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Application of Fuzzy Hierarchical Analysis for Developing Near-field Communication Chip for Tracking Aromatherapy Products

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The increasing consumer demand for product quality, safety, and sustainability highlights the limitations of traditional tracking methods in the aromatherapy industry, which faces significant environmental and ethical challenges. For the development of an efficient near-field communication (NFC) chip to track the product history of aromatherapy products, we identified and evaluated on the basis of a questionnaire survey of scholars, manufacturers, and consumers the following criteria: "environmental footprint", "product transparency", "supply chain management", "social responsibility", and "overall system design". FAHP analysis was conducted on the basis of triangular fuzzy numbers and defuzzification, and the results revealed high consistency in the perceived importance of these criteria, with "overall system design" and "product transparency" scoring the highest. The overall consistency score was 0.702. The results indicated the necessity of the miniaturized, energy-efficient NFC chip development. The chip with high-performance sensors and an intelligent control system enables precise tracking, remote product operation, and personalized user experiences. This NFC solution is expected to significantly enhance product traceability and transparency, enhancing consumer trust and brand loyalty and enabling manufacturers to improve quality control and sustainable production throughout the entire product lifecycle.

1. Introduction

As consumers' requirements for product quality and safety increase, product history tracking systems have been developed and widely used. Traditional methods to track the production history of aromatherapy products lack transparency of information and have low efficiency in collecting and managing the data. As the aromatherapy industry impacts the environment during the production process owing to resource consumption and waste disposal, technology

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providing tracking and sustainable designs is required to improve product transparency and reduce its environmental impact. Since global climate change has become severe with increasing ecological awareness, more sustainable production models are necessary across industries than previously observed. The aromatherapy industry was no exception, as consumer demand for environmental friendliness has increased.[1,2]

Recently, aromatherapy technology has been developing rapidly with various new aromatherapy products. Intelligent and wearable aromatherapy devices have been developed using sensors and microprocessors to provide smart aromatherapy. However, existing aromatherapy products are not sustainable in terms of ingredient procurement and energy consumption. While pursuing economic benefits, the aromatherapy industry is facing sustainability challenges such as overharvesting herbal plants, chemicals used in synthesis, and waste disposal, which threaten the environment. Labor rights, fair trade, and cultural heritage were also regarded as serious problems in the aromatherapy industry.[3] Aromatherapy companies have put their efforts into sustainable product development by adopting organic farming, fair trade, and recyclable packaging materials. However, more investment is mandated to establish a complete sustainable management and production system to meet consumers' increasing needs for sustainable aromatherapy products with certified ingredients and production processes for eco-friendliness. Companies in the aromatherapy industry must pay more attention to product transparency and communication with consumers to obtain their trust.

Therefore, it is essential to integrate technological innovation, especially near-field communication (NFC) chips in the whole production process of aromatherapy products. To meet such consumer needs and enhance the industry's competitiveness and sustainable development, an NFC chip is used to track product production, transportation, and sale. The chip contains a microprocessor, memory, and wireless communication module for processing and storing data. The wireless communication module transmits data to external devices such as smartphones and tablets. The NFC technology has been widely used in food, medicine, and luxury goods to ensure product safety and traceability. By scanning the quick response (QR) code on the chip using the NFC technology, consumers can be aware of the production history, including production date, location, manufacturer, and inspection report.[4]

To identify the requirements for the development of NFC chips for aromatherapy products, we conducted a fuzzy analytic hierarchical analysis (FAHP) through questionnaire surveys. FAHP is a multi-criteria decision-making method that combines fuzzy theory with AHP, which decomposes complex problems into different levels and calculates the weights of criteria and solutions through pairwise comparison to select the best solution. On the basis of the analysis results obtained using triangular fuzzy numbers, consumers' preferences, needs, expectations, perceptions, and assessments of the sustainability of aromatherapy products with an NFC chip were identified.[5] The results of this study provide a reference for developing NFC chips for diverse products, to which consumers pay considerable attention to sustainability and eco-friendliness.

2. Background Knowledge

Tracking and management are important in logistics. By adopting NFC technology, the production, transportation, and sales information of aromatherapy products can be effectively tracked and securely stored. The technology allows consumers to produce history information by scanning the QR code. FAHP is used in this study to assess consumer preference to design a chip to track the information on the ingredients and products and their logistics.

2.1 NFC technology

NFC is used for short-range wireless communication with a communication protocol between devices such as mobile phones.[6] In the NFC chip, the production information and history are stored through scanning or sensing at each step from procurement to delivery. By integrating IoT, big data, and blockchain technology, NFC technology is evolving rapidly.[7]

NFC operates on the basis of the principle of electromagnetic induction. When two NFC devices come within their operating range, they automatically establish a connection. NFC technology is used for secure and convenient data exchange for contactless payment, access control, and information sharing through contactless point-to-point data transmission over short distances. The principle of NFC technology is similar to that of radio frequency identification (RFID) technology, but NFC emphasizes interactivity and security between devices (Fig. 1).[4] NFC operates at a frequency of 13.56 MHz in a few centimeters, making it ideal for secure data exchange.[1,2] NFC technology has three operation modes as follows.

1) Reader/writer mode

NFC devices read or write information on NFC tags on posters, business cards, or products.

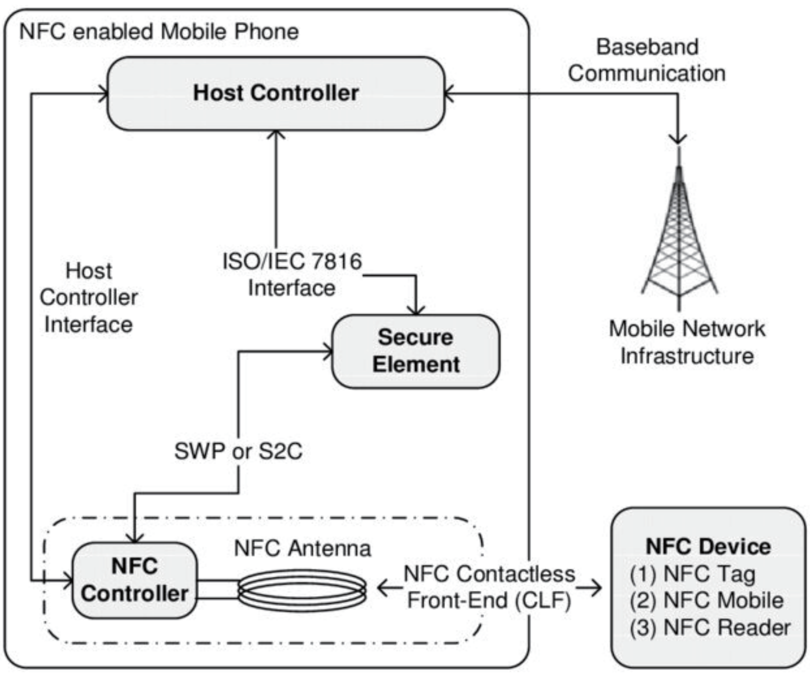

Fig. 1. Architecture of NFC technology application.[4]

2) Peer-to-peer mode
   Two NFC chips directly exchange data by transferring files, photos, or contact information.
3) Card emulation mode
   The NFC chip is analogous to a credit or transportation card for contactless payment or identity verification.

The working mechanism of NFC involves the following processes: First, the NFC device sends out and receives a radio wave signal in its operation range through an induced current. NFC technology has advantages in its speed, convenience, and security enabling wide application in various industries.(4) However, current NFC technology still presents potential security risks. Although short-range and high-frequency communication is secured in NFC technology, NFC devices are vulnerable to hacking and malware infiltration, which results in data breaches or various forms of fraud. Therefore, the security and privacy protection of NFC technology are crucial.

2.2 FAHP

FAHP is used to solve fuzzy decision-making problems. In FAHP, triangular fuzzy numbers are used to represent the relative importance of criteria (factors), and the fuzzy weight of each decision criterion is calculated.(8) The triangular fuzzy numbers are introduced into the pairwise comparison matrix to solve the fuzzy problems generated in criterion measurement and judgment by using fuzzy positive and negative value matrices. The geometric mean is used to calculate each fuzzy matrix's weight. The priority of each alternative is sorted using the membership function of its alternative.(9) Triangular membership functions are used to compare the criteria, while the extent analysis method is used to calculate each factor's fuzzy synthetic extent value. By comparing the degree of possibility of each element in each unit, the lower possibility is calculated to estimate the non-fuzzy value of each component through data normalization.(10) Laarhoven and Pedrycz used triangular fuzzy numbers to replace the explicit values generated by pairwise comparisons in the hierarchical analysis method, and they also used logarithmic least squares to calculate the fuzzy weights of each criterion.(11) The FAHP method incorporates fuzzy theory to overcome the shortcomings of traditional AHP methods, ensuring that final decisions align more closely with observed data and realities.

2.2.1 Fuzzy theory

Fuzzy theory is used to process imprecise and ambiguous data for efficient and precise decision-making based on fuzzy data through rigorous mathematical calculations.(12) Fuzzy data comprise various subjective assessments, including, but not limited to, overall effect, shape, color, decoration, pleasantness, safety, and processability. As these parameters are difficult to quantify, linguistic variables are introduced to quantify fuzzy information for quantitative evaluation using fuzzy mathematics.(13) Fuzzy sets, fuzzy operations, or defuzzification techniques are used for the quality assessment of complex and imprecise descriptions. However, in the fuzzy theory, the relationships among engineering requirements are not considered. Therefore, a quality function needs to be defined. In the FAHP procedure, an influencing factor set, a factor weight set, a parameter evaluation set, and a single factor evaluation matrix are established to perform fuzzy evaluation.(13)

(1) Influencing factor set

In fuzzy evaluation, the factors (criteria) that affect evaluation parameters are first determined. For influencing factors $u_1, u_2, ..., u_m$, the factor set with the factors is established as a standard set $U = \{u_1, u_2, ..., u_m\}$.

(2) Factor weight set

The influence or importance of each factor on parameters is different. Therefore, the weight of each factor must be different. The factor weight set $A = \{a_1, a_2, ..., a_m\}$ comprises the weight coefficients that quantify the degree of influence each factor exerts on the parameters. The weight is calculated using Eq. (1), whereas the value of the weight set is calculated using Eq. (2).

$$\sum_{i=1}^{n} a_i = 1,\ a_i \geq 0\ (i = 1, 2, 3, \ldots, a_n) \tag{1}$$

$$A = \frac{a_1}{u_1} + \frac{a_2}{u_2} + \frac{a_3}{u_3} + \ldots + \frac{a_n}{u_n} = \{a_1, a_2, a_3, \ldots, a_n\} \tag{2}$$

The weights of factors are determined using the weight coefficient through hierarchical analysis, paired comparison, or Likert scale according to the needs of problems to solve. Regardless of methods, a human element is involved with a different degree of credibility. To quantify the importance of the parameters, scores are calculated using weight coefficients a_i.

$$a_i = k_i / \sum_{i=1}^{n} k_i \tag{3}$$

Here, k_i is the total score of each evaluation object [Eq. (4)] and n is the number of evaluation objects.

$$\sum_{i=1}^{n} k_i = \frac{n^2 - n}{2} \times 4 = 2\left(n^2 - n\right) \tag{4}$$

(3) Parameter evaluation set

The evaluation set is a collection of evaluation results The evaluation set $V_i = \{v_1, v_2, ..., v_n\}$ (i = 1, 2, 3, …, n) includes various evaluation results. The purpose of fuzzy evaluation is to consider all influencing factors to obtain the best evaluation on the basis of the evaluation set. The relation of v_i to V needs to be normalized.

(4) Single-factor evaluation matrix

The single-factor evaluation matrix is used to evaluate factors and determine the membership degree of the evaluation object to the assessment set elements. The evaluation object is assessed according to factor u_i in the factor set. The membership degree of the elements in the evaluation set R_i is defined as r_{ij}, and a fuzzy set is expressed as the result of the evaluation of V_i.

$$R_i = \frac{r_{i1}}{V_1} + \frac{r_{i2}}{V_2} + \dots + \frac{r_{in}}{V_n} \tag{5}$$

The single-factor evaluation set corresponding to each factor is defined as

$$\begin{aligned} R_1 &= \left(r_{11}, r_{12}, \dots, r_{1n}\right) \\ R_2 &= \left(r_{21}, r_{22}, \dots, r_{2n}\right) \\ &\vdots \\ R_m &= \left(r_{m1}, r_{m2}, \dots, r_{mn}\right). \end{aligned} \tag{6}$$

The fuzzy matrix $\boldsymbol{R}$ is composed of the membership degrees in each factor evaluation set and called the single-factor evaluation matrix [Eq. (7)]. $\boldsymbol{R}$ is constructed using a fuzzy relationship matrix through fuzzy transformation.

$$\boldsymbol{R} = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_i \\ \vdots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2j} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} & \cdots & r_{im} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nj} & \cdots & r_{nm} \end{bmatrix} \tag{7}$$

With many factors at different levels, single-factor fuzzy evaluation is challenging. Therefore, fuzzy evaluation is employed, and influencing factors are grouped into several levels. A multi-factor evaluation matrix is adopted with its factor sets grouped in several layers according to their characteristics.

(5) Fuzzy synthesis operation

When the fuzzy evaluation matrix is determined, its product B is defined as

$$B = A \bullet R = \left[b_1, b_2, \dots b_j, \dots b_m\right], \tag{8}$$

where '●' presents the fuzzy synthesis operation.

<u>Model 1</u>

In the $M(\wedge,\vee)$ algorithm,

$$b_j = \overset{m}{\underset{i=1}{\vee}} \left(a_i \wedge r_{ij} \right); j = 1, 2, ..., n. \tag{9}$$

Model 2

In the $M(\bullet, \vee)$ algorithm,

$$b_j = \overset{m}{\underset{i=1}{\vee}} \left(a_i r_{ij} \right); j = 1, 2, ..., n. \tag{10}$$

Model 3

In the $M(\wedge, +^{\circ})$ algorithm,

$$b_j = \min\left\{1, \sum_{i=1}^{m} \left(a_i \wedge r_{ij} \right)\right\}; j = 1, 2, ..., n. \tag{11}$$

Model 4

In the $M(\bullet, +^{\circ})$ algorithm,

$$b_j = \min\left\{1, \sum_{i=1}^{m} a_i r_{ij}\right\}; j = 1, 2, ..., n. \tag{12}$$

Here, $\vee$ denotes the logical OR operation, which combines inputs to determine if at least one condition is true, $\wedge$ represents the logical AND operation, which checks if all the conditions are true, and $+^{o}$ represents the bounded sum operation to combine values in the fuzzy logic system.

When a_i is normalized as $\sum_{i=1}^{m} a_i = 1, \sum_{i=1}^{m} a_i r_{ij} << 1$, the model becomes $M(\bullet, +)$ in which Eq. (13) is applied.

$$b_j = \sum_{i=1}^{m} a_i r_{ij}; j = 1, 2, ..., n; \sum_{i=1}^{m} a_i = 1, \tag{13}$$

where $\sum_{i=1}^{m} a_i = 1$.

The model considers the influences of all factors and all retained information from single-factor judgments. In the equations, no upper limit is imposed on a_i and r_{ij} (i =1, 2, ..., m; j = 1, 2, ..., n), and only a_i is normalized. The model is used in the fuzzy evaluation and optimization of engineering design parameters with excellent results.

2.3 AHP

AHP is widely used in decision-making in uncertain situations using multi-criteria and with a concise hierarchical structure.[13] In AHP, the relative importance of two criteria is compared at the same level. On the basis of the result, a pairwise comparison matrix is established to determine the relative importance of the requirements. Then, the total priority vector of the overall hierarchy is calculated through hierarchical concatenation, and the weight of each evaluation criterion is determined. The result is used to quantitatively evaluate alternative options. To determine the priority of the options and reduce the risk of wrong decision-making, the pairwise comparison of AHP is replaced with voting AHP (VAHP). VAHP is more straightforward than AHP in calculating weights. In VAHP, the advantages and disadvantages of the options are compared in the following process:

- Step 1: Define the decision problem.
- Step 2: Create a hierarchical structure.
- Step 3: Establish a pairwise comparison matrix. Table 1 shows the evaluation scale and relative definition.
- Step 4: Calculate the eigenvalue.
- Step 5: Verify the consistency.

The eigenvector in step 4 is calculated through the normalization of the row average, the normalization of the average of normalized columns, the normalization of the geometric mean of the rows, and the normalization of the reciprocal mean of the rows.

The consistency is evaluated to confirm if the preference relationship between criteria shows recursiveness. Consistency index (*CI*) and consistency ratio (*CR*) are calculated to verify consistency [Eqs. (14) and (15), respectively]. If the *CI* and *CR* values are smaller than 0.1, the pairwise matrices are considered to be consistent.

$$CI = \frac{\lambda_{max}}{n-1}, \tag{14}$$

where λ_{max} is the largest eigenvalue of the matrix and n is the matrix order (the number of parameters).

Table 1
Evaluation scale and relative definition of hierarchical analysis.

Evaluation scale	Definition
1	Equally important
3	Slightly important
5	Important
7	Extremely important
9	Absolutely important
2, 4, 6, 8	Interpolated values

$$CR = \frac{CI}{RI},\tag{15}$$

where n is the number of evaluation criteria and RI is a stochastic indicator whose value increases with the number of criteria (Table 2).

3. Research Method

3.1 Design elements of NFC chips for aromatherapy products

To design an NFC chip for aromatherapy product tracking, a hardware architecture, software, an interface, and an embedded system must be decided to select appropriate components and circuit boards and conduct coding and system debugging. The NFC chip needs to ensure testability, verifiability, and scalability for diverse applications. In this study, we explored the users' perception of "environmental footprint", "product transparency", "supply chain management", and "social responsibility" of aromatherapy products.[14] To identify the importance of the five factors in the NFC chip development for aromatherapy products, we conducted a questionnaire survey and analyzed the results using the FAHP method to calculate the weight and preference of the factors (Table 3).[15,16] On the basis of the factors, we determined the tracking process of aromatherapy product manufacturing (Fig. 2).

Table 2
Random index.

Degree	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.44	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Table 3
Requirements for NFC chip development to track aromatherapy products.

Criteria	Assessment
Environmental footprint	environmental impact of historical chip technologies during production, use, and disposal, such as carbon emissions, water consumption, and waste generation.
Product transparency	whether the history chip technology can improve product transparency and allow consumers to trace the product's origin, production process, and quality information.
Supply chain management	whether the chip technology can improve supply chain management and ensure suppliers meet sustainability standards, such as labor rights and environmental protection.
Social responsibility	whether the CV chip technology can promote social responsibility, such as supporting fair trade, protecting cultural heritage, and promoting community development.
Overall system design	overall system design based on the overall appearance, color configuration system, and aesthetics.

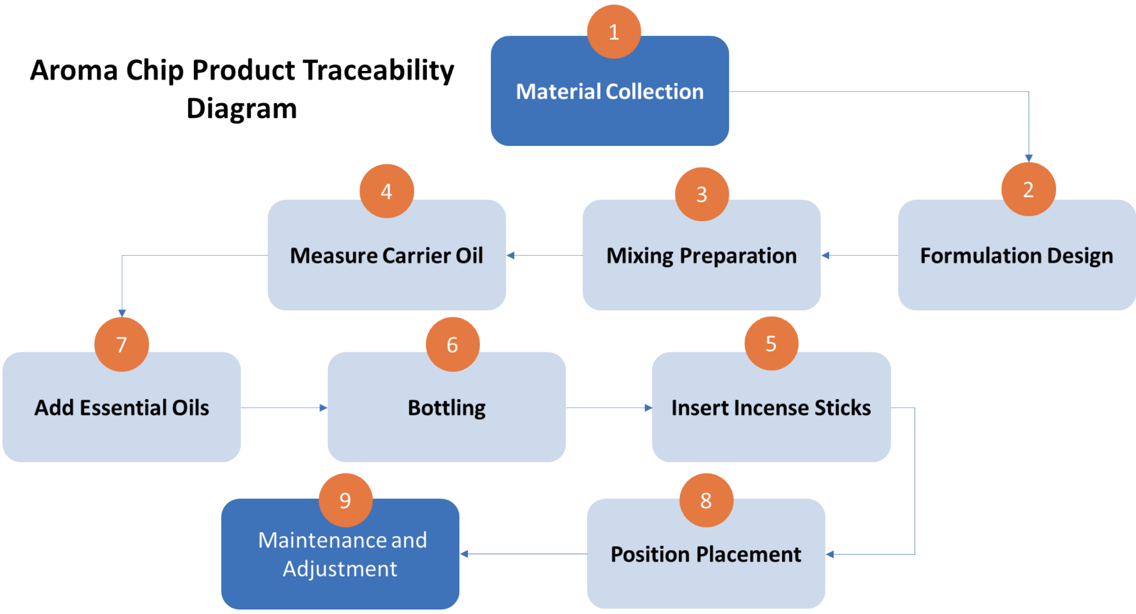

Fig. 2. (Color online) Tracking of aromatherapy ingredients and products.

3.2 Evaluation

The evaluation criteria and subcriteria of the development of the NFC chip for tracking aromatherapy products are presented in Fig. 3. On the basis of previous study results, five evaluation criteria were identified: environmental footprint (U1), product transparency (U2), supply chain management (U3), social responsibility (U4), and overall system design (U5). The subcriteria of the five criteria were identified as follows.

U1 = {environmental assessment (u11), environmental impact (u12)}

U2 = {product process (u21), product practicality (u22), product material safety (u23)}

U3 = {source of materials (u31), convenient management (u32), qualified supply chain (u33)}

U4 = {sustainable material (u41), easy to recycle (u42), sustainable use (u43)}

U5 = {color (u51), texture (u52), assembly method (u53)}

The relative importance of the criteria was assessed using five levels—"very consistent", "consistent", "ordinary", "inconsistent", and "very inconsistent"—which were assigned numerical values of 1, 3, 5, 7, and 9, respectively. To determine the evaluation index of the criteria and subcriteria, fuzzy multi-criteria decision-making was adopted.

MATLAB was used to create a MATLAB graphic user interface (GUI) for data entry and demand assessment after data collection and professional consultation (Fig. 4).

4. Results

Fifty-five valid questionnaires were collected in this study. The respondents included 15 scholars, 25 aromatherapy product manufacturers, and 15 consumers. Males and females

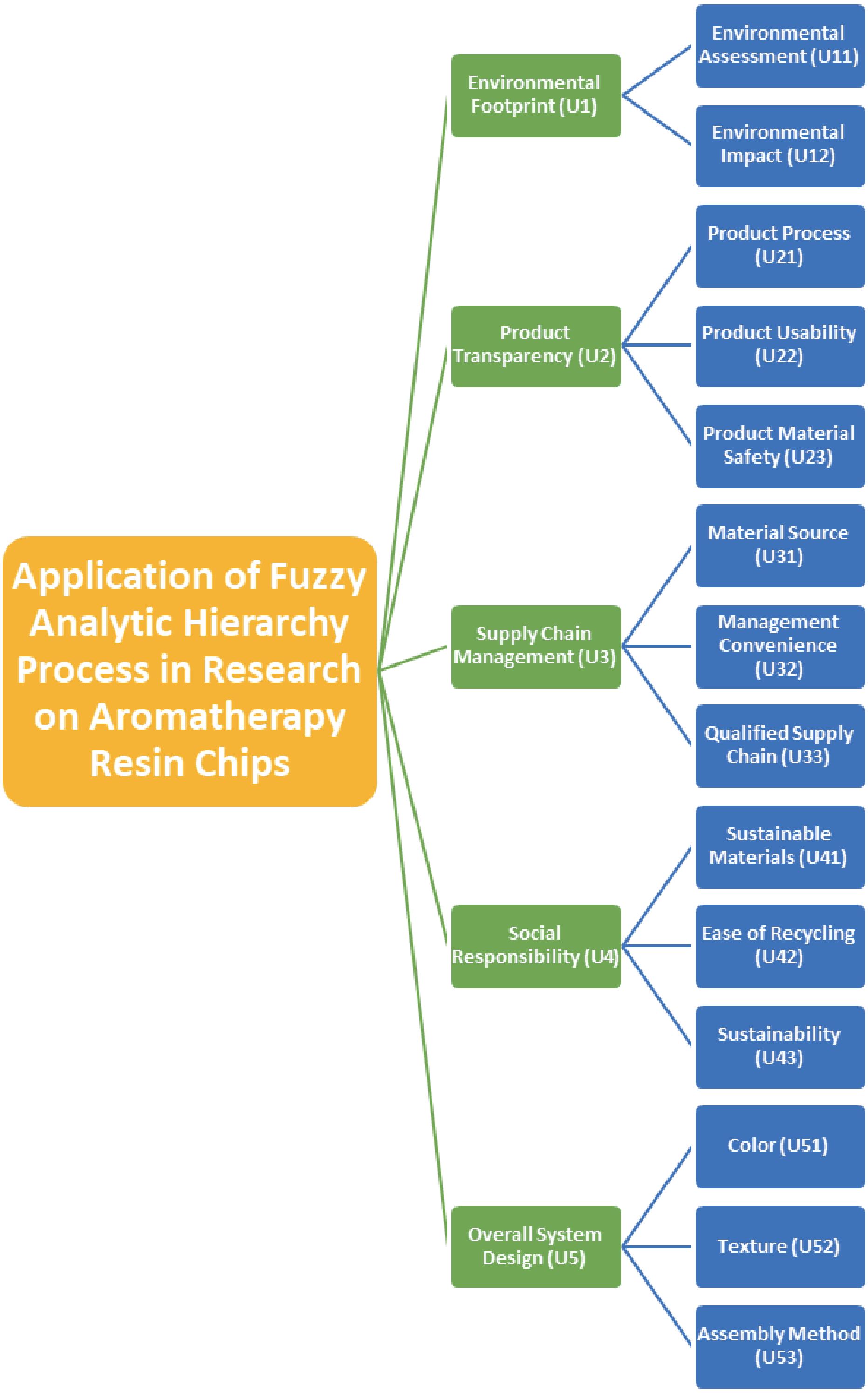

Fig. 3. (Color online) Evaluation criteria and subcriteria of development of NFC chip for tracking aromatherapy products.

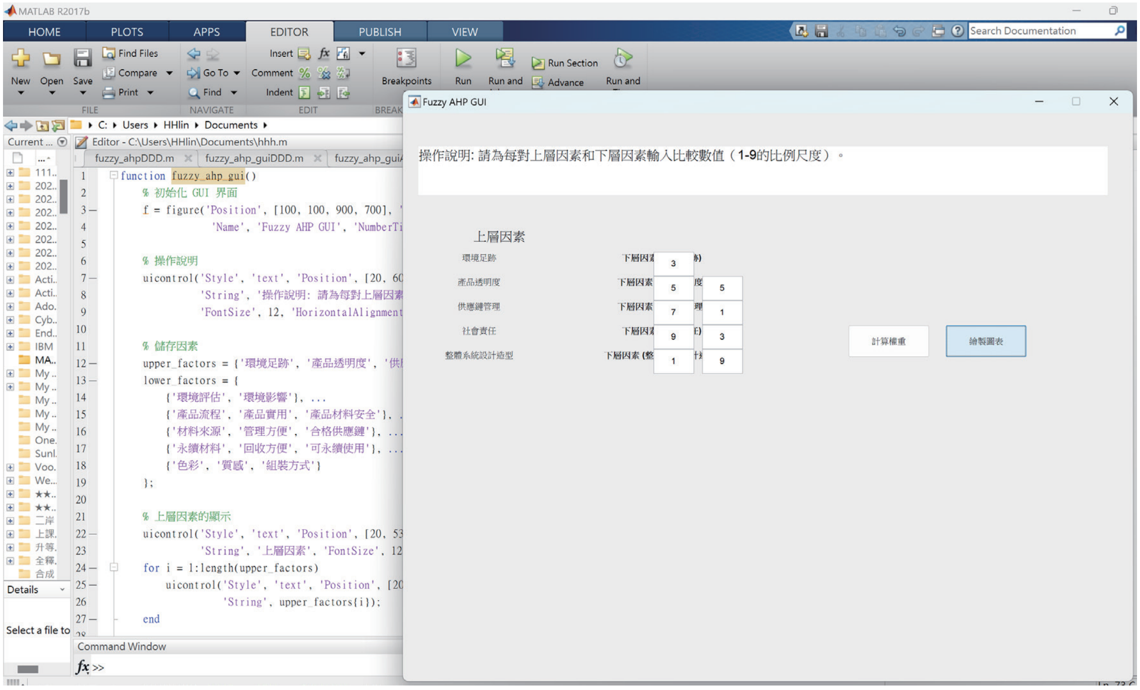

Fig. 4. (Color online) MATLAB GUI created in this study.

accounted for 40 and 60% of all respondents, respectively. The average age of the respondents was 35 years old, ranging from 25 to 65 years old. Eighty percent had a college degree or higher. The average work experience period was 12 years, ranging from 3 to 30 years. We invited experts to evaluate criteria and subcriteria. All the data were analyzed to obtain descriptive statistics and calculate the fuzzy weights of the subcriteria. MATLAB was used to determine the weights of the criteria and subcriteria (Fig. 5).

On the basis of the results, the criteria were evaluated using the fuzzy evaluation matrix. The fuzzy evaluation matrix for each criterion was constructed using the fuzzy synthesis method [Eq. (12)]. The synthesis method was used to normalize the weights. The weights of the subcriteria were obtained as follows.

$$\begin{aligned}
\text{Environmental footprint: } \hat{B}_1 &= \tilde{W}_1 \cdot R_1 = [0.2540.3830.3240.0450.000] \\
\text{Product transparency: } \tilde{B}_2 &= \tilde{W}_2 \cdot \tilde{R}_2 = [0.2540.3830.3240.0450.000] \\
\text{Supply chain management: } \tilde{B}_3 &= \tilde{W}_3 \cdot \tilde{R}_3 = [0.2080.2610.4080.1310.000] \\
\text{Social responsibility: } \tilde{B}_4 &= \tilde{W}_4 \cdot \tilde{R}_4 = [0.2530.4060.2650.0780.000] \\
\text{Overall system design: } \tilde{B}_5 &= \tilde{W}_5 \cdot \tilde{R}_5 = [0.2770.4380.2220.0590.000]
\end{aligned} \tag{16}$$

We employed the maximum membership method and the weighted average method to convert fuzzy values into real values through defuzzification. The fuzzy data were defuzzified to transform into numerical data for comparison and sorting in the final stage. The weighted average method was applied for the following grade assignment: V = {very consistent, consistent,

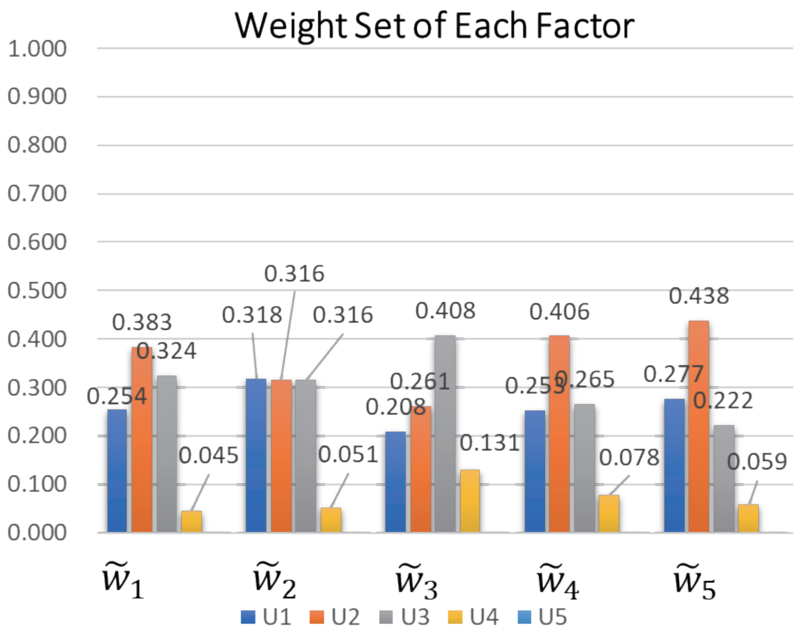

Fig. 5. (Color online) Weights of criteria and subcriteria in FAHP.

average, inconsistent, very inconsistent} = {1, 0.75, 0.50, 0.25, 0} to obtain the defuzzified score set *D* of the evaluation result (Tables 4 and 5).

The evaluation criteria "overall system design model" using defuzzification scored 0.731, which was "very consistent" in selecting the NFC chip. "Product transparency factor", "environmental footprint", "social responsibility", and "supply chain management" scored 0.725, 0.714, 0.710, and 0.640, respectively. Table 5 shows that the overall score of the NFC chip in the FAHP method was 0.702, indicating that the score was "very consistent" and "consistent".

5. Discussion

Digital tracking and management are crucial to recording information on production, transportation, and sales, making it accessible to consumers. Furthermore, this technology extends to controlling the operation of aromatherapy products via smart devices. The application of FAHP was instrumental in identifying key criteria for the NFC chip's development, directly reflecting user and expert preferences for sustainable aromatherapy products. The high defuzzified scores were determined for "overall system design" (0.731), "product transparency" (0.725), "environmental footprint" (0.714), and "social responsibility" (0.710). The strong preference for product transparency and environmental footprint underscored the necessity of robust tracking capabilities for sustainable practices, including detailed carbon footprint estimation across the product lifecycle (procurement, manufacturing, transportation, usage, disposal) in line with the International Organization for Standardization (ISO) 14067 and the Publicly Available Specification (PAS) 2050. Monitoring product transparency and environmental footprint promotes sustainable raw material procurement, environmentally friendly extraction methods, energy-saving production, and the use of recyclable or biodegradable packaging materials.

Table 4
Grade and defuzzified score of criteria.

Criteria	Very consistent	Consistent	Ordinary	Inconsistent	Very inconsistent	Defuzzified score
Environmental footprint	0.254	0.383	0.324	0.045	0.000	0.714
Product transparency	0.318	0.316	0.316	0.051	0.000	0.725
Supply chain management	0.208	0.261	0.408	0.131	0.000	0.640
Social responsibility	0.253	0.406	0.265	0.078	0.000	0.710
Overall system design	0.277	0.438	0.222	0.059	0.000	0.731

Table 5
Overall score of criteria in FAHP method.

Very consistent	Consistent	Ordinary	Inconsistent	Very inconsistent	Defuzzified score
0.125	0.352	0.241	0.135	0.147	0.702

Therefore, the NFC chip's design, including its hardware architecture, software, interface, and embedded system, needs to ensure testability, verifiability, and scalability for more widespread applications. The integration of high-performance sensors for odor detection, temperature, and humidity measurement is also needed to ensure accuracy and reliability in product monitoring to minimize energy consumption. The intelligent tracking system, which enables the automated control and customization of aroma release and remote operation via smartphone applications, needs to be developed to align with the high preference for "overall system design" and to enhance user experience and convenience.

The NFC technology in aromatherapy product development and manufacturing enhances product traceability and transparency. Consumers can readily access comprehensive information, including ingredient lists, usage recommendations, and safety tips. Such instant access to reliable product information fosters consumer trust, alleviates concerns about quality and origin, and increases brand loyalty. The technology also enables interaction between consumers and manufacturers, allowing for feedback to improve quality and refine the products continuously. The emphasis on system design, product transparency, environmental footprint, and social responsibility is related to user experience, technological innovation, and economic benefits in the development of aromatherapy products.

6. Conclusions

Consumers' increasing demand for product transparency, responsibility, and sustainability pushes manufacturers to adopt environmentally conscious practices and enhance the sustainable development of products. The NFC technology plays an important role in the trend as it significantly improves product traceability and transparency while fostering consumer interaction, brand trust, and production efficiency. The NFC technology is used across the entire product lifecycle, from procurement and manufacturing to transportation, sales, usage, maintenance, and waste disposal. For the design and evaluation of an NFC chip for tracking aromatherapy products, we identified and evaluated the following criteria for the development of the NFC chip using FAHP: "environmental footprint", "product transparency", "supply chain management", "social responsibility", and "overall system design". The criteria showed high consistency in the perceived importance, with "overall system design" (0.731) and "product transparency" (0.725) scoring the highest. The overall consistency score is 0.702 for the NFC chip's design. The results provide a guide for the NFC chip development, resulting in a miniaturized, energy-efficient design through nanoprocessing and three-dimensional packaging. The NFC chip with high-performance sensors and an intelligent control system ensures precise tracking, remote product operation, and personalized user experiences and enhances product traceability and transparency, fostering consumer trust and brand loyalty. The chip also enables manufacturers to improve quality control and sustainable practices throughout the entire product lifecycle. The results of this study confirmed the consistency and efficacy of the NFC technology to meet sustainability and user-centric demands.

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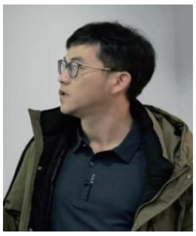

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