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Analyzing Success Factors in Developing Mobile Applications for Farmers in Thailand Using Analytic Hierarchy Process Technique

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ABSTRACT

This study applies the Analytic Hierarchy Process (AHP) as a robust decision-making framework to address critical gaps in risk management and criteria prioritization within mobile application development for the agricultural sector, specifically focusing on Thai rice farmers. The research identifies essential factors influencing technology adoption through input collected from 100 rice farmers in Surin Province. Using AHP, these factors were systematically ranked, with "ease of use," "provision of up-to-date information," and "support" emerging as the most significant criteria. Based on these insights, three mobile application prototypes were developed, with Mobile App 1 achieving the highest AHP score of 0.633, demonstrating superior alignment with user requirements. Subsequent evaluations of user satisfaction reinforced these findings, with "ease of use" scoring the highest (4.60), followed by "perceived usefulness" (4.10). The findings underscore AHP's efficacy in mitigating risks and aligning application features with user demands, thereby enhancing adoption effectiveness. This study contributes novel insights into leveraging AHP as a precision tool for guiding mobile application development in agriculture and provides a replicable framework for addressing user-centric challenges. Future research should investigate integrating AHP with emerging technologies to drive innovation and sustainable solutions in agricultural practices.

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1. INTRODUCTION

Farmers in Thailand, particularly rice farmers, are a crucial part of the country's economic and social framework. However, a decade-long survey conducted by the University of the Thai Chamber of Commerce from 2012 to 2022 revealed a persistent decline in farmers' incomes alongside a continuous rise in production costs. This situation has led to economic instability among Thailand's largest agricultural group. To address these issues, the government and relevant organizations have proposed measures aimed at reducing production costs and increasing farmers' incomes, with a focus on promoting the use of modern technologies and innovations to enhance productivity and mitigate risks in agriculture [1-4]. Examples of technological interventions include weather forecasting systems and farm resource management tools [5-7], which are essential for improving global competitiveness and ensuring the sustainability of Thailand's agricultural sector.

Despite the development of various technologies to support the agricultural sector over the past five years, such as mobile applications, many farmers remain unprepared for consistent adoption. This is partly due to a lack of understanding of users' specific needs and insufficient user involvement during the initial development stages. As a result, applications often fail to meet genuine user demands, leading to wasted resources in the development process [8-12]. Related studies have identified key factors influencing the success of agricultural technology projects, including users' technological readiness and external support mechanisms such as innovation hubs [13]. However, numerous studies have also highlighted issues related to application discontinuation among Thai farmers, primarily due to design-related factors and a lack of alignment with users' needs. For example, that trust issues and inadequate design responsiveness contributed to the short-term use of the Mobile application [14]. Furthermore, the study revealed that rural farmers face challenges in adopting smart farming technologies due to insufficient support and poor design compatibility [15]. Similarly, studies have highlighted the limitations in the design and usability of market and logistics applications for elderly farmers in Thailand, presenting significant challenges to their sustainable usage [16]. Finally, the research found that changes in land use in northern Thailand have indirectly impacted the adoption of agricultural technologies, potentially leading to their discontinuation [17]. While research has explored factors influencing farmers' acceptance of technology, there remains a gap in studies prioritizing these factors in the specific context of Thailand. This lack of analysis has led to inefficient application development that fails to meet users' needs, exacerbating economic risks for farmers and leading to unnecessary expenditure by developers. Prioritizing the factors that influence application development could help mitigate these risks and create opportunities for developing applications that better align with user demands. By addressing these challenges, the agricultural technology sector could see improved adoption rates and long-term success.

Various methods are employed to analyze user requirements. Among them, the Analytic Hierarchy Process (AHP) has been widely recognized for its effectiveness in prioritizing diverse factors [18], making it particularly suitable for addressing agricultural challenges. An integrated approach combining the Analytic Hierarchy Process (AHP) with Fuzzy Multi-Criteria Decision Making (Fuzzy MCDM) has been implemented, demonstrating that AHP excels in handling qualitative data effectively. [19]. There is research utilizing the Analytic Hierarchy Process (AHP) to prioritize options for forest management, illustrating that AHP effectively reduces subjective errors more efficiently than other methods [20]. Finally, there is research that summarizes the advantages and limitations of the Analytic Hierarchy Process (AHP), emphasizing its suitability for problems requiring traceability and transparent evaluation [21]. Drawing insights from the aforementioned studies, this research employs AHP to address the challenges of misaligned application development that fails to meet the needs of farmers. AHP is a multi-dimensional analytical process capable of prioritizing both qualitative and quantitative factors. This study aims to identify and rank the factors influencing farmers' selection of rice cultivation planning applications. Three application development options are proposed, allowing a sample of 1 0 0 rice farmers in Surin Province, Thailand, to choose the application best suited to their needs. The results of the AHP analysis will guide the development of a prototype mobile application, which will subsequently be tested for performance and user satisfaction. AHP was chosen for its ability to incorporate input from multiple stakeholders and establish a structured development framework tailored to the specific needs of Thai farmers. This approach is expected to reduce the rate of application discontinuation and enhance the long-term success of agricultural technology project

2. RESEARCH METHOD

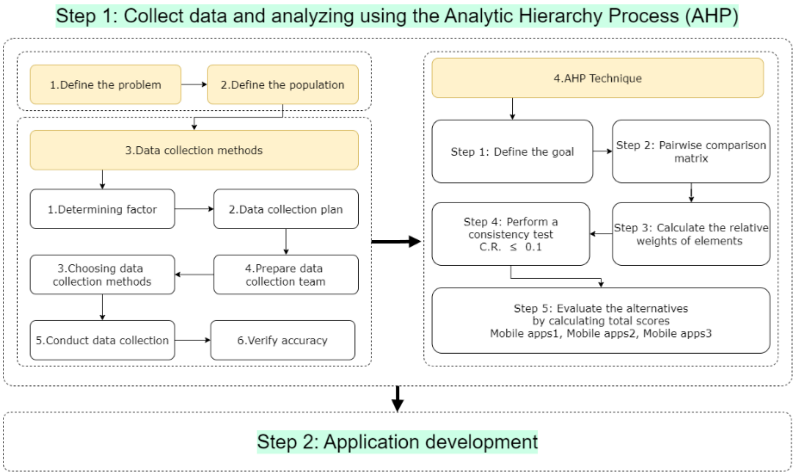

Figure 1. Research Methodology

Figure 1 illustrates the overall research process, which consists of two main stages: Step 1 involves data collection and analysis using the Analytic Hierarchy Process (AHP), and Step 2 focuses on application development. In Step 1, the process begins with defining the problem and target population, planning data collection, selecting appropriate data collection methods, preparing the data collection team, conducting data collection, and verifying the accuracy of the collected data. The AHP process is then applied, which includes defining the goal, constructing a pairwise comparison matrix, calculating the relative weights of factors, performing a consistency test ($C.R. \leq 0.1$), and evaluating the alternatives to select the best option (e.g., Mobile App 1, Mobile App 2, Mobile App 3). In Step 2, insights derived from the AHP analysis are utilized to guide the development of a mobile application. The detailed operations of each stage are as follows.

2.1. Collect data and analyzing using the Analytic Hierarchy Process.

2.1.1. population and sample

The population of this study comprised rice farmers in Surin Province, with a sample size of 100 participants selected through purposive sampling [22]. This method was employed to ensure that participants met the criteria relevant to the research objectives. The selection criteria included possession of a mobile phone with internet connectivity and a basic understanding of mobile application usage.

2.1.2. Data collection included the following 6 steps:

1) The steps for defining the factors that were studied.

2) The sample group was used in the previous step for the data collection process. The data collection process involved obtaining information directly from the sample group. Figure 2 illustrates the data in the AHP table format [23-24], gathered through a questionnaire administered by the research team during their visit to the region. The data collection spanned two months, (from 1st February to 31st March 2023).

3) In order to fully comprehend the sample data, the data collectors, which consisted of 8 research teams, successfully completed data collection clarification and testing meetings.

4) Procedures for selecting data collection methods included the research team visiting the area to collect data directly from the sample groups, which was 100 persons divided into 20 people at a time. Data collection, began with an introduction of the research team and the purpose of gathering research data. Then, the questionnaire was delivered to the sample group, along with an explanation of each element. The sample group had to input the required score values in the factor comparison table. The research team then asked each of the 20 people to enter their scores for each question simultaneously. The research team examined the correctness of the scores until the number of factor pairs for comparison was attained.

5) The process of collecting real data involved splitting the field visit into five sessions, each comprising a sample group of 20 individuals, and adhering to the previously outlined approach.

6) The accuracy of the information was confirmed by examining the individual scores for each item among 100 persons. This process helped identify any errors in data entry and ensured that the assigned score aligned accurately with the specified scoring criteria.

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
C1																		C2
C1																		C3
C1																		C4
C1																		C5
C1																		C6
C1																		C7

Figure 2. Sample data questionnaire

Figure 2 illustrates an example of a pairwise comparison questionnaire used in the Analytic Hierarchy Process (AHP) to prioritize criteria relevant to mobile application development in the agricultural context. Each factor (C1 to C7) represents an evaluation criterion, such as Perceived Ease of Use and Perceived Usefulness. Respondents compare the relative importance of each pair of factors and assign a priority level using a scale ranging from 1 (equally important) to 9 (extremely more important). The responses are then utilized to calculate the relative weight of each factor, followed by a consistency check using the Consistency Ratio (CR) to ensure the reliability of the data [25].

2.1.3. Analysis and interpretation of results using the Analytic Hierarchy Process technique (AHP)

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology developed to prioritize and evaluate multi-dimensional factors, particularly in complex scenarios involving both qualitative and quantitative data. The process begins by breaking down the decision problem into a clear hierarchy comprising the main objective, evaluation criteria, and possible alternatives. Decision-makers then perform pairwise comparisons of various factors to determine the relative weights of each criterion. These comparisons use a numerical scale to assess consistency and refine decision-making accuracy while minimizing potential biases. AHP is distinguished by its transparency, systematic approach, and flexibility. The process consists of five key steps: 1) Define the problem and construct a hierarchy, including the main goal, criteria, and alternatives. 2) Conduct pairwise comparisons of factors at each level of the hierarchy. 3) Calculate the relative weights of each factor using matrix analysis. 4) Evaluate the consistency ratio to ensure the reliability of the comparisons. 5) Summarize the results and rank the alternatives to support effective decision-making. Each step is designed to provide clarity and structure to decision-making, ensuring robust and efficient outcomes [20-21, 26]. A detailed explanation of each step is provided below.

Step 1: Decision-making goals were set by identifying criteria and possible choices. The decision-making hierarchy and the Analytic Hierarchy Process share a structure that mirrors the human mind. Consequently, a hierarchical chart was created to emulate the cognitive process of humans during decision-making. The diagram was segmented into various levels determined by the complexity of the issue. This study employed seven decision criteria and outlined three options for the development of mobile applications. Table 1 provides a breakdown of the specifics for each choice.

Table 1. Alternative Description (Mobile Application)

Alternative	details
Mobile Apps 1	This application presents current agricultural details on the cultivation of rice. It offers information on rice types suitable for specific regions, links to marketing data, showcases extended weather forecasts, and provides contact channels for both farmers and officials. The presentation format is user-friendly and easily achievable.
Mobile Apps 2	This application exhibits weather details, precipitation statistics, reservoir water levels, river basin information, radar images, and functions as a platform for requesting Royal Rainmaking services. It also allows users to track the service status and their location in motion, potentially minimizing battery consumption. Furthermore, it records data related to agriculture, including planting and harvesting timelines.
Mobile Apps 3	This application integrates information and technology, encompassing details on the production technology of field crops, horticultural crops, vegetables, medicinal plants, pest control, fertilization, GAP standard crop production, organic crop production, and more.

Step 2: The comparison of importance of judgment criteria was done using a pairwise evaluation to establish the importance weights between paired criteria. This comparison employs numerical substitution to calculate the overall importance score for each option, which is facilitated by a matrix table. This table can be used to assess the alternatives' sensitivity to priority and consistency of logical thinking, as indicated by the weight values and score level descriptions presented in Table 2. After gathering information from a sample of 100 persons, it compiled the results into a matrix table, which is represented by Equation 1. The GEOMEAN equation [27-28] was implemented to determine the average score in each pair based on the average sum score of each factor from a sample of 100 persons.

Table 2. Scale of comparison

Numerical value	**Comparative judgments**
9	Extreme importance
7	Very strong importance
5	Strong importance
3	Moderate importance
1	Equal importance
2-4-6-8	For a compromise between the above values

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{22} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \tag{1}$$

Step 3: After acquiring the weight value assessed by experts, the criterion's weight was established, and the outcome expressed numerically. Subsequently, the significance weight for each class was ascertained based on this numerical value. The analysis proceeded systematically from the highest to the lowest levels, evaluating all levels derived from Equation 2, followed by computing the matrix average $\bar{A}$ by using Equation 3. The result of calculation is the Eigenvector value.

$$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \tag{2}$$

$$w_i = \frac{\sum_{i=1}^{n} \bar{a}_{ij}}{n} \tag{3}$$

Step 4: Verification of the Consistency Ratio (C.R.) involved using experts' comparison standards to compute the Eigenvector value and assess its appropriateness. The steps for calculation are illustrated in Figure 3, while Equations 4 and 5 were employed to calculate C.I. and C.R., respectively.

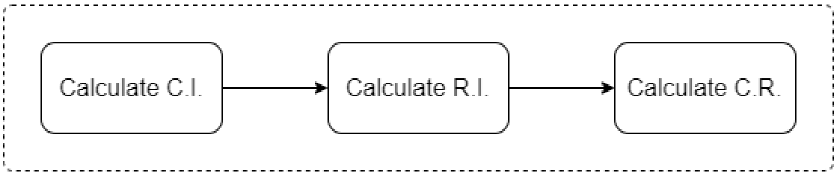

Figure 3. Steps for calculating C.R.

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{4}$$

$$CR = \frac{CI}{RI} \tag{5}$$

The computed consistency ratio (C.R. value) serves as a means to assess the validity of the questionnaire responses based on two criteria. If C.R. is ≤ 0.1, the factor values are deemed consistent, and the eigenvector can be employed as the weight. Conversely, if C.R. > 0.1, it suggests inconsistency in the factor values. To address this, the factors are modified or assigned new values until C.R. becomes < 0.1, and then the eigenvector value is utilized.

Step 5 : The options for each criterion were organized by entering values into the matrix table following step 4. Once a satisfactory Consistency Ratio (C.R.) value was achieved (below 0.1), the highest weight value for each criterion and wc_i the top-ranking option for each criterion across all items were considered. This research involves evaluating 7 criteria and 3 options. The arrangement of options was subsequently determined using Equation 6.

$$TotalScore_j = \sum_{i=1}^{n} wc_i wa_{ij} \quad \text{for all } j \tag{6}$$

The score for every option was calculated and then applied to rank all of the options. This study divided the options into 3 approaches: Mobile Apps 1, Mobile Apps 2, and Mobile Apps 3, which were utilized to make decisions on generating apps in the following sequence.

2.2. Application Development Process

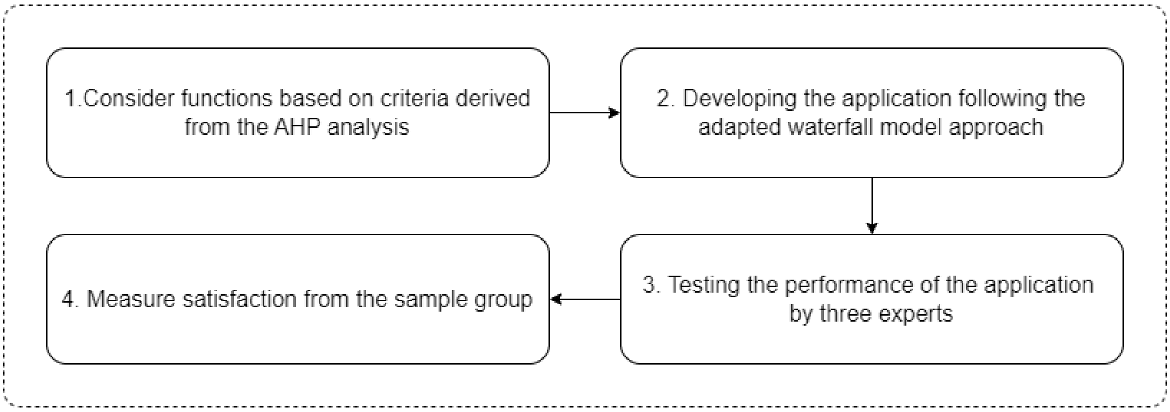

Figure 4. The process of developing the mobile application

Figure 4 illustrates the process framework for developing and evaluating a mobile application based on the Analytical Hierarchy Process (AHP) analysis. Step 1 begins with identifying and selecting application functions derived from the criteria prioritized through AHP analysis. This ensures that the application design aligns with the needs and expectations of users. In Step 2 , the application is developed using an adapted waterfall model approach, a structured, stepwise methodology for software development [29-30]. Step 3 involves performance testing conducted by three information system development experts to evaluate the application's functionality, usability, and technical aspects. Finally, in Step 4 , the application is deployed to the sample group, where user satisfaction is assessed. This systematic approach integrates user-driven insights, rigorous development practices, and iterative validation to ensure that the application is reliable and meets the needs of users in the agricultural sector.

3. RESULTS AND DISCUSSION

The methodology for this research was divided into 2 steps: 1) analysis of factor values using the AHP technique to determine the importance of factors, which was implemented as a guideline for developing the application, and 2) application development procedure to be as user-friendly as possible. To assess the research's performance, the application development outcomes were evaluated using satisfaction values.

3.1. The findings of each phase of the analysis, which used the AHP technique

3.1.1 Selection of criteria

Selection of criteria used in consideration This study collected criteria from related research studies on analyzing variables impacting application selection and then presented them to a team of three information scientists and three agricultural academics with the objective of identifying the most relevant criteria. The consideration findings allowed for the selection of 7 factors for data collection from the sample group. Table 3 presents all criteria.

Table 3. Criteria

Code	Criteria	Description	Reference
C1	Ease of use	Making the application easy and convenient for farmers to use	[31-32]
C2	Benefits	Being valuable to farmers' work, such as lowering management time, assisting with decision making, or enhancing productivity	[31-33]
C3	Trial Capability	The ability for farmers to conduct trials of the application before deciding to go full-scale	[34]
C4	Support	Availability of technical support and maintenance from service providers	[31, 35]
C5	Provision of up-to-date agricultural information	Information is updated regularly about weather conditions, farmland and other agricultural information	[33]
C6	Decision making support	Provision of useful information for decision making, such as managing plant disease problems, water management, or plant planning	[36]
C7	Prediction	The ability to predict weather conditions, yields, or other agricultural problems that can help with agricultural planning	[37]

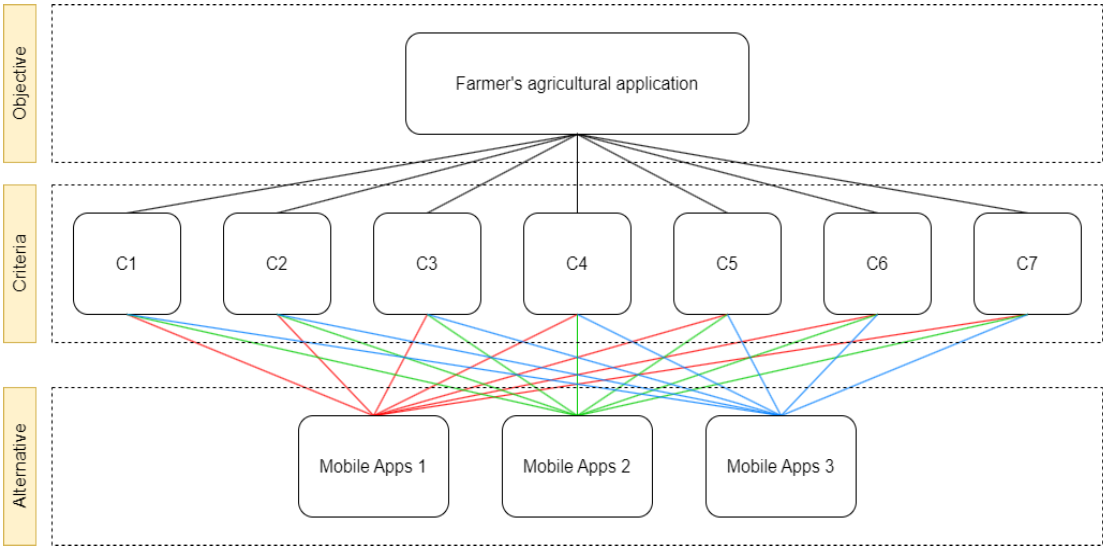

Figure 5. AHP Hierarchical Model Structure

Figure 5 illustrates the hierarchical structure utilized in the Analytical Hierarchy Process (AHP) for evaluating and selecting the most suitable mobile application for agricultural use. At the top level (Objective), the overarching goal is to determine the optimal farmer's agricultural application. The second level (Criteria) consists of seven evaluation criteria (C1 to C7), including "ease of use," "provision of up-to-date information," and "support," which form the basis for comparing the alternatives. The third level (Alternative) comprises the three proposed mobile applications: Mobile Apps 1, Mobile Apps 2, and Mobile Apps 3 . The connections between the objective, criteria, and alternatives demonstrate the pairwise comparisons conducted during the AHP process, which determine the relative weights of each criterion and their respective influence on the alternatives. This structured framework ensures a comprehensive and systematic evaluation, enabling the selection of the application that best meets user requirements and agricultural demands.

3.1.2. Pairwise decision comparisons

The weight of each criterion was determined by the examination of a sample of 100 people. The average score for each criterion in the sample was calculated using the GEOMEAN equation (if more than one person answers the question), as indicated in Table 4.

Table 4. Matrix table showing pairwise decision comparisons

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	1	2.06	0.72	0.85	0.53	0.75	0.94
C2		1	3.32	2.11	1.24	1.56	2.62
C3			1	1.31	0.88	0.89	2.28
C4				1	1.44	1.17	1.93
C5					1	2.04	3.29
C6						1	2.14
C7							1

3.1.3. Eigenvalues and inconsistency values of criteria

After comparing the criteria for consideration from the sample group, the Eigenvector value was calculated to evaluate the significance of each criterion under discussion. This study focused on rating the results for each criterion in order to ensure they that they could be utilized as a guideline for future application development. Figure 6 represents the results of the score-value ranking. The C.R. value was then generated for consistency testing under the conditions where there were more than 5 criteria examined [26]. The C.R. value for comparison should be less than 0.1 (C.R. < 0.1) [38-39]. The calculation that was conducted resulted in 0.070, which is an acceptable value.

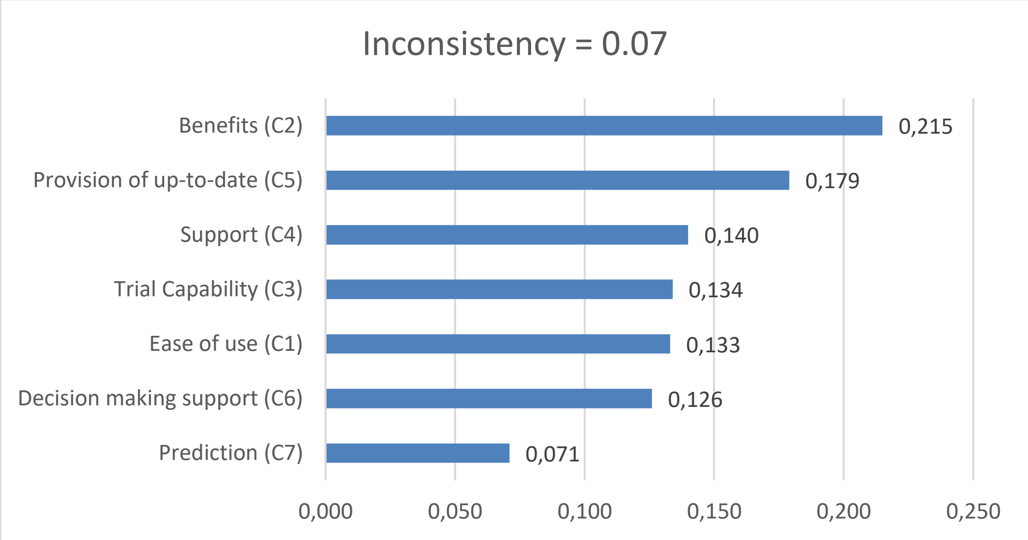

Figure 6. Eigenvalues and inconsistency values of criteria

Figure 6 illustrates the analysis results derived from the Analytic Hierarchy Process (AHP), showcasing the relative importance (Eigenvalues) and inconsistency (Consistency) of seven criteria influencing the effectiveness of mobile applications. The results indicate that "Usefulness" (C2) holds the highest importance, with a weight of 0.215, followed by "Up-to-date Information" (C5) at 0.179. Conversely, "Forecasting" (C7) is ranked lowest, with a weight of 0.071. The overall Consistency Ratio (CR) is 0.07, which is within the acceptable threshold (CR ≤ 0.1), confirming that the pairwise comparisons are consistent and reliable. These findings align with prior research highlighting that "perceived usefulness" is a pivotal factor influencing the adoption of Industry 4.0 technologies in the agricultural sector. Furthermore, accurate and timely information has been shown to play a critical role in fostering trust and supporting user decision-making [40, 41]. The lower importance assigned to "Forecasting" (C7) may reflect usability limitations of forecasting technologies, particularly among farmers with limited technical expertise. Research has emphasized that the adoption of smart agricultural technologies is significantly influenced by factors such as ease of use (C1) and adequate support (C4), both of which play vital roles in enhancing user acceptance. Moreover, the complexity of advanced technological functions, particularly those requiring substantial technical knowledge, has been identified as a barrier to adoption in agricultural contexts [42]. These findings align with the outcomes of this research, where "Ease of Use" and "Support" were highly prioritized, whereas "Forecasting" (C7) was ranked lower, further substantiating the usability challenges faced by farmers. In conclusion, designing applications for farmers should prioritize simplicity, responsiveness to practical needs, and continuous support to enhance user acceptance and long-term usage [43]. Additionally, Figure 6 underscores the effectiveness of AHP in prioritizing criteria that influence application development. This systematic approach aids development teams in making clear and transparent decisions. The research confirms that AHP enhances the accuracy of prioritizing factors in agricultural technology projects, thereby improving decision-making processes and development outcomes [18].

3.1.4. Scores of all alternatives

The following step was to determine the weight of each option in each consideration criterion. This study separated the options into three groups and assessed the C.R. consistency value, which was 0.09 (less than 0.1 is acceptable) displayed in Table 5. The weights of the options were subsequently combined to classify them, and the available options were utilized to assist with further decisions. The findings of the calculation are displayed in Figure 7.

Table 5. Scores of all alternatives

Criteria	**Alternatives**			**Consistency**
	Mobile Apps 1	**Mobile Apps 2**	**Mobile Apps 3**	
C1	0.595	0.276	0.128	0.005
C2	0.708	0.178	0.112	0.051
C3	0.748	0.108	0.142	0.070
C4	0.493	0.310	0.195	0.051
C5	0.686	0.186	0.126	0.090
C6	0.660	0.208	0.131	0.051
C7	0.549	0.209	0.240	0.017

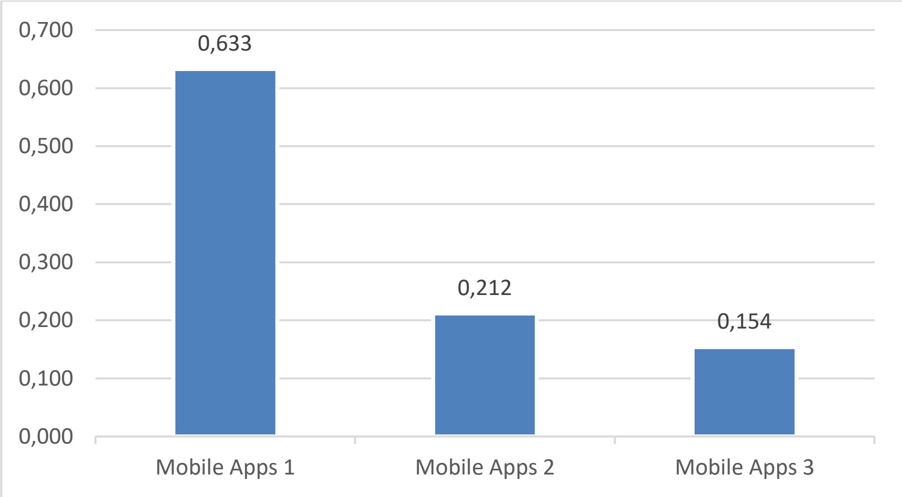

Figure 7. Total score of each alternative

Figure 7 illustrates the analysis of the overall scores of the three mobile applications using the Analytic Hierarchy Process (AHP) revealed that Mobile App 1 achieved the highest total score of 0.633, significantly aligning with user requirements compared to Mobile App 2 (0.212) and Mobile App 3 (0.154). Key factors contributing to the success of Mobile App 1 include ease of use (C1), provision of up-to-date information (C5), and support (C4). The findings of this study align with research emphasizing that ease of use and accurate, timely information play crucial roles in the acceptance of technology among farmers [43].

3.2. Results of application development

The priority criteria generated from the AHP technique was used to classify the developed application into four functions consisting of 1) Weather forecasting 2) Selection of rice varieties suitable for specific areas 3) Agricultural commodity price information 4) Communication channels with relevant agencies, as demonstrated in Figure 5-6.The application underwent black-box testing [44] by experts. The satisfaction evaluation findings obtained from 100 system users likert scale 5 level [45] are shown in Figure 10.

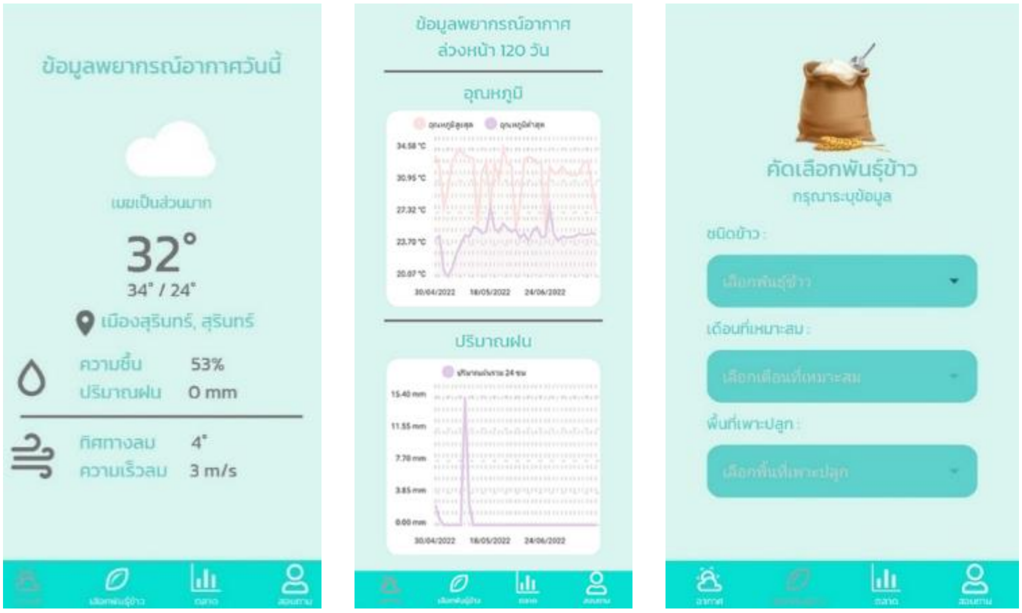

Figure 8. Results of application development function 1-2

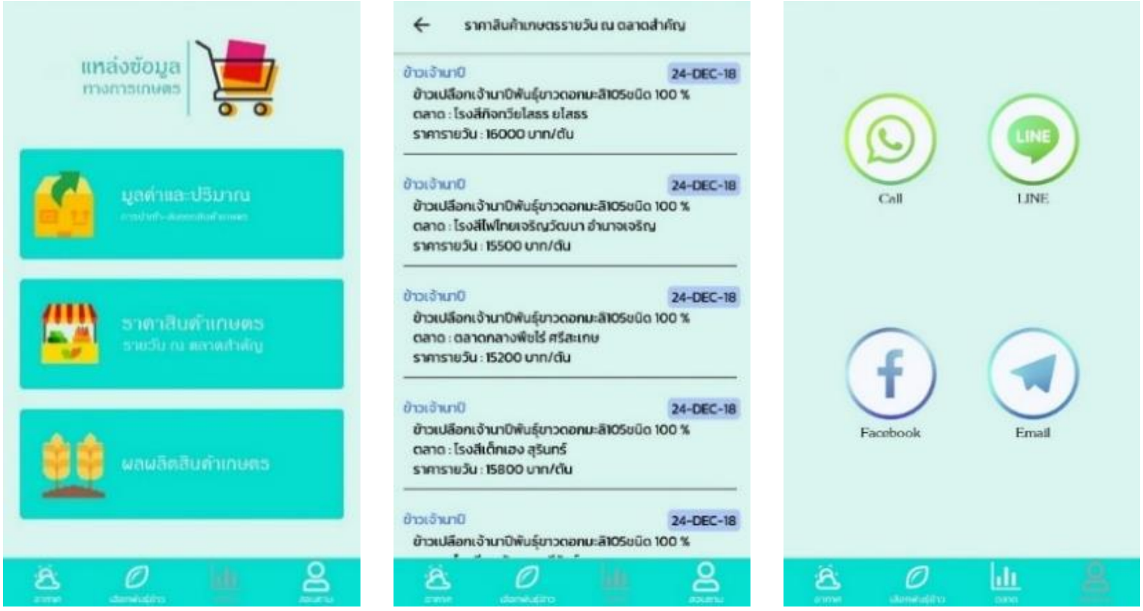

Figure 9. Results of application development function 3-4

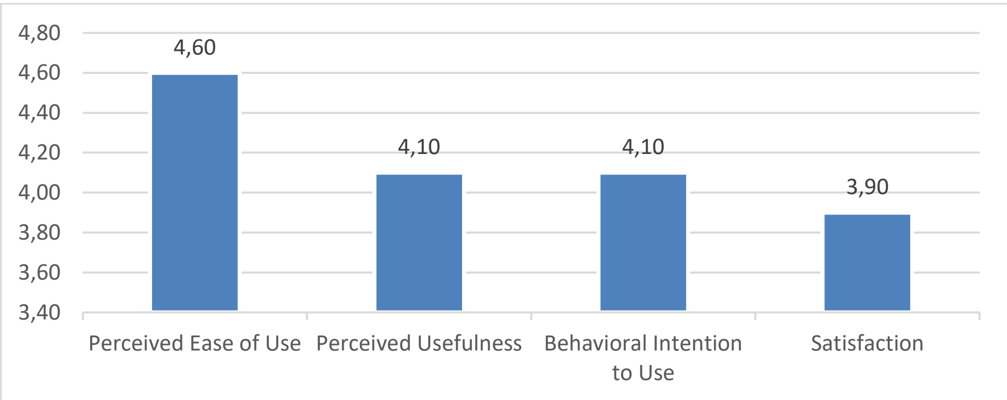

Figure 10. Satisfaction evaluation results from the sample group.

The analysis using the Analytic Hierarchy Process (AHP) to prioritize criteria influencing mobile application development revealed that Mobile App 1 achieved the highest overall score and best met user requirements. Notably, criteria with higher weightings, such as Perceived Ease of Use and Perceived Usefulness, were significant contributors to this outcome. These findings were utilized in the subsequent development phase of Mobile App 1, which was then tested with the target group. Figure 10 illustrates user satisfaction evaluation results, showing that Perceived Ease of Use received the highest score (4.60), followed by Perceived Usefulness (4.10) and Behavioral Intention to Use (4.10). These results align with the prioritizations derived from the AHP analysis, demonstrating the accuracy and efficacy of AHP in guiding application development and ensuring the resulting application meets user needs effectively. These findings are consistent with the conclusions of previous research, which emphasized that the Analytic Hierarchy Process (AHP) enhances transparency in software development and facilitates the precise prioritization of features [46].

4. CONCLUSION

This study demonstrates the effective application of the Analytic Hierarchy Process (AHP) in identifying and prioritizing criteria critical to the development of agricultural applications, aligning with the objectives outlined in the introduction. Mobile App 1 was identified as the most suitable alternative based on the AHP analysis, emphasizing the importance of factors such as perceived ease of use and perceived usefulness. The subsequent development and user satisfaction evaluation of Mobile App 1 validated the alignment between the analytical results and actual user needs, with ease of use receiving the highest score (4.60), followed by perceived usefulness (4.10). Despite these positive outcomes, the study has some limitations, including the focus on a specific agricultural context and a limited sample size, which may affect the generalizability of the findings. Future research could address these limitations by applying the framework to a broader range of agricultural technologies, incorporating additional criteria, or integrating AHP with advanced machine learning models to enhance decision-making precision.

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