was developed by the Rand Corporation Company and involved the maximise agreement heuristic (MAH) method. The MAH process comprises three steps:

1) Gathering numerical data from stakeholders.
2) Calculating the average of all decision data.
3) Considering the average values derived from all decision-makers.

Table 5 presents the results of the relative weight scale obtained through the Delphi MAH technique. The relative weights were computed the Expert Choice software with input from stakeholder brainstorming, as shown in Figure 3.

The pairwise comparison of the decision criteria revealed that the criterion "community's need to solve the problem" held the highest importance among the decision criteria, with a significance of 61.5%. Following this, the next most significant decision criteria were "budget for problem-solving" (22.2%), "time period for solving the problem" (10.6%), and "difficulty in solving the problem" (5.7%).

The calculation of the C.R. involved the following steps:

1) Calculation of the relative weight and maximum eigenvalue (λ_{max}) for each matrix based on the number of decision criteria (n), as indicated in Table 6.
2) Computation of the consistency index (CI) for each matrix based on the number of decision criteria (n) using the formula: CI = $(\lambda_{max} - n)/(n-1) = (4.12-4)/(4-1) \approx 0.04$.

Table 5: Pairwise comparison matrix and the resulting relative weight vector

Criteria (C.R. = 0.05 < 0.1)	Difficulty in Solving the Problem	Budget for Problem Solving	Community's Need to Solve the Problem	Time Period for Solving the Problem	Priority Value
Difficulty in solving the problem	1	1/3	1/9	1/3	0.057
Budget for problem solving	3	1	1/3	3	0.222
Community needs to solve the problem	9	3	1	7	0.615
Time period for solving the problem	3	1/3	1/7	1	0.106

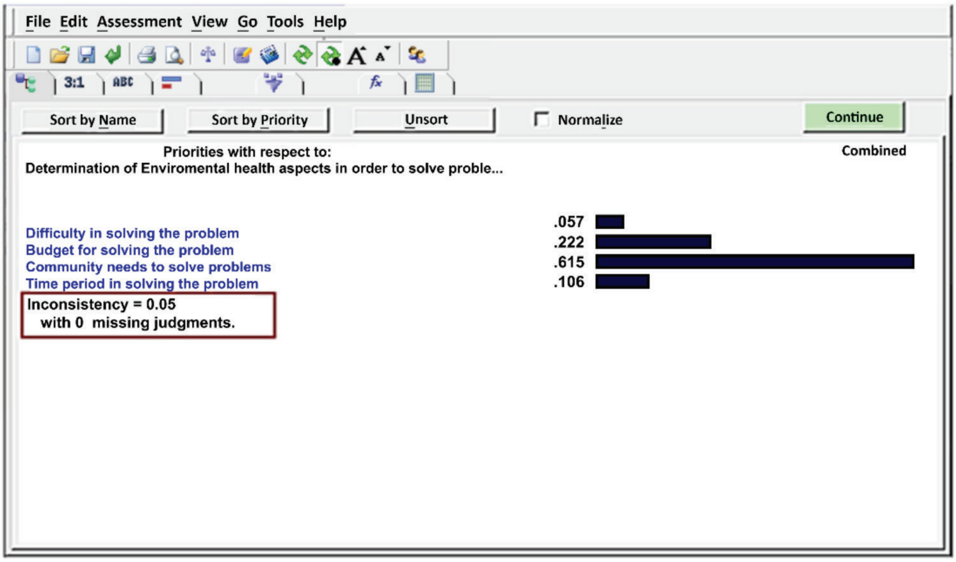

Figure 3: The relative weight values of the decision criteria with the consistency ratio (C.R.) as shown in the Expert Choice software

Table 6: Maximum eigenvalue (λ_{max})

Calculation Guidelines	Sum of value				Total
Vertical sum of value	16.00	4.66	1.58	11.33	
Horizontal sum of value	0.057	0.222	0.615	0.106	
Maximum eigenvalue (λ_{max})	0.912	1.035	0.972	1.201	4.12

3) Determination of the Consistency Ratio (C.R.), which was calculated as C.R. = CI/RI ≈ 0.05.

The relative weight values of the decision alternatives when compared with each decision criterion are shown in Tables 7 and 8, and Figure 4.

The results showed that solid waste management held the highest priority when compared with the "difficulty in solving the problem" criterion, with a significance of 49.8%. Air pollution management was the most important, with a significance of 49.7%, when compared with the "budget for problem-solving" criterion. Similarly, solid waste management was rated the most important at 47.0% when compared with the "community's need to solve the problem" criterion, while wastewater management was the most important at 48.8% when compared with the "time period for solving the problem" criterion. Currently, there have been no recent reports comparing environmental health aspects alternative with decision criteria using the AHP method. This gap in research can be attributed to the exclusion of most stakeholders from the decision criteria due to a lack of participatory solutions within the community. The relative weights for the assessment were determined by multiplying the significance of th decision alternative with the relative weights of the decision criterion. Regarding the calculation of assessment scores through the AHP method as shown in Figure 5, Morales and de Vries (2021) highlighted the application of AHP in establishing criteria for natural hazard mapping. This approach is consistent with the work of other researchers

Table 7: Pairwise comparison matrix of decision alternatives

Alternative (Criteria 1)	**A**	**B**	**C**	**D**	**E**	**Alternative** (Criteria 2)	**A**	**B**	**C**	**D**	**E**
A	1	1/4	1/2	2	2	A	1	1	2	1/5	1/2
B	4	1	2	8	8	B	1	1	1	1/6	1/4
C	2	1/2	1	4	4	C	1/2	1	1	1/9	1/5
D	1/2	1/8	1/4	1	1	D	5	6	9	1	2
E	1/2	1/8	1/4	1	1	E	2	4	5	1/2	1
Alternative (Criteria 3)	**A**	**B**	**C**	**D**	**E**	**Alternative** (Criteria 4)	**A**	**B**	**C**	**D**	**E**
A	1	1/7	2	1/2	1/4	A	1	2	1	1/3	1/5
B	7	1	9	3	2	B	1/2	1	1/2	1/8	1/9
C	1/2	1/9	1	1/4	1/5	C	1	2	1	1/5	1/8
D	2	1/3	4	1	1/2	D	3	8	5	1	1/2
E	4	1/2	5	2	1	E	5	9	8	2	1

Note:
Criteria 1 = difficulty in solving the problem
Criteria 2 = budget for problem-solving
Criteria 3 = community's need to solve the problem
Criteria 4 = time period for solving the problem
A = water consumption and quality
B = solid waste management
C = food safety and sanitation management
D = air pollution management
E = wastewater management

Table 8: Relative weight values of decision alternatives

Decision criteria	**Decision alternative**	**Priority value**
Difficulty in solving the problem (C.R.=0.07 < 0.1)	Water consumption and quality	0.110
	Solid waste management	0.498
	Food safety and sanitation management	0.288
	Air pollution management	0.045
	Wastewater management	0.059
Budget for problem-solving (C.R.=0.05 < 0.1)	Water consumption and quality	0.106
	Solid waste management	0.079
	Food safety and sanitation management	0.045
	Air pollution management	0.497
	Wastewater management	0.273
Community's need to solve the problem (C.R.=0.08 < 0.1)	Water consumption and quality	0.068
	Solid waste management	0.470
	Food safety and sanitation management	0.038
	Air pollution management	0.176
	Wastewater management	0.247
Time period for solving the problem (C.R.=0.08 < 0.1)	Water consumption and quality	0.089
	Solid waste management	0.038
	Food safety and sanitation management	0.067
	Air pollution management	0.318
	Wastewater management	0.488

such as Subramanian and Ramanathan (2012), Baby (2013), Ren and Lützen (2017), Algarín *et al*. (2017), Habiba Ibrahim Mohammed *et al*. (2018), Muhammad Waris *et al*. (2019), and Chauvy *et al*. (2020), who have employed AHP in decision-making processes related to environmental issues.

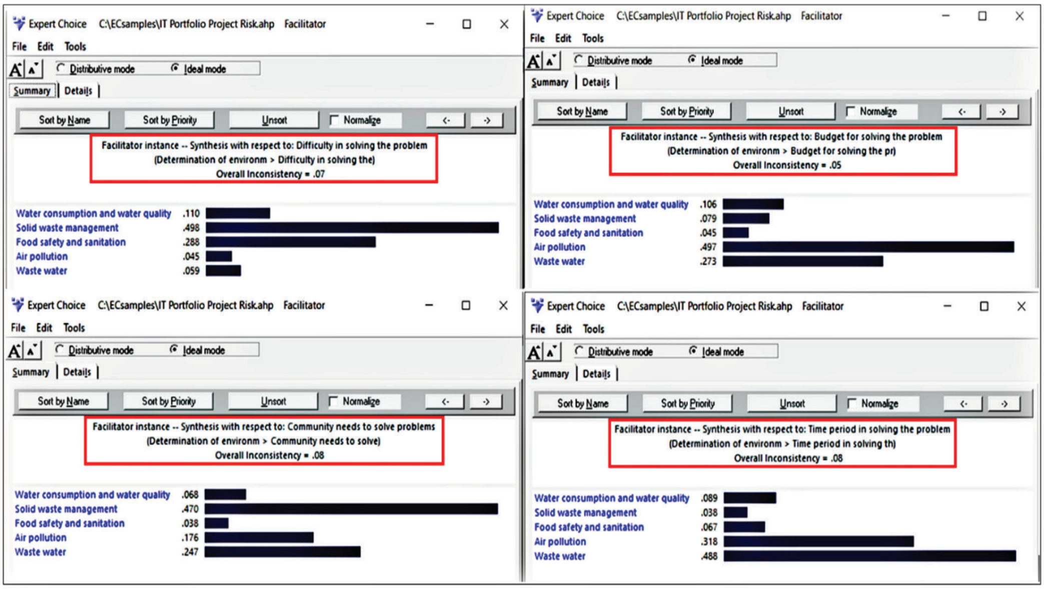

Figure 4: The relative weight values of decision alternatives with the C.R. as displayed in the Expert Choice software

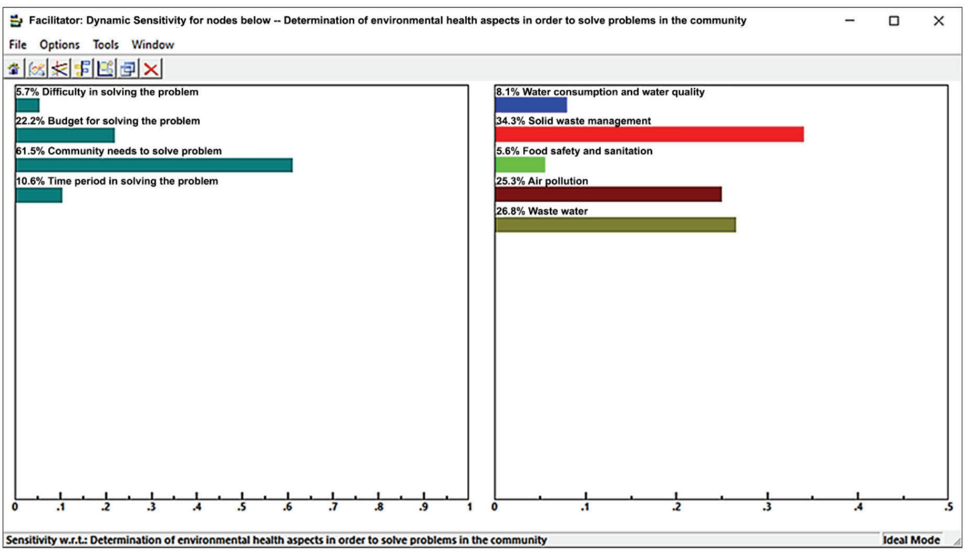

Figure 5: The percentage of each decision alternative calculated using the Expert Choice software

The findings revealed that solid waste management received the highest score, comprising 34.3% of the total, followed by wastewater management at 26.8%, air pollution management at 25.3%, water consumption and quality at 8.1%, and food safety and sanitation management at 5.6%.

Conclusion

Environmental health problems within the community constitute a complex issue involving multiple criteria and stakeholders. The establishment of a multicriteria hierarchy to select decision alternatives for addressing environmental health aspects in community problem-solving is feasible AHP is a crucial tool for making informed decisions in selecting reasonable alternatives. Additionally, the use of the Expert Choice software facilitated the involvement of stakeholders in the judgement process. The assessment of consistency through the C.R. in the pairwise comparison matrices revealed that solid waste management emerged as the most critical alternative. This underscores the significance of solid waste management in addressing community problems. Based on these findings, it is recommended that active reuse and recycling initiatives be implemented in all municipalities of Pathum Thani province. Furthermore, the Pathum Thani provincial office can assume a major role in promoting the 3R (reduce, reuse, and recycle) concept. Finally, cleaner production practices should be encouraged within the realm of solid waste management to foster sustainable development within community.

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