2025-1409 IJOI
https://www.ijoi-online.org/

International Journal of Organizational Innovation

USING CFAHP AND IPGA METHOD TO ESTABLISH THE IMPORTANCE CRITERIA ON THE HACCP SYSTEM FOR HOSPITAL KITCHENS IN TAIWAN

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Abstract

In this study, we present an integrated approach that combines Consistent Fuzzy Preference Relations Analytic Hierarchy Process (CFAHP) with Importance-Performance Gap Analysis (IPGA) to identify key criteria for the Hazard Analysis and Critical Control Point (HACCP) system, a management framework for food production and safety. The results highlight three critical factors: meal quality, employee training and education, and environmental cleanliness, including food hygiene. Notably, 26 sub-items were identified as having high importance but low performance, with particular emphasis on enhancing employees' professional attitudes and fostering a sense of accomplishment. This novel method offers a framework for developing a critical control point system tailored to hospital kitchens in Taiwan, providing practical guidance for hospital managers in establishing robust food safety systems.

Keywords: Consistent Fuzzy Preference Relations Analytic Hierarchy Process, Food Safety, Hazard Analysis and Critical Control Point, Importance Performance Gap Analysis, Quality of Meals

Introduction

Food safety has become a critical concern during the COVID-19 pandemic due to the heightened demands placed on the food production system. In the 21st century, advancements in food technology have introduced increasingly complex food safety challenges within the supply chain (Liu, 2017). The

globalization of the food supply system, facilitated by cross-border trade, has further amplified the risk of food contamination (He, 2021). Aday and Aday (2020) emphasized that ensuring food safety is essential to prevent the transmission of coronavirus among producers, retailers, and consumers during the pandemic. For medical institutions, it is particularly vital to provide safe, hygienic, and nutritious meals in hospital kitchens to safeguard patient health.

According to the Taiwan Ministry of Health and Welfare (2024), medical facilities reported seven food poisoning incidents affecting 145 individuals in 2019, and three incidents affecting 446 individuals in 2024, marking a nearly threefold increase. These cases highlight that even in hospital kitchens supervised by dietitians, food poisoning can still occur. Ensuring food safety is a critical priority for hospitals and medical institutions. The Hazard Analysis and Critical Control Point (HACCP) system, a globally recognized food safety management framework, has been developed to safeguard food production processes. Effective implementation of HACCP requires strong managerial support and commitment. Grintzali and Babatsikou (2010) warned that poorly developed or inadequately supported HACCP programs can create a false sense of security and lead to significant issues. Similarly, Abdul et al. (2020) observed that food hygiene and safety controls are consistently regarded as top priorities in most Malaysian hospitals

The Hazard Analysis and Critical Control Point (HACCP) system is a globally recognized, systematic, and preventive approach designed to address biological, chemical, and physical hazards by focusing on anticipation and prevention rather than relying solely on end-product inspection and testing (Grintzali & Babatsikou, 2010). In this study, we employ an integrated methodology that combines Consistent Fuzzy Preference Relations Analytic Hierarchy Process (CFAHP) and Importance-Performance Gap Analysis (IPGA) to identify the critical criteria for implementing the HACCP system in hospital kitchens in Taiwan.

Literature Review

The Hazard Analysis and Critical Control Point (HACCP) system is a systematic approach for identifying, evaluating, and controlling food safety hazards. It is built upon Good Hygiene Practices (GHP) and the Sanitation Standard Operating Procedure (SSOP), making it a comprehensive and advanced preventive framework (Lee & Ji, 2016; Terkuran & Erginkaya, 2019). GHP serves as a fundamental step in managing food hygiene throughout the supply chain to ensure food safety and suitability for consumption. All food businesses are required to implement GHP to maintain hygienic conditions during manufacturing, processing, blending, packaging, transportation, storage, sales, and import/export processes, thereby reducing contamination risks (Ministry of Health and Welfare, FDA, 2014). Xie et al. (2019) emphasized that implementing the HACCP system, along with comprehensive monitoring of physical, chemical, and biological hazards and

regular training for kitchen managers and staff, significantly enhances overall food safety and customer satisfaction.

Chang et al. (2003) analyzed a HACCP-based hospital service center in South Korea, comparing hospital kitchen employees' performance before and after HACCP education and training. Their findings revealed significant improvements in employees' knowledge of time and temperature control, sanitation practices during food cooling, and equipment hygiene. Implementing HACCP in hospital nutrition departments serves as an effective food safety management system that not only ensures safe food preparation but also enhances customer satisfaction, reduces complaint rates, prevents food poisoning, and mitigates unnecessary costs (Fereshteh et al., 2014).

Kokkinakis et al. (2011) emphasized that key elements for the effective implementation and operation of the HACCP system in hospital kitchens include comprehensive training for kitchen and food management personnel, proper handling of minimally processed foods, regular inspections of kitchenware, strict monitoring of food storage conditions, and the use of HACCP-certified suppliers. Similarly, Terkuran and Erginkaya (2019) highlighted that temperature monitoring of prepared meals is a critical component of the HACCP system and an essential requirement for ensuring food safety.

Hospitals have a critical responsibility to provide diners with safe food, and studies have shown that implementing the HACCP management system leads to higher food quality standards in hospital meal services. High-quality meals in hospital kitchens can encourage patients to consume hospital-provided food more willingly (Aminuddin et al., 2018). Traditionally, food quality has been defined by factors such as shape, color, grade, texture, and flavor. However, modern standards require that food production processes also comply with food safety regulations and meet consumer expectations for quality. In this study, the term "food quality" is redefined as "meal quality," emphasizing that hospitals must meet diners' expectations across all aspects of their meal experience.

Stakeholders in the food industry are responsible for ensuring employee education, maintaining workplace cleanliness, preventing pest infestations, and implementing effective quality control processes. Drawing from the literature, this study categorizes the key research dimensions into six areas: enhancement of kitchen equipment and layout planning, environmental cleanliness and food hygiene, employee training and education, employee growth and motivation, meal quality, and overall performance

Methodology

The traditional Analytic Hierarchy Process (AHP), first introduced by Saaty in 1980, is one of the most effective methods for addressing problems in multiple-criteria decision analysis. However, AHP has a notable limitation: its effectiveness tends to diminish as the

Table 1: the pairwise comparison of two groups

	9	8	7	6	5	4	3	2	1	2	3	4	5		6	7	8	9	
A					V														B
B											V								C
C			V																D
D																V			E

number of items increases (Chen & Huang, 2016). To address this issue, Herrera et al. (2004) proposed the Consistent Fuzzy Preference Relations (CFPR) method, which led to the development of the Consistent Fuzzy Preference Relations Analytic Hierarchy Process (CFAHP).

In an n / n evaluation matrix, when the AHP method is used, n (n-1) / 2 pairwise comparisons need to be performed. If the CFAHP method is used, only (n-1) pairwise comparisons are needed. Therefore, CFAHP decreases the number of times that pairwise comparisons need to be done. Moreover, for CFAHP the pairwise comparisons between attributes has more transitivity. For example, if A is better than B and B is better than C, then A is definitely better than C.

Although CFAHP offers significant improvements over the traditional AHP, user-friendly software for implementing CFAHP is currently unavailable. This study aims to develop an easy-to-use Excel-based procedure for CFAHP.

CFAHP Calculation Steps

This study is structured into six main frameworks, encompassing a total of 26 items, based on a thorough review of the literature. The hierarchical structure includes the following dimensions:

(A) improvement of kitchen equipment and layout planning, (B) cleanliness of the environment and food hygiene, (C) employee training and education, (D) growth and motivation,(E) quality of meals, and (F) overall performance.

The steps involved in the Consistent Fuzzy Preference Relations Analytic Hierarchy Process (CFAHP) are as follows:

Step 1:

CFAHP conducts a questionnaire survey of HACCP industry experts and scholars to collect research data.

The questionnaire content includes (a) the definition of the scale (b) sample answers (c) pairwise comparison question items. (See table 1)

In the AHP method, the relative importance of the criteria is measured on a scale of 1 to 9. The scale is defined as '1: Equal', '3: Moderate importance', '5: Strong importance', '7: Very strong importance', '9: Extreme importance' and '2,4,6,8 : Intermediate'.

In the pairwise comparison (Table 1), when comparing "A" and "B", the left side 5 is selected, indicating that "A" is more important than "B". Comparing "B" and "C," 3 is selected on the right, indicating that "B" is of more importance than "C". As for the comparison between "C" and "D", 7 is selected on the left, indicating that "C" is very strongly important than "D". Comparing "D" and "E", the right side 7 is selected, indicating that "E" is very strongly important than "D"

Step 2:

Calculate Data: convert the above answer questionnaire to Excel data file as below (Table 2).

Table 2: The matrix data in the Excel file

	A	B	C	D	E
A	1	5			
B		1	1/3		
C			1	7	
D				1	1/7
E					1

After inputting the data from all of the industry experts and scholars, hospital nutritionists and kitchen staff questionnaires, the geometric mean method was used to calculate them.

Step 3:

Perform CFAHP Calculation.

A fuzzy preference relation P on a set of alternatives A is a set on the product set A×A with membership function $\mu p : A \times A \rightarrow [0, 1]$. The fuzzy preference relation is represented by the n×n matrix $P=(p_{ij})$, where $p_{ij}=\mu p(a_i,a_j)$ for every $i, j \in \{1,. . ., n\}$. Here, p_{ij} is the preference ratio of alternative ai to aj: $p_{ij}=1/2$means that no difference exists between ai and aj, $p_{ij}=1$ indicates that ai is absolutely better than aj, and pij>1/2 indicates that ai is better than aj. In this case, the fuzzy preference matrix P is generally assumed to be an additive reciprocal, $p_{ij} + p_{jj} =1$ for every i, j = 1,. . .,n (Chen & Lee, 2015).

Proposition 1. Consider a set of alternatives, $A=\{a_1,\ldots, an\}$, associated with a reciprocal multiplicative preference relation $A=(a_{ij})$ for $a_{ij} \in [1/9,9]$.

Then, the corresponding reciprocal fuzzy preference relation, $P= (p_{ij})$ with $p_{ij} \in [0,1]$ associated with A is given as $p_{ij} =g(a_{ij})=(1/2)(1+ \log 9 a_{ij})$.

Proposition 2. For a reciprocal fuzzy preference relation P=(p_{ij}), the following statements are equivalent: p_{ij} + p_{jk} + p_{ki} =(3/2), for every i,j,k. pij + pjk + pki =(3/2), for every i<j<j<j.

Proposition 3. If a decision matrix P with entries that are not in the interval [0, 1], but in an interval [−m, 1+ m], m > 0 can be obtained by transforming the obtained values using a transformation function that preserves reciprocity and additive consistency.

We can get the new fuzzy preference relation P' that is obtained as P'=f(P), The function f :[−m, 1+ m]→[0, 1], f(x)=(x+m)/(1+2m). The fuzzy preference relation A' is obtained as A' = f(P') such that A' =(a' ij)， a ' ij=$9^{2p'ij-1}$. Therefore, it can obtain the sum of every row in matrix A' using ri =Σn j=1(a' ij). Then we can obtain the weight of each item by Wi = ri /Σn i=1(ri). On the other hand, if a decision matrix P with entries that are in the interval [0, 1], we directly use the fuzzy preference relation A= f(P) such that A=(a_{ij}) ， a_{ij}=$9^{2p'ij-1}$. Then, it can obtain the sum of every row in matrix A using ri =Σn j=1(a_{ij}). Then we can obtain the weight of each item by Wi = ri /Σn i=1(ri).

This method can overcome the inconsistency problem of AHP and reduce the questionnaire load on respondents, making it superior to the conventional AHP method. We collected 11 valid questionnaires from industry experts and scholars, and found out the importance of priorities when a hospital kitchen is practicing an HACCP system.

Importance Performance Gap Analysis (IPGA) method

Martilla and James (1997) propose Importance Performance Analysis (IPA) which combines measures of customers' perceived performance and importance into a two-dimensional plot to facilitate data interpretation.

This chart classifies attributes into four quadrants to set the priorities in allocating limited resources. Therefore, each quadrant within the standard IPA plot indicates a different strategy for helping managers to identify the areas of concern as well as the necessary actions for improving customer satisfaction (Sever, 2015). The four quadrants are typically identified as 'keep up the good work' (Q1), 'possible overkill' (Q2), 'low priority' (Q3) and 'concentrate here' (Q4), see figure1.

Quadrant 1: 'keep up the good work,' high importance, high performance: represents major strengths and potential competitive advantages of a product or service. The attributes situated in this quadrant are considered to be performing well and need continued investments.

Quadrant 2: 'possible overkill' area, low importance, high performance: contains attributes of low importance to customers, which are performing strongly, indicating possible waste of limited resources that are inefficiently used and could be reallocated elsewhere.

Quadrant 3: 'low priority' area, low importance, low performance: it is not performing exceptionally well, but is

considered to be relatively unimportant to customers; therefore, managers should not be overly concerned with these attributes. They represent minor weaknesses and poor performance is not a major problem.

Quadrant 4: 'concentrate here' area: high importance, low performance, it is the most crucial region in the plot. Attributes situated in this quadrant are considered to be underperforming and, as such, represent the product's major weaknesses and threats to its competitiveness. These attributes have the highest priority in terms of investments.

In summary, relying solely on the Importance-Performance Analysis (IPA) model to enhance service quality is insufficient. Recent studies have frequently employed the traditional IPA model to evaluate the service quality of enterprises, with a growing emphasis on incorporating gap analysis to strengthen the results. Gap analysis assesses the disparity between customers' expectations and their actual perceptions of the service. Fontenot, Henke, and Carson (2005) suggested that combining gap analysis with the prioritized importance of service attributes enhances the accuracy and reliability of the analytical results. Likert 5 scales to investigate importance and satisfaction respectively, 1=very unimportant (very dissatisfied), 2=not important (dissatisfied), 3=average, 4=important (satisfied), 5=very important (very satisfied).

Results

Table 3 presents the results based on questionnaires collected from 11 industry experts and scholars, including 7 males and 4 females, with an average of 10.

This study utilizes the IPGA analysis tool and a questionnaire to examine the distribution of importance and satisfaction levels after implementing the HACCP system. A total of 76 valid samples were collected, yielding a valid response rate of 85%. The respondents were kitchen staff with HACCP certification from four hospitals in Taiwan.

Table 3 the importance and ranking of 6 dimensions of HACCP system

Items	CFAHP	Rank	Importance	Rank
A. Improvement of kitchen equipment and layout planning	0.049	6	3.85	6
B. Cleanliness of the environment and food hygiene	0.153	3	4.34	2
C. Employee training and education	0.184	2	4.01	3
D. Growth and motivation	0.118	4	3.89	4
E. Quality of meals	0.413	1	4.35	1
F. Overall performance	0.083	5	3.88	5

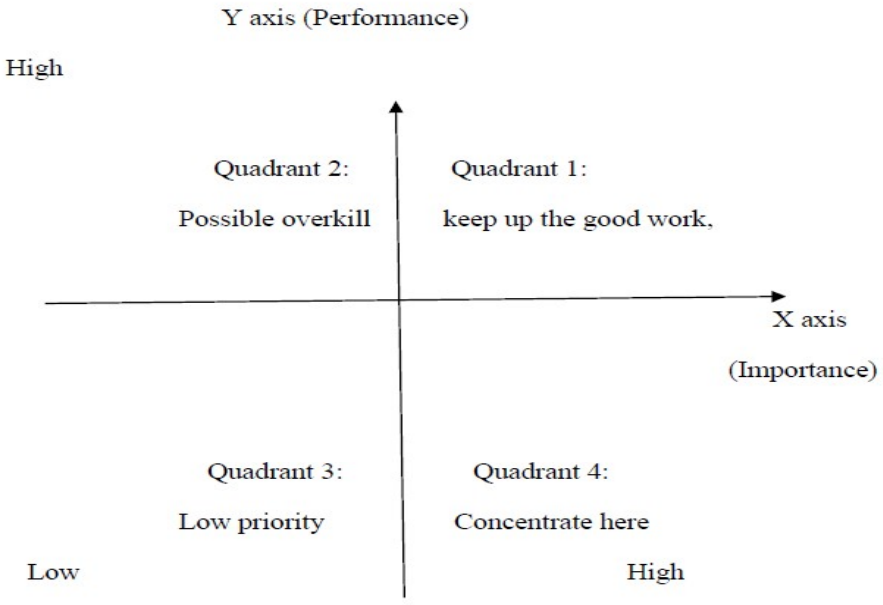

Figure 1: The standard IPA

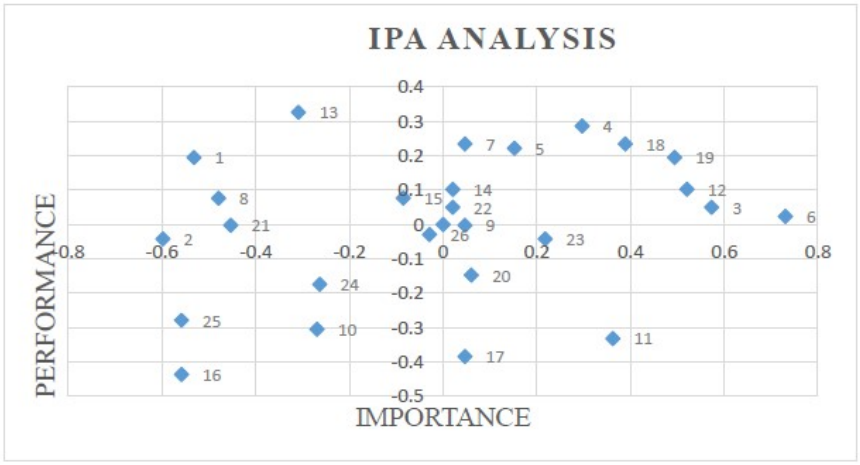

Figure.2 IPA scatter diagram

years of professional experience. The primary goal was to gather their insights on the implementation of the HACCP system in hospitals and to assess the relative importance of various factors. According to the geometric mean results derived from the CFAHP analysis, the weights and rankings of the factors are summarized in Table 3. The experts prioritized the six dimensions in the following order of importance: (E) Quality of meals, (C) Employee training and education, (B) Cleanliness of the environment and food safety, (D) Growth and motivation, (F) Overall performance, and (A) Improvement of kitchen equipment and layout planning

According to the results of the questionnaire survey on the importance and satisfaction levels of hospital kitchen staff certified in HACCP, the key dimensions of the HACCP system in Taiwanese hospital kitchens are ranked as follows: (E) Quality of meals, (B) Cleanliness of the environment and food safety, (C) Employee training and education, (D) Growth and motivation, (F) Overall performance, and (A) Improvement of kitchen equipment and layout planning.

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An IPA analysis was conducted using six major dimensions and 26 sub-items. Figure 2 displays a scatter diagram divided into four quadrants, illustrating the critical actions required to improve kitchen staff satisfaction.

The 26 sub-items of the HACCP system are outlined as follows: 1. Re-planning of hardware and equipment; 2. Ensuring employees are skilled in using equipment and appliances; 3. Proper planning of the flow of people and goods; 4. Maintaining sanitation, hygiene, and sterilization of equipment and appliances; 5. Conducting regular vector control in the kitchen and workplace; 6. Preventing cross-contamination of food during prepar-ation; 7. Ensuring hot food remains hot and cold food remains cold during service; 8. Requiring kitchen employees to hold relevant certifications; 9. Enhancing employees' professional knowledge; 10. Improving employees' professional skills; 11. Strengthening employees' professional attitudes; 12. Promoting employees' self-management; 13. Conducting regular hygiene training for kitchen staff; 14. Expanding personal professional knowledge; 15. Developing personal professional skills; 16. Receiving supervisor approval; 17. Fostering a sense of accomplishment; 18. Implementing food traceability control for ingredients; 19. Preparing food in compliance with food safety and hygiene standards; 20. Maintaining food at a safe temperature (above 60°C) during delivery; 21. Securing support and recognition from the hospital; 22. Enhancing overall kitchen work efficiency; 23. Cultivating self-management habits in employees; 24. Reducing the number of customer complaints; 25. Increasing the order rate; and 26. Ensuring proper hygiene control of ingredients and reducing waste rates.

As shown in Figure 2, managers of Taiwanese hospitals should prioritize the fourth quadrant (high importance, low performance) in resource allocation. These areas include: 11. strengthening employees' professional attitudes, 17. fostering a sense of accomplishment, 20. maintaining food at a safe temperature

(above 60°C) during delivery, and 23. cultivating employees' self-management habits. However, when gap analysis is combined with IPA, Table 4 reveals that the top priorities in the fourth quadrant are 11. strengthening employees' professional attitudes and 17. fostering a sense of accomplishment. This is because no significant gap was found between the importance and performance for items 20. maintaining food at a safe temperature (above 60°C) during delivery and 23. cultivating employees' self-management habits.

Table 4 further indicates that 13 out of the 26 sub-items of the HACCP system show significant differences between their perceived importance and actual performance.

Conclusion and Policy Recommendations

The purpose of this research is to construct the importance and ranking of the 6 research dimensions and 26 sub-items considered by industry experts and scholars after the hospital kitchen has obtained HACCP certification. Moreover, we use the innovative method which combines Consistent Fuzzy Preference Relations Analytic Hierarchy Process (CFAHP) and IPGA to find out the importance of the HACCP system. The IPA scatter diagram was utilized to examine the distribution of 26 sub-items across four quadrants, while gap analysis was applied to enhance the accuracy of the IPA results. This approach enables hospital kitchen managers to clearly identify areas that require continued focus and those that need targeted improvement.

Based on the questionnaire responses from industry experts, scholars, and kitchen staff, the results of the CFAHP and IPGA analyses indicate that the most critical factors for HACCP-certified hospital kitchens are meal quality, employee training and education, and environmental cleanliness and food safety. These findings align with those of Chang et al. (2003) and Liu (2017) Additionally, key priorities include controlling ingredient and food traceability, maintaining food at a safe temperature (above 60°C) during delivery, and ensuring food preparation adheres to safety and hygiene guidelines.

Furthermore, the IPGA analysis, based on survey responses from hospital kitchen staff certified in HACCP, highlights areas of high importance but low performance in the implementation of HACCP procedures. These findings provide hospital managers with a clear understanding of the current state, enabling them to allocate limited resources more effectively. Key areas for improvement include strengthening employees' professional attitudes and fostering a sense of accomplishment. For example, hospital manager can conduct regular workshops on workplace professionalism, communication skills, and time management, and offer mentorship programs where senior employees model professional behavior.

These results can serve as valuable guidelines for hospital kitchens in Taiwan seeking to establish a robust food safety system. Additionally, they

Table 4 the importance and ranking of 26 subitems of HACCP system for IPA and Gap analysis

Items	Importance	Performance	*t value*	Gap	Quadrant
1.Replanning of hardware and equipment	3.50	4.29	-7.655	0.79	2
2.Employees skilled at using equipment and appliances	3.43	4.05	-5.665	0.62	2
3.Proper planning of flow of people and goods	4.61	4.14	5.190	0.47	1
7.When serving meals, keep hot food always hot and cold food always cold	4.08	4.33	-2.663	0.35	1
8.Employees in the kitchen possess related certifications	3.55	4.17	-6.479	0.62	2
11.Strengthening employees' professional attitudes	4.39	3.76	5.796	0.63	4
12.Employees' self-management	4.55	4.20	3.131	0.35	1
13.Giving regular lectures on hygiene to kitchen workers	3.72	4.42	-6.911	0.70	2
15.Improving one's own professional skills	3.95	4.17	-2.569	0.22	2
17.Possessing a sense of accomplishment	4.08	3.71	3.197	0.37	4
19.Food is prepared in accordance with food safety and hygiene guidelines	4.53	4.29	2.439	0.24	1
21.Support and affirmation from the hospital	3.58	4.09	-5.535	0.51	2
25. Increasing the order rate	3.47	3.82	-3.418	0.35	3

offer practical insights for hospital managers to prioritize resource allocation based on the relative importance and performance of HACCP implementation.

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